

## **Decontamination of Chemical Agent Contaminated Structures and Equipment**

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### **ABSTRACT**

Operations involving chemical agents such as manufacture, loading, storage, and demilitarization have resulted in the contamination of buildings and a wide variety of processing equipment. The contamination has been caused by a number of chemical agents with the most persistent being mustard. Materials that are contaminated include concrete (in floors and walls), metals (in piping, and process equipment), and wood. All of these materials exist in both painted and unpainted forms.

Many of the contaminated facilities have potential reuses or monetary value as excess property if they can be properly decontaminated. Much of the contaminated process equipment also has monetary value as scrap material if properly decontaminated. Currently this value can not be realized since the only acceptable decontamination method involves destruction and incineration of the contaminated material.

Past efforts at resolving this situation have identified some 56 concepts which could be utilized with five having been evaluated under laboratory conditions. These concepts include thermal, abrasive, chemical, and extractive removal schemes. Each of these technologies was evaluated based on destruction efficiency, mass transfer, safety, damage to existing materials, penetration depth, applicability to complex surfaces, cost, and waste management. Based on these comparisons hot gas technology was identified as the most suitable methodology.

Currently a full scale demonstration is in the design phase for implementation at Rocky Mountain Arsenal. The chosen site was originally contaminated with mustard and mustard degradation by-products from past demilitarization activities. The building contains concrete approximately eighteen inches thick, large metal storage tanks, process piping, motors, and pumps.

### **INTRODUCTION**

The Department of Defense owns a large inventory of real property and process equipment which has been operationally contaminated by chemical warfare agents. Typically this

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contamination has been the result of manufacturing or demilitarization operations at military industrial complexes. The contaminated material and equipment has always been rapidly decontaminated to a 3X status, which indicates surface decontamination but no action for agents which might have penetrated into the material. This doubt has meant that 3X certified materials can not be released from government control without being processed to attain a 5X rating. The only currently accepted method of attaining a 5X status is to expose the item to 1000 degrees F for fifteen minutes. This requirement requires that complex or large items must be dismantled prior to treatment and the thermal extremes also physically alter many materials and reduce the value of the excess property. Also, since this is an operational scenario and not an analytically established standard the release of the treated material is not assured. Prior to the end of the Cold War, and the accompanying shift in the World political order, this glut of excess property could be accepted, but with the shift to a smaller military excess non-productive property can no longer be tolerated.

#### **Current Decontamination Methods**

A number of methods have been employed in attempts to eliminate this problem, however, none has proven totally satisfactory and effective. The most common technique has been the use of fire. The use of fire typically centers on the use of a flash furnace or burning. In either case a number of drawbacks can be found in these thermal treatments. Both flashing and burning can be subjected to regulatory requirements since the procedures create air emissions and public opinion could prevent efficient operations if perceptions of thermal treatment as incineration arise. The flashing furnace relies on thermal initiation to decontaminate any residual agents. This procedure again results in a surface decontamination and cannot adequately treat complex surfaces or machinery. In the case of burning complete decontamination occurs but the physical structure and inherent value of the contaminated material is altered resulting in the government realizing a lower value for the recovered scrap.

#### **Novel Decontamination Concepts Development**

In 1982 the U.S Army Toxic And Hazardous Materials Agency (USATHAMA) started a project to offset these same problems for items contaminated with energetics. The energetics oriented project was aimed at developing an effective decontamination procedure suitable for both process equipment and scrap materials. The goal of this project was to develop a safe decontamination technology which produces little or no waste while completely removing energetic materials from complicated items. Typical compounds targeted for removal were military explosives such as

trinitrotoluene (TNT), hexahydro-1,3,5-trinitro-s-triazine (RDX), octahydro-1,3,5,7-tetranitro-1,3,5,7-tetrazocine (HMX), di- and tri-nitrobenzene compounds, smokeless powders, and ammonium picrate (Yellow-D). Research efforts were centered on developing a technique that could be applied to a number of structural materials such as metal, concrete, and painted surfaces. This capability provided for the secondary goal of being able to apply the emerging technology not only for process equipment and scrap material but also to large structures. This alternative provided the first indication novel approaches could be applied to the problem of dealing with 3X rated chemical agent facilities and equipment.

The initial stage of the energetics development program required a review of existing methodologies and any novel methods. Battelle Columbus Laboratories was awarded a contract to perform an analysis of existing explosives decontamination techniques and develop descriptions of emerging concepts. Battelle representatives gathered information from government and private sector energetics manufacturers as well as visiting and analyzing government facilities and equipment contaminated with explosives. In July of 1983 Battelle provided a report detailing the analysis of the technologies. These technologies were centered on the four main concepts of thermal decomposition, abrasive removal, extraction, and chemical treatment. Each technology was judged based upon the following characteristics; destruction efficiency, mass transfer, safety, damage to existing structures, applicability to complex surfaces, penetration, operating and capital costs, and waste residue and disposal. A number of combined methodologies were also considered and evaluated. At the same time the similarities between the energetics and agent contamination problems indicated that the same results were possible for an agent oriented decontamination system. This possibility led to the Battelle Columbus Laboratories being contracted to evaluate novel agent decontamination procedures. The evaluated technologies (refer to Table 1) focused on the same areas and criteria used in developing the energetics decontamination system.

Within the realm of thermal decomposition the use of hot gases received the highest overall ranking and favorable results in all the evaluated categories. The hot gas concept is built upon exposing contaminated items to hot gases in order to volatilize and decompose the contaminant. The resulting stream of hot gases, vaporized agents, and break down products are then destroyed in an afterburner unit. Burning was regarded fairly well in most categories but received the lowest possible ratings for safety and structural damage. The flashblast process was found to be highly effective as a surface decontamination system and was recommended for evaluation as a complimentary element in a combined technology.

All of the abrasive removal methods were rejected for further development, largely because of the high costs of waste stream treatment and disposal. These concepts also were deemed to be

unacceptable because of their relatively shallow penetration depth (without causing physical damage).

In terms of extractive removal, external steam generation was evaluated with high scores. This system involves the pumping of steam into the contaminated structure, or equipment, to purge the contamination. Freon vapor circulation was also judged to merit further development.

Of the chemical treatment technologies three were found to be suitable for further development. The concepts chosen were N-Octyl-pyridinium 4-aldoxime bromide (OPAB) solution, Monoethanolamine (MEA) solution, and ammonia gas.

**TABLE 1: Evaluated Technologies**

	Thermal Decomposition	
Flashblast	Contact Heating	Hot Plasma
Microwave Heating	Infrared Heating	Hot Gases
Solvent Soak/Burn	Flaming	CO <sub>2</sub> Laser
Burning		
	Abrasive Removal	
Electropolishing	Acid Etch	Scarifier
Sandblasting	Demolition	Drill and Spall
Ultrasound	Cryogenics	Hydroblasting
Vacu-blast		
	Extract Removal	
Solvent Circulation	Supercritical Fluids	Ultrasonic
Surfactants	Strippable Coatings	Manual Steaming
External Steam Generator	Vapor Phase Solvent Extraction	
	Chemical Treatment	
STB	Base Initiated Decomp.	Decomp. W/ DS2
Molten Decomposition	Microbial	Sodium Borohydride
Sulfur Based Reduction	Reduction Cleavage	Reactive Amines
Ultraviolet	Gamma Radiation	Chromic Acid
Ozone	Ascorbate	Gels
Foams	Chlorine/Chlorite	Ligands
Hydrolysis	Enzymes	

A total of sixty-five technologies and combined technologies were evaluated and considered for further development. Of these technologies six (see table 2) were found to be suitable for further investigation.

## Table 2: Phase 2 Technologies

Hot Gases  
External Steam  
OPAB  
MEA  
Freon Vapor Circulation  
Ammonia Gas  
Flashblast (Complimentary to One of The Above)

### Laboratory Testing

Having found six technologies suitable for additional investigation the program entered a second phase of development which provided more detailed analysis. The most important aspect of this phase was the laboratory testing designed to determine the range of applications and efficiency of decontamination. The laboratory testing was directed at determining the evaluated technology's effectiveness to decontaminate structural materials (both painted and unpainted) such as mild steel, stainless steel, concrete. The testing utilized measured GB, VX, and HD contamination to determine effectiveness. These tests revealed a number of cases where residual agent levels were below detection limits and each technology was found to have its own unique advantages and disadvantages. The widest applicability and greatest degree of decontamination was found with the use of the hot gas system. Steam extraction was also found to provide a high degree of application and agent removal. These two systems were subjected to a detailed engineering and economics analysis which suggested that both methods were feasible but that in terms of overall costs the hot gas process should be pursued.

Detailed analysis during the energetics evaluation also showed that the hot gas method entailed some unique features. During laboratory testing it was noted that explosive crystals formed on the outer (uncontaminated) surface of concrete coupons. This formation indicated that the hot gas system caused explosives to migrate through concrete rather than destroying the energetic material. Since chemical agents had previously been found to be reactive with concrete this hot gas induced diffusion was thought to be an effective means of removing these breakdown products. The energetic spiked concrete coupons were also found to be dried out because of the high operating temperature of the hot gas technique. This drying caused a noticeable loss of strength within individual concrete coupons which implied that the hot gas system would require tailoring to specific facilities and conditions.

### Pilot Test

In order to evaluate the hot gas concept on a large scale a

pilot test was conducted by Battele Laboratories at Dugway Proving Ground in 1987. Dugway Proving Ground was chosen because of its ability to provide test chambers that provided environmental control, containment, and the possibility of remote operations. The pilot test was centered on the full scale ability of the hot gas process to remove a controlled amount of HD (earlier studies had proven Mustard to be one of the most persistent and widespread contaminants) typical building and equipment materials. The test was conducted within a chamber containing walls made from poured concrete, concrete blocks (both solid and hollow), and mild steel. These materials were initially spiked with known concentrations of HD and then subjected to incremental heating until ambient temperatures reached 750 degrees F. This condition was maintained for one hour and then a cool-down period was instituted (approximately 38 hours reach temperatures below 100 degrees F). Air monitoring equipment indicated that agent volatilization began almost immediately and reached a peak approximately 40 minutes after reaching 750 degrees F. Analysis of the test structures also revealed that no HD residuals existed above the detection limit (verified to be 500 parts per billion) after exposure to the hot gas process. Overall the lot test served to demonstrate the effectiveness of the hot gas system and that engineering requirements had been sufficiently identified to move on to full scale field demonstration. Additionally, the pilot test demonstrated the fact that portable heating units could be used in the field and that the tailoring requirement identified in the energetics development could be met.

### **Field Demonstration**

Currently a full scale field demonstration is scheduled to begin in February 1993 at Rocky Mountain Arsenal. The selected test structure, the thaw pit contained in Building 537, was contaminated during the loading and demilitarization of H and HD munitions. The pit area is composed of concrete walls and floors (approximately eighteen inches thick) and steel piping and process equipment. The full scale demonstration equipment is currently being designed and sized for installation in the December time frame.

### **Available Documentation**

1. Final Technical Report: Development of Novel Decontamination and Inerting Techniques for Explosives-Contaminated Facilities, Phase I - Identification and Evaluation of Novel Decontamination Concepts, USATHAMA Report DRXTH-TECR-83211, July 1983.

2. Final Technical Report: Development of Novel Decontamination and Inerting Techniques for Explosives-Contaminated Facilities, Laboratory Evaluation of Concepts, Phase II - Laboratory Evaluation of Novel Explosives Decontamination Concepts, USATHAMA Report

AMXTH-TE-TR-85009.

3. Final Report: Development of Novel Decontamination Techniques For Chemical Agents (GB, VX, HD) Contaminated Facilities, USATHAMA Report AMXTH-TE-TR-85012, June 1985.

4. Final Technical Report: Decontamination of the Hot Gas Decontamination System For Chemical Agents, Task 3, USATHAMA Report CETHA-TE-CR-89168, August 1989.

5. Final Report: Contamination Assessment Report, Building 537, Rocky Mountain Arsenal, Colorado, USATHAMA Report CETHA-TE-CR-89167, June 1989.