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U.S. EPA R&D Program for Disposal of Building Decontamination Residue

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ABSTRACT

In the event of a terrorist attack on buildings, transportation hubs, or other structures where chemical or biological agents are used, significant quantities of building decontamination residue (BDR) can be generated during cleanup and restoration activities. This BDR primarily consists of porous materials formerly contained within the building, and although it has undergone decontamination, current sampling limitations prevent assurances that no remaining traces of the contamination agent is present in the BDR. In addition, the BDR could contain residual decontamination chemicals and decomposition by-products from the contaminating agent. The completion of the restoration process requires that the BDR be sent for ultimate disposal. Likely disposal options include high temperature thermal incineration, landfilling, and steam autoclaving. This paper describes the U.S. EPA's current program to 1) consolidate available information and lessons learned for BDR disposal into technical guidance for responders, permitting agencies, and the disposal industry; and 2) perform experimental research to help close existing data gaps.

INTRODUCTION

Because of the anthrax attacks on various government and news media buildings in 2001, the EPA created a new organization within its Office of Research and Development, the National Homeland Security Research Center (NHSRC). NHSRC provides R&D support to the Agency and other parts of the federal government to address issues related to the EPA's responsibilities under Homeland Security Presidential Directives (HSPDs) 7, 8, 9, and 10 (1, 2, 3, 4):

- HSPD 7: Critical Infrastructure Identification, Prioritization, and Protection - Specifically designates EPA as the agency responsible for infrastructure protection activities for the nation's drinking water and wastewater systems.
- HSPD 8: National Preparedness - Establishes policies to strengthen the preparedness to prevent and respond to threatened or actual domestic terrorist attacks, major disasters, and other emergencies by establishing mechanisms for improved delivery of federal preparedness assistance to state and local governments.
- HSPD 9: Defense of United States Agriculture and Food - EPA is to develop a robust, comprehensive surveillance and monitoring program to provide early warning in the event of a terrorist attack using biological, chemical, or radiological contaminants. HSPD 9 also directs EPA to develop a nationwide laboratory network to support the routine monitoring and response requirements of the surveillance program.
- HSPD 10: Biodefense for the 21st Century - Provides directives to further strengthen the Biodefense Program through threat awareness, prevention and protection, surveillance and detection, and response and recovery.

The work related to restoration of buildings is being performed in NHSRC's Decontamination and Consequence Management Division (DCMD, formerly the Safe Buildings Program) located in Research Triangle Park, NC.

After a building has gone through decontamination activities following a terrorist attack with chemical warfare (CW), biological warfare (BW) agents, or toxic industrial chemicals (TICs), there will be a significant amount of residual material and waste to be disposed. This material is termed "building decontamination residue" (BDR). Although it is likely that the BDR to be disposed of will have already been decontaminated, the possibility exists for trace levels of the toxic contaminants or their by-products, to be present in absorbent and/or porous material such as carpet, fabric, ceiling tiles, office partitions, furniture, and personal protective equipment (PPE) and other materials used during cleanup activities. There could also be wastes from the decontamination process itself, such as scrubber slurries or activated carbon from scrubbers used to remove fumigants such as chlorine dioxide (ClO_2) from the buildings. In addition, there may be additional contaminated materials such as carbon adsorption beds and high-efficiency particulate arrestant (HEPA) filters from the building's heating, ventilation, and air conditioning (HVAC) system. It is likely that much of this material will be disposed of in landfills or high-temperature thermal incineration facilities, such as medical/pathological waste incinerators, municipal waste combustors, and hazardous waste combustors.

Disposal is the final step in the restoration process, after the initial response and decontamination activities have taken place. However, issues related to disposal are inextricably linked with the entire process that came before, including:

- Impact of event containment activities on waste quantities and level of contamination
- Impact of decontamination technologies on waste quantities and characteristics
- Impact of tradeoffs between decontamination costs and disposal costs
- Impact of decontamination effectiveness and residual contamination levels on waste classification for transportation and disposal

In May 2003, a workshop was held in Cincinnati, OH, which brought together various stakeholders to discuss issues related to BDR disposal (5). In response to this workshop, DCMD initiated a research program to 1) consolidate available information and lessons learned for BDR disposal into guidance for responders, permitting agencies, and the disposal industry; and 2) perform experimental research to help close existing data gaps.

This research program is moving forward under the assumption that the disposal of all the BDR will be done in accordance with existing regulations. This would include: proper transportation to the disposal site as defined in U.S. Department of Transportation (DOT) rules; proper packaging and handling of the materials as per the Occupational Safety and Health Association (OSHA), and the operational permits of the disposal facilities as governed by RCRA and the Clean Air Act.

The primary clients for this program will be: 1) emergency response authorities who have to decide the most appropriate decontamination methods and disposal of the resulting residues; 2) state and local permitting agencies, who have to make decisions about which facilities will be allowed to dispose of the materials; and 3) the waste management industry, that needs to safely dispose of BDR without affecting the operation of its facilities and without violating any of its environmental permits.

The issues related to disposal of BDR are being investigated using experimental and theoretical approaches as well as by gathering available information from publicly available sources. The goal of this effort is to develop a comprehensive decision-support tool from which the available technical information can be used to help relevant parties plan for disposal activities, evaluate alternatives, and make preliminary decisions during the crisis management phases of a response activity, and to aid in the decision-making process in the consequence management phase of the response activity.

The information needed to plan and carry out disposal activities, and anticipated sources for that information are listed in Table 1. Some of the information can be found in parts of the U.S. Environmental Protection Agency such as the Office of Solid Waste (OSW) or the Office of Air Quality Planning and Standards (OAQPS). Other government agencies such as DOT, Department of Defense (DoD), the Centers for Disease Control (CDC), or the National Institute of Occupational Safety and Health (NIOSH) may have some of the information. Other valuable information sources may include industrial stakeholder groups such as the Integrated Waste Services Association (IWSA), the National Solid Waste Management Association (NSWMA), or the Coalition for Responsible Waste Incineration (CRWI), groups of state regulators such as the Association of State and Territorial Solid Waste Management Officials (ASTSWMO), or professional organizations such as the American Society of Mechanical Engineers (ASME) or the Air and Waste Management Association (AWMA), or the Solid Waste Association of North America (SWANA). Some information is available by adapting methods that are used in similar situations (e.g., Superfund cleanups, asbestos remediation, oil spill cleanups). Some of the critical information is not available from any source. This information will be developed through an experimental and theoretical approach.

Table 1. Information needed for disposal activities and likely sources of that information

Information	**Source**
Regional capacity/locations of disposal facilities	EPA/OSW, EPA/OAQPS, ASTSWMO, IWSA, NSWMA, SWANA
Incinerator design/operation criteria	ASME, AWMA , CRWI, IWSA, EPA/OSW, EPA/OAQPS
Landfill design/operation criteria	EPA/OSW, NSWMA, SWANA
Transportation and packaging	DOT, CDC
Environmental regulatory issues	EPA/OSW, EPA/OAQPS, ASTSWMO
Worker safety issues	CDC, NIOSH
Thermal destruction behavior of CW/BW contaminants in BDR	DoD, Experiments, modeling
Landfill behavior of CW/BW contaminants bound in BDR	Experiments, modeling
Performance of autoclaves on contaminated BDR	Experiments

The next sections of this paper will discuss in detail the various activities that are being undertaken in the DCMD waste disposal program.

PROGRAM DETAILS

Figure 1 shows a diagram of the various elements of the waste disposal program and how they interact with each other.

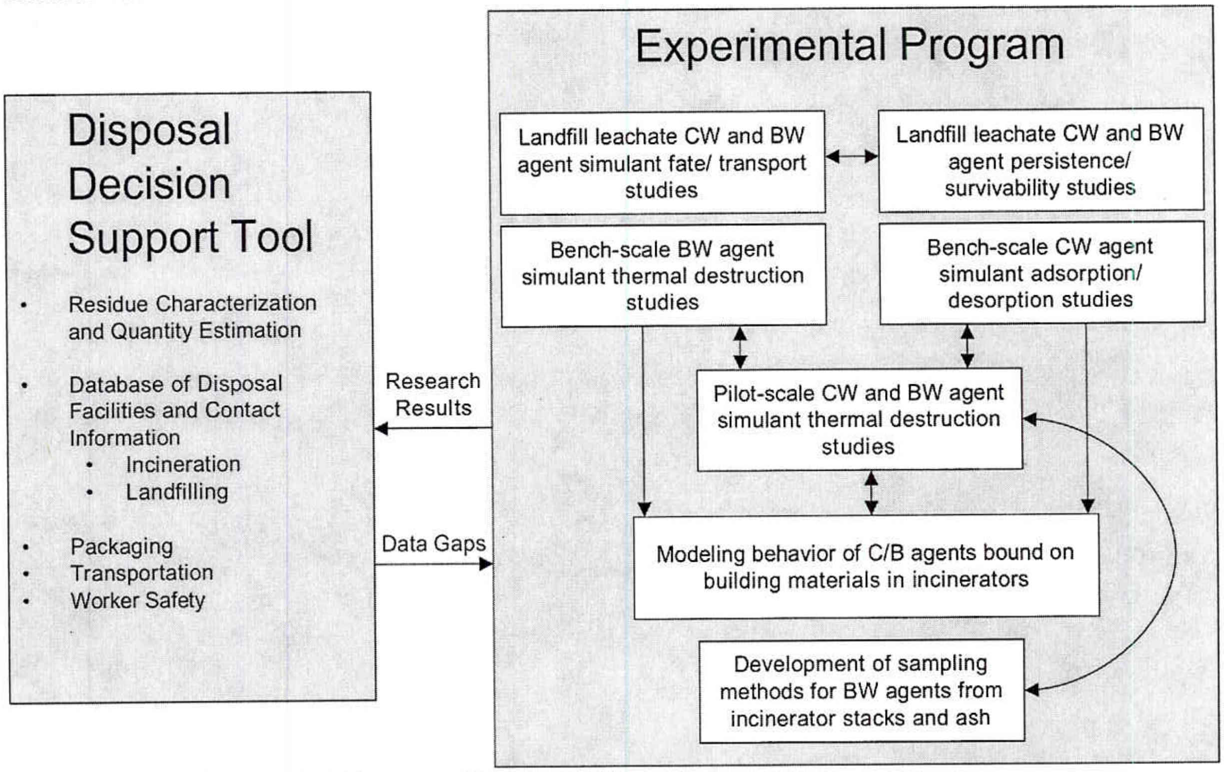

Figure 1. Diagram of DCMD Waste Disposal Program Elements.

Online Decision Support Tool

As an emergency response activity unfolds, the responders will be confronted with decisions that will impact the cost and timing of the restoration of the building to normal operation, perhaps in a significant manner. Unnecessary delays and excess expenses in the disposal process are not in the best interests of the contaminated site, the various stakeholders, the government, or the public. This program is developing an online decision support tool (DST) in partnership with industry, state and local government, and federal agencies.

Data has been collected from the open literature, from state and federal regulatory agencies, and from landfill and incinerator industry stakeholder groups, to develop technical guidance for disposal of BDR and related residues. This project addresses the following issues:

- Estimation of BDR quantities and characteristics
- Available disposal options and capacity for the different categories of BDR on a geographical basis (currently limited to incinerators and landfills)
- Contact info for the potential disposal facilities
- Expected behavior of the BDR in the selected facility

- On-site preprocessing of BDR to make the material more amenable for disposal in a given facility
- Packaging to minimize risk to workers handling the BDR, to the disposal facility workers, and to people along the transportation route to the disposal facility, and to minimize potential for contaminating the disposal facility
- Issues related to transporting the BDR
- Minimum and optimum time and temperature requirements needed to destroy contaminants to ensure an adequate margin of safety to the public and to disposal personnel
- Characteristics of residues formed during the incineration process, and requirements for their safe disposal
- Fate and transport of these materials in a landfill environment
- Permit implications for facilities disposing of these materials

The information is available in a web-based application (access granted upon request to NHSRC) that will be centrally updated as new information becomes available, and old information (such as contact information for key personnel) changes.

Experimental Efforts

Some of the information needed to complete the decision support tool is not currently available. This includes information such as the behavior of CW/BW agents bound on BDR in a landfill or incinerator environment. Table 2 lists the various components of BDR material that will be examined during this R&D program and the agent surrogates/simulants that will be used in the event that it is not practical or possible to perform experiments with live agents. Contaminants will consist of various toxic industrial chemicals (TICs) to be used as simulants for CW agents, and spores such as *Geobacillus stearothermophilus*, an organism that is commonly used to verify performance of autoclaves for steam sterilization, will be used as BW agent simulants.

Table 2. Potential Substrates and Contaminants to be Tested

BDR Substrates	**CW agent simulants**	**BW agent simulants**	**TICs**
Carpeting	Dimethyl methyl phosphonate (DMMP)	*bacillus subtilis*	Monochlorobenzene
Ceiling tiles	Chloroethyl ethylsulfide (CEES)	*Geobacillus stearothermophilus*	Malathion
Wallboard	Ethylene glycol		
Particle board			
Activated carbon			

Landfill survivability/persistence and fate/transport studies

The fate and transport of BW and CW agents in landfill environments is not well established. A theoretical and experimental program is ongoing to evaluate movement and survivability/persistence of biological and chemical agents in the landfill environment. Modeling is being performed using equilibrium bounding calculations to help guide experimental designs. Initial experiments will examine whether BW agents are inactivated or if they exhibit growth in leachate, and to assess the potential for transport of BW and CW agents into landfill gas. The leachate survivability/persistence studies are being performed using live agents at a DoD facility, whereas the fate and transport studies will be performed using surrogate materials. These studies will answer the following questions:

- What is the likely mode of transport (air, waste, leachate) for chemical and biological agents within/from a landfill;
- How well will the landfill environment reduce the survival time/persistence of active agents and protect against survival of active agents;
- Can BW and CW agents be transported into landfill gas?

Bench-scale thermal treatment studies

The thermal destruction of building materials contaminated with CW and BW agents is complicated by matrix effects associated with the contaminant and the material on which it is bound. It is important to know the relative difficulty of destroying these toxic agents when bound on different materials to assure that minimum solid phase residence times will be achieved and so that residual solids (such as fly ash and bottom ash) and gaseous emissions leaving the system are free of contaminants. To provide guidance on minimum solid phase residence times, a fundamental knowledge must be gained of the combustion behavior of CW and BW agents bound on common building materials, and the desorption behavior of CW agents and TICs from building materials and filter media such as activated carbon.

Bench-scale research is being conducted using laboratory reactors to examine the destruction of surrogate biological agents (6) and the adsorption/desorption of surrogate chemical agents (7) that are present on or within several common building materials including carpeting, furniture and drapery fabrics, ceiling tiles, and wallboard. The effects of substrate material, time-temperature profiles, and furnace conditions are being investigated.

The results from these studies will be used to evaluate incineration technologies for appropriateness for disposal of contaminated building materials, and to generate information for modeling of the incineration process.

Pilot-scale incineration studies

Pilot-scale testing is being performed to provide scale-up from the bench-scale testing and to investigate issues related to operational difficulties that might result from burning larger quantities of building decontamination residues. The pilot-scale testing will be performed in the EPA's rotary kiln incinerator simulator (RKIS), a rotary kiln equipped with a secondary combustion chamber (SCC), each with a nominal firing rate of 73 kW (250,000 Btu/hr). The RKIS is capable of burning a variety of solid and liquid materials. Emphasis will be placed on minimum time/temperature environments required to assure adequate destruction of the contaminants, so that technical guidance may be given to facilities and permitting entities regarding proper incineration of waste materials recovered from building decontamination activities. This research will also examine the impact on air emissions from combustion of BDR.

Initial pilot-scale testing thus far has focused on issues related to combustion of carpeting, particularly on the potential impacts of carpet combustion on air permits granted under the Clean Air Act (8), and on destruction of spores bound in carpeting (9).

Modeling of BDR in Incineration Systems

In order to minimize problems associated with thermal destruction of CB-contaminated BDR, modeling will be performed to examine potential incinerator failure modes (defined as nonstandard operating conditions that result in incomplete combustion and excess emissions) that might arise. This modeling, using an approach developed for the U.S. Army chemical demilitarization program (10), couples computational fluid dynamics (CFD) with complex chemical kinetics to predict concentration distributions of contaminants and their combustion byproducts within the incinerator. Two common incinerator designs will initially be modeled: a modular starved-air incinerator design similar to that used for medical waste incineration; and a rotary kiln incinerator similar to those used for hazardous waste combustion. The bench- and pilot-scale experimental studies will be used to help develop the pieces of the model and to calibrate the models. Initial comparisons between model results and experimental results (9) have been promising (11).

Sampling and analytical methods development

Since the mobility of biological contaminants within landfills and thermal treatment devices has not been well explored, it is critical that sampling and analytical methods be available to determine efficacy of destruction and permanence of land disposal. Preliminary sampling and analytical methods (12) for some microorganisms have been developed for potential use on medical waste incinerator stack gases and ash residues, but these methods have not been validated, and have not been tested for some of the primary biological warfare (BW) agents of concern (e.g., anthrax). This project will adapt and expand upon existing sampling and analytical methods for BW agents in combustor stacks and ash residues.

The primary goals of this project are:

- Investigate relevant sampling/analytical measurements issues such as sample collection efficiency, stability, preservation, etc;
- Investigate/determine potential method detection limits;
- Develop a draft procedure suitable for field-testing.

Field Test at a Commercial Autoclave

Autoclaves are commonly used to perform steam sterilization of medical equipment and to dispose of regulated medical waste. It is unknown however, whether the standard practices for steam sterilization (121 °C for 15 minutes) are sufficient to kill pathogens bound inside porous materials like BDR. This project will test the performance of a commercial autoclave while processing BDR materials (carpet, ceiling tile, wallboard) packaged using various methods. Thermocouples will be used to measure the temperature of the BDR inside the autoclave and biological indicator strips containing *Geobacillus stearothermophilus* spores placed inside the bundles of BDR will be used to verify sterilization levels.

SUMMARY

The U.S. EPA's NHSRC initiated an R&D program to address issues related to disposal of residue resulting from decontamination of buildings after a terrorist attack with chem./bio agents or TICs. The target audience for this program will be: 1) the emergency response personnel who have to make decisions about decontamination methods and disposal of the resulting residues; 2) state and local permitting agencies, who have to make the decisions about which facilities will be allowed to dispose of the materials; and 3) the waste management industry, that needs to be able to safely dispose of the building decontamination residues without affecting the operation of its facilities and without violating any of its environmental permits.

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