

Remediation of *Bacillus anthracis* Contamination in the U.S. Department of Justice Mail Facility

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The U.S. Department of Justice (DOJ) mail facility in Landover, Maryland, was contaminated with *Bacillus anthracis* spores as a result of the 2001 anthrax bioterrorism attacks through the U.S. postal system. Surface environmental sampling within the facility indicated that the contamination was due to receipt of mail that had come in contact with *Bacillus anthracis* spores from the source letters at the Brentwood postal facility in Washington, DC. The DOJ adopted a two-pronged approach for remediating the facility, using aqueous chlorine dioxide to decontaminate hard, nonporous surfaces and paraformaldehyde to fumigate two pieces of mail equipment. Before the start of the remediation activities, all porous materials were removed from the mail area. Since all postremediation environmental samples were negative for growth of *Bacillus anthracis* spores, the remediation was judged to be effective. The facility remained closed for almost 4½ months. The cleanup activities took about 2½ months, with source reduction activities being the most time-consuming. Of the seven facilities that performed fumigations to remediate *Bacillus anthracis* contamination, the DOJ mail facility was the second building to be reopened.

LATE IN 2001, several terrorist attacks took place in which *Bacillus anthracis* spores were transmitted through the U.S. postal system. In at least two of the attacks, letters entered the mail system through the Trenton Processing and Distribution Center in Hamilton, New Jersey; the first set of letters went to media outlets in New York City, and the second letters were addressed to Senators Daschle and Leahy. A letter or package was sent to American Media Incorporated (AMI) in Boca Raton, Florida. Twelve cases of cutaneous anthrax and 11 cases of inhalational anthrax resulted from these attacks.^{1,2} Five of the people with inhalational anthrax died.

Numerous sites were contaminated with *B. anthracis*

spores either directly or through cross-contamination. Among the sites were media offices, postal facilities, office buildings on Capitol Hill, and private residences. The contaminated postal facilities included large processing and distribution centers such as the Trenton facility and the Brentwood Center in Washington, DC. Numerous smaller U.S. Postal Service (USPS) facilities also experienced contamination, as did a number of federal government mail facilities in the Washington, DC, area that were downstream of the Brentwood facility.

This article describes the remediation performed at the Department of Justice (DOJ) mail facility, known as the Landover Operations Center. The building is a one-story

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warehouse comprising 81,437 square feet of interior space located in an industrial park in Landover, Maryland. The DOJ used this facility to store equipment and office supplies, print documents, and process mail. The mail processing center comprises 8,806 square feet within the Landover Center.

Prior to October 2001, mail was received directly from the Brentwood Processing & Distribution Center in Washington, DC. Mail was delivered to the loading dock and then moved through an x-ray machine onto the automated mail sorter. The mail was opened by an Omaton stamping device machine and then transferred to mailboxes in the mail referral unit, a secure area with no traffic from other areas in the warehouse, to be reviewed prior to further processing.

The mail facility also contained a forms area where Code of Federal Regulations and other DOJ documents were stored on long metal shelves. In October 2001, 5 DOJ employees and 30 contractors worked at the Landover Operations Center. All of the DOJ employees and 21 of the contract employees were engaged in mail-related activities.

CHARACTERIZATION ENVIRONMENTAL SAMPLING

The DOJ closed the Landover Center on October 22, 2001, based on the diagnosis of four postal workers from the Brentwood Center with inhalational anthrax and the closing of that facility on October 21, 2001, and based on concern that federal mail facilities downstream of Brentwood might be contaminated. On October 24, 2001, the Federal Bureau of Investigation collected 32 dry wipe surface samples from high mail traffic areas within the mail room, several small adjacent offices (e.g., Accountable Mail), and the mail referral unit. Since this was an initial screening sampling event, samples were collected from work stations and mail slots within the mail traffic pattern, but not from the heating, ventilation, and cooling system. Samples were analyzed by the Special Pathogens Sample Test Laboratory, United States Army Medical Research Institute of Infectious Diseases (USAMRIID) using standard microbial procedures and confirmed with gamma phage testing.

Eight of the 32 samples were positive for growth of *B. anthracis* cells. Areas in the Landover Operations Center with positive results were those having direct contact with the mail. Positive samples were found in the following locations:

- Automated sorting machine in main mail room (1 positive sample)
- Accountable Mail Office (1 positive sample)

- Work stations within the mail referral unit (5 positive samples)
- Mail slot in the mail referral unit (1 positive sample).

To further characterize the contamination, the U.S. Public Health Service Division of Federal Occupational Health (USPHS/FOH) collected an additional 42 wet wipe samples on November 19, 2001, from louvers on the roof, the secure mail storage area, the warehouse, offices, hallways, restrooms, exhaust air grills, and the Omaton stamping device. Locations with positive samples from the FBI testing were not resampled; however, areas around those locations were sampled to determine the extent of contamination. Samples were analyzed by the Southern Research Institute (SRI) laboratory in accordance with the Centers for Disease Control and Prevention (CDC) protocol.³ Positive samples were sent to CDC for confirmatory analysis. Of the 42 samples collected, only 1 sample on the Omaton stamping device was confirmed to be positive; the samples from the 9 exhaust grills in three rooms, including the one above the Omaton device, were all negative.

Based on the results of all 74 samples, it was concluded that contamination was limited to surfaces that had come into direct contact with the mail in the mail referral unit, the main mail room, and the Accountable Mail Office, and that aerosolization of spores had likely not occurred. Hence, it was decided that fumigation of the entire Landover Operations Center was not needed.

SITE REMEDIATION

The DOJ decided on a two-pronged approach to decontaminating the facility—namely, treating nonporous surfaces in the contaminated area with aqueous chlorine dioxide, and then fumigating the two mail machines with paraformaldehyde. It was determined that the fumigant could migrate to hard-to-reach, nonporous surfaces in and on the equipment, which would have been difficult and more time-consuming to remediate using surface cleaning treatments alone.

Site Preparation Activities

Prior to starting the decontamination activities, a number of actions were taken to prevent further spread of *B. anthracis* contamination. The mail room was isolated from the rest of the Landover Center using poly barriers. Windows, external doors, and vents were covered with 14 mil black sheeting and tape. The HVAC system was confirmed to be turned off, and the mail room was closed to everyone except remediation workers. A three-stage airlock/decontamination station was constructed to pro-

vide access to the mail room and for the removal of essential items and waste materials from the containment area. Negative air machines were installed in the containment area to ensure that air pressure in the work area was negative to the outside. The tent for the fumigation of the mail machines was then constructed in the mail room.

Source Reduction Activities

Porous items, which were divided into essential documents and nonessential items, were then removed from the contaminated areas within the facility. The onsite treatment and eventual disposition of these two types of items were different. Essential documents were those that needed to be retained, including Freedom of Information Act documents, certified mail receipts, Codes of Federal Regulations, computer disks, notebooks, and rubber stamp inserts for the Omaton machine. These items were packaged in Tyvek bags for offsite treatment in an ethylene oxide sterilization chamber. Only the exteriors of the bags were treated with dilute bleach solution; the items were not pretreated with bleach because residual chlorine from such pretreatment could have interacted in a harmful way with the ethylene oxide. Twelve Gaylord boxes of essential items were treated with ethylene oxide.

Porous nonessential items (e.g., personal effects, desk-top items, paper) were sprayed with dilute bleach solution to minimize the spread of *B. anthracis* contamination and then placed in poly bags, the exteriors of which were also treated with bleach. Paper items constituted the majority of the nonessential items. Modular work stations and other porous furniture items were cleaned using high-efficiency particulate air (HEPA) vacuums, disassembled, and removed, as was carpeting. A total of more than five truckloads of porous nonessential items were processed in two medical waste incinerators.

Decontamination of Hard Surfaces with Aqueous Chlorine Dioxide

The DOJ selected aqueous chlorine dioxide as the surface antimicrobial cleaning agent based on its ease of application, successful decontamination of hard surfaces in buildings on Capitol Hill, and availability for prompt use. Since aqueous chlorine dioxide had not been registered for use as a chemical pesticide effective against *B. anthracis* spores, DOJ applied for and received a crisis exemption for its use from EPA on November 9, 2001.⁴ Airless sprayers were used to apply a mist of aqueous chlorine dioxide at a concentration of 500 mg/L to the surfaces. A contact time of at least 30 minutes was maintained, after which the surfaces were wiped with sterile cloths. Since chlorine dioxide breaks down when exposed to ultraviolet light, windows were covered with dark cloths. No procedures were used to control tempera-

ture or relative humidity of the environments being treated.

Treated surfaces included desktops, floors, counters, shelves, and portions of walls. The external and internal surfaces of all filing cabinets and drawers were also treated. Ladders and a man lift/moveable scaffold were used to reach high shelf areas and horizontal ledges. Ceilings, overhead light fixtures, and ducts were not treated, on the advice of the USPHS/FOH, nor were surfaces that were considered inaccessible or where there was low probability of contact with building occupants. Precleaning of certain surfaces (e.g., surfaces with significant amounts of dust) was performed using a colloidal micelle agent prior to the chlorine dioxide treatment.⁵ Treatment of surfaces with aqueous chlorine dioxide took place between February 13 and 18, 2002.

Monitoring for exposure to chlorine dioxide was conducted in areas external to the treatment area. The OSHA Permissible Exposure Limit of 0.1 parts per million (ppm) was not exceeded in the air samples collected in the uncontaminated areas.⁶ Sensidyne detector tubes were used to collect the air samples in the contaminated areas, and readings as high as 0.3 ppm were recorded there. These concentrations were not a significant concern, because workers applying aqueous chlorine dioxide in the contaminated areas wore personal protective equipment and powered air-purifying respirators with a protection factor of up to 1,000-fold. An evacuation plan was prepared prior to use of the chlorine dioxide in case concentrations outside the contaminated areas exceeded the permissible exposure limit, but activation of this plan was not required.

Paraformaldehyde Fumigation

Paraformaldehyde was chosen for the fumigation of the mail equipment based on its extensive history of effective treatment of *B. anthracis* spores and the well-defined application conditions for its use. The active fumigant, formaldehyde, is generated by heating the paraformaldehyde prills. The DOJ wanted this facility returned to operation quickly. Thus, a crisis exemption was issued on January 7, 2002, for the use of unregistered paraformaldehyde prills (CAS #30525-89-4), manufactured by Hoechst Celanese and containing 95% paraformaldehyde.⁷

A containment tent with a total volume of 8,330 cubic feet and a single stage air lock were constructed around the mail sorting machine and Omaton stamping device. The tent was taped in place to help ensure minimal leakage of the gas to the surrounding areas. A negative air machine equipped with HEPA filters and a remote on/off switch was connected to the tent, with flexible ducting to allow venting of the tent's atmosphere to the outside. An

exhaust fan connected to ductwork was used to help evacuate the tent following the fumigation process. Prior to the fumigation, the tent was tested for leaks. A non-corrosive smoke bomb was placed within the tent, and smoke was generated. The exhaust fan and emergency ventilation procedures were used to remove the smoke. No leaks were detected.

Frying pans connected to electric heaters and filled with paraformaldehyde prills were placed in the tented area. A relative humidity and temperature probe was placed in the tent through a port to continuously monitor those parameters throughout the fumigation cycle. No monitoring was performed of the formaldehyde concentration within the tent. Approximately 0.33 grams paraformaldehyde prills per cubic foot of space (about 2.75 kilograms) were placed in the frying pans in the tented area, which exceeded the guidelines calling for sublimation of 0.3 grams of paraformaldehyde per cubic foot of space,⁸⁻¹⁰ to compensate for concentration variances in the event that total sublimation did not occur. Three fans were used in the tent during the fumigation process to achieve distribution of the formaldehyde gas throughout the tented volume.

Pans containing ammonium bicarbonate (1.5 g per gram of paraformaldehyde) were also placed inside the tent for neutralization of the formaldehyde gas following treatment. The relative humidity in the tent was raised to at least 50%. The tent was then sealed, and heaters for the pans containing paraformaldehyde were turned on.

Following 6 hours of exposure to formaldehyde, the pans containing ammonium bicarbonate were turned on until sublimation was complete. Fifteen minutes later, the negative air machine was turned on for 1 hour to exhaust residual gas to the atmosphere. Clean makeup air was provided from outside the building. The mail sorting machine was then turned on for a brief period to allow reaerosolization of any *B. anthracis* spores remaining within the machinery. A second 6-hour fumigation cycle then ensued to help ensure total destruction of *B. anthracis* contamination within the tent. This yielded a total exposure time of 12 hours. Following the second treatment with ammonium bicarbonate, a small amount of residual powder from the reaction of formaldehyde with ammonium bicarbonate on the machines was wiped off with water. Biological indicators in the form of surrogate spore strips were not used as a measure of the effectiveness of the gas treatment.

As a part of the emergency response plan for the fumigation process, the OSHA Short Term Exposure Level of 2 ppm for formaldehyde¹¹ outside the tent was used as the action level for ceasing the fumigation. During the fumigation, formaldehyde samples were continuously collected using an MSA Formaldemeter, a real-time direct reading monitor. Concentrations ranged from 0.04 to

0.54 ppm, well below the action level.¹² The decontamination work plan specified that as the tent was evacuated, monitoring for formaldehyde was to take place outside the building downwind of the point of release at the rooftop. No data on such monitoring were provided.

No visible effects from formaldehyde contact with the treated machines (e.g., corrosion, pitting, discoloration) were observed following the fumigations, and the two machines functioned normally when put back into service.

QUALITY AND CLEARANCE ENVIRONMENTAL SAMPLING

During the remedial activities at the Landover Operations Center, the USPHS/FOH collected 70 environmental wipe samples from floor areas as part of a quality control program to confirm that workers were not tracking *B. anthracis* spores out of the containment area. All 70 samples collected between mid-December 2001 and mid-February 2002 were negative, providing evidence that the worker decontamination process was effective.

Following the decontamination, clearance environmental surface sampling was conducted in the containment area to check for viable *B. anthracis* spores. Of the 51 samples collected, 44 were wet wipe samples and 7 were HEPA-vacuum samples. The last set of 11 samples was taken in the tent following the fumigation process; they consisted of seven wipe and four vacuum samples. All 51 samples were negative for growth of *B. anthracis* cells.¹²

TIME FRAME FOR DECONTAMINATION ACTIVITIES

The time from closing the Landover Center to its reopening (October 22, 2001–March 4, 2002) was almost 4½ months. The duration of all the remediation activities (December 12, 2001–February 26, 2002) was about 2½ months.

The remedial process for the DOJ mail facility took longer than originally anticipated, mainly because of the need to remove more porous material from the facility than projected. Source reduction activities lasted about 1½ months. Overall, the fumigation process took about a week, including the time needed to construct the tent early in the cleanup process. The actual fumigations were performed over a 2-day period. Figure 1 presents the time line from the passage of the *B. anthracis*-contaminated letters through the Brentwood facility to the reopening of the Landover Operations Center.

The treatment of the essential porous items with ethylene oxide in an offsite sterilization chamber took place in

FIGURE 1. TIME LINE OF EVENTS RELATED TO THE DOJ DECONTAMINATION PROCESS

Date	Event
October 11–12, 2001	<i>B. anthracis</i> –contaminated letters to Senators pass through Brentwood facility
October 15, 2001	Letter to Senator Daschle opened in his office in Hart Senate Office Building
October 19–21, 2001	Four postal workers at the Brentwood facility hospitalized with inhalational anthrax
October 21, 2001	Brentwood facility closes
October 22, 2001	DOJ facility closes
October 24, 2001	FBI/Prince Georges County (Md.) HAZMAT team collect samples in DOJ facility
November 19, 2001	USPHS/FOH collects additional samples
December 7, 2001	Public Notice issued by DOJ communicating discovery of contamination at Landover Operations Center and future remediation that will occur there
December 12–17, 2001	Cleanup activities begin. Personnel decontamination station constructed in Landover Center; workers briefed
December 18–20, 2001	First team enters hot zone to set up negative air machines and poly barriers to section off work area
December 21, 26–28, 2001	Construction of fumigation containment tent
December 31, 2001; January 3–17, January 22– February 12, 2002	Bagging/removal of porous essential and nonessential items from facility
January 17, 22, 29, 2002; February 11, 2002	Truckload of waste transported to Virginia waste incineration facility on each date
February 13–18, 2002	Decontamination of nonporous items with aqueous chlorine dioxide
February 14, 2002	Clearance sampling performed in mail referral unit area
February 18, 2002	Clearance sampling performed in main mail room and Accountable Mail Office
February 19, 2002	Preparation of tent for paraformaldehyde fumigation; smoke test in tent
February 20–21, 2002	Paraformaldehyde fumigation of two mail machines in tent
February 22, 2002	Clearance sampling performed within tent
February 26, 2002	Demobilization of site
February 28, 2002	Truckload of waste to Fort Detrick
March 4, 2002	Landover Operations Center reopened

Fall 2002, after DOJ received a separate crisis exemption from EPA for the treatment.¹³

COST CONSIDERATIONS

The overall cost of the remediation was \$463,916 (Table 1). The total cost of environmental sampling and analysis was \$51,334, with costs of \$4,763 for preremediation sampling and \$46,571 for the subsequent environmental sampling, including the 70 quality control surface samples, 51 clearance surface samples, and ambient air monitoring for chlorine dioxide and formaldehyde.

The total amount paid to AEG, the cleanup contractor, through a fixed-price contract, was \$238,850. The cost for the offsite treatment of essential items with ethylene oxide was \$81,858; an additional \$3,078 was expended for the construction of Gaylord boxes to transport these items.

The DOJ experienced additional costs not directly related to the remediation of the facility, which are not shown in Table 1. These costs arose because the DOJ mail operations had to be relocated during remediation activities. The total of these additional business continuity costs, including rent and related expenditures, through April 2002 was \$253,552.

DISCUSSION

Fumigation-Specific Issues

Paraformaldehyde has been routinely used for decades to decontaminate biosafety hoods and research and clinical laboratories.^{10,14} It was also used to fumigate containment facilities and buildings used in the U.S. biowarfare program prior to its termination.¹⁵ It was employed to decontaminate at least one textile mill that processed goat

TABLE 1. SUMMARY OF COSTS ASSOCIATED WITH THE REMEDIAL INVESTIGATION OF LANDOVER OPERATIONS CENTER

	<i>Activity</i>	<i>Cost</i>	<i>Total</i>
Preremediation	FBI (32 samples)	\$1,260	
sampling	USPHS/FOH (42 samples)	\$3,503	
Postremediation	USPHS/FOH (70 QC	\$46,571	
sampling	samples plus 51 postremediation samples)		
Total			\$51,334
Disposal	AWI, Inc.	\$26,761	
	Fort Detrick (miscellaneous)	\$8,200	
Total			\$34,961
Remediation	AEG Fixed Price Contract	\$210,950	
	AEG (contract scope modification granted by DOJ)	\$27,900	
	USPHS/FOH Oversight	\$53,835	
	Gaylord Boxes	\$3,078	
Total			\$295,763
Decontamination offsite	Essential Paper Documents	\$81,858	\$81,858
TOTAL CLEANUP COST			\$463,916

hair¹⁶ and a biomedical research laboratory facility in Reston, Virginia, contaminated with Ebola virus.¹⁷

Paraformaldehyde has been demonstrated to be an effective biocide, killing both vegetative cells and endospores.^{10,14} A standard has been issued by the National Science Foundation/American National Standards Institute for the use of paraformaldehyde to decontaminate Class II biosafety cabinetry,⁹ and the National Institutes of Health recommended formaldehyde as the chemical of choice for space disinfection in its 1979 Laboratory Safety Monograph.⁸

Paraformaldehyde is not recommended for fumigating porous surfaces because it does not appear to penetrate surfaces efficiently.^{8,14,18} In addition, polymers may be formed in porous materials, inhibiting further fumigant access.¹⁹

The four process variables—concentration, contact time, temperature, and relative humidity—are key determinants of the efficacy of fumigation processes. A concentration of 0.3 g of paraformaldehyde per cubic foot of space to be fumigated has been recommended by a number of organizations.^{8,9,20} More than 0.3 g formaldehyde per cubic foot of space was used in the tent to account for potential losses from incomplete sublimation.

Requirements for contact time of formaldehyde gas with contaminated areas vary from a minimum of 2 hours⁸ to at least 6 hours and preferably overnight,⁹ to 12-

hour exposures¹⁰ and even to 16–18 hours.^{21–23} The total exposure time of 12 hours at the Landover Center was in the midrange of recommended contact times.

Further, using an experimental protocol that specified two fumigations of 6 hours each with operation of the mail sorting machine between the fumigations was advantageous to the cleanup process. Running the machine between the fumigations increased the probability that aerosolizable spores would be accessible for treatment during the two fumigations.

The recommended temperatures range from a minimum of 20°C⁸ to a maximum of 28°C.^{9,14,22} Recommendations of optimum relative humidity vary from below 63%^{10,22} to at or above 70%.^{8,14,20} The relative humidity within the tent was raised to at least 50%, in accordance with U.S. Naval Military Research Institute guidelines.¹² The minimum relative humidity for this cleanup was lower than those specified in all but one source.

Formaldehyde is an acutely toxic and irritating compound, as well as a probable human carcinogen.^{24,25} The treatment with ammonium bicarbonate effectively removed it, preventing significant exposure to cleanup workers and mail workers upon their return to the facility. Also, at the Landover Operations Center, for each gram of paraformaldehyde used, 1.5 gram of ammonium bicarbonate was added for neutralization purposes. This

was more conservative than the NIH guidelines⁸ and the USAMRIID regulation,¹⁰ which specify the use of 1.1 gram for each gram of paraformaldehyde.

Biological indicators consisting of surrogate spore strips are ordinarily used as one important measure of the efficacy of the fumigation process, but such strips were not used in this fumigation process. This was not in keeping with guidance in the National Response Team (NRT) Technical Assistance Document for anthrax cleanups, which recommends the use of spore strips to assess the efficacy of building fumigations.²³ Further, spore strips were used in the other six facilities at which fumigations were performed for anthrax contamination. In addition, the USAMRIID regulation for containment areas prescribes the use of two types of spore strips.¹⁰ However, neither the NSF standard⁹ nor the NIH guideline⁸ calls for the use of biological indicators.

Nevertheless, all 11 clearance environmental samples collected in the containment tent were negative for the growth of *B. anthracis* cells, as were the other 40 clearance environmental samples. At the six other sites with fumigations, the ultimate criterion of effectiveness of the cleanups was no growth of *B. anthracis* cells from all postremediation environmental samples.²⁶ Hence, the fumigation with paraformaldehyde met the ultimate criterion for effectiveness employed for the anthrax cleanups.

Surface Decontamination Agents Used at Landover

Aqueous chlorine dioxide was used for decontamination of nonporous surfaces in the Landover Center. Chlorine dioxide is a yellow-green gas at room temperature with an odor similar to that of chlorine. It contains one atom of chlorine and two atoms of oxygen, and it exists almost totally as a free radical monomer. It is a strong oxidizing agent that is soluble in water and quite stable in solution at neutral pH, in the absence of light and at room or lower temperatures.²⁷ It must be prepared shortly before use. At the Landover Center, actions were taken to block out light in the containment area during the aqueous chlorine dioxide treatment.

Aqueous chlorine dioxide was first registered in 1967 for use as a sanitizer and disinfectant. The EPA has tested the efficacy of liquid chlorine dioxide against *B. subtilis* spores on hard, nonporous surfaces and determined that a concentration of 500 ppm chlorine dioxide is effective after a 30-minute contact time.²⁸

As part of the source reduction process, diluted sodium hypochlorite solution (bleach) was applied to the surfaces of nonessential porous items and to the exteriors of all bags containing porous items prior to their removal from the facility. Sodium hypochlorite is a basic, yellowish liquid that is a strong oxidizer. It dissociates in water

to form hypochlorous acid, a moiety with strong antimicrobial properties. Bleach was first registered for use as an antimicrobial pesticide in 1957. Because bleach is effective against a wide range of microorganisms, it is registered for many uses such as sanitization and disinfection of household premises, food processing plants, and agricultural settings.²⁹ The microbiocidal efficacy of sodium hypochlorite on hard, nonporous surfaces is enhanced significantly when the pH of the diluted solution is adjusted to 7.³⁰ However, this solution was not effective on porous surfaces.

Overall Landover Remediation Process

Source reduction activities at the Landover Operations Center took a month and a half (Figure 1), consuming the most time of all site remediation activities. This is consistent with the experience at other facilities at which fumigations took place. For example, at the State Department mail facility in Sterling, Virginia, source reduction activities took 8 months, while the fumigations with vaporized hydrogen peroxide took place over a 2-month period.³¹ The significant time required for source reduction activities needs to be factored into decontamination plans for future events. Thought also should be given to reducing the load of porous items in facilities, where possible.

The USPHS/FOH oversaw the activities of AEG, serving in a quality assurance capacity. The USPS used a similar approach in the cleanup of the Morgan Processing & Distribution Center in New York City, through which the contaminated letters to the New York media outlets passed.³² Having an independent contractor oversee the activities of the prime cleanup contractor provides additional confidence that the remediation has been effective.

Waste disposal was an important issue during the cleanup, both in terms of total cost and availability of sites to accept the waste. The disposal cost of nearly \$35,000 does not include the costs of treating and packaging waste prior to transport to the waste disposal facility. These costs were included in the overall remediation costs. The facility initially designated to accept the waste had already received significant amounts of waste contaminated with *B. anthracis* spores from another site and could not process all the waste in the needed time frame. Thus, arrangements had to be made with another facility that ultimately received about 80% of the Landover Center waste (Table 1). The significant cost of waste disposal and the willingness of facilities to accept waste contaminated with *B. anthracis* spores were issues that had to be addressed at all sites that underwent fumigations following the 2001 anthrax attacks. Developing a waste disposal strategy will be an important aspect of preparedness planning for future cleanups.

Fumigation Experience in Response to 2001 Anthrax Attacks

Fumigations were performed at five mail facilities and two office buildings in response to the 2001 attacks. Three different agents were used—namely, paraformaldehyde, gaseous chlorine dioxide, and vaporized hydrogen peroxide. Paraformaldehyde was used at Landover, vaporized hydrogen peroxide was used at two facilities, and chlorine dioxide was employed at the remaining four facilities. The volumes fumigated at one time ranged from 8,300 cubic feet at Landover to over 14 million cubic feet at Brentwood.²⁶

Landover was the second facility returned to productive use. The Hart Senate Office Building was the first site to be reopened. Fumigations at two of the other sites took place in 2002; two more were fumigated in 2003. The fumigation of the last site, the privately owned AMI Building, took place in July 2004.

The cleanups involving fumigations have been quite costly. The cleanup cost of the Landover Center was by far the least expensive. The remediation of the office buildings on Capitol Hill cost about \$28 million, and the cost for remediating the Brentwood and Trenton Centers was about \$200 million.³³

A key lesson learned from the 2001 anthrax attacks is that remediations that include fumigations are complex, time-consuming, and costly processes.

CONCLUSIONS

Environmental sampling played a key role in the Landover remedial process at a number of stages. The DOJ decided to perform mainly a surface cleanup based on the results from the 74 surface samples collected during two initial rounds of environmental sampling. The negative results from all 51 clearance environmental samples served as the basis for the conclusion that the overall remediation was effective. The DOJ decided to fumigate the two mail machines and selected paraformaldehyde based on its long record of safety and efficacy for decontaminating equipment and facilities.

The total cost of remediating the Landover Operations Center was about \$464,000. The Center was closed for nearly 4½ months after the discovery of *B. anthracis* contamination. The remediation took about 2½ months. The DOJ remediation met its goal of eliminating detectable *B. anthracis* contamination and returning the Landover Center to operation in a relatively short period of time at a reasonable cost.

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