Biosecurity and Bioterrorism: Biodefense Strategy, Practice, and Science
Volume 10, Number 1, 2012 © Mary Ann Liebert, Inc.
DOI: 10.1089/bsp.2010.0053

BSP-2010-0053-ver9-Schmitt_1P

# Total Decontamination Cost of the Anthrax Letter Attacks

Ketra Schmitt and Nicholas A. Zacchia

All of the costs associated with decontamination following the 2001 anthrax letter attacks were summarized, estimated, and aggregated based on existing literature and news media reports. A comprehensive list of all affected structures was compiled. Costs were analyzed by building class and decontamination type. Sampling costs and costs of worker relocation were also included. Our analysis indicates that the total cost associated with decontamination was about $320 million.

In September and October of 2001, 7 letters containing *Bacillus anthracis* (ie, anthrax) were sent to political and media targets throughout the eastern United States.[1] The event was the first of its kind, and remediation efforts took years. Previous studies have addressed the potential cost of a large-scale anthrax attack, indicating the possibility for devastating decontamination costs.[2,3] However, no complete accounting of decontamination costs associated with the anthrax letter attacks exists.

This is the first of a series of articles aimed at estimating the total economic impact of the anthrax letter attacks, and the focus of this article is solely on decontamination. Establishing the total costs associated with decontamination is especially difficult given the scarcity of data surrounding the events. Nevertheless, understanding the costs of this decontamination effort is important for informing decisions on antiterrorism policy and for developing decontamination policies for future bioterror events. This article serves to bridge the current knowledge gap by quantifying the costs specifically associated with the decontamination efforts necessitated by the anthrax letter attacks, commonly referred to by their U.S. Federal Bureau of Investigation (FBI) case name, Amerithrax.

Decontamination took many forms at the various sites and included extensive sampling. Areas producing positive samples were cleaned and resampled. In some cases, sensitive or important items were taken offsite and cleaned using nondestructive methods such as chlorine dioxide gas, ethylene oxide, and irradiation.[4,5] Irradiation is an effective decontamination technique; however, it is expensive and can damage some materials, including electronics. Other sites were cleaned with bleach, liquid chlorine dioxide, an antimicrobial pesticide, or Sandia foam.[4] These wet methods disinfect surfaces through a number of biological and/or chemical processes. The efficacy of a particular chemical depends on the surface to which it is applied, the concentration of anthrax spores, and the time period over which it is left on a surface. Large or highly contaminated sites were fumigated with chlorine gas, vaporized hydrogen peroxide, or paraformaldehyde. These are vaporous methods in which gas is released in a confined space to decontaminate material that cannot be cleaned by other methods, such as porous materials or materials sensitive to wet methods. Vaporous methods were also used when large volumes needed to be decontaminated. Finally, HEPA vacuuming was used to remove spores without re-releasing, since HEPA filters have openings smaller than the smallest anthrax spore.[4] These are all of the decontamination techniques employed following the anthrax letter attacks.

In 2001, significant uncertainty existed regarding decontamination efficacy and/or safety for all of these contaminants.

Ketra A. Schmitt, PhD, is an Assistant Professor, Centre for Engineering in Society, Concordia Institute for Information Systems Engineering, and Nicholas A. Zacchia is an Undergraduate Research Assistant, Mechanical and Industrial Engineering; both are with the Faculty of Engineering and Computer Science, Concordia University, Montreal, Quebec, Canada.

Subsequently, EPA conducted benchmark testing and issued crisis exemptions for their use during the Amerithrax events.

In this article we focus solely on the Amerithrax events and attempts to estimate total costs of the associated decontamination. The results from this work can be used to inform cost models that pertain to future, potentially larger attacks; however, the goal of this article is solely to assess costs from this single historical event. Understanding the costs associated with the anthrax letter attacks is important for policymakers and government agencies to be able to effectively plan for future events. It is clear that extrapolating from the anthrax letter events to future bioterror events will be difficult; decontamination costs stemmed from the particularities of the attack and the affected businesses. In particular, the United States Postal Service (USPS) and office workers (including those on Capitol Hill) can fairly easily move operations to another site, but other types of businesses are less flexible and may not be able to function during a closure.

We aggregate decontamination costs in order to construct an overall estimate. The results of this and subsequent research will form the basis of a comparison of costs associated with the Amerithrax events and the policy responses to those events. Since the anthrax letter attacks presented novel decontamination challenges, much of the subsequent work relied on learning and developing specific decontamination experience and knowledge. Therefore, results can be used to assess the relative costs of decontamination methods and to test whether learning or economies of scale occurred.

## Methodology

Because of our interest in the policy implications of the Amerithrax events, we chose to use the higher cost estimates when equally valid, competing estimates exist. Using the higher estimate provides a best case for the value of the policy intervention, the ultimate goal of this series of articles.

The literature includes a variety of methodological frameworks to estimate the economic impact of a terrorist event, including input-output (I-O), computable general equilibrium models (CGE), and modifications of both to estimate lost productivity and incorporate behavioral impacts.[6-8] Several articles have evaluated aspects of decontamination costs following the Amerithrax events.[9-11] A National Academies panel reviewed the events and used these to suggest future protocols for reopening facilities as well as policy improvements for developing and maintaining up-to-date decontamination standards.[12] These efforts are an important part of understanding the potential for avoided costs in developing antiterrorism policy. When creating estimates of past economic harm, however, a first step is to understand exactly what direct costs occurred. This article seeks to do just that for the decontamination costs associated with the Amerithrax events.

We developed the following approach for determining these costs. First, we determined, by consulting government and news reports, which buildings were contaminated and what type of remediation was used. We cross-checked building names by address to eliminate double counting. The Government Accounting Office (GAO) compiled contracting data for decontamination on Capitol Hill, which was a particularly important resource for this and subsequent steps. Next, we compiled existing cost estimates as reported in government documents and news reports. We next contacted affected parties for specific decontamination and cost information. We then contacted GAO to request background information on buildings for which more data was required.

No nongovernment parties responded to our requests for information, and GAO record retention policies are such that data are no longer available beyond their published reports. Thus, no cost estimates were located for a number of buildings. Therefore, we constructed cost estimates by using existing data. We also used this method to compare costs between buildings for which data were available. For both missing data and comparison purposes, we applied learning factors from the literature. We calculated cost estimates on a per building basis and discussed the merits and drawbacks of calculating costs on a square footage basis.

A key challenge in this research was identifying reliable data. We define reliable data as data that can be verified in more than 1 source. Where multiple estimates exist, we picked the most recent source, the source from a peer-reviewed journal, GAO report, or court testimony.

## Data

Tables 1 and 2 contain a complete list of contaminated buildings. Table 1 lists 7 fumigated buildings, and Table 2 lists 35 nonfumigated buildings. Decontamination cost estimates were available for 6 fumigated buildings, 1 nonfumigated building, and an aggregate cost for 6 nonfumigated buildings located on Capitol Hill. These costs varied from $0.5 million to $130 million for fumigated buildings and $1.8 million to $15 million for nonfumigated buildings. (All costs are given in 2001 US dollars.) Both the average cost and standard deviation in cost were roughly an order of magnitude smaller for nonfumigated buildings (mean of $3.9 million and standard deviation of $4.9 million) versus a mean of $38 million and standard deviation of $52 million for fumigated buildings. Note that the standard deviation is larger than the mean in both categories. Costs for both classes are clearly heterogeneous.

We also explored the data on a cost per square foot basis. We were able to identify square footage for 11 buildings and estimate area for 2 remaining buildings based on the area of geographically similar buildings. For the 11 buildings for which area data were available, the mean building

Table 1. Fumigated Buildings Including Fumigation Type, Building Volume, and Total Cost per Affected Building

| *Building* | *Volume (in 1,000s ft$^3$)* | *Type of Fumigant* | *Area Fumigated* | *Known Cost (in $1,000s)* | *Cost per Cubic Foot* |
|---|---|---|---|---|---|
| Department of State Annex 32 Mail Facility | 1,400[19] | Vaporized hydrogen peroxide (VHP) | Entire facility | $9,000[19] | $6.43 |
| GSA Building 410 (aka Anacostia Naval Yard Post Office) | 1,400[19] | VHP | Entire facility | | |
| Hart Senate Office Building | 90[19] | Chlorine dioxide | Part of two floors | $14,300[20] | $155.56 |
| Brentwood PDC (aka Curseen-Morris P&DC) | 14,000[19] | Chlorine dioxide | Entire facility | $130,000[2] | $9.29 |
| Trenton PDC (aka Hamilton Processing Facility) | 7,000[19] | Chlorine dioxide | Entire facility | $70,000[2,19] | $10.00 |
| U.S. Department of Justice Mail Facility (aka Landover) | 8.3[19] | Para-formaldehyde | Area around 2 mail sorting machines | $464[5] | $55.90 |
| AMI building | 670[19] | Chlorine dioxide | Entire facility | $5,000[12] | $7.46 |

size was 23 million square feet, and the standard deviation was 41 million square feet. While the sizes of the entire buildings are available, no data exist on the size of the area contaminated at each building. In some cases, it appears that most of the building was treated. In others, however, decontamination efforts were restricted to small areas of the building.

For fumigated buildings, estimating on a volume basis is feasible since the entire facility was fumigated in 5 out of 7 cases. Only the Hart Building and the Department of Justice mail facility had less than building-wide fumigation. In contrast, for nonfumigated buildings, the area(s) contaminated dictated how much remediation had to be done and generally how long it took.[10,13] The correlation between cleaning time and cleaning cost suggests that buildings that showed low contamination (1 or 2 positive samples) and were cleaned within a short time period (24 to 48 hours) were less costly to clean than buildings that showed dozens of positive samples and took weeks or months to clean.[10,13] Since the actual areas that were decontaminated are not available, there is little utility in considering decontamination efforts on an area basis; thus, estimates were based on per building cost.

## Identification of Buildings Remediated

Based on our review, at least 42 buildings had some contamination. No source found listed all contaminated buildings, and identifying unique contamination sites was complicated by the fact that at least 5 buildings are referred to by different names in different documents or simply by their location. When a building appears in the literature under different names, it is listed in the tables with an "aka" in parentheses. A comprehensive list of all buildings believed to have been contaminated is provided in Tables 1 and 2.

While testing was performed at 26 buildings around Capitol Hill, remediation was undertaken at just 7 locations: the P Street Warehouse, the Supreme Court Building, the Dirksen Building, the Ford Building, the Hart Building, the Longworth Building, and the Russell Building.[4] The Department of Justice (DOJ) Mail Facility was also heavily remediated.[5] Centers for Disease Control and Prevention (CDC) documents and news reports indicate that an additional 3 government facilities provided at least 1 positive sample: the Walter Reed Complex; the Bureau of Alcohol, Tobacco and Firearms; and the Washington, DC, Veterans Affairs Medical Center.[14] Our search of published CDC documents turned up no reports on either decontamination activities or costs for each location. Press reports from that time indicate that contamination at these facilities was extremely low. For example, a single detected spore was reported at the Walter Reed Complex.[15,16] From these reports, as well as the lack of documentation from government agencies, we infer that the scale of contamination and remediation at these sites was minimal and done at minimal cost.

Further, a majority of contaminated USPS buildings required only minimal decontamination.[10] Published

Table 2. Identification of Nonfumigated Buildings with Occupant Type and Square Footage

| *Nonfumigated Buildings* | *Occupant* | *Location* | *Area ($ft^2$)* |
|---|---|---|---|
| West Palm Beach Post Office PDC | USPS | 3200 Summit Blvd., West Palm Beach, FL | 185,000 |
| Blue Lake Post Office | USPS | 4560 Communication Ave., Suite 100, Boca Raton, FL | |
| Boca Raton Post Office | USPS | 301 S. Federal Hwy., Boca Raton, FL | |
| Greenacres Post Office | USPS | 4300 S. Jog Rd., Greenacres, FL | 30,661 |
| Lake Worth Post Office | USPS | 4151 Lake Worth Rd., Lake Worth, FL | 19,682 |
| Lucerne Post Office | USPS | 720 Lucerne Ave., Lake Worth, FL | 11,590 |
| Jackson Main Post Office | USPS | 4396 Lafayette St., Marianna, FL | |
| Princeton Post Office | USPS | 213 Carnegie Ctr., Princeton, NJ | |
| Princeton-Palmer Square Station Post Office | USPS | 20 Palmer Square East, Princeton, NJ | 920 |
| Rocky Hill Post Office | USPS | 130 Washington ST., Rocky Hill, NJ | 4,150 |
| Southern NJ PDC | USPS | 501 Benigno Blvd., Bellmawr, NJ | 375,500 |
| Trenton Station E Post Office | USPS | 20 S. Montgomery S., Trenton, NJ | |
| Dulles Post Office | USPS | Near Washington Dulles International Airport | 119,144 |
| Friendship Station Post Office | USPS | 4005 Wisconsin Ave., NW, Washington, DC 20016 | 26,133 |
| Pentagon Station Post Office | USPS | 3118 Washington Blvd., Arlington, VA | 33,774 |
| Raleigh PDC | USPS | 1 Floretta Pl., Raleigh, NC | 386,506 |
| Southwest Station Post Office | USPS | 45 L St., SW, Washington, DC | |
| Morgan Station PDC | USPS | 341 Ninth Ave., New York, NY | 2,100,000 |
| Indianapolis Critical Parts Center & Repair Facility | USPS | Near Indianapolis International Airport | 72,000 |
| Kansas City Stamp Fulfillment Services | USPS | 8300 Underground Dr., Pillar 210, Kansas City, MO | 300,000 |
| Southern Connecticut P&DC (aka Wallingford PDC) | USPS | 24 Research Parkway, Wallingford, CT | 350,000 |
| P Street Warehouse | Capitol Hill | Located on P St., Washington, DC | |
| Supreme Court Building | Capitol Hill | Corner of 1st St., NE, and East Capitol St., NE, Washington, DC | |
| Dirksen Building | Capitol Hill | Corner of 1st St., NE, and Constitution Ave., NE, Washington, DC | 750,520 |
| Ford Building | Capitol Hill | Corner of D St., SW, and 2nd St., SW, Washington, DC | 594,966 |
| Longworth Building | Capitol Hill | Corner of C St., SE, and S. Capitol St., SW, Washington, DC | 702,608 |
| Russell Building | Capitol Hill | Corner of Delaware Ave., NE, and Constitution Ave., NE, Washington, DC | 698,921 |
| Kuser Road Office Building | Corporate Office | Kuser Rd., Hamilton, NJ | |
| NBC Nightly News Office | Corporate Office | 30 Rockefeller Plaza, #701, New York, NY | |
| CBS News Office | Corporate Office | 524 W. 57th St., New York, NY | |
| ABC News Office | Corporate Office | 100 W. 43rd St., New York, NY | |
| New York Post Office | Corporate Office | 1211 Avenue of the Americas, New York, NY | |
| Walter Reed Complex | Government Mail Facility | 6900 Georgia Ave., NW, # 77, Washington, DC | |
| Washington, DC, Veterans Affairs Medical Center | Government Mail Facility | 50 Irving St., NW, Washington, DC | |
| Bureau of Alcohol, Tobacco and Firearms | Government Mail Facility | 99 New York Ave., NE, Washington, DC | |

reports indicate that either the U.S. General Services Administration (GSA) Building 410 in Anacostia or the post office in the Anacostia Naval Yard were decontaminated.[14,17] This is the only case where definitive data on building identity were not found. We assume these are the same building and treat them as such in our cost model.

Additionally, 6 corporate offices were found to have been contaminated with some amount of anthrax. These include the offices of NBC Nightly News, CBS News, ABC News, the *New York Post,* and American Media, Inc. (AMI). The sixth office building was the Kuser Road office building, likely exposed through cross-contaminated mail that resulted in 1 case of cutaneous anthrax.[18] No cost data are available for these buildings, with the exception of the cleanup costs at the AMI building, which was self-reported by the company that did the remediation. None of the companies above responded to our requests for data.

Twenty-three buildings produced positive environmental samples at USPS facilities.[13] At least 3 large Processing and Distribution Centers (PDCs) required extensive decontamination. Two of these, Brentwood and Trenton, required total fumigation because of evidence of aerosolization of anthrax spores. Costs for these 2 buildings were very high. A third PDC, Morgan Station, required more extensive and costly cleanup. The USPS reported 20 other buildings that tested positive for anthrax spores but generally had low levels of contamination, mainly through the handling of cross-contaminated letters. For many of these sites, "cleanup procedures were very limited, " with remediation restricted to disposal of a few contaminated items or treatment with a bleach solution of the area(s) that produced a positive sample.[10,13] Fourteen of these USPS sites produced only 1 positive sample.[13] (For a comprehensive list of contaminated USPS sites and remediation work done, see reference 13.)

## *Fumigated Buildings*

Reliable cost estimates for total decontamination efforts were found for 6 of the 7 fumigated buildings—all but GSA Building 410. Decontamination at these buildings involved partial to full fumigation, sampling both to ascertain the extent of decontamination and the effectiveness of fumigation, as well as removal and disposal of materials, surface cleaning, and the technical and administrative costs associated with these activities. No source was found that differentiated specifically between costs associated with fumigation versus costs associated with other types of remediation. The most detailed costing in the literature relies on contracts awarded to companies that used combinations of the remediation techniques listed above.[4,5]

Table 1 shows cost estimates for fumigated buildings on a volume basis. It shows that the Hart Building was the most expensive to fumigate per cubic foot if we divide total costs by area fumigated. However, much of the remediation at this site did not involve fumigation. As there are no records detailing the exact area contaminated, we assume that contamination was restricted to fumigated areas, which skews the cost per square foot since more than just the fumigated space was cleaned. The Hart Building was also the first to be fumigated and incurred high technical and support costs because no project of this type had ever been attempted. Additionally, one of the remediation goals was to open the facility as quickly as possible; therefore, work was conducted on a 24-hour basis.[19] The National Academies report states that the response on Capitol Hill was "uncoordinated, and it was marked by inconsistencies," which may partially explain the elevated costs.[12(p68)] A separate report, produced by the Government Accountability Office, found that while many uncertainties existed, the EPA "used its contracting capabilities effectively."[4(p4)] As GAO commended EPA on their contracting, the extra costs may have resulted from developing novel response protocols. Experience gained at this site may have helped guide the decontamination of other facilities, since many of the same companies contracted to do the cleanup here were involved in later cleanups elsewhere. "Remediation of the AMI and NBC buildings was done by private companies; EPA led the remediation effort in the Capitol and USPS buildings."[12(p56)]

Likewise, the costs for fumigating the DOJ Mail Facility appear high because at this site only a small volume around 2 mail sorting machines was fumigated, while the rest of the building was remediated using more conventional methods. The total costs including other types of decontamination are included in the sum, which is averaged over the small volume that was actually fumigated.

The DOJ mail handled cross-contaminated letters and had to be remediated. Work included cleaning with a bleach solution, disposal and incineration of nonessential porous items, decontamination of essential items and documents with ethylene oxide, and the fumigation of 2 mail sorting machines with paraformaldehyde, a total volume of about 8,000 cubic feet.[5] Remediation was involved and took about 2.5 months. Canter et al determined the total remediation cost of the site to be $460,000.[5] The DOJ Mail Facility was closed for 4.5 months, during which time normal activities were moved elsewhere, incurring an additional cost of $250,000.[5] Total cost for this extensive cleanup (involving fumigation), building closure, and relocation was $720,000, with over one-third of that cost due to relocating.

The other fumigated facilities were cleaned at a slower pace and benefited from previous experience with anthrax decontamination.[20] Cost per cubic foot for these buildings was much lower. From values for remediation costs and volume fumigated in Table 1, the price per cubic foot of fumigating with chlorine dioxide was between $7.50 and $10.00, while fumigation with vaporized hydrogen peroxide cost about $6.00 per cubic foot.

## *Nonfumigated Buildings*

Table 2 shows all nonfumigated buildings: 21 USPS buildings, 6 Capitol Hill buildings, 5 corporate office buildings, and 3 government mail facilities. Existing data on nonfumigated buildings includes $15 million for the Morgan PDC and a total cost of $2.1 million for 6 Capitol Hill buildings. Since the entire facilities were not decontaminated, considering data on a per square foot basis does not make sense. For these buildings, per square foot costs are $7.14 and $3.10, respectively. The high variance between these can be explained by several factors; most significant is the lack of knowledge about the actual area decontaminated.

## *Capitol Hill Buildings*

Collectively the cost of remediating the buildings on Capitol Hill was about $27 million.[4] These buildings are discussed separately from all others for a number of reasons. First, detailed contractual information is available for these buildings. More important, the cleanup cost for Capitol Hill buildings is likely significantly higher than it was for other comparable sites. The National Academies Board on Life Sciences conjectured that "[t]he high-profile users of the buildings undoubtedly created pressure to reopen the buildings quickly, yet a conservative definition of 'clean' was adopted by EPA. More important, there was a lack of a standard protocol to drive remediation, which in some cases led to repeated decontamination."[12(p66)]

Office buildings on Capitol Hill were reopened in a matter of 3 months, whereas some large USPS PDCs stayed closed for years. The standard for anthrax removal was initially considered to be "no detectable, viable anthrax spores."[4(p8)] As this is not possible to demonstrate, the EPA set the standard as "zero *B. anthracis* growth on any samples taken" and "[t]o ensure credibility, EPA took a large number of samples," more than 9,000.[12(p67)] By comparison, USPS took about 10,000 samples in total for its 23 contaminated buildings as well as the 286 other buildings it sampled.[21] This difference demonstrates an exacting standard of cleanup exercised on Capitol Hill.

In addition to the large number of samples taken on Capitol Hill, the comparatively quick turnaround, 24/7 cleanup schedule, media quotes, and public addresses assuring the public that they were safe, as well as the act of taking nasal swabs from anyone in the region who requested one, all demonstrate that more effort went toward remediating the Capitol Hill buildings.[4,12] Nasal swabs are a particularly good indication that extra care was taken on Capitol Hill, primarily because they were already known to have no diagnostic value and their function in the Capitol Hill cleanup was largely to "…convey[ed] the message that the hazard that building occupants might face was being taken seriously."[12(p68)] Comments made by a Capitol Police spokesman illustrate the prevailing sentiment: "It cost what it cost. The bottom line is we have to ensure the public safety."[22]

The only Capitol Hill facility fumigated was the Hart Senate Office Building, costing at least $14.3 million, approximately half of the $27 million Capitol Hill cleanup.[4,22] Therefore, each of the remaining 6 Capitol Hill sites cost about $2.1 million to decontaminate. At the Capitol Hill sites, technical contracts accounted for over 26% of total costs for nonfumigated buildings, while "technical contracts typically account for about 10 percent of total contract costs at a cleanup site."[4(p15)]

## *Corporate Office Buildings*

Corporate buildings affected by the Amerithrax attack included the offices of NBC Nightly News, CBS News, ABC News, the *New York Post,* and American Media, Inc., as well as an office building on Kuser Road, exposed through cross-contamination.[18] Of these buildings, the American Media, Inc., building, which housed the *National Enquirer* newspaper office, was the most contaminated. The owners of the building decided simply to move and sold the building for $40,000 to Sabre Technical Services, a company that was involved in remediation at USPS facilities.[23] According to a Sabre spokesperson, the building cost "significantly less than 5 million dollars" to decontaminate and they were able to sell it in 2007 for $9.3 million.[12,24] Details about the remediation done at this building were not released, and it is important to remember that Sabre Technical Services was the only stakeholder in this operation, likely expediting the decontamination effort. However, from this we can say that it is at least feasible to decontaminate a building like this for under $5 million. This value results in a fumigation cost of $7.70 per cubic foot. This is lower than the $9 to $10 per cubic foot for the Trenton and Brentwood PDCs and validates the idea that remediation (at least in theory) became easier and cheaper over time.

The offices of NBC Nightly News, CBS News, ABC News, and the *New York Post* were all contaminated; however, little public information is available on the extent of contamination or the cost of cleanup. Inquiries into the subject received no response. None of these sites showed evidence of aerosolized anthrax, nor were there any cases of inhalation anthrax associated with these sites. However, contamination seems not to have been localized. At NBC there were 3 areas contaminated by anthrax spores. They included the set of NBC Nightly News, a security room, and the mail room.[12] Ensuring the safety of employees and earning their confidence seemed important at least to NBC, whose "management went overboard" with the standards they set themselves.[12(p65)]

The office building on Kuser Road was the site of one case of cutaneous anthrax. After extensive environmental sampling, the only area to produce a positive result was a mail bin that had likely contained a cross-contaminated

letter. At this site remediation was restricted to cleaning the area around where the positive sample was taken.[18]

## USPS Buildings

The greatest amount of remediation was done at USPS sites. Contaminated letters passed through a number of post offices and PDCs, which use high-speed mail sorting machines. Anthrax spores were often spread when letters passed through these machines. USPS had to do major remediation at 5 main sites as well as 18 other buildings.

Major decontamination efforts took place at 3 PDCs: Trenton, Brentwood, and Morgan. The 2 largest sites were the Trenton and Brentwood PDCs located in New Jersey and Washington, DC, respectively. At both sites there was evidence of widespread aerosolizing of anthrax spores,[25] and mail workers at both facilities developed inhalation anthrax.[25] The decision was made to do complete fumigations of both buildings with chlorine dioxide. The complete remediation, including fumigation, took over 2 years and, for both buildings, cost $200 million.[2,26]

In addition to fumigation and decontamination costs, remediation at these sites included miscellaneous costs. For example, $4.5 million was spent busing postal employees from their usual Brentwood or Trenton workplaces to other locations while cleanup was happening.[27] Additionally, after the fumigation, USPS spent $10.8 million renovating the Trenton PDC to refurbish the facility.[28] We assume these expenses are included in the overall remediation costs of these sites.

The other large PDC to be significantly contaminated was the Morgan PDC in New York City, which occupies 2.1 million square feet.[27] The cleanup at this facility involved closing only a section of the facility for about 2 weeks while decontamination was going on 24 hours a day at a cost of about $15 million.[29]

There were 20 other USPS facilities that produced positive environmental samples.[13] Contamination at these sites was generally low and usually thought to have occurred through direct physical contact of cross-contaminated letters. Many sites produced just 1 or 2 positive samples, and in some cases remediation involved cleaning the area of the room around the positive sample. In some cases, potentially contaminated items were disposed of.[13] According to the Vice President of Engineering for USPS, "…15 locations had very small amounts of contamination. Cleanup procedures were very limited; closing was generally a 24 to 48 hour time period. Again, no employees at these locations ever became infected."[10(p114)] Given the extremely low level of decontamination necessary in these buildings, we construct a lower bound estimate on cost by assuming that no additional cost was incurred decontaminating these buildings (eg, current staff and resources were used to decontaminate).

However, we present the data here to illustrate. For these buildings, per square foot costs are $5.70, $7.14, and $3.10, respectively. The high variance between these estimates can be explained by several factors; most significant is the lack of knowledge about the actual area decontaminated. In addition, the Department of Justice Mail Facility was partially fumigated and thus would be expected to have higher costs.

## Cost of Sampling

When the Amerithrax event occurred, the extent of contamination was difficult to ascertain, especially before the source and route of the bacterium was known. Samples were taken to discover the extent of exposure, including dry and wet swab samples and nasal swabs.

At least 10,775 nasal swabs were taken; 33 came back positive: 2 in Florida, 3 in New York, and 28 on Capitol Hill. Among those exposed were at least 9 people who directly handled contaminated letters as well as people who were in immediate or adjacent proximity to where letters were handled or opened.[30,31] Environmental samples were also collected by the CDC, EPA, and USPS and included the sampling of 286 postal facilities.[32] Nationwide, approximately 120,000 samples were taken, placing great strain on many laboratories' ability to process the samples.[32]

Environmental samples included both dry and wet wipes or swabs, HEPA vacuum samples, air quality samples, and other samples that included control samples used to ensure the efficacy of fumigation. At the DOJ Mail Facility, dry samples cost approximately $40 each, while wet samples were $85 each.[5] We assume that HEPA vacuum and air quality samples as well as "other" type samples also cost $85 each. Sampling performed at 23 USPS sites shows that about 28% of samples were of the dry type.[32] Generalizing this distribution and multiplying by the respective costs yields a value of about $8.7 million.

For the purposes of our model, we consider these to be unique costs and add them to the overall decontamination costs.

## Cost Estimates for Unknown Buildings

No cost estimate could be obtained for 29 contaminated buildings. First, we consider the case of GSA 410. The other 4 completely fumigated buildings showed relatively consistent costs on a per unit volume basis. GSA 410 has similar dimensions to and was remediated in the same manner as Department of State Annex 32. Therefore, we assume identical decontamination costs ($9 million) for the 2 buildings.

Very little data was available for nonfumigated buildings. In order to better inform policy decisions, we created an

upper bound, lower bound, and most probable estimate of these costs. For sites where decontamination was not performed on the entire building, these extrapolations do not hold, since area contaminated does not necessarily correlate to building area. We thus estimated costs on a per building basis.

Costs for the 6 nonfumigated buildings on Capitol Hill serve as a baseline for an upper bound, both because we have accurate cost information about them ($2.1 million each) and because they represent nonaerosolized contamination. If we assume every building had equally costly remediation, we arrive at a total of about $60 million for unknown buildings. We use a learning factor of 90% suggested by Wein et al for our most probable estimate.[2] We chose a value of $2.4 million for the first building remediated on Capitol Hill in order to be consistent with this learning factor. Applying this learning factor to the rest of the unknown buildings yields a cost of $46 million.

Working from the most probable estimate, we then assigned zero cost to the last 15 buildings as per Day's report AU2 ▶ that cleanup was very limited.[10] This yields a cost of lower bound estimate of $22 million.

## Total Decontamination Cost of Amerithrax

Decontamination efforts for the Amerithrax event involved varied methods, extensive cost, and efforts that in some cases took several years, making expenditure comparisons difficult due to inflation. For reference a summary has been made of unique decontamination efforts with all dollar values corrected to 2001 dollars T3 ▶ (Table 3).

Our model indicates that environmental decontamination for the Amerithrax attack cost about $320 million. If, as discussed under USPS Buildings above, miscellaneous cleanup costs were not included in fumigation costs and if no learning occurred between building cleanups, the overall decontamination costs could be as high as $350 million. On the other hand, if sampling costs are already accounted for in overall cost summaries and no additional costs were incurred for 18 mildly contaminated USPS buildings, overall decontamination costs could be as low as $290 million.

Table 3. Final Cost Totals for Unique Decontamination Efforts, Adjusted to 2001 Dollars

| *Cost Category* | | *Cost (in $millions)* |
|---|---|---|
| Known Buildings | | 257 |
| Estimates for Unknown Buildings | High | 69 |
| | Mid | 55 |
| | Low | 31 |
| All Samples Taken | | 8.7 |
| Total: | High | 330 |
| | Mid | 320 |
| | Low | 300 |

## Discussion

We estimated total cost for building decontamination in 3 ways: we applied an average per building cost to all buildings, which produces a high estimate; we applied a learning factor to each successive building decontamination cost, which produces a best guess estimate; and we produced a low estimate by assuming no additional cost was incurred in decontaminating 15 mildly contaminated USPS buildings. Scaling decontamination cost by area was not feasible, since the actual decontaminated area is not available and decontaminated area is not related to total building area. Thus, one of the most significant data gaps (besides per building cost) is the actual area decontaminated in each affected building. Further, this limits any potential method for estimating decontamination costs, including pricing labor and materials directly. The high degree of variability seen in existing data might be explained if we were able to ascertain the actual area decontaminated. Clearly, more information is needed to fully explain cost variability and determine whether or not learning occurred. The private firms affected by the Amerithrax events could greatly aid policymakers by making their decontamination and cost data available. Based on our investigation and inquiries, we do not believe more data exist in government agencies. Although more data would be useful to track costs and learning, the overall uncertainty in our estimate is far less than an order of magnitude and is unlikely to matter for the purposes of policy comparison. Nevertheless, one of the most useful things that could be done in the event of a future bioterror attack would be careful and detailed record keeping on the extent and location of contamination and costs of decontamination efforts.

While GAO investigated and reported on spending and cleanup protocols on Capitol Hill and the National Academies have released a report on future cleanup needs, at the time of cleanup no official protocols for cleanup existed, nor does there seem to have been a single agency in charge of documenting cleanup. This likely contributed to cost overruns and slowed the process of decontamination. Moreover, the lack of reporting and data collection complicates efforts to accurately compare economic outlays associated with the Amerithrax events with the cost of policy responses.

In the months and years following the Amerithrax attacks, pressure was put on government agencies and public facilities to create contingency plans for dealing with a biological attack. However, without thorough research and technical knowledge, some plans fell short of their goals.[33] The Department of Homeland Security (DHS) proposed federal guidelines for decontamination protocols in 2009 in draft form.[34] These guidelines do much to address the uncertainty that hampered decontamination efforts in 2001. Although concerns remain regarding decontamination of large outdoor spaces, these guidelines are likely to result in more efficient decontamination in any future bioterror attack.[11]

While progress has been made, current decontamination plans still lack federal standards for cleanup. In particular, no rule currently states what level of decontamination is necessary. Without knowing what level to clean facilities to, future decontamination efforts will naturally be hampered.

## Conclusion

This article is part of ongoing research planned to estimate the total costs associated with the Amerithrax attacks. Ten years after the anthrax letter attacks, no accurate accounting of the economic impacts associated with that event exists. While this article focused on the costs associated with decontamination, we cannot accurately understand the economic impacts associated with the Amerithrax attacks until similar analyses have been performed for costs associated with medical expenditures, consumer response, investigative costs, and prevention, as well as the broader economic impact using models of economic interaction (such as input-output) or impacts of business shutdowns or diversions.

Early estimates of the costs for decontamination varied significantly; initial estimates for Capitol Hill decontamination climbed steadily from $5 million to $28 million over the 7 months following the attacks (compared to an actual cost of $27 million) and for USPS as high as $1 billion a year after the attack (compared to our estimated cost of $320 million for all affected sites). Clearly, initial policy decisions could be made only on the basis of available data.[4] However, understanding the costs associated with this event is essential to crafting successful bioterrorism policy. Our analysis indicates that the total decontamination costs were under $330 million in 2001 dollars. A larger attack may well lead to higher levels of decontamination; however, lessons learned from the Amerithrax attacks, newer technologies and protocols, and economies of scale would all contribute to a decrease in per unit decontamination cost. This analysis demonstrates that decontamination costs, at least for an attack of this magnitude, do not seem likely to be drivers for major economic impacts.

## References


1. National Institute for Occupational Safety and Health. Evidence Package for the National Academies' Review 2006-2007. NIOSH Respiratory Diseases Research Program. http://www.cdc.gov/niosh/nas/RDRP/ch6.2.htm. Accessed December 1, 2011.
2. Wein LM, Yifan L, Leighton TJ. HEPA/vaccine plan for indoor anthrax remediation. *Emerg Infect Dis* 2005;11(1): 69-76.
3. National Security Council. *National Strategy for Countering Biological Threats*. Washington, DC: The White House; November 2009. http://www.whitehouse.gov/sites/default/files/National_Strategy_for_Countering_BioThreats.pdf. Accessed December 1, 2011.
4. U.S. General Accounting Office. *Capitol Hill Anthrax Incident: EPA's Clean Up Was Successful; Opportunities Exist to Enhance Contract Oversight*. GAO-03-686. Washington, DC: General Accounting Office; June 2003. http://www.gao.gov/new.items/d03686.pdf. Accessed December 1, 2011.
5. Canter D, Gunning D, Rodgers P, O'Connor L, Traunero C, Kempter CJ. Remediation of Bacillus anthracis contamination in the U.S. Department of Justice mail facility. *Biosecur Bioterror* 2005;3(2):119-127.
6. Lee B, Gordon P, Moore JE II, Richardson HW. Simulating the economic impacts of a hypothetical bio-terrorist attack: a sports stadium case. *Journal of Homeland Security and Emergency Management* 2008;5(1):article 39.
7. Rose A, Oladosu G, Liao S. Regional economic impacts of a terrorist attack on the water system of Los Angeles: a computable general disequilibrium analysis. In: Richardson H, Gordon P, Moore J II, eds. *Economic Costs and Consequences of a Terrorist Attack.* Cheltenham, UK: Edward Elgar; 2007.
8. Giesecke JA, Burns WJ, Barrett A, et al. Assessment of the regional economic impacts of catastrophic events: CGE analysis of resource loss and behavioral effects of an RDD attack scenario. *Risk Anal* 14 Jan 2011; doi: 10.1111/j.1539-6924.2010.01567.x.
9. Rose AZ. A framework for analyzing the total economic impacts of terrorist attacks and natural disasters. *Journal of Homeland Security and Emergency Management* 2009; 6(1):article 9.
10. Day TG. The autumn 2001 anthrax attack on the United States Postal Service: the consequences and response. *Journal of Contingencies and Crisis Management* 2003;11(3):110-117.
11. Franco C, Bouri N. Environmental decontamination following a large-scale bioterrorism attack: federal progress and remaining gaps. *Biosecur Bioterror* 2010;8(2):107-117.
12. Committee on Standards and Policies for Decontaminating Public Facilities Affected by Exposure to Harmful Biological Agents: How Clean is Safe? National Research Council. *Reopening Public Facilities After a Biological Attack: A Decision-Making Framework.* Washington, DC: National Academies Press; 2005.
13. United States Postal Service. *Response to the General Accountability Office Recommendations on the Anthrax Attacks of 2001.* United States Postal Service Safety Performance Management. August 2004.
14. Holtz TH. Inhalation anthrax—New York City 2001. Presentation to the International Conference on Emerging Infectious

Diseases; New York City Department of Health and the Center for Disease Control and Prevention; March 26, 2002.
15. Twomey S, Goldstein A. Va. case alters anthrax equation; hospitalized sorter for State Dept. handled mail from DC facility. *Washington Post* October 26, 2001.
16. Anthrax traces found at Washington VA hospital. *CNN.com.* November 3, 2001.
17. U.S. Environmental Protection Agency. *Anthrax spore decontamination using hydrogen peroxide vapor.* Washington, DC: U.S. Environmental Protection Agency; July 2007. http://www.epa.gov/pesticides/factsheets/chemicals/vhp_factsheet.htm. Accessed December 1, 2011.
18. Pennsylvania Department of Health. Health Alert #21. November 2, 2001. http://www.portal.state.pa.us/portal/server.pt. Accessed December 1, 2011.
19. Canter DA. Remediating anthrax contaminated sites: learning from the past to protect the future. *Chem Health Saf* July/August 2005.
20. U.S. Senate Committe on Environment & Public Works. Statement of Governor Christine Todd Whitman, Administrator, U.S. Environmental Protection Agency, Before the Committee on Environment and Public Works, September 24, 2002. http://epw.senate.gov/107th/Whitman_092402.htm. Accessed December 1, 2011.
21. U.S. Government Accountability Office. *Anthrax Detection: DHS Cannot Ensure That Sampling Activities Will Be Validated*. GAO-07-687T. Washington, DC: Government Accountability Office; March 2007.
22. Kenen J. Hart Senate Building reopens, anthrax-free. *Reuters* January 22, 2002. http://www.ph.ucla.edu/epi/bioter/hartbuildinganthraxfree.html. Accessed December 5, 2011.
23. Barton J. Boca building fumigated for anthrax. *Associated Press* July 12, 2004.
24. Palm Beach County Property Appraiser's Office. *Property Appraiser's Public Access System.* http://www.pbcgov.com/papa/. Accessed December 1, 2011.
25. Sanderson WT, Stoddard RR, Echt AS, et al. Bacillus anthracis contamination and inhalational anthrax in a mail processing and distribution center. *J Appl Microbiol* 2004; 96(5):1048-1056.
26. Day TG. Presentation to National Research Council Committee on Standards and Policies for Decontaminating Public Facilities Affected by Exposure to Harmful Biological Agents: How Clean is Safe? Washington, DC; January 2004.
27. U.S. Government Accountability Office. *US Postal Service: Better Guidance Is Needed to Ensure an Appropriate Response to Anthrax Contamination.* GAO-04-239. Washington, DC: Government Accountability Office; 2004.
28. Campanelli M. USPS board OKs $10.8M for Trenton P&DC. *Direct Marketing News* May 17, 2004.
29. APWU, AFL-CIO, New York Metro Area Postal Union, Senate of New York, 27th District, Council, 2nd District, Transport Workers Union of America v. John E. Potter, Postmaster General of the United States. 343 F.3d 619. United States Court of Appeals (2nd Circuit 2003).
30. Pennsylvania Department of Health. Health Alert #17. October 25, 2001.
31. U.S. Centers for Disease Control and Prevention. Update: investigation of anthrax associated with intentional exposure and interim public health guidelines, October 2001. *MMWR Morb Mortal Wkly Rep*. 2001 Oct 19;50(41):889-893. http://www.cdc.gov/mmwr/preview/mmwrhtml/mm5041a1.htm. Accessed December 1, 2011.
32. U.S. Government Accountability Office. *Anthrax Detection: Agencies Need to Validate Sampling Activities in Order to Increase Confidence in Negative Results*. GAO-05-251. Washington, DC: Government Accountability Office; March 2005.
33. U.S. Government Accountability Office. *Diffuse Security Threats: USPS Air Filtration Systems Need More Testing and Cost Benefit Analysis Before Implementation*. GAO-02-838. Washington, DC: Government Accountability Office; August 2002.
34. U.S. Department of Homeland Security, U.S. Environmental Protection Agency, White House Office of Science and Technology Policy. *Draft Planning Guidance for Recovery Following Biological Incidents*. May 2009. http://www.trivalleycares.org/comments/DHSDraftGuidance.pdf. Accessed December 1, 2011.

*Manuscript received October 4, 2010;*
*acceptedfor publication November 8, 2011.*

Address correspondence to:
*Dr. Ketra Schmitt*
*Assistant Professor*
*Centre for Engineering in Society*
*Faculty of Engineering and Computer Science*
*Concordia University*
*1455 de Maisonneuve Boulevard West, EV-2.229*
*Montréal, Québec H3G 1M8 Canada*

*E-mail:* kschmitt@encs.concordia.ca