Decontamination Options for Sensitive Equipment in Critical Infrastructure following a *Bacillus anthracis* Incident

**Purpose**

This technical brief provides decision makers with practical information on decontamination methods that could be used to restore critical infrastructure during a response to a release of *Bacillus anthracis*, the causative agent of anthrax. This brief reviews fumigation technologies that have been shown to decontaminate sensitive equipment contaminated with *B. anthracis* or surrogate spores and provides an overview of the on- and off-site decontamination processes.

**Introduction**

Critical infrastructure represents a wide range of possible functions, institutions or businesses. After a wide-area release of *B. anthracis*, the functionality of affected power plants, water and sewer services, law enforcement, fire protection, and hospitals and other health care institutions must be restored. Restoring the functionality of infrastructure requires technologies capable of decontaminating sensitive equipment such as mechanical, electronic, or other powered devices that are necessary for facility operations.

Although several decontamination technologies are capable of effectively inactivating *B. anthracis* spores, every technology has limitations, safety issues, and material-compatibility constraints. Some decontamination technologies may cause corrosion or other collateral damage to sensitive equipment necessary for the functionality of critical infrastructure. Therefore, a Remedial Action Plan should include decontamination procedures for the entire facility, as well as the special handling and non-destructive decontamination methods required to prevent damage to the sensitive equipment located within the facility.

EPA has identified the effectiveness as a function of operational parameters for several volumetric decontamination methods that may be considered to decontaminate areas contaminated by *B. anthracis* spores. These methods include fumigation techniques using methyl bromide (MeBr), chlorine dioxide (ClO₂), formaldehyde, hydrogen peroxide (H₂O₂), ethylene oxide (EtO), methyl iodide, and ozone; and fogging with sporicidal liquids [1]. Additionally, some of these methods have been evaluated by EPA specifically for use with sensitive equipment. This brief delivers an overview of such methods.
Decontamination Methods for Electronic Equipment

The compatibility of sensitive equipment and decontamination agents should be understood when deciding on a cleanup approach for a *B. anthracis* incident. EPA has completed a number of material compatibility fumigation studies on electronic equipment (desktop computers, monitors, fax machines, cell phones, CDs) using ClO₂, H₂O₂, MeBr (with 2% chloropicrin), and EtO. The materials and electronic systems used in these studies were chosen to be characteristic of equipment, components, and materials found in critical infrastructure or high-value items. For example, computer systems were employed that included sub-components often found in high-end medical, communication, and security equipment. A summary of details on the test parameters and material compatibility from the EPA studies can be found in the *Assessment of the Impact of Decontamination Fumigants on Electronic Equipment* technical brief [2]. Table 1 summarizes some of the findings on the fumigants tested and their impacts on electronic equipment.

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<tr>
<th>Fumigant</th>
<th>Findings from Fumigant Testing</th>
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<tr>
<td>Ethylene Oxide [3]</td>
<td>Little or no impact on materials tested; generally, the most material-compatible method for decontamination of high-value and/or irreplaceable objects; treatment is typically performed in a small, controlled chamber and must be performed precisely. EtO is not suitable for whole-building fumigation and equipment should be removed to another location (ex situ) within the site or off-site in a controlled environment.</td>
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<td>Methyl Bromide (with 2% Chloropicrin) [4]</td>
<td>Power supplies in all MB-fumigated computers failed, some catastrophically, due to the chloropicrin; some corrosion of low carbon steel and steel outlet/switch boxes was observed; other materials with potential for damage include metal bearings and CD/DVD drives. Chloropicrin has been shown to cause oxidation or adverse effect on the electronics [5]. (Without the use of chloropicrin, MeBr may be suitable for whole-building/room decontamination of porous sensitive items. EPA is currently conducting a study on the impacts of MeBr without chloropicrin on electronic equipment.)</td>
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<td>Hydrogen Peroxide [6]</td>
<td>Fumigation did not appear to affect the electronic components tested; computer performance did not appear to be significantly affected up to one year following fumigation. With proper control of humidity and exposure time, H₂O₂ is suitable for whole-building/room decontamination with sensitive items.</td>
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<td>Chlorine Dioxide [4, 6-8]</td>
<td>At 3000 ppm, fumigation caused some corrosion around the edges of desktop computers. It left powdery residue and damaged some CD/DVD drives. With the exception of some DVD drives, the computers were still in operation with no replacement parts one year after fumigation. A separate study [8] showed less detrimental impact on computer functionality when fumigating with lower levels of ClO₂.</td>
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*It is important to note that the results are for the specific conditions to which the material or equipment was exposed during testing. Less impact is expected when fumigating at lower concentration or RH.*
Fumigation with EtO is generally the most material-compatible method for fumigation of high-value and/or irreplaceable objects. EtO was used successfully to treat items (at an off-site facility) retrieved from the Hart Senate Office Building during the 2001 anthrax incident [9]. Overall, the findings from EPA studies show EtO fumigation [3] to have the least impact electronic equipment. However, because EtO is both highly toxic and flammable, it must be used in an extremely well-ventilated area. EtO is not suitable for wide-area fumigation, such as in a building or in any environment where an ignition source might be present or possible. Therefore, it is recommended that EtO fumigation occur with the object removed to another location (ex situ) within the site or off-site in a controlled environment. Off-gasing of EtO from treated materials should also be considered.

Hydrogen peroxide fumigation can be considered a valid option for whole-building/room decontamination with sensitive items, but process humidity and exposure time must be very carefully planned and controlled to minimize damage to sensitive items.

Methyl bromide can also be considered for whole-building/room fumigations. Due to its toxicity to humans, MeBr is frequently mixed with 2 percent chloropicrin (tear gas) to warn users of exposure. However, chloropicrin should not be added to fumigations for sensitive equipment because chloropicrin has been shown to cause oxidation or adverse effect on the electronics [5]. EPA is currently conducting a study on the impacts of MeBr without chloropicrin on electronic equipment.

For whole-building/room fumigations, ClO₂ is more effective on a broader range of materials than H₂O₂ [10]. However, computers fumigated with ClO₂ were more prone to physical/functional deterioration than those fumigated with H₂O₂ [2]. Additionally, results show that relative humidity during fumigation should be maintained between 65 percent and 75 percent to maximize compatibility for most materials [7] and that there will be less detrimental impact on computer functionality when fumigating with lower levels of ClO₂ [8].

On- And Off-Site Decontamination Techniques for Sensitive Equipment

Sensitive equipment should be identified prior to remediation of the critical infrastructure. It may be necessary to encapsulate or remove sensitive equipment prior to conducting the facility decontamination, then determine non-destructive decontamination methods. On-site decontamination can be performed for non-removable equipment in its original place (in situ) or equipment can be removed for decontamination to another location (ex situ) within the site or off-site. In situ and ex situ techniques are described below and Table 2 reviews the pros and cons of each of these decontamination techniques.
<table>
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<tr>
<th>Decontamination Technique</th>
<th>Pros/Cons</th>
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<td><strong>In Situ</strong></td>
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<tr>
<td>Protect material/equipment before whole-building/room decontamination and decontaminate material/equipment with a compatible method.</td>
<td>Can allow for readily available and affordable decontamination options for decontamination of the whole-building/room and overall effectiveness of decontamination throughout the facility. Decontaminating equipment separately will require more preparation time for the enclosing/encapsulation requirements and decontamination processes.</td>
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<tr>
<td>Leave material/equipment unprotected for whole-building/room decontamination inclusion.</td>
<td>Less time required for preparation and decontamination processes. Will limit decontamination options to methods that are compatible only with sensitive equipment and could reduce the overall effectiveness of decontamination throughout the facility.</td>
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<tr>
<td><strong>Ex Situ</strong></td>
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<tr>
<td>Remove the material/equipment for on-site or off-site decontamination.</td>
<td>Can allow for readily available and affordable decontamination options for decontamination of the whole-building/room and overall effectiveness of decontamination throughout the facility. The dismantling, enclosing/encapsulation, and transport requirements for removed material/equipment will likely be time consuming and costly.</td>
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**In Situ Decontamination**

*In situ* decontamination of non-removable equipment will involve either covering the equipment to protect it from the whole-building/room decontamination process and later decontaminating the equipment with a compatible method or leaving equipment unprotected for inclusion of a whole-building/room decontamination process that is compatible with sensitive equipment. The decontaminant to be used on the sensitive material/equipment should be selected based on material compatibility decontamination studies and usage in previous incidents. The general procedures for preparing the equipment for a compatible decontamination method and protecting equipment prior to whole-building/room decontamination are listed below. Modifications can be made on-site as deemed necessary.

- Enclose/cover the material/equipment, using one of these or other possible techniques:
  - If fogging or fumigating, bag the item or cover it with heavy duty plastic and seal it shut, leaving enough air space in the enclosure for introduction of decontaminant.
  - Enclose the item in a small portable tent that is sealed or boxed and sealed, leaving enough enclosed space to perform the selected decontamination process. The tenting materials need to be compatible with both facility and sensitive equipment decontaminants.
Follow the preparation procedures for the specific decontamination method selected. The placement of fans to distribute or dry the decontaminant or other modifications to the enclosed space, such as adding ports for air and/or gas exchange, may be needed prior to conducting decontamination.

**Ex Situ Decontamination**

In many instances, sensitive equipment may need to be removed because it cannot be decontaminated in place. For *ex situ* decontamination, the sensitive item may be moved to a Conex box or other enclosure for decontamination at the site or off-site. The decontaminant should be selected based on material compatibility decontamination studies and usage in previous incidents. Once inside the enclosure, items can be decontaminated in accordance with procedures for the selected decontamination method.

Prior to removing the sensitive items, a label/tag system should be established to track items. Several labeling options are available, such as using evidence tags or labeling bags with a predetermined nomenclature system. Bar coding or other electronic tracking may be the most efficient method given the large quantity of items to be handled.

Below is a list of guidelines for removing sensitive items. Detailed procedures are not presented here, as these will be determined during a response by decision-makers.

- **Bag** the item. First, double bag sensitive items using heavy-duty plastic bags most resistant to punctures. Large and/or heavy items, can be double wrapped in heavy duty plastic sheeting, such as Visqueen™ (British Polythene Ltd., London, UK).
- **Tape** the bags shut with duct or other tape with similar or better adhesive properties. Large items wrapped in plastic sheeting should be taped to secure all edges of the plastic to the item.
- **Label or tag** the bag using a labeling system devised for sensitive items to be moved. Label the bag or the wrapped item using permanent markers and labels, and ensure that markings are dry so that they are not smudged during transport.
- **Document** items on a chain-of-custody form and any other form/logbook as decided upon during the response.
- **Decontaminate** the container/bag outer surface prior to placing the container in a shipping area/container.
- **Transport** the bags to a secure location for *ex situ* decontamination. It may be necessary to further place the bags into another container for transport, such as a drum, Gaylord box, or roll-off box.
- **Track** the location and disposition of the sensitive item electronically (database or spreadsheet) in accordance with an approved data management plan.
Conclusion

Sensitive equipment should be identified prior to remediation of the critical infrastructure. A whole-building/room decontamination approach that is compatible with sensitive equipment may be selected, but it could limit decontamination efficacy throughout the facility. If sensitive equipment cannot be included in the whole-building/room decontamination approach, it will be necessary to encapsulate or remove the items prior to decontamination of the facility, then determine non-destructive decontamination methods for the items. Material compatibility needs to be carefully understood when considering the cleanup of the sensitive equipment associated with the functionality of critical infrastructures. Overall, the findings from EPA studies show EtO fumigation [2, 3] to have the least impact electronic equipment. However, it is recommended that EtO fumigation occur with the object removed to another location (ex situ) within the site or off-site in a controlled environment, which will limit its use in a wide-area incident. Hydrogen peroxide and MeBr (without chloropicrin) could be considered valid options for whole-building/room fumigations with sensitive items. A study is currently underway to look at the impacts of MeBr without chloropicrin on electronic equipment. In general, physical and functional deterioration of sensitive equipment is more likely with ClO₂ vs. H₂O₂ fumigations [2]. However, for whole-building/room fumigations, ClO₂ is more effective on a broader range of materials than H₂O₂ [10] and fumigating with lower levels of ClO₂ will allow for less detrimental impact on computer functionality [8]. For both fumigants, process humidity and exposure time must be very carefully planned and controlled to minimize damage to sensitive items.

Disclaimer

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References


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