

Surface Decontamination Methodologies for a Wide-Area *Bacillus anthracis* Incident

PURPOSE

To provide decision makers practical information on surface decontamination options for consideration during a *Bacillus anthracis* response. This brief will review a wide range of technologies (e.g., liquids, foams, gels, wipes, etc.) that have been shown to decontaminate surfaces contaminated with *B. anthracis* spores.

INTRODUCTION

EPA has comprehensively evaluated numerous decontaminants for their efficacy against *B. anthracis* spores on a variety of indoor and outdoor surfaces. The tactical procedures for decontaminating a wide-area contaminated with *B. anthracis* spores are limited and knowledge gaps exist. However, recommendations can be made by extrapolating experimental findings from the lab to the field. In many cases, technologies used for indoor decontamination (e.g., fumigants, liquid or foam sporicides), may be employed for outdoor areas contaminated with *B. anthracis*. The decontamination approach chosen for a particular surface may need to be evaluated in the field (at pilot scale or within a small zone) and refined as necessary during the course of the response until the desired effectiveness and process-knowledge is established for wide-scale applications.

This brief is designed to deliver an overview of the surface decontamination technologies evaluated by EPA, provide potential surface decontamination options based on surface material type, and discuss current research that may be considered for the decontamination of outdoor surfaces such as building materials and soil.

PRODUCTS AND APPLICATION PROCEDURES

Liquid based sporicides with hydrogen peroxide/peracetic acid (H_2O_2 /PAA) or hypochlorous acid (HOCl) as active ingredients have generally been shown to be the most effective for surface decontamination. Although, it is important to note that no one sporicidal decontaminant is effective for all material types and all environmental conditions. Therefore, technical support from decontamination subject matter experts should be sought during decontaminant selection. Additionally, in the event of wide-area contamination, resources are likely to be overwhelmed and depleted rapidly. Not all chemicals and equipment may be readily available and economical. Many surface decontamination approaches will require extensive manpower and will generate large volumes of waste. Decision makers will need to consider the available resources, cost, waste production, and the available waste management options before selecting a method.

Although numerous surface decontaminants have been comprehensively evaluated by EPA's Homeland Security Research Program (HSRP), only two liquids and one fumigant are currently registered as sporicidal decontaminants for inactivation of *B. anthracis* spores on pre-cleaned, hard, non-porous surfaces: PERIDOX® with Electrostatic Decontamination System (EDS), Steriplex Ultra™, and DIKLOR G Chlorine Dioxide Sterilant Precursor. (These three registered sporicidal decontaminants have been tested by the vendors themselves and have not been evaluated by HSRP; the vendor supplied data have been approved by EPA's Office of Chemical Safety and Pollution Prevention (OCSP). The liquid decontaminant, pH-adjusted bleach (pAB), was previously granted a Federal Insecticide, Fungicide, and Rodenticide Act (FIFRA) crisis exemption for use against *B. anthracis* spores. Additionally, EPA recently issued a quarantine exemption for the use of multiple liquid products against *B. anthracis* including: Oxonia Active, Vortexx, Spor-klenz Ready to Use, and bleach. In addition, several fumigation products were exempted and include: ethylene oxide, paraformaldehyde, and hydrogen peroxide vapor. The products listed in the quarantine exemption are supported by available safety and efficacy data, including data from EPA cited in this brief.

Table 1 lists a summary of surface decontamination technologies evaluated by EPA and found to be effective against spores of *B. anthracis* (and/or simulant) contamination on a variety of surface types. The table reviews the application procedures and the decontamination efficacy associated with each researched technology. As a note on the measure of efficacy, products demonstrating a ≥ 6 Log Reduction (LR) on relevant surfaces are considered effective in accordance with the FIFRA sporicidal decontaminant testing¹. This does not suggest that a product is thereby registered or exempted under FIFRA.

Figure 1 provides a flow chart with options for surface decontamination based on surface material type.

The table and flow chart can be used together to guide decision makers in determining a practical decontamination approach for several of the surface materials that will be required to be decontaminated in a wide-area incident.

¹ For information visit the U.S. EPA Scientific Advisory Panel website at www.epa.gov/scipoly/sap/meetings/2007/071707_mtg.htm

Table 1. Surface Decontamination Technologies evaluated by EPA and found to be effective against *B. anthracis* (and/or simulant) contamination.

	Item #	Surface Decontaminant: Product; Manufacturer; Active Ingredients; EPA Registration #; Product Label	Application Procedures/Conditions	Efficacy (Spore and Material Type Tested)	Comments	Ref #
EPA Liquids Registered Against <i>Bacillus anthracis</i>	1	PERIDOX® with EDS; Biomed Protect, LLC; hydrogen peroxide (24.0%), peroxyacetic acid (1.2%); 88089-3 (Sporicidal – <i>B. anthracis</i>) http://www3.epa.gov/pesticides/chem_search/ppls/081073-00002-20110316.pdf	The product label includes an instruction manual detailing the procedures and techniques for the use of a fully assembled EDS containing PERIDOX® solution mixed per label instructions. The application process entails wetting the surface with PERIDOX®, allowing for a 3 minute contact time, then illuminating the wetted surface with UV light from the EDS light wand.	Vendor supplied Data obtained by EPA Office of Pesticide Programs.	Registered sporicidal decontaminant for inactivation of <i>Bacillus anthracis</i> spores on dry, pre-cleaned, hard, non-porous surface. Not tested by NHSRC. Application procedures may need to be modified for wide area field use.	
	2	STERIPLEX Ultra™; sBioMed; Silver (0.03%), hydrogen peroxide (22.0%), peracetic acid (15.0%); 84545-8 (sporicidal – <i>B. anthracis</i>); http://www.epa.gov/pesticides/chem_search/ppls/084545-00008-20111220.pdf	The product label includes a training manual detailing the procedures and techniques for preparing and using the two-part decontaminant system. The application process entails wetting the surface with a thin film of product at room temperature, allowing for a 30 minute contact time, and then rinsing the surfaces with a clean cloth or sponge several times with running water.	Vendor supplied Data obtained by EPA Office of Pesticide Programs.	Registered sporicidal decontaminant for inactivation of <i>Bacillus anthracis</i> spores on dry, pre-cleaned, hard, non-porous surface. Not tested by NHSRC. Application procedures may need to be modified for wide area field use.	
Hydrogen Peroxide/Peracetic Acid Liquids *	3	Minnicare® Cold Sterilant; Minntech Corp.; Hydrogen Peroxide (22%), Peracetic Acid (4.5%); 52252-4 (sterilant, disinfectant, sanitizer); http://www3.epa.gov/pesticides/chem_search/ppls/052252-00004-20130924.pdf	Prepare according to manufacturer's instructions on the day of application. Apply the solution to the surface using a handheld spray bottle (or chemical resistant liquid pump sprayer), from a distance of 12 inches until the surfaces is fully wetted. Allow solution to remain in contact with the surface 10 minutes for decorative laminate, glass, wallboard paper, and metal ductwork; 30 minutes for carpet, and cinder block.	Quantitative efficacy for both <i>B. anthracis</i> and <i>B. subtilis</i> was ≥ 7.5 LR on industrial-grade carpet, decorative laminate, galvanized metal ductwork, painted wallboard paper, painted cinder block, and glass.	Lower efficacy values were found on bare pine wood, for which efficacy results for <i>B. anthracis</i> and <i>B. subtilis</i> were 5.40 and 6.00 LR, respectively. Evaluated in laboratory testing. Application procedures may need to be modified for wide area field use.	1
	4	Oxonia Active®; Ecolab, Inc.; Hydrogen Peroxide (27.5%), Peracetic Acid (5.8%); 1677-129 (sterilant, disinfectant, sanitizer) http://www.kellysolutions.com/erene/wals/documentsubmit/KellyData%5CV A%5Cpesticide%5CProduct%20Label%5C1677%5C1677-129%5C1677-129 OXONIA ACTIVE 10 31 2005 1 1 00 14 AMSecured.Pdf	On day of application, prepare according to the vendor's instructions. Apply the diluted Oxonia Active® using a chemical resistant liquid pump sprayer from a distance of about 12 inches until the surface is fully wetted, and then reapplied every 10 minutes after the initial application for a total contact time of 60 minutes.	Quantitative efficacy for <i>B. anthracis</i> was ≥ 7.0 LR on industrial-grade carpet, decorative laminate, galvanized metal ductwork, painted wallboard paper, painted cinder block, and glass.	No visible damage observed on any of the test materials after 60 minutes contact time. Lower efficacy values were found on bare pine wood (4.64 LR.) Evaluated in laboratory testing. Application procedures may need to be modified for wide area field use.	1, 2

	Item #	Surface Decontaminant: Product; Manufacturer; Active Ingredients; EPA Registration #; Product Label	Application Procedures/Conditions	Efficacy (Spore and Material Type Tested)	Comments	Ref #
	5	Peridox® RTU, Biomed Protect, LLC; Hydrogen peroxide (4.4%), peracetic acid (0.22%); 88089-4 (sterilant, disinfectant, sanitizer); http://www3.epa.gov/pesticides/chem_search/ppls/088089-00004-20150508.pdf	Follow vendor specifications for contact time, spray pressure, application and reapplication procedures, etc. Apply to surface until fully wetted, and then reapplied as necessary to keep the coupons wetted throughout the contact time. With non-porous materials, the contact time is 30 minutes with reapplication at 10 and 25 minutes after the first application. With porous materials, the contact time was 60 minutes, with reapplication at 10, 20, 30, 40, and 50 minutes after the first application.	Quantitative efficacy for <i>B. anthracis</i> was ≥ 6.65 log reduction on stainless steel, glass, aluminum, porcelain (glazed), granite (sealed surface), treated wood, and butyl rubber with no viable spores found on any of these seven test materials after decontamination. Efficacy was high (7.22 LR) on asphalt paving, but a small number of viable spores were found on one of the replicate asphalt test coupons after decontamination.	No visible damage was observed on any of the test materials after the 30 or 60 minute contact times in the quantitative efficacy testing or seven days later after completion of the qualitative assessment of residual spores. Evaluated in laboratory testing. Application procedures may need to be modified for wide area field use.	3
	6	Spor-Klenz® RTU; STERIS Corp.; Hydrogen peroxide (1.0%), Peracetic acid (0.08%); 1043-119 (sterilant/sporicidal, bactericidal, sanitizer), 1043-120 (concentrate); http://www.gru.edu/research/animal/resources/SporKleanz%20label.pdf	Apply Spor-Klenz® RTU from a distance of 30.5 cm using the handheld spray bottle (or chemical resistant liquid pump sprayer), until all test coupon surfaces are fully wetted by the solution. Reapply as needed to keep surfaces wet for a 30 minute contact time for nonporous surfaces, 60 minutes for porous materials (reapplication at 30 minutes after the initial application regardless of the wetness of the coupons). Allow surface to air dry.	Quantitative efficacy for <i>B. anthracis</i> was ≥ 7 LR on stainless steel, glass, aluminum, porcelain (glazed), granite (sealed surface) and ≥ 7.27 LR on brick and butyl rubber. Efficacy on unpainted concrete, asphalt paving, and treated wood was approximately 1.02, 2.56, and 6.16 LR, respectively.	No visible damage was observed on the test materials after the 30 min contact time for non-porous materials or the 60 min contact time for the porous materials. Corrosive damage to a gas-powered sprayer was observed [16]. Evaluated in laboratory testing. Application procedures may need to be modified for wide area field use.	3, 4
Hydrogen Peroxide Liquids/Foams*	7	Decon Green; Developed by the U.S. Army; Hydrogen Peroxide (35%); 1043-121 (sterilant, disinfectant, virucide, fungicide); http://www3.epa.gov/pesticides/chem_search/ppls/001043-00121-20071206.pdf	Follow vendor specifications for contact time, spray pressure, application and reapplication procedures, etc. For most surfaces, apply to surface until fully wetted, and then reapply 30 minutes after the initial application for a total contact time of 30 minutes.	The quantitative efficacy for <i>B. anthracis</i> was ≥ 7.32 LR on stainless steel, glass, aluminum, porcelain (glazed), granite (sealed surface) materials, and ≥ 7.25 and ≥ 6.94 LR on brick and butyl rubber, respectively with no viable spores were found after decontamination. Efficacy on concrete, asphalt, and treated wood was 4.00, 2.97, and 1.91 LR, respectively.	No visible damage was observed on any of the test materials after the 60 minute contact time with Decon Green in the quantitative efficacy testing, or seven days later after completion of the qualitative assessment of residual spores. Evaluated in laboratory testing. Application procedures may need to be modified for wide area field use.	3
	8	EasyDECON® 200; EFT Holdings, Inc.; Hydrogen peroxide <8%; 74436-1 (Part 1), 74436-2 (Part 2) (disinfectant, mildewstat, virucide); http://www3.epa.gov/pesticides/chem_search/ppls/074436-00001-20110401.pdf ;	Follow vendor specifications for contact time, spray pressure, application and reapplication procedures, etc. Apply to glass, aluminum, and porcelain until fully wetted, and then reapply 10 and 20 minutes after the initial application, with a total contact time of 30 minutes. Apply to stainless steel and granite until fully wetted, and then reapplied 5, 10, 15, 20, and 25	The quantitative efficacy for <i>B. anthracis</i> was ≥ 7.51 LR on stainless steel, glass, aluminum, porcelain (glazed), granite (sealed surface) materials, and approximately ≥ 7.14, ≥ 7.28 and ≥ 6.99 LR on the porous materials unpainted concrete, brick, and butyl rubber,	No visible damage was observed on any of the test materials after the 30 or 60 minute contact times in the quantitative efficacy testing, or seven days later after completion of the qualitative assessment of residual spores.	3

	Item #	Surface Decontaminant: Product; Manufacturer; Active Ingredients; EPA Registration #; Product Label	Application Procedures/Conditions	Efficacy (Spore and Material Type Tested)	Comments	Ref #
		http://www3.epa.gov/pesticides/chem_search/ppls/074436-00002-20141007.pdf	minutes after the initial application, with a total contact time of 30 minutes. Apply to porous materials until they were fully wetted, and then reapplied 10, 20, 30, 40, and 50 minutes after the initial application, with a total contact time of 60 minutes.	respectively. Efficacy on asphalt and treated wood was 1.63 and 0.82 LR, respectively.		
Hypochlorous acid Liquids/Foams*	9	CASCAD™ Surface Decontamination Foam (SDF); Allen-Vanguard Corp.; Hypochlorite, hypochlorous acid; none	A specialized sprayer is required to generate the foam. Cover contaminated area with foam according to label for a 30 minute contact time, 60 minutes for porous materials (reapplication at 30 minutes after the initial application, for a total of two applications).	Quantitative efficacy was ≥ 7.0 LR for both <i>B. anthracis</i> and <i>B. subtilis</i> on industrial-grade carpet, decorative laminate, galvanized metal ductwork, painted (latex, semi-gloss) cinder block, and glass. Lower efficacy values were found only on painted wallboard paper and bare pine wood. Another study (Ref. 3) showed quantitative efficacy for <i>B. anthracis</i> was ≥ 6.80 LR on stainless steel, glass, aluminum, porcelain (glazed), granite (sealed surface), concrete, brick, asphalt paving, treated wood, and butyl rubber.	Paint peeled away from the primer coat on painted cinder block coupons. No visible damage was observed on any of the test materials after either the 30 min or the 60 min contact	1, 3
	10	pH-adjusted Bleach (pAB) EPA developed – no single vendor exists; Sodium Hypochlorite, Hypochlorous acid; 67619-8 (CPPC Ultra Bleach 2 is registered as a disinfectant, but pAB is not). The solution has been granted several FIFRA crisis exemptions for use against <i>B. anthracis</i> spores on pre-cleaned hard non-porous surfaces.	The pAB solution is made by combining 1 part bleach (containing 5.25% to 6.0% sodium hypochlorite), 8 parts water, and 1 part white vinegar. The bleach (Ultra Clorox® or store brand non-scented bleach) and white vinegar (store brand) are not combined directly together. Bag and remove porous materials (i.e., ceiling tile, mattresses, couches, etc.) and then decontaminate the remaining items and surfaces by spraying them with the pAB solution using gas-powered chemical sprayers. Allow for a 5-minute contact time. Then, reapply the decontaminant to the same surfaces for another 5 minutes. Repeat this process until every surface in the entire area has had a 10-minute contact time accomplished by spraying with decontaminant two consecutive times. Allow surfaces to air dry. If necessary squeegee and wet HEPA vacuum all standing decontaminant liquids from the horizontal non-porous surfaces.	The decontamination efficacy for <i>B. anthracis</i> was ≥ 7.62 LR on stainless steel, glass, aluminum, porcelain (glazed), granite (sealed surface) materials, and was ≥ 6.94 LR on the porous materials brick and butyl rubber. Concrete, asphalt, and treated wood exhibited lower efficacy values, at 6.27, 3.60 and 1.90 LR, respectively. Another Study (Ref. 4) showed that pAB was highly effective for <i>Bacillus atrophaeus</i> (approximately 6 LR) on wood and concrete when used with a thirty-minute contact time and two applications.	No visible damage was observed on the test materials after the 60 min contact time with pH-amended bleach. While this is a readily available and efficacious approach, its shortcomings include the need for extensive manpower, the potential for PPE upgrades due to chlorine gas generation), and the generation of large volumes of waste.	1, 3, 4, 5, 6, 7

	Item #	Surface Decontaminant: Product; Manufacturer; Active Ingredients; EPA Registration #; Product Label	Application Procedures/Conditions	Efficacy (Spore and Material Type Tested)	Comments	Ref #
Liquids/Fumigants for Soil Decontamination*	11	Chlorine Dioxide (ClO ₂) Gas (non-registered products are available and have been tested). EPA registered against <i>B. anthracis</i> : DIKLOR G ClO ₂ Sterilant Precursor; Sabre Oxidation Technologies, Inc.; sodium chlorite (25%); 73139-3; http://www.epa.gov/pesticides/chem_search/ppls/073139-00003-20140128.pdf	Fumigation: Target concentration of 3,000 ppmv, 2 hour contact time, with minimum 75% RH and 22 °C. Since ClO ₂ is unstable as a compressed gas, it must be produced on site. For the laboratory study, aqueous solutions of ClO ₂ were first prepared, and then pumped into a sparging column to transfer the ClO ₂ from the liquid to gas phase. Air from the test chamber was used in the sparging process and recirculated to establish the desired gaseous ClO ₂ concentration of 3,000 ppmv.	Fumigation tests conducted at a target concentration of 3,000 ppmv, with an RH of either 75% or 85% and indoor ambient temperature (~ 22 °C) provided > 6 LR of <i>B. anthracis</i> spores on the AZTD samples at a 2 cm depth (2-4 hr contact time). Topsoil proved to be more difficult to decontaminate.	Increasing contact time did significantly improve efficacy for topsoil. Changing the RH level did not significantly affect the LR results. Evaluated in laboratory testing. Application procedures and fumigation parameters will need to be modified for wide area field use.	8
	12	Klozur®; FMC Corporation; Sodium Persulfate, activated with hydrogen peroxide; none	Prepare according to vendor's instructions. The procedure involves application of Klozur®, followed by application of the hydrogen peroxide (H ₂ O ₂) activating solution, consistent with the recommended approach for soil remediation. Klozur® is injected into contaminated soil or groundwater, and activated by mixing in appropriate proportions with H ₂ O ₂ solutions of up to 8% H ₂ O ₂ by weight, according to instructions published by FMC Corporation at http://www.peroxychem.com/media/128552/peroxyc-hem-klozur-h2o2-activation-april-2015.pdf	Quantitative efficacy was 3.5 LR on topsoil containing <i>B. anthracis</i> spores was substantially greater with the 48-hour contact time (3.5 LR) than with the 24-hour contact time (1.65 LR). (Ref. 9) Additional studies showed ≥ 7 LR for <i>B. anthracis</i> spores in garden topsoil and Arizona Test Dust (AZTD) when using three applications (all applied within the first two hours) and a one week contact time.	Highly effective in killing <i>B. anthracis</i> spores in soil. Can overcome organic loading in soil. Soils tested include: Earthgro® Topsoil, Agvise® Topsoil, and AZTD. Preliminary unpublished data shows a ≥ 6 LR on outdoor material including bare pine wood, brick, concrete, and asphalt. (Ref. 11)	9, 10, 11
	13	Metam Sodium; Buckman Laboratories, Inc.; Sodium N-methyldithiocarbamate (42.5%), methyl isothiocyanate (MITC); 1448-107 (pesticide); http://www3.epa.gov/pesticides/chem_search/ppls/001448-00107-20140820.pdf	For optimum performance, it is recommended that the soil be free of clods and soil moisture be between 50-80% of field capacity. Metam sodium is applied as a liquid and converts to gas when it reacts with soil moisture. It can be applied with tillers, sprinklers, or other means of distribution to mix into the soil. Once the metam sodium is added to the soil, it is common practice to place a tarp or cap over the soil to prevent the loss of MITC.	For all but one of the eight tests with AZTD, <i>B. anthracis</i> was completely inactivated, whereas just one test with <i>B. anthracis</i> -contaminated topsoil resulted in complete inactivation. Metam sodium was effective (≥ 6 LR) against <i>B. anthracis</i> on topsoil with a 7 day contact time.	This decontaminant was significantly more effective on the AZTD compared to the topsoil for the majority of the tests. The effect of moisture content on decontamination efficacy of the metam sodium is readily apparent in the results for <i>B. anthracis</i> on topsoil, which shows that efficacy increases with increasing levels of moisture.	10
	14	Methyl Bromide; Matheson Tri-Gas; 99.5% methyl bromide gas with 0.5% chloropicrin added as a warning irritant; none	Fumigation: 212 mg/L methyl bromide, 36 hour contact time, no drying of soil.	212 mg/L methyl bromide and 36 hour contact time (no drying of soil) resulted in complete inactivation of <i>B. anthracis</i> spores on AZTD and ≥ 7.0 LR on topsoil.	Evaluated in laboratory testing. Application procedures and fumigation parameters may need to be modified for wide area field use.	10
	15	pAB; Sodium Hypochlorite, Hypochlorous acid (see item number 10)	See item number 10 for preparation instructions. Application for laboratory testing consisted of injecting pH-amended bleach into each sample every	Successful in decontaminating AZTD with ≥ 7.0 LR obtained for both <i>B. anthracis</i> and <i>B.</i>	Not efficacious for <i>B. anthracis</i> contaminated topsoil.	10

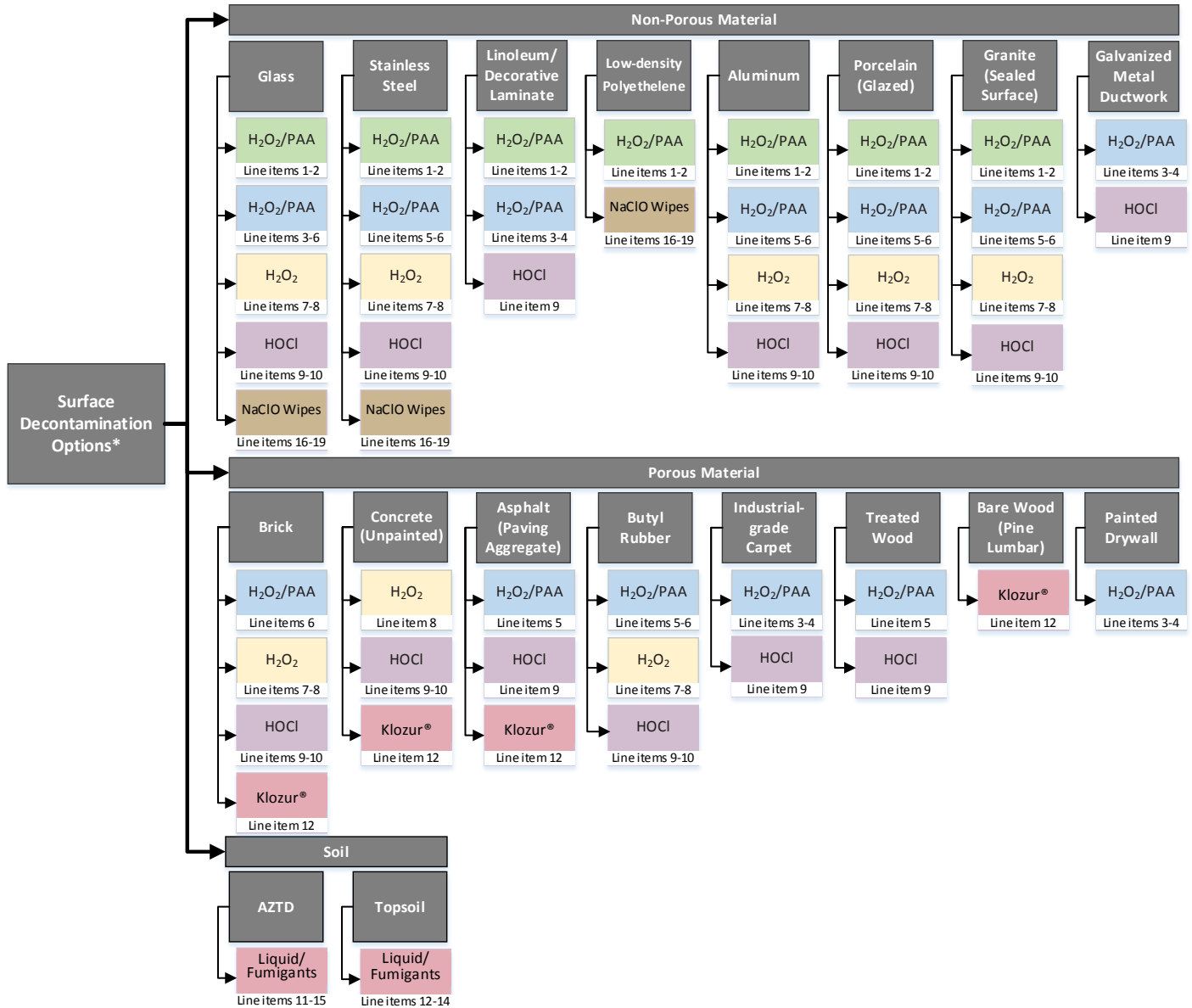
	Item #	Surface Decontaminant: Product; Manufacturer; Active Ingredients; EPA Registration #; Product Label	Application Procedures/Conditions	Efficacy (Spore and Material Type Tested)	Comments	Ref #
			30 minutes for 2 hours (4 total applications) and mixing the soil and pAB solution thoroughly in the sample jar using a glass stirring rod.	<i>subtilis</i> with four applications and a two-hour contact time.	Evaluated in laboratory testing. Application procedures will need to be modified for wide area field use.	
Commercial Off-the-Shelf Sodium Hypochlorite Wipes*	16	Clorox® Healthcare™ Bleach Germicidal Wipe; Clorox Professional Products Co.; Sodium hypochlorite (0.1–1.0%); 67619-12 (<i>Cl. difficile</i>)	Wipe the area using overlapping S-strokes. 3 min contact time (for sporicidal wipes, contact time reflects the prescribed time the surface is to be wet).	All commercially available sodium hypochlorite-based wipes completely inactivated all <i>B. atrophaeus</i> spores ($\geq 7 \log_{10}$) on glass, stainless steel, composite epoxy and low-density polyethylene materials.	Application procedures may need to be modified for wide area field use.	12
	17	Sani-Cloth® Bleach Germicidal Disposable Wipe; Professional Disposables Internationals, Inc.; Sodium hypochlorite (<1.0%); 9480-8 (<i>Cl. Difficile</i>); http://www3.epa.gov/pesticides/chem_search/ppls/009480-00008-20130716.pdf	Wipe the area using overlapping S-strokes. 4 min contact time (for sporicidal wipes, contact time reflects the prescribed time the surface is to be wet).	All commercially available sodium hypochlorite-based wipes completely inactivated all <i>B. atrophaeus</i> spores ($\geq 7 \log_{10}$) on glass, stainless steel, composite epoxy and low-density polyethylene materials.	Application procedures may need to be modified for wide area field use.	12
	18	Dispatch® Hospital Cleaner Disinfectant Towel with Bleach; Clorox Professional Products Co.; Sodium hypochlorite (<1.0%); 56392-8 (<i>Cl. Difficile</i>); http://www3.epa.gov/pesticides/chem_search/ppls/056392-00008-20130814.pdf	Wipe the area using overlapping S-strokes. 5 min contact time (for sporicidal wipes, contact time reflects the prescribed time the surface is to be wet).	All commercially available sodium hypochlorite-based wipes completely inactivated all <i>B. atrophaeus</i> spores ($\geq 7 \log_{10}$) on glass, stainless steel, composite epoxy and low-density polyethylene materials.	Application procedures may need to be modified for wide area field use.	12
	19	Hype-Wipe® Disinfecting Towel with Bleach; Current Technologies, Inc.; Sodium hypochlorite (0.525%), 70590-1 (<i>Cl. Difficile</i>); http://www3.epa.gov/pesticides/chem_search/ppls/070590-00001-20131030.pdf	Wipe the area using overlapping S-strokes. 4 min contact time (for sporicidal wipes, contact time reflects the prescribed time the surface is to be wet).	All commercially available sodium hypochlorite-based wipes completely inactivated all <i>B. atrophaeus</i> spores ($\geq 7 \log_{10}$) on glass, stainless steel, composite epoxy and low-density polyethylene materials.	Application procedures may need to be modified for wide area field use.	12

*Requires crisis exemption by the EPA – has not been specifically registered under FIFRA for use against *B. anthracis* spores.

Notes:

- Use of all products will be in accordance with all applicable precautions and directions specified on the registered labels (or by the vendor) and the requirements listed in the crisis exemption.
- During indoor material removal and decontaminant application procedures, negative air machines (NAMs) can be used to maintain negative pressure inside the building relative to the outside to reduce spore exfiltration. NAMs can also be utilized after decontamination to increase airflow through the facility and to aid in drying the surfaces.

Effective Surface Decontamination Options According to Surface Type – Reference Item Number on Table 1 for the Specific Technology and Application Procedures.



*Some of the decontamination options presented here have been proven successful during real-world responses. In contrast, other approaches have demonstrated to be effective during laboratory testing and have not been fully evaluated at the field-scale level and are recommended based upon a combination of best professional judgment and experience of both scientists and emergency responders.

Figure 1. Surface Decontamination Options According to Surface Type

OUTDOOR SURFACE APPROACHES

Before employing decontamination technologies outdoors, several outdoor elements need to be considered, including the following:

- Potential effect of natural attenuation
- Ability to maintain decontaminant concentrations, temperature and RH requirements, and contact time on surfaces
- Effects of organic loading in soil
- Complexity (porosity, irregularity in shape, etc.) of materials
- Collection and containment of liquid runoff
- Management of waste in an outdoor setting
- Surface corrosion or degradation caused by decontaminants
- Potential impacts on the environment

The primary difference to be expected with decontamination of outdoor materials is that outdoor materials may be more heavily grimed, most likely diminishing the efficacy of liquid sporicides such as bleach due to organic loading. In general, most liquid sporicides are more effective when there is less organic matter present, therefore the pre-cleaning to remove dirt/grime may be necessary in order to effectively decontaminate the surface. Transport of viable *B. anthracis* spores in liquid media (e.g., in runoff) or as aerosols during pre-cleaning step should be considered; containment may be necessary to avoid spreading contamination or increasing risk of exposure.

If outdoor decontamination is determined necessary, some of the evaluated technologies could be suitable for outdoor decontamination. The sections below discuss current research that may be considered for the decontamination of outdoor surfaces, including building materials and soil. Potential decontamination approaches such as gross wash down, use of liquid, fumigation, and germination-based decontamination are discussed.

GROSS WASH DOWN

A large-scale spraying or wash down using water hoses, fire trucks, or similar truck-mounted water spraying systems can distribute water or surfactants in large quantities to help provide immediate but low level reduction of spores. If performed properly with appropriate containment actions, spraying and wash down methods may limit the spread of contamination, reduce agent reaerosolization and therefore reduce exposure risk. However, it will be critical to evaluate the wash down method in the field to ensure that it will improve the situation, rather than spread contamination.

In an EPA study, pAB spray-based decontamination procedures were evaluated parametrically with respect to the physical removal, inactivation, and overall fate of spores on “medium-sized” coupons (35.6 cm x 35.6 cm or 14 in by 14 in) of indoor and outdoor materials [13]. Samples

were collected from the runoff/rinsate and analyzed quantitatively to determine the disposition of viable spores in this medium. Efficacy results for 15-second pAB applications (no rinse) on outdoor materials showed low LR values on the surface and viable spores in the rinsate indicating physical removal of the spores. This study supports the need for containment actions during a wash down. Prior to large-scale wash down, appropriate methods for runoff collection, containment, and subsequent decontamination of the contained liquid would need to be identified. The Publicly Owned Treatment Works (POTW) would need to be included early in any remediation planing involving large-scale wash down and/or decontamination approaches.

GERMINATION-BASED DECONTAMINATION

Some research has focused on the possibility of using germinants to convert spores to vegetative cells, facilitating inactivation of the cells through natural attenuation or other decontamination processes. The EPA conducted an investigation of the persistence of vegetative cells of *B. anthracis* both with and without exposure to UV-A/B radiation (representing sunlight) on several surfaces including glass, bare pine wood, unpainted concrete, and topsoil [14]. The results show that natural attenuation may also be a viable option for the decontamination of non-soil materials, provided that germination is effective in converting spores to vegetative cells. (As of the writing of this brief, no germinants have been demonstrated to be 100% effective in converting all spores to vegetative cells.) For soils, natural attenuation may also be a viable decontamination option provided that longer attenuation times (e.g., approximately a week) are acceptable, and the soil can be kept relatively dry.

APPLICATION OF LIQUID SPORICIDE OR FOAM

Numerous liquid and foam decontaminants have been comprehensively evaluated for their efficacy against spores of *B. anthracis* on non-porous and porous building materials and soil. Several studies [6, 14-17] have shown that the most effective sporicidal liquids (spray-applied to the test coupons and remained in contact for exposure times ranging from 10 to 70 min) for outdoor materials are H₂O₂/PAA, and HOCl chemistry. Examples of H₂O₂/PAA technologies include Minncare® Cold Sterilant and Oxonia Active® (see Table 1, items 3 and 4). Both of these are EPA registered sterilants. Examples of HOCl-based decontaminants are CASCAD™ SDF, pAB (see Table 1, items 9 and 10), and the electrochemical generation of anolyte solution (generated using the EcaFlo® system [18]).

However, due to organic loading, pAB is not effective at decontaminating *B. anthracis* in soil [10], and this will likely be the case with other decontaminants utilizing HOCl chemistry. Although, the use of pAB with a surfactant such as trisodium phosphate (TSP) may be useful in decontaminating heavily grimed surfaces that are found in urban areas [13]. Another evaluated chemical, sodium persulfate (see Table 1, item #12), which is made commercially for soil remediation, may be the best liquid sporicidal option for decontamination of soil or other high organic material, such as grime. An EPA study showed that sodium persulfate activated with hydrogen peroxide can overcome organic loading in soil [10].

An EPA study that evaluated pAB, CASCAD™ SDF, Oxonia Active®, and Klozur® (sodium persulfate) for decontaminating test coupons of topsoil containing *B. anthracis* spores found that efficacy was slightly better with the 120-minute contact time than with the 60-minute contact time for pAB, CASCAD™ SDF, Oxonia Active®. However, efficacy with these three decontaminants never exceeded about 1 LR, even with several applications onto the topsoil coupons. With Klozur®, efficacy was substantially greater with the 48-hour contact time than with the 24-hour contact time, and both Klozur® efficacy results were significantly higher than any efficacy result with the other three decontaminants. [9]

EPA is currently completing a study evaluating the efficacy of sodium persulfate against spores of *B. anthracis* on outdoor materials. Preliminary unpublished data shows a > 6 LR on outdoor material such as wood, brick, concrete, and asphalt under certain parameters. [11]

USE OF FUMIGANTS

Gaseous or vaporized products (often applied in the same manner as fumigants used in the agricultural industry) may be used to decontaminate soil and outdoor building materials. Methyl bromide has been shown to decontaminate *B. anthracis* on outdoor building material [19]. Test data also support the notion that ClO₂ (see Table 1, item #11) may be an effective decontaminant for soil [8] and surfaces covered with dirt or grime [20].

Additionally, metam sodium and methyl bromide have shown effectiveness against spores of *B. anthracis* in soil (see Table 1, item # 13 and 14). Metam sodium is the most widely used soil fumigant in the United States. It is applied as a liquid and converts to gas when it reacts with soil moisture. A study showed that metam sodium was effective (≥ 6 LR) against *B. anthracis* on topsoil. In the same study, methyl bromide was effective (≥ 6 LR achieved) against *B. anthracis* on topsoil at 25 °C when using a concentration of at least 180 mg/L and contact time of 36 hours [10].

CONCLUSION:

Many surface decontamination technologies exist. Some of the decontamination approaches presented in this brief have proven successful during real-world responses. In contrast, other approaches have been demonstrated to be effective during laboratory testing and have not been fully evaluated at the field-scale level. Therefore, many of the recommended techniques are based upon a combination of best professional judgment and experience of both scientists and emergency responders. During the response, users of this brief may need to evaluate and modify the decontamination techniques presented here to help establish the process-knowledge required for the environmental- and site-specific conditions.

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