Fixatives Application for Risk Mitigation Following Contamination with a Biological Agent

US EPA Decontamination Research and Development Conference

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14. ABSTRACT
This presentation gave an overview of the use of fixatives for use after a biological event. The presentation provided background, problem, current solution, advantages of fixatives, examples for radiological application, risk mitigation and rapid return to service, relative cost, potential for scale up, and challenges and possible solutions.

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WARRP, Fixatives, Biological Agent

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Talk Outline

- Background & Problem: Spore Resistance to Decontamination
- Current Solutions
- Advantages of Fixatives
- Examples for Radiological Applications
- Risk Mitigation and Rapid Return to Service
- Relative Cost
- Potential for Scale-up
- Challenges and Possible Solutions

Few Options Exist for Wide-Area Outdoor Decontamination of B. anthracis Spores

- **Gruinard Island**
  5% formaldehyde

- **Sverdlosk Release**
  UNKNOWN: but washing, chloramines, soil disposal believed to have been used

- **Danbury, Connecticut**
  nonporous surfaces treated with ~6% pH-amended bleach

Sources:
Manchee et a l., 1994, Meselson et al., 1994 , EPA, 2007
http://petra.wijnsema.nl/pictures/train_trip.htm
http://yosemite.epa.gov/opa/admpress.nsf/names/r01_2007-12-12_danbury
http://www.thesahara.info/medical/anthrax_gruinard_island.jpg
http://news.bbc.co.uk/olmedia/1455000/images/_1457035_gruinard_island_150map.gif

EPA Testing on Outdoor Materials Provide Options for Hard Nonporous Surfaces

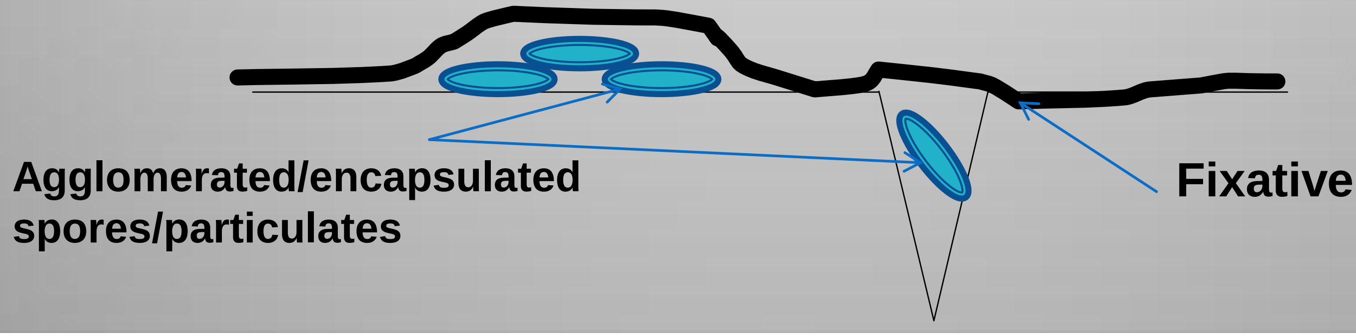
Disinfectant	**>6 Log Reduction on Materials** (EPA, 2010a,b; Wood et al., 2011)	**Missing Surfaces That May Be Targets For Fixatives**
pH-amended bleach (sodium hypochlorite)	Stainless Steel, Glass, Aluminum, Porcelain, Granite, Concrete, Brick, Butyl Rubber	Asphalt, Greasy/Oily Surfaces, Soils, Vegetation, Roadway Gutters…
Hydrogen peroxide /peroxyacetic acid (Peridox, Spor-Klenz, Oxonia)	Stainless Steel, Glass, Aluminum, Porcelain, Granite, Brick, Treated Wood, Butyl Rubber, Galvanized Metal	Asphalt, Greasy/Oily Surfaces, Soils, Vegetation, Roadway Gutters…
Aqueous chlorine dioxide (ClO_2) (DioxiGard, SanDes)	Galvanized Metal, Glass	Asphalt, Greasy/Oily Surfaces , Soils, Vegetation, Roadway Gutters…
Hydrogen peroxide and other agents (Decon Green)	Stainless Steel, Glass, Aluminum, Porcelain, Granite, Brick, Butyl Rubber	Asphalt, Greasy/Oily Surfaces Soils, Vegetation, Roadway Gutters…
Sodium dichloroisocyanurate (CASCAD)	Stainless Steel, Glass, Aluminum, Porcelain, Granite, Concrete, Brick, Asphalt, Treated Wood, Butyl Rubber	Greasy/Oily Surfaces, Soils, Vegetation, Roadway Gutters…
Methyl Bromide	Galvanized Metal, Glass (has potential for soils)	Asphalt, Greasy/Oily Surfaces, Soils, Vegetation, Roadway Gutters…

Challenges for Outdoor Decontamination of B. anthracis Spores

- High disinfectant concentrations increase operational costs and risk to human health and the environment
- Disinfectants are corrosive, damaging to surfaces/materials
- Disinfectants may be consumed in organic/chemical backgrounds in the environment
- Decontamination activities could promote spore transport in liquid or air phase (reaerosolization), or fomites
- No disinfectants have been demonstrated to be effective in soils or on vegetation
- Disinfectants pose long-term human health and environmental impacts

Fixatives

- The "Fixatives" approach employs available liquid materials to temporarily or permanently fix *B. anthracis* spores to surfaces.
- Through agglomeration and fixation, the concentration of spores that may be resuspended in the respirable particle size range (1-10 µm) should be reduced.
- Fixative applications may then be employed as a risk mitigation step during first response and initial recovery activities to limit exposure and further spead of contamination.



Fixatives

- Fixatives may be an inexpensive, rapid, and effective means to prevent reaerosolization and spread of outdoor biological/radiological agents is needed for large-scale incidents.
- Fixatives that can agglomerate and/or stabilize particles to prevent reaerosolization and reduce inhalation health risks.
- Fixative applications may support Rapid Return to Service (RRS) for key transport corridors (roads) and critical infrastructure.

Common Fixative Applications

- Radiological Contamination (Fukushima Nuclear Power Plant, Chernobyl)
- Methamphetamine Cleanup
- Hazardous Waste Management
- Soil Contamination Encapsulation (common for PCBs)
- Asbestos Encapsulation

http://www.aimcontracting.com.au/roofing_coating_asbestos_encapsulation.htm

Fukushima Example

- Two fixative materials have been used in Japan following the events at the Fukushima Diiachi plant:
  - KuriCoat 720, originally developed to prevent dust and sand from being blown off reclaimed and developed land
  - AGUA3000, originally developed to encapsulate asbestos on ocean-going ships - no VOCs, incombustible and odor-free, low viscosity, fast permeating solution

http://www.japanprobe.com/2011/04/02/spraying-resin-to-prevent-the-spread-of-radioactivity/
http://www.kurita.co.jp/products/kuricoat.html, http://www.aguajapan.co.jp/pdf/1105brochure.pdf

Controlling Contamination Extent

- Spore may wash off surfaces with rainfall. Studies by the US EPA have found that wash off and rinsate of decontaminant solutions may still contain significant levels of viable spores (Ryan, 2010).
- Once washed off surfaces, how far will the spores travel? What critical infrastructure, natural resources, or political boundaries are downstream?
- Fomite transport has been demonstrated to occur (Van Cuyk et al. 2011, Weis et al., 2002)
- Fixatives may be employed along transport pathways at high risk/consequence for downstream contamination.

Moya, emergencias 2007;19:144-150

Spore Reaerosolization & Exposure

- Preventing reaerosolization is critical for reducing exposure
- Trees contaminated with spores could contribute to exposure and increase the extent of the problem
- There are no methods to decontaminate trees, so removal may be the only option
- Given the time required for tree removal, fixatives may provide a rapid approach to reduce this potential source

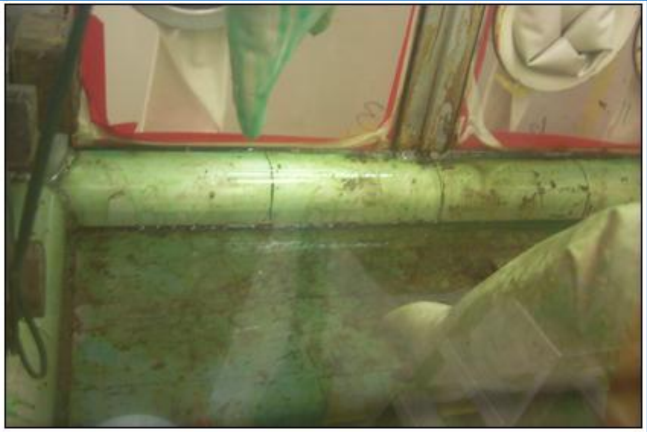
Blowing Pollen From Cedar Trees

Rapid Return to Service

- Rapid Return to Service (RRS) strategies must include major transport corridors.
- Evacuation Routes and roadways to critical infrastructure will need to be reopened quickly and the time for characterization , decontamination, and clearance made not be available.
- Fixatives could potentially be applied to roadways and the surrounding area for temporary egress into and out of, as well as transportation bypass around contaminated areas.

Example – Pu & Fixatives

- Fixatives that are designed to be peeled off are also termed "strippable coatings"
- LLNL tested CBI DeconGel 1101 strippable coating on a glove-box containing Pu contamination
  - >99% effectiveness in removing contamination from aluminum surfaces
  - Can be rolled, brushed or sprayed on surfaces




Sutton et al.(2008) LLNL-TR-404723

Relative Cost

- Clorox bleach estimated material cost = $4 to $9 per gallon decontaminant solution
- Fixatives are typically more expensive, in some cases 2-10x the cost of bleach, depending on whether the fixative is also a strippable coating, and on the coverage needed (area, surface material, porosity) etc.
- Fixatives can also include paint, oils and other commonly available materials, which are cheaper than commercial fixatives

Potential for Scale-up

Type of application equipment	Volume capacity (gal)	Reported liquid application rate (gpm)	Apparatus cost[b] ($)
Plot scale—limited decontamination (<0.5 acre)[c]			
Backpack sprayers Portable sprayers (on dolly or rollers)	2 to 50	<10	≤10K
Mesoscale—small structures or roads (0.5 to 5 acres)			
Skid-mounted spray systems Horizontal boom sprayers Tree sprayers Vertical boom sprayers	100 to 3,200 (modular)	<100	10K to ≥100K
Large-scale—large buildings, ports, or parking lots (5 to 50 acres)			
Fire trucks, fire boats, and hydrants Agricultural sprinklers Small aircraft	120 to 2,000	1,000 to 1,500 trucks and hydrants up to 20,000 fire boats (total) 74 to 695 sprinkler heads (aircraft not available)	10K to 100K
Wide-area—large, uniform areas (>50 acres)			
Larger aircraft (C-130 or DC-10) Super tanker aircraft (747)	3,000 to 20,000	Not available	50K to ≥100K

[a] Data from DHS (2007); Cal Fire (2010); Hsu (2006); company websites; and customer sales representatives.
[b] Approximate cost for equipment purchase or rental does not include staffing, reagents, or other deployment costs.
[c] Area scales estimated for ~1 day (4 hr for application, 2 hr for setup, and 2 hr for teardown). When estimating acreages, include total vertical and horizontal surfaces to be treated.

Agricultural and Other Spray Technologies

- Liquid application rates: 10^{-3} to 1 L/m^2
- Deposition layers: 1 to 10^3 µm
- Work rates: 3 to 600 ha/hr
- Droplet size (diameter): 10 to 10^3 µm
- Droplet velocities: 10^{-1} to 10^1 m/s


http://www.kirtland.af.mil/photos/mediagallery.asp?galleryID=2467


http://www.aero-news.net/index.cfm?do=main.textpost&id=07a7bbca-6124-4eae-ab7f-94f9806c9cc0


http://www.spraycontractor.com/

Challenges to Fixative Efficacy

- Uniformity of application
- Long-term stability and resistance to weathering
- Future decontamination and waste management issues
- Environmental impacts of fixatives (oil or water based, toxicity, etc…)

Opportunities & Possible Solutions

- The DHS S&T Wide Area Recovery and Resiliency Program (WARRP) has funding an study of fixative application for biological contamination
- There are opportunities to leverage knowledge from radiological applications
- Appropriate application and scale-up issues can be assisted by lessons learned from agricultural spray technologies
- With additional investigation we can assess whether fixatives are another option to add to the list of potential response technologies following a biological release

Collaboration

- **LLNL colleagues:**
  - Dr. Staci Kane (microbiology and fixative testing)
  - Dr. Joe Tringe (engineering and spray technology for other applications)
- **Partner with UNLV colleagues for efficacy testing**
  - Dr. Mark Buttner
    Optimization of germinant and disinfectant application (formulation and delivery parameters)
- **Partner with UC-Davis colleagues for dissemination technology**
  - Dr. Ken Giles
    Optimization of germinant and disinfectant application (formulation and delivery parameters)
- **Partner with US EPA National Homeland Security Research Center (NHSRC):**
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    Experimental design and data analysis of microcosm studies and EPA chamber studies

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