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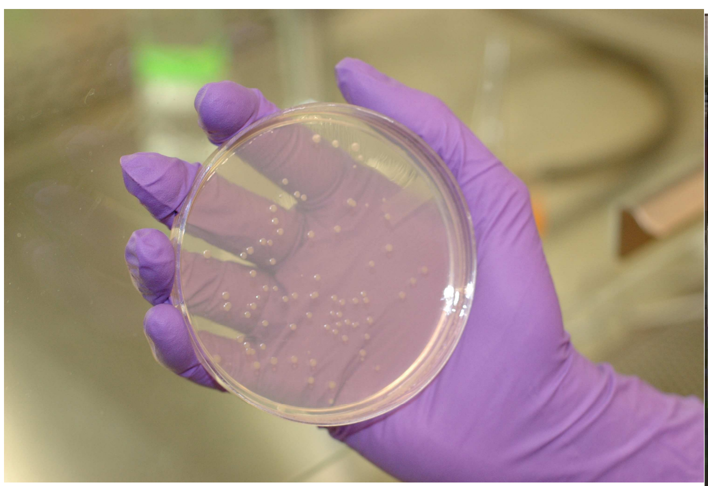
Decontamination Research



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Mission

Provide expertise and guidance
on the selection and implementation of
effective decontamination technologies
for indoor and outdoor CBRN events
and
provide the scientific basis for a significant
reduction in the time and cost

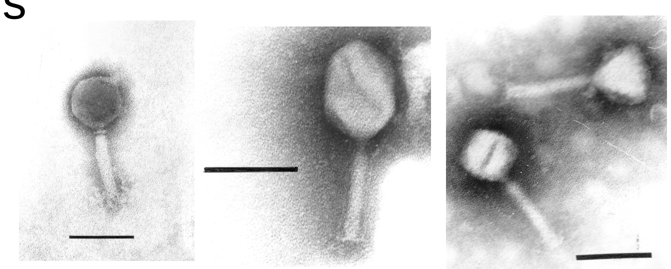
Integrated Research Process

- Decontamination demonstrations (e.g., chamber and field studies)
- **Decontamination technology application studies (e.g., generation rates, material/equipment compatibi containment)**
- **Technology evaluations (e.g., TTEP, systematic decontamination studie**
- Agent Fate (e.g., persistence, penetration)
- **Efficacy test methods**
- Decontamination method developmen

Decontamination Methods Development

Bacteriophage methods

- Collaboration with the US Army and vendor
- Targets are pathogenic *E. coli* strains
- Phage cocktails



- Surfaces: glass, gypsum board, Foods (tomatoes, broccoli, spinach, ground beef)
- Effective kill at higher phage concentrations
- Tests just begun on *Y. pestis* (plague)

Efficacy Test Method Development: Factors to Consider

- Operating conditions
  - Concentration
    - Contaminant
    - Decontamination chemical/physical method
  - Temperature
  - Relative Humidity
  - Materials compatibility
    - Material damage
    - Material demand
  - Persistence of contaminant

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Efficacy Test Method Matrix

- Agents
  - Biological
    - B. *anthracis,* Variola virus, Y. *pestis,* F. *tularensis,* ricin toxin, B. *suis*
  - Chemical:
    - malathion, dimethyl methylphosphonate (DMMP), Sarin (GB), thickened Soman (TGD), VX
- Materials
  - Non-porous
  - Porous
- Technologies
  - Liquids
  - Fumigants
- Operating Conditions
  - Concentration of active decontamination agent
  - Environmental conditions

Testing Approach

- Two-phased approach:
  - Evaluation of persistence
  - Parametric decontamination testing

- Positive controls maintained at ambient conditions to determine efficacy corrected for "natural attenuation"

- Materials:

- Particle board
- Industrial-grade carpet
- Glass
- Painted concrete cinder block
- Galvanized metal ductwork
- Decorative laminate
- Compressed cellulose insulation

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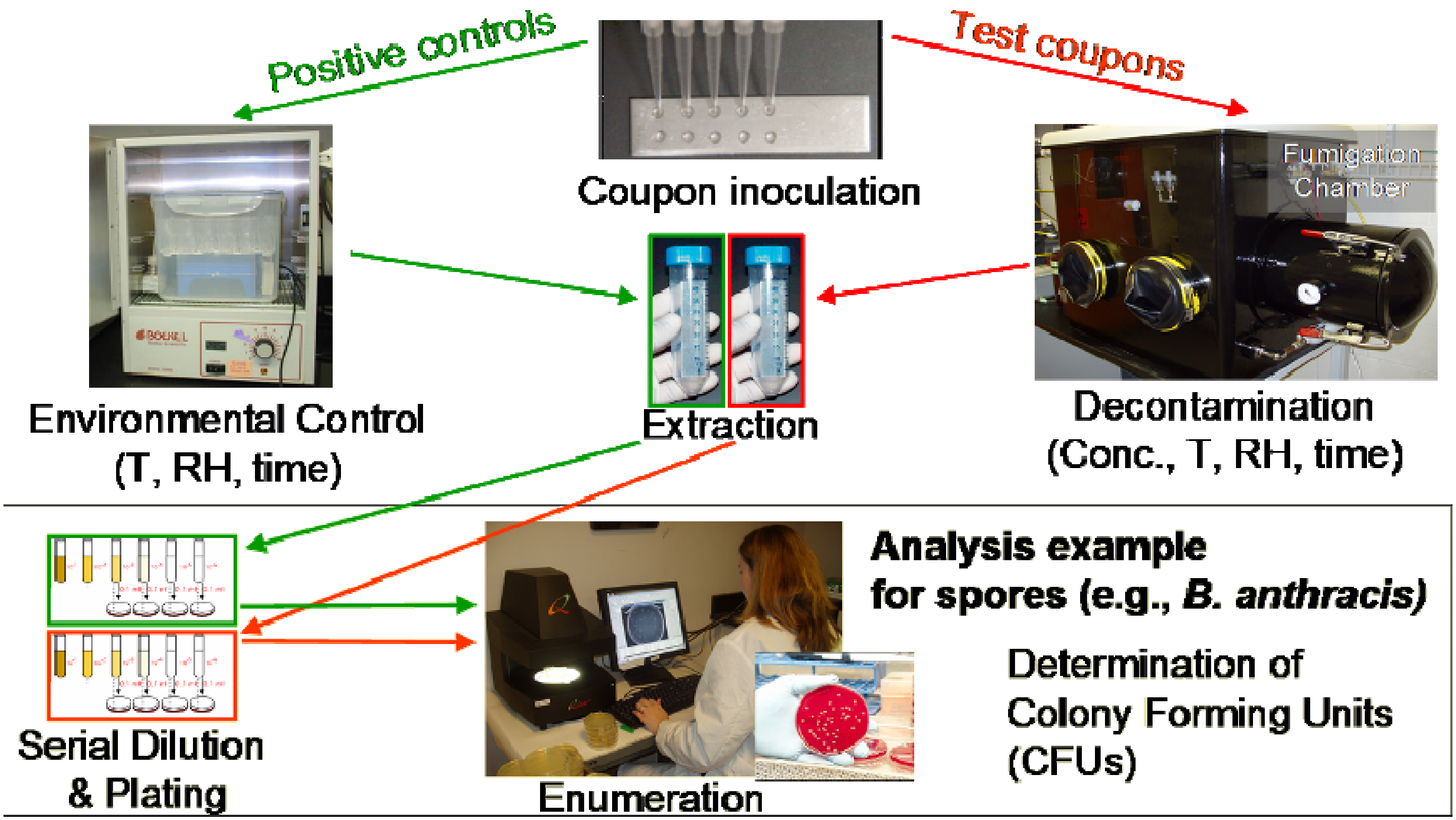
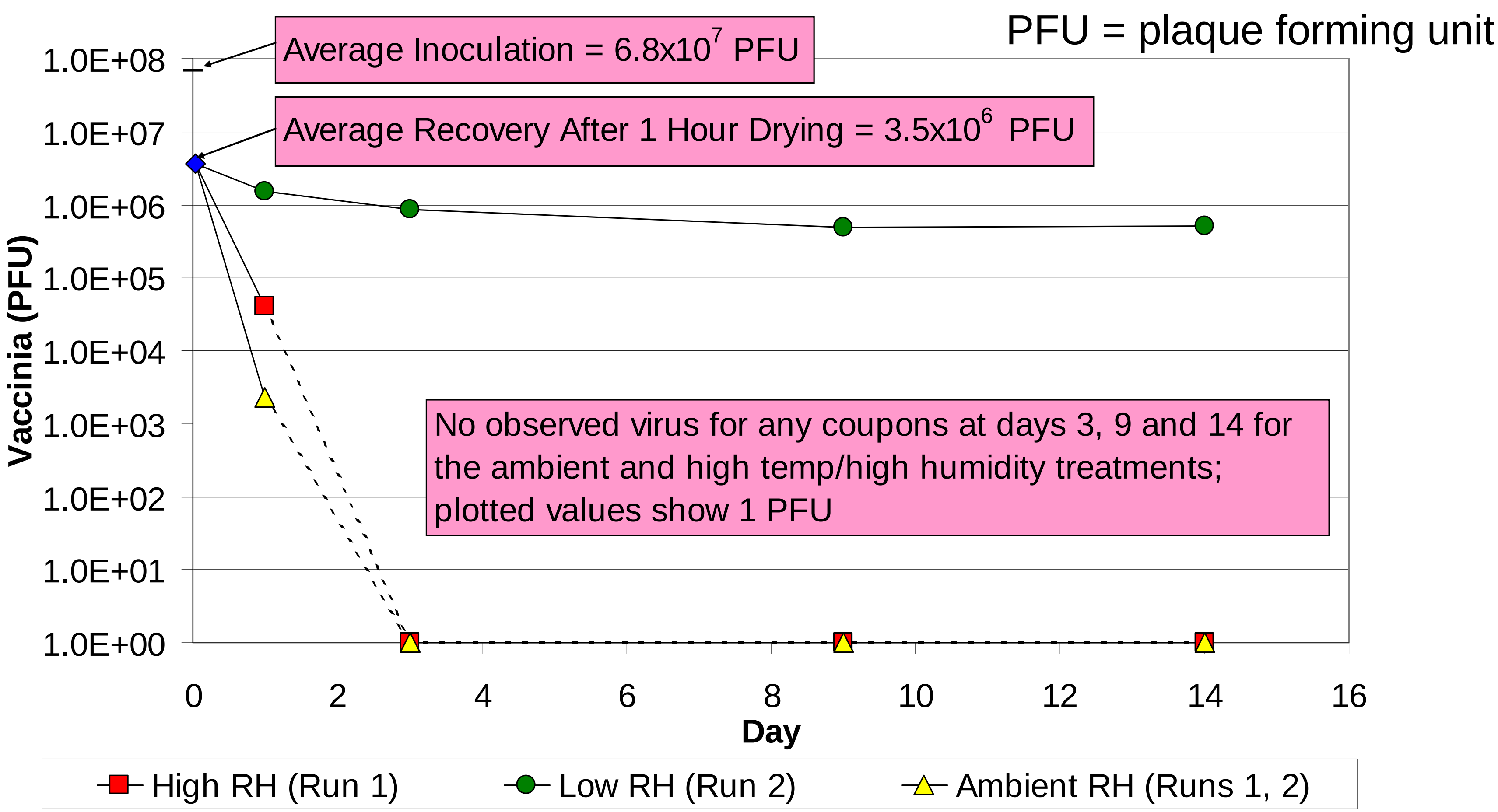
Description of Testing

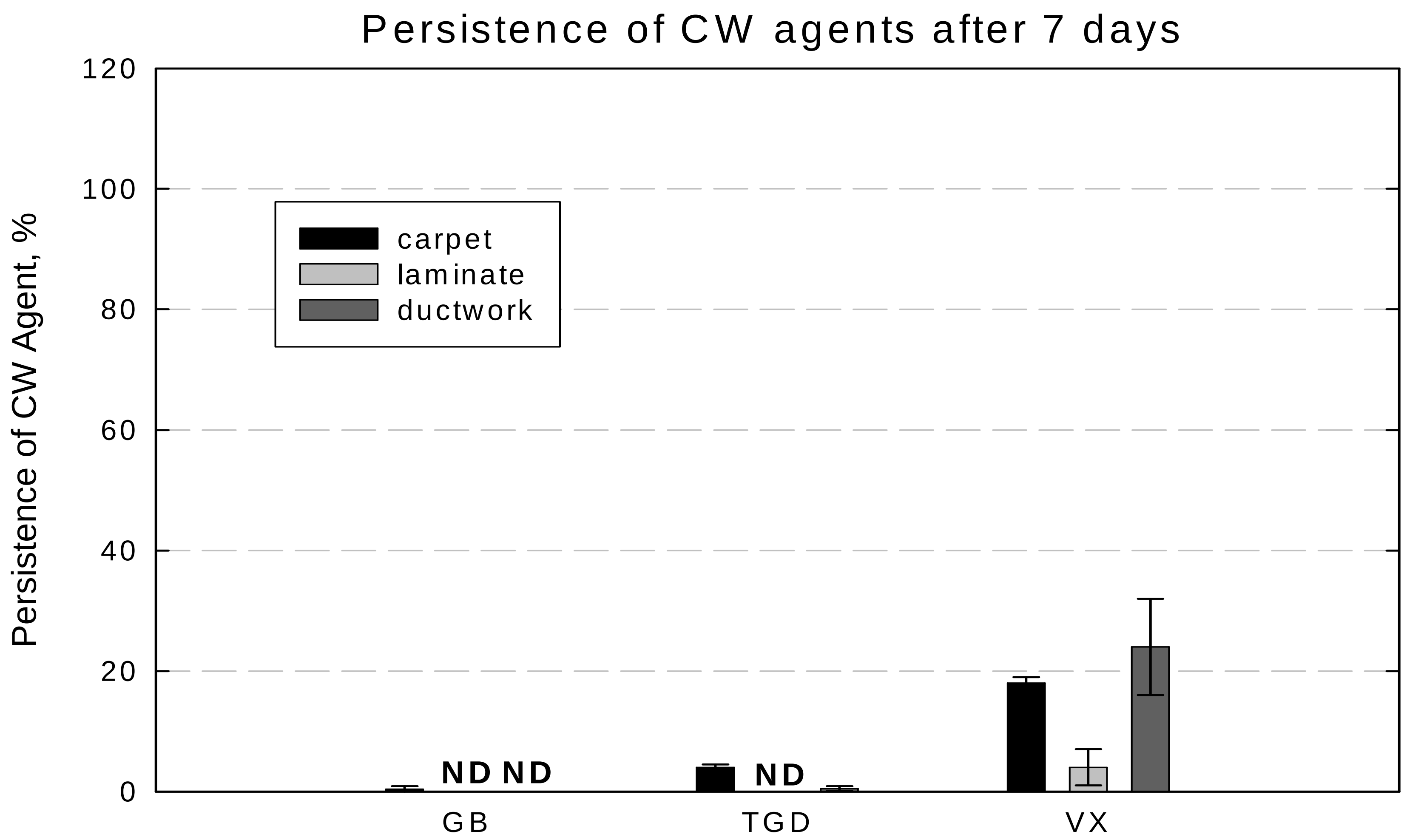


Natural Attenuation (BWA Persistence)

Persistence of Vaccinia Virus on Galvanized Metal



Natural Attenuation (CWA Persistence)



Decontamination Technologies Tested

Technology	Relevance
ClO_2 gas (Sabre, ClorDiSys, CDG)	Crisis exemptions for Sabre ClO_2 use in "anthrax" cleanups and mold remediation
Paraflormaldehyde (CERTEK)	Crisis exemption for fumigation of postal equipment in the 2001 anthrax remediations
Methyl bromide (MeBr) gas	Used as pesticide; lab and field tests on *Bacillus* spores
Hydrogen peroxide fumigant (STERIS VHP®, BIOQUELL HPV)	Crisis exemption for STERIS VHP® used in remediation of State Dept. mail facility; VHP® is a registered sterilant (not for *B. anthracis* in buildings)
Amended Bleach; CASCAD SDF; DeconGreen; DIoxiGuard; EasyDecon 200; Exterm-6; HI-Clean 605; HM-4100; KlearWater; Peridox; Selectrocide	11 liquids screened for effectiveness against *B. anthracis* on glass; CASCAD SFD, HI-Clean 605, KlearWater, and Peridox further tested on 3 materials and 3 spore types
Amended bleach	Crisis exemption for use in several anthrax responses
Exterm-6	Aqueous ClO_2 used in the Hart Senate Office Bldg
SporKlenz®	Used in SA-32 remediation for anthrax contamination

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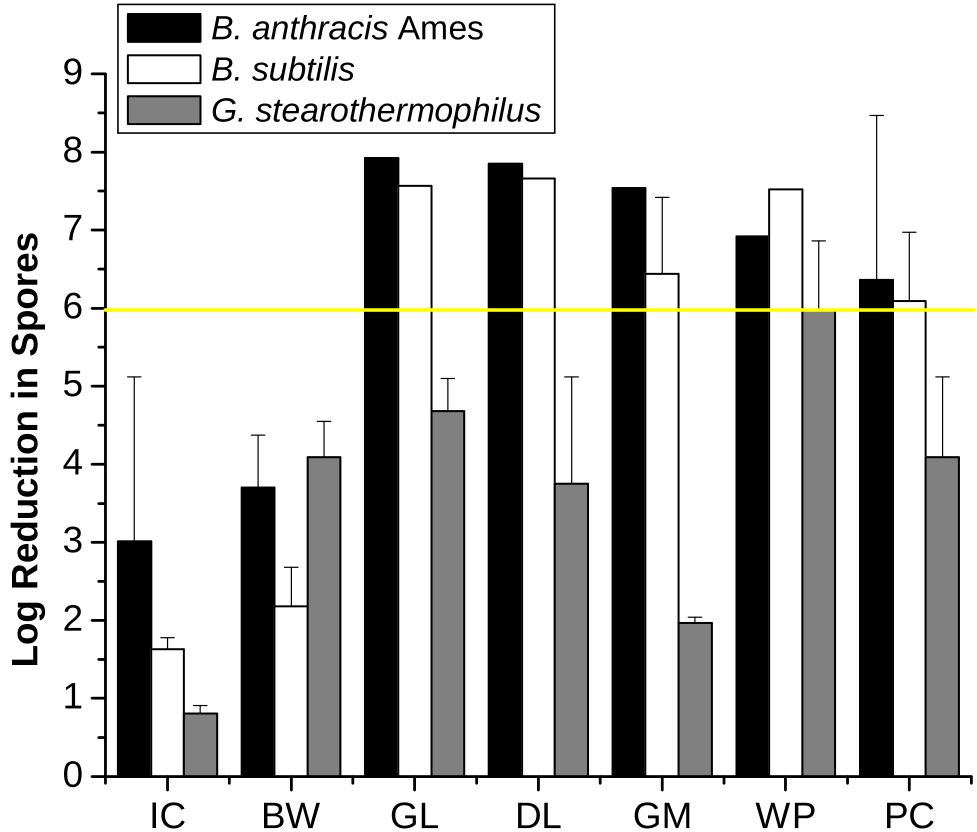
Examples of Fumigation Chambers (Gases/Vapors)

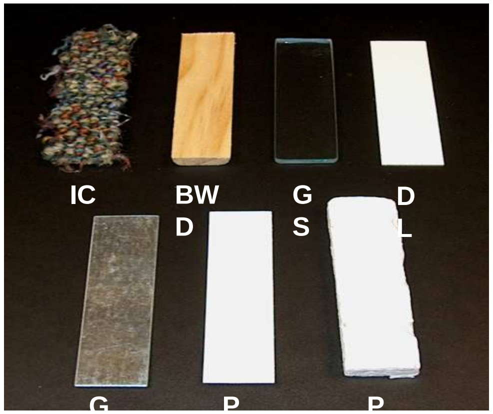
- Temperature and relative humidity (RH) controlled
- Fumigant generation external to chamber
- Real-time, and/or periodic, gas or vapor concentration monitoring
- Coupons removable at incremental exposure times for some gases or vapors

Technology Testing Results: Anthrax

BIOQUELL HPV Fumigation

>1000 ppmv, 20 min, 40-91 % RH, 22-38 °C



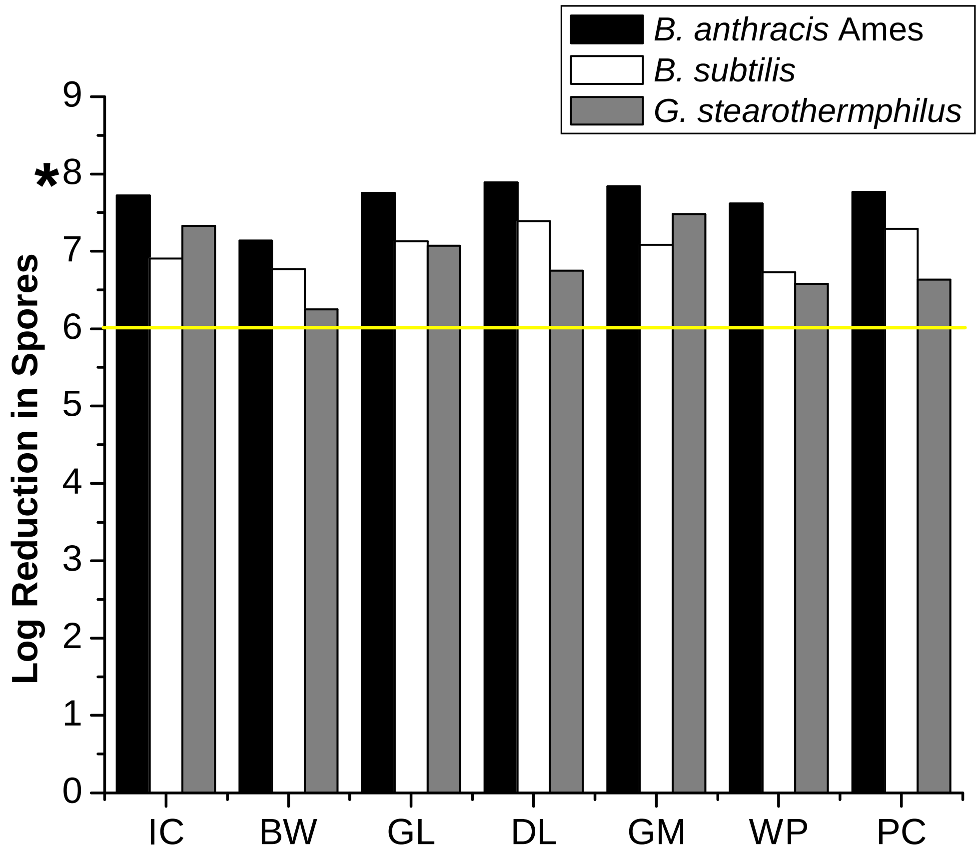


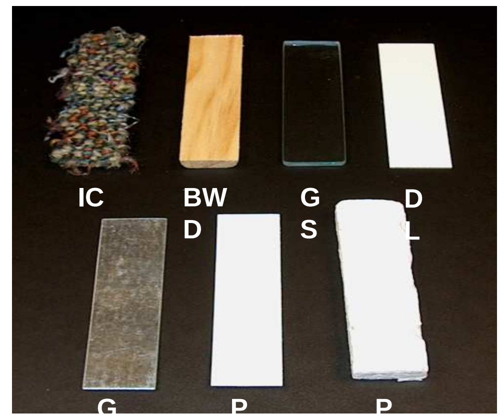
IC = Industrial Carpet
BW = Bare Wood
GL = Glass
DL = Decorative Laminate
GM = Galvanized Metal Ductwork
WP = Latex-painted Wallboard Paper
PC = Painted Concrete

Technology Testing Results: Anthrax

Sabre ClO_2 Fumigation

3000 ppmv, 3 hrs, 75-90 % RH, 22-35 °C





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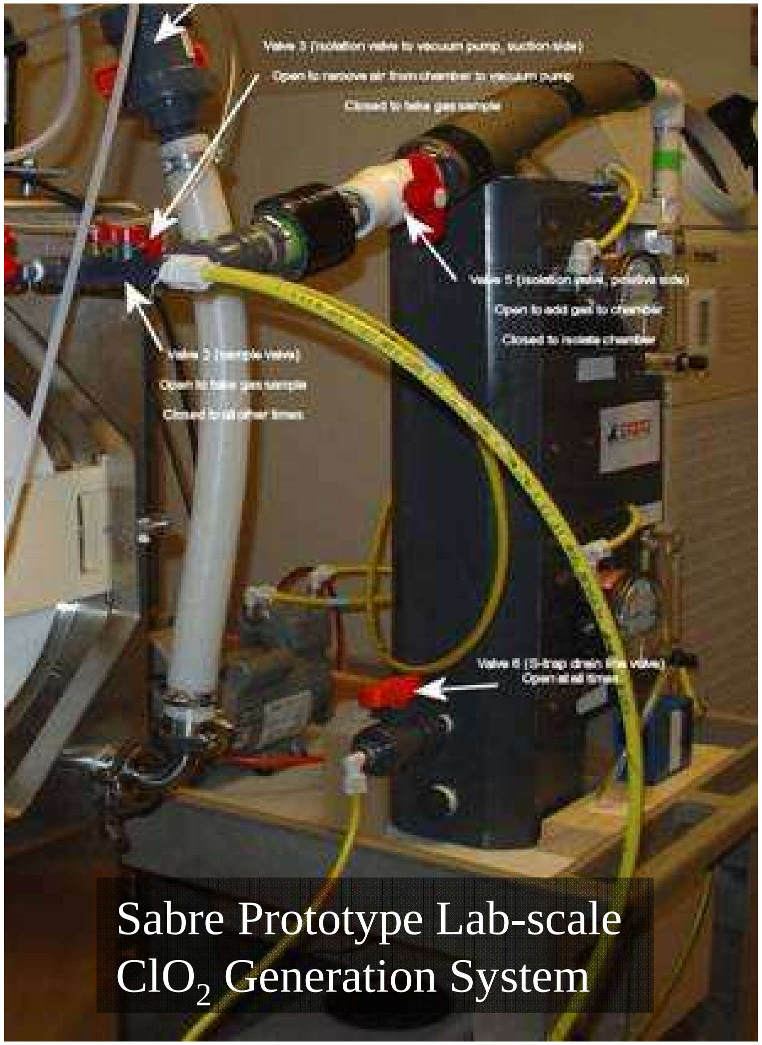
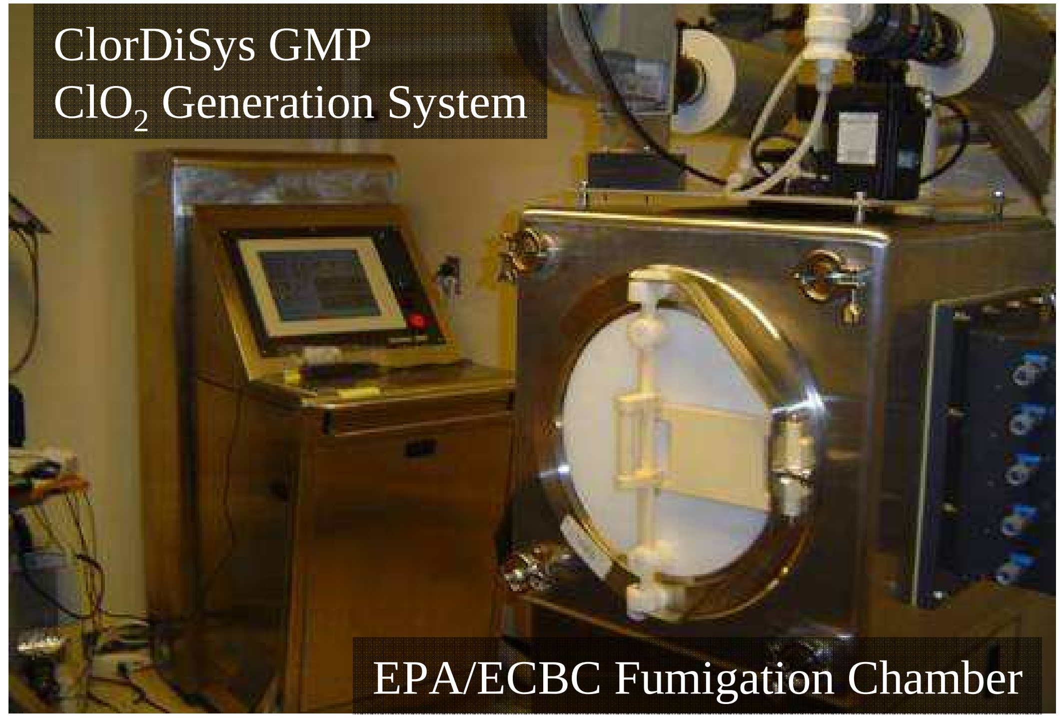
*Note: “no growth” from any coupon

Fumigation: ClO_2

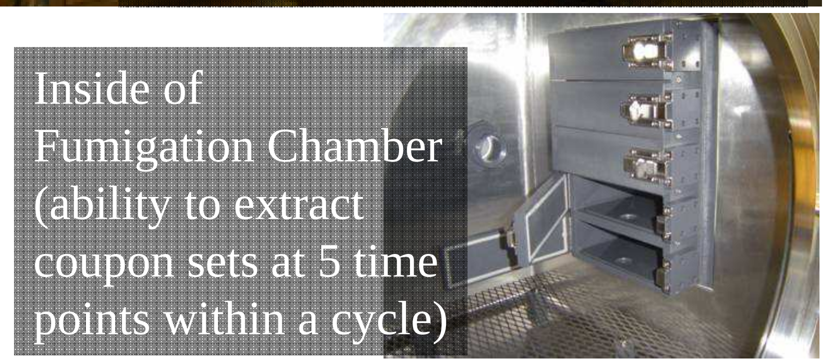


Sabre Prototype Lab-scale ClO_2 Generation System



ClorDiSys GMP ClO_2 Generation System

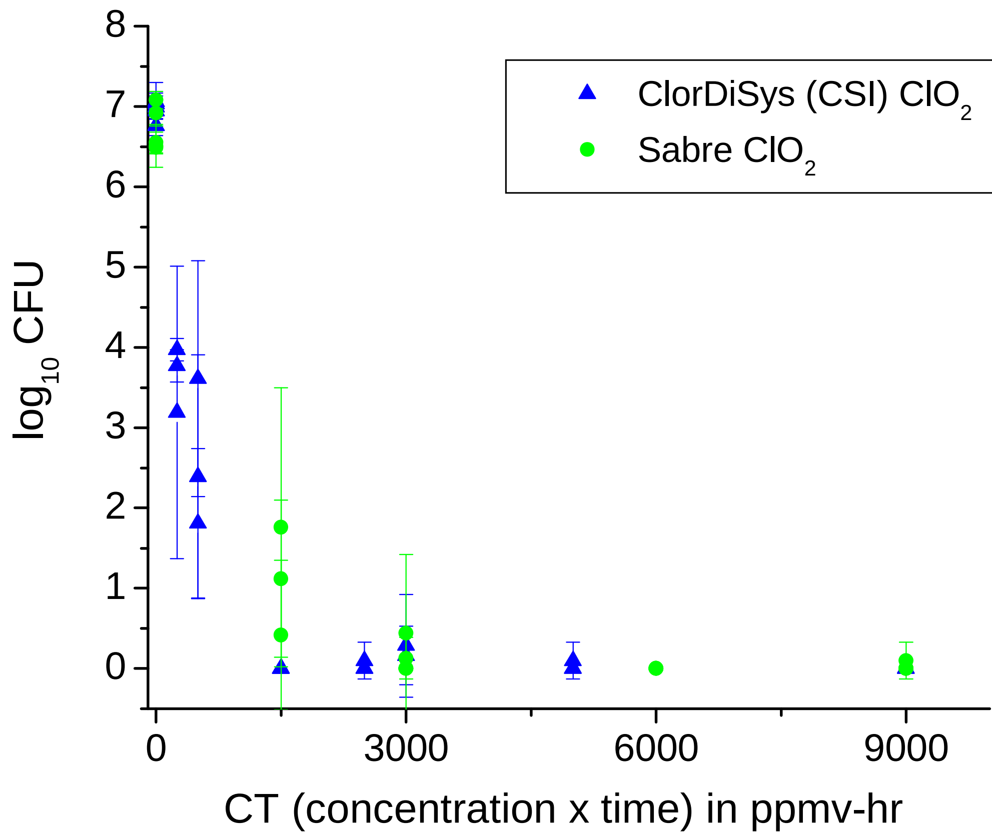
EPA/ECBC Fumigation Chamber



Inside of Fumigation Chamber (ability to extract coupon sets at 5 time points within a cycle)

Fumigation: ClO_2

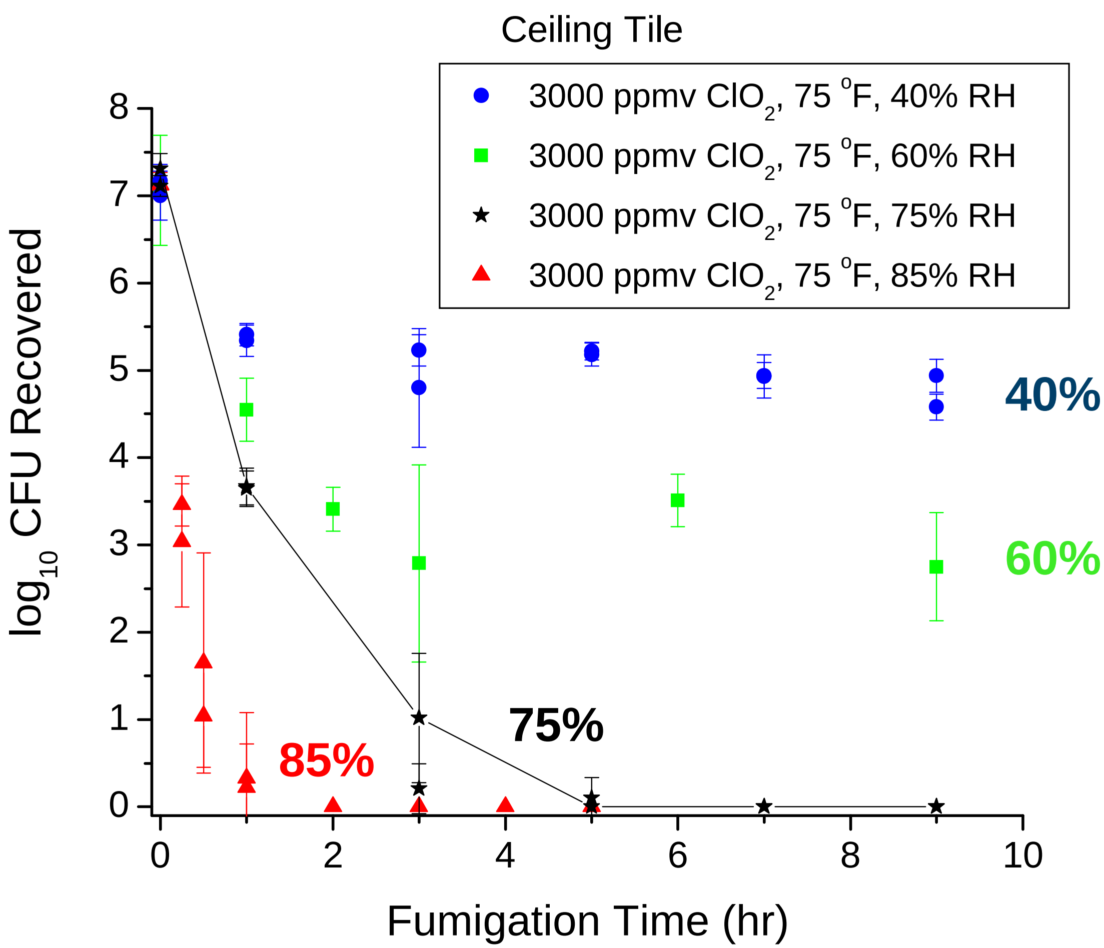
Decontamination of *B. anthracis* NNR1Δ1 spores on industrial carpet (NHSRC/ECBC)



- Decontamination of materials (carpet shown) as a function of ClO_2 concentration (500, 1000, 1500, 3000 ppmv) and time at 75 % RH and 75 ^oF
- Large variability in data at low CT
- Kill curve and variability not a function of ClO_2 generation method
- No growth from any carpet sample after fumigation with a CT ≥ 6000 ppm-hr

Impact of Operating Conditions on Efficacy

Effect of RH on the Inactivation of *B. anthracis* with ClO_2



- Inactivation of *B. anthracis* NNR1Δ1 spores on ceiling tile with CloriDiSys ClO_2
- Past requirement has been >75% RH at 75 °F (noted by black stars on the graph)
- Current results suggest the reduction in viable spores is a strong function of RH (even above 75%)

Ryan, Rastogi et al., 2007

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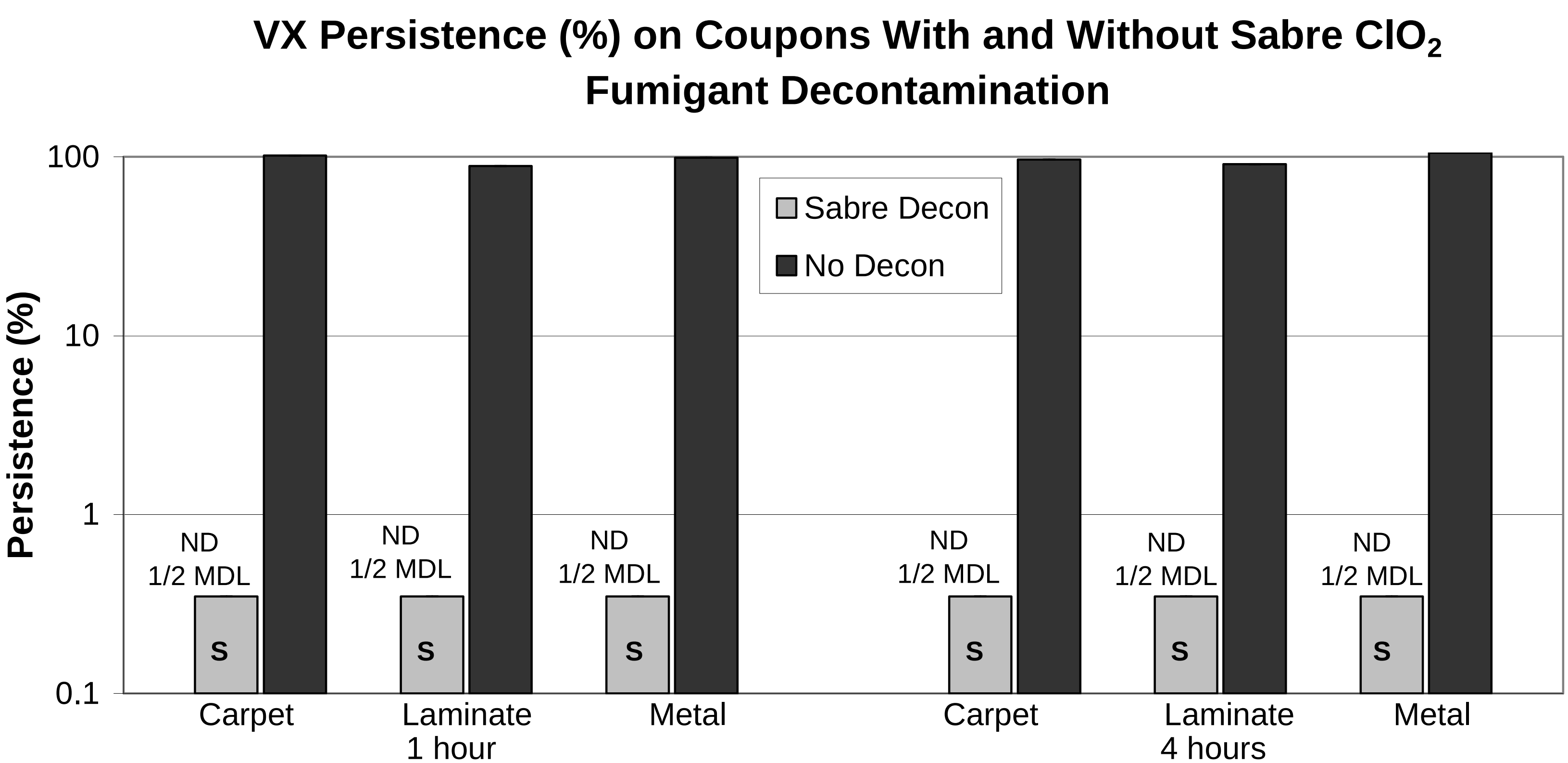
Fumigation: Efficacy of ClO_2

- Complete inactivation (>6 LR) of *B. anthracis* spores on plastic (computer keyboard keys) and painted wallboard paper within 20 minutes at 3000 ppmv, 75% RH, and 75 ^{o}F

- Complete inactivation of ricin toxin and vaccinia virus (smallpox vaccine strain) using ClO_2 gas on all materials (porous and non porous) investigated was observed at ~150 ppmv-hr (200-300 ppmv for 30 minutes at 75^{o}F, 75% RH); lowest CT studied

- Additional work underway to determine "kill" curves as a function of time at constant ClO_2 concentration for multiple agents on four materials; subsequent study for BIOQUELL HPV to follow
  - Agents: *B. anthracis, F. tularensis, Y. pestis, B. suis,* botullinum toxin, smallpox vaccine strain

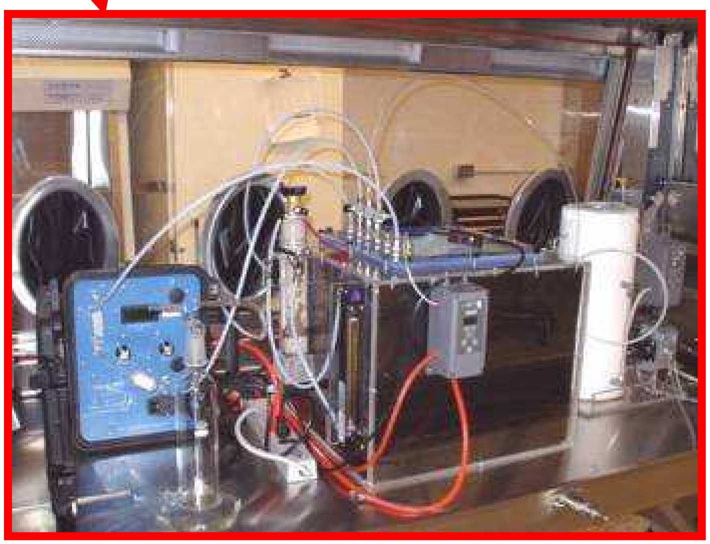
Fumigation: Efficacy of ClO_2



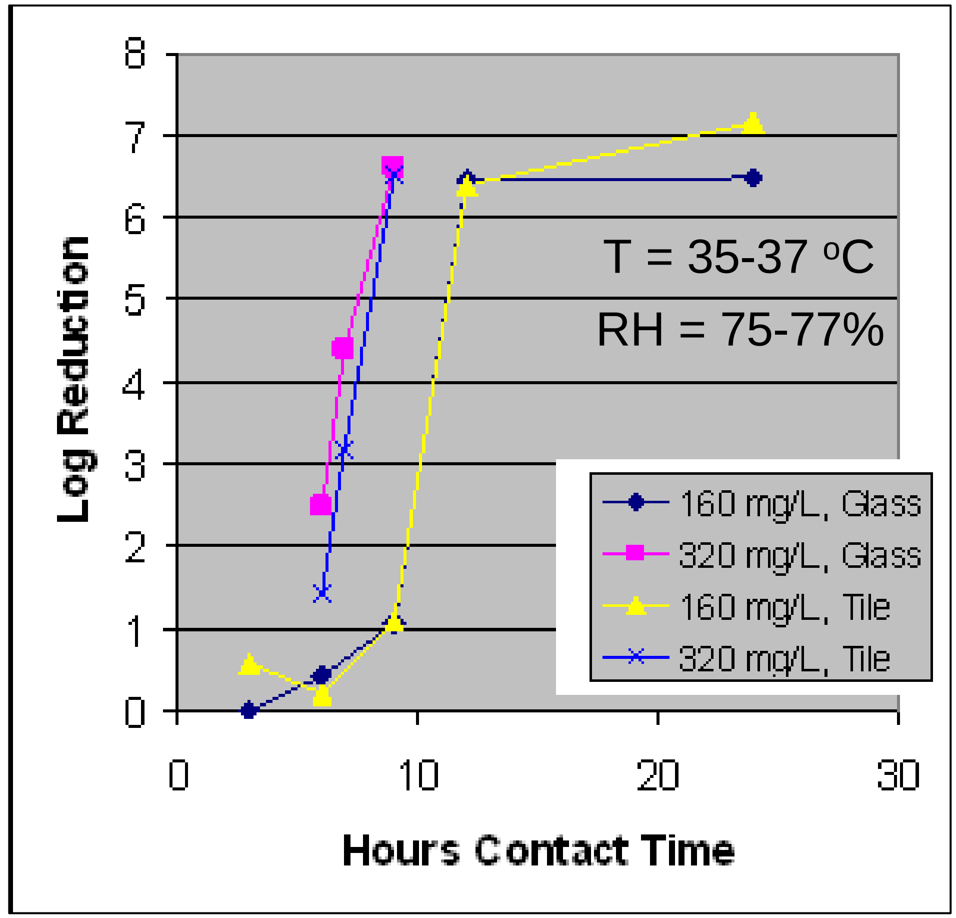
S Denotes persistence statistically significantly less with Sabre ClO_2 fumigant decontamination

- ClO_2 was highly effective at neutralizing VX; by-products not analyzed for
- Limited to no effectiveness for TGD or GB (not shown)
- Similar results for aqueous ClO_2

Fumigation: Methyl bromide (MeBr)



Log Reduction of *B. anthracis* Ames on Glass and Ceiling Tile



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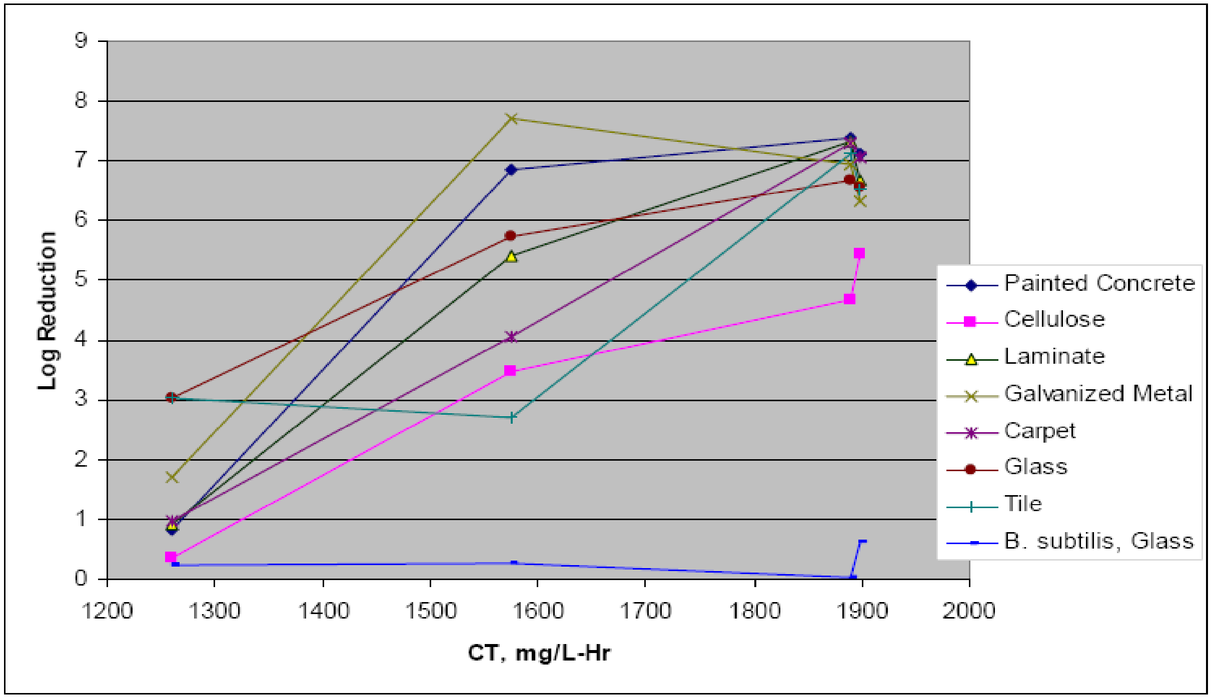
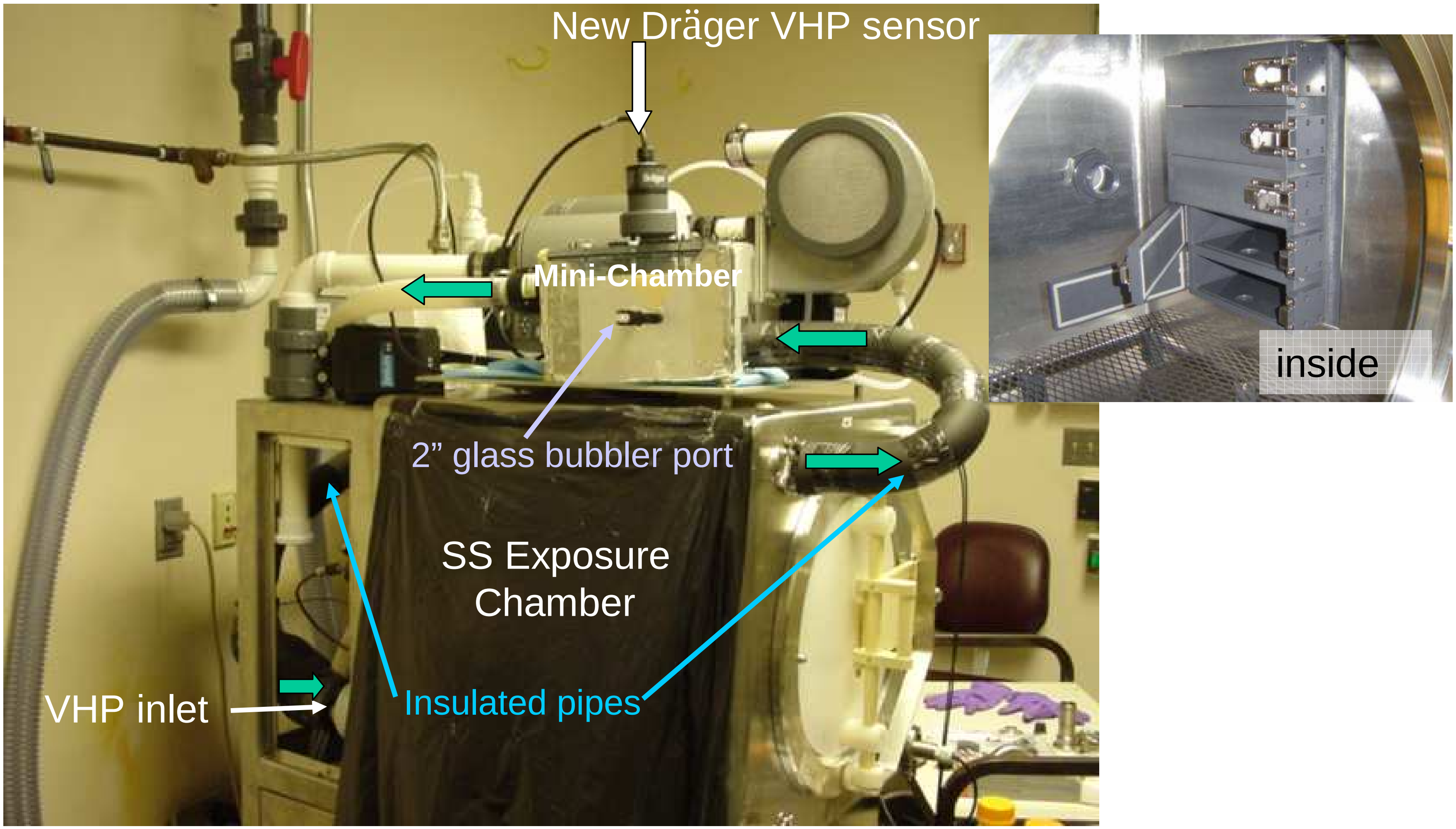
Fumigation: Methyl bromide (MeBr)



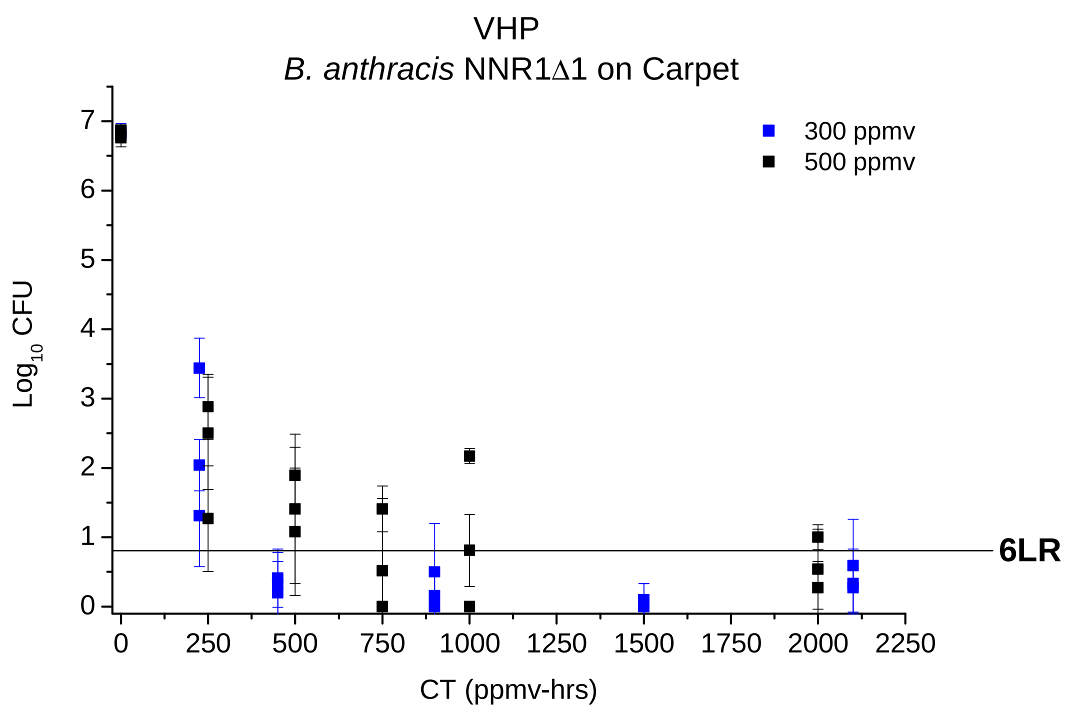
- Particle board
- Industrial-grade carpet
- Glass
- Painted concrete cinder block
- Galvanized metal ductwork
- Decorative laminate
- Compressed cellulose insulation

Fumigation: VHP®



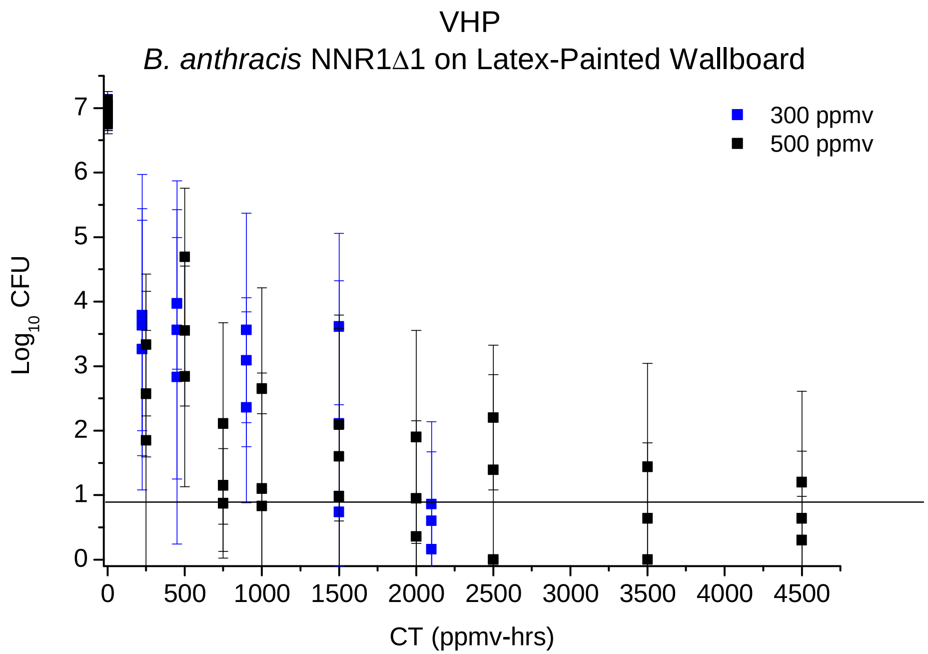
Fumigation: VHP®

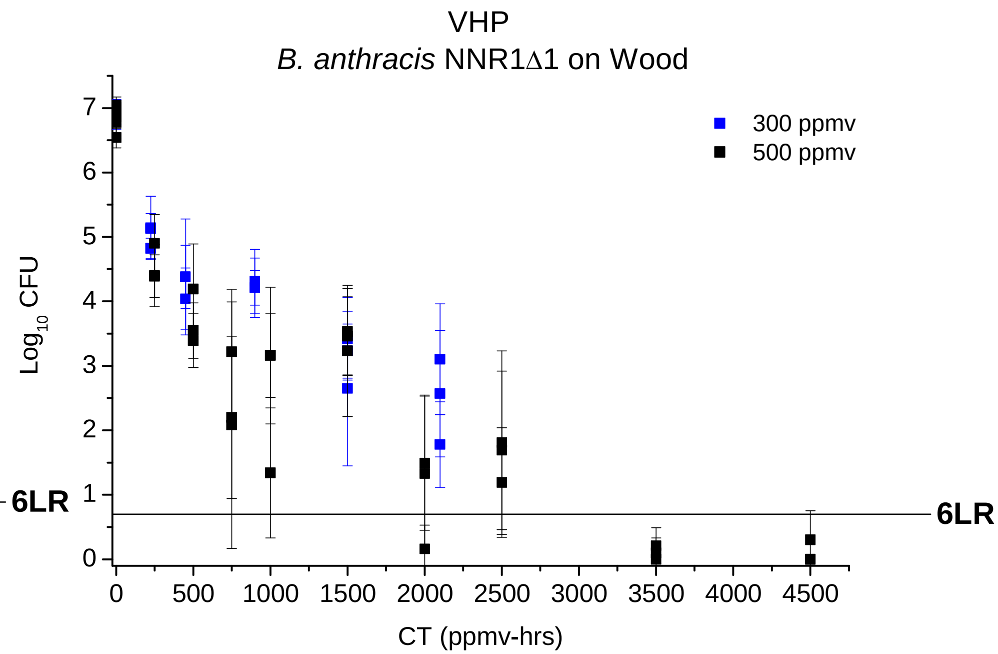
Decontamination of *B. anthracis* NNR1Δ1 spores on industrial carpet (NHSRC/ECBC)



- Decontamination of materials (carpet shown) as a function of VHP® concentration and time
- Large variability in data at low CT
- Kill observed to be a function of CT; no difference in effectiveness observed at the different concentrations

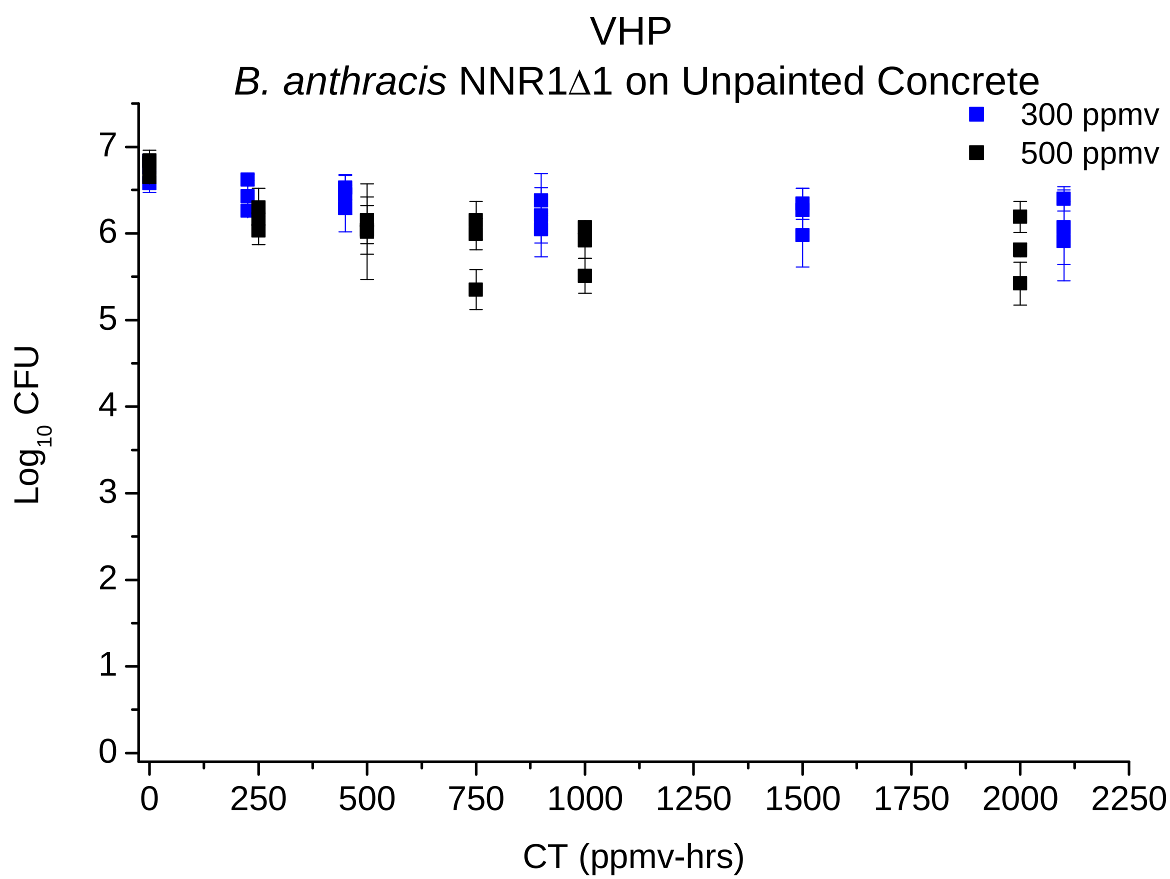
Fumigation: VHP®





- CT required for to achieve a 6 log reduction in CFUs was observed to be a strong function of material type
- CTs required for most sealed (painted) or porous materials was much greater than those achieved in past field applications (e.g., 1000 ppmv-hrs)

Fumigation: VHP®



- No effectiveness of VHP® for *B. anthracis* spores on concrete block

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CWA - Bleach Decontamination Results

CWA	Material	Time	Mean Recovery, % of Mass Recovered at Time 0 ± SD	
			Without Decontamination (in air in a sealed vial)	**With Bleach Decontamination**
GB	Carpet	10 min	93 ± 7	ND, <0.1[a]
TGD	Carpet	10 min	121 ± 33	ND, <0.1
	Laminate	10 min	90 ± 10	3.7 ± 1.9
	Ductwork	10 min	130 ± 39	3.2 ± 1.9
VX	Carpet	30 min	107 ± 7	ND, <0.7
	Laminate	30 min	102 ± 6	ND, <0.7
	Ductwork	30 min	95 ± 11	ND, <0.7

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Chlorine Dioxide Liquid Decontamination Results

CWA	**Material**	**Time**	**Without Decontamination (in acidified water)[b]**	**With ClO_2 (Liquid) Decontamination**
VX	Carpet	10 min	5.0	ND, <0.7
	Laminate	10 min	1.9	ND, <0.7
	Ductwork	10 min	ND, <0.7	ND, <0.7

FIFRA Requirements

How does the available data [e.g., method(s) used to determine efficacy)] apply to the current application?

- Pesticide products or devices used in or on inanimate surfaces are regulated by EPA under Federal Insecticide, Fungicide, and Rodenticide Act (FIFRA)
  - EPA approval for a pesticide under FIFRA is either by <u>registration</u> (i.e., license) or by <u>exemption</u> (i.e., emergency, quarantine or crisis)
    - No products are currently registered for *B. anthracis* spores
    - For anthrax cleanups, EPA issued 28 crisis exemptions and rejected 35 in response to 63 requests.

- The EPA/ORD/NHSRC/DCMD is collaborating with EPA/OPP to provide science for registration or exemption decisions through the decontamination research program

FIFRA Requirements: Research Efforts

- Determine the efficacy of promising technologies to inactivate spores of *Bacillus anthracis* using three test methods at conditions of high, medium, and low efficacy

  – AOAC Sporicidal Activity of Disinfectants Test 966.04 – data currently required for FIFRA registration (qualitative test); use of porcelain penicylinders and silk suture loops

  – Three-Step Method, as modified by EPA (mTSM) – currently use of small glass coupons being proposed as registration alternative (quantitative test)

  – Current quantitative TTEP Standard Operating Procedures for porous and non-porous building materials (iSOP)

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Technology Application Studies

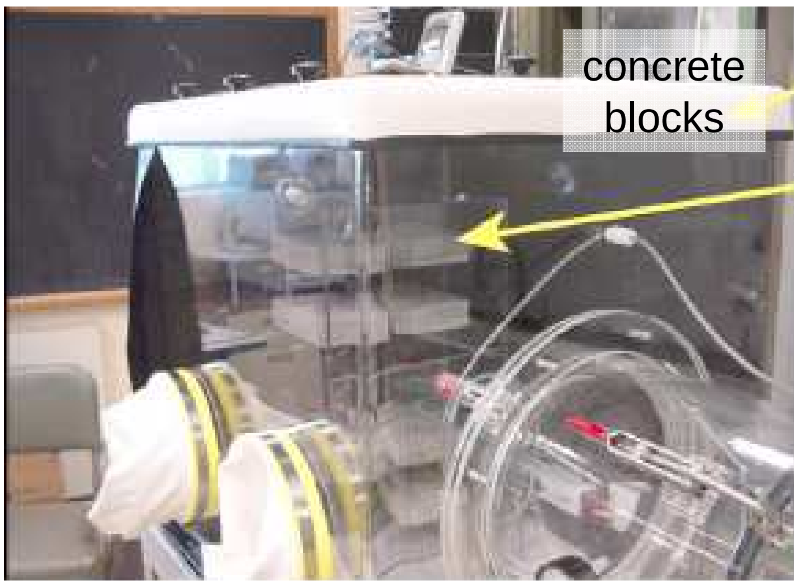
- Applying lab results to field application
- R&D on application related issues for efficacious technologies
  - What application issues must be considered in selection and implementation of a technology?
    - e.g., material demand and material/equipment compatibility, fumigant penetration
  - What are the best ways to improve effectiveness and decrease cost of application?
    - e.g., fumigant containment
- Decontamination Technologies Research Lab (DTRL) located in RTP; focus on fumigation research and analytical support

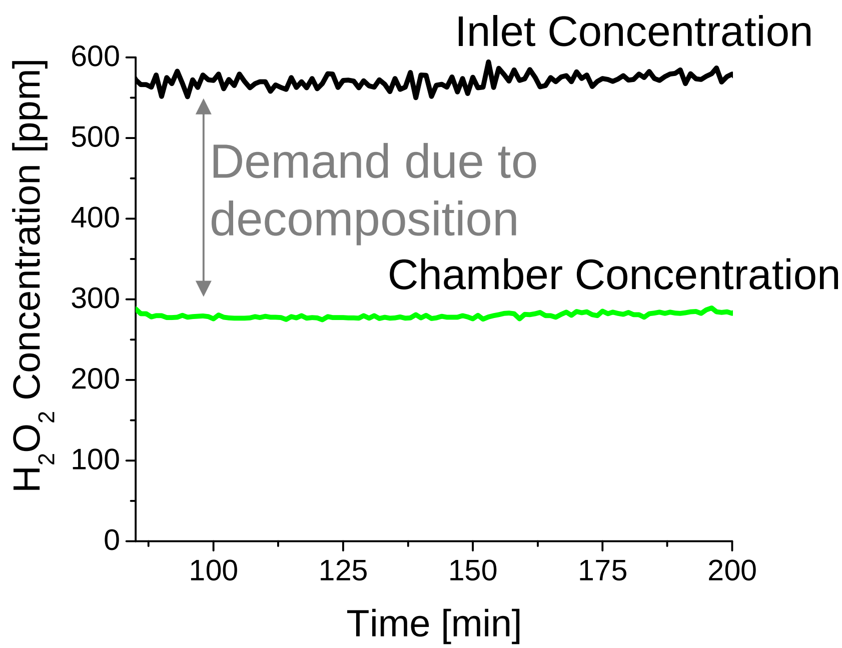
DTRL Research Overview

- Process parameter measurements (e.g., gas/vapor concentration, RH)
- Permeability of fumigants through materials and containments
  - Which materials are best to contain fumigants?
  - How well do fumigants penetrate building materials?
- Fumigant adsorption capacity or reaction rate on sorbents/catalysts
  - Which materials are best to scrub gases/vapors from fumigation emissions?
- Material demand
  - What is the impact of materials on fumigants (what generation capacity is required to achieve target gas concentrations and concentration x time (CT) values)?
- Fumigant/material by-products
- Material/equipment compatibility

Material Demand

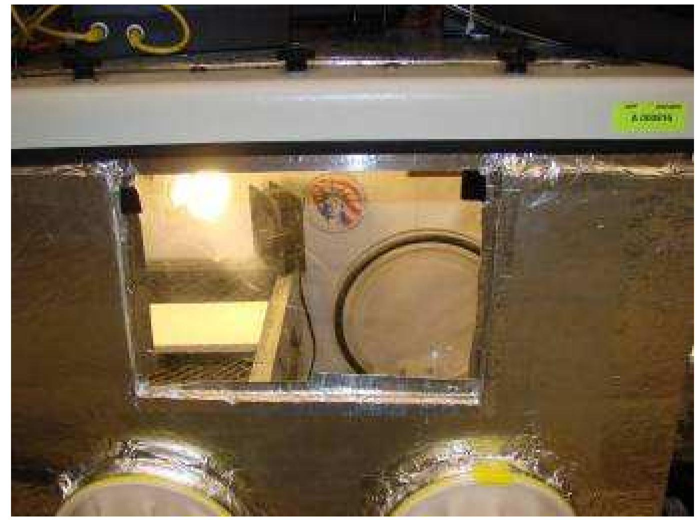
- **Materials can substantially impact the ability to achieve the target fumigant concentration within a defined volume**
  - What generation rate is required to achieve target fumigant concentrations within a volume based on homogeneous decomposition and material interactions?

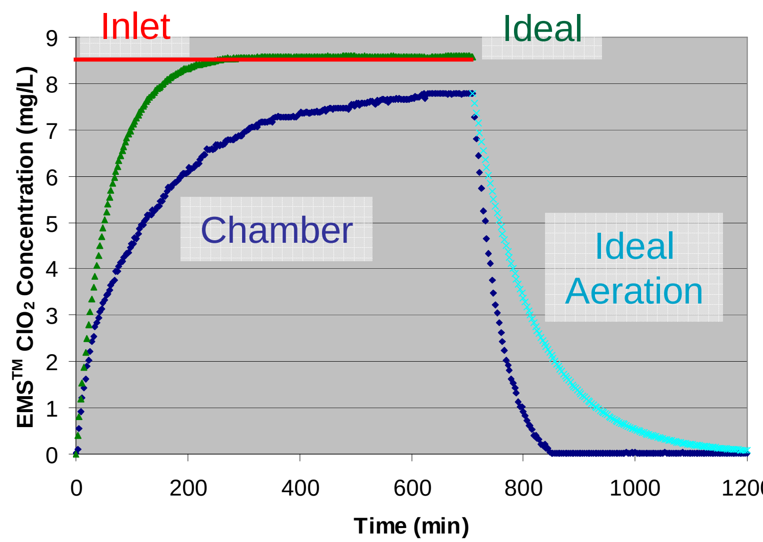




Material Demand

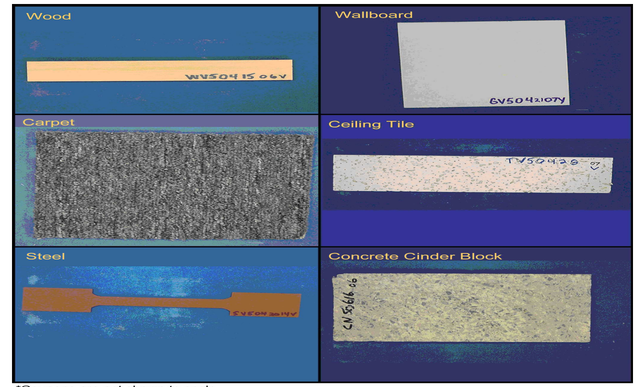
- Initial focus on ClO_2 due to high efficacy for BWAs observed on all non porous and porous materials investigated
- Investigation of material demand as a function of material, inlet ClO_2 concentration, and operating conditions (T, RH)
  - Homogeneous decomposition (light, heat)
  - Material Demand
    - Ceiling tile
    - Galvanized metal ductwork
    - Wallboard
- Data used for modeling to develop a "simple" **material demand calculator tool**





Material Demand

- Prior work with Edgewood Chemical and Biological Center (ECBC) on ClO_2 and VHP® concluded significant demand for some materials:
  - ClO_2: ceiling tile > wallboard
  - VHP®: concrete > ceiling tile, wallboard, wood
  - EPA/ECBC work done at limited conditions to determine potential importance of material demand for fumigant/material combinations



*Coupons are not shown to scale

- Expanding on work in-house (DTRL) to support and develop a tool (material demand calculator) to determine material demand as a function of fumigation conditions and construction materials
  - Technology selection and implementation:
    - Does the generation system have enough capacity to overcome demand?
    - Decon/Disposal paradigm

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Material/Equipment Compatibility

- Impact of fumigation on materials and equipment investigated as a function of fumigation conditions

- Initial work done as part of work with ECBC on ClO_2 and VHP® material demand
  - No aesthetic impacts on materials tested
  - No significant impacts determined during ASTM physical strength tests
    - Published report available at www.epa.gov/nhsrc

Material/Equipment Compatibility

- Extension of material/equipment compatibility continuing in DTRL
- Initial work on ClO_2; plans to extend material demand and material/equipment compatibility studies to an HP technology in FY 08
- Includes aesthetic and functionality testing over time
  - Material/equipment down-select:
    - Aluminum, copper, and carbon steel coupons
    - Stranded wires, house wiring insulation, switches
    - Sealants (e.g., silicon), gaskets
    - Laser and ink-jet printed paper
    - Photographs and media (e.g., CD's, DVD's)
    - Small electronics (e.g., PDA, cell phone, fax machine, and telephone)

Material/Equipment Compatibility: Computer Studies

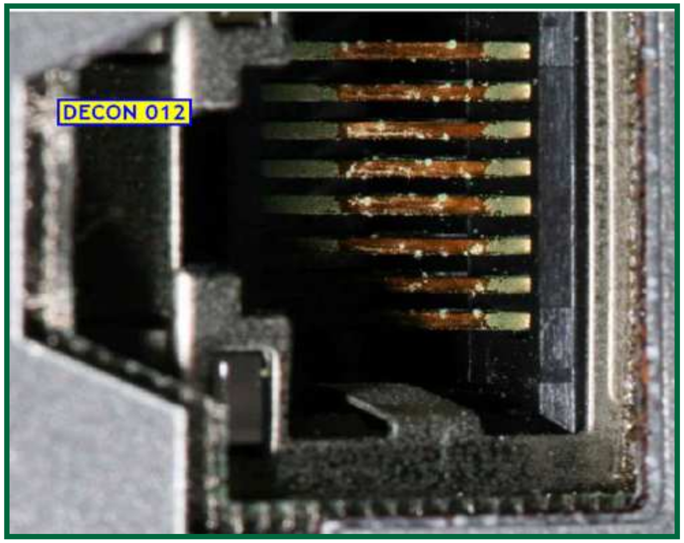
- Corrosion due to fumigation with ClO_2 observed to be a function of fumigation conditions

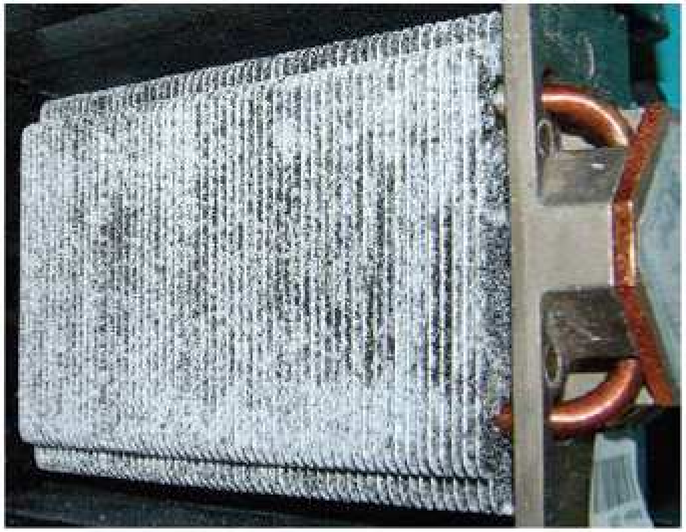
- High concentration and high RH conditions resulted in most significant impacts

- Most impacted components in terms of operability were CD/DVD drives; damage to plastic optics

- ClO_2 attacked any connector where gold plating was 0.5 µm or less ("standard" is 1 µm)

- Observed formation of by-product of fumigation (aluminum chloride) on one type of Ni coated-Aluminum heat sink





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Summary

- Selection of a decontamination strategy is scenario specific; there is no single broadly applicable solution to be applied

- Development of the decontamination strategy for a site should balance time/cost of decontamination/disposal/restoration

- Considerations:
  - Area to be decontaminated (size and complexity)
    - Include cost/options for disposal in selection of the decontamination strategy
  - Efficacy of the technologies considering the contaminated surfaces
  - Generation capacity of the technology
    - Can material demand be overcome to achieve successful decontamination conditions in the field application?
  - Fumigant containment and measurement
    - Health and Safety concerns
    - Achieving target conditions
  - Effect of the decontamination process on materials/equipment
  - Potential interactions with materials (e.g., by-products)

Decontamination Research: Completed Products

- Report on available biological decontamination methods
- Technology evaluation of decontamination methods
  - H_2O_2 (2 vendors)
  - ClO_2 (2 vendors)
  - HCHO
  - methyl bromide
  - liquids and foams (15)
- Field evaluation of a portable ClO_2 system
- Annual workshops on advances in decontamination technologies with case studies of usage; attendees from:
  - 29 U.S. Government agencies,
  - 18 private developers,
  - 6 academic institutions, and
  - 7 foreign countries

Decontamination Research: Future Plans

- Comparison of efficacy results for spores as a function of aerosol deposition (likely dissemination) vs. liquid inoculation (standard laboratory method)
- Scale-up of decon efficacy and engineering studies (larger equipment for RDD; room-size, furnished chamber for chem/bio)
- TIC decon – additional threat chemicals
- Biological agent decon
  - Parametric liquid testing (impact of field formulations)
  - Studies of technology application in large, office chamber
- Decon technologies for sensitive areas/items
  - MeBr

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Questions?