# Report on The

# 2015 U.S. EPA International Decontamination Research and Development Conference

# Appendix C

## Presentation Slides

# 2015 U.S. EPA International Decontamination Research and Development Conference

## Tuesday, May 5, 2015

## General Session 1

### Connecting Response and Research Activities





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# Research - Education - Training:
# *An Academic Responder Perspective*


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## Institute for Crisis, Emergency and Risk Management

- Interdisciplinary chartered Institute since 1994.
- Based in Engineering Management & Systems Engineering
- Wide-ranging research program including PH and Healthcare Systems
- Graduate Education Program in Crisis, Emergency and Risk Management

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## Barbera response experience

Wide range in years and emergency types:

- Three decades…
- Earthquakes, Hurricanes & Tsunami
- Terrorism (Oklahoma City, Pentagon/ WTC for 9-11, Anthrax DC)
- Hospital and Trauma Center mass casualties
- Other…

## *Post-Earthquake Import/Export Building*

*Luzon Province, Philippines (1990)*

Nepal Earthquake Survivor

Pemba Tamang is carried on a stretcher after being rescued by Nepalese policemen and U.S. rescue workers from a building that collapsed five days ago in Kathmandu, Nepal, Thursday, April 30, 2015. Crowds cheered Thursday as a Tamang was pulled, dazed and dusty, from the wreckage of a seven-story Kathmandu building that collapsed around him five days ago when an enormous earthquake shook Nepal. (AP Photo/Niranjan Shresta)

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# Research - Education - Training: *An Academic Responder Perspective*

Presentation outline

- ❑ The problem…
- ❑ "Emergency" Response vs. Everyday Emergency
- ❑ The Emergency Context…
- ❑ Research on Management Process
- ❑ Research on Technical Tools
- ❑ Guidance Development
- ❑ Education & Training

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# The problem statement…

Conducting Research & Using Scientists in emergencies and complex, major remediation can generate "issues"…

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EDITORIAL

## A community for disaster science

During disasters such as the 2010 Deepwater Horizon oil spill, engaging the expertise of the academic community helped responders make critical decisions. A major barrier to such engagement, however, is the cultural gap between academia's reward system and that which prevails in the disaster response community. Given the importance of developing smart approaches to disasters, whether natural or human-caused, we need to bridge this gap.

Responders are often focused on ending an emergency quickly, with minimal damage. Academics are driven to understand the basic science of these events first, as a basis for proposed actions. Each community is used to speaking to different audiences and delivering answers on their own time scales. But these differences should not discourage attempts to connect these communities.

One approach is to foster a cohesive community of

ing to oil spills, forest fires, earthquakes, hurricanes, and other emergencies. Researchers would develop ties with relevant industries (oil companies, utilities, insurance companies, etc.) and help all sides identify vulnerabilities, increase resilience, and better coordinate the scientific response. Together, responders and affected industries could create funds to support prioritized research.

The advantage of building a community for all disasters, rather than for just one type, is that researchers maintain momentum between emergencies, which may be decades or more apart for any one class. Every disaster poses similar challenges: knowing when to speak to the press and what to say; how to develop "no regrets" actions; how to communicate with decision-makers and the public; how to keep proprietary industry information confidential; how to get rapid, actionable peer review of relevant analyses and proposed actions.

So how can such a community be fostered? Scien-

*Marcia McNutt*
*Editor-in-Chief*
Science *Journals*

Science
4/3/2015

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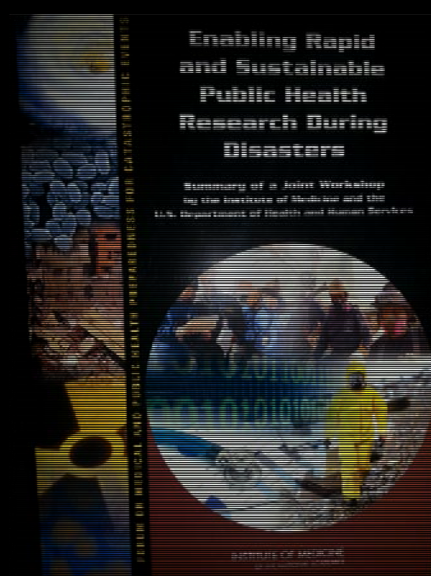
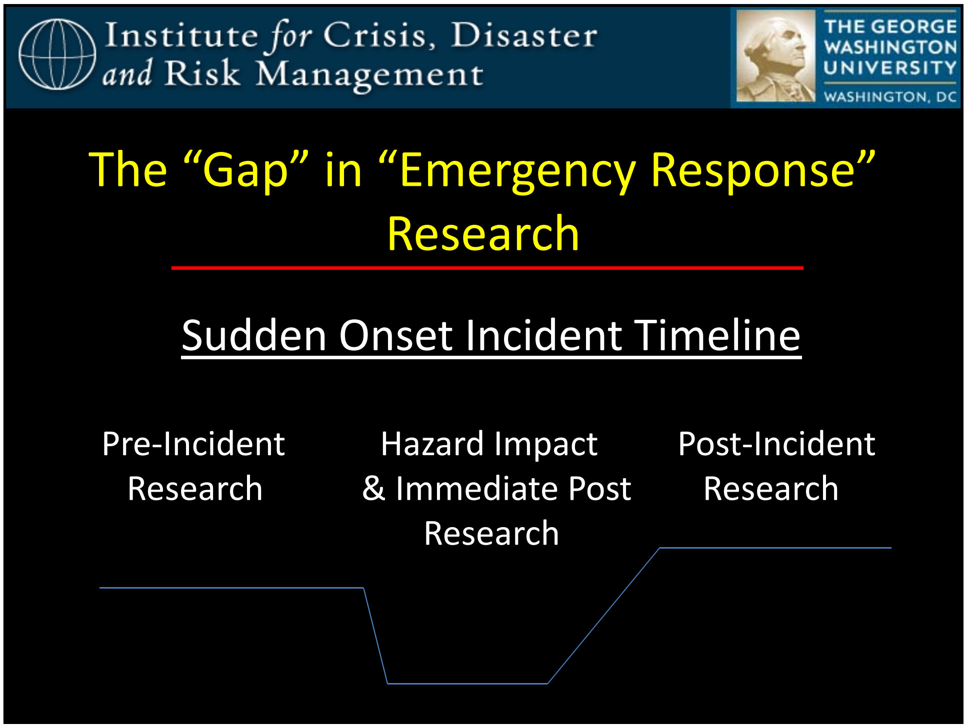
Gaps Recently Highlighted by the Ebola Outbreak & Other Public Health Emergencies

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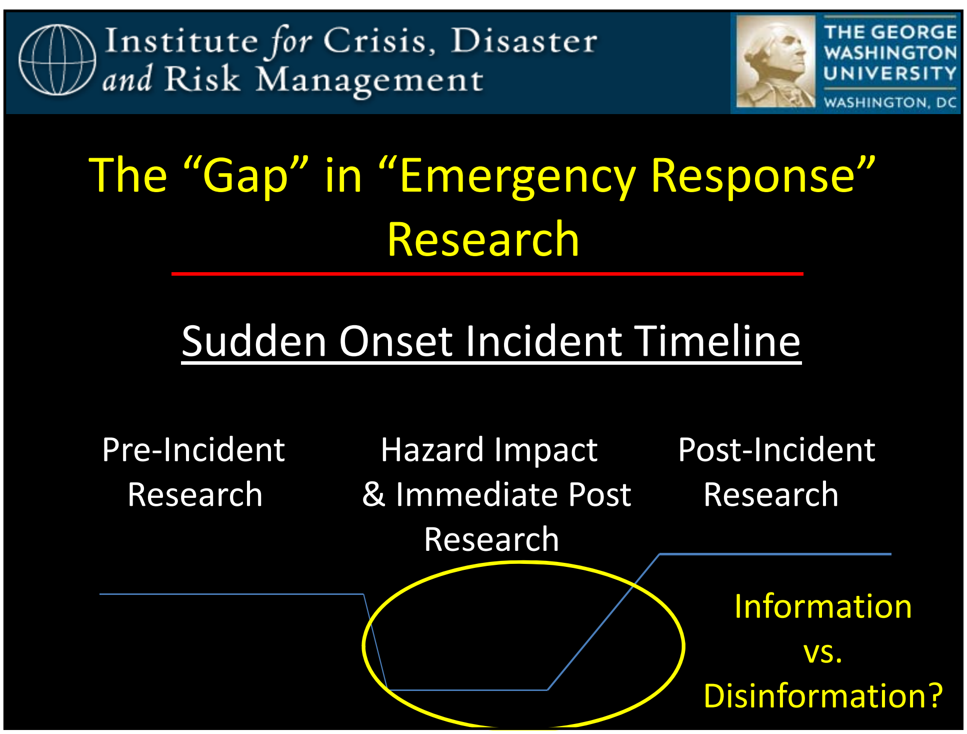
The "Gap" in "Emergency Response" Research
Sudden Onset Incident Timeline
Pre-Incident Research
Hazard Impact & Immediate Post Research
Post-Incident Research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The "Gap" in "Emergency Response" Research
Sudden Onset Incident Timeline
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Post-Incident Research
Information vs. Disinformation?

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## Two Critical Areas for Research

- ❑ Technical research: What needs done?
- ❑ Management research: How to get it done?
  - ✓ Optimal situation awareness – reducing uncertainty
  - ✓ Management of decision-making and decision implementation
  - ✓ Management of coordination across organizations & levels of government

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## "Emergency" vs. "Everyday Emergency Work"

There is a major difference between every day "emergencies" and major emergency/ disaster response & research

- – For Emergency Medicine
- – For Fire and EMS
- – For FEMA and other federal agencies

Analogous to early remediation response in unusual situations – very different from every day remediation

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Worst case…

*"Preparing for the never experienced…"*

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Research during/after major emergencies & disasters

*Plenty of issues…*

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## Important concepts

Important concepts:

- Perishable data
- Inadvertent memory revisions
- The narrow angle lens view
  - Preceding two are why we advocate for incident review before team dispersal…
  - All three require specific strategies to overcome.
- Data availability and variability…

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## The issue of "perishable data"

Issues:

- "Its there and then its not…"
  - ✓ The scale and scope and chaos can obscure the detail.

EXAMPLE (Philippines EQ 1990)

## Baguio City, Luzon Province, Philippines 1990



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## The issue of "perishable data"

"Its there and then its not…"

"about 400…"

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## The issue of "perishable data"

Issues:

- Capturing the emergency context for accurate data interpretation…

Example: Philippines, 1990


***Baguio City, Luzon Province, Philippines 1990***


MILO

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## The issue of "inadvertent memory revision"

Issues:

- From honest & unvarnished to processed, rationalized reporting…

Example: Northridge Earthquake reporting…

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## The issue of "memory revision"

Issues:

- From assistance seeking to liability protecting…

EXAMPLE: "Here's our problems and needs" to "everything is beautiful… in its own way…"

EXAMPLE: H Katrina New Orleans defense of some hospitals' medical performance…

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## The issue of "narrow view"

Issues:

- "The way I see it… this is what happened."
  EXAMPLE: Haiti earthquake

## *Oklahoma City Bombing: "Bubba and his 'ambalance'…"*

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## The issues of "researchers in a emergency response"

Issues:

- <u>Perception</u>: It's a major emergency/disaster because of inadequate resources, so research resources are viewed as displacing response…
- <u>Sensitivity</u>: "Researching on <u>my</u> misfortune to help people in your country/agency/etc.?"
- <u>Competency</u>: Interfering with or skewing response… or skewing later reassessment of the response decisions/actions

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## *OKC bombing - sensitivities*

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## Sensitivity & Competency

A "foreign" technical expertise in an emergency responder world... attitude issues:

- Methods for your capability are not understood
- Perceived value to other responders is not there
- Perceived risk of delaying and complicating exists
- All magnified when you are perceived as primarily a regulatory agency

Recognize and dispel through good printed & oral briefings…

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## Competency:

- Applying new knowledge in uncertain situations: Great ideas from a lab or brainstorming can turn out to be very problematic in the emergency context

- "Field testing" is critical
  EXAMPLE: SMRT

"What did I say, Boris? . . . These new uniforms are a crock!"

## Testing in the realistic context


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## Potential solutions

Ideas:

- Capturing data: Sending researchers versus training responders to capture research data?
    - ✓ Pluses and Minuses…

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## Potential solutions

Ideas:

- Understanding and using/participating in ICS.

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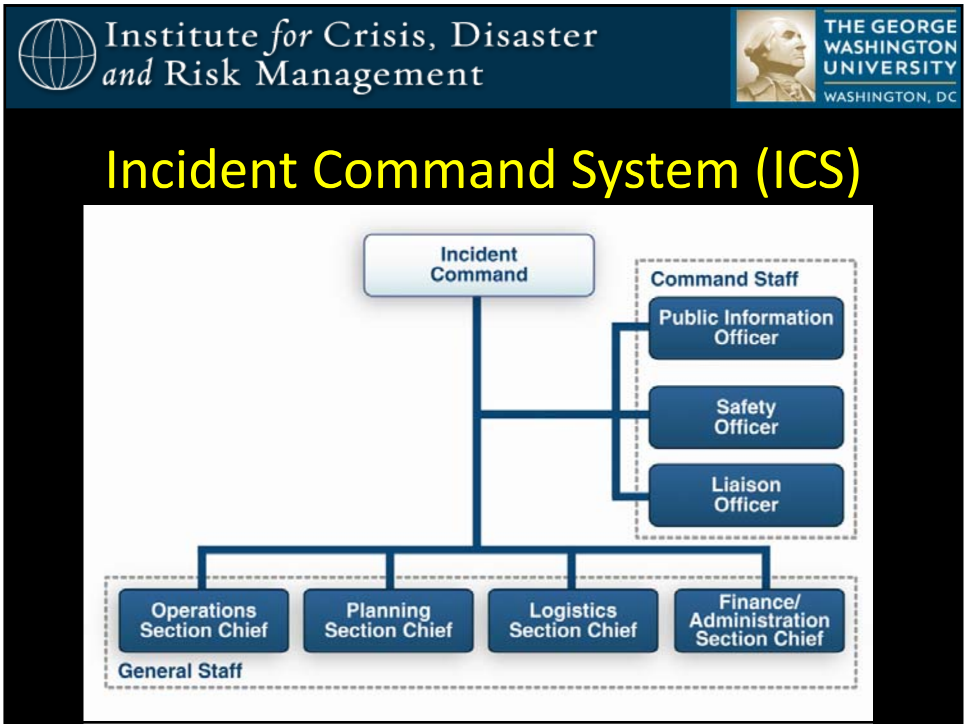
## National Incident Management System (NIMS)

- Gain an “operational level of proficiency”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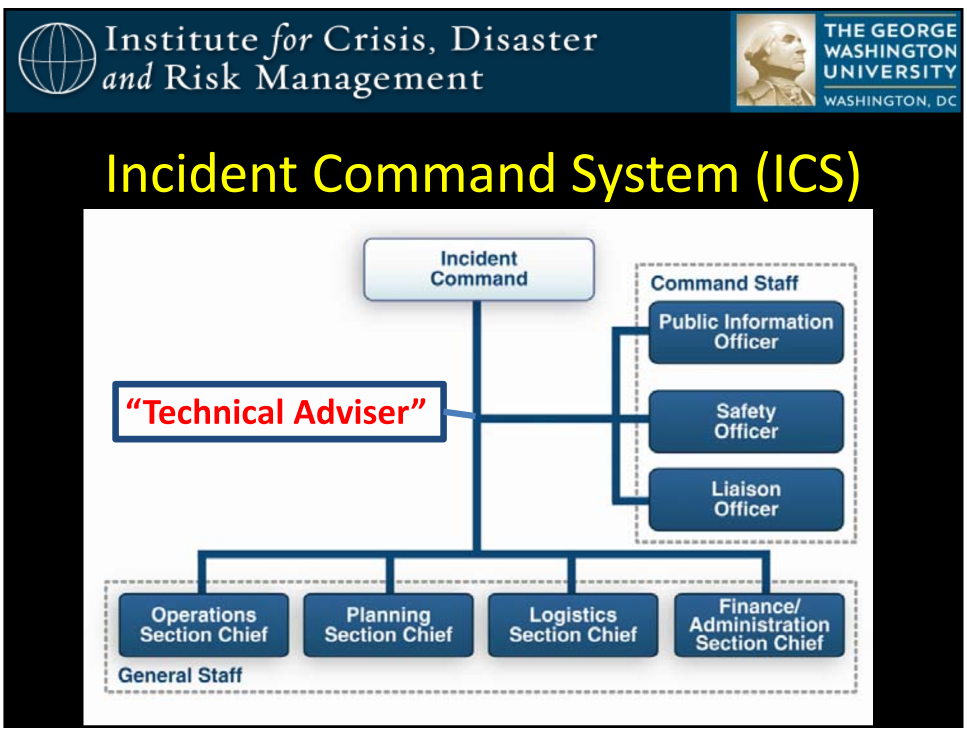
Incident Command System (ICS)
Incident Command
Command Staff
Public Information Officer
Safety Officer
Liaison Officer
Operations Section Chief
Planning Section Chief
Logistics Section Chief
Finance/ Administration Section Chief
General Staff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Incident Command System (ICS)
Incident Command
Command Staff
"Technical Adviser"
Public Information Officer
Safety Officer
Liaison Officer
Operations Section Chief
Planning Section Chief
Logistics Section Chief
Finance/ Administration Section Chief
General Staff

# National Incident Management System (NIMS)

- Performing in/with Planning Section functions.


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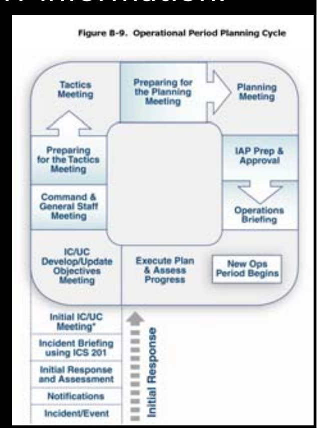
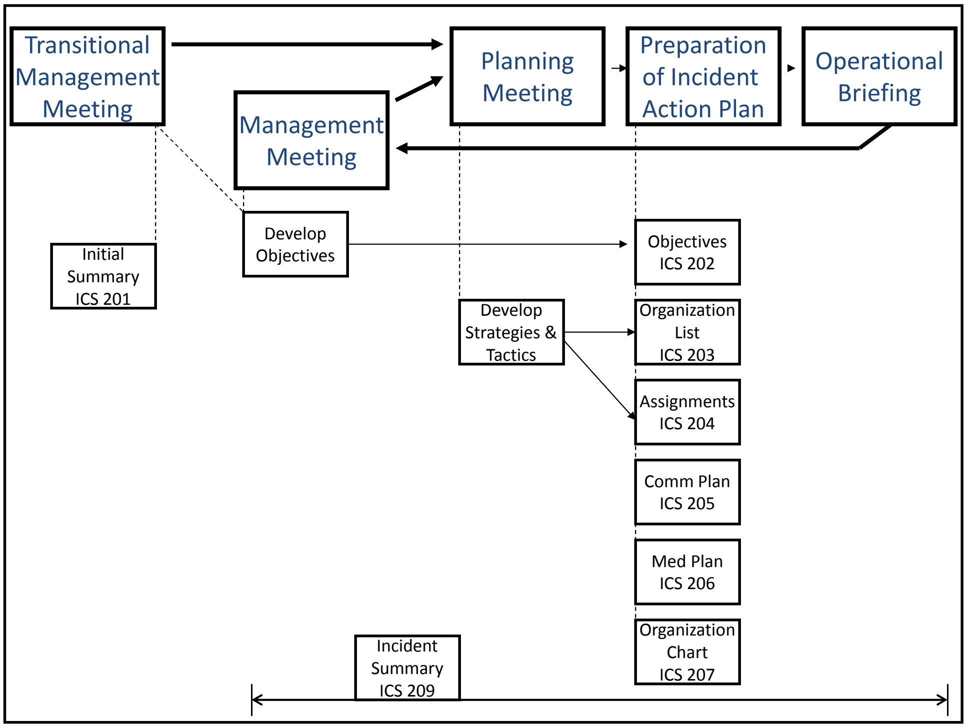
# Potential solutions

Ideas:

- Capturing research data from IMT information.

✓ Incident Command System Incident Action Plan and its component forms…






## ICS Forms in Incident Action Planning

| Initial Situation | Operational Planning Mtg | Incident Action Plan | Executive Summary | Resource Tracking | Misc. |
|---|---|---|---|---|---|
| 201: Incident Briefing | 215: Planning Worksheet | 202: Incident Objectives | 209: Incident Summary | 210: Status Change | 213: General Message |
| | | 203: Organization List | 230: Meeting Schedule | 211: Check in list | 214: Unit Log |
| | | 204: Assignments | | 219: T cards | |
| | | 205: Comm plan | | 221: Demob Checkout | |
| | | 206: Medical plan | | | |
| | | 207: Org chart | | | |

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## Potential solutions

Ideas:

- Training and supporting researchers.
  - ✓ Methods for rapid deployment & transport to incident.
  - ✓ Integration into incident in assigned roles (even if "just research") – BUILD TRUST
  - ✓ Safety and protective knowledge, skills and equipment.
  - ✓ Self-sustainment (food , water, billeting).

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## Potential solutions

Ideas:

- Access through **Emergency Operations Centers**.
  - ✓ Emergency Operations Center directly supporting the IMT.
  - ✓ Integration through the Health Department Operations Center or equivalent.
  - ✓ Understand the interface between the operations centers and "the field".
  - ✓ All of the preceding slides' suggestions apply.

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## Potential solutions

Strategies:

- Be of use to the response.
  - ✓ Collect data and rapidly disseminate raw aggregate for use by appropriate responders.
  - ✓ Data is collected for response/remediation – later can be used professionally for research.
  - ✓ "Remediation data" can be important for responder health… and vice versa!

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## Potential solutions

Strategies:

- Be of use to the response.
  - ✓ Be available to provide competent (i.e., situational) technical advice while conducting research mission.
  - ✓ Contribute to situation reports for incident action planning.

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# Potential solutions

Strategies:

- Be of use to the response.
  - ✓ Consider "applied research" and "exploratory research" where the rules are looser (or at least don't "dis" this research).
  - ✓ The follow-on response experience can become the research "proof of concept".

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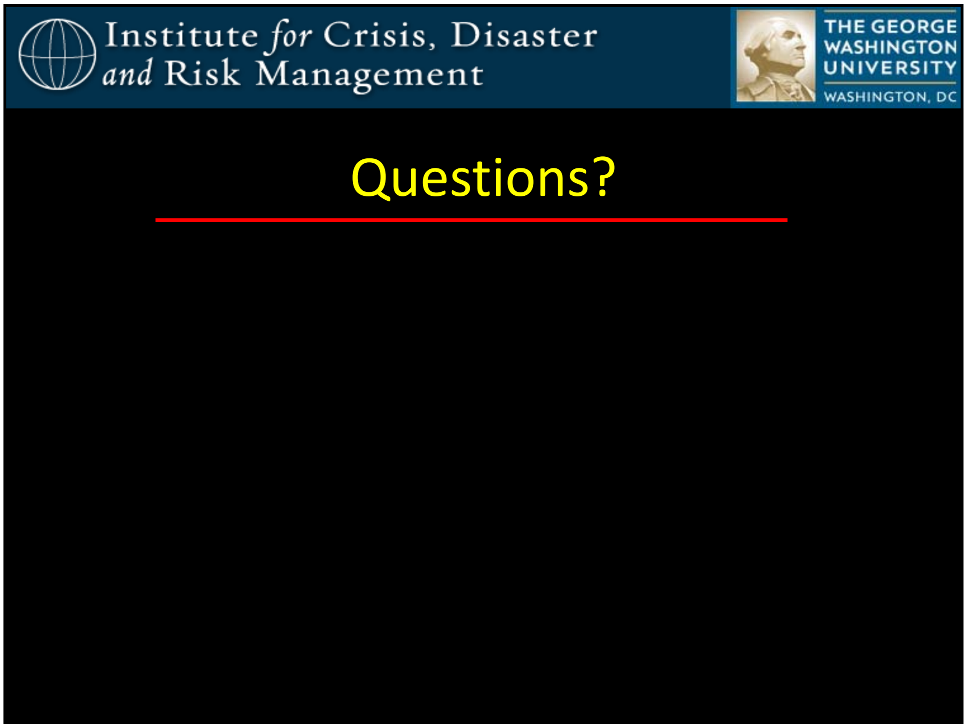
## Potential solutions

Strategies:

- Be of use to professionals post-incident.
  - ✓ Provide data and interpretation for the After Action Report (AAR) process.
  - ✓ Provide and interpret research findings for use in professional education and training.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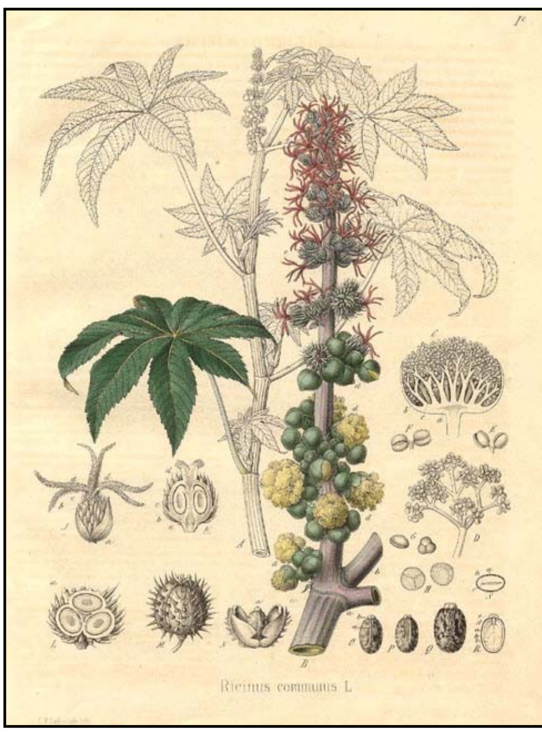
Questions?

UNITED STATES ENVIRONMENTAL PROTECTION AGENCY
EPA
CBRN CMAT
CONSEQUENCE MANAGEMENT ADVISORY TEAM

# Ricin Lessons Learned

2015




## Incident Summaries

- National Capitol Region (NCR) – April 2013
- Mississippi – April to July 2013
- Oklahoma – May 2014 to January 2015
- Wisconsin – October 2014 to January 2015

## SUMMARY: National Capitol Region April 2013

- The source of this ricin was from the Mississippi case (discussed next);
- Region provided consultative/support role to FBI, Secret Service, mail handling facilities;
- EPA provided technical consultation. No EPA contractor's were mobilized;
- Handheld assays initially identified the ricin and CDC analysis was used to determine clearance; and
- Decontamination of facilities was conducted by the owner/operators.

## SUMMARY: Mississippi – April to July 2013

- Suspected source of ricin production sent to the NCR
- A commercial building and storage trailer were affected
- EPA conducted characterization, decontamination and clearance sampling
- Used various analytical techniques

## SUMMARY: Oklahoma – May 2014 to Jan 2015

- Residential property
- EPA attempted to have property owner conduct EPA supervised clean-up
- Eventually EPA conducted characterization, decontamination and clearance sampling
- Analytical techniques included PCR (Polymerase Chain Reaction) and TRF (Time Resolved Fluorescence)

## SUMMARY: Wisconsin – Oct 2014 to Jan 2015

- Residential Property
- EPA conducted characterization, decontamination and clearance sampling
- EPA and START conducted sampling and surficial bleach decon
- Analysis conducted by National Guard Civil Support Team using PCR and ECL (Electro Chemical Luminescence)

## Tupelo, MS Ricin Locations

## DETAILS: Ricin Event Tupelo, MS

- Mid April 2013 - President of the US, MS US Senator and a county judge received a letter containing ricin.
- Late April 2013 - FBI traces the letter to a suspect in Tupelo, MS and identifies ricin at two locations.
- Mid May 2013- FBI finishes investigation at two locations and transitions Sites to MS DEQ, MS DOH and EPA R4.
- End of May 2013 – EPA R4 fully engages and conducts Removal Action.

## Internal EPA Coordination

- Region 4 coordinated with R3 OSC, CMAD and NSHRC
  - Discussed actions in R3 to ensure a coordinated approach to sampling and decontamination.
  - CMAD provided Ricin Quick Reference Guide, sampling plan development and decontamination advice.
  - CMAD/NHRC provided advice on decontamination and sample analysis.
  - NHSRC also provided control samples of stainless steel coupons that had been decontaminated with bleach and that were analyzed for fluorescence by the LRN.

## Dojo Decontamination

- There was carpet in a small area. Bleached the carpet, cut it in small pieces and removed it.
- Used a garden sprayer and sponge mop to decontaminate all hard surfaces (walls, concrete floors, and hard surfaced items)
- Let it sit over night and did not wash the surfaces

## Tupelo MS Lesson Learned

- Even though the FBI was very inclusive and shared their data, they need to have a better format in turning over the data for public health use.
- The issue of bleach affecting ricin analysis needed evaluation by the LRN to be determine the impact of bleach on clearance analysis.
- BOTE and BioWatch activities were instrumental in the Region's bio response preparedness.
- Including DOH and the LRN early in to the response was very beneficial and made the response run very smoothly.

# DETAILS: OKC Ricin Home Event

11217 N Mckinely Ave, Oklahoma City, Oklahoma

# Oklahoma Ricin Incident Timeline

- April 17th
  - FBI HMRU responds to residence and collects evidence documenting a murder for hire plot.
  - Oklahoma City County Health Department (OCCHD) placards residence as a health hazard and prohibits entry.
- May 6
  - Burglars break into residence.
  - Region 6 and CMAD provided remote technical support to OCCHD regarding PPE, sampling, decon strategies, etc.

## Oklahoma Ricin Incident Timeline (cont…)

- May – Fall 2014
  - OCCHD unsuccessfully worked with the homeowner's contractor in an attempt to conduct an action. HAZWOPER requirements couldn't be attained by contractor.
- January 10-16, 2015
  - R6, under authority of Action Memo, mobilizes to Oklahoma City to conduct decon of residence including: HEPA vacuuming, bleach washing of hard surfaces and disposal of porous material.

## Oklahoma Ricin Incident: Home

# Oklahoma Ricin Incident: Home

**Sampling Plan**

- Collect 30 Swab Samples from the two rooms where previous samples from FBI were positive for Ricin
- Samples from the two rooms will be analyzed by the LRN PCR to confirm Castor plant DNA is present and by TRF to confirm the toxicant is active
- Collect 30 Swab samples from the remaining areas of the house and analysis by ECL from locations designated by VSP or chosen by the sampling team

# DETAILS: Oshkosh Wisconsin Ricin Incident

**OCT/NOV 2014 – Initial Response**

- UW-Oshkosh student asked chemistry professor about extracting protein from castor beans in order to end life.
  - Professor calls police
  - Search warrant issued and executed
- Oshkosh police asked for assistance from FBI HMRU and 54$^{th}$ CST

# Oshkosh WI Ricin House Incident, (Cont…)

**OCT/NOV 2014 – Initial Response**

- Winnebago County Health Department placarded house as uninhabitable after warrant execution.
- CST & FBI HMRU sampled home
  - 5 locations came back positive for viable ricin

# Oshkosh Ricin House Incident: Planning

- Health Department
  - In constant communication with health official
    - key for buy in of tactics & analytical strategy
    - They are clearing the house
  - Handled all press inquiries/releases
  - Knows community and connected with local resources
  - Office in original Oshkosh 'B-gosh company HQ building!

PublicHealth
Prevent. Promote. Protect.
Winnebago County Health Department

## Oshkosh Ricin House Incident: Planning

- Consequence Management Advisory Division (CMAD)
  - Recommendations for sampling and decontamination of home/personnel
  - Analytical options
  - Identifying labs available
  - On-site support
  - Access to other EPA national experts

## Oshkosh Ricin House Incident: Response

- Tactics
  - Initial Analytical
    - Run samples in CST lab
      - PCR – Presence of Ricin - need chains A & B to be toxic
      - ECL (Electro Chemical Luminescence) – Viability of Ricin Toxin
    - Original plan, have data from both technologies for clearance.
    - Potential pitfalls
      - Availability of reagents
        - CST got game! PCR supplier screwed up…
      - Bleach interference
        - CST bench test showed no interference

## Oshkosh Ricin House Incident: Response

- Tactics
  - Draft Final Analytical
    - Run samples in CST lab
      - ~~PCR – Presence of Ricin~~
      - ECL (Electro Chemical Luminescence) – Viability of Ricin Toxin
      - HHA (Hand Held Assay) – Ricin specific reagents
    - Winnebago County Health still wanted two technologies for clearance
    - HHA - Availability of reagents
      - Again, CST got game! 81st CST in IL does too!
    - HHA - Bleach interference
      - Not tested

## Oshkosh Ricin House Incident: Response

- Results…
  - Positive hits for Ricin in non decontaminated areas
  - Negative results were in areas we decontaminated
- What are the options to confirm clearance for the whole house?

## Oshkosh Ricin House Incident: Response

- Implemented Option
  - Detection limit of CST ECL method is very low (0.026 ng/cm2)
    - Possible explanation of positive hits…
  - Is there a clearance level to which we can compare the results??

## Oshkosh Ricin House Incident: Response

- 3 isn't always the magic number
    - **190 ng/cm$^2$**
- Health Official signed off on clearance level
    - New direction for mobile lab
- Finally final analytical tactic
  - Utilize dilutions and method detection limits to assign a value to samples.
  - Target dilution calculations to be below the site clearance level – 190 ng/cm$^2$

## Oshkosh Ricin House Incident: Response

**DECON**


## Oshkosh Ricin House Incident: Response

- Waste Characterization and Disposal
  - Solid waste – should be easy right??
    - That all depends on the landfill…
  - Luckily the Outagamie County landfill has good contractors
    - Certificate of decontamination
    - Dig a special hole
    - Personally put waste in hole – unfortunately no pictures were taken
    - Pay $260 ($250 digging fee, $10 for bags of waste)

## Commonalities of Responses


### 1. FBI = Initial lead federal agency

- May/may not deploy Quantico resources for evidence collection/ analytical support
- Transition of response to EPA is crucial
- Ensure that the FBI's sample results and sample location information is obtained. Photos are also helpful in planning entry, sampling plan, etc.

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## Commonalities of Responses

### 2. Involve Local Public Health Officials early

- Include them in the sample design, decon option evaluation, and clearance criteria
- Ideally if a clean up target can be agreed to that will impact analytical strategies.
- For example negative PCR results might be acceptable for characterization.

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# Commonalities of Responses

### 3. Determine Waste Disposal Options

- Define prior to generating any waste including PPE
- Disposal maybe easier than characterizing/decon/clearance

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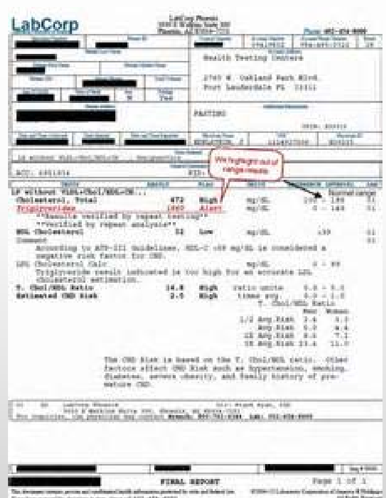
# Analytical Options – Characterization Sampling

- Characterization
  - Obtain FBI results:
    - sample methods,
    - locations,
    - etc



## Analytical – Characterization (Continued)

- Tiered approach
  - Hand Held Assays (HHA)
  - PCR
    - Currently CDC does not support providing ricin reagents to LRNs – PROBLEM
    - PCR analysis evaluates for two ricin chains
      - Chain A detects the toxic enzyme
      - Chain B presence facilitates the toxin into the cell/body
    - Need both ricin chains for substance to be toxic
  - Ideally use the same analytical process for Characterization and Clearance Sampling (if required)

## Analytical – Characterization (Continued)

- Time-Resolved Fluorescence Immunoassay (TRF)
  - TRF can be used in characterization sampling
  - Difficult to use for clearance sampling due to bleach interferences
  - Might be difficult to find a lab because CDC doesn’t support reagents

# Analytical Options – Clearance Sampling

- Clearance for Post Decon Sampling after using liquid bleach decon
- Tiered Analytical Preferences:
  - Electro Chemical Luminescence (ECL)
    - Available on all CST mobile lab vehicles
    - Wisconsin CST indicated ECL is not impacted by bleach. Confirm.
    - Required DoD reagents and commitment for support
    - If a ‘detection limit’ is below the CST’s normal instrument calibration need to coordinate with Science Officer.
  - Time Resolved Fluorescence Immunoassay (TRF)
    - Bleach interferes with TRF
    - Not recommended for Clearance Sampling

# Clearance Sampling

- Ricin Component Multiplex Assay (RCMA)
  - Only available at CDC. Maybe difficult to access.
- Ricin Mass Spectrometry Activity Assay (RMSAA)
  - Only available at CDC National Center for Environmental Health – Difficult to access
- Matrix Assisted Laser Desorption Ionization Mass Spectrometry (MALDI-MS)
  - Under development by CDC for use at LRN Labs

## On-Going Efforts for Ricin Analyses

1. Coordination with OEM ERLN and CDC LRN to develop EPA access to LRN labs directly (Currently ERLN labs with Ricin capability are also LRN members and need authorization from LRN to analyze samples for EPA- roadblock).

2. OEM working on agreement with DoD for access to DoD laboratory network and DoD reagents/assays.

3. OEM/NHSRC working on further TRF method development with Lawrence Livermore National Lab – to resolve bleach interference issue.

## On-Going Efforts for Ricin Analyses

4. OEM working on establishing lab capability/capacity at Livermore for EPA use.

5. Potential relationship with National Bioforensics Analysis Center (NBFAC).

6. CDC concerned with EPA's use of "screening techniques for site characterization (i.e. according to CDC, PCR, ECL and TRF are only screening techniques).

## Conclusions

- Determine acceptable analytical methods and identify who will conduct the analysis.
- Obtain information from law enforcement to support environmental efforts.
- Determine waste disposal options
- Keep it simple, if you can.

## Questions?

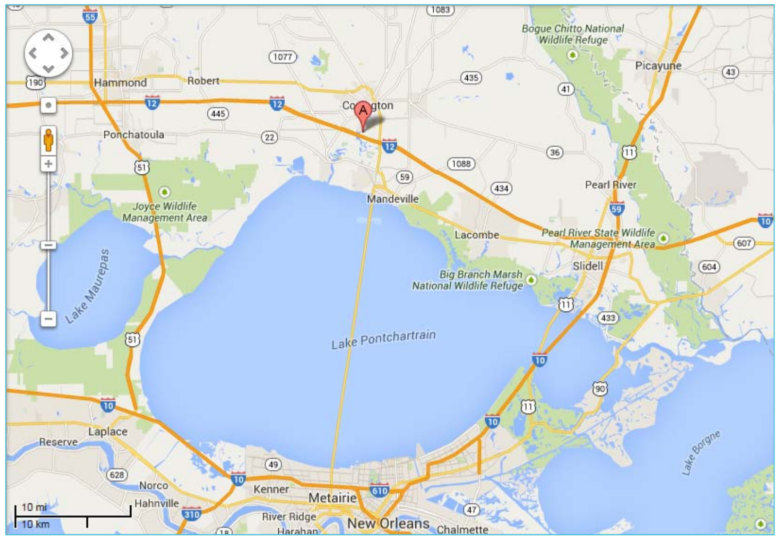
## Tulane Incident - EPA Region 6


## **T**ulane **N**ational **P**rimate **R**esearch **C**enter

- The Tulane National Primate Research Center (TNPRC) in Covington, Louisiana is a **biomedical research facility** **and** **USDA Class B animal dealer** licensed to sell and purchase animals for research purposes.
- TNPRC's **biomedical research is focuses on human health research**. TPNRC maintains breeding colonies, but the non-human primates are not experimentally exposed to infectious agents.
- The property consists of 500 acres, of which 167 acres are currently in use and is divided into the **North Campus and South Campus** which is geographically divided by Three Rivers Road.
- The **North Campus** houses research and administrative buildings, while the **South Campus** is utilized for non-human primate living areas and TNPRC's wastewater treatment plant.

## TNPRC Location

*Covington, LA*




## "Deadly bacteria release sparks concern at Louisiana lab"

USA TODAY 6:02 p.m. EST March 1, 2015

**"Officials are investigating how a deadly type of bacteria was released from a high-security laboratory at the Tulane National Primate Center in Louisiana. Officials say there is no risk to the public."**

## Tulane Incident

*Situation Summary*

- Two macaques at the TNPRC were infected with the bacteria ***Burkholderia pseudomallei (Bp)*** which is the cause of **Melioidosis** in **November, 2014**.
  - One animal was euthanized on November 26th and the second animal initially recovered, but fell ill and was euthanized on February 19, 2015.
  - Five additional macaques have recently tested positive for antibodies and are being monitored or euthanized.
- According to the CDC, ***Bp*** **is a bacterium endemic to Southeast Asia and Northern Australia, and is typically found in contaminated water and soil**. It is spread through direct contact with the contaminated source.
- In February 2015, an **USDA employee tested positive for antibodies** to ***Bp***. Further investigation concluded that this person had been possibly exposed to ***Bp*** while on travel to the an endemic region.
- Recently, another **TNPRC employee tested positive for *Bp antibodies*** but has not presented symptoms and is being monitored.
- **All Select Agent Research has been suspended by USDA and CDC.**

## Tulane Incident

*EPA's "Initial" Role*

- R6 OSC, CMAD and START contractors mobilized to TNPRC **February 2, 2015**.
- Per direction from the Unified Command, an environmental sampling plan was developed to evaluate potential *Bp* contamination in the South Campus.
- CMAD convened an EPA Technical Working Group (TWG) that:
  - Developed a Sampling and Analysis Plan including sample collection techniques;
  - Facilitated lab coordination; and,
  - Prepared Decontamination options for the South Campus (inside and outside the field cages).
  - Members of the TWG included CMAT and NHSRC staff.
- The environmental sampling plan from **February 7th to 12th** and included:
  - **42 soil samples;**
  - **15 water samples;**
  - **12 swab samples;**
  - **and 12 air samples.**


# Tulane Incident

## Tulane Incident

## TNPRC Incident

## Tulane Incident

*Project Organization*

| | |
|---|---|
| **Unified Command:** | GOHSEP, CDC, LDHH, St Tammany Parish OHSEP |
| **JIC:** | CDC, Tulane, EPA, GOHSEP, LDHH, LDAF, St Tammany Parish |
| **Agency Reps:** | EPA, Tulane, USDA, LDAF, LDHH, LDEQ, FBI, DHS? |
| **Branch 1 - Investigation:** | CDC |
| **Branch 2 – Remediation/Response:** | EPA |
| **Science Working Group:** | CDC, USDA, EPA, LDHH, LDAF, LDEQ, LDWF, Tulane |

## Tulane Incident

*CDC/USDA completed investigation*

- **March 13, 2015 CDC Press Release:**

**"CDC has found no evidence to date to suggest the organism was released into the surrounding environment and therefore it's unlikely there is any threat to the general population.**"

- CMAD / NHSRC provided final options for cage decontamination:
  - **Methyl bromide**
  - **Excavate and Treat**
- On March 30, EPA participated on panel during Public Meeting.
- USDA and LDAF is continuing its domestic animal/wildlife investigation both on the TNPRC and surrounding areas.
- Tulane has "hired" an international expert from Northern Arizona to assist in site sampling, remediation, and development of a soil sampling plan to augment wildlife seropositive. Science Working Group (Feds and State) will review plans.

- QUESTIONS?

# 2015 U.S. EPA International Decontamination Research and Development Conference

## Tuesday, May 5, 2015

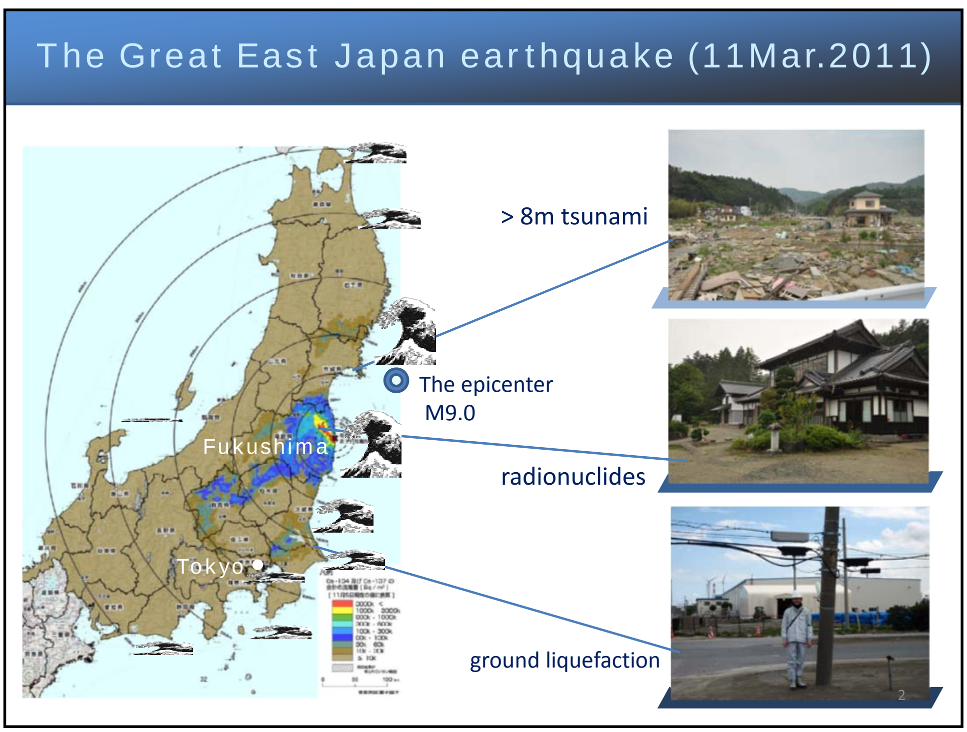
## General Session 1

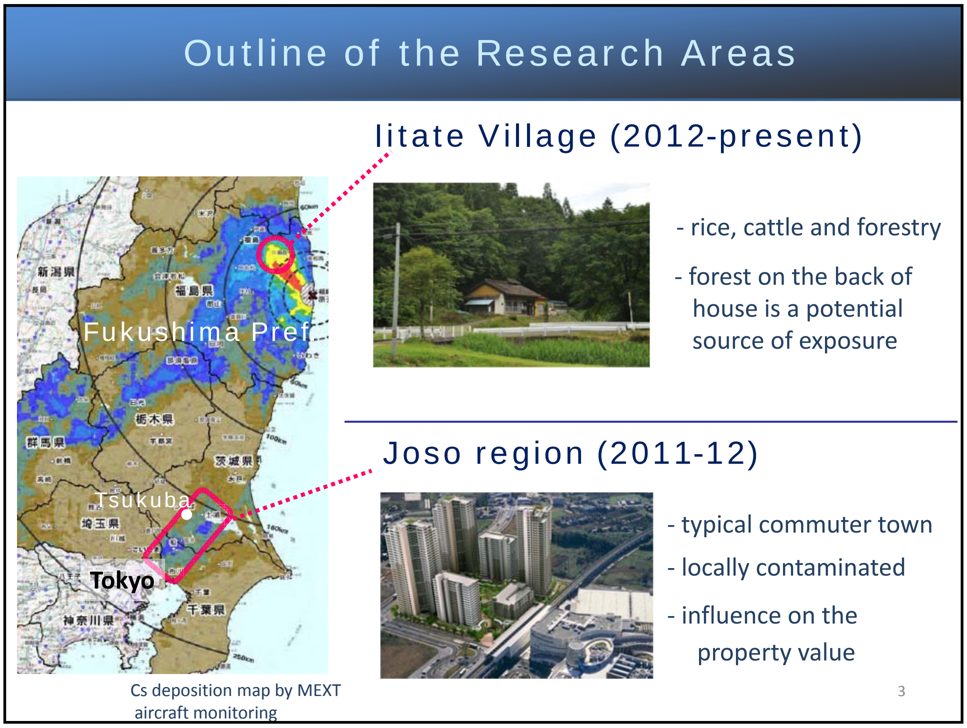
CBR Response Activities and Recovery Handbooks

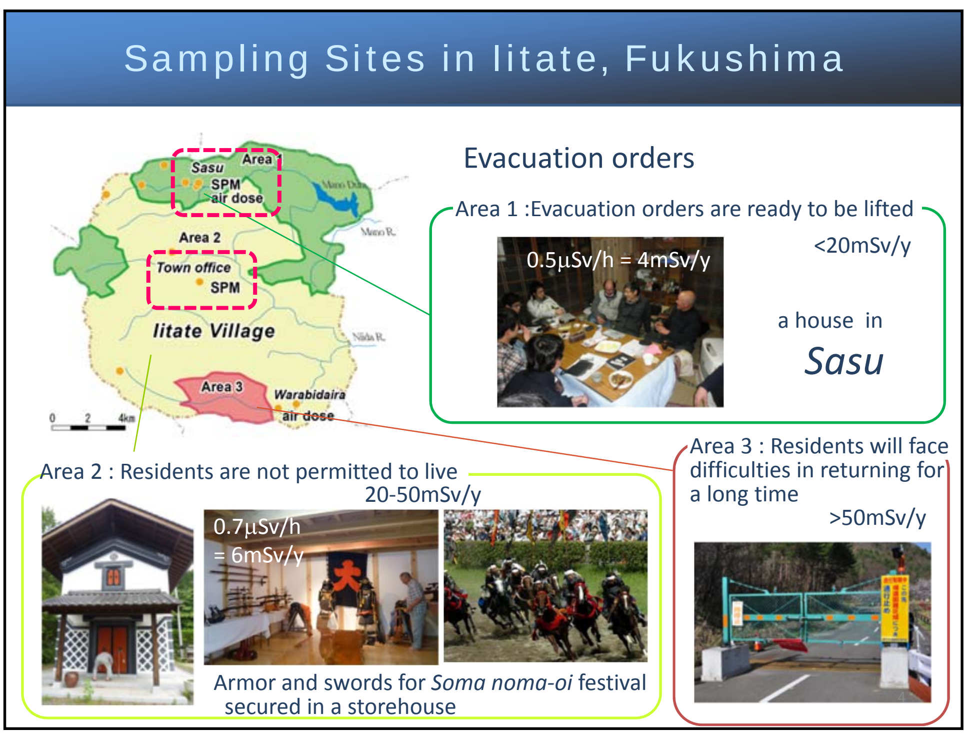





Indoor Contamination
from the Fukushima Nuclear
Power Plant Incident
National Institute for Environmental Studies
Atsushi Tanaka, Mai Takagi,
Taeko Doi, Haruhiko Seyama,
Yasuyuki Shibata, Shoji F. Nakayama


The Great East Japan earthquake (11Mar.2011)
> 8m tsunami
The epicenter
M9.0
Fukushima
radionuclides
Tokyo
ground liquefaction
2


Outline of the Research Areas
Iitate Village (2012-present)
Fukushima Pref.
Tsukuba
Tokyo
- rice, cattle and forestry
- forest on the back of house is a potential source of exposure
Joso region (2011-12)
- typical commuter town
- locally contaminated
- influence on the property value
Cs deposition map by MEXT aircraft monitoring
3

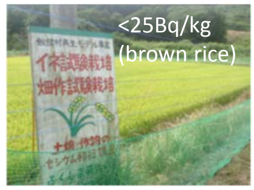

Sampling Sites in Iitate, Fukushima
Sasu
Area
SPM
air dose
Area 2
Town office
SPM
Iitate Village
Area 3
Warabidaira
air dose
Evacuation orders
Area 1 :Evacuation orders are ready to be lifted
0.5μSv/h = 4mSv/y
<20mSv/y
a house in
Sasu
Area 2 : Residents are not permitted to live
20-50mSv/y
0.7μSv/h
= 6mSv/y
Armor and swords for Soma noma-oi festival secured in a storehouse
Area 3 : Residents will face difficulties in returning for a long time
>50mSv/y

## Life in Iitate (飯舘村の暮らし)

**Agriculture is inhibited**

Paddy fields are devastated

Test cultivation of rice




Fields and houses are invaded by

wild boars
monkeys
rats
&


Vigilante patrol

Removal of topsoil and temporary storage


Mr. Kanno, our counterpart is changing air filter

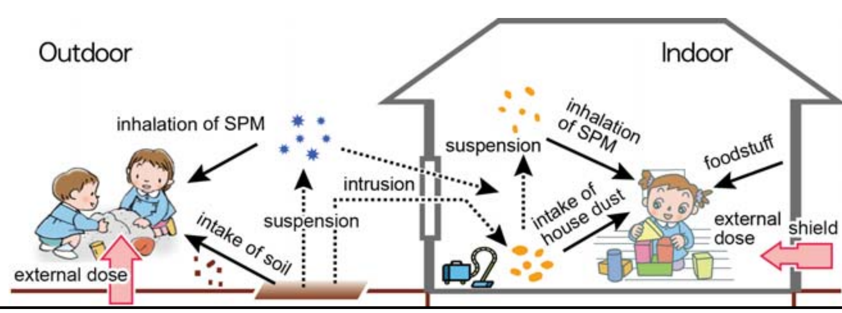
5

## House Dust as a Sources of Internal Exposure

External dose is dominant (>90%) ⇨ Need of physical decontamination and effective shielding

Internal exposure sources ⇨ food > house dust >> soil >> air (ingestion: food > house dust; inhalation: soil >> air)

- Unavoidable exposure to house dust unlike contaminated food
- Little information about radioactivity and sources
- Effective decontamination or mitigation way

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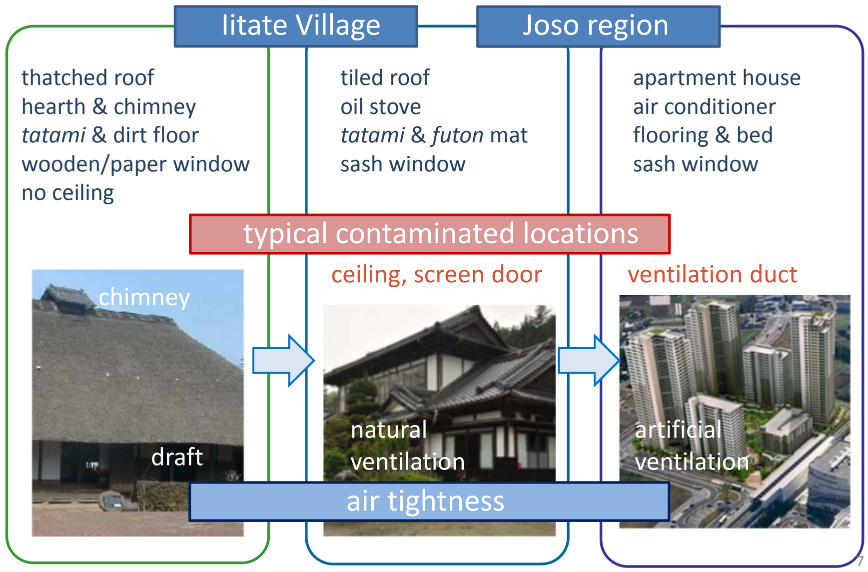
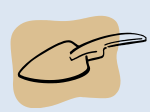
# Traditional and Modern Japanese Houses




# Material and Methods

**House dust (vacuum cleaner dust)**
**bulk — sieved (>2mm, <250μm)**

**Surface soil**
**bulk — sieved (<250μm)**



**SPM (HV, quartz filter)**

**Food (duplicate diet)**

**Extraction with 1ppm Cs** ➔ **Evaluation of Cs solubility**
- **solution (<0.45μm)**
- **fibrous residue (>500μm)**
- **powdery residue (>0.45μm)**

**Acid digestion** ➔ **Elemental composition**

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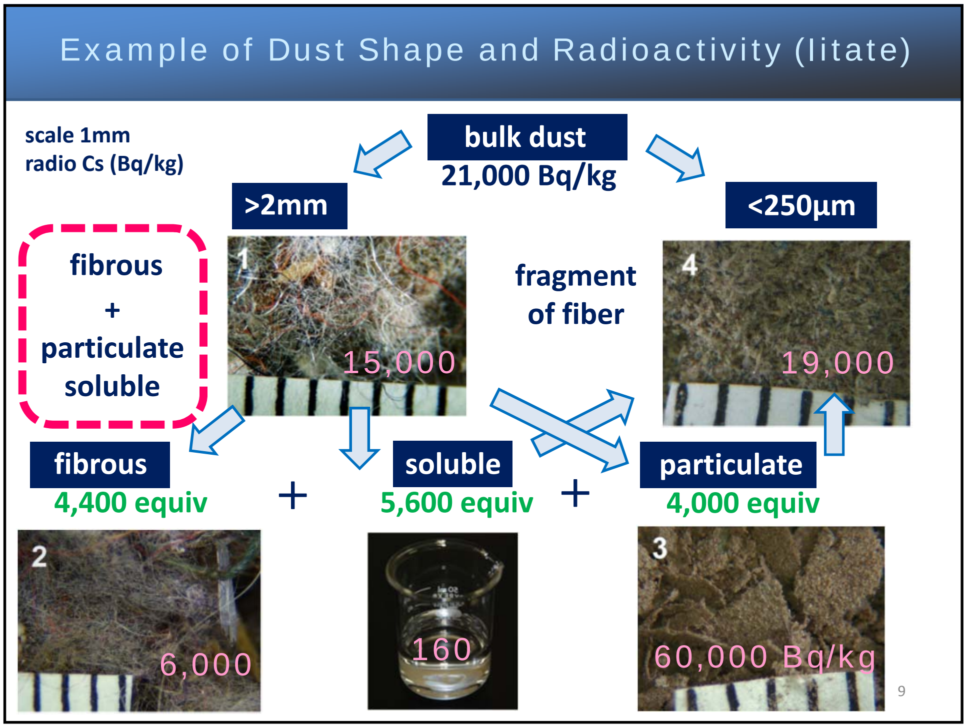
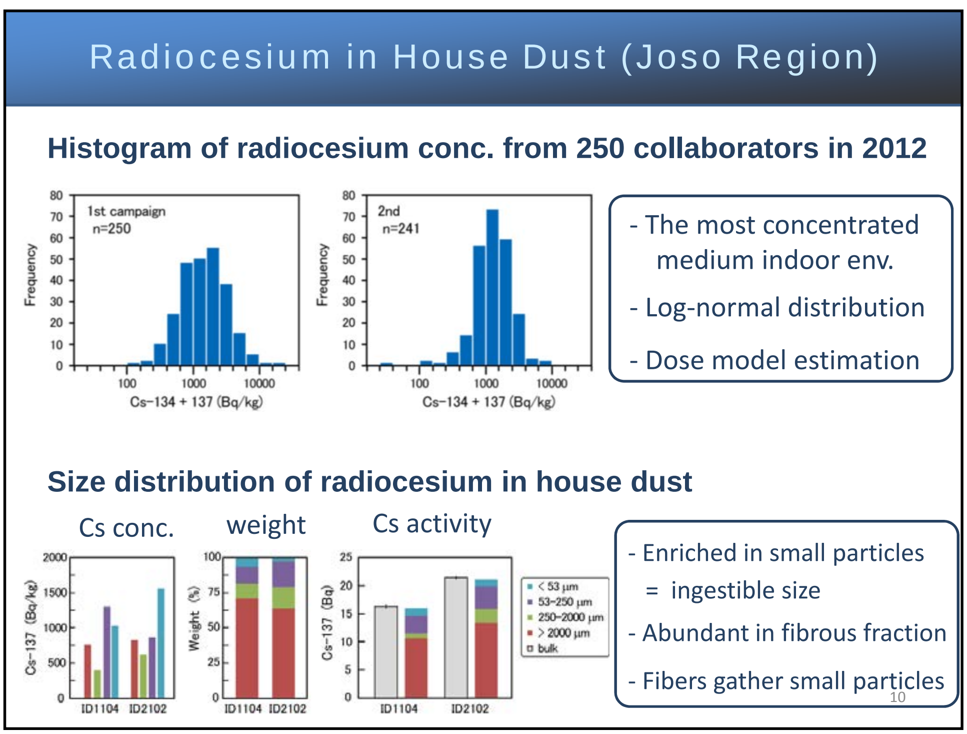
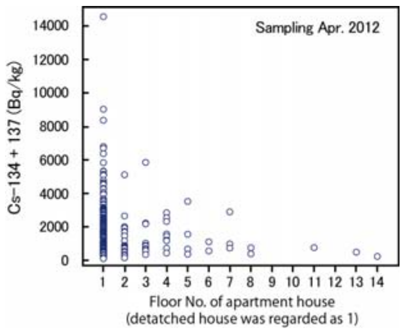

Example of Dust Shape and Radioactivity (Iitate)
scale 1mm
radio Cs (Bq/kg)
bulk dust
21,000 Bq/kg
>2mm
<250µm
fibrous
+
particulate
soluble
1
15,000
fragment
of fiber
4
19,000
fibrous
4,400 equiv
+
soluble
5,600 equiv
+
particulate
4,000 equiv
2
6,000
160
3
60,000 Bq/kg
9

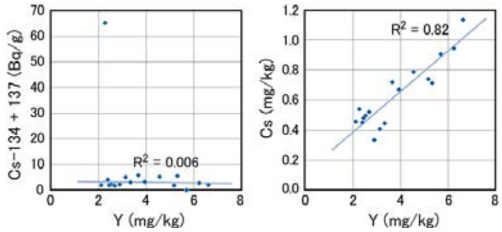

Radiocesium in House Dust (Joso Region)
Histogram of radiocesium conc. from 250 collaborators in 2012
1st campaign
n=250
2nd
n=241
Frequency
Cs-134 + 137 (Bq/kg)
- The most concentrated
medium indoor env.
- Log-normal distribution
- Dose model estimation
Size distribution of radiocesium in house dust
Cs conc.
weight
Cs activity
Cs-137 (Bq/kg)
Weight (%)
Cs-137 (Bq)
ID1104
ID2102
< 53 µm
53-250 µm
250-2000 µm
> 2000 µm
bulk
- Enriched in small particles
= ingestible size
- Abundant in fibrous fraction
- Fibers gather small particles
10

# Statistical Analysis (Joso Region)

**Relationship between story and radiocesium conc. in house dust**




Elemental compositions of house dust




- Cs decrease by story (sig.)
- Possibility of soil track-in

- Same apartment but different floors
- Stable Cs is related to lithophile elements
- Radio Cs has no relation
- Negative evidence for soil origin

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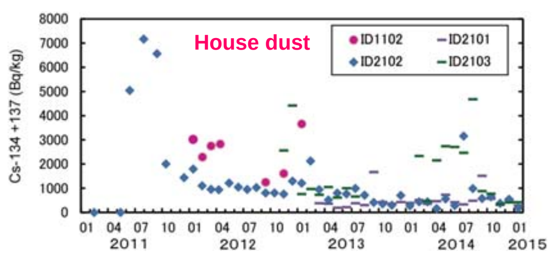
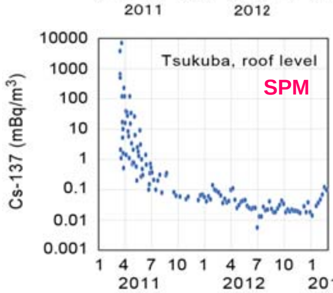
# Sources of Radiocesium in House Dust

**Trends of radiocesium in house dust and SPM**




- Opening windows and outbreak in sync (ID2102, 10th floor)
- Gradually decrease = cleaning
- No seasonal but irregular variation = cleaning




- Cs-137 in air decreases more than 5 orders in one year
- Ventilation of the peak day determined the issue
- Tsunami and quake damaged house

**Initial contamination + Additional intrusion (soil, SPM and cleaning)**

12

KEK & NIES (2013) http://www.kek.jp/ja/Research/ARL/RSC/Radmonitor/

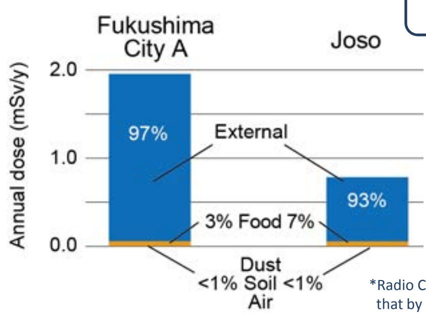
# Exposure Model Including House Dust

## Internal exposure model

$$E_{int}(L,\ Y,\ i) = E_{int,f} + E_{int,w} + E_{int,s} + E_{int,d} + E_{int,ina} + E_{int,outa}$$

Location
Age group
Nuclide

Cs distribution
Enrichment factor to small particles = 2.2
Intake 60mg/d (1-6 years old)
Conversion factor to effective dose




0.001 – 0.007 mSv/y (Joso)
(50 and 95 percentile)
0.003 - 0.03 mSv/y (Fukushima)

*Radio Cs in food used in this model was much higher than that by duplicate diet method or market basket method.

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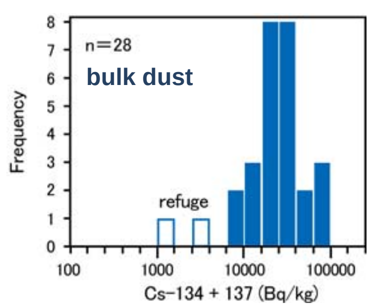
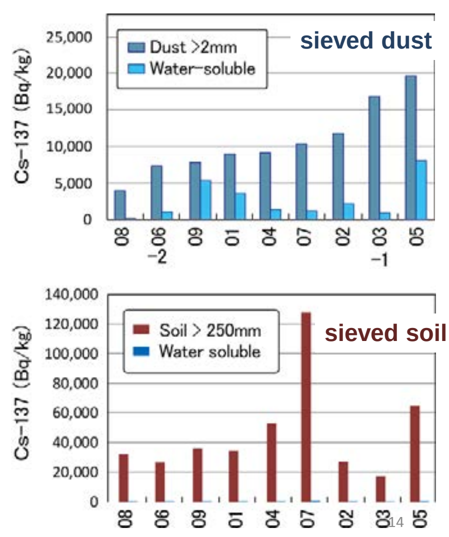
# Radiocesium in House Dust (Iitate)

## Histogram of radiocesium




- One order higher than Joso
- No relation between dust & soil Cs
- Dust contains soluble Cs, soil contains little or no soluble Cs
- Cs of non-soil origin exists in dust

## Solubility of radiocesium

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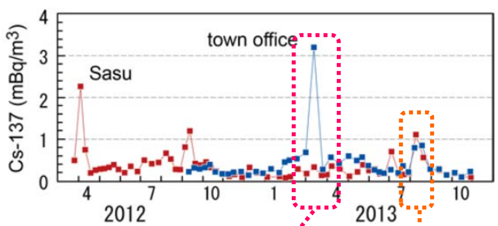
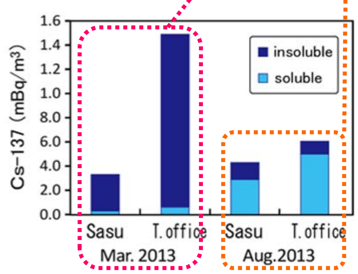
## Radiocesium in SPM (Iitate)

### Trend of radiocesium in SPM




- Radiocesium ranged 0.1-3 mBq/m$^3$
- Size max. was several μm
  Not concomitant with soil particles

### Solubility at two peak events




- Peak in Mar. : local effect
  Decontamination work of pavement
  Soluble Ca was also high
- Peak in Aug.: wide range contamination
  Solubility was high
  Airborne Cs was not soil origin

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## Cleaning Test Using Mock Dust

### Labeled mock dust with fluorescence reagent

**Experimental**

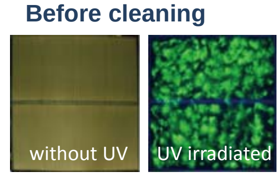
- Inorganic : gamma-alumina
- Organic : cellulose powder

- Test floor:
  boarded, *tatami* mat
  carpet (5mm pile length)
- Cleaner:
  cyclone (c), robot (r1&2)
- Effort :
  5min (c), 7min x 2 (r1&2)
- Recovery : weighing, XRD

**Recovery**

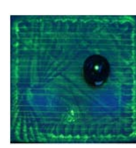
| Cleaner type | Floor type | Recovery (%) |
|---|---|---|
| robot1 | boarded | 80 |
| robot1 | tatami | 60 |
| robot1 | carpet | 10 |
| robot2 | tatami | 85 |
| cyclone | boarded | 95 |
| cyclone | tatami | 97 |
| cyclone | carpet | 86 |

**Before cleaning**

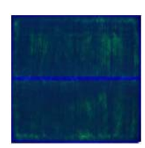



*tatami* mat (176x176cm)

**After cleaning**



robot1
boarded
floor



robot1
*tatami*
mat

- Cyclone type powerfully works
- Robot type automatically works in evacuated houses
- Particles remain in the mesh of *tatami* or root of pile
- Spread and trace experiment is feasible

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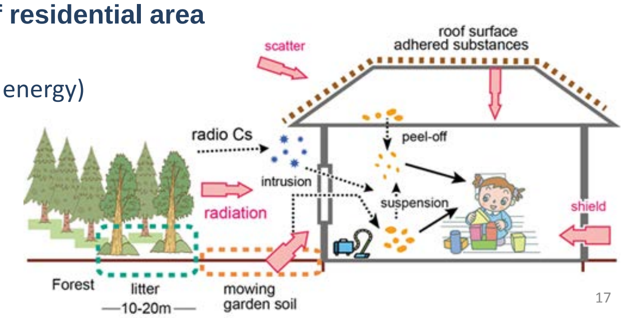
## Decontamination Work and Indoor Environment

**Before decontamination**

**After decontamination**


**Decontamination of residential area**

- radiation
  (intensity, direction, energy)
- material
  (chemodynamics)

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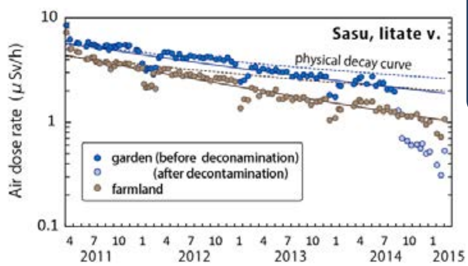
## Air Dose and External Exposure Dose

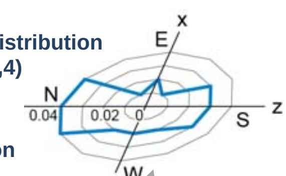
**Trend of air dose rate**



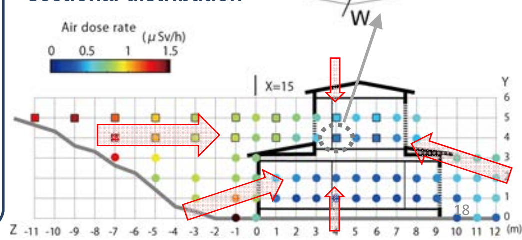

- Faster decrease than expected by physical decay constant
- Decontamination is effective

**Detailed air dose distribution**

directional distribution
(x,y,z)=(15,4,4)




sectional distribution




- Back hill is a radiation source
- Shield with wall, ceiling and floor
- Distance attenuation is distinctive
= Decontamination of garden acts positively
- Roll of backyard forest is unsolved

18

## Conclusion

### House dust

- **Highest** Radiocesium containing **medium** indoor env.
- No radiation source, internal dose is equivalent to food
- PM in the **initial plume** might be a major origin
  Addition of SPM and soil cannot be excluded
- Fibrous dust captures small particles of high radioactivity
- **Daily cleaning** results in self-decontamination
- Overlooked places cannot be overlooked because
  particles of high Cs might be latent
- Thorough cleaning and **wet wiping** required prior to return
- Abandonment, harmful animals are more serious problem

**High air dose rate** thwarts speedy return

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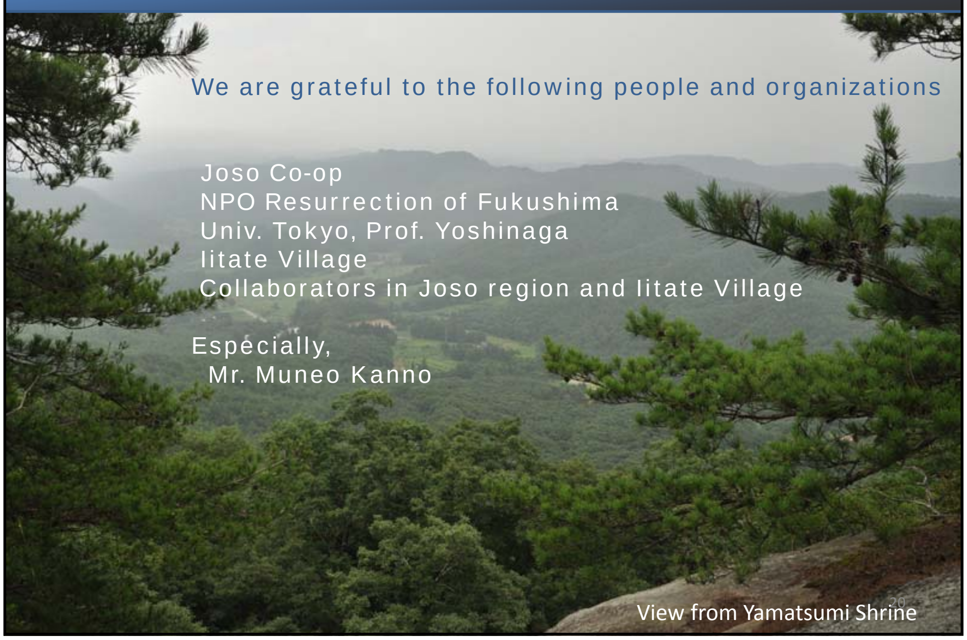
## Acknowledgements


We are grateful to the following people and organizations

Joso Co-op
NPO Resurrection of Fukushima
Univ. Tokyo, Prof. Yoshinaga
Iitate Village
Collaborators in Joso region and Iitate Village

Especially,
Mr. Muneo Kanno

Public Health England

# UK Recovery Handbook for Biological Incidents (UKRHBI)

Tom Pottage
Public Health England, UK

Biological.recovery@phe.gov.uk

Public Health England

## Why do we need a Biological handbook?

- Biological incidents occur
- Remediation isn't always straightforward
- Remediation needs to be tailored to the type of contamination
    - Area contaminated
    - Funds available
    - Public perception

NEWS HAMPSHIRE & ISLE OF WIGHT

Home World UK England N. Ireland Scotland Wales Business Politics Health Education

13 September 2013 Last updated at 17:54

**Sainsbury's recalled watercress came from UK farms**

**Bagged watercress withdrawn by Sainsbury's over an outbreak of E. coli was produced by a Hampshire company.**

The Food Standards Agency (FSA) said 19 people had fallen ill and the store's watercress was one line of inquiry.

Vitacress, based near Andover, said it supplies all of Sainsbury's watercress and some 200,000 bags may be withdrawn.

Sainsbury's said the recall was a precaution

on mak
v guid
o work

VILLAGERS' FURY AT ANTHRAX CLEAN-UP

s

## What is the UKRHBI?

Handbook to aid decisions in the recovery phase after a Biological incident

Based on the methodology and approach of the UK Recovery Handbooks (Chemicals (HPA, 2012) and Radiation incidents (HPA, 2009)

Incorporates lessons learned from responses to incidents

Followed by Decision Support Tool (future aspect/ next phase of the project)

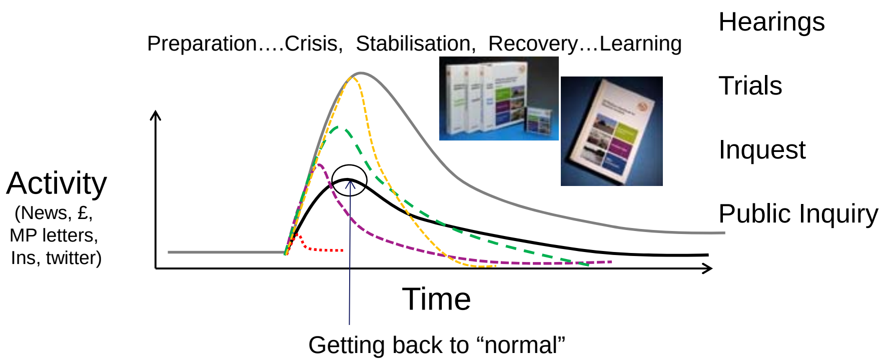
**Aim:** reduce exposure and return to **'normality'**



## Scope

- Focus on clean up and restoration.
- Does not address all aspects of the recovery phase
  - Risk assessment protocols
  - Sampling or monitoring strategies
- **Not** a substitute for specialist advice but will **aid** decision makers in the development of a recovery strategy

Public Health England




- Injury and illness
- Worry or concern
- Political
- Media



Public Health England

# Stakeholder Involvement

There are a wide range of stakeholders and PHE steering group members to help steer the knowledge base and direction of the Handbook

Public Health England

HSC Public Health Agency

The Scottish Government

Home Office

defra Department for Environment Food and Rural Affairs

Food Standards Agency

Department of Health, Social Services and Public Safety

## Audience ~ who will use the Handbooks?

- National and local authorities
- Central government departments and agencies
- Environmental and health protection experts
- Industry
- Emergency services
- Others that may be affected by a biological incident



## The Handbook

Public Health England

# Practical application of the Handbook

Robust scientific and technical advice, presented in a simple format as checklists, decision tree's and "steps" to lead users through the stages of developing a recovery strategy.


9 UK Recovery Handbook for Biological Incidents

Public Health England

# Handbook approach

Prioritised agents and scenarios:

- 23 agents
- 3 scenarios

Gathered from the Stakeholder and PHE Steering groups

Agent data sheets

- Encompass data that is required for decision makers
- Persistence, resistance, transmission route, background levels, etc.

10 UK Recovery Handbook for Biological Incidents

## Gathering the evidence base

**Persistence database**

Review of the prioritised agents presented in/on a variety of environments, looking at;

- Peer reviewed scientific papers
- Biological agents safety data sheets

Other organisms not on the agent list but included in the studies were added to the tables.

**Disinfection database**

Developed as several decontamination techniques are grouped together in recovery options

Prioritised list and use of surrogates

- Technologies often tested against worst case scenarios.
- Surrogates also used in the place of high hazard agents
- Standard agents



## Recovery options database

Collection in two methods:

- Retrospective questionnaire
- Literature review

Search criteria

Used search engines – Google scholar, Pubmed

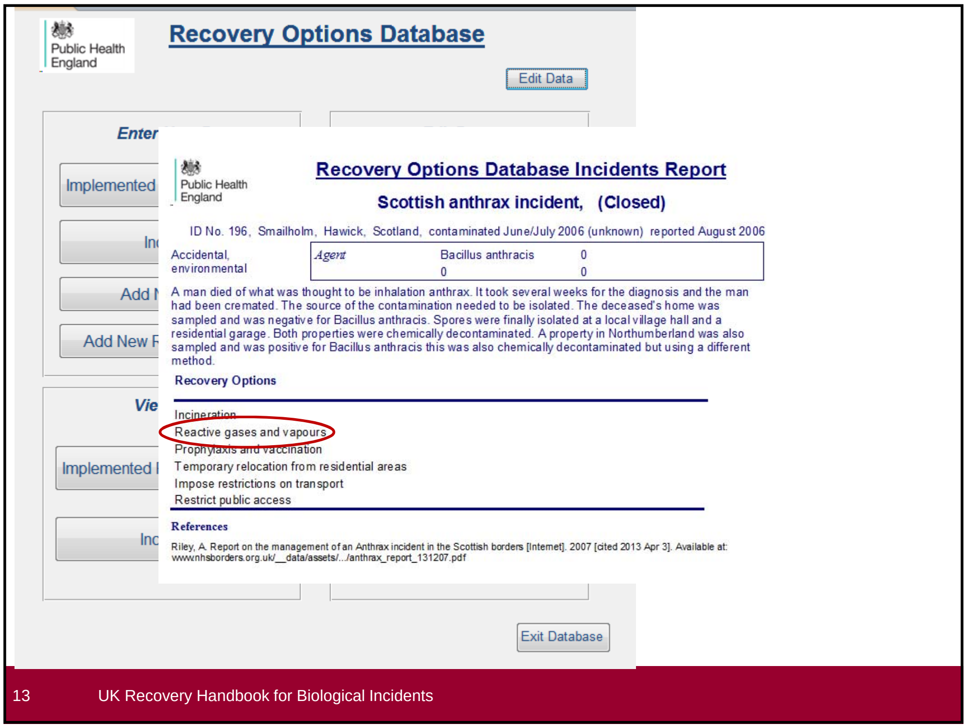
Peer-reviewed scientific papers

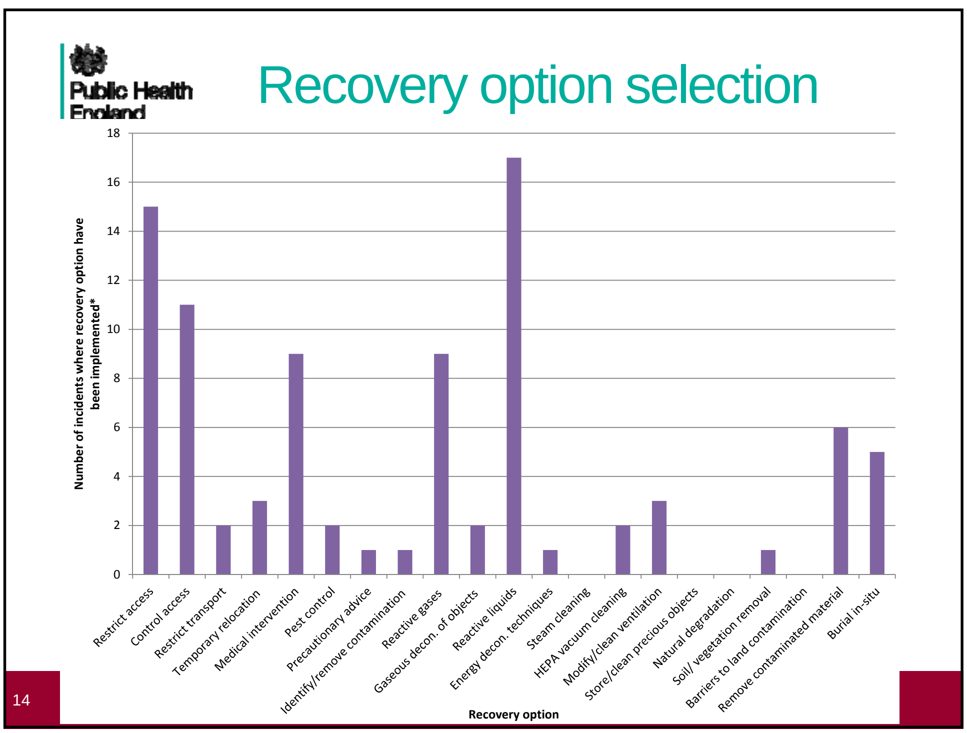
Inclusion

1) A true contamination event/ outbreak of infection occurred

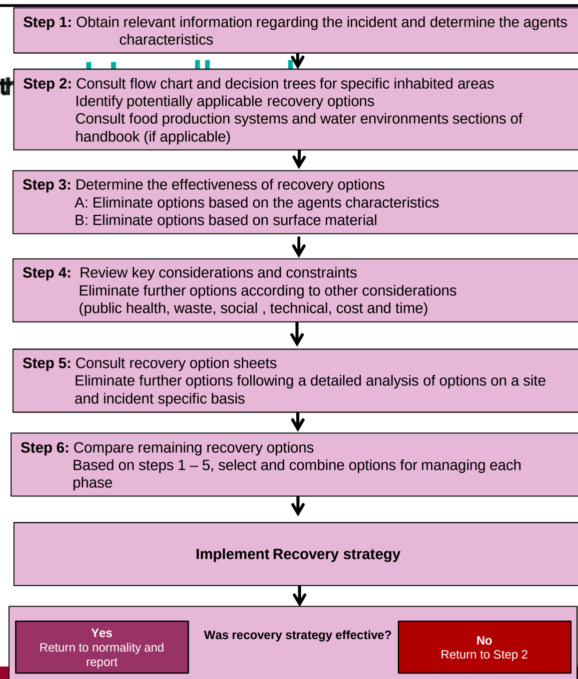
2) At least one recovery option was mentioned/ used

3) The paper detailed lesson learnt from the incident


Public Health England
Recovery Options Database
Edit Data
Recovery Options Database Incidents Report
Scottish anthrax incident, (Closed)
ID No. 196, Smailholm, Hawick, Scotland, contaminated June/July 2006 (unknown) reported August 2006
Accidental, environmental
Agent
Bacillus anthracis 0
0 0
A man died of what was thought to be inhalation anthrax. It took several weeks for the diagnosis and the man had been cremated. The source of the contamination needed to be isolated. The deceased's home was sampled and was negative for Bacillus anthracis. Spores were finally isolated at a local village hall and a residential garage. Both properties were chemically decontaminated. A property in Northumberland was also sampled and was positive for Bacillus anthracis this was also chemically decontaminated but using a different method.
Recovery Options
Incineration
Reactive gases and vapours
Prophylaxis and vaccination
Temporary relocation from residential areas
Impose restrictions on transport
Restrict public access
References
Riley, A. Report on the management of an Anthrax incident in the Scottish borders [Internet]. 2007 [cited 2013 Apr 3]. Available at: www.nhsborders.org.uk/__data/assets/.../anthrax_report_131207.pdf
Exit Database
13
UK Recovery Handbook for Biological Incidents


Public Health England
Recovery option selection
18
16
14
12
10
8
6
4
2
0
Number of incidents where recovery option have been implemented*
Restrict access
Control access
Restrict transport
Temporary relocation
Medical intervention
Pest control
Precautionary advice
Identify/remove contamination
Reactive gases
Gaseous decon. of objects
Reactive liquids
Energy decon. techniques
Steam cleaning
HEPA vacuum cleaning
Modify/clean ventilation
Store/clean precious objects
Natural degradation
Soil/ vegetation removal
Barriers to land contamination
Remove contaminated material
Burial in-situ
Recovery option
14

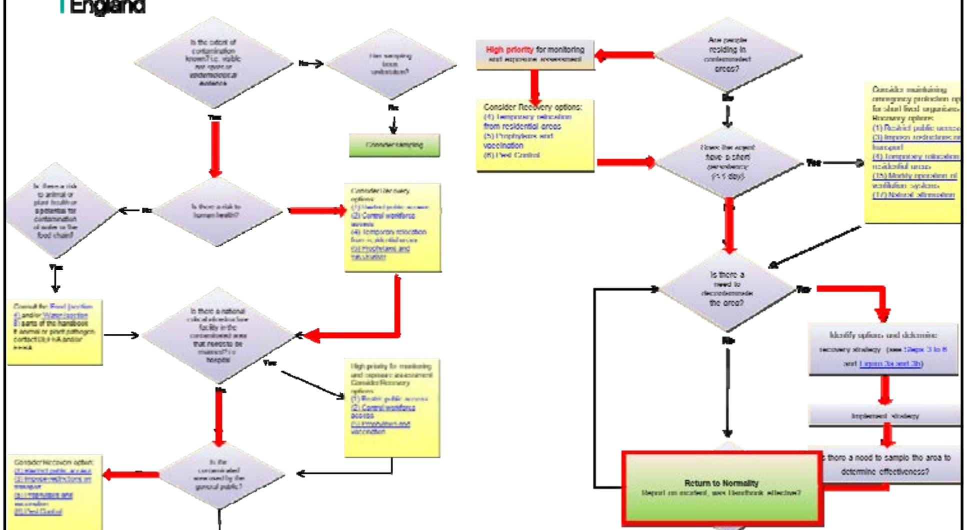
Public Health England




15 UK Recovery Handbook for Biological Incidents

Public Health England

# Decision trees




16 UK Recovery Handbook for Biological Incidents

## Recovery options

The list of recovery options has been compiled for the handbook

Workshops were used to test the recovery option selection

Separated into protection, remediation and waste disposal options

| | Radiation | Chemical | Biological |
|---|---|---|---|
| Food production systems | 40 | 39 | 28 |
| Inhabited areas | 51 | 24 | 21 |
| Water environments | 6* | 22 | 17 |

* Drinking water supplies only



## Recovery options datasheets

Form the majority of the Handbook

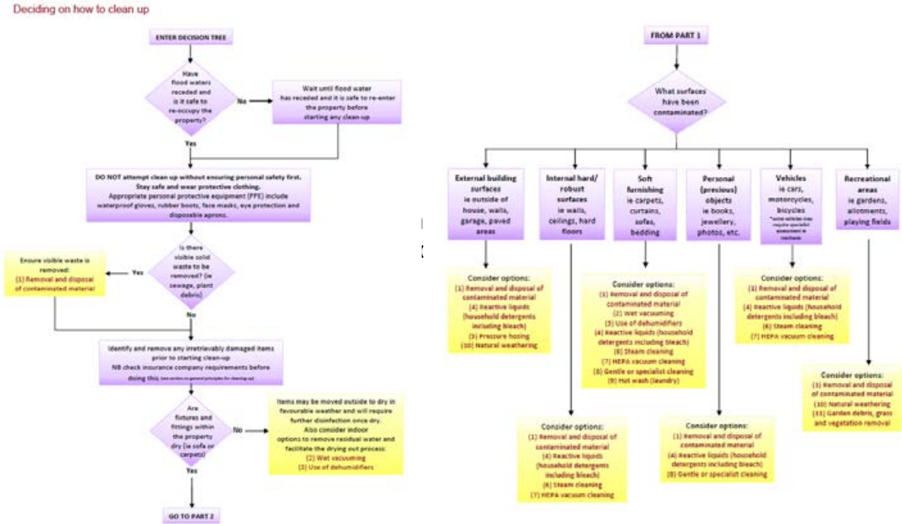
Contain 8 sections to describe the option in more detail:

- General information – *Objective, key information, linked options*
- Considerations – *Public health, legal, social*
- Effectiveness – *Technical factors*
- Feasibility and intervention costs – *Equipment, consumables, safety*
- Waste – *Type, factors influencing waste issues*
- Exposure – *Averted exposure*
- Other considerations – *Public information*
- Additional information – *Practical experience, key references*

## What next?



### Deciding on how to clean up



# Ebola response

## Decontamination advice for public places (including transport links) following suspected exposure to VHF (including Ebola Virus)

A Bennett and S Wyke



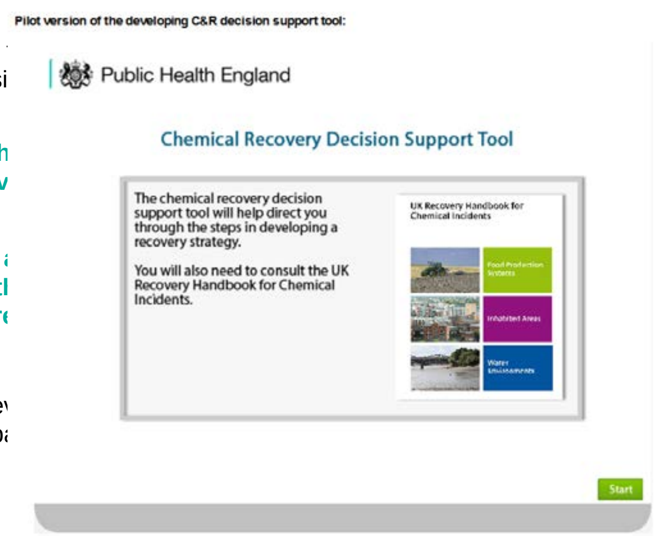
# Online recovery support tool

To make friendly
by usi pport
tool)

**Assist th thin the**
**recov oks)**

**Provide mptions**
**and tl rategy**
**(i.e. re selected)**

Being de et)
comp



# PHE are committed to;

- Maintain and update the Recovery Handbooks
- Take forwards areas of research to improve and further develop guidance for the recovery and remediation of the environment following an incident
- Continue to build the evidence base of recovery options recommended within the handbooks (biological incident review)

## Contact details:

For more information on the recovery handbooks and projects, to attend workshops, or participate in the retrospective reviews of biological incidents, please email;

https://www.hpa-surveys.org.uk/TakeSurvey.aspx?SurveyID=8lKJ76lM



# Acknowledgements

**Project team**

Emma Goode

Clare Shieber

Stacey Wyke

Sara Speight

Allan Bennett

# 2015 U.S. EPA International Decontamination Research and Development Conference

## Tuesday, May 5, 2015

## General Session 1

### Field Demonstration and (International) Program Review





# Methyl Bromide Fumigation: *Bacillus anthracis* Inactivation, Emissions Containment, and Conservation of Sensitive Materials

**Rudolf Scheffrahn*, Worth Calfee, Neil Daniell, Marshall Gray, Tim McArthur, Leroy Mickelsen, William Kern Jr., Renato Perez, Shannon Serre, and Joe Wood**

*speaker

UNITED STATES ENVIRONMENTAL PROTECTION AGENCY
EPA
CBRN CMAT
CONSEQUENCE MANAGEMENT ADVISORY TEAM

CSS-Dynamac
Scientific Minds. Common Sense Solutions.

UF UNIVERSITY of FLORIDA
IFAS Research
Fort Lauderdale Research and Education Center

September 11, 2001

http://www.september11news.com

October 5, 2001

**Officials: Florida anthrax case 'isolated'**

**WASHINGTON (CNN) -- A Florida man diagnosed with anthrax is an "isolated case," the top United States health official said Thursday, and his illness is not linked to any threats of bioterrorism.**

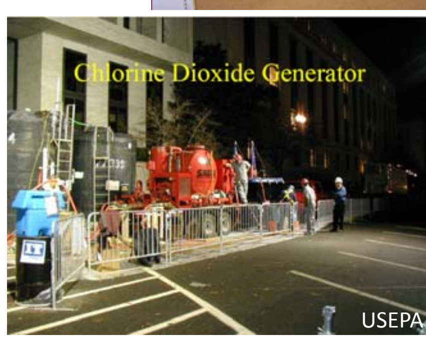
http://archives.cnn.com/2001

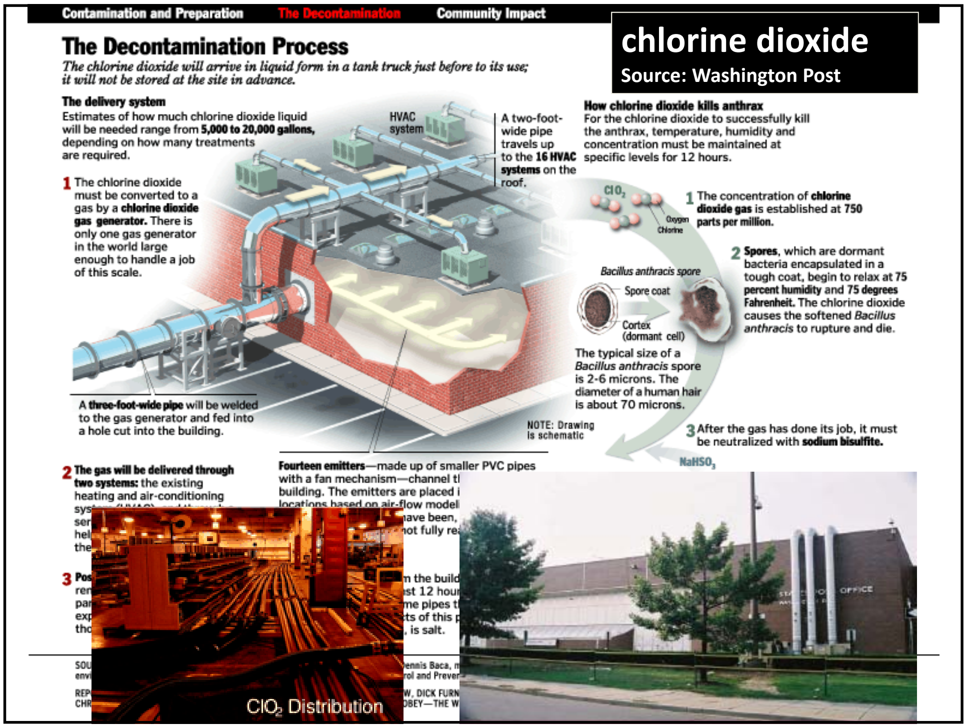
Former headquarters, American Media Incorporated, Boca Raton, FL

## Main decon options considered by USEPA in 2001-2:

- HEPA vacuuming
- Liquid or foam antimicrobials
- Fumigation



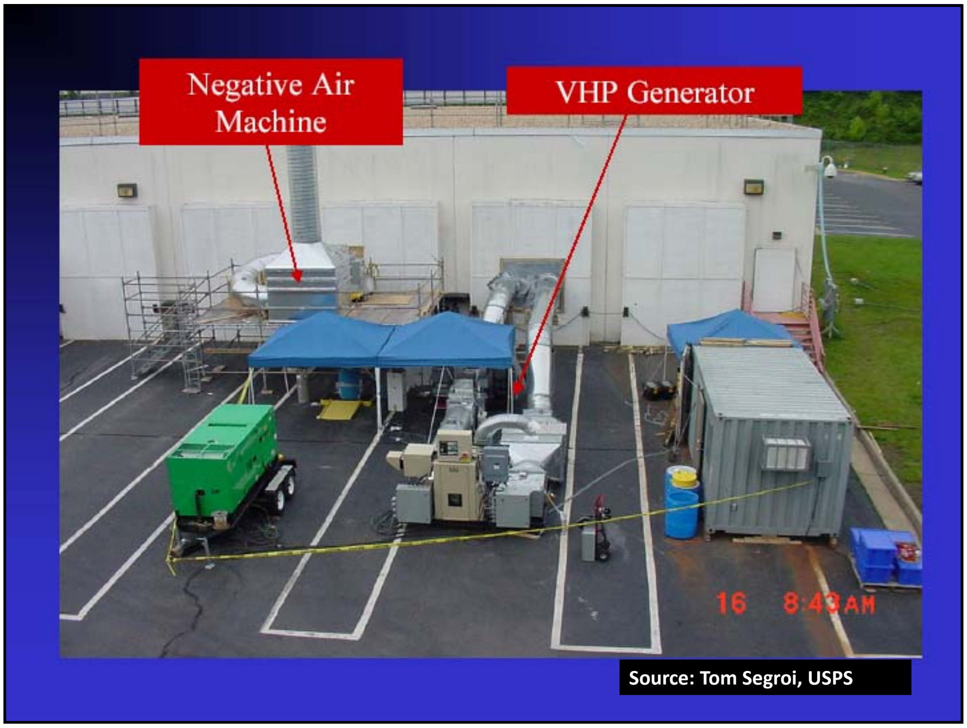





Decon of the Department of State Diplomatic Mail Facility (SA-32) in Virginia*

- Remove all material from building
- destroy non-essential contents
- fumigate essential contents (mail) with ethylene oxide
- Fumigate the empty building with vaporized hydrogen peroxide

*__Canter DA__, Sgroi TJ, O'Connor L, Kempter CJ. 2009. Source reduction in an anthrax-contaminated mail facility. Biosecurity and Bioterrorism: Biodefense Strategy, Practice, and Science 7: 405-412


Negative Air Machine
VHP Generator
16 8:43AM
Source: Tom Segroi, USPS


Before
01/07/2003
After
02/27/2003
Source: Tom Segroi, USPS

Decon of the Department of State Diplomatic Mail Facility (SA-32) in Virginia*

Decon time: 16 months
Cost: $8.6 million

***Canter DA**, Sgroi TJ, O'Connor L, Kempter CJ. 2009. Source reduction in an anthrax-contaminated mail facility. Biosecurity and Bioterrorism: Biodefense Strategy, Practice, and Science 7: 405-412

Methyl bromide, if effective in killing anthrax spores, is superior to chlorine dioxide and vaporized hydrogen peroxide:

- MB is a non-corrosive gas (methylating agent)
- MB is stable, penetrating
- MB is part of commercial fumigation infrastructure
- MB is an EPA-registered pesticide

EPA's objection: MB is an ozone depleter

Methyl bromide

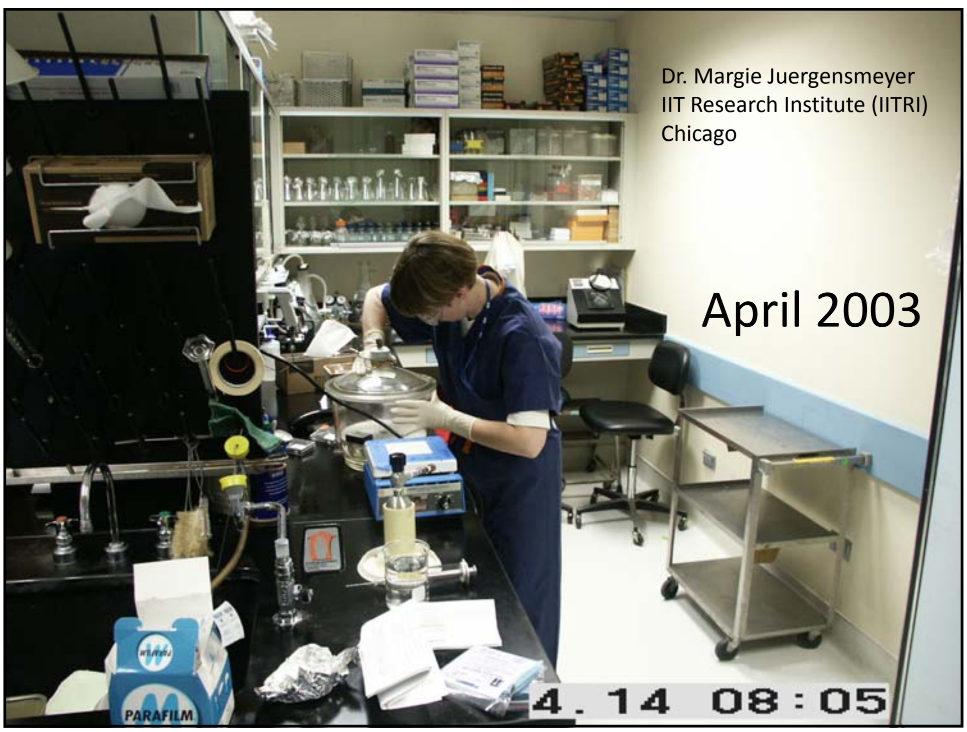
## Lab Trials

**Spore strips were fumigated at controlled temperature**

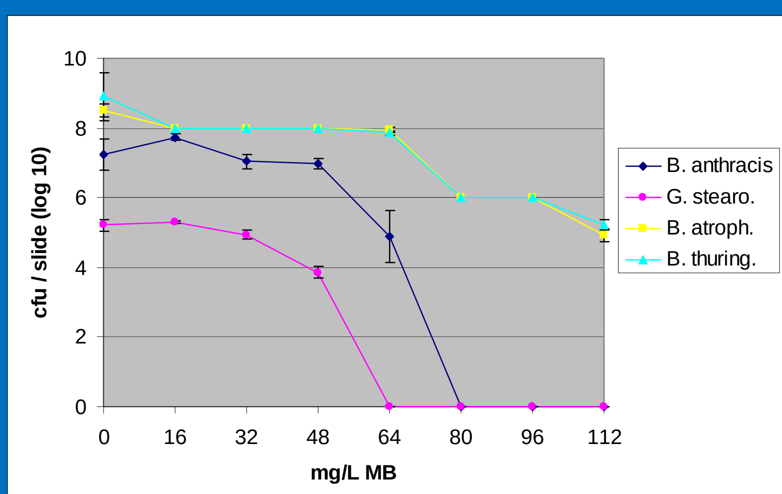
Early 2002

UF

Carlton J. Kempter, MS, Senior Advisor, Antimicrobials Division, Office of Pesticide Programs, Environmental Protection Agency, Arlington, Virginia




## Spore count vs. methyl bromide conc. at 37°C for 48-hour fumigation




64 mg/L = 16,500 ppm

UF

**United States Patent** **7,153,471** **December 26, 2003**

Method of decontamination of whole structures and articles contaminated by pathogenic spores

Inventors: **Weinberg; Mark J. (Cudjoe Key, FL),**
**Scheffrahn; Rudolf H. (Plantation, FL)**

Appl. No.: **10/623,428** Filed: **July 18, 2003**


Big Pine Key, Sept. 2004
9.17 17:00


9.18 12:05

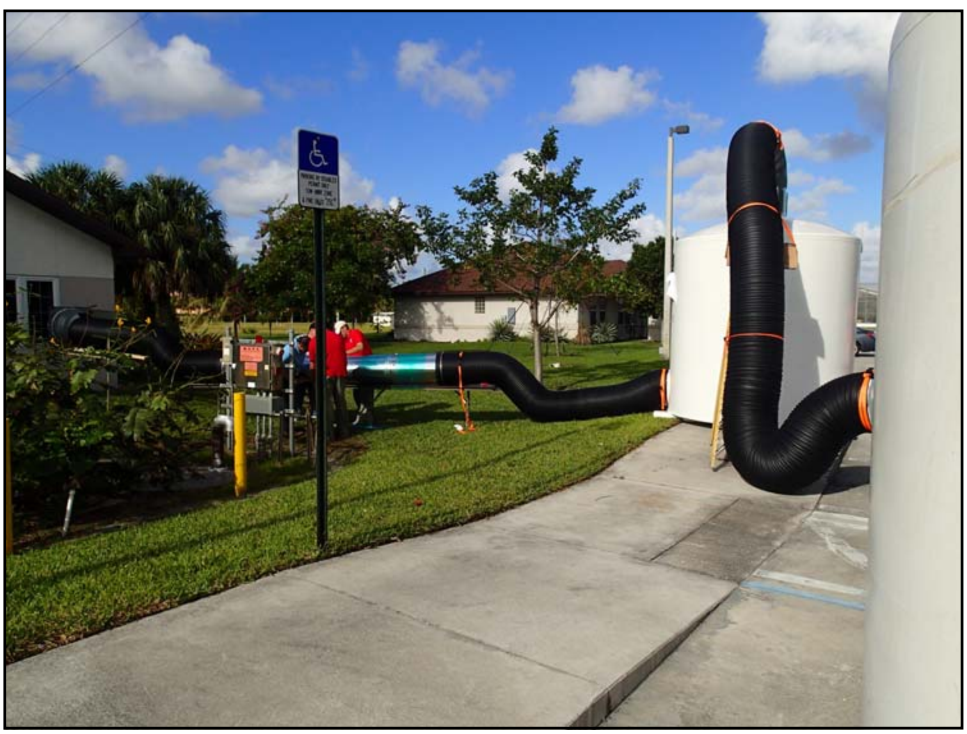

Fume School Nov. 2010


FLREC Dec. 2013
52,000 ft³ UF conference building i.e. "Hurricane House"
in Davie, Florida

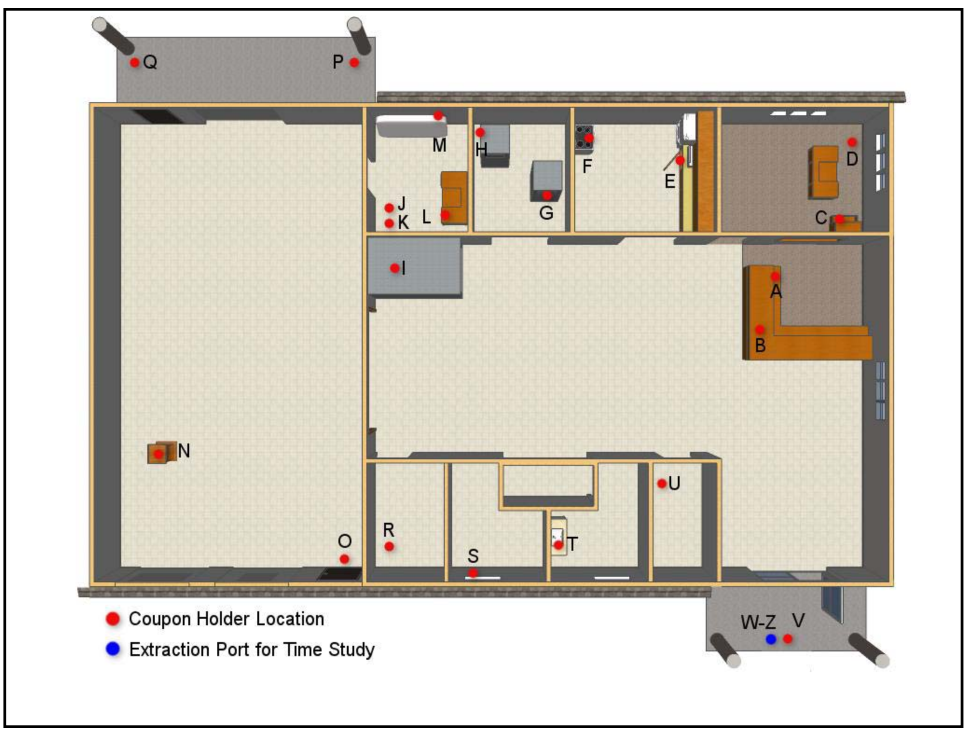

FLREC Dec. 2013
University of Florida Emergency Response Support Team
UF
RESEARCH IN PROGRESS
RESTRICTED AREA


5 Dec 2013


two 2,500 kg charcoal vessels for scrubbing methyl bromide




Placement of 87 wood and 87 glass coupons each containing ca. 1 x 10^6 colony forming units of *Bacillus anthracis* Sterne


Q
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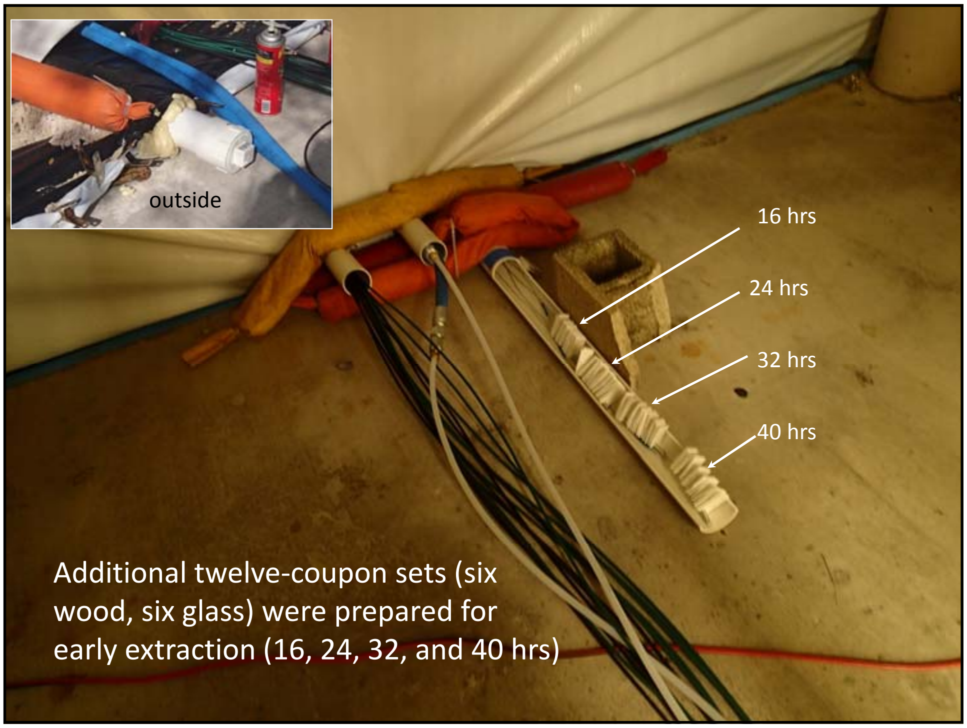
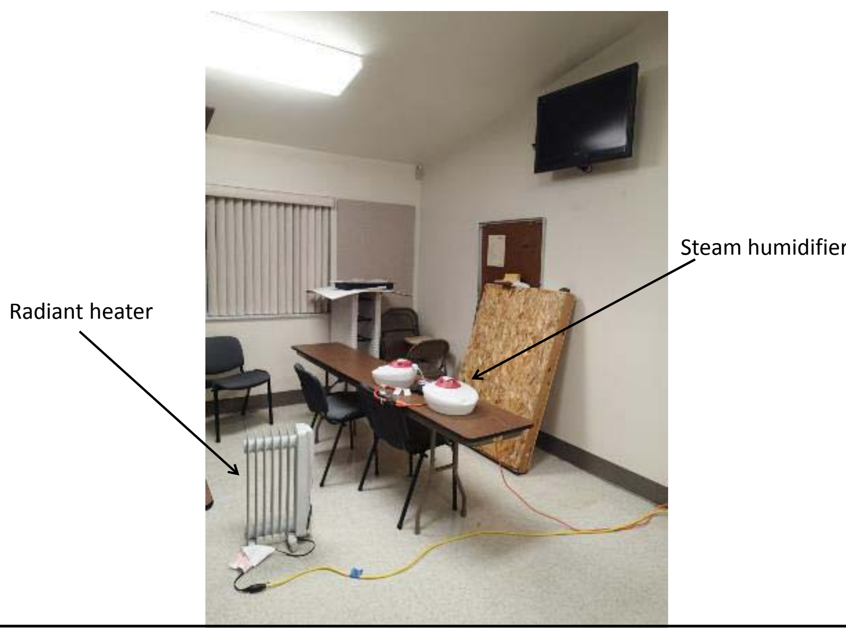
T
W-Z
V
Coupon Holder Location
Extraction Port for Time Study



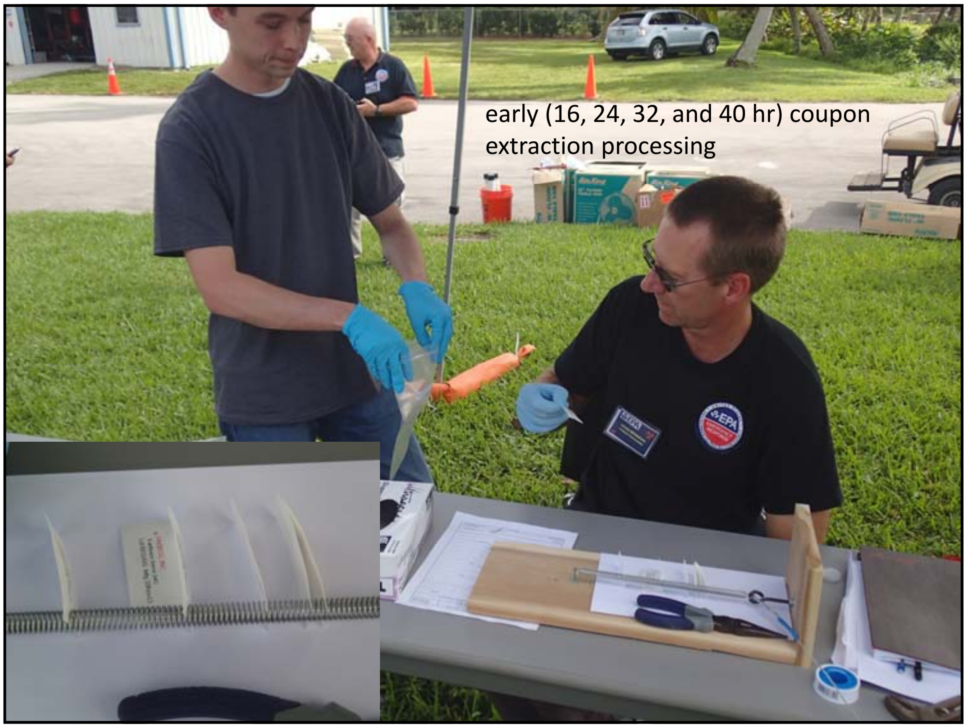

Interior conditions for MB fumigation:
28°C and 83% RH




CAUTION / CUIDADO


OHAUS


GH


early (16, 24, 32, and 40 hr) coupon
extraction processing

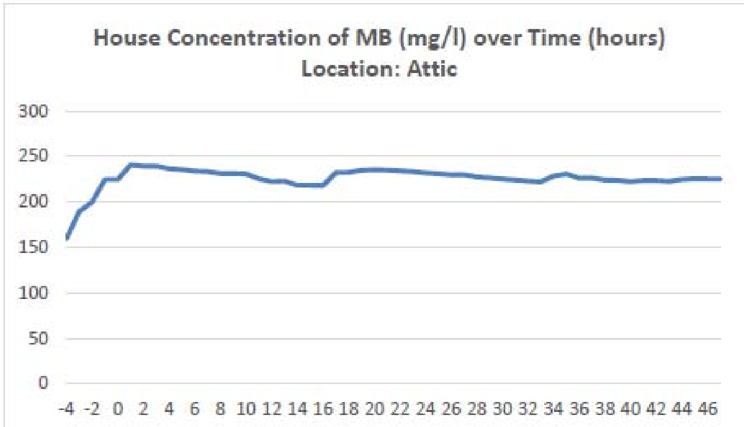
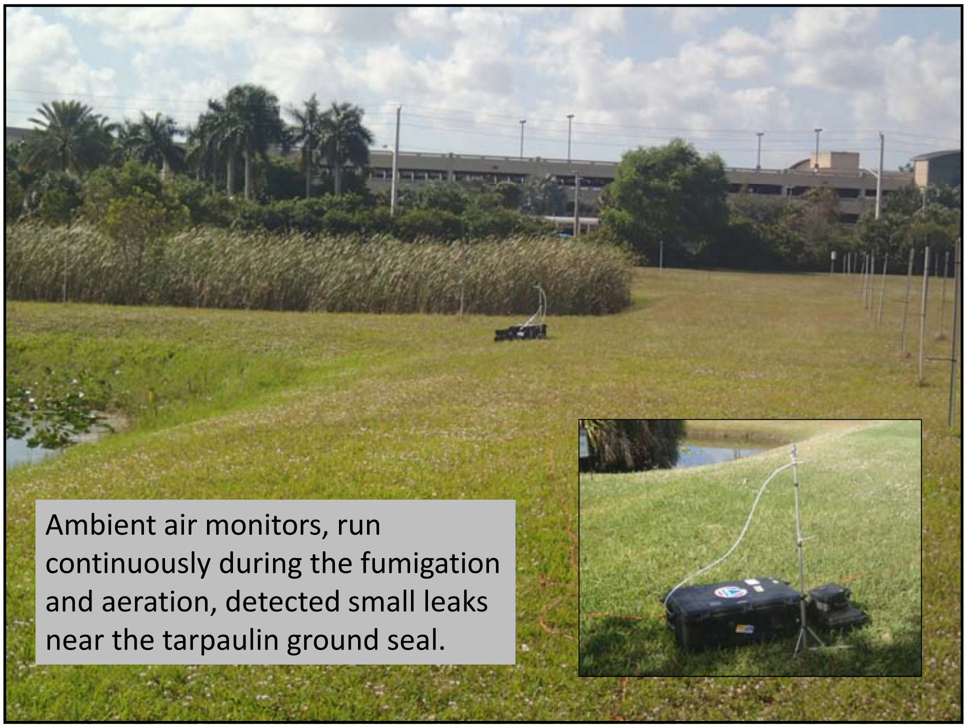
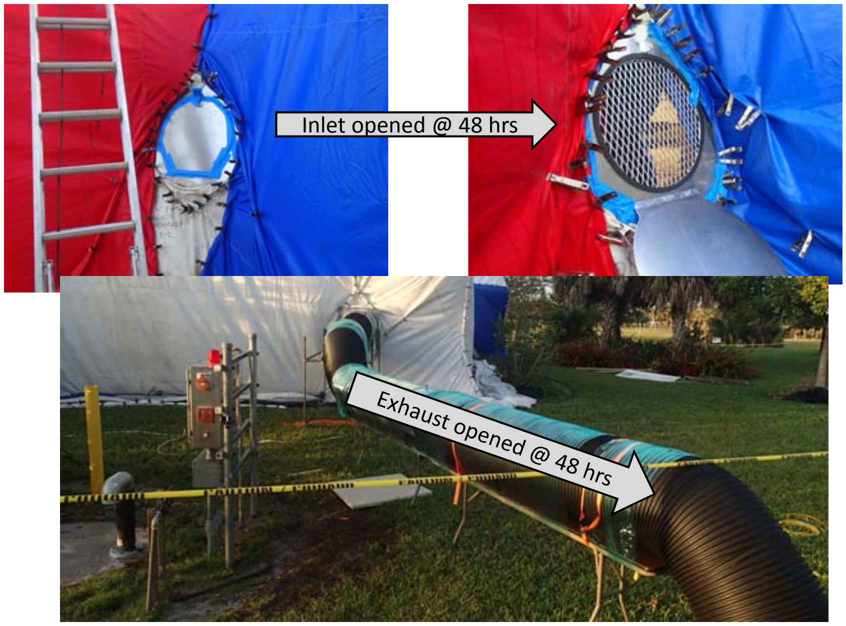



**Figure 30. Concentration of MB (mg/l) over Fumigation Time (hr), Attic Location**



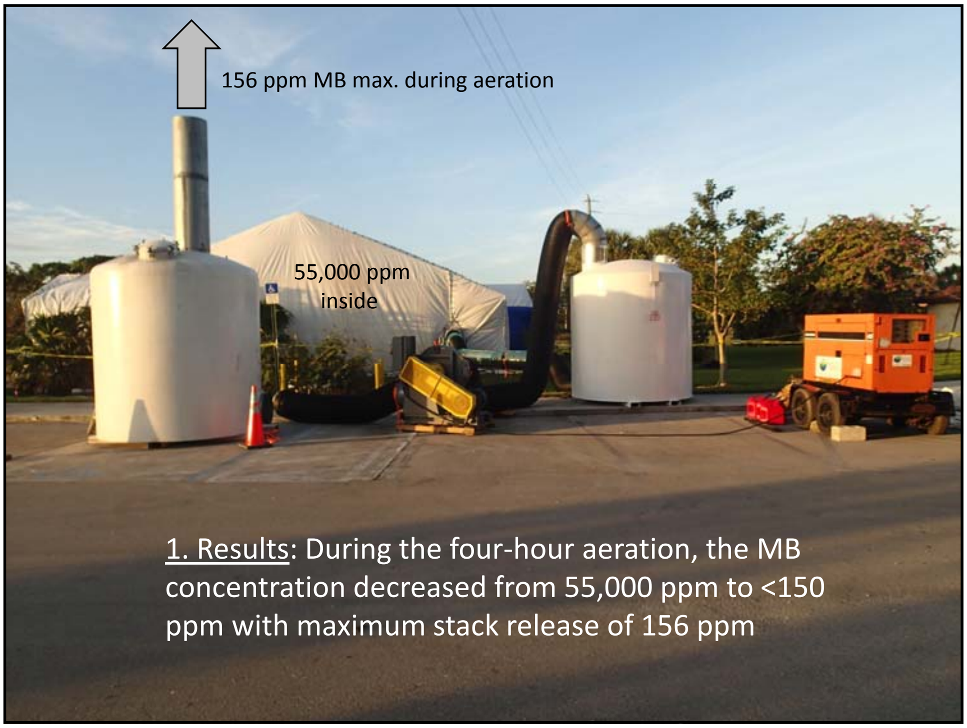


During the fumigation/aeration, there were no sustained elevated MB levels >0.5 ppm at any of the five monitoring sites located ca. 30 m from the building



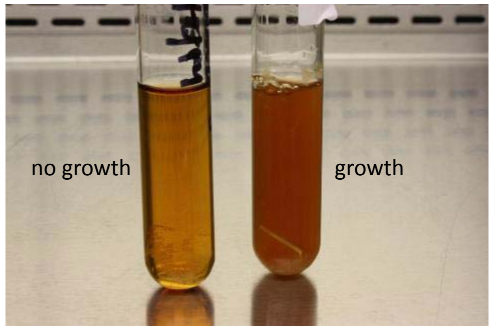

After 48 hours of fumigation, the building was duct-aerated forcing the MB-laden building air through the charcoal scubbers


UF
AUTHORIZED PERSONNEL ONLY




1. Results: During the four-hour aeration, the MB concentration decreased from 55,000 ppm to <150 ppm with maximum stack release of 156 ppm


2. Results: No visible or functional effects to the structure or its contents including computers and router, LCD monitors and projector, kitchen appliances, or HVAC.




3. Results: No colony forming units of *Ba* were detected on coupons fumigated for more than 16 hours with one exception:

A single wood coupon from 16-hour set yielded ca. 2 x $10^3$ cfu (500-fold reduction in viable spores)

Results of Dec. 2013 Hurricane House methyl bromide fumigation :

- Anthrax spores were killed in 16 hours
- MB was contained under special seal conditions
- 99.99% of MB in H House was collected in scrubbers
- All electronics functioned normally after fume


Thank you…….Questions?

Unclassified

# Hazard Mitigation Science and Technology Program for the DoD Chemical and Biological Defense Program (CBDP)

*Charles A. Bass, Jr., Ph.D., P.E.*
*Defense Threat Reduction Agency (DTRA)*

Unclassified

Unclassified

## J9-CB executes the JSTO function


2

Unclassified

Unclassified

# Chemical and Biological Threats


- *Chemical*
  - ✓ **Traditional chemical warfare agents**
    - (e.g., nerve agents, vesicants)
  - ✓ **Toxic industrial materials and toxic industrial chemicals**
  - ✓ **Emerging and non-traditional agents**
- *Biological*
  - ✓ **Traditional biological threat agents**
    - (e.g., anthrax)
  - ✓ **Emerging diseases**
    - (e.g., SARS, Ebola Virus Disease)
  - ✓ **Enhanced threats**
    - (genetically engineered or especially virulent)


Unclassified 3

Unclassified

# Current Hazard Mitigation (HM) Paradigm

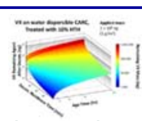
**Immediate**
- Individual and operator
- Skin decon; Operator spray-down
- Minimize causalities; save lives
- Limits spread of contamination

**Operational**
- Crew and unit
- MOPP gear exchange; Operator wash-down
- Limits contamination spread and exposure
- Temporary relief from MOPP

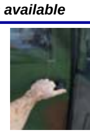
**Thorough**
- Specialized units
- Detailed personnel, equipment decon
- Reduces MOPP level
- Reconstitutes combat power

*More time needed/ Less Effective/ Less assets available*

**Important Considerations:**



*Time-to-Action*



*Operational Risk*

*Material Compatibility*

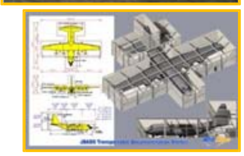
*Life-Cycle Management*

4 Unclassified

Unclassified

## Joint Biological Agent Decontamination System (JBADS)

- JBADS congressionally approved Joint Capability Technology Demonstration (JCTD) to demonstrate:
  - Biological decontamination of Anthrax Simulate using hot (170 ºF) humid (80-90% RH) Air
  - 6-log reduction in 72 hours
  - Aircraft interior/exterior decon:
    - Operational Utility Assessment (OUA)
    - Using Aircraft Enclosure (AE)
    - Retiring C-130H
    - Nov–Jan 2014 at test site in Orlando International Airport (IAP), FL
    - Follow-on interior environmental release of simulant
    - Follow-on field demonstration of rapid biological indicator



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5

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## JBADS Progress

2003

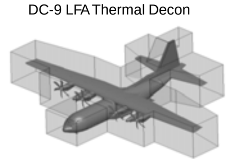
Large Frame Aircraft (LFA) Decon Demo

2008

DC-9 LFA Thermal Decon

2011

C-130 JBADS Interior Only Decon Demo



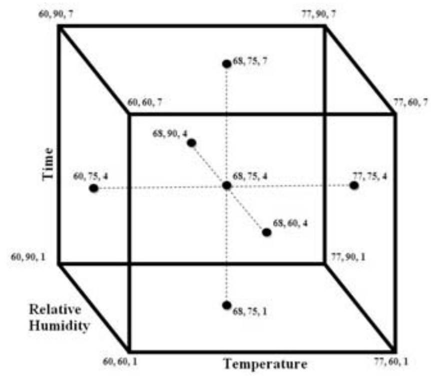
2014/15

JBADS JCTD Inter/Ext Decon Demo

Unclassified

6

# Design of Experiments



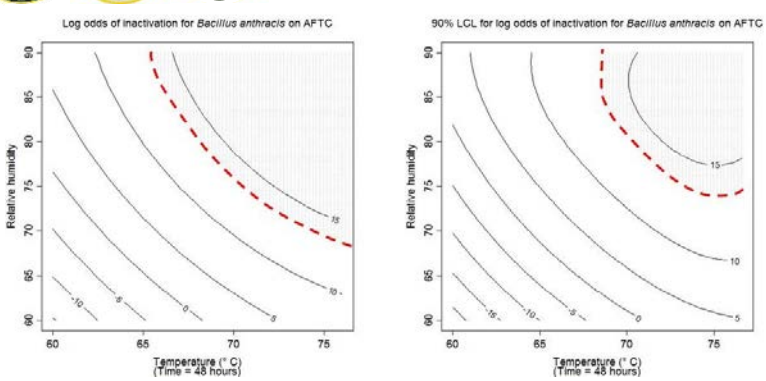

<u>Material Coupons</u>

Aircraft Performance Coat (APC)
Wiring Insulation
InsulFab
Anti-skid
Nylon
Plastic





# Performance Contours




B. anthracis ΔSterne on APC at 48 hours of treatment with hot humid air. The shaded area on the upper right represents a log reduction of greater than or equal to 6 logs of the fitted equation. The left plot shows average values. The right plot shows the 90% lower confidence limit for the average.

Unclassified

## JBADS JCTD OUA Activities

| | |
|---|---|
| • Pre Operational Test Activities | •Construction of Aircraft Enclosure (AE)<br>•Aircraft Decon Units (ADU) integrated with AE<br>•Air Mapping |
| • *27 Oct – 20 Nov* | •72 hour test run<br>•Removal and analysis of BtK coupons<br>•Limited Preflight maintenance tasks and Hot Wash (HW) |
| • OD #1: 170F/90RH<br>• *1-12 Dec* | •96 hour test run<br>•Removal and analysis of BtK coupons<br>•Limited Preflight maintenance tasks and HW |
| • OD #2: 170F/80 RH | •72 hour test run<br>•Removal and analysis of BtK coupons<br>•HW |
| • *13 Dec – 9 Jan* | •View Demo test site and equipment set-up<br>•JBADS briefings and discussion at area hotel<br>•AO only meetings 1300-1500 |
| • OD #3 (Optional)<br>• *10-20 Jan* | •Provides data for TRL-7 assessment<br>•Verification protocol for clearance level standards<br>•Rapid field Biological Indicators System test |

Unclassified 9

Unclassified

## Rapid Biological Indicator

- A self-contained biological indicator (BI) and an incubator/detector system
- Demonstrated the utility of BI system with Bt Al Hakam Spores as decontamination assurance system during JBADS field testing of an aircraft decontamination with hot, humid air
- BI detector is fast, quantitative, portable and easy to use

*The BI detector has 12 wells to incubate the biological indicators at 37 ºC and monitor the fluorescence generation; touch screen is used for user interface and data display; single spore can be detected within 8 – 10 hours*

Unclassified 10

# Field Methods

| | | | |
|---|---|---|---|
| C | T | C | T |
| B | C | T | C |
| T | B | C | T |

| | |
|---|---|
| C | T |
| T | C |

Cockpit Sampling Grid
C = Control Sample sites
T = Test Sample sites

Cargo Hold Sampling Grid
C = Control Sample sites
T = Test Sample sites
B = Background sites






# Environmental Release Results

- Post-dissemination/decon swabbing of cargo bay and cockpit
  - Total number of CFU on all 98 post-dissemination, pre-decontamination control swabs was 5.45e8 CFU
  - Equivalent to ~5-6 logs on a 2cm x 2cm coupon
- Rapid BIs - all were negative
- Environmental samples:
  - 87/98 swabs had 0 CFU
  - There were a total of 47 CFU in 11 swabs over 7 grids (including the cargo bay and the cockpit)
  - After outlier statistics, there were 10 CFU in 7 swabs over 4 grids

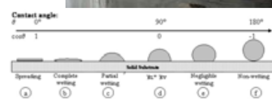
# Enhanced CB Survivability Coatings

**Problem:** Permanent/durable coatings (paints and topcoats) have limited agent resistance

**Objectives:** Develop an improved acceptance standard for chemical agent resistance; investigate new more resistant and potentially reactive coatings; develop a coating for legacy aircraft with improved capabilities

**Program Alignment:** Item MIL-DTL specification modifications

**Payoffs:** Significantly reduced risk to warfighter and reduction in burden of current decontamination approach



**Approach:**

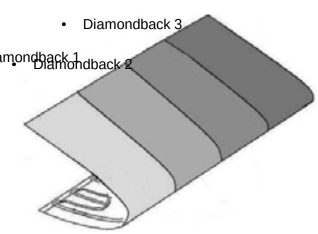
- Update CARC MIL-DTL to a relevant acceptance standard for chemical resistance
- Demonstrate strippable preparatory coatings that can quickly remove contamination
- Develop permanent/durable coatings that are actually resistant
- Develop responsive coatings that lock-down and continue to mitigate the effects of contamination
- Demonstrate/ flight test aircraft coatings on C-130 panels (Diamondback Demonstration)





# Field Test Concept

- Objective: Conduct a field test comparing the performance of newly formulated Diamondback to the baseline/control MIL-PRF-85285 Type IV polyurethane topcoat
- Approach: Paint selected C-130 wing leading edge panels in equal sections with the baseline MIL-PRF-85285 Type IV and up to three Diamondback formulations




Note: Four shades of gray shown for clarity - actual coatings, which all meet MIL-PRF-85285 Type IV, should exhibit little color difference

## Coating Additive Testing


Pre-scored, frangible panel breaks into 12 2"x2" coupons
VX 2-μL droplets at 10 g/m² loading
24 hour aging
Pressure wash with water alone, & w/ cleaning compound

*VX on standard Coating – 24-hour Aging*

*VX on Coating with Additives – 24-hour Aging*

- Additives produce a qualified coating with additional advantages: (e.g. stain resistance, deicing, drag)
- Coatings w/ additives leave sessile agent droplets after aging & reduce spreading
- Additives reduced agent retention after decon by 10 fold on some coatings; others show no improvement
- Additives appear work better with some coating products
- Impact of weathered coating is unknown
  - FY15/16 test weathered frangible coupons
  - FY16/17 test aircraft panels





## Enzyme Based Mild Decon

**Problem:** Aircraft and other platform interiors are sensitive to aggressive decontaminants

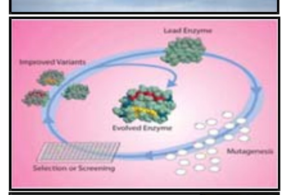
**Objective:** Apply new microbiology tools to evolve new more stable and broader spectrum enzymes to decontaminate organophosphate agents, and improve agent disclosure

**Program Alignment:** DFoS, Joint Sensitive Equipment System (JSES)

**Payoffs:** Ability to decontaminate sensitive platforms using a non-toxic, green decontaminant with excellent materials compatibility that is more effective than soapy water

**Approach:**

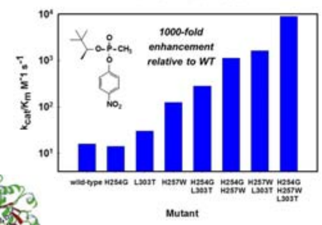
- Directed evolution of OPH/PTE enzyme for improved stability, and enhanced activity against V agents and NTAs
- Meet cost and shelf life improvement goals for agent disclosure spray




Unclassified

# Enzymatic Decon Progress

*H254G/H257W/L303T*




| Variant | $(k_{cat}/K_m)$ $R_p$ $M^{-1}\,min^{-1}$ | $(k_{cat}/K_m)$ $S_p$ $M^{-1}\,min^{-1}$ | Ratio $R_p : S_p$ |
|---|---|---|---|
| Wild Type | $6.4 \times 10^3$ | $2.6 \times 10^2$ | 25 : 1 |
| VRN-GVQF | $4.0 \times 10^3$ | $1.3 \times 10^5$ | 1 : 31 |
| L7ep-3aG | $4.2 \times 10^4$ | $1.6 \times 10^5$ | 1 : 4 |

*620-fold Enhancement*

**Limitations**

- Solubilization of agent limits reaction
- Buffer needed to manage reaction byproducts (enzymes are inactivated in absence of buffer)
- High concentrations (>5%) of surfactants limit rxn
- Solvents limit the reaction and can inactivate enzymes
- Buffers limit performance of surfactants
- Buffers can be corrosive (even at neutral pH)
- PTE/OPH is limited to nerve agents
- Life-cycle cost of enzymes

**Path Forward**

- Continue to refine formulation issues
- Explore synthetic enzymes that are more robust and broad spectrum (reflag effort as "catalytic-based mild decon")
- Explore enzymes that are anti-microbial or induce germination of spores

Unclassified 17

Unclassified

# Agent Disclosure Spray

**Program Goals**

- Indicate presence of agents down to threshold contact levels within 5 minutes
- Reduce logistics burden of decontamination by indicating presence and location chemical warfare agents
- Pre-decon to locate contamination; post-decon for process assurance

**Continued S&T Work**

- Plant expression of critical enzyme
- UV stimulated indicator for low-light operations
- Blister agent disclosure refinements

***Acquisition Program Begins (Milestone B) in May 2015***

18

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# Wide Area Decontamination of Anthrax Spores

**Problem:** *B. anthracis* spores are persistent and resists decontamination

**Objective:** Develop a new spore germinant/decontaminant to mitigate the effects of wide area dissemination of *Bacillus anthracis* spores that provides a militarily relevant capability

- 100X less decontaminant mass required than current decon
- Non-hazardous to environment, personnel, and materials
- 99.99% spore inactivation in relevant heterogeneous environments

**Program Alignment:** TBD

**Payoffs:** Faster cleanup at lower cost, less manpower, while deterring terrorists

**Approach:**

- Biological approaches (germinants, scavengers and lytic enzymes)
- Directed energy
- Agrochemical application techniques

S. Korea Sea Port Of Debarkation RSOI Exercise

Brentwood Postal Facility $130M over 2.2 years

19 Unclassified

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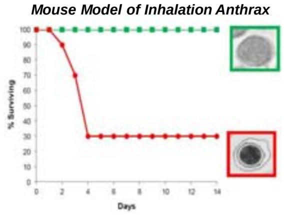
# Germination as a Mitigation Approach

- Germination reduces virulence

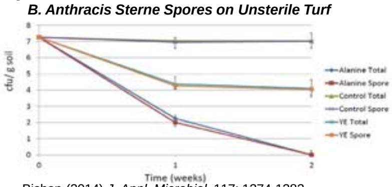
*Mouse Model of Inhalation Anthrax*




Cote *et al*. (2009) *J Med Microbiol* 58:6 816-825

- Germinated spores don't survive in the environment

*B. Anthracis Sterne Spores on Unsterile Turf*




Bishop (2014) *J. Appl. Microbiol*. 117: 1274-1282

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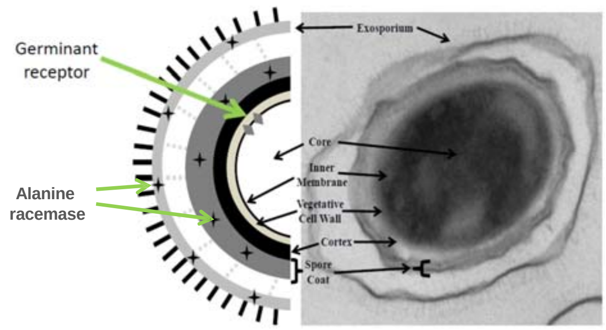
# Germination Strategies




- Germinant nutrient receptors
- Cortex lytic enzymes
- Spore coat disruption

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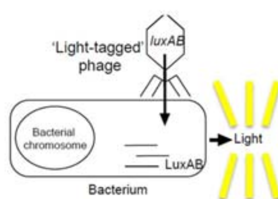
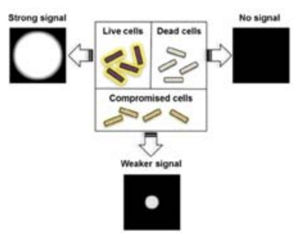
# Wide-Area Assessment

- Composite sampling:
  - Proof of concept to show no loss of sensitivity when pooling samples
  - Demonstrated in the presence of dust/soil
- Reporter phage:
  - Integrate *luxAB*(light) reporter genes into phage genome
  - Capable of transducing bioluminescent phenotype to target bacteria
  - No target present; no signal
  - Phage by itself cannot bioluminesce; dead cells; no signal
  - 10 CFU in 10 hours




Unclassified 22

Unclassified

# Wide-Area Application

- Significant levels of germination on surfaces can be achieved using agricultural technologies.
- Spores deposited from aerosols germinate more effectively than those spotted onto surfaces.
- Germination in turf can be achieved BUT the germinant must be delivered correctly.

Silsoe Spray Applications Unit

Unclassified 23

Unclassified

# Personnel Decontamination and Contaminated Human Remains

**Problem:** Limited capability exist to decontaminate individual human remains and manage personal effects following exposure to CWAs/NTAs/TICS/TIMs

**Objectives:** Determine the fate and residual hazard of chemical, biological, and radiological warfare agents (CBRs) o r contaminated human remains and personal effects; Develop technological options to remove/neutralize CBR hazards from individuals human remains and personal effects

**Program Alignment:** Program TBD

**Payoffs:** Quantify risks associated with contaminated human remains; increase efficacy; enhance processing rates and materiel compatibility; and reduce logistics challenges

**Approach:**

– Conduct of current alternatives and maturity to proceed with a program
– Support Mortuary Affairs Science & Technology Working Group
– Conduct ‘Postmortem’ Decontaminant Studies

24 Unclassified

# Questions ?

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# Infrastructure mitigation for rapid response after a radiological incident

***Wenxing Kuang, Konstantin Volchek, Pervez Azmi, Vladimir Blinov and Carl E. Brown***, Environment Canada, Ottawa, Ontario, Canada
***Matthew Magnuson and Sang Don Lee***, US Environmental Protection Agency, National Homeland Security Research Center, USA
***Jaleh Semmler***, Canadian Nuclear Laboratories, Chalk River, Ontario, Canada
***Pavel Samuleev and David G. Kelly***, Royal Military College, Kingston, Ontario, Canada
***Stephen Sunquist and David Clarke***, Ottawa Fire Services, Ottawa, Ontario, Canada

2015 EPA International Decontamination Research and Development Conference, May 5-7 Triangle Park Campus, North Carolina

## Infrastructure mitigation for rapid response after a radiological incident

- Background
- Rationale
- Objectives
- Approach
- Project team
- Technology
- Outcomes

Page 2

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# Background

Not all radiological releases are alike - specific recommendations will differ

Wide area contamination has additional logistical challenges

Responders need accurate information and guidance during early phases of an incident

Some data and technology exist, but need to adapt data and technology to:

- particular locations,
- different types of radiological releases, and
- wide area releases

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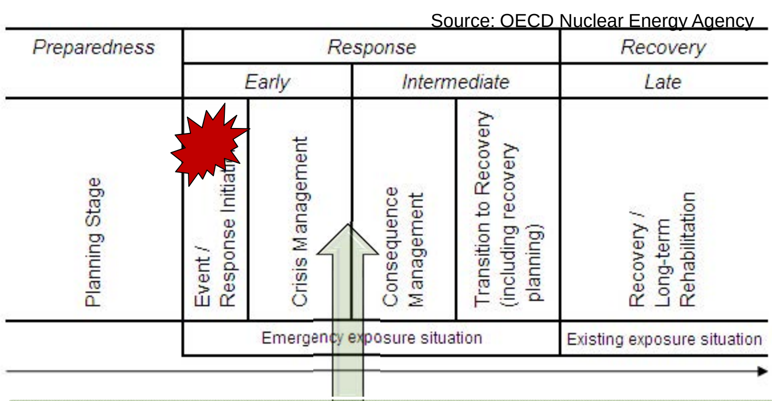
# Rationale




To reduce exposure to radiological/nuclear (RN) hazards for first responders/emergency crews

To use readily available, simple, and fast-acting mitigation methods

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## Mitigation vs. decontamination

| Factors | Mitigation | Decontamination |
|---|---|---|
| Timing | Short term | Medium to long term |
| Likely actors | First responders | Decontamination contractors |
| Equipment | Readily available to first responders | Specialized |
| Deactivation efficiency | Speed may be equally important | Set by clearance committee |

Once the radiological/nuclear (RN) contamination is mitigated, decontamination can be carried out later as a planned operation





## Project objective

**To optimize and demonstrate technology for mitigating critical infrastructure contaminated in a radiological/nuclear incident. This technology is:**

- Usable by first responders
- Rapidly deployable over a wide area
- Low-cost
- Compatible with the existing commercial equipment
- Environmentally friendly

# Project team

- Environment Canada – project lead
- US EPA National Homeland Security Research Center
- Canadian Nuclear Laboratories
- Royal Military College
- Ottawa Fire Services

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# Technology

- Can be applied using fire trucks and/or existing dispensing equipment available to first responders
- Formulation
  - Water-based formulation
  - Cocktail of ion exchange and chelating agents
  - Can be mixed with firefighting foams (Class A or B) and other ingredients


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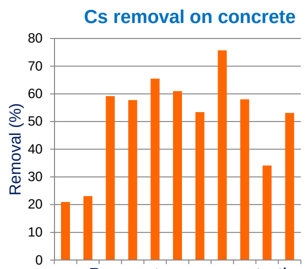
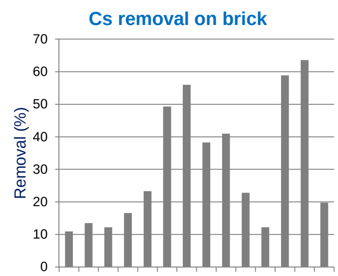
# Parameter optimization

Test parameters for water-based formulation

- Non-radioactive isotopes of Cs and Co
- Coupons: concrete, brick, asphalt
- Concentrations of individual components of the formulation
- Spiking: spray vs. spot
- Quick wash vs. slow wash
- pH




Parameters: concentration, exposure time, washing time, etc.

Source: Environment Canada





# Confirmation tests on radionuclides

## Removal of Cs-137

| Materials | Removal (%) | Decontamination Factor |
|---|---|---|
| Concrete | 71 ± 6 | 3.4 |
| Brick 1 | 62 ± 4 | 2.6 |
| Brick 2 | 80 ± 10 | 5.0 |
| Asphalt | 44 ± 11 | 1.8 |

Total Cs-137 recovery approx. 90%
Coupon size: 2” x 2”
Source: Royal Military College of Canada

## Pilot-scale tests at the Canadian Nuclear Laboratories

- Radionuclides (Co-60, Sr-85, Cs-137, Am-241)
- Concrete, brick, limestone, asphalt, glass, aluminum
- Coupon Size: 6” x 6”
- Waste collection system

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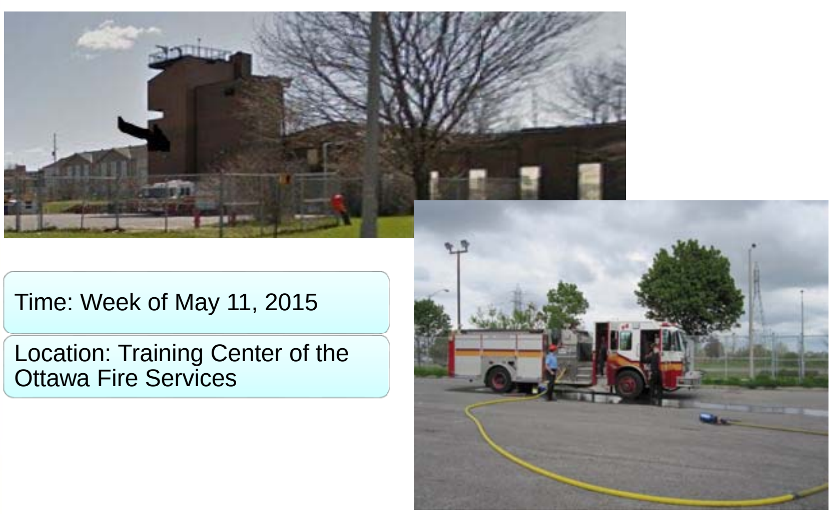
## Dry run



- Time: Week of May 11, 2015
- Location: Training Center of the Ottawa Fire Services

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## Field demonstration trial

- Led by US EPA/Battelle
- Week of June 22, 2015
- Columbus, Ohio
- 1000 sq. ft. five-story building
- Vehicle mitigation
- Waste management
- Classroom presentation
- Observer feedback

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## Project deliverables

- New rapid CBRN response technology developed and demonstrated
- Users' feedback received
- Technology guide developed and delivered to users
- Milestone in technology commercialization achieved

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# Contact information

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Acknowledgement: This work was funded in part by the Canadian Safety and Security Program, Defense Research and Development Canada, under Project CSSP-2013-CP-1029.

# 2015 U.S. EPA International Decontamination Research and Development Conference

## Tuesday, May 5, 2015

## Concurrent Sessions 1

### Biological Agent Decontamination





DSO

# *Development of Microemulsion Decontaminant against Chemical & Biological Agents*

Ang Lee Hwi
aleehwi@dso.org.sg

2015 EPA International Decontamination Research and Development Conference

5 May 2015

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Slide 1

DSO

## *Agenda*

- Introduction
- Approach and Challenges
- Test Methodologies
- Performance
- Detector Interference Studies
- Material Compatibility Studies
- Conclusion

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Slide 2

# Introduction

- DSO completed the development of the Demul-X macroemulsion decontaminant in 2004
  - Able to degrade a wide range of chemical agent and biological spores.
  - Kinetically stable and therefore requires considerable mechanical effort during preparation by the users.

- A microemulsion system was therefore formulated to
  - Improve ease of preparation and efficienty
  - Capitalise on a smaller droplet size to increase reactive surface area

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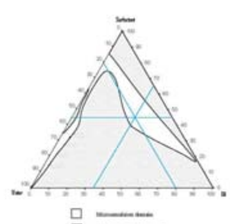
# Approach & Challenges

(1) Enhanced efficiency & ease of preparation

* Identification of potential microemulsion systems
* Collaboration with Dstl, UK
* Non-ionic surfactant system (less sensitive to ionic strength)

(2) Non-toxic & non-aggressive

* Modification – replacement of organic solvent
* Must retain microemulsion property and good solubility of agents!



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# Approach & Challenges

(3) Thermal stability

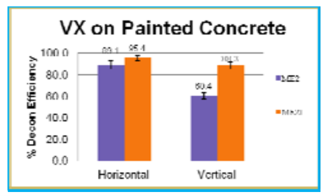
* Local environmental conditions
* Modification – Replacement of co-surfactant

(4) Good pot-life of > 4 hours

* Selection & tuning of the active ingredients
* Optimal pH for efficient degradation of agents of different nature

(5) Good surface adherence

* Addition of gelling agent
* To increase contact time
* Not to compromise ease of removal

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# Test Methodologies for CWA

- Degradation efficiency studies

  - Agent-to-decontaminant ratio of 1:200, with a contact time of 30 minutes.
  - Liquid-liquid extraction
  - Analysis on GC-FID

- **Surface Decon efficiency studies**

  - Materials tested: 5 cm × 5 cm test coupons of painted concrete & ceramic tiles
  - Contamination level: 10 g/$m^2$
  - Residence time: 3 hours
  - Vertical and Horizontal orientation
  - Decontaminant applied with commercial sprayer
  - Contact time: 30 min
  - Solvent extraction of test panel
  - Analysis on GC-FID

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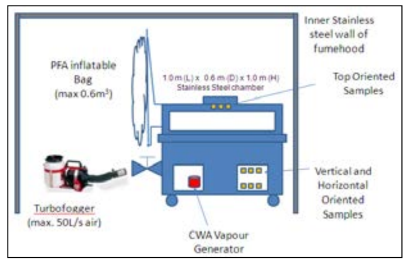
# Test Methodologies for CWA

- **Vapour Removal efficiency studies**

  - Aerosol chamber: a customized 1.0 m (L) x 0.6 m (D) x 1.0 m (H) stainless steel chamber
  - Inflatable PFA bag (max. 0.6m$^3$) to accommodate voluminous air from fogger
  - CWA vapour generated through heating liquid CWA at 40 or 60 °C for 1.5 hours
  - ME21 applied into the chamber as a fog via COTS fogger
  - CWA vapour concentration monitored through air sampling with Tenax® adsorbent tubes over 22 hours
  - Analysis on ATD-GCMS

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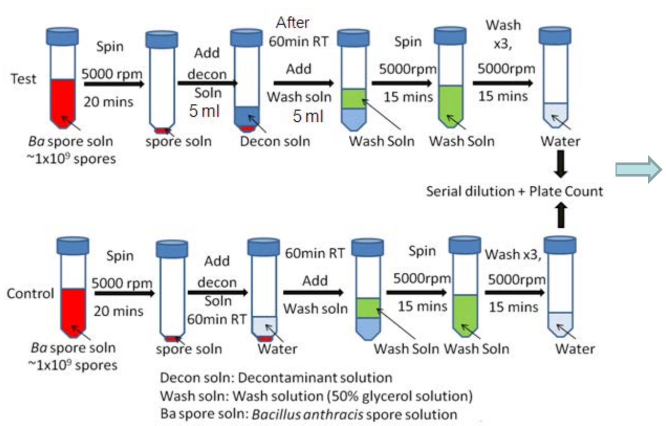
# Test Methodologies for BWA

- **Killing efficiency studies**




- An aliquot (100 µL) of the undiluted extract and each serial dilution plated onto tryptic soy agar plates in triplicate, allowed to dry, and incubated overnight at 35º C to 37º C for *B. anthracis*.

- Plates enumerated within 18 to 24 hours of plating. The number of CFU/ml was determined by multiplying the average number of colonies per plate by the reciprocal of the dilution.

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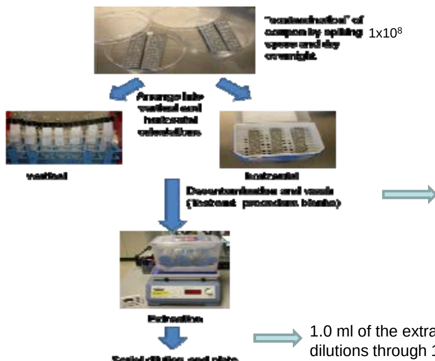
# Test Methodologies for BWA

- **Surface Decon efficiency studies**
  - 1.9 cm x 7.5 cm painted concrete and ceramic tiles
  - EPA test/QA plan for “Evaluating Liquid and Foam Sporicidal Spray Decontaminants” spray decontaminants protocol for evaluation of surface decontamination efficacy was adopted and modified.




- 5 ml of decontamination solution was added onto the surface using surgical pipette and left to contact for 30 minutes.
- After 30 minutes, the coupons were washed with approximately 10 ml of milliQ water.
- The decontaminated and control coupons (not decontaminated, not washed) are placed into a 50ml falcon tube each containing 10 ml PBS with 0.1% Tritron X-100 and agitated on an orbital shaker at 200rpm for 15 minutes.

1.0 ml of the extract will be removed and a series of dilutions through $10^{-7}$ will be prepared in sterile water.

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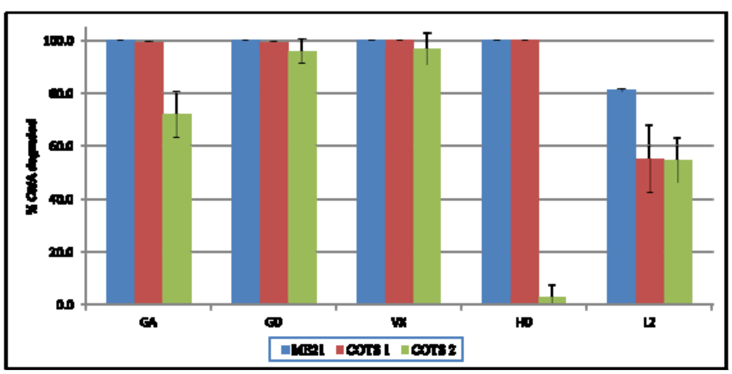
# Performance against CW Agents

## *CWA Degradation*




* More consistent performance across the range of CW agents.

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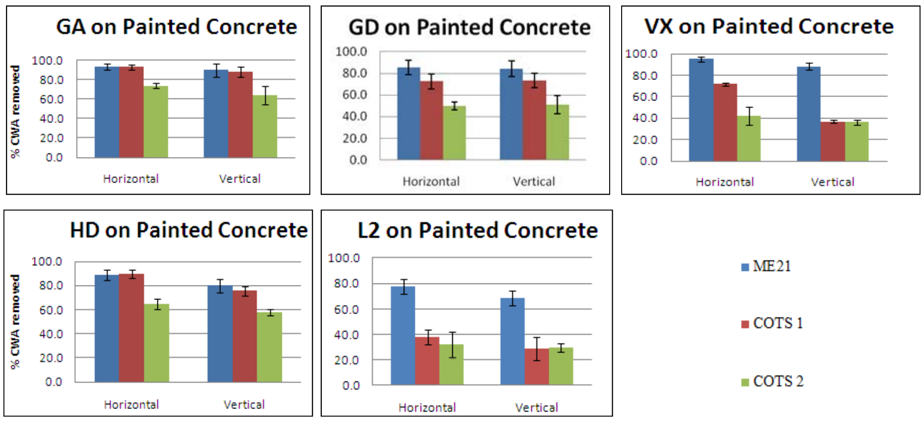
## Performance against CW Agents

### Surface Decon (CWA)




Higher surface decon efficiency in particular for VX and L2.

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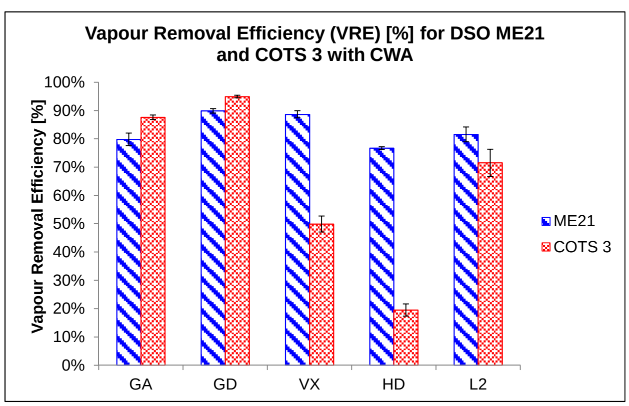
## Performance against CW Agents

### CWA Vapour Decon




- Higher vapour removal efficiency in particular for VX and HD.

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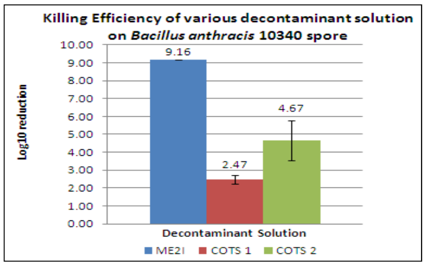
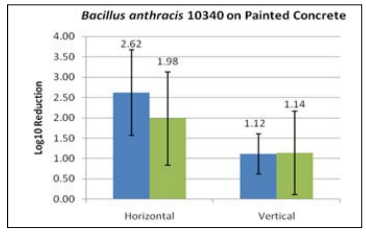
# Performance against BW Agents

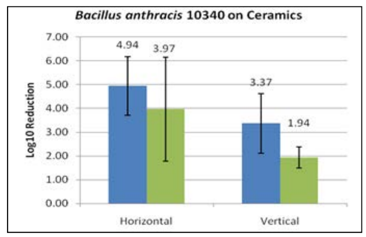
## Killing efficiency




- ME2I achieved > 9 log kill
- Surface decon is limited by extensive penetration of spores
- COTS 1 achieved < 3 log reduction of *B. anthracis*, and thus not evaluated on materials.

## Surface Decon efficiency




* The decontaminant were not sprayed, but applied onto the coupon.

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# Detector interference studies

- To establish the range of false alarms triggered by the decontaminants among the array of different detectors
- Detectors studied- AP4C(Proengin), CAM and HGVI (Smiths Detection)

| Detector | Direct Exposure to ME21 |
|---|---|
| AP4C | No CWA alarm |
| CAM | G-agent alarm |
| HGVI | No CWA alarm |

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# Material compatibility studies

- Methodology
  - Immersion of the materials in the decontaminant for 24 hours
  - Decontaminant removed via washing with water
- Air-dry for 24 hours before determining the weight
- Further drying and weight determination till constant weight
- Visual assessment of any surface damage

| Material | Compatibility | |
|---|---|---|
| | Weight Change | Visual Observation |
| Black Alkyd | < 1% | No change |
| White Alkyd | < 1% | Stripping of paint and undercoat |
| Matt PU | < 1% | No change |
| Glossy PU | < 1% | No change |
| Vinyl | < 1% | No change |
| Painted concrete | 1% to 4% | Peeling of paint |
| White glazed ceramics (with porous backing) | > 4% | No change |
| Grey ceramics (with non-porous backing) | < 1% | No change |
| ABS, sandblasted | < 1% | No change |
| Polycarbonate | < 1% | No change |

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# Conclusion

- A single decontaminant for multiple chem-bio threats, applicable for both surface and vapour decontamination (ME21)
- Proven effective against wide spectrum of CWAs and anthrax spores
- Can be applied with various COTS dispenser (spray and aerosoliser) for source mitigation, surface and vapour decontamination
- Relatively non-aggressive to surfaces and contains relatively non-toxic ingredients


Simple mixing produces ME21 in 5 min.

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# Acknowledgement


## Team Members

Ang Linda, Lim Meiyun, Loh Gek Kee, Low Hwee Teng, Ng Liu Yun Jasmine, Ng Ming Horng George, Eunice Sim, Tan Yoke Cheng

## Funding and Support Agencies

Chemical, Biological, Radiological and Explosive Defence group, (CBREDG), SAF

Future Systems & Technology Directorate (FSTD), MINDEF


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## Novel Decon Concept - DeconGel™

# Novel Decon Concept DeconGel™

## Bio-efficacy against Spores

**Vipin K. Rastogi[1], Markos Dasakalakis[2], Garry Edgington[2], and Lisa Smith[1]**

1. **R&T Directorate, US Army – ECBC, APG, MD**
2. **CBI Polymers, Inc., Honolulu, HI**

**Presented at the 2015 EPA's International Decon Conference**

TECHNOLOGY DRIVEN. WARFIGHTER FOCUSED.

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## Novel Decon Concept - DeconGel™

### Concept Description

- Apply a viscous hydrogel polymer over the contaminated surface → let dry → peel and dispose
- CBIP developed the technology to clean and decontaminate surfaces contaminated with toxic chemicals and radioactive materials
- During the drying process, the gel traps and encapsulates the surface contaminants
- Can the DeconGel be reformulated to decontaminate C/B/R/N threat materials?

### Origin of Requirement

- **Why is this a novel decon approach?**
  - Current options somewhat corrosive and require pre/post-rinsing generating hazardous waste
  - For Biological Warfare Agents (BWAs), spore reaerosolization is a an issue
  - A single technology for CBRN threat materials is highly desirable
- **Who is interested in this novel technology?**
  - Department of Homeland Security
  - Department of Defense
  - US EPA
  - Defense Threat Reduction Agency

### Concept Pictures

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# Bio-DeconGel™



## Unique Advantages

- Reduced hazardous waste
- No re-aerosolization of spores, as gel locks in the threat material
- Gel matrix allows penetration through other contaminants to the spore surface
- Gel matrix improves wetting of active ingredients through the spore surface
- Gel matrix increases exposure time of active ingredients
- Forensic evidence preserved and retrievable
- No special trainings required
- Corrosiveness and material incompatibility issues significantly reduced or eliminated
- Long shelf-life reduces replacement cost / logistical burden
- Multiple options for application – spraying, pouring and spreading, brush painting







# Bio - Four Formulations



1. Formulation 1 - additive 1 (1.5% by weight) added to hydrogel 1128A
2. Formulation 2 - additive 2 (4% by weight) added to hydrogel 1128A
3. Formulation 3 - additive 2 (6% by weight added to hydrogel 1128D (optimized for high efficacy for a period of 4 hours after preparation
4. Formulation 4 - additive 1 (2% by weight) added to hydrogel 1128D (optimized for high efficacy for a period of 4 hours after preparation)

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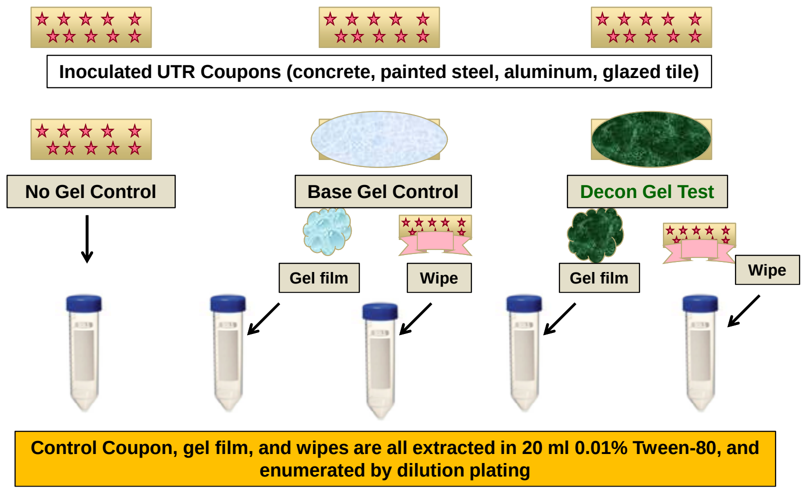
# Experimental Flow-chart

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# *B. anthracis* Spore QA/QC

**Table 1. QA/QC of BaDS spores used in small-chamber efficacy testing at ECBC**

| Sample | Dilution | CFU | CFU | CFU/ml | Log(CFU) | Log Reduction |
|---|---|---|---|---|---|---|
| HCl 1 | 0.001 | 300 | 300 | 3000000 | 6.48 | 1.02 |
| HCl 2 | 0.001 | 300 | 300 | 3000000 | 6.48 | 1.02 |
| HCl 3 | 0.001 | 300 | 300 | 3000000 | 6.48 | 1.02 |
| | | | | Average | 6.48 | |
| 0.01% Tween 80 | 0.00001 | 39 | 28 | 28000000 | 7.45 | |
| 0.01% Tween 80 | 0.00001 | 30 | 28 | 28000000 | 7.45 | |
| 0.01% Tween 80 | 0.00001 | 41 | 39 | 39000000 | 7.59 | |
| | | | | Average | 7.50 | 1.02 |

*a. 10-μL aliquots were exposed to 2.5-N HCl for 10-min.*
*b. Control and treated samples were enumerated by dilution plating*

**Table 2. QA/QC of BaDS spores used in small-chamber efficacy testing at ECBC**

| Sample | Dilution | Plate 1 | Plate 2 | Average | CFU/ml | Log |
|---|---|---|---|---|---|---|
| Control | 10-8 | 36 | 40 | 38 | 3.80E+10 | 10.58 |
| Heat Shock BadS | 10-8 | 46 | 40 | 43 | 4.30E+10 | 10.63 |

*a. 200-μL aliquots were exposed to 65 ºC for 30-min.*
*b. Control and treated samples were enumerated by dilution plating*

**Spores used in this study are 'Hardy', as they are heat-resistant and acid-resistant**

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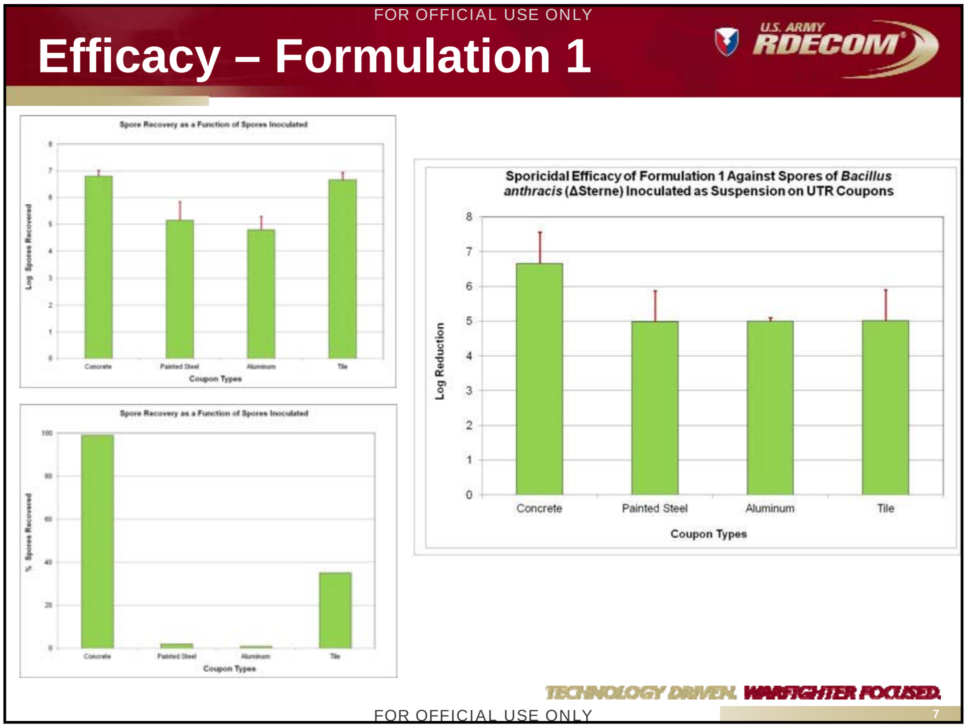
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Efficacy – Formulation 1
U.S. ARMY RDECOM
Spore Recovery as a Function of Spores Inoculated
Log Spores Recovered
Concrete
Painted Steel
Aluminum
Tile
Coupon Types
Spore Recovery as a Function of Spores Inoculated
% Spores Recovered
Concrete
Painted Steel
Aluminum
Tile
Coupon Types
Sporicidal Efficacy of Formulation 1 Against Spores of Bacillus anthracis (ΔSterne) Inoculated as Suspension on UTR Coupons
Log Reduction
Concrete
Painted Steel
Aluminum
Tile
Coupon Types
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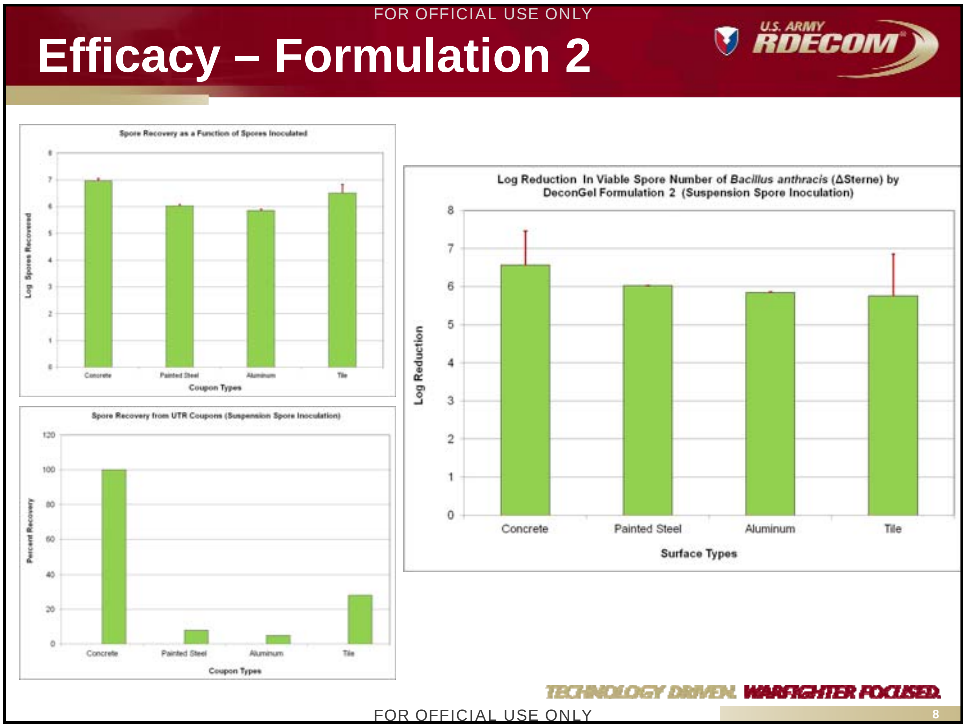
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Efficacy – Formulation 2
U.S. ARMY RDECOM
Spore Recovery as a Function of Spores Inoculated
Log Spores Recovered
Concrete
Painted Steel
Aluminum
Tile
Coupon Types
Spore Recovery from UTR Coupons (Suspension Spore Inoculation)
Percent Recovery
Concrete
Painted Steel
Aluminum
Tile
Coupon Types
Log Reduction In Viable Spore Number of Bacillus anthracis (ΔSterne) by DeconGel Formulation 2 (Suspension Spore Inoculation)
Log Reduction
Concrete
Painted Steel
Aluminum
Tile
Surface Types
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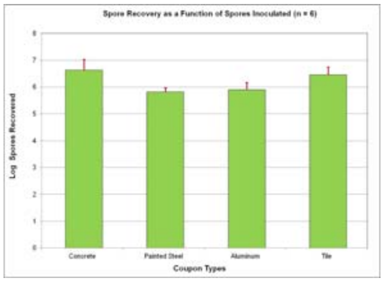
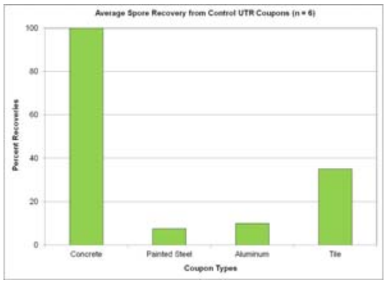
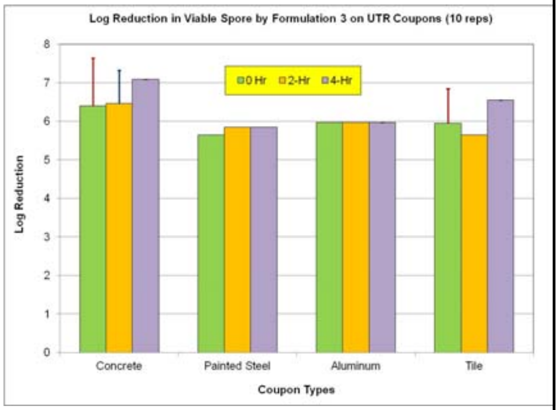
# Efficacy – Formulation 3

U.S. ARMY RDECOM

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# Efficacy – Formulation 4

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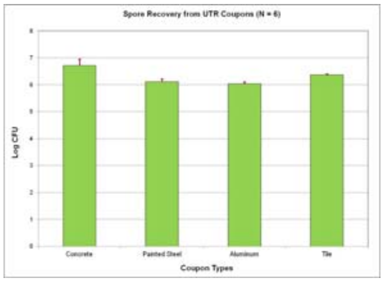


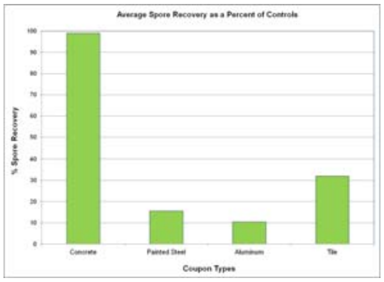


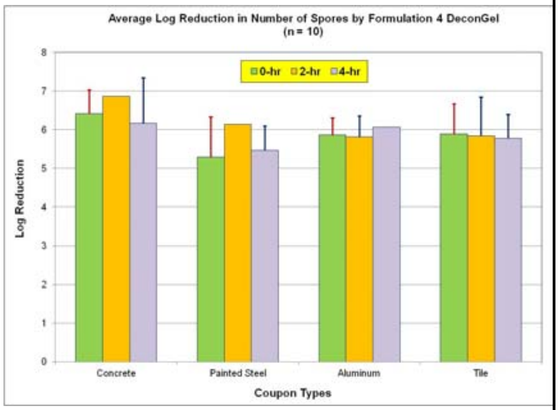


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# Bio-efficacy → Phase 2

U.S. ARMY RDECOM

- Phase I was the subject of this presentation
- Phase II has been also been completed, and the report is pending review
- In phase 2, sprayable version of the gel was used after formulation

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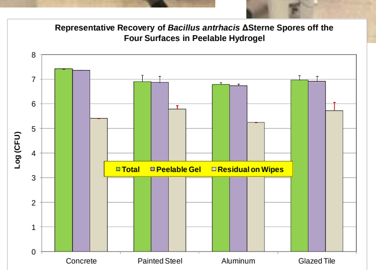
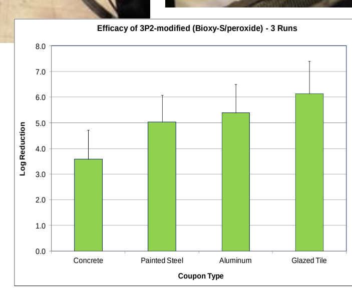
# Sprayable DeconGel

U.S. ARMY RDECOM

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## Bio-DeconGel™ → CW Decon?

### Where do we go from here?

- Formulations effective against BWAs completed
- Formulations effective against CW threats needs to be investigated
- Combine this technology with previously developed DeconGel technology effective in the decontamination of toxic chemicals and radioactive materials
- Overall Goal – To develop an advanced CBRN Decon Technology Demonstration for different scenarios, e.g., building interiors, sensitive equipments, and transport systems, including train cars and aircraft





## Conclusions

- Under the UTR program, four relevant surfaces selected, concrete, painted steel, aluminum, and glazed tile
- Spore recovery from painted steel and aluminum a challenge, since barely 6-log recovered, even though 7-logs inoculated
- Two Formulations out of four are very effective with sporicidal efficacy >6-logs
- Large chamber testing completed in Phase II of DHS contract

## CREDITS



- **Dr. Donald Bansleben, S&T PM, DHS**
  - Funding and Program Direction
- **Dr. Shannon Sere and Dr. Shawn Ryan, U.S. EPA's NHSRC**
  - For Test Plan Review
- **Ms. Lisa Smith, Michelle Ziemski, and LTC L Burton (ECBC)**
- **Dr. Markos Daskalakis (CBIP)**





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## (Back-up) Business Case

U.S. ARMY RDECOM

- Why Invest in a decontamination method that may not meet military specifications?
  - Demonstrated and effective C/B/R DeconGel gives the military a valid second source option should GPD or JSEW not prove adequate in operational use
  - The unique capabilities of the proposed technology enable it to work with current decontamination methods as a force multiplier effect
  - The inherent capabilities of DeconGel to encapsulate radiological isotopes and TICs and TIMs gives the military a commercialized capability that does not require POM support
  - Commercialized C/BW capability also does not require POM support unless the military decides to stockpile the capability
  - The technology gives the military an additional viable option for urban centers of gravity decontamination (ops centers, transportation hubs, communication nodes)
  - The friendly nature of the product gives the military a viable option to train with the same technology they would use in urban settings

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Homeland Security
Science and Technology

# *New Advanced Oxidant Generation Method for Large Area Biological Decontamination*

Brian France, Ph.D.

2015 EPA International Decontamination Research and Development Conference
May 5, 2015

TDA Research

# Outline

- Regulatory requirements
- Traditional aqueous oxidants
- New method to generate chlorine dioxide
- Applications
- Performance
- Summary
- Acknowledgements

TDA Research

## Regulatory Requirements

- Products with antimicrobial claims are regulated by the EPA under FIFRA
  - – Microorganisms (including anthrax)
- Efficacy is verified
- Toxicity and environmental impact are evaluated
- EPA pesticide registration notice 2008-2 restricts sales of anthrax related products to military, FOSC and their trained contractors

TDA Research

## Traditional Aqueous Oxidants

- Bleach
  - – pH adjusted bleach
- Hydrogen peroxide
- Peracetic acid solutions
- Chlorine dioxide
  - chemically or electrochemically generated
  - $ClO_2$ has known advantages in efficacy, but its use has been limited by the requirement for on-site generation

TDA Research

## Features Desired for Aqueous Oxidants

- Long storage life at ambient temperature
  - A particular challenge with bleach and peroxide
- Easy shipping/transportation
- Conveniently applied with standard equipment
  - Easy to control the concentration
- Materials compatibility
- Safe for operators
  - Personal Protective Equipment
  - No respiratory protection needed

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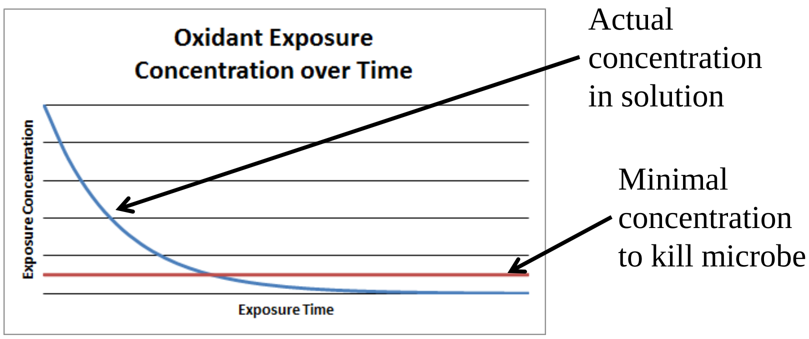
## Sustained Oxidant Concentration

- For safety and materials compatibility, a decon solution should produce the minimal effective concentration and sustain it as long as possible.
- Unfortunately, current products produce an initial high concentration of oxidants that rapidly decreases

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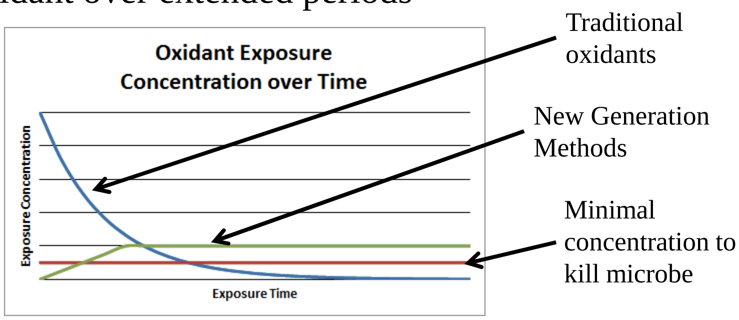
# New Oxidant Generation Method

- Invented by Procter & Gamble
  - P&G continues to develop for consumer markets
  - TDA is developing the chemistry for other applications
- New method sustains a low but effective level of oxidant over extended periods

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# New Oxidant Generation Method

- Improved storage life and ease of shipping
  - Store and transport a powder solid, not a reactive solution
- Easy to apply with standard commercial sprayers
  - Oxidant concentration species fixed by formulation
- Improved materials compatibility due to low concentration
- Safe for operators – no respiratory protection needed

TDA Research

# New Oxidant Generation Method

- Chlorine dioxide is photochemically generated from chlorite ion in aqueous solution
  - Photoactivator absorbs light, removes electron from chlorite to produce $ClO_2$
  - Multiple photoactivators are available
    - Including materials that are food grade, GRAS list
- Chlorine dioxide kills microbes and is reduced back to chlorite
  - Can be catalytically cycled
  - Works using visible light
- Biodegradable surfactants help wet surfaces, improve contact with oxidizing solution

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# Technology Details

- Two packets are dissolved in water on-site
  - Packet A: Sodium chlorite
  - Packet B: Photoactivator and surfactant
- Use outdoors, or indoors with standard light sources
- As long as the ingredients are wet they will continue to work
- Ingredients may be viable after rewetting, days or weeks later
- Logistics
  - Low cost, competitive with bleach
  - ~2 grams of consumable per liter of decontaminant

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# Consumer Applications

- The safety, ease of use, and low cost make this product a good consumer product
- Its use for consumer applications has been demonstrated

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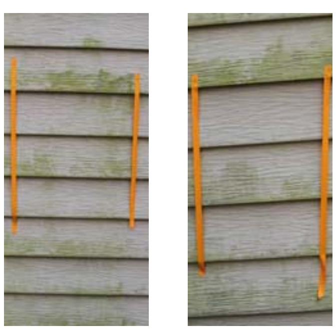
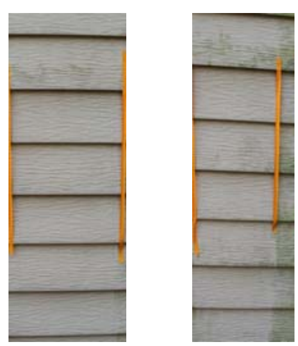
# Aluminum Siding

Before



After 24 hours



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# Wooden Deck

Before

After 24 hours

TDA Research

# Brick Under Deck

Initial

96 hour follow-up

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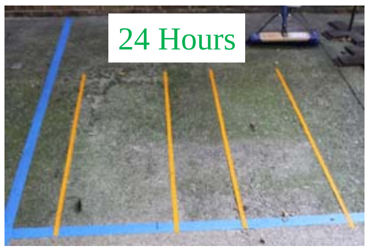
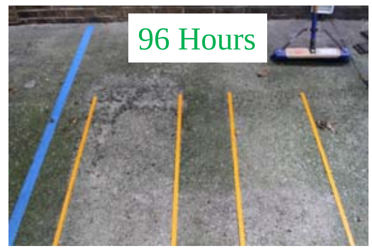
# Concrete Patio

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# Extended Benefit

After 9 months

Treated with photo-$ClO_2$

Treated with bleach

Initially both sides looked equivalent, however the one exposed to photo-$ClO_2$ had extended benefit.

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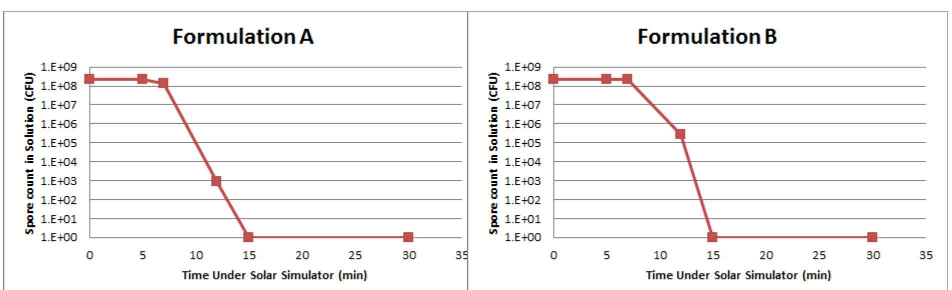
# National Security

- Demonstrated antimicrobial performance on relevant surfaces
- TDA tested efficacy against anthrax surrogates

TDA
Research

# Photo-$ClO_2$ Sporicidal Efficacy

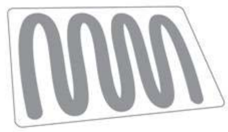
- Multiple formulations showed **8 log kill within ~15 min**
  - *B. subtilis* – commercially available spore prep
    - a surrogate for Anthrax
  - In solution




Research

# Surface Decontamination Efficacy

- **Goal:** Demonstrate ability to decon spore contaminated surfaces
- **Challenge**: $10^6$ *B. thuringiensis* CFU
- **Substrates**: Glass, plastic, painted drywall and soil (Arizona Test Dust)
- **Procedures**: Contaminate substrate and allow spore suspension to dry, decontaminate, use CDC spore sampling procedures to sample substrate for remaining viable spores. Plate and count to determine spore reduction



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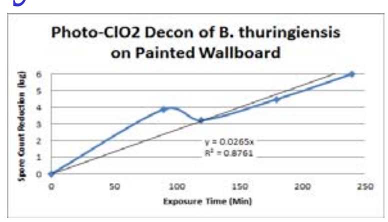
# Surface Decontamination Efficacy

| Substrate | Time | Efficacy |
|---|---|---|
| Glass | 60 min | sterilization, 6 log reduction |
| CPVC Plastic | 60 min | sterilization, 6 log reduction |
| Painted Wallboard | 240 min | sterilization, 6 log reduction |
| Soil 250mg/ml | 45 min | sterilization, 6 log reduction |
| Soil 500mg/ml | 60 min | 3.7 log reduction |




- Efficacy testing at reduced chlorite concentrations
  - Varied chlorite concentration over two orders of magnitude
- As chlorite concentration decreases, time to kill increases
- Tests confirm that the photo-$ClO_2$ solution remains active for hours (must remain wet, activity can continue if dried and rewetted)
- Lower chlorite concentration increases materials compatibility, lowers cost and improves logistics

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## Chemical Decontamination Performance

- Chlorine Dioxide is known to neutralize CW agents VX and HD (mustard)
- In preliminary tests at TDA, the photo-$ClO_2$ system showed reactivity against CEPS,
  - CEPS is an HD simulant that is slower to oxidize than agent HD
    - (~4x slower than HD)

TDA Research

## Making a Viable National Security Bio-Decon Product

- EPA registration of a product with claims of efficacy against anthrax is required
  - A single-use product is not sustainable
- Photo-$ClO_2$ has consumer applications that will make the technology available when needed
- Consumer and national security products are being developed together

TDA Research

# Summary

- The U.S. requires the ability to respond to an attack with biological agents, including anthrax
- Tests at TDA have shown that the Photo-$ClO_2$ system is effective against spores on both indoor and outdoor surfaces
- Sustained generation of a low concentration of oxidant affords good efficacy, with improved storage life, shipping and handling, and operator safety

TDA Research


# Acknowledgements

- Collaborators at P&G
- DHS SBIR Phase I funding
  - Dr. Don Bansleben, DHS
  - Contract: HSHQDC-14-C-00049


TDA Research

# Decontamination of large spaces
# Scopes and limitation

**Marek Kuzma**

## Introduction

- **Institute of Microbiology of the ASCR, v. v. i.**

- - **Chemical, biological decontamination**
  - **Development of the equipment**

**Cooperation**

- **Army facilities - BSL4 workplace**
- **Institute of Virology, SAS Bratislava**
- **Private companies**

# Large area decontamination

**Impulses for large area decontamination development**

**Japan, Tokio** 1995 [1]
10x 900 ml Sarine
12 dead
50 severely injured
1000 people with temporary vision problems

**USA Washington D.C.,** 2001 Amerithrax [2]
5 dead, 17 infected
total damage exceeded $1 billion

**Large area definition**
indoor space with complex geometry and/or high strategic importance, high migration of people, high risk of terrorist attack or epidemic infection or industrial accident

buildings (government, post offices, hospitals, hotels)
industrial facilities, halls, depots
transport infrastructure (railway station, subway, airports)

1) http://en.wikipedia.org/wiki/Tokyo_subway_sarin_attack
2) http://en.wikipedia.org/wiki/2001_anthrax_attacks

# Large area decontamination

**Wet methods**
- **not full covered surface**
- **damage of the interior**
- **danger to staffs**
- **large, trained team**
- **cleaning of the dirt**

**Gaseous methods**
- **full treated surface by the diffusion**
- **low number of staffs**
- **minimal damage of the interior**
- **only surface action**
- **could be automated, reduced human factor**

**The main gas fumigants:**
- **Ethylen oxide - flammable**
- **Methyl bromide - ozone layer destroyer**
- **Formaldehyde**
- **Chlorine dioxide**
- **Hydrogen peroxide (VPHP)**

**the most useful for large areas**

## Ideal decontamination agent

**W.A. Rutala and D.J. Weber [3]**

**High efficiency and activity**
**Material compatibility**
**Non-toxicity**
**Odorless**
**Non-staining**
**Resistance to organic material**
**Monitoring capability**
**Environment-friendly use**
**Prolonged reuse life**
**Long shelf life**
**Unrestricted disposal**
**Cost-effectiveness**

3) Rutala W.A. and Weber D.J.; *Infect Control Hosp Epidemiol* **20**:69–76 (1999)

## Decontamination methods comparison

| | $ClO_2$ | VPHP | Formaldehyde |
|---|---|---|---|
| 1. OSHA 8 hr TWA (time weighted average) | 0.1 ppm | 1.0 ppm | 0.75 ppm |
| 2. Odor Detection | Yes | No | Yes |
| 3. Cycle Time (Risk of Exposure) | 3-4 hours | 4-7 hours | 9-15 hours |
| 4. Carcinogen | NO | NO* | YES |
| 5. Typical Concentrations | 1800 ppm | 1000 ppm | 8000-10000 ppm |
| 6. Penetration & Distribution | Yes (gas) | No (Vapor) | Yes (gas) |
| 7. Penetrate Water | Yes | No | Yes |
| Penetrate Oil | No | No | No |
| Penetrate Grease | No | No | No |
| 8. Emergency Aeration Time | 5-30 min | 1-6 hours | 1 hour + cleanup |
| 9. Residues | None | None | Yes |
| 10. NSF approvals | Yes | No | Yes |
| 11. U.S. EPA approvals | Yes | Yes | No |
| | | | |

* IARC, NTP, and OSHA do not list hydrogen peroxide as a carcinogen. ACGIH lists hydrogen peroxide as an A3 animal

4) Czarneski M. A., Lorcheim K.; *Applied Biosafety* **16**: 1, 2011

## Large area fumigations parameters

**Method operation parameters:**

- **Medium** - Toxicity
  - Decomposition products / residues
- **Device** - Mobility, Storage, Supply needs
- **Target area** - Preparedness, Material compatibility
- **Price**

**Method efficiency is determined by:**

- **Concentration in the target**
- **Physical conditions (temperature, humidity..)**

## Large area fumigations parameters

### Concentration in the target depend on:

- **Decomposition of fumigant**
- **Sorption of fumigant to the materials**
- **Penetration of fumigant through the materials**
- **Temperature profiles**
  - ➢ **condensation**
- **Dynamic process**
  - ➢ **proper distribution by mixing and diffusion**

## Scale up of Fumigation methods

**Methods for**
**Small simply defined space X Large complex space**

**Comparison of commercial solutions based on small defined areas applications [5,6]**

**Understanding the process:**
- basic laboratory research
- laboratory study of simulated conditions
- implementation to large applications

**Application of the large processes:**
- based on laboratory data
- complex proces in large scales
- direct scale up is not fully successful

5) EPA 600/R-11/052 (2011) www.epa.gov/ord
6) EPA/600/R-13/168 (2013) www.epa.gov/ord

## Fumigant target concentration

**Proper action = sufficient concentration**

**For $H_2O_2$ levels 800 ppm, the microbicidal activity of the VPHP is found to be independent from humidity.[7]**
**Issue of complicated geometry of decontaminated area/surfaces**
**Issue of diffusion into gaps and lumens (width < 4 mm, depth > 30 mm)[8]**
**according to the reported and our data - sterility failure in the lab due to poor distribution**

**For the better activity - potentiation of the fumigant**
- More active fumigant → low concentration is sufficient
- Lower concentration →lower corrosive properties

7) Unger-Bimczok, B., Kottke, V., Hertel C., Rauschnabel, J.; *J. Pharm. Innov.* **3**: 123-33 (2008)
8) Unger-Bimczok, B., Kosian, T., Kottke, V., Hertel C., Rauschnabel, J.; *J. Pharm. Innov.* accepted to print (2011)

## Sporicidal activity potentiation by VPHP

**Several additives to improve sporicidal effect of the fumigant was laboratory tested**

**Number of killed test spots of *Bacillus Stearothermophylus* without barrier dependent on used decontaminant (pure additive or mixture with VPHP) and time of exposition**

**One test spot = 1 x $10^6$ spores**

| Time of | Decontaminant | | | | |
|---|---|---|---|---|---|
| exposition [min] | VPHP | ADD 1 | ADD 2 | MIX 1 | MIX 2 |
| 5 | | | | (1/3) | (0/3) |
| 10 | | | | (3/3) | (0/3) |
| 15 | (0/3) | (0/3) | (0/3) | (2/3) | (1/3) |
| 20 | | | | (3/3) | (0/3) |
| 25 | | | | (3/3) | (0/3) |
| 30 | (1/3) | (2/3) | (0/3) | (3/3) | (0/3) |
| 35 | | | | (3/3) | (2/3) |
| 40 | | | | (3/3) | (1/3) |
| 45 | (2/3) | (3/3) | (0/3) | (3/3) | (2/3) |
| 50 | | | | (3/3) | (2/3) |
| 55 | | | | (3/3) | (3/3) |
| 60 | (1/3) | (3/3) | (0/3) | (3/3) | (3/3) |
| 75 | (3/3) | (3/3) | (0/3) | (3/3) | (3/3) |
| 180 | (3/3) | (3/3) | (0/3) | (3/3) | (3/3) |

## Success / fail evaluation

**Result of bio decontamination process generally evaluated by biological coupons/bioindicators**

**No clean surfaces occurs in large areas**

**Main influence - penetration of the fumigant through diffusion barriers (soil, blood, grease, etc.)**

**Sterile biological coupon yet doesn't mean sterile area.**

**Reproducibility and reliability of biological coupons**

- **Observed errors, reported errors of sterility evaluation by biological coupons[9]**
- **Complex process: spores, used materials, used medium, preparation, cultivation**

**Main influence - penetration of the fumigant through diffusion barriers (Spores are covered by a pouch and dry medium)**

**Developed „penetration sterility test“**

- **Simulate the organic dirt and transport barrier**

9) Sandle, T., *Journal of Validation Compliance*, **20**: 1, (2014)

## Penetration tests

Number of killed test spots of *Bacillus Stearothermophylus* dependent on used decontaminant, penetration depth and time of exposition  One test spot = $1 \times 10^6$ spores

| Decontaminant | penetration depth | time of exposition [h] | | | |
|---|---|---|---|---|---|
| | | 4 | 8 | 12 | 16 |
| VPHP | 1st layer, 0.135 mm | (5/5) | (5/5) | (5/5) | (5/5) |
| | 2nd layer, 0.270 mm | (0/5) | (5/5) | (5/5) | (5/5) |
| | 3rd layer, 0.405 mm | (0/5) | (0/5) | (5/5) | (5/5) |
| | 4th layer, 0.540 mm | (0/5) | (0/5) | (0/5) | (5/5) |
| MIX 1 | 1st layer, 0.135 mm | (5/5) | (5/5) | (5/5) | (5/5) |
| | 2nd layer, 0.270 mm | (5/5) | (5/5) | (5/5) | (5/5) |
| | 3rd layer, 0.405 mm | (0/5) | (5/5) | (5/5) | (5/5) |
| | 4th layer, 0.540 mm | (0/5) | (0/5) | (5/5) | (5/5) |
| | 5th layer, 0.675 mm | (0/5) | (0/5) | (0/5) | (5/5) |
| | 6th layer, 0.810 mm | (0/5) | (0/5) | (0/5) | (3/5) |
| MIX 2 | 1st layer, 0.135 mm | (5/5) | (5/5) | (5/5) | (5/5) |
| | 2nd layer, 0.270 mm | (1/5) | (5/5) | (5/5) | (5/5) |
| | 3rd layer, 0.405 mm | (0/5) | (2/5) | (5/5) | (5/5) |
| | 4th layer, 0.540 mm | (0/5) | (0/5) | (1/5) | (5/5) |
| | 5th layer, 0.675 mm | (0/5) | (0/5) | (0/5) | (5/5) |

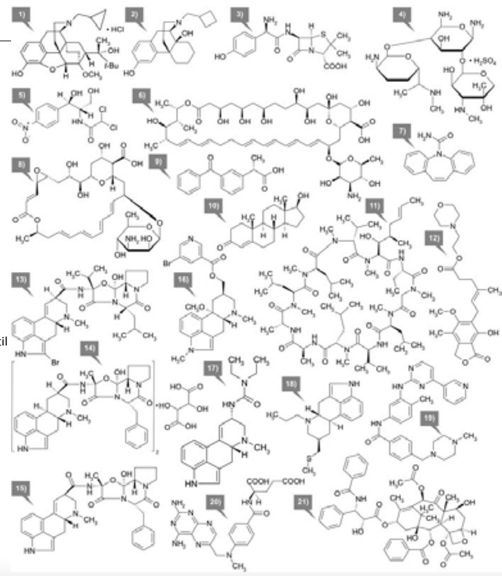
## Fumigation methods-potential for chemical decontamination

- **Challenge – To develop a universal chemical/bio decontamination method**
- **The high redox potential[10] of $H_2O_2$ 1.8V give to VPHP ability to be used for chemical decontamination**
- **Potentiation of the process by amines, UV-C**
- **Tested on active pharmaceuticals and organophosphates**

10) http://en.wikipedia.org/wiki/Hydrogen_peroxide

# Degradation of pharmaceutical substances[11]

| No. | Pharmaceutical substance |
|---|---|
| 1 | Buprenorphine |
| 2 | Butorphanol |
| 3 | Amoxicillin |
| 4 | Gentamicin sulfate |
| 5 | Chloramphenicol |
| 6 | Nystatin |
| 7 | Carbamazepine |
| 8 | Pimaricin (Natamycin) |
| 9 | Ketoprofen |
| 10 | Testosterone |
| 11 | Cyclosporine |
| 12 | Mycophenolate mofetil |
| 13 | Bromocriptine |
| 14 | Dihydroergotamine |
| 15 | Ergotamine |
| 16 | Nicergoline |
| 17 | Lisuride |
| 18 | Pergolide |
| 19 | Imatinib |
| 20 | Methotrexate |
| 21 | Paclitaxel |



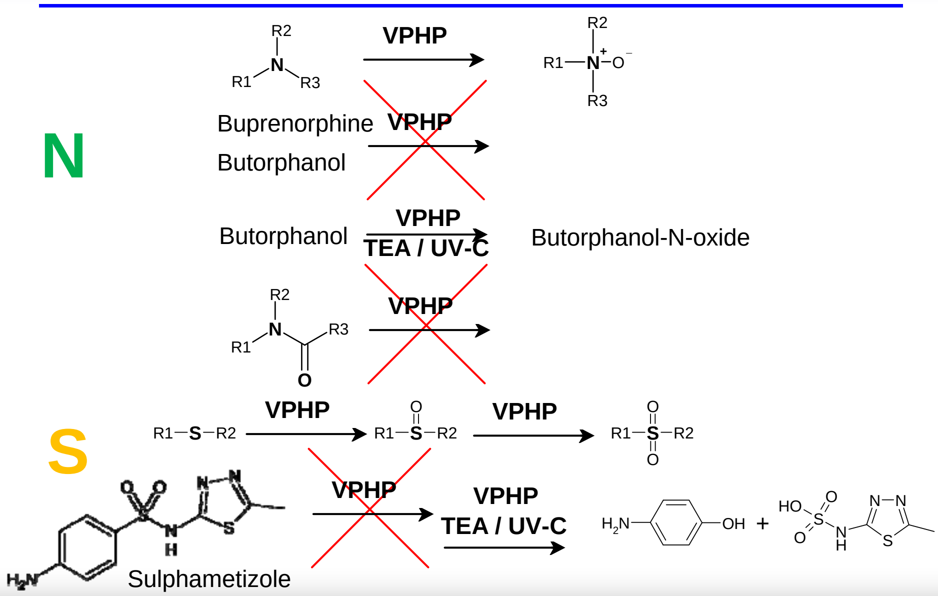
Summary of the results:

**Degradation by VPHP**

| YES | NO |
|---|---|
| 3 | 1 |
| 14 | 2 |
| 15 | 4 |
| 16 | 5 |
| 17 | 6 |
| 18 | 7 |
| 19 | 8 |
| 20 | 9 |
| | 10 |
| | 11 |
| | 12 |
| | 13 |
| | 21 |

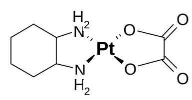
11] Svrcek, Jiri; Syslova, Kamila; Stibal, David; Kuzma, Marek; Kacer, Peter, Degradation of biologically active substances by vapor-phase hydrogen peroxide, RESEARCH ON CHEMICAL INTERMEDIATES, 40(2), 619 – 626 (2014).

# Susceptible function groups



# Susceptible function groups

**C=C**

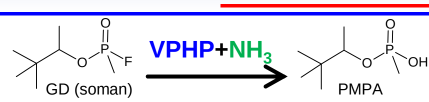



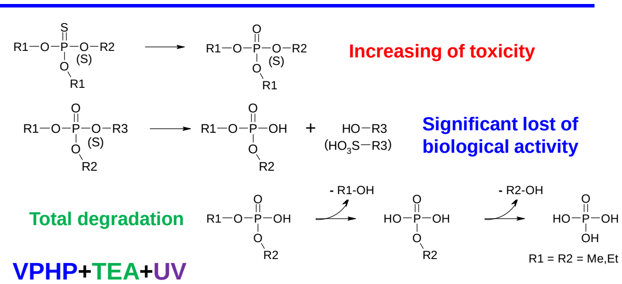

**VPHP** → Pt aqua and hydroxo-complexes

**40** substances —**VPHP**→ **15** intact —**VPHP / TEA / UV-C**→ **6** intact

# Decontamination of organophosphate pesticides

**G. W. Wagner & al. [12]**
**Potentiation of VPHP by $NH_3$**
**for GD warfare agent decontamination**

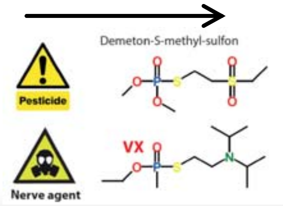



Tested pesticides:

- **Parathion**
- **Pirimiphos-methyl**
- **Chlorpyrifos**
- **Dimethoate**
- **Demeton-S-methyl-sulfon**
- **Famphur**
- **Malathion**

**VPHP+TEA+UV** → **Decomposition products**




**Total disappearance**
**all tested pesticide substrates**
**and toxic oxone intermediates**

12) Wagner G.W.,* Sorrick D.C., Procell L.R., Brickhouse M.D., Mcvey I.F., Schwartz L.I.;*Langmuir* **23**, 1178-1186 (2007)

## Conclusions

**Decontamination of large areas is multiparametric complex process where simple decon routine:
"Push the button and do not care" couldn't exist.**

**Success/fail limitation factor – sufficient concentration in the target area.**

**Improvement of fumigant activity increase the probability of successful decontamination.**

**Reliability of bio-indicator coupon is still issue.**

## Conclusions

**VPHP seems to be the most promising decontamination method for large scale areas applications.**

**VPHP have a potential capability for universal bio and chemical decontamination.**

**Potentiation of VPHP by chemical additives, UV or photocatalysts could be solution of transport and chemodecontamination issues.**

**Monitoring of fumigant concentration in target area seems to be helpful.**

**Unification and control production of bioindicator could increase the explanatory power of cultivation test results.**

## Acknowledgment

**Jaroslav Červený**
**Dušan Pavlík**
**Petr Kačer**
**David Kačer**
**Jiří Švrček**
**Libor Pánek**

# Thank you for your attention

## Methyl Bromide Decontamination of Indoor and Outdoor Materials Contaminated with *Bacillus anthracis* Spores

*Morgan Wendling (Battelle), Joseph Wood (US EPA)*

*May 5, 2015*

Presented at US EPA Decontamination Conference, US EPA Research Triangle Park Campus, NC

1

# Acknowledgements

**Battelle**

- **William Richter**
- **Andrew Lastivka**
- **Young Choi**
- **James Rogers**
- **Zack Willenberg**

**EPA**

- **Leroy Mickelsen**
- **Richard Rupert**

2

## Objective

- To determine the decontamination efficacy ($log_{10}$ reduction, or LR) of methyl bromide (MeBr) fumigant to inactivate *Bacillus anthracis* Ames at relatively lower RH levels and/or temperatures, making MeBr fumigation easier to implement

- Comparison of MeBr results with other spore-forming microorganisms to assess their potential as representative surrogates for *B.a.* Ames

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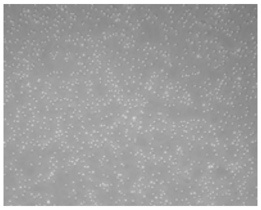
## Microorganisms

- Virulent Strain:
  - *B.a.* Ames (Battelle Lot B21)
- Avirulent Strains:
  - *Geobacillus stearothermophilus* (*G.s.*) (ATCC 12980)
  - *B.a.* NNR1Δ1 (Edgewood Chemical and Biological Center)
  - *B.a.* Sterne 34f2 (Colorado Serum Company)



- All strains diluted to ~1 x $10^9$ CFU/mL

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## Materials

| Material |
|---|
| Ceiling Tile |
| Carpet |
| Glass |
| Painted Wallboard Paper |
| Bare Pine Wood |
| Unpainted Concrete |

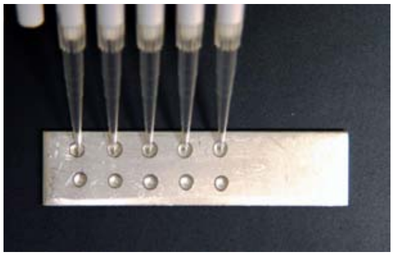
All coupons 1.9 cm by 7.5 cm





## Inoculation of spores

- Inoculation of Coupons
  - 100 µL volume (~1 x $10^8$ CFU) on each material
  - Contained inside BSC III
  - Dried overnight at ambient conditions prior to initiation of decontamination cycle



# Materials and Methods


- Methyl Bromide
  - Chemtura, Philadelphia, PA
    (EPA Reg. No. 5785-11)
  - Colorless, odorless Gas
  - 0.5% chloropicrin added as a warning irritant (lacrimator)
  - 100% phase out except for allowable exemptions (soil and quarantine fumigant) in 2005
  - Still roughly 7 millions pounds used each year

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# Materials and Methods

Methyl Bromide Monitoring

- MeBr concentration was measured continuously during the contact period using a Fumiscope™ (Key Chemical and Equipment Company)
- MeBr concentration maintained within 10% of target through automated control system


MeBr Fumiscope

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# Materials and Methods

Methyl Bromide Testing Chamber

9 Business Sensitive

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# Materials and Methods

Methyl Bromide Testing Chamber

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# Materials and Methods

DECONTAMINATION

- Decontamination run started when chamber equilibrated to desired temperature and RH
- MeBr slowly injected until target concentration was reached
- Chamber remained sealed until end of contact time
- MeBr turned off, seal of the chamber broken by removing lid
- Test chamber and glove box allowed to off-gas until the MeBr levels in the chamber reached 0 mg/L

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# Materials and Methods

SAMPLE PROCESSING

→ Extract for 15 min
0.1% Triton X-100 in PBS
Orbital Shaker @ 200 rpm

→ Dilution Plating

↓

Enumeration

12

# MeBr Test Matrix

| Materials | Microorganisms | MeBr Concentration (mg/L) | Temperature (°C) | RH (%) | Contact Time (hours) |
|---|---|---|---|---|---|
| Glass<br>Ceiling Tile<br>Carpet<br>Painted Wallboard<br>Paper<br>Bare Pine Wood<br>Unpainted Concrete | *B. anthracis* Ames<br>*G. stearothermophilus*<br>*B. anthracis* NNR1Δ1<br>*B. anthracis* Sterne | 212<br>300 | 22<br>27<br>32 | 45<br>75 | 18<br>24<br>36<br>48<br>72 |



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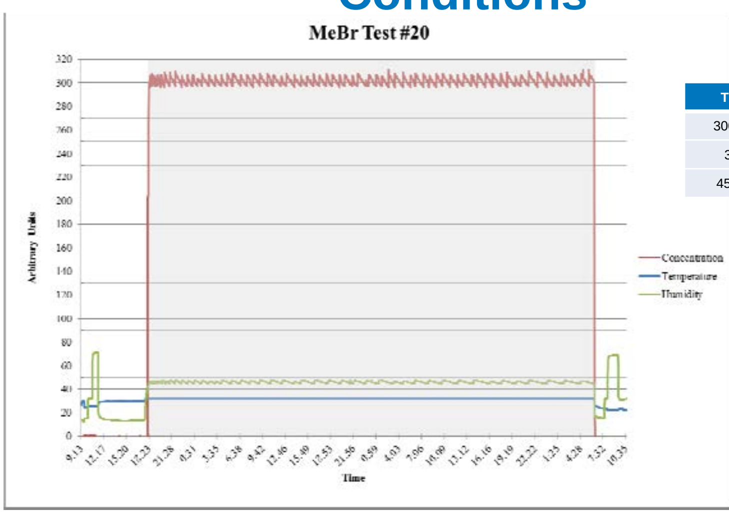
# Results – Typical Fumigation Conditions




| Target | Actual (average) |
|---|---|
| 300 mg/L | 301.53 mg/L |
| 32 °C | 32.14 °C |
| 45% RH | 45.87% |



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# Results – Effect of Materials

| Material Type | Average LR Ames strain for Tests 1-8 | Material Type | Average LR for Tests 9-20 |
|---|---|---|---|
| Glass | 3.96 | Glass | 4.56 |
| Ceiling Tile | 5.11 | Ceiling Tile | 5.69 |
| Carpet | 6.00 | Carpet | 6.04 |
| Painted Wallboard Paper | 6.87 | -- | -- |
| Bare Pine Wood | 3.89 | Bare Pine Wood | 4.02 |
| Unpainted Concrete | 6.52 | -- | -- |

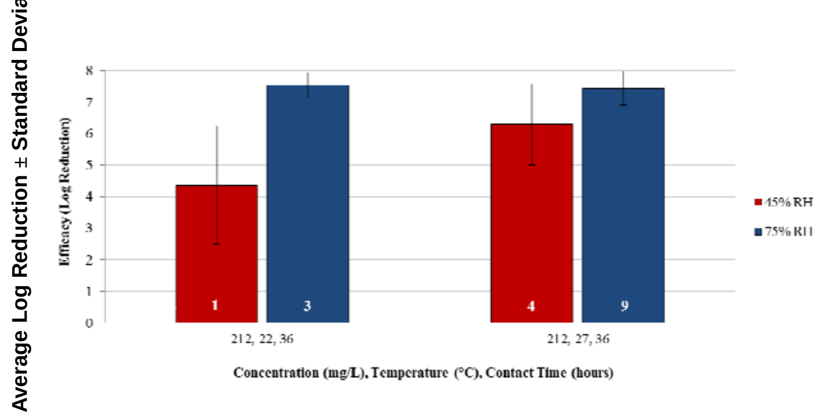




# Results – Effect of Microorganism

- ***G.s.*** **was less resistant than *B.a.* Ames**
- ***B.a.*** **NNR1∆1 was more resistant than *B.a.* Ames in all tests, but in some cases *too* resistant (greater than 6 LR difference)**
- ***B.a.*** **Sterne was less resistant than *B.a.* Ames at 45% RH**
- ***B.a.*** **Sterne was more resistant than *B.a.* Ames at 75% RH**

# Results – Effect of RH




- Efficacy of MeBr increased with increasing RH
- No tests conducted at 45% RH resulted in >6 LR for all materials tested

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# Contact time needed for *B.a.* Ames

| MeBr Concentration (mg/L) | Temperature (° C) | RH (%) | Hours Required to Achieve >6 LR on All Materials |
|---|---|---|---|
| 212 | 22 | 45 | > 60 |
| 212 | 22 | 75 | 36 |
| 212 | 27 | 45 | > 48 |
| 212 | 27 | 75 | 36 |
| 212 | 32 | 45 | > 72 |
| 212 | 32 | 75 | 24 |
| 300 | 22 | 45 | > 60 |
| 300 | 22 | 75 | 24 |
| 300 | 27 | 45 | > 60 |
| 300 | 27 | 75 | 18 |
| 300 | 32 | 45 | > 60 |

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## Primary Findings

- *B.a.* (Sterne) seems to be a reasonable surrogate with testing at 75% RH
- No MeBr fumigation was successful at the 6 LR level at 45% RH, even after testing up to 72 hours contact time
- Required contact time for successful decontamination ranged from 18-36 hours, depending on concentration, temperature, and RH
- Glass and wood most difficult materials to decontaminate

# 2015 U.S. EPA International Decontamination Research and Development Conference

## Tuesday, May 5, 2015

## Concurrent Sessions 1

### Radiological Agent Response and Recovery





# DHS S&T's RNRR Portfolio

Providing First Responders with Scientifically Based Tools, Easy-to-Understand Protocols and Actionable Guidance for Radiological/Nuclear Response and Recovery

Homeland Security
Science and Technology

**Benjamin Stevenson**

Project Manager
National Urban Security Technology Laboratory (NUSTL) – New York, NY
Rad/Nuc Response & Recovery (RNRR)
DHS Science and Technology Directorate

# DHS Rad/Nuc Support to State/Locals

**DNDO** provides technical support and equipment for detection and interdiction capabilities

**FEMA** provides technical support for preparedness and planning

**S&T** provides technology and scientific guidance **in advance** so state and locals can initiate response in first 72 hours

**FEMA** initiates support to state and locals

**FEMA** coordinates an integrated federal response

DOE, EPA and other agencies provide technical support and assets

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Identifying First Responder Needs
National Preparedness Goal
National Response Framework
Planning Guidance for Response to a Nuclear Detonation
1
2
3
4
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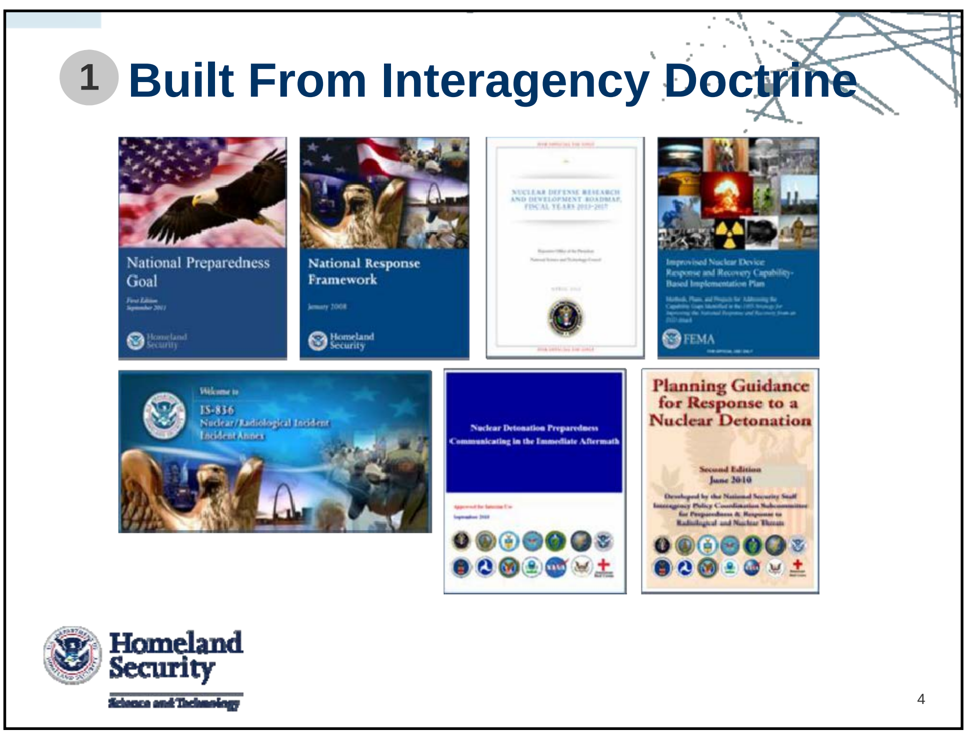
1
Built From Interagency Doctrine
National Preparedness Goal
First Edition
September 2011
Homeland Security
National Response Framework
January 2008
Homeland Security
NUCLEAR DEFENSE RESEARCH AND DEVELOPMENT ROADMAP, FISCAL YEARS 2013-2017
Improvised Nuclear Device Response and Recovery Capability-Based Implementation Plan
FEMA
Welcome to
IS-836
Nuclear/Radiological Incident
Incident Annex
Nuclear Detonation Preparedness
Communicating in the Immediate Aftermath
Planning Guidance for Response to a Nuclear Detonation
Second Edition
June 2010
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# 2 RNRR Capability Domains

These capability domains represent broad operational categories of emergency response and denote areas where similar needs are consistently identified:

| | |
|---|---|
| **Manage the response** | Capability to rapidly establish situational awareness of scope of RN incident, establish communications and control measures and coordinate the number of response assets available |
| **Characterize the incident** | Capability to make rapid protective and response action recommendations based upon most up-to-date model projections, measured data and protective action guidance |
| **Initial response** | Capability to identify protective actions; make entry, extraction, decontamination and incident stabilization decisions |
| **Medical triage & initial care** | Ability to predict immediate health effects, estimate priority of patient treatment needs and appropriate treatment locations, determine required assets and provide mass care |
| **Post-incident casualty & evacuee care** | Ability to perform long-term population medical and psychological monitoring, medical care and mass fatality management |
| **Stabilization & control of the impacted area** | Capability to mitigate additional incident-related consequences in affected areas to support response operations |
| **Site cleanup & recovery & restoration of essential functions** | Capability to control contaminant migration, perform wide–area decontamination of incident sites, conduct long-term environmental monitoring and manage population displacement |

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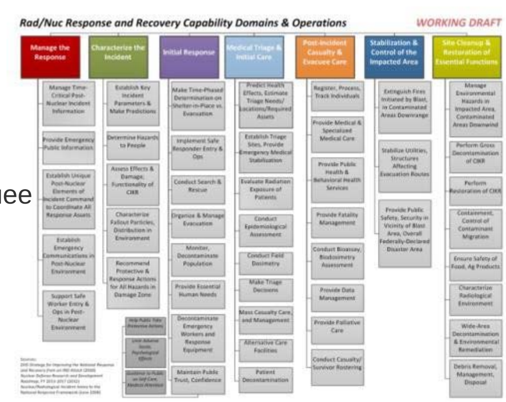
# RNRR Capability Requirements

- Manage the response
- Characterize the incident
- Initial response
- Medical triage & initial care
- Post-incident casualty & evacuee care
- Stabilization & control of the impacted area
- Site cleanup & restoration of essential functions

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# 3 Discussion with Responders

- **27 emergency responders** and receivers participated in **4 focus group sessions**
- **25 SMEs** participated in the **3 technology focus groups**

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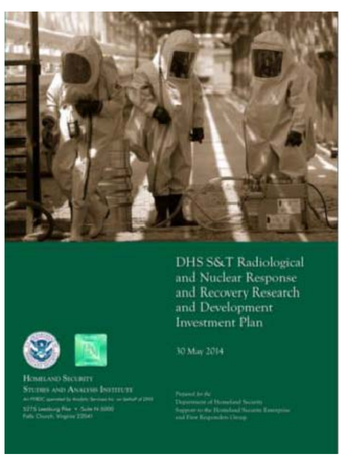
# 4 DHS S&T RNRR Investment Plan




DHS S&T RNRR R&D Investment Plan for FYs 15-19 includes analyzed data from stakeholder feedback that was synthesized into Response Technology Objectives (RTO) for DHS investment

31 RTOs were identified that correspond to capability needs

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## Responder Capability Priorities

1. **Manage the Response:** ability to make immediate command and management decisions with limited information
2. **Manage the Response:** ability to communicate with government entities, responders and public, both verbally and digitally, during and after RN event
3. **Initial Response**: ability to rapidly advise public about specific and time-sensitive protective and response actions following RN event
4. **Characterize the Incident:** ability to identify direction and speed of radioactive particles in environment and project fallout contamination

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## RNRR R&D Investment Plan: Priority Responder Technology Objectives

- Contaminant Migration Modeling and Prediction
- Improved Identification and Characterization of Multiple Hazards
- Disaster Resistant Communications Systems
- Post-incident Multi-Modal Information Dissemination
- Translation of RN-specific Technical Data
- Protective Action Decision Support

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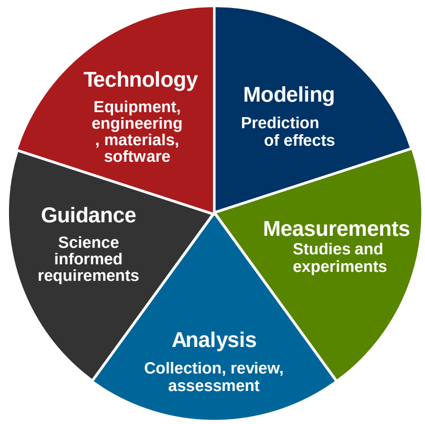
## R&D Products to Improve Capability

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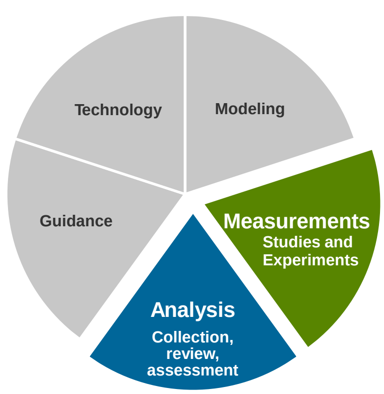
## Actionable R&D Products – Analysis and Measurements




When initiating studies, experiments and reviews:

- Answer specific research questions identified by responders/end-users to tie research to requirements of an operational problem set
- Assess scientific and/or social landscape to provide recommendations or evaluations that can lead to new technology and other products

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# Actionable R&D Products - Guidance


When providing guidance:

- Understand how end users intend to use before developing
- Offer guidance that can be operationalized
- Provide checklists, job aides, quick sheets and other tangible "pocket" products for end users to leverage easily in preparedness and in real-time
- Develop trainings and other learning opportunities to ensure guidance is understood appropriately

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# RNRR Capability Domains

These capability domains represent broad operational categories of emergency response and denote areas where similar needs are consistently identified:

| | |
|---|---|
| Manage the response | Capability to rapidly establish situational awareness of scope of RN incident, establish communications and control measures and coordinate the number of response assets available |
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| Site cleanup & recovery & restoration of essential functions | Capability to control contaminant migration, perform wide–area decontamination of incident sites, conduct long-term environmental monitoring and manage population displacement |

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## RNRR Investment Plan:

*Responder Capability Needs for Decontamination and Site Cleanup*

- Ability to contain contaminants after RN event, including controlling contaminant migration
- Ability to manage wastewater generated by decontamination activities
- Ability to manage RN contaminated waste to reduce public's exposure
- Ability to measure and manage environmental hazards in immediate blast area and other contaminated areas

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## DHS S&T FRG and EPA Partnership

Early Phase Radiological Decontamination Electronic Application

| Containment of Contamination | Gross Mitigation of Hazard | Initial Waste Management |
|---|---|---|

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# *Radiological Contaminant Stabilization Technologies*

U.S. EPA Decon Conference
May 5th – 7th 2015

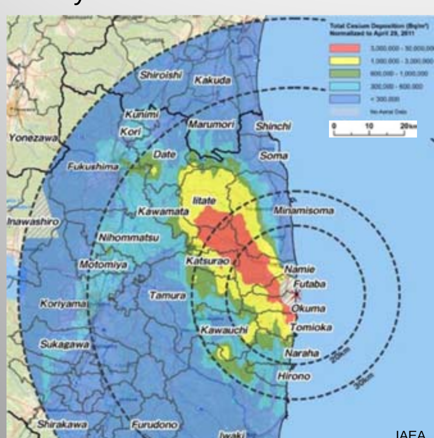
Mark Sutton,
Dianne Gates-Anderson,
Kip Harward,
Sang Don Lee (EPA/ORD/NHSRC)

Lawrence Livermore National Laboratory

This work was performed under the auspices of the U.S. Department of Energy by Lawrence Livermore National Laboratory under Contract DE-AC52-07NA27344. Lawrence Livermore National Security, LLC
LLNL-PRES-669835

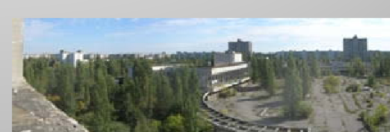
## Problem

After an intentional radiological release or nuclear power plant accident, contamination is likely to spread across a large urban area with complex variety of surfaces.



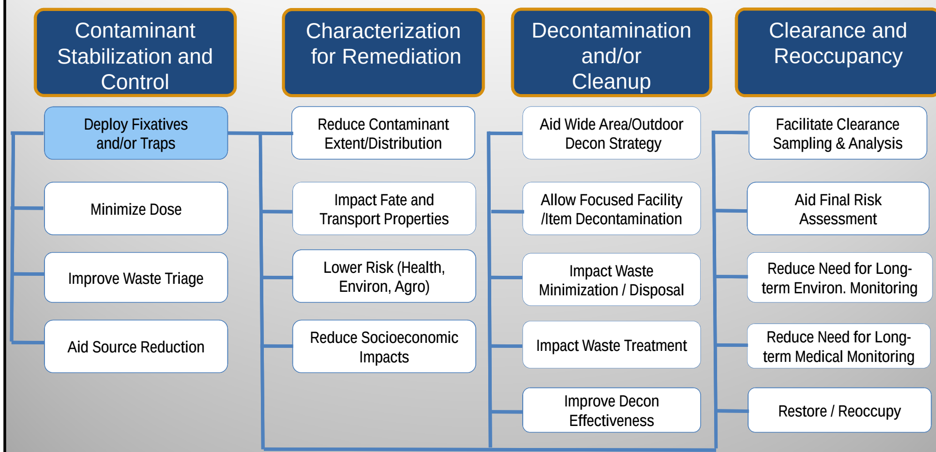

IAEA

http://www.cnn.com/2012/12/23/world/asia/eco-japan-fukushima-village-cleanup/



http://en.wikipedia.org/wiki/Pripyat

## Containment and Stabilization Can Impact All Phases of an Incident

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## Radiological Containment and Stabilization

Readily available stabilization materials can keep particulate contamination in place prior to decon, allowing additional time for decision makers.

Approaches and materials exist for other applications and may work for rad incidents, too.

Lawrence Livermore National Laboratory LLNL-PRES-669835 4

## Radiological Containment and Stabilization

### Approach

- Literature search on potential containment technologies
- Stakeholder input/ranking of technologies
- Identify technology gaps
- Perform research to address gaps



## Radiological Containment and Stabilization

### Technology Requirements

- Suppression of particle resuspension and reduction in the spread of contamination
- Reduction in dose to responders and public
- Minimization of waste consequences
- Stability over time
- Compatibility with the ultimate decontamination process
- **Available in a reasonable quantities and time-frame to responders**

## Radiological Containment and Stabilization

Technologies were grouped into 3 tiers

IMMEDIATE


LOCAL

City Public Works

SPECIALIZED (PROVEN)



Deployment time →

← Availability



## Radiological Containment and Stabilization

Literature Search

Product info, cost, deployment guidance, pros, cons

- Tier 1: Fire-Fighting Materials
  - e.g., water, wet/dry foams, fire extinguishers, fire retardant
- Tier 2: Locally Available Materials
  - e.g., soil/dust suppression, road stabilization, clay, paint, road oil, lignin
- Tier 3: Rad-Specific Materials
  - e.g., acrylic, epoxy, foam, gel, polymer, oxide cakes

↓

Stakeholder Input & Ranking

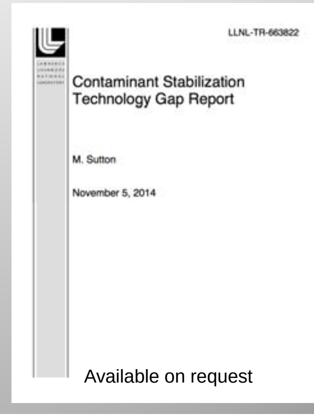
## Radiological Containment and Stabilization

### Identify Technology Gaps

Missing information on the efficacy, application, stability and waste considerations for non-traditional stabilization materials.

Prioritize gaps

Propose experimental research and demonstration to address gaps.


LLNL-TR-663822

Contaminant Stabilization Technology Gap Report

M. Sutton

November 5, 2014

Available on request



## Radiological Containment and Stabilization

### Addressing Technology Gaps

- Laboratory studies
  - Stabilization
  - Dose attenuation
- Field studies
  - Outdoor application and testing
- Demonstration
  - Battelle June 23rd - 24th 2015


http://en.wikipedia.org/wiki/Fire_retardant

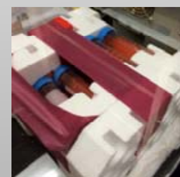
http://ddemulsionsinc.com/dust-bond-dust-control/100_1558/

# Radiological Containment and Stabilization

## Laboratory Studies

- Handling and drying
  - Effects of curing

- Stabilization
  - Sorption of Cs-137 to high viscosity fire retardants
  - Binding and solubility of Cs-137 on contaminated materials using chloride salt deposits and dust wetting agents

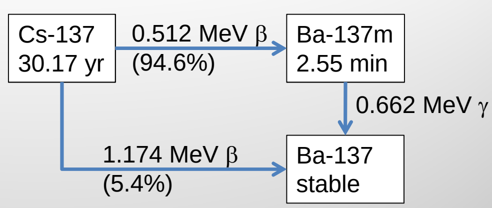


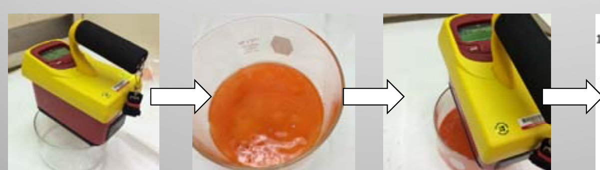


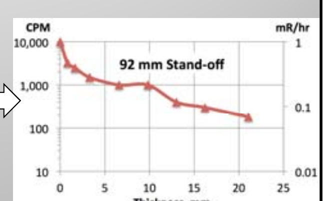
# Radiological Containment and Stabilization

## Laboratory Studies

- Dose Attenuation
  - Effect of layer thickness, powder : water ratio and drying of fire retardant on observed activity and dose from Cs-137





# Radiological Containment and Stabilization

## Outdoor Field Studies

- Time-phased evaluation of fire retardant, chloride salts and dust wetting agents
- Effectiveness for reducing particulate resuspension by natural weathering and traffic (foot and vehicular)
- Evaluation of impacts to decontamination and waste management
- Fluorescent surrogate contamination, Arizona road dust
- LLNL parking lot and material coupons (concrete, asphalt, wood, metal)



# Radiological Containment and Stabilization

## Operational Technology Demonstration

- Realistic operational conditions using brick building and surrounding area (including parking lots) in Columbus, OH.
- Surrogate contaminants such as particle tracers will be used in several demonstrations.
- Collect operational information:
  - Containment capacity/efficacy
  - Ease of use
  - Utilities (electric, water, etc.)
  - Worker skill needed
  - Cost of the application

# Radiological Containment and Stabilization


Acknowledgements:

- Dr. Ben Stevenson, Department of Homeland Security Science and Technology Directorate




Lawrence Livermore National Laboratory LLNL-PRES-669835 15


http://ngm.nationalgeographic.com/2011/12/japan-nuclear-zone/craft-text

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# Towards Best Practices for Gross Mitigation Methods in a Radiological Response


*Michael Kaminski,[1] Carol Mertz,[1] Nadia Kivenas,[1] and Matthew Magnuson[2]*

[1]Nuclear Engineering Division, Argonne National Laboratory
[2]U.S. EPA National Homeland Security Research Center, Cincinnati, OH



## Gross Mitigation

## Mitigation and Decontamination -- Wash Collection

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## Slurry Filtration

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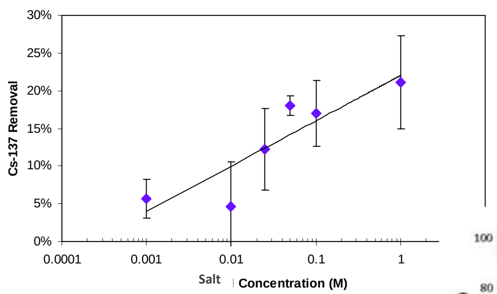
## Removal and Disposal

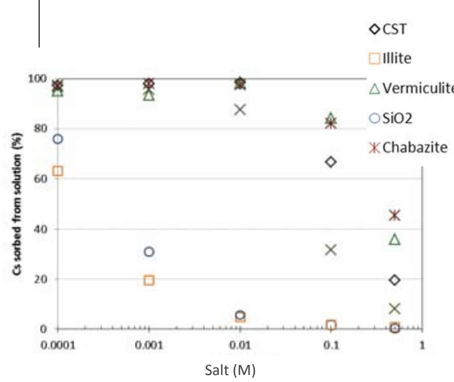
The Nautilus Bag™ and the Truck Bag ™ for transporting radioactive packages by Strategic Packaging Systems LLC.



## Salt and Sequestering Agents for Cesium-137 RDD

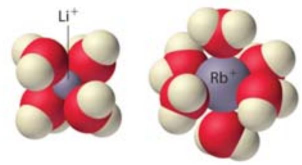
Decontamination of Cs-137 (in % removed) from coarse aggregate of concrete derived from river rock as a function of salt concentration.



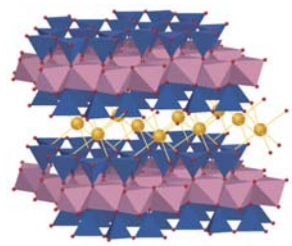



## Strontium-90 ($Sr^{2+}$) Aqueous Chemistry

- Highly soluble ($Sr^{2+}$) in natural waters, in high alkalinity, or acidity
- Forms *mostly* insoluble (in water) sulfates, carbonates, fluorides
- Reacts by ion exchange onto surfaces
  - Primarily clays and organic materials (humic and fulvic acids)
- Ordinary Portland Cement (calcium aluminum silicate hydrate) is a very efficient scavenger of $Sr^{2+}$, which replaces $Ca^{2+}$ in the cement.
  - Forms $SrOH^{2+}$ at pH>13.




http://chemwiki.ucdavis.edu/@api/deki/files/16786/Li,_Rb_complexes.jpg?revision=1





## Research Approach

- Ionic Wash
  - Literature survey and down select of potential additives for testing
  - Common salts, surfactants, flocculants, etc.
  - $Ca^{2+}$ and $Ba^{2+}$ and chelators predominantly reported in literature.
- Sequestering Agents
  - We expect to test up to five different sorbents with preference towards those that *also* have selectivity toward cesium.
  - Testing will evaluate the sorption behavior of strontium onto the down-select materials as a function of time, additive type and concentration, and slurry concentration.

| $K_d$ | V/m | % removed |
|---|---|---|
| 1000 | 1000 | 50 |
| 500 | | 33 |
| 100 | | 9 |
| 10 | | 0.99 |
| 1000 | 100 | 90.9 |
| 500 | | 83 |
| 100 | | 50 |
| 10 | | 9 |
| 1000 | 10 | 99.0 |
| 500 | | 98.0 |
| 100 | | 90.9 |
| 10 | | 50 |
| 1000 | 1 | 99.9 |
| 500 | | 99.8 |
| 100 | | 99.0 |
| 10 | | 90.9 |

## $Sr^{2+}$ Sequestration from Literature Survey

| | Sorbent | Natural(N) or Synthetic(S) | Normalized Kd Value (mL/g) |
|---|---|---|---|
| **1** | **Amberlite (aminodiacetate)** | **S** | **>900,000** |
| 2 | Duolite (aminophosphoric acid) | S | 310,000 |
| **3** | **Sodium Titanosilicate** | **S** | **>163,000** |
| 4 | IE-911 (engineered crystilline silico-titanate) | S | 70,000 |
| **5** | **IE-96 (chabazite)** | **S** | **68,900** |
| 6 | K-pharmacosiderities (-167) | S | 64,690 |
| **7** | **K-pharmacosiderities (-176)** | **S** | **60,040** |
| 8 | Sodium Titanate | S | 58,000 |
| **9** | **Smectite Cay (FEBEX Bentonite)** | **N** | **56,200** |
| 10 | Na-zirconium Silicates (-147) | S | 51,650 |

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| | Sorbent | Natural(N) or Synthetic(S) | Normalized Kd Value (mL/g) |
|---|---|---|---|
| **11** | **KMS-1** | **S** | **46,344** |
| 12 | Natural Zeolite | N | 13,600 |
| **13** | **Bentonite** | **N** | **5,012** |
| 14 | Geothite | N | 3,471 |
| **15** | **Na-kaolinite** | **N** | **3,360** |
| 16 | Na-mica | N | 2,404 |
| **17** | **Nitrate-impacted Sediments** | **N** | **1,330** |
| 18 | Na-montmorillonite | N | 1,011 |
| **19** | **Smectite Bentonite (J250 and L290)** | **N** | **900** |
| 20 | Amorphous Silica | N | 785 |

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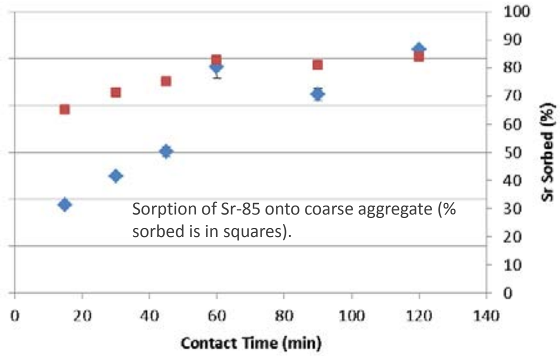
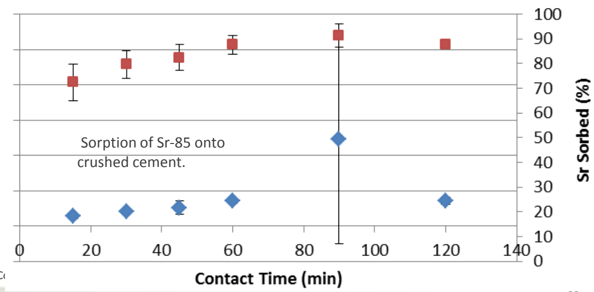
## Sorption of $Sr^{2+}$ from Water onto Coarse Aggregate of Concrete and Crushed Cement



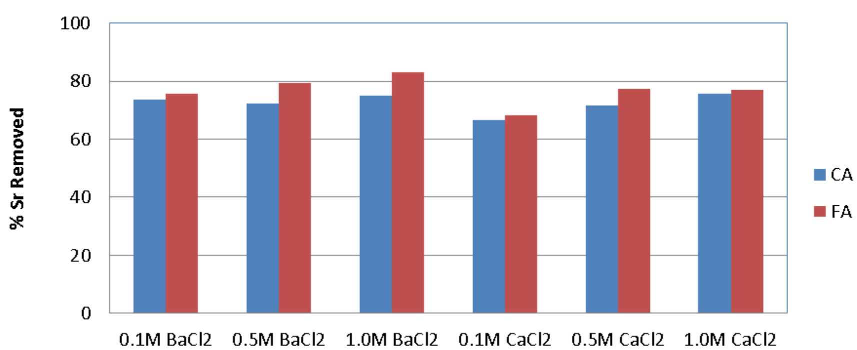

- Mix $^{85}Sr^{2+}$ water with sieved aggregate and filter.
- Sorption onto brick is weak (<10%).



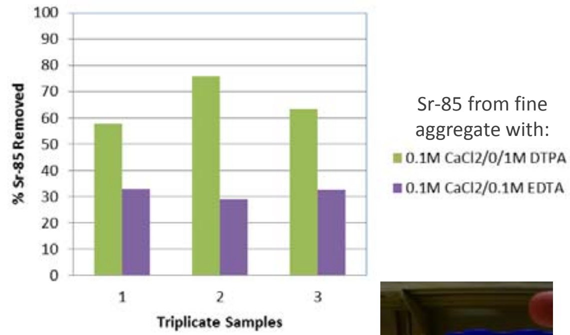


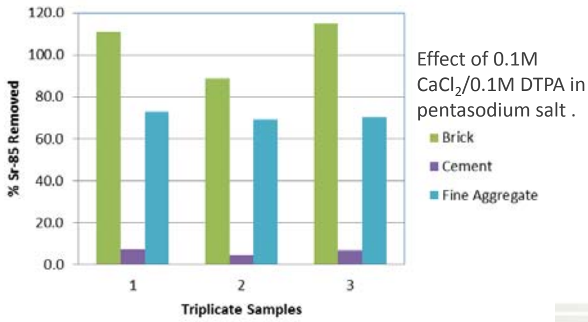

## Desorption of $Sr^{2+}$ from Aggregate of Concrete as Function of Salt and Concentration

- Mix Sr-loaded aggregate with salt solution and filter
- ~120 min to reach equilibrium



## Desorption of $Sr^{2+}$ from Materials in EDTA and DTPA plus $CaCl_2$

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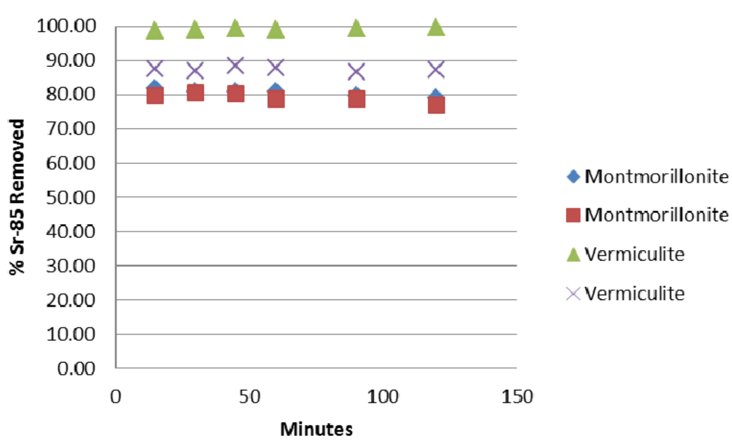
## Sequestration of $Sr^{2+}$ onto Clay from Pure Water

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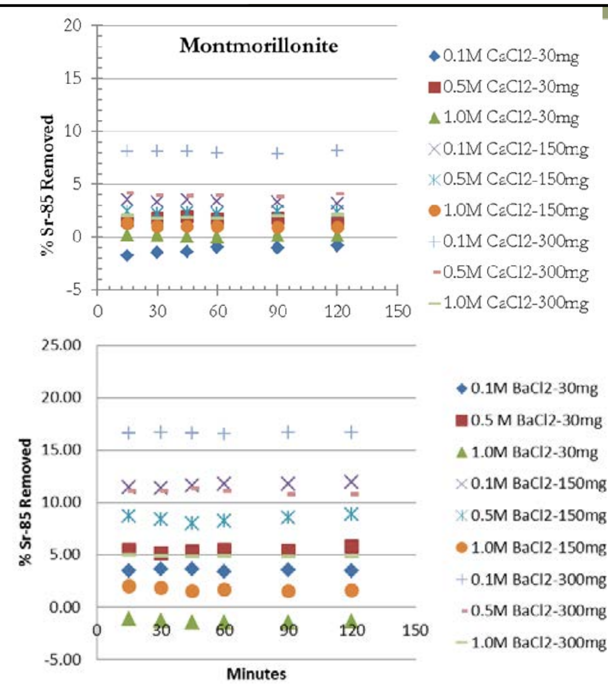
## Sequestration of $Sr^{2+}$ onto Montmorillonite Clay

- Calcium interferes with strontium sorption

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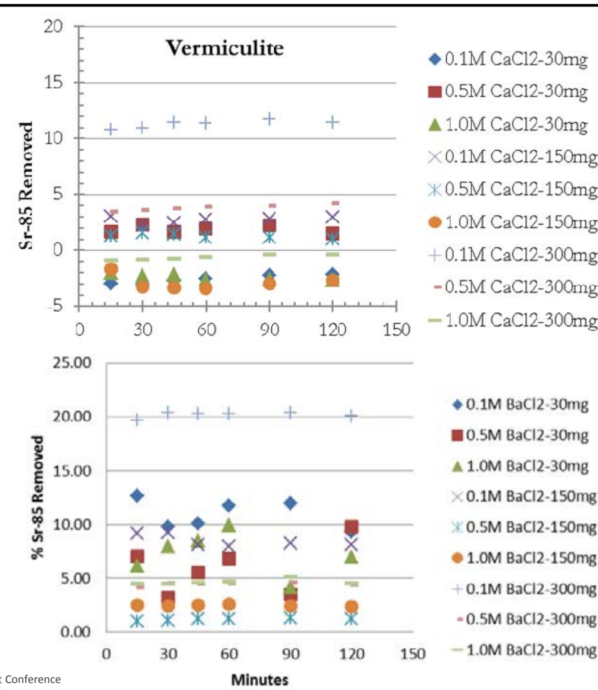
## Sequestration of $Sr^{2+}$ onto Vermiculite Clay

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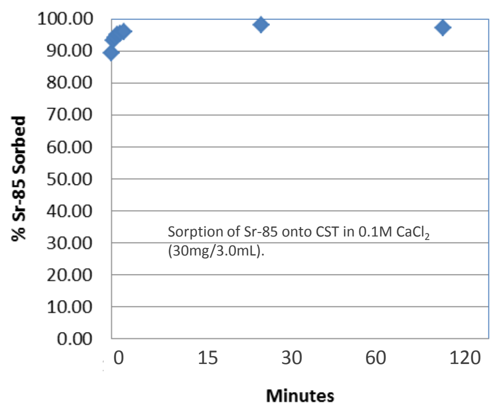
## Sequestration of $Sr^{2+}$ onto Engineered Silico-Titanate

- >90% removal at $CaCl_2$ concentrations up to 1.0M.






## Summary

- Investigation is preliminary.
- $CaCl_2$ effective in removing soluble $Sr^{2+}$ from aggregate but not for cement !!
  - How about Strontium particulate?
- Chelator ineffective in desorbing from cement.
- Common solid sequestering agent similar to Cs Wash Aid may not be as effective.
- Coupon tests with concrete, brick, asphalt upcoming.

## Acknowledgments


- Work supported by Department of Homeland Security and Technical Support Working Group.
- The U.S. EPA through its Office of Research and Development funded in part the research described in this presentation. It has been reviewed by the Agency but does not necessarily reflect the Agency's views. No official endorsement should be inferred. EPA does not endorse the purchase or sale of any commercial products or services.

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# Technology Demonstration

## "Toolbox of Options" for Radiological Incident Mitigation Technology

**Columbus, Ohio**
**June 22-25, 2015**



## Radiological Release Scenarios

- Possibility of RAD attacks is coupled by reality of fallout/contamination
  - Need for immediate and longer term recovery tools
  - Need to provide options for 1st responders
- What decontamination and mitigation approaches could be used?
- How effective are they?
- Can they be scaled up?

## Toolbox of Options for RAD Response

3

- Assist responders in making decisions in the early phase related to containment, gross decontamination, and waste management
- Pre-planning for these together is essential
- Toolbox of Options
- An easy-to-use toolbox/tool will be developed for use
- Web based app is under development


## DHS/EPA Technology Demonstrations

4

- Operational demos (no RAD)
- Scalable decontamination technologies (building)
- Containment technologies (particle/liquid/foam)
- Preview and debrief sessions
- Live technical demonstrations
- Battelle - Columbus, OH June 22-25

Battelle building to be used for demonstration (scheduled for demolition in July 2015)

# Technologies demonstrated by incident timeline

5

**Early phase**

Timeframe: less than ~72 hrs

Includes: mostly local responders

**Clean-up phase**

Timeframe: days-years

Includes: local, state, tribal, contractors, EPA, etc.

- Particle containment
- Low Tech washing and rad water containment
- DOD/TSWG-EPA Wash Aid System
- HESCO rad water containment system
- Separmatic rad water treatment system
- DHS/USDA Portable Vehicle Wash Tunnel
- Environmental Canada (EC) Foam Based system

- CBI DeconGel
- EAI SuperGel
- Bartlett StripCoat™
- EAI Rad-Release II
- EC Universal Decon Foam
- Large building applicators

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# Particle Containment

- Demonstrated by spreading fluorescent particles over parking space, applying containment technology
- Drive vehicle through particles
- Place vehicle under black light for determination of spreading contamination
- Demonstration to be performed in large tent to protect from wind and precipitation


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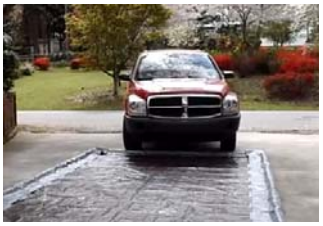
# Low-tech Approaches

- Demonstrated by washing vehicle inside of low-tech containment
- Determine effectiveness of rinse containment



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# DOD/TSWG-EPA Wash Aid system with HESCO Portable Berm System

- Demonstrated by washing response vehicle inside berm
- Determine effectiveness of rinse containment
- Also will be demonstrated on building

8

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## Automated CBR Wash Tunnel

- Demonstrated by washing response vehicle inside tent
- Determine effectiveness of rinse containment


9

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## Environment Canada Foam-Based System

- Joint EPA-EC project thru Canadian Security Sciences
- Demonstrated by applying to 1,000 $ft^2$ of building side
- Document operational details and impact on surfaces


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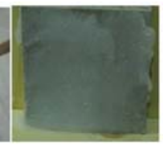
# Several Scalable Technologies

- Demonstrated by applying to 1,000 ft$^2$ of building side
- Removed either by vacuum, rinsing, or stripping off
- Additional surfaces included by stand-alone surfaces
- Bosan chair application
- DeconGel, Stripcoat TLC, EAI Rad-Release II, EAI SuperGel, and Env. CA Foam



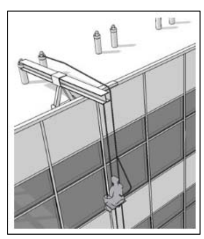







# Bosan Chair and Stand-Alone Applications

- Bosan chair application is proof of concept application (not a usual method)




- Stand-alone surfaces demonstrated to allow attendees closer access and additional surface types (granite, quartz, marble, and limestone)


# Summary

Who:

- First responders, particularly RAD responders (local, state, federal)
- RAD decontamination professionals
- Related organizations for all response phases (early and late)
- U.S. or abroad

When: June 22-25, 2015

Where: Battelle, Columbus, OH

If interested in attending, talk with:

Sang Don Lee (919-541-4531/Lee.Sangdon@epa.gov)

Matthew Magnuson (513-596-7321/ Magnuson.Matthew@epa.gov) of EPA NHSRC.

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# Early-Phase Waste Staging for Wide-Area Radiological Incidents

P. Lemieux
US EPA

R. Sell
Battelle

Office of Research and Development
National Homeland Security Research Center

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## Background

- **EPA is working with DHS to support radiological response as part of their efforts to improve "community resiliency"**
- **Many actions that first responders do can impact EPA-led intermediate and long-term response activities**
  - EPA is involved through the Area Contingency Planning Process, which is a joint effort with other Federal Agencies, as well as State & local governments & communities
- **Overall DHS-EPA project focuses on four tasks**
  - Containment
  - Gross decontamination/mitigation
  - Early phase waste staging
  - Development of an "app" for responder use

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## Importance of Waste Staging

- **Temporary waste storage has been identified as an obstacle when initiating early-phase waste management (WM) activities**
- **Limited availability of final disposal options makes identification of waste staging areas critical in early-phase**
- **Gives decision makers time to develop on-site treatment approaches and prevent repeated handling of waste**
- **Takes WM activities off the critical path to reoccupancy**
- **WM planning activities should result in a documented plan with operational procedures (e.g., as part of the Area Contingency Plan)**

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## Waste Staging is a Process

- **Should be part of the Area Contingency Plan**
- **Pre-incident selection criteria for staging areas**
- **Pre-incident selection of potential staging areas (more controversial)**
- **Allocation of appropriate amount of space**
- **Allocation of space based upon shielding, distance , types of waste, security & monitoring of radioactivity levels**
- **Activities at waste staging areas**
  - Segregating waste into different waste streams
  - Isolating radioactive waste from non-radioactive waste
  - Isolating waste with higher from lower radioactivity
  - Treating various waste streams on-site for volume reduction
  - Temporarily storing waste until final disposal
  - Monitoring of radioactivity levels

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## Need for Operational Guidelines

- **Pre-incident WM planning**
- **Waste generation begins immediately after the onset of the incident**
- **User needs for a rad incident may be different on a case by case scenario (RDD, IND, NPP)**
- **Decisions could be made early in the incident that might make intermediate- and late-phase cleanup difficult (e.g., using rail yards for responder deployment may inhibit using rail haul for WM)**
- **Segregate higher radioactivity waste from lower**
- **Select temporary waste storage areas with proper shielding, distance, types of waste, security and monitoring**

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## Purpose of Operational Guidelines

- **Best practices or "operational guidelines" rather than "guidance"**
- **Leverage existing guidelines (e.g., FEMA debris guidelines) for proper application to radiological incidents**
  - FEMA guidance lacks necessary considerations with regard to managing rad waste
  - Some debris management concepts can be utilized provided that unique aspects of rad waste are addressed (e.g., ample space considerations)
- **Supplement pre-incident WM planning efforts**
- **Give first responders basic information to plan for and support their WM decisions during initial stages of incident**
- **Give WM decision makers (e.g., state/local/tribal) information to plan for and support their activities developing/identifying waste staging areas**

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## Scope of Operational Guidelines

- **During Pre-Incident WM planning activities**
- **During the early phase (within first 72 hours) following the onset of the incident**
- **During the early-intermediate phases of the incident when state, local & tribal decision makers begin their response**
- **Intended audience**
  - First responders (fire, police, hazmat)
  - EOC director/personnel
  - Incident Command/Unified Command (IC/UC) personnel
  - Federal, state, local & tribal response personnel
  - Public health officials
  - Emergency planners & managers

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## Operational Guideline Approach

- **Planning is unlikely to capture all contingencies**
- **Document will NOT be regulatory guidance**
- **Will present best practices, options, and relevant technical information**
  - –Advantages and disadvantages
  - –Site-specific considerations
- **Appropriate options are presented, and decision makers decide what best practices to apply**
- **Part of a framework of an overall integrated containment/ mitigation/ decontamination/ waste management plan for response and recovery**

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## Example Scenario

- **WARRP RDD Scenario**
  - –Downtown Denver near US Mint
  - –Truck bomb with 2300 Ci of $^{137}Cs$

# Anticipated Waste Types

- Contaminated debris near detonation site or from demolition activities
- Class A low-level radioactive waste (LLRW) (majority of the waste material)
- Class B LLRW (higher levels from blast zone or onsite concentration efforts)
- LLRW with asbestos (i.e., old steam pipes from demolished buildings)
- LLRW with polychlorinated biphenyls (PCBs) (i.e., PCB transformer oils coating demolished building exteriors)
- LL Mixed Waste = Hazardous Waste (HW) and LLRW
- Personal protective equipment (PPE) waste
- Sludge from onsite decontamination efforts & wastewater treatment plants
- Laboratory samples
- Medical waste (both radiologically-contaminated and non-contaminated)
- Bags of contaminated clothing outside homes and businesses.
- Non-radiological solid or HW for disposal in RCRA C or D landfills
- Contaminated water generated from PPE washing, early gross decontamination activities, early containment operations, ill-timed precipitation, and other sources
- DON'T FORGET NORMAL WM ACTIVITIES ASSOCIATED WITH URBAN AREA

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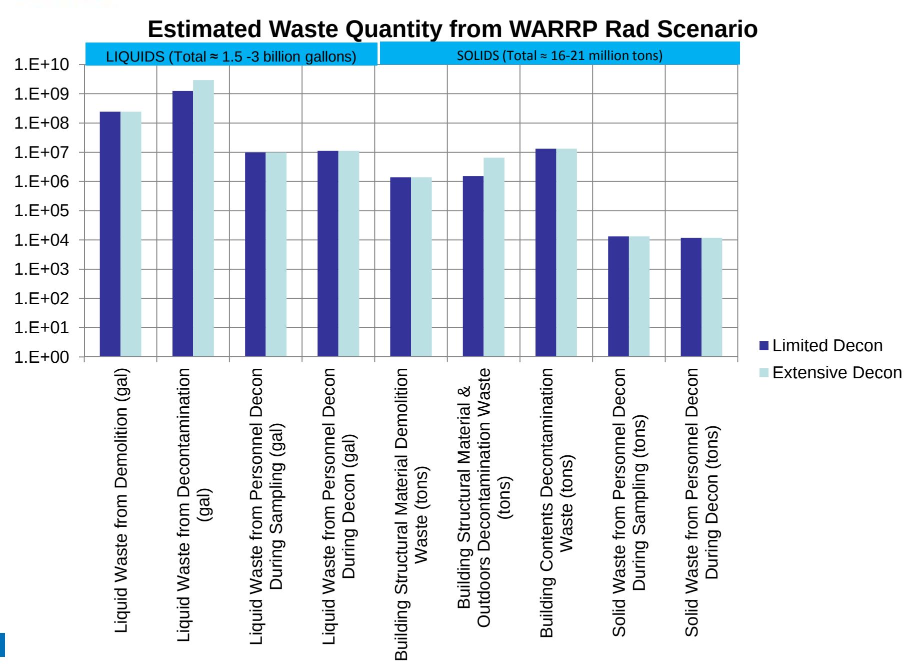
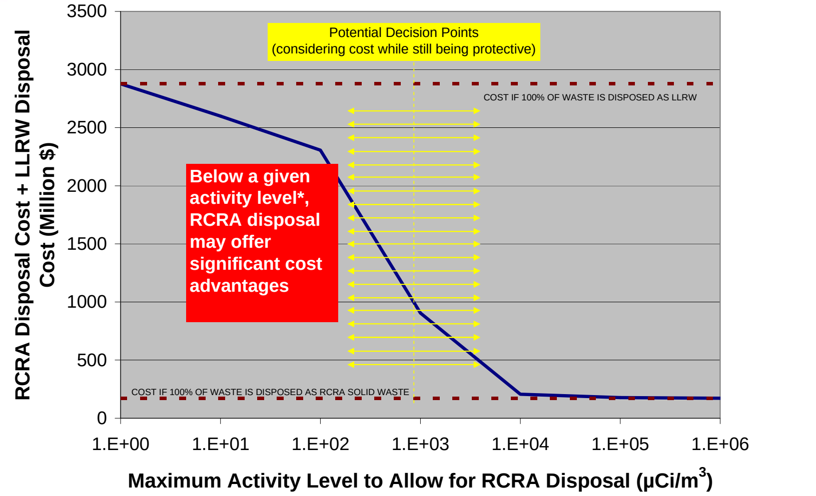


## Estimate: Cost vs. Disposal Option




NOTE: Assumed $300/m³ for RCRA disposal and $5000/m³ for LLRW disposal

* Where RCRA disposal is protective of public health and safety

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## Temporary Staging Site Examples

- **Commercial/industrial facilities**
- **Licensed Rad facilities (e.g., nuclear power plant)**
- **Federal facilities (DOE and DoD facilities)**
- **State/local facilities (Solid Waste Management and HW Facilities)**
- **Recycling facilities**
- **Permitted Landfills**
- **Transfer stations**
- **Vacant lots or buildings**
- **Corporation yards**
- **Parks, parking lots & right-of-ways**
- **City/county-owned properties**
- **Private non-residential properties**
- **For liquid waste, consider storage areas, tanker trucks and rail cars, ponds, or "deep tunnels", etc.**

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## Criteria to Evaluate Staging Sites

- Location (e.g., distance to hospitals, schools, etc.)
- Existing site operations & Site security
- Radioactivity of the waste and necessary time, distance, and shielding (need for HPs)
- Waste staging site and equipment size/capacity
- Condition of materials/waste to be staged
- Ease of accessibility/travel conditions
- Procedures to minimize multiple handling of waste
- Other considerations



## Staging Location Considerations

- Potential dose to responders and public due to the existence of the waste staging site (time, distance, shielding)
- Impact of noise, traffic, and environment
- Minimize multiple handling of materials
- Ingress/egress to maximize efficiency of flow of traffic and materials
- Impacts on neighboring communities of trucks hauling to sites
- Is the area geologically stable?
- Relatively impervious ground conditions are preferable to minimize potential groundwater contamination
- Abandoned quarries not preferred due to potential for exposing groundwater to the debris leachate
- Consider prevailing wind direction
- Consider visibility from the surrounding area
- Avoid environmentally/culturally sensitive areas
- Site security

## Staging Operation Considerations

- **Drainage/ collection/ treatment of wash water, and storm water management across the staging area**
- **Volume reduction**
- **Segregation according to level of contamination**
- **Tipping areas (unloading)**
- **Loading areas for processed waste/debris prior to final disposition**
- **Drop-off centers for the general public (this may include vegetative, recycling, or construction and demolition debris)**
- **Household hazardous waste (HHW) storage**
- **Monitoring locations at both the ingress and egress points**
- **Equipment, fuel, and water/wastewater storage**
- **Soil decontamination operations**
- **Flexibility to delineate areas for different operations and move boundaries as needed**

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## Staging Site & Equipment Size/Capacity

- **Appropriate to the scale of the type and quantities of waste/debris anticipated**
- **Large equipment requires large areas for storage**
- **Packaging & transportation of radioactive waste has special requirements that may require additional space**
- **Historic disasters have shown that it takes 100 acres of land (average) to process 1 million cubic yards of debris**
  - Note: this was for conventional disaster debris, not radiological waste/debris; which likely will require more space
- **Truck/railcar capacities**
  - 48' open top semi-trailer => 50,000 pounds or 85 cubic meters
  - 53' tanker that can haul liquid => 9,000 gallons
  - 40' open top semi-trailer => 58,600 pounds or 67.7 cubic meters

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## Condition of Materials

- **RDD with conventional explosives and NPP will likely produce only small quantities of comingled debris at the incident epicenter**
- **IND likely to produce large quantities of contaminated comingled debris in blast zone**
  - Cleanup of blast zone may be lower priority than cleanup of dangerous fallout zone
- **RDD and off-site NPP waste as well as IND waste from the dangerous fallout zone will likely be highly homogeneous (i.e., not like comingled debris like from a hurricane)**
- **Moisture content (e.g., free liquid) may be key factor for shipment (final disposal)**

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## Other Staging Considerations

- **Importance of state/local decision makers**
  - In most cases, regulatory authority for WM is with the states
  - Technical input from those closer to the incident
  - Understanding local policies/customs
- **Need for Health Physicists to assess potential radiation dose to workers & surrounding public**
- **Staging site ownership/site leasing**
  - Pre-negotiated/pre-placed contracts
- **Length of storage time**
- **Security and signage (ensure radiological postings)**
- **Sites for designated materials**
  - concrete, bricks, soil, etc.
- **Waste acceptance criteria for temporary storage could theoretically be established before an incident**
  - waste exhibiting less than a certain radioactivity level may be able to go under a tarp within a controlled staging area

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## Community Issues

- It may be controversial to pre-select staging areas
- It may be less controversial to develop staging area selection criteria ahead of time
- Consider noise, lights, traffic nuisances to surrounding community
- Consider public perceptions about the risks of radioactive material/waste

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## Conclusions

- EPA, in collaboration with DHS, developed "Standard Operating Guidelines" to support the selection and implementation of waste staging/temporary storage areas during early-phase response activities from radiological incidents
- Document is currently in EPA review process
  - Technical review (complete)
  - Management review (ongoing)
  - Program Office review (ongoing)
- Expected publication date October 2015

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# 2015 U.S. EPA International Decontamination Research and Development Conference

## Wednesday, May 6, 2015

## General Session 2

Data Models, Research Overviews and Remediation Plans





## Systems Analysis of the Data and Models Used for Federal Emergency Management

2015 EPA International Decontamination R&D Conference

May 6, 2015

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## The project

- Determine what information is needed by whom
- Develop an ontology to categorize the information requirements
- Identify and characterize the data and models used for federal emergency management: hurricanes, earthquakes, and INDs
- Perform network analysis to define gaps and identify linkages between resources and users/producers
- Build an interactive inventory cataloging the resources

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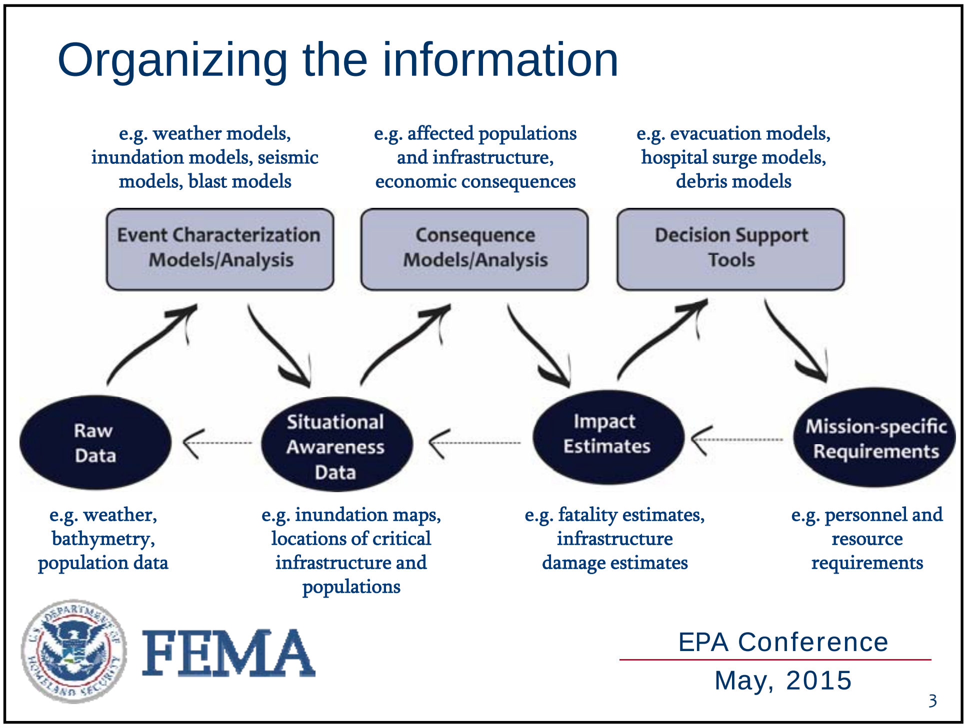
2


Organizing the information
e.g. weather models, inundation models, seismic models, blast models
e.g. affected populations and infrastructure, economic consequences
e.g. evacuation models, hospital surge models, debris models
Event Characterization Models/Analysis
Consequence Models/Analysis
Decision Support Tools
Raw Data
Situational Awareness Data
Impact Estimates
Mission-specific Requirements
e.g. weather, bathymetry, population data
e.g. inundation maps, locations of critical infrastructure and populations
e.g. fatality estimates, infrastructure damage estimates
e.g. personnel and resource requirements
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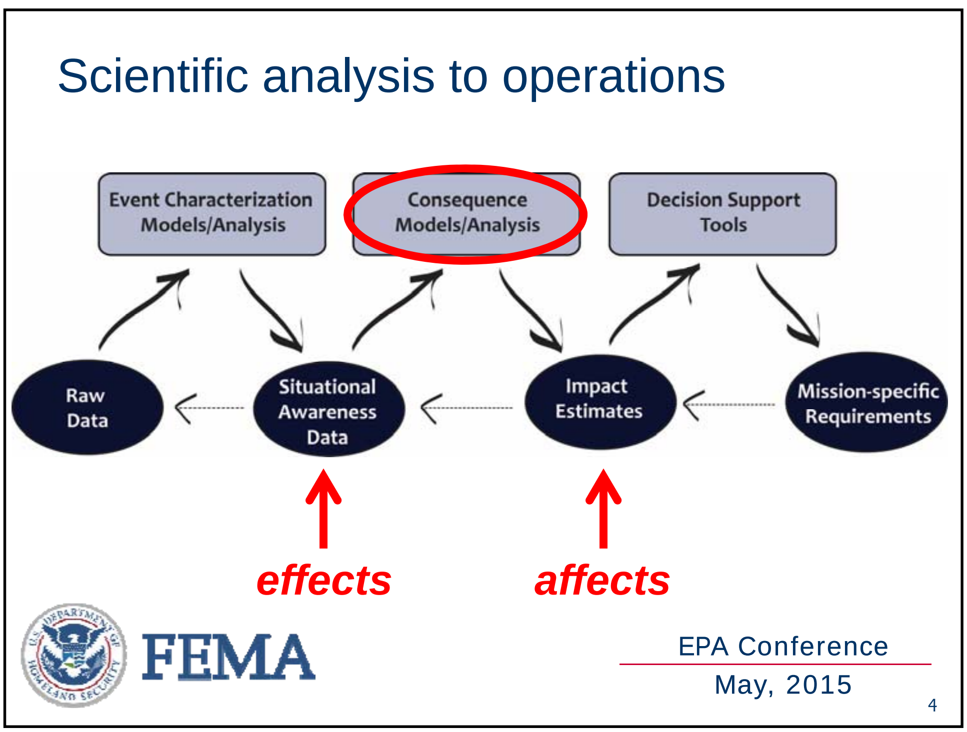
Scientific analysis to operations
Event Characterization Models/Analysis
Consequence Models/Analysis
Decision Support Tools
Raw Data
Situational Awareness Data
Impact Estimates
Mission-specific Requirements
effects
affects
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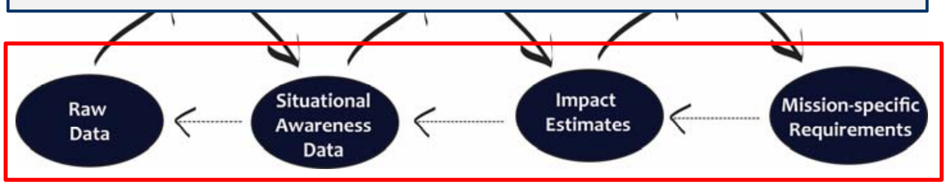
## Defining "data"

*Defined as repositories of steady-state or event-specific information used for emergency management*

**Includes visualization tools that do not transform the data**

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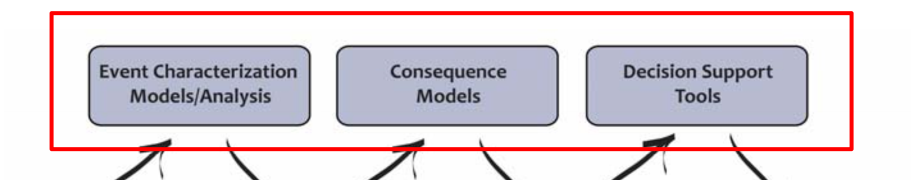
## Defining "models"

***models or data analysis tools***




*Defined as programs, algorithms, or computational tools that transform or process data to produce new information*

***Analysis capabilities or centers not included***

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## Data Collection

- Over 200 interviews conducted with ~250 people representing 54 federal agencies, divisions, or groups
- Resource inventory includes:
  - >500 resources identified and vetted
  - 162 included in the inventory of hurricane, earthquake, IND, and all-hazards resources
  - ~20 metadata categories describe each resource

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## Analysis Results: Hurricane Inventory

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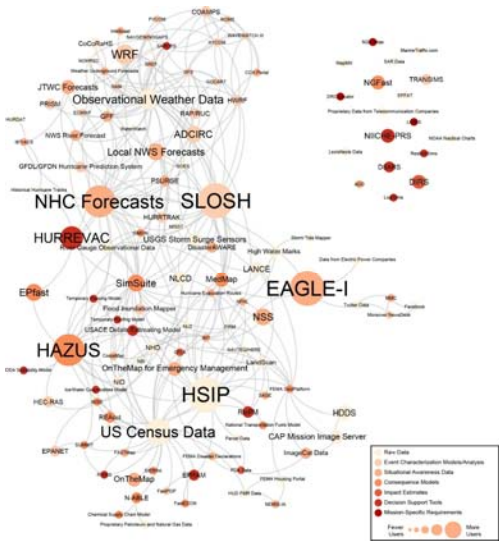
## Hurricane resource network

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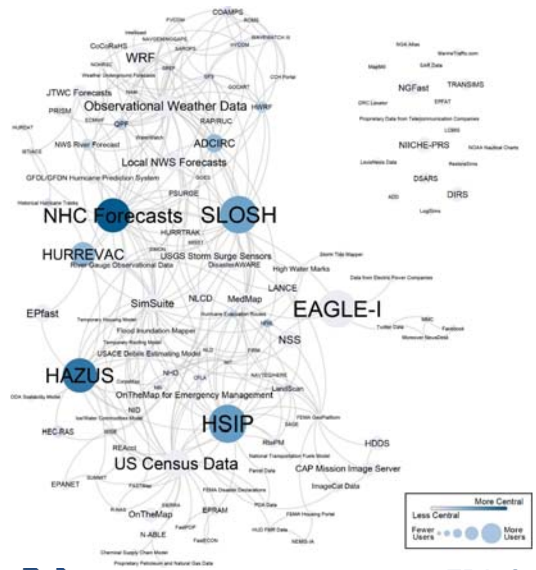
## Most used resources

**Resources with the most federal agency users**

| Resources | Users | Hazards | Resource Types | Descriptions |
|---|---|---|---|---|
| **EAGLE-I** | 10 | All-Hazards | situational awareness data | Monitors, aggregates, and displays energy system data |
| **HSIP** | 10 | All-Hazards | raw data | Critical infrastructure and key resource data |
| **SLOSH** | 10 | Hurricane | event characterization models/analysis | Estimates storm surge heights |
| **HAZUS** | 9 | Multi-Hazard | consequence model | Estimates economic impacts of select natural disasters |
| **NHC Forecasts** | 9 | Hurricane | situational awareness data | Predicts hurricane intensity and track |
| **PAGER** | 7 | Earthquake | consequence model | Predicts the economic and health impacts from an earthquake |
| **ShakeMap** | 7 | Earthquake | event characterization models/analysis | Outputs ground-shaking maps |
| **US Census Data** | 7 | All-Hazards | raw data | Regional populations, demographics, and survey items |

# Bridges in the hurricane network: Centrality

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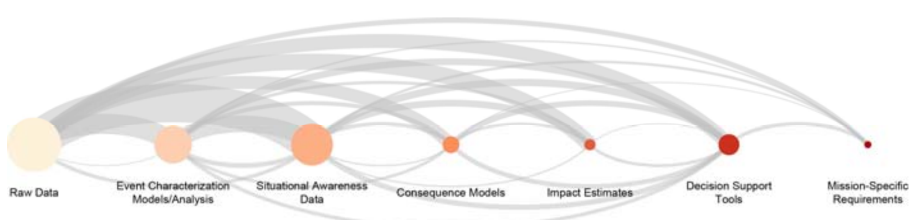
# Bulk flow of information

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## Conclusions, gaps, and COAs

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## Project findings

1. Lack of robust connections between resources
   - Orphan resources with no linkages
   - Widely-used resources with few linkages
   - Linking resources that fill gaps
2. Networks rely on a few highly central, widely used resources with varying levels of support
3. Unconnected, redundant situational awareness viewers

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## Systems-level gaps

1. Lack of operations-focused resources
   - Consequence modeling output libraries
   - Rapid-run models with outputs designed for operations
     - Would provide decision support and concrete mission specific requirements
2. Operations-focused resources poorly connected to real-time event data
3. Lack of emergency response modeling for operations

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## Courses of action: Disaster Reduction

- Develop real-time operational consequence and response modeling/analysis tools
  - May be available through national labs
  - Involve operations personnel in development
- Develop emergency response models
  - Tools to test response, recovery, and mitigation priorities
- Improve operational information-sharing between ESFs

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## Courses of action: Disaster Reduction

- Utility of the Resource Inventory
  - Additional scenarios: biological, cyber, flood
  - Robust, on-going hosting and maintenance
  - Use during exercises: Train around the resources available
  - Interagency access

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## Questions?

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# Points of contact

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# Update on Homeland Security Research Program R&D for Bio Decontamination

**Joseph Wood, Shawn Ryan, Worth Calfee, Lukas Oudejans, Sang Don Lee, Marshall Gray, Kathryn Meyer, Jenia Tufts, Shannon Serre**

**Presented at US EPA – Decontamination Conference, Research Triangle Park, NC, May 5-7, 2015**



EPA United States Environmental Protection Agency

# Acknowledgements and Disclaimer

- Many people/partners involved in EPA's Homeland Security Research Program's decontamination R&D
  - EPA/ORD Researcher
  - Post-graduate fellows
  - EPA Response Community
  - Federal Partners: DHS, DoD, USDA, National Labs, et al.
  - Contractor tech support
    - Arcadis, Battelle

Disclaimer: The U.S. Environmental Protection Agency through its Office of Research and Development (funded and managed) or (partially funded and collaborated in) the research described here under (contract number) or (assistance agreement number) to (contracting company name). It has been subjected to the Agency's review and has been approved for publication. Note that approval does not signify that the contents necessarily reflect the views of the Agency. Mention of trade names, products, or services does not convey official EPA approval, endorsement, or recommendation.

EPA United States Environmental Protection Agency

## Outline of Presentation

- Background on program
- Update/approach on bio decon R&D
  - Facilitating use of "established" fumigants
    - Demonstrated effective application
    - Improve implementation (e.g., easier to achieve conditions)
  - New application methods for liquid sporicides
  - "Emerging" decontaminants

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EPA United States Environmental Protection Agency

## Background of Problem

- Remediation efforts could be extensive following an aerosol release of *Bacillus anthracis* spores in an urban area and will challenge the capabilities of government agencies and decontamination contractors.
- We know many decontaminants to be effective, but would they be useful in a wide area scenario?
  - Effective on many materials?
  - Widely available?
  - Economical?
  - Compatible with materials?
  - Easy to use, less resources required?


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## Background on Program

- Focus is primarily on *B. anthracis* spores, although some R&D effort for non-spore formers
- Primarily chemical based approaches
- Lab scale efficacy studies >>> pilot scale >>> field scale
- Related R&D:
  - Material compatibility, containment of decontaminants
- Verify surrogate spore species appropriate for each technology
- Decon for niche uses, environments, materials

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## Materials Used in Decontamination Studies

- Varies by purpose of study
- Focus on interior building materials, those found outdoors, or both
  - e.g., ceiling tile, carpet, laminate, painted wallboard, soil
- Include porous and non-porous materials
  - e.g., concrete, wood, glass, stainless steel

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## Facilitating Use of Established Fumigants: Chlorine dioxide

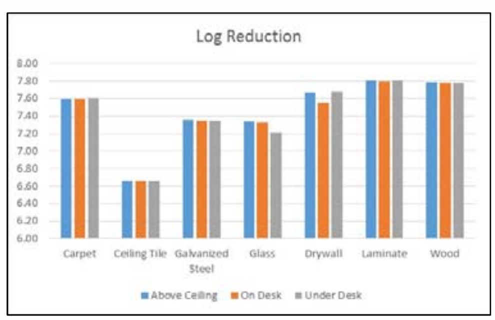
- Recent work has shown that low levels coupled with longer contact times effective on number of materials:
  - Mock office environment
  - Mock HVAC system
  - Concrete, grime
  - Less detrimental impact on materials

Currently investigating required contact time for effective decon at low RH – on subway tunnel concrete



## Facilitating Use of Established Fumigants: Hydrogen peroxide vapor

- Recent testing has shown that low levels (~ 5 ppm) coupled with longer contact times (a week) effective on number of materials
- Can be disseminated using home humidifiers
- Possible self help approach



## Facilitating Use of Existing Fumigants: Hydrogen Peroxide Vapor

- Registered VHP fumigation conditions (eg 400 ppm for 30 minutes) confirmed inadequate for effective decontamination of a number of materials
  - May need as high as 400 ppm for 6 hours



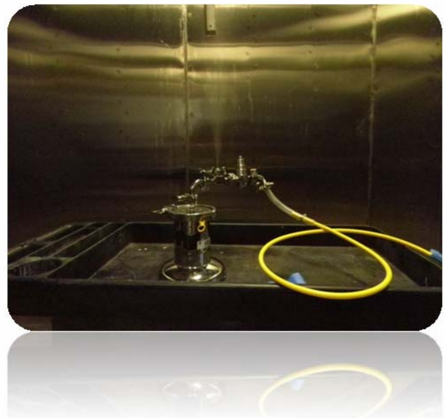
## Facilitating Use of Existing Fumigants: Methyl Bromide

- Lab study has shown efficacy with *B. anthracis* at
  - 212 mg/L, 75% RH, 22° C, 36 hr
  - *B. anthracis* Sterne a good surrogate at these conditions
- Ineffective at 45% RH
- Activated carbon easily captures MeBr following fumigation

- Demonstrated in lab and field

## Liquid Sporicides Update

- Liquid sporicides can be applied as:
  - Spray
  - Immersion
  - Fog
  - Wipes
  - Gels/foams
- Most effective liquid sporicides use peracetic acid or hypochlorous acid as active ingredient



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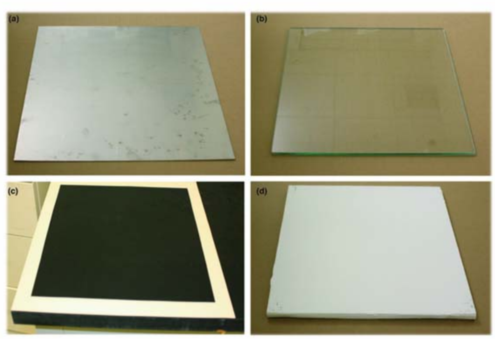
## Liquid Sporicides Update- Sodium Hypochlorite (aka Bleach)

- Previous R&D focused primarily on acidified bleach (pH adjusted, aka pAB)
- Off the shelf wipes with sodium hypochlorite (bleach) effective at < 1% hypochlorite
- Wipes made in lab with pAB bleach not as effective

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## Liquid Sporicides Update- Sodium Hypochlorite (aka Bleach)

- Dilute bleach (with no pH adjustment) shown to effective at <2% hypochlorite concentration
- Tested commercial off the shelf (COTS) cleaning products (<2% hypochlorite)
- See similar results with COTS as with diluted bleach
- Simple to use straight out of the bottle
- Some products have colors in them – can see where it has been applied


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## Liquid Sporicides Update- Bleach

- Immersion tests using bleach - waste materials decon
  - Acidified bleach more effective than diluted bleach
  - Most waste materials were effectively decontaminated by a 15 minute immersion in pAB, with the exception of carpet
  - Decontamination inside closed books and gloves not always effective


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## Liquid Sporicides Update - Peracetic Acid (PAA)

- Activated hydrogen peroxide (provided by Sandia National Laboratory) tested by EPA
  - Produced in situ, forms PAA when $H_2O_2$ activated with triacetin
  - Highly effective on all materials with two spray applications

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## Liquid Sporicides Update- Peracetic Acid

- Parametric testing of four PAA formulations prepared in lab
  - Tests conducted in suspension demonstrated efficacy
  - PAA developed from over the counter ingredients < 0.1 % PAA, not effective on materials
- In separate wipe study, low level PAA (0.15%) not effective

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## Liquid Sporicides Update- Peracetic Acid

- Fogging of mock HVAC using 4.5% PAA (Minncare Cold Sterilant) was effective
- Humidifier test
  - Low tech approach using humidifier shown to be effective with SporKlenz (low level PAA) 1 week contact time
- Currently testing fogging of railcar materials with PAA


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## Emerging Decontaminants- Sodium Persulfate

- Highly effective on soil
  - Only liquid demonstrated to be effective in killing *B. anthracis* spores in soil
- Effective on outdoor materials
- Patent application submitted

| Oxidant and Reactions | Electrode Potential |
|---|---|
| $S_2O_8^{2-} + 2\ e^- \rightarrow 2\ SO_4^{2-}$ | 2.1 V (persulfate) |
| $SO_4^- + e^- \rightarrow SO_4^{2-}$ | 2.6 V (sulfate radical) |

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## Emerging Decontaminants- Methyl Iodide

- Pesticide alternative to MeBr
- Found to be effective under numerous conditions for numerous materials
- Not effective at low RH (similar to MeBr)

| Target MeI Concentration (mg/L) | Target Temperature (°C) | Target RH (%) | Time (hours) Required to Achieve >6 LR on All Materials | | | Test Number Reference[a] |
|---|---|---|---|---|---|---|
| | | | *B.a.* Ames | *B. atrophaeus* | *B.a.* Sterne | |
| 100 | 25 | 70 | ≤48[c] | --[b] | >48 | 14 |
| 200 | 25 | 70 | >12 and ≤24 | -- | >24 | 11, 13 |
| 300 | 25 | 45 | >36 | -- | >36 | 10, 12 |
| 300 | 25 | 70 | >12 and ≤24 | >36 | >12 and ≤24 | 6, 8, 9 |
| 300 | 37 | 70 | >24 and ≤36 | >36 | ≤36[c] | 1, 2, 5, 7 |
| 400 | 37 | 70 | ≤12[c] | >24 | -- | 3, 4 |

* Materials tested were glass, ceiling tile, carpet, painted wallboard paper, bare pine wood and unpainted concrete.

[a] Contact times and microorganism tested may be variable between tests. Detailed data from each test number can be referenced in Tables A-1 through A-3 in Appendix A.

[b] "--" Not Tested.

[c] ≤ indicates that no experiment was conducted to assess efficacy less than the listed contact time and that >6 LR was achieved at this contact time.



## Emerging Decontaminants- Ethylene Oxide (EtO)

- Typically used for sterilization of medical equipment
- Effective against *B. anthracis* spores at 37° C, 75% RH, ≥300 mg/L EtO for ≥90 minutes, and other conditions
  - Tested on sensitive materials, such as those found at a museum
- Minimal effects on materials tested

## Emerging Decontaminants-Carpet Cleaning

- Minimal decon efficacy using the wet vacuum carpet cleaner (using surfactant)
- Spores difficult to recover after wetting
- But effective when cleaner replaced with peracetic acid



## Summary

- Lots of research being conducted, lots of partners involved
- Over 60 reports/papers published on bio decon since NHSRC inception


**http://www2.epa.gov/homeland-security-research**

# Environmental Response and Remediation Plan for a Biological Agent Incident in NYC

Shannon Serre
USEPA/CBRN CMAD

Kobria Karim
NYC DOHMH

May 6, 2015

## Project Background

- What would we do if a biological incident happened today in NYC?
- What information is available to help with the response?
- Goal is to develop <u>operational</u> and <u>tactical</u> guidance to help NYC to: prepare for, characterize, remediate, clear and re-occupy contaminated areas following a biological incident
- Focused on *B. anthracis* - no specific scenario
- Plan that is scalable
  - One building
  - Multiple buildings
  - Wide area including streets and vegetation
- Identify gaps/research needs

# Collaborative Effort

- USEPA
  - OEM/Consequence Management Advisory Division
  - Office of Research and Development/NHSRC
  - Office of Resource Conservation and Recovery
  - Environmental Response Team
  - Office of Chemical Safety and Pollution Prevention
  - Office of Water
  - Office of Homeland Security
  - Regions 2, 3, and 5
- NYC
  - Department of Health and Mental Hygiene
  - Department of Environmental Protection
  - Emergency Management
- NYS – Department of Environmental Conservation
- Sandia National Laboratories
- Metropolitan Transportation Authority
- Contractor Support
  - Dynamac
  - Booz Allen Hamilton
  - UF

# Work Groups

- Focused on Consequence Management Phase
  - Sampling and Analysis
  - Decontamination
  - Subway Systems
  - Waste Management
  - Health and Safety
  - Clearance Criteria
  - Risk Reduction (“Self-Help”)
  - Building Engineering Study

# Sampling and Analysis

- Resource analysis
  - Determine resource picture for the response from notification until maximum resource deployment
- Laboratory analysis
  - Lab Capacity – ERLN, LRN, NYS Labs, and mobile labs
  - Laboratory Methods Strategy: create recommended strategy for lab methods depending on response phase
  - Pop-Up Labs Guidance – Can non-certified labs process samples?
- Sampling strategies
  - Develop general strategies for key sampling programs and identify methods for creating scalable sampling plans.
  - SAP templates (characterization and clearance)
  - Waste sampling guidance (gap)

# Decontamination

- Decontamination Options and Challenges
  - Options
    - Volumetric – fumigation, fogging, etc.
    - Surface treatment options
  - Compatibility issues
  - Porous/non-porous materials
  - Waste disposal considerations
- Develop Operational Strategies
  - Indoor
  - Outdoor
  - Vehicles

## Subway System

- Subway specific issues – unique environment
  - Subway infrastructure
    - Tracks, signaling, tunnels, platform, etc.
    - Combination > 100 yr old mechanical and modern computerized electronic equipment
  - Rolling stock – different types of trains in use
  - Passive and active ventilation
  - Tunnel vs tubes
  - Many types of ballast
  - How do we sample ballast?
  - Limited Return to Service
  - Electrical hazards with 3rd rail


## Waste Management

- Waste
  - Quantities likely to exceed local, state & regional WM resources & assets
  - Cannot be managed like natural disaster debris
  - USDOT & NY State DEC requirements for packaging, labeling, marking & transport
- Plan
  - Pre-identify resources, facilities, assets, personnel & constraints
  - May require the need for longer term use of vehicles and secure staging areas
  - Prioritize critical infrastructure/key resources for decon & WM activities
- Gaps in Waste Sampling/Analysis Methods
  - Method development needs additional work
  - Additional samples to analyze – additional laboratory resources

## Health and Safety

- Health and safety guidance for response operations
- Does not include health and safety for the public
- Develop guidance document on PPE, site controls, training, etc. for various response tasks
- Provide Quick Reference Guides (QRGs)
- SDS for fumigants and other chemicals
- Provide a template for a site-specific Health and Safety Plan (HASP)

## Clearance

- Developed a charter for the Technical Working Group (TWG) and Environmental Clearance Committee (ECC)
- Developed a recommended clearance goal and clearance strategy for indoor, outdoor, subway, and vehicles
  - Consideration of using the same clearance goal (no detection) for all environments, but deviating in terms of developing different strategies/CONOPS for results above non-detect (for example, define what action is triggered by a positive detection outdoors versus indoors)

## Risk Reduction ("Self-Help")

- Focussed on locations outside the hot-zone:
  - Residential
    - Porous (carpet, rugs, furniture)
    - Non-porous surfaces (countertops, hard flooring)
    - Pets
    - Clothing
    - Cars
  - Businesses/Commercial
- Measures that do not require specialized equipment or materials
- What to do, as well as, what not to do
- Contractor selection checklist

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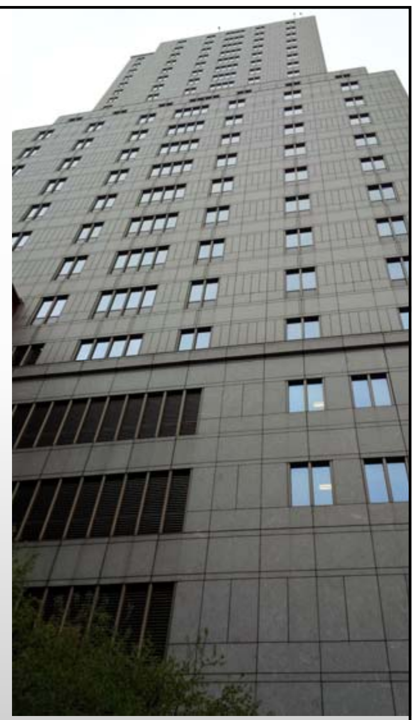
## Building Engineering Study



- GSA building in NYC (33 Stories)
- Surveyed floors under EPA control
  - Offices, conference rooms, break rooms, file rooms, etc.
- Evaluated the feasibility of building containment for fumigation
- Estimated potential waste generation
- Logistics for staging areas for materials
- Logistics for waste decontamination and packaging

# Info from Survey

| | |
|---|---|
| Laminate/Formica/Tile Loading, tons | 98 |
| Wood Loading, tons | 4 |
| Drywall Loading, tons | 754 |
| Carpet Loading, tons | 491 |
| Paper Loading, tons: | 11,704 |
| Furniture, tons: | 19,128 |
| Special Items: Thermostats, #: | 372 |
| Special Items: Smoke Detectors, #: | 4 |
| Special Items: Fluorescent Tubes (Large), #: | 14,086 |
| Special Items: Fluorescent Tubes (Small), #: | 3,276 |
| Special Items: Fire Extinguishers, #: | 240 |
| Special Items: Refrigerators, #: | 48 |
| Special Items: X-Ray Machines, #: | 1 |
| Structural Items: HVAC Units Below Window, #: | 1,989 |
| Structural Items: Floor panel outlets, #: | 2,557 |
| Structural Items: Fire Alarms, #: | 426 |
| Structural Items: Light Switch/Receptacles, #: | 1,509 |
| Electronics Items, tons: | 32 |
| Porous Items, tons: | 9 |
| Non-Porous Items, tons: | 938 |
| Personal Items, ft3: | 2,068 |

# Gaps and Lessons Learned

- Need additional info on outdoor decontamination (trees, grass, etc.)
- Large buildings will be a challenge to fumigate
- Vehicle decontamination
- Waste sampling/analysis methods have not been addressed
- Large quantities of wastewater will need to be treated
- Subway system challenges – UTR is a new program to help fill in gaps

## Challenges

- NYC is the largest and most populated city in the USA
- 8.2 million residents
- ~ 26,000 persons/sq mile and ~ 70,000/sq mile in Manhattan
- > 3.2 million housing units
- ~ 5.6 million subway commuters per average workday
- The busiest commuter rail line in the country (LIRR)
- > 4,500 buses carrying ~ 2.4 million daily passengers
- ~ 60 hospitals
- > 1,400 public schools attended by 1.1 million children

NYC Health

## Challenges

- **Characterization**
  - Defining zones of contamination – how do you define the hot zone?
  - Evacuation vs. remain in place
  - Limited sampling and analytical capacity
- **Prioritization**
  - Process for identifying which critical assets and infrastructure to remediate first
- **Remediation**
  - Clearance goal: no detection of viable spores
    - Can this realistically be achieved in a timely fashion (months vs decades) for a wide area release in NYC?
  - How do you remediate skyscrapers?
  - Fumigation – how do you contain the building? Where do you set up staging areas?
  - Limited resources/contractors
  - What will be the new “normal” of acceptable risk?

NYC Health

## Challenges

- **Waste Management**
  - Lack of federal guidance on waste management
  - Very stringent NYS DEC proposed waste regulations
  - Limited transporters and storage, treatment and disposal sites
- **Clearance Process**
  - It is not feasible to conduct clearance sampling in each affected area/building
  - Can a CONOPS be developed and shown to be effective in clearing areas as opposed to conducting stringent clearance sampling in each affected area?
  - What actions should be taken if a sample is positive?

## Next Steps

- Hold an internal NYC Health Department workshop to resolve policy issues
- Hold a Technical Working Group (TWG) workshop
- Develop additional tools to support characterization, remediation, clearance and re-occupancy
- Hold an interagency workshop with local, state and federal partners to roll-out the Bio Remediation Plan
- Continue work with other city agencies to develop the NYC Interagency Biological Incident Operational Plan and to integrate the Bio Remediation Plan as an annex to this Plan

# THANK YOU!

- Erica Canzler and Shannon Serre - *US EPA*
- Group leads - *US EPA*
  - Mark Durno, Marissa Mullins, Chris Jimenez, Worth Calfee, Rich Rupert, Paul Lemieux, Leroy Mickelsen, Schatzi Fitz-James, Mario Ierardi, Marshall Gray, Larry Kaelin, Mike Nalipinski, Jayson Griffin, and Elise Jakabhazy
- Donna Edwards - *Sandia National Laboratories*
- Allan Woodard - *NYS Department of Environmental Conservation*
- Greg Recer – *NYS Health Department*
- Afrosa Amin, Peter Chen, and Christina Kendrot – *NYC Department of Environmental Protection*
- Charles Burrus and Mike Gemelli – *NYC Transit*
- Stephanie Servetz, Mark Andrew, Laura Black, and Johanna Miele – *NYC Emergency Management*
- Kobria Karim, Laurie van Vynck, Ray Nieves, Jeanine Prud'homme, Ava Blagrove Ken Peskowitz, Colin Stimmler – *NYC DOHMH*

# EPA Water Security Division (WSD): Update on Water Decontamination Activities


Marissa Lynch- US EPA

George Gardenier- US EPA ORISE FELLOW


2015 EPA International Decontamination Research and Development Conference

5/6/2015

water.epa.gov

## Outline

- **EPA Homeland Security Roles**
- Available Products
- On-going Projects
- Upcoming Projects
- Supporting Research by EPA's Homeland Security Research Program

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## EPA Homeland Security Roles

- Protecting water and wastewater infrastructure
- Indoor and outdoor clean-up following attack or natural disaster
  - can use **millions of gallons of water**
  - can **result in even more contaminated wastewater**
- Development of a **nationwide laboratory network**
- **Reducing vulnerability** of chemical & hazardous materials
- **Cyber security**

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## Water Security Projects

Multi Use → Homeland Security
→ Catastrophes: Natural Disasters, Accidents, etc.
→ "Normal" Operations

Many homeland security practices may also **benefit day-to-day operation.**

For example, decontamination approaches for use after intentional contamination might also be **useful after natural disasters and industrial accidents.**

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## Outline

- EPA Homeland Security Roles
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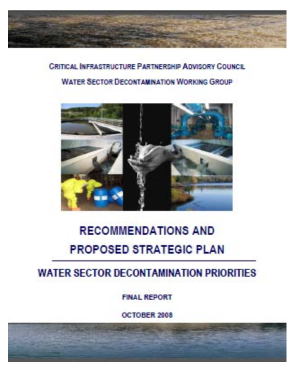
## Report on Progress of 2008 CIPAC Recommendations

- Water Sector Decontamination Priorities
- Critical Infrastructure Partnership Advisory Council (CIPAC) **Decontamination Workgroup**
- Strategic Plan – October 2008
  - **Priority Issues (16)**
  - **Recommendations (35)**

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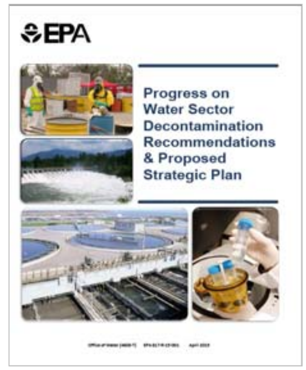
## Progress on Water Sector Decontamination Recommendations & Proposed Strategic Plan

The document addresses progress to address the CIPAC workgroup recommendations in the areas of:

- Providing guidance regarding decontamination
- Containing and disposing of contaminated water
- Developing planning documents to facilitate preparation and response to a contamination event
- Evaluating results from studies on the persistence of target contaminants in water systems and the efficacy of treatment technologies and protocols
- Developing web-based resources
- Conducting decontamination-specific training

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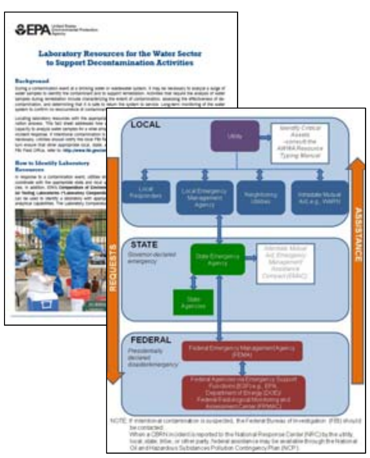
## How Can Water Utilities Obtain Critical Assets to Support Decontamination Activities?




- **Factsheet** for utilities for identification of critical assets during pre-incident planning and in response to a contamination incident
- **Flowchart** demonstrating the general coordination between Local, State, and Federal Levels

http://water.epa.gov/infrastructure/watersecurity/emerplan/decon/upload/epa817f15012.pdf

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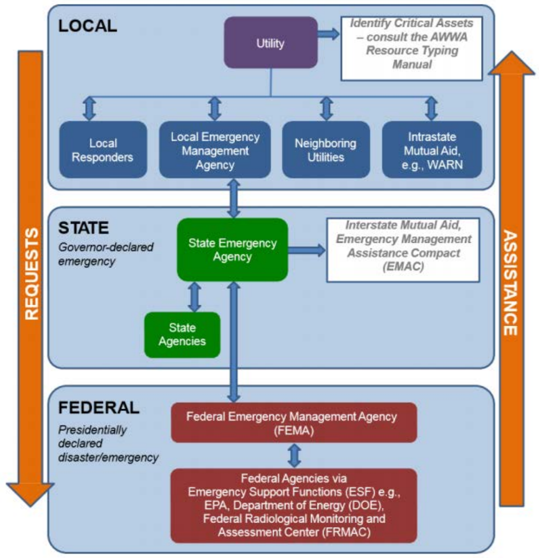
## Accessing Critical Assets for Decontamination

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## How Can Water Utilities Obtain Critical Assets to Support Decontamination Activities?

### What is a critical asset?

- Personal protective equipment
- Sampling teams with up-to-date environmental technique training
- Qualified analytical laboratory personnel
- Fate and transport modeling and sampling-design experts
- Data management and documentation specialists
- Decontamination teams capable of verifying decontamination, treating contaminated water, and decontaminating sites or items
- Chemicals for treatment

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## Outline

- EPA Homeland Security Roles
- Available Products
- **On-going Projects**
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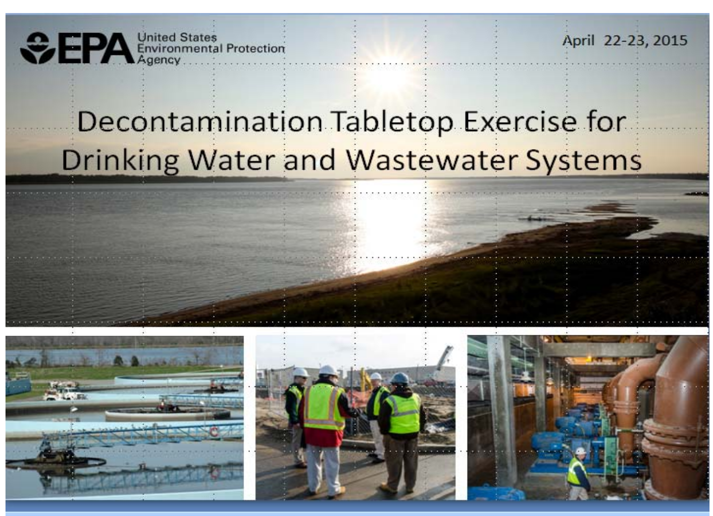
## EPA Decontamination Tabletop Exercise



## EPA Decontamination Tabletop Exercise (continued)

### Exercise purpose

Through these exercises, participants are able to:

- Define critical decontamination issues for utilities and what options utilities have to address these issues
- Understand roles and responsibilities of stakeholders and response partners
- Identify key resources to inform decision-making for decontamination efforts
- Network and learn from each other

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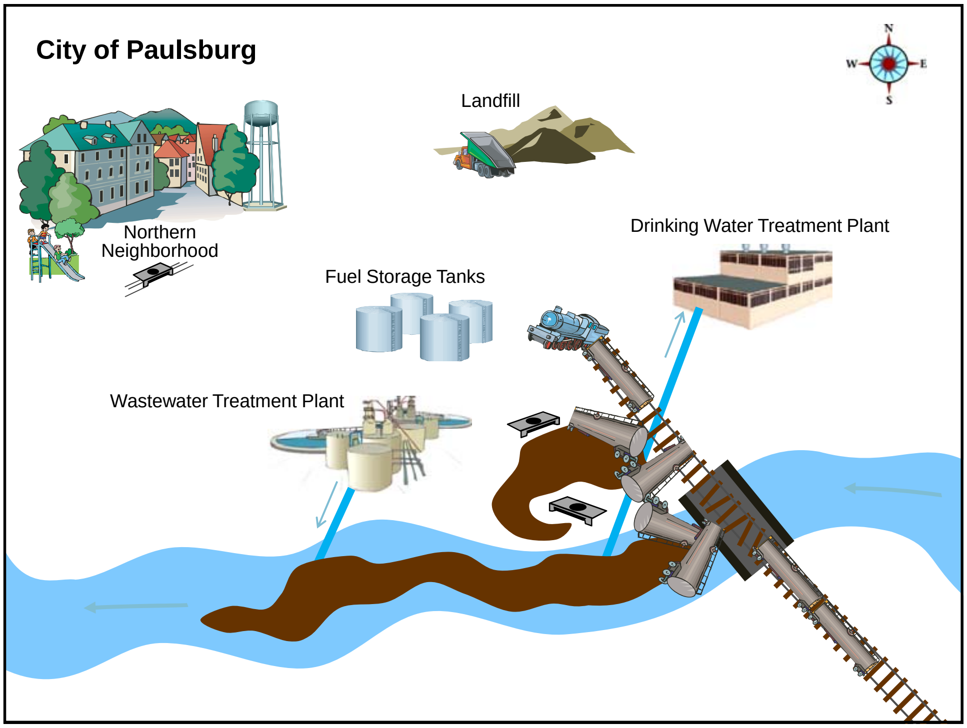
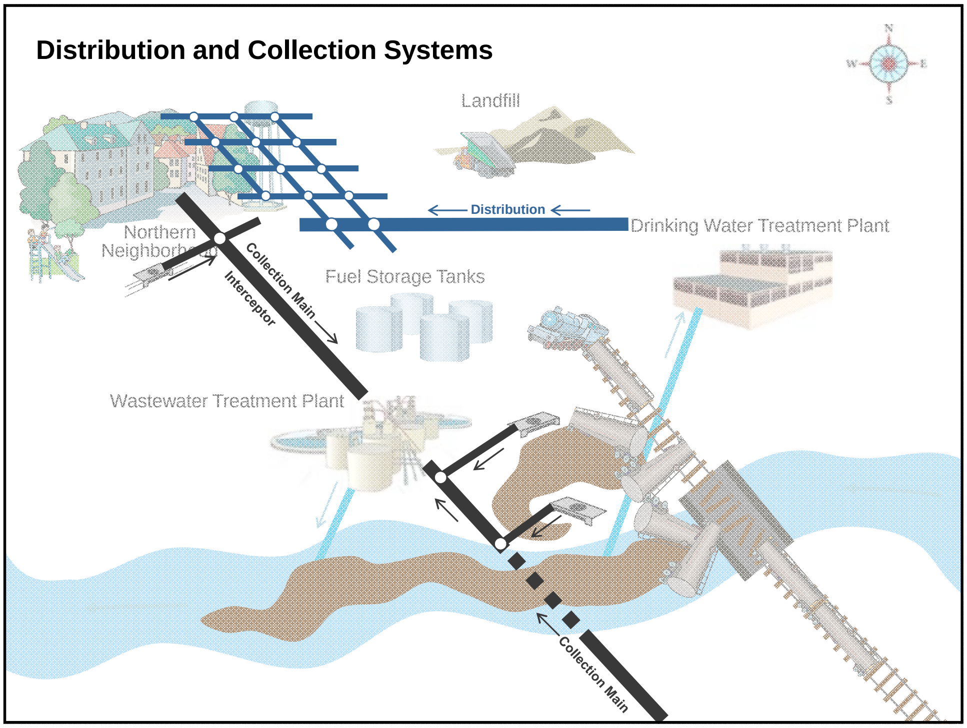
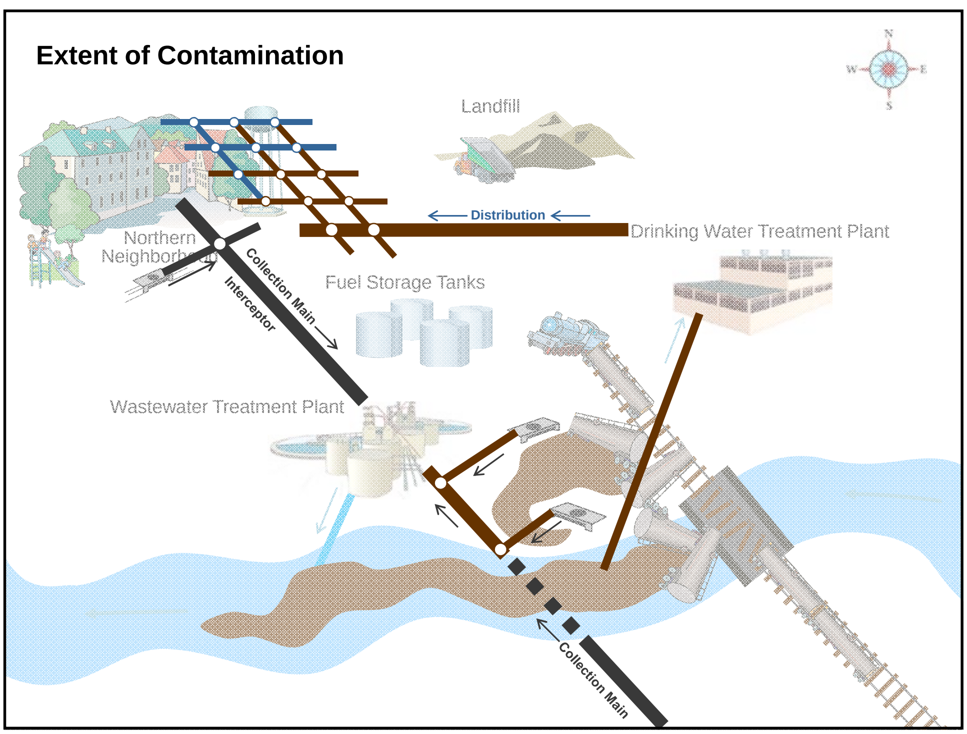
## City of Paulsburg





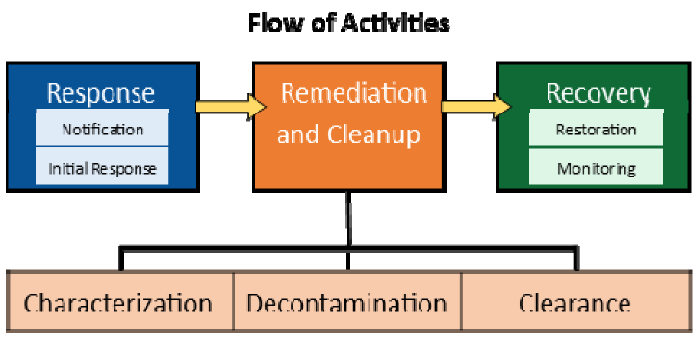
Distribution and Collection Systems
N
W
E
S
Landfill
Distribution
Drinking Water Treatment Plant
Northern
Collection Main
Interceptor
Fuel Storage Tanks
Wastewater Treatment Plant
Collection Main

Extent of Contamination
N
W
E
S
Landfill
Distribution
Drinking Water Treatment Plant
Northern
Collection Main
Interceptor
Fuel Storage Tanks
Wastewater Treatment Plant
Collection Main

## EPA Decontamination Tabletop Exercise (continued)

The exercise is designed to walk the participants through the **three phases of remediation and clean-up** (Characterization, Decontamination and Clearance), while reflecting on a hypothetical scenario that contaminated a drinking water and wastewater utility.

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## EPA Decontamination Tabletop Exercise (continued)

### EPA Region 4 - Exercise Feedback

- Many participants indicated that the **open discussions and exchange of ideas among peers from across the Water Sector** in response to the injects during the tabletop was very beneficial
- Exercise participant: *"We would love to offer this training TTX to more smaller size utilities in rural parts of Georgia to help smaller/med size utilities better understand the process/preparedness of responding to emergencies."*
- Exercise participant: *"This was my first tabletop exercise and it won't be my last."*

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## EPA Decontamination Tabletop Exercise (continued)

### Participant Information

| Participant Affiliation | D.C. TTX | EPA Region 4 TTX | EPA Region 6 TTX |
|---|---|---|---|
| Utility | 7 | 22 | 9 |
| Public health | 1 | — | 3 |
| Emergency management | 1 | 2 | — |
| Local or state government | 2 | 9 | 6 |
| Association | 3 | — | — |
| Private Sector | 3 | 1 | — |
| EPA | 15 | 7 | 10 |
| CDC | — | 4 | — |

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## EPA Decontamination Tabletop Exercise (continued)

### Upcoming Exercises – June 2015

EPA Region 8: City of Riverton, Wyoming

EPA Region 9: Orange County, California

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## Outline

- EPA Homeland Security Roles
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## Decontamination Preparedness and Assessment Tool (DPAT)


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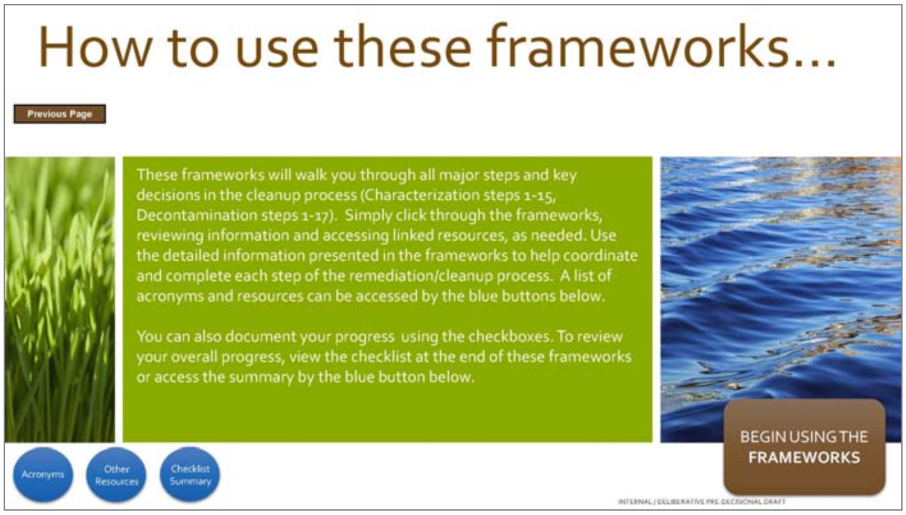
## Decontamination Preparedness and Assessment Tool (DPAT)

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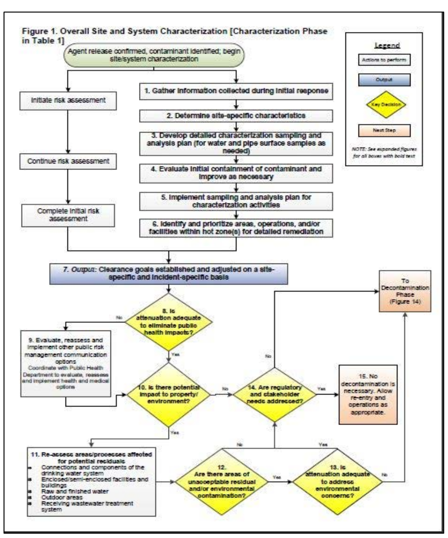
## Decontamination Preparedness and Assessment Tool (DPAT)




- The DPAT includes Flowcharts and an **interactive PDF** for the decision-making frameworks
- Includes **roles and responsibilities**

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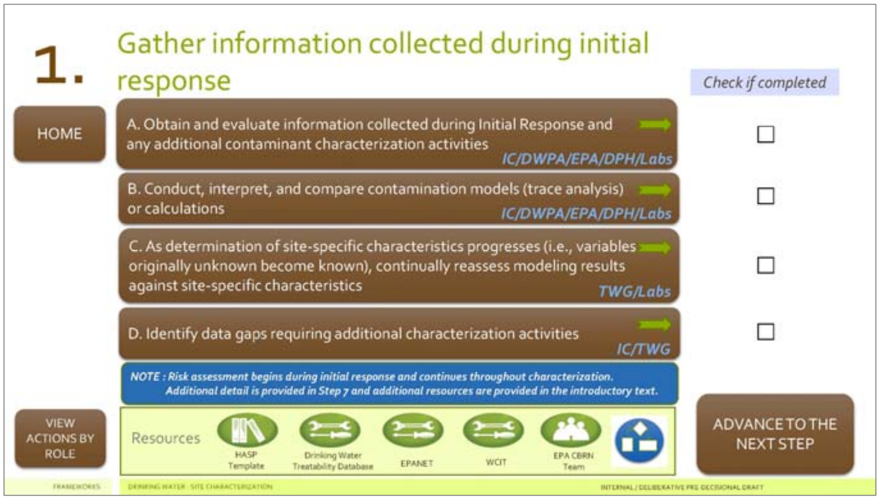
## Decontamination Preparedness and Assessment Tool- CHARACTERIZATION PHASE

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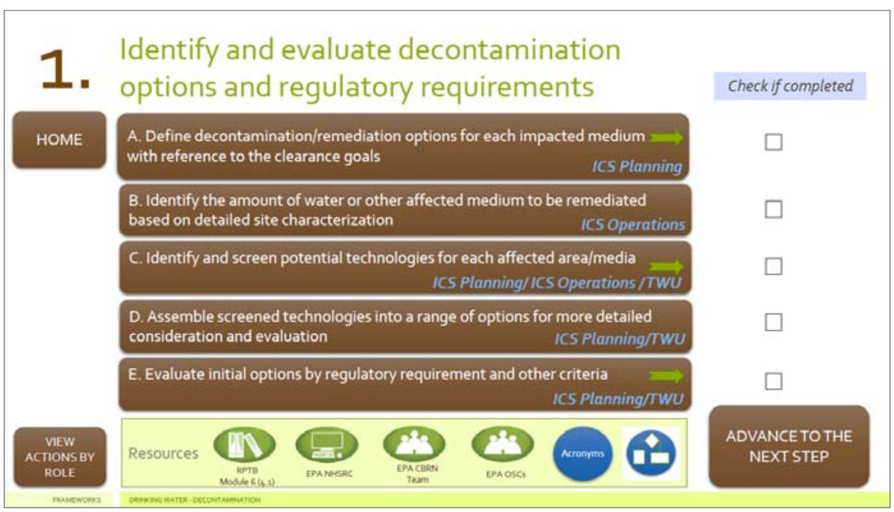
## Decontamination Preparedness and Assessment Tool- DECONTAMINATION PHASE

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## Decontamination Preparedness and Assessment Tool- CHECKLIST

Decision-Making Frameworks - Drinking Water Checklist

| Steps in Characterization Phase | |
|---|---|
| | 1. Gather information collected during initial response |
| ☑ | A. Obtain and evaluate information collected during Initial Response and any additional contaminant characterization activities |
| ☑ | B. Conduct, interpret and compare contamination models (trace analysis) or calculations |
| ☑ | C. As determination of site-specific characteristics progresses (variables originally unknown become known), continually reassess modeling results against site-specific characteristics |
| ☑ | D. Identify data gaps requiring additional characterization activities |
| | 2. Determine site-specific characteristics for utility |
| ☑ | A. Determine contamination vulnerability and characteristics for all components within affected utility areas based on understanding of potential pathways of contaminant dispersion, including runoff |
| ☑ | B. Compile list of geographically located potential contamination areas using utility system maps and distribution system hydraulic models |
| ☐ | C. Determine the dimensions of impacted areas (surface area and volume) and map potential contamination areas and affected populations |
| ☐ | D. Update models with site-specific characterization information as appropriate |
| ☐ | E. Develop characterization priorities |
| | 3. Develop detailed characterization sampling and analysis plan |
| ☐ | A. Develop a Comprehensive Characterization Sampling Strategy |
| ☐ | B. Write incident specific Characterization Sampling and Analysis Plan (SAP) for environmental sampling |
| ☐ | C. Approve Characterization SAP |
| | 4. Evaluate initial containment of contamination and improve as necessary |
| ☐ | A. Evaluate and provide recommendation to update initial hot zone boundaries and subsequent adjustments to warm and cold zones using new information from characterization efforts |
| ☐ | B. Approve update to initial hot, warm and cold zone boundaries |
| ☐ | C. Adjust boundary controls, as necessary (hotline, contamination control line) |
| ☐ | D. Recommend additional agent containment and source reductions (i.e., isolate water distribution systems within hot zone to contain contamination) |
| ☐ | E. Approve recommendation for additional containment |
| ☐ | F. Implement recommended strategies for additional containment |
| | 5. Implement Sampling and Analysis Plan for Characterization Activities |
| ☐ | A. Conduct characterization sampling for water, outdoors and enclosed/semi-enclosed structures |
| ☐ | B. Analyze water, surface and air samples from potentially contaminated areas |
| ☐ | C. Evaluate results of characterization sampling and analysis efforts to determine if data are sufficient or if additional sampling is required |
| ☐ | D. Monitor, re-evaluate and adjust sampling strategy, plans and methods as necessary |
| | 6. Identify and prioritize areas, operations and/or facilities within contaminated area for detailed remediation |
| ☐ | A. Identify geographic parameters within zone(s) requiring PPE (e.g. areas served by contaminated drinking water distribution system) |

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## On-line Decontamination Training for Water Sector

### Training Course Outline: Drinking Water and Wastewater

- Module 1: Introduction
- Module 2: Characterization Phase
- Module 3: Decontamination Phase / Clearance
- Module 4: Waste Management
- Module 5: Case Study

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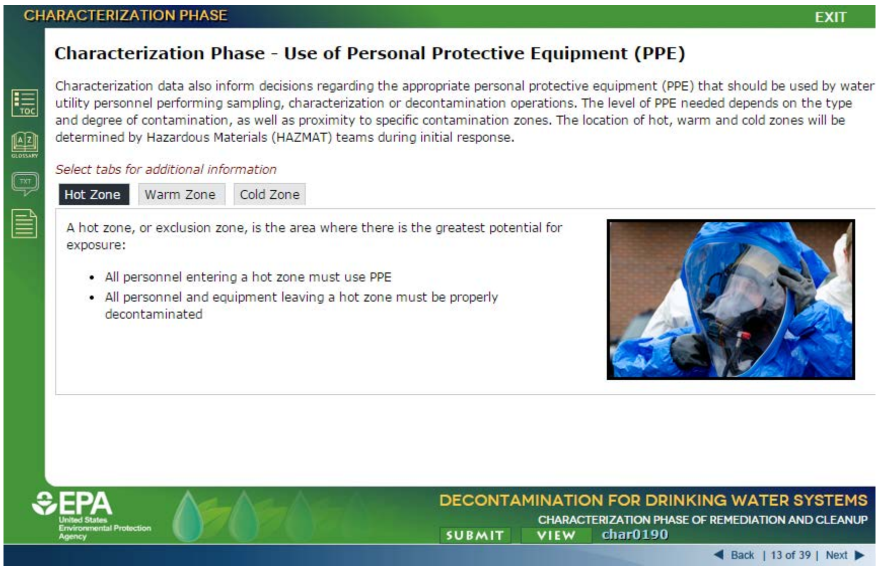
## On-line Decontamination Training for Water Sector

### Example Training Page

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## Outline

- EPA Homeland Security Roles
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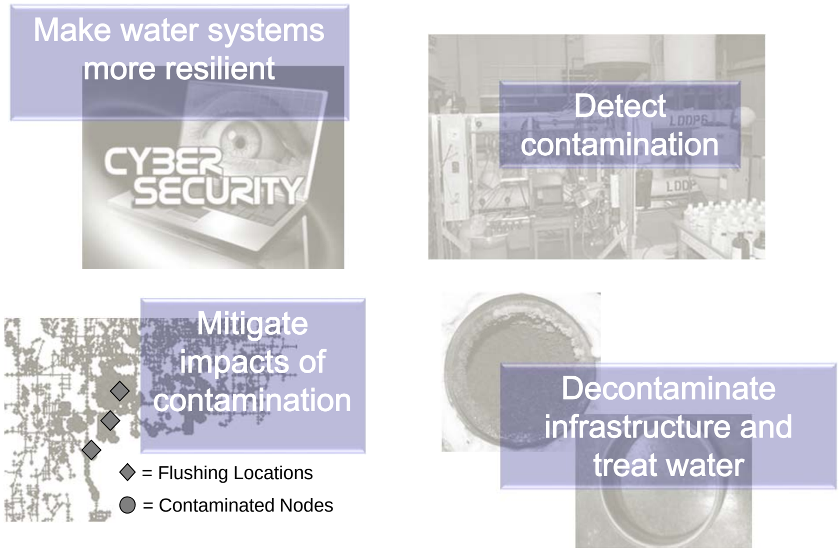
## Supporting Research by EPA's Homeland Security Research Program




http://www.epa.gov/nhsrc

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## Contact Information

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**Decontamination website:**
http://water.epa.gov/infrastructure/watersecurity/emerplan/decon/index.cfm

**Research website:**
http://www.epa.gov/nhsrc

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# 2015 U.S. EPA International Decontamination Research and Development Conference

## Wednesday, May 6, 2015

## Concurrent Sessions 2

### Biological Agent Detection





MRIGlobal
National Solutions Worldwide Impact

# Sample Preparation Considerations for Detection of Biological Threat Agents in Complex Environmental Matrices

Richard Winegar, PhD

Chief Scientist for Biosurveillance & Diagnostics

**2015 EPA International Decon R&D Conference**

Defense Energy Health

## MRIGlobal Overview

- Independent not-for-profit organization
- Founded in 1944 as Midwest Research Institute
- Performs contract research and development for government, industry, and academia
  - – Global Health
  - – Energy
  - – National Security

**FOUNDATIONAL BIOSURVEILLANCE PROGRAMS**

**United States Air Force**

- >10 year biothreat detection program
  - ➢ Sample preparation and characterization
  - ➢ Complex environmental samples
  - ➢ Trace level agent detection
  - ➢ Engineering – collector and collection matrix assessment

**Federal Bureau of Investigation**

- Amerithrax (one of four labs)
  - ➢ Developed Morph B, D assays
  - ➢ Evidentiary analysis

**NCR Operational Biosurveillance**

- Daily and non-routine biothreat analysis
  - ➢ Established following Anthrax letters in October 2001
  - ➢ Operated without interruption (24/7/365)
  - ➢ Multiple Clients with NCR



Global Health Security 2

## The Opportunities: New Technologies

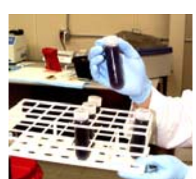
- Detection technologies are continually improving
- Smaller
- Faster
- More Sensitive
- Higher multiplexing
- Next Generation Sequencing (NGS) provides promise of ultimate level of characterization



## The Challenge: Sample Preparation

- Sample Preparation often doesn't get the same attention as new detection technologies
- Automated sample preparation technologies input requirements usually limited to small volumes and relatively clean samples
- Can lead to disconnects between user requirements
  - Sample type
  - Detection limits
- NGS presents further challenges

- Small
- Pure
- Concentrated
- Intact



- Large (vol or mass)
- Complex
- Trace-level
- Degraded

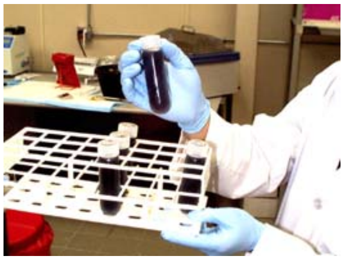
## "Standard Sample"

- Small
- Relatively clean
- Target present at relatively high levels
- Validated protocols available
- Examples
  - Swabs
  - Wipes
  - Low-volume air collectors



## Challenging Samples

- Environmental samples may be in varied forms
  - Soil
  - Water sediments
  - Large water volumes
  - Bulk items
  - Vegetation
  - Etc.
  - Depending on sampling site, even "standard" samples may be heavily soiled



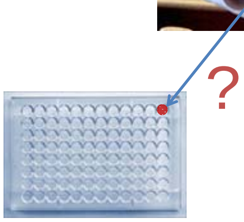
### 3D Challenge

- Dirty
- Degraded
- Dilute

6/10/2015 Global Health Security 7

### Dirty

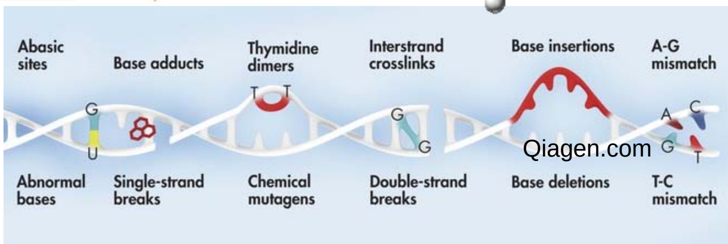
- Bulky
  - Must work against tyranny of the microtiter plate
- Interferences with extraction
  - Clays
  - Organic materials
- PCR inhibitors
  - Humic acids
  - Fulvic acids
  - Polyphenols
  - polysaccharides
  - Metals
  - Extraneous DNA
- Near genetic neighbors




Global Health Security 8

## Degraded

- Environmental stresses
  - UV, heat, chemical and biological degradation
- DNA may be outside of cell or virus
- Nonviable—can't confirm positives by culture
- DNA may be too fragmented to be analyzed by certain methods
- Situation likely to be even worse for RNA

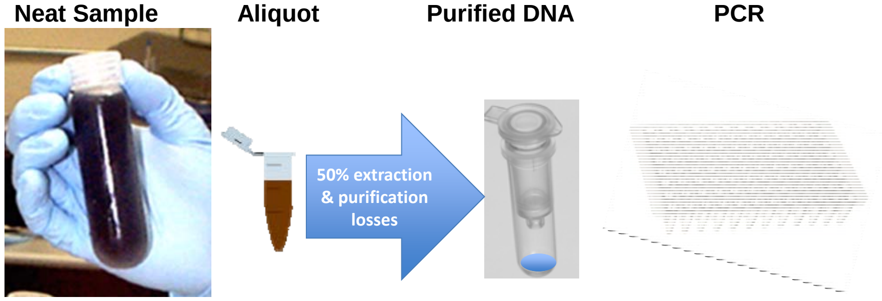






## Dilute

- Trace-level of target in bulk sample
  - Sample aliquot may not have sufficient level of target
- Sensitivity of assays
  - Assay may have 10-copy sensitivity, but will 10 copies make it through entire process?
- Contamination
  - Important for all PCR, but particularly for trace-level detection
  - Can you believe low level detection results?

**Neat Sample** **Aliquot** **Purified DNA** **PCR**




| | Neat Sample | Aliquot | Purified DNA | PCR |
|---|---|---|---|---|
| **Sample vol** | 10,000 | 1000 | 100 | 5 µL |
| **Target** | 1,000 | 100 | 50 | 2.5 copies |

## Next Generation Sequencing

**Opportunities**

- Non-biased total sequencing of sample
  - Identify threat agents without prior knowledge
- Strain/sub-strain-level ID
- Metagenomic profiles
- RNA seq
  - Determine viability with pre-rRNA transcripts?

**Challenges**

- Complex microbial background
  - Produces large number of "wasted" reads
- Near genetic neighbors
- Sample preparation
  - Generate sufficiently clean and concentrated sample compatible with library prep
- Library preparation
  - Complex procedure
  - Limited input mass and vol
- Inhibitors
  - May be different than PCR inhibitors
- Stability of genetic material
- Bioinformatics



## Example Development Process

**Conceptualization**

- Define Requirements
- Workflow Concept
- Protocol Development Plan

**Protocol Development**

- Baseline Characterization
- Optimization
- Integration
- Verification

**Validation**

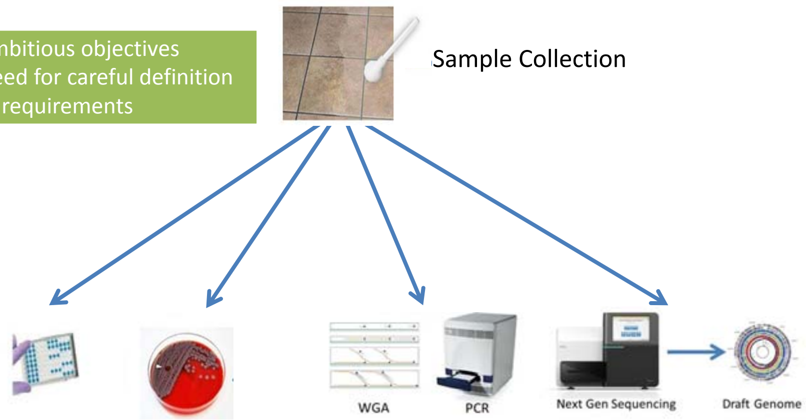
- Internal Verification Test
- Training
- External verification (TT)
- Inter-Laboratory Validation (PVaT)

**Publication**

## Initial Program Concept

*Validate integrated workflow for sample collection, processing and analysis of bioforensic samples*

- Ambitious objectives
- Need for careful definition of requirements






## Concept Elements: Sample Collection

### Considerations

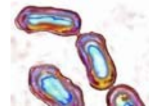
- Partitioning or duplicate samples needed to provide sample/portion for live culture, NA and archiving
- Compatibility of devices to common extraction methods

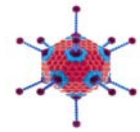
### Elements

- **Devices:**
  - Puritan Environmental Sample Swab (ESS)
  - MRIGlobal Bioforensics Collector with *in situ* extraction
- **Surface:** glazed ceramic floor tile
- **Background:** Non-sterile loam soil
- **Replicates**
  - Swabs
    - 1 collection for nucleic acids
    - 1 collection for live culture and immunoassays
  - BFC
    - 1 collection for all assays
- **Archiving:** Portion of extract

## Concept Elements: Organisms

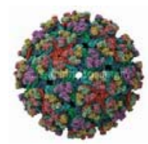
- *B. anthracis* Sterne spores (Gram positive)
- *Y. pestis* A1122-vegetative cells (Gram negative)
- Adenovirus (DNA virus)
- Venezuelan Equine Encephalitis virus TC-83 (VEEV) (RNA virus)
- Ricin (toxin)





**Considerations**

— Live culture recovery of various targets require different methods and growth conditions



— Obtaining pure isolates will be confounded by presence of other targets/organisms

— Stability of targets is variable

— Can't validate every possible organism, but these represent the spectrum of threat agents



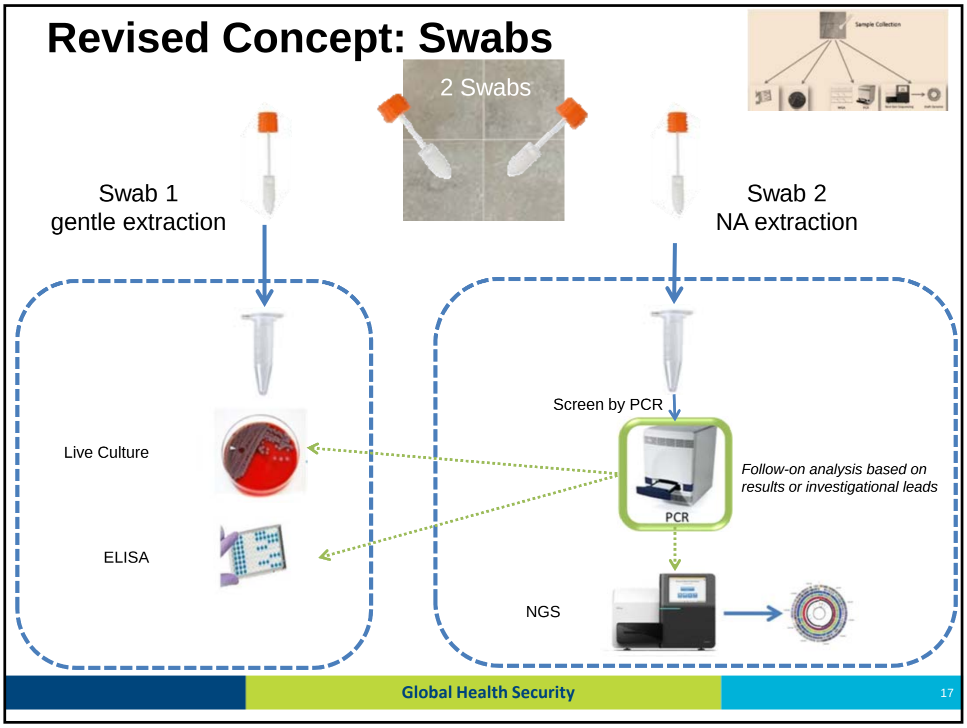
## Concept Elements: Analysis Methods

- Real Time PCR
- Next Generation Sequencing
- Live Culture
- Immunoassay-ELISA

**Considerations**

– Differences in assay/method sample requirements and sensitivities (each analytical method will have its own LoD)

– Limited extract volume from single sample needs to accommodate multiple analyses


Revised Concept: Swabs
2 Swabs
Swab 1
gentle extraction
Swab 2
NA extraction
Screen by PCR
Live Culture
ELISA
PCR
Follow-on analysis based on results or investigational leads
NGS
Global Health Security
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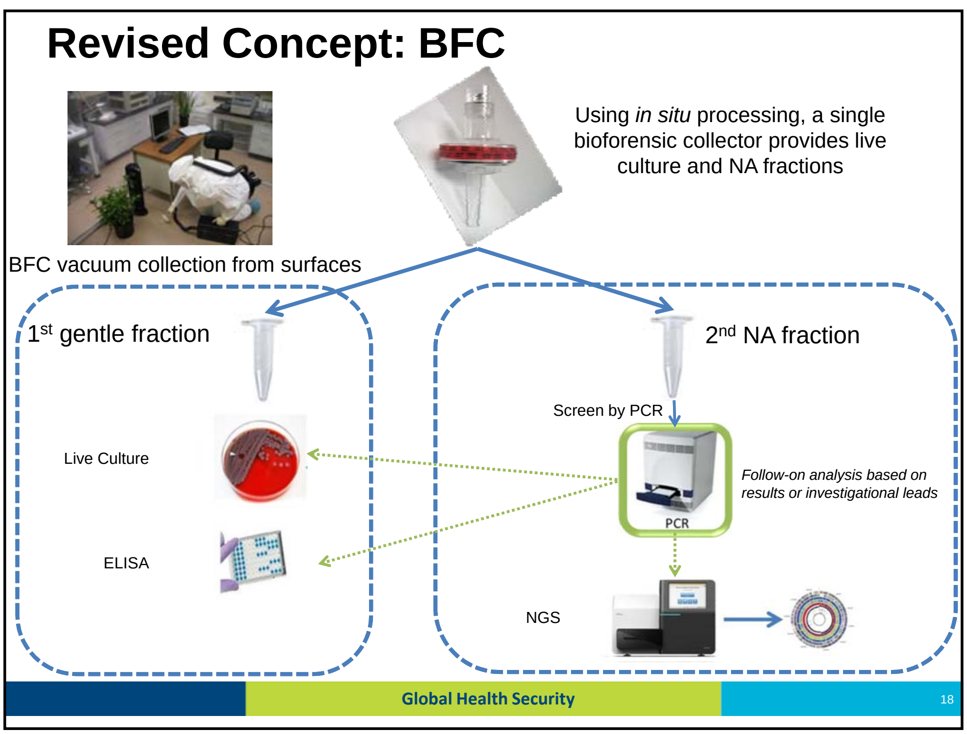
Revised Concept: BFC
Using in situ processing, a single bioforensic collector provides live culture and NA fractions
BFC vacuum collection from surfaces
1st gentle fraction
2nd NA fraction
Screen by PCR
Live Culture
ELISA
PCR
Follow-on analysis based on results or investigational leads
NGS
Global Health Security
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## Phase 2: Protocol Development

**Baseline Characterization**
- Evaluate candidate methods for live culture and nucleic acid extraction

**Optimization**
- Maximize target recovery
- Enhance sensitivity

**Integration**
- Integrate methods into workflow
- Determine LRD, ruggedness and robustness

**Internal Verification Test**



## Phase 3: Validation Tasks

Each phase of validation supported by Test Plans and Summary Reports for **Go/No Go** decision points to move forward through each phase of validation

**Validation**
- Protocol Verification Test (PVT)
- **Technical Transfer**
  - Training and transfer of SOPs to receiving laboratory
  - Provide oversight for receiving lab PVT
- Manage Inter-Laboratory Validation Test
  - Provide blinded samples
  - Conduct validation test simultaneously with receiving lab

**Publication**

## Points to consider

- **Sampling**
  - sample aliquot contain sufficient analyte
  - Adequate extraction method?
  - Interfering substances
- **Extraction**
  - Input volumes
  - Losses
  - Form of analyte targeted
    - spore, cellular, free DNA
  - Inhibition removal
  - Output vol. and analyte concentration
  - Compatibility with downstream analysis
- **PCR**
  - Controls for inhibition & Contamination
  - Sensitivity
  - Input volumes
  - Follow-up confirmatory methods
- **NGS**
  - Range of organisms of interest
  - Genetic near neighbors
  - Enrichment
  - Targeted or shotgun
  - DNA and/or RNA
  - Appropriate library prep method
  - Depth & breadth of required coverage
  - Analytical Objective: detection, characterization, viability?
  - Appropriate bioinformatics tools

Workflow conceptualization helps identify and integrate the most appropriate methods for the particular challenge



## Acknowledgments


- DHS Chemical and Biological Division, Science and Technology Directorate, Bioforensics Research and Development Program for funding support. Contract # HSHQDC-12-C-00050
- Various stakeholders who provided valuable feedback
- MRIGlobal staff
  - Valorie Ryan, PhD
  - Jennifer Rannings
  - Joe Carrano
  - Candy Health
  - Brittany Knight
  - Jennifer Stone
  - Robert O’Shea

# 2015 U.S. EPA International Decontamination Research and Development Conference

## Wednesday, May 6, 2015

## Concurrent Sessions 2

### Water Infrastructure Decontamination





# DECONTAMINATION AND RESTORATION OF CRITICAL WATER AND WASTEWATER INFRASTRUCTURE

**2015 EPA International Decontamination Conference**



## Disclaimer

The U.S. EPA through its Office of Research and Development funded the research described in this presentation. It has been reviewed by the Agency but does not necessarily reflect the Agency's views. No official endorsement should be inferred. EPA does not endorse the purchase or sale of any commercial products or services.

ADVANCING OUR NATION'S SECURITY THROUGH SCIENCE

# Outline

- **EPA Homeland Security Roles and Water Research**
- **Overview of decontamination and restoration of critical water and wastewater infrastructure**
- **Facilities for Decontamination and Treatment Research**



# EPA Homeland Security Roles

- Protecting drinking water and wastewater **infrastructure**
- Indoor and outdoor clean-up following an attack, natural disaster, industrial accidents, etc.
  - can use **millions of gallons of water**
  - can **result in even more contaminated wastewater**
- Development of a **nationwide laboratory network**
- **Reducing vulnerability** of chemical & hazardous materials
- **Cyber security**

## Water Security Projects

Multi Use → Homeland Security

Multi Use → Catastrophes: Natural Disasters, Accidents, etc.

Multi Use → "Normal" Operations

For example, decontamination approaches for use after intentional contamination might also be **useful after natural disasters and industrial accidents**, **as well as routine system maintenance.**



## Research to Support Water Systems

- **Make water systems more resilient**
- **Mitigate impacts of contamination**
- **Detect contamination**
- **Treat water**
- **Decontaminate infrastructure**

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# Outline

- EPA Homeland Security Roles and Water Research
- <u>Overview</u> of decontamination and restoration of critical water and wastewater infrastructure
- Facilities for Decontamination and Treatment Research

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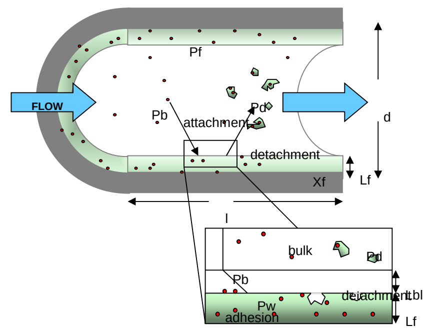
# Selected Projects

- State of science review of water system decontamination
- Persistence and removal of CBR contaminants from drinking water pipes studied with USEPA's pipe decontamination experimental design (PDED)
- Impact of CBR contaminated sediments on flushing and decontamination of drinking water storage facilities
- Decision support tools for responding to water distribution incidents and decontaminating infrastructure

EPA ORD's Homeland Security Research Program 9

## State of science review of water system decon

- Publications from EPA represent the majority of research in some areas
- Provides data for decontamination resources
- Reference key to literature
- Gap analysis to guide research

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## Current Report Considerations

- Chemical: inorganics (As, Hg), petroleum products, toxins, CWA, pharmaceuticals, organics (chlordane, chloropyrifos, parathion, sodium fluoroacetate and p-dichlorobenzene)
- Biological: spore forming bacteria, vegetative bacteria, viruses
- Radionuclide: cesium, strontium, cobalt
- Infrastructure materials: unlined iron (corroded), cement-mortar lined iron, PVC (plastic), copper
  - Other materials were included if compelling data was identified
- Type of experimental system: how representative of reality is it?

## Future considerations

- The current report identifies gaps in the current literature with respect to contaminant-infrastructure persistence data that is not available
- It also provides suggestions for future decontamination work in areas where persistence is observed
- The report will be updated and reissued periodically as new data is published
- EPA/NHSRC will perform research to fill those gaps
  - **We hope others will too**

Szabo, J. G. and S. Minamyer. Decontamination of Chemical Agents…, *Environment International*, 72:119-123, (2014).
Szabo, J. G. and S. Minamyer. Decontamination of Biological Agents…, *Environment International*, 72:124-128, (2014).
Szabo, J. G. and S. Minamyer. Decontamination of Radiological Agents…, *Environment International*, 72:129-132, (2014).



## Selected Projects

- **State of science review of water system decon**
- **Persistence and removal of CBR contaminants from drinking water pipes studied with USEPA's pipe decontamination experimental design (PDED)**
  **(see 11:05 talk in this session by Ryan James)**
- **Impact of CBR contaminated sediments on flushing and decontamination of drinking water storage facilities**
- **Decision support tools for responding to water distribution incidents and decontaminating infrastructure**

# Background

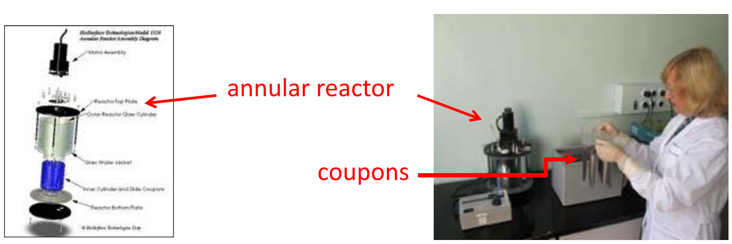
- Problem: Drinking water pipes can sorb contaminants that are introduced either accidentally or by some purposeful means.
- Objectives: Provide data to help decision makers develop a decontamination strategy for contaminated pipe materials




# EPA's Pipe Decon Experimental Design (PDED)

**Design for realistic studies of persistence and decon**

- Can be implemented in reproducible fashion across laboratories and for various contaminants and pipe materials
- Conditions within operational drinking water pipes are simulated in annual reactors (ARs)
- ARs contain coupons of pipe materials: copper, PVC, cast-iron, and mortar lined ductile iron
- Contaminants: chem, bio, rad
- Decontamination methods: flushing and hyperchlorination



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# Selected Projects

- **State of science review of water system decon**
- **Persistence and removal of CBR contaminants from drinking water pipes studied with USEPA's pipe decontamination experimental design (PDED)**
- **Impact of CBR contaminated sediments on flushing and decontamination of drinking water storage facilities**
  **(see 11:30 talk in this session by Jeff Szabo)**
- **Decision support tools for responding to water distribution incidents and decontaminating infrastructure**

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# Background

- Problem: Sediments in drinking water tanks can adsorb and act as reservoirs for toxic substances introduced either accidentally or by some purposeful means.
- Objectives: Results useful for assessing impacts of an incident and selecting effective methods for handling contaminated sediments and decontaminating the tanks.

# Approach


Tank cleaning company collecting sediments

Lab contaminant adherence studies

Sediments from different tanks can vary a lot!



# Selected Projects

- **State of science review of water system decon**
- **Persistence and removal of CBR contaminants from drinking water pipes studied with USEPA's pipe decontamination experimental design (PDED)**
- **Impact of CBR contaminated sediments on flushing and decontamination of drinking water storage facilities**
- **Decision support tools for responding to water distribution incidents and decontaminating infrastructure**

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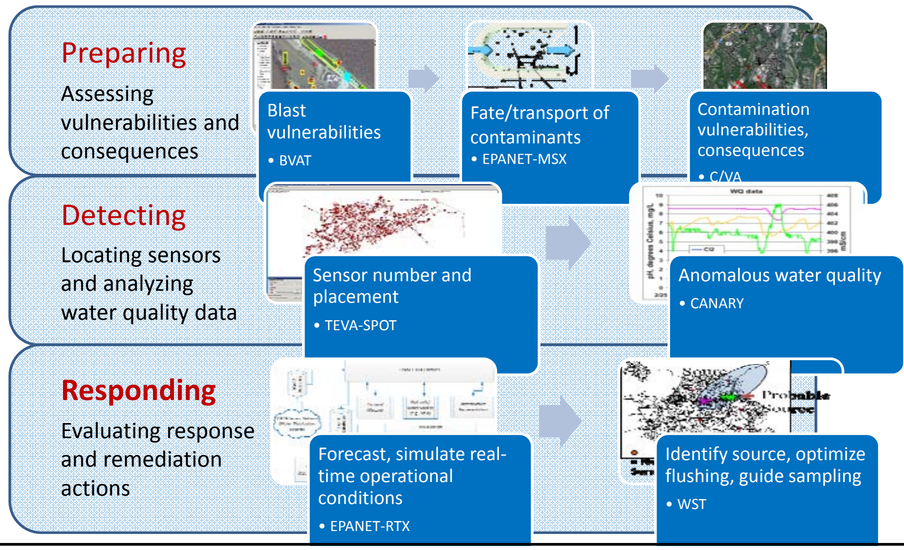
## Suite of Water Security Tools

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# Water Security Toolkit (WST)

**Objective:** Integrate a suite of cutting-edge, automated modeling, simulation, and optimization tools into a user friendly software tool in order to support rapid and effective water utility decision making

**WST will help identify:**

- Best sensor locations to detect contamination
- **Origin of contamination in the network**
- **Best sampling locations to confirm contamination or clean-up**
- **Tanks and/or areas that need to be isolated**
- **Best injection location of chlorine or other decontaminating agents to neutralize and/or inactivate contaminant**
- Region of system that needs public notification
- **Best hydrants to flush out contaminated water**

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## Intended Use of WST

- Plan for response to natural disasters and terrorist attacks and compare response actions
  - Develop consequence management plans
  - Inform large-scale exercises/training
- Plan for response to traditional utility challenges (pipe breaks, water quality problems, …)
  - Evaluate implications of different response strategies
- Optimize and implement response actions in real-time
  - Use data from event detection software, sensor stations, field investigations
- Incorporate software tools to create real-time situational awareness tool (future vision)

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## Outline

- **EPA Homeland Security Roles and Water Research**
- **Overview of decontamination and restoration of critical water and wastewater infrastructure**
- **Facilities for Decontamination and Treatment Research**

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Some unique facilities for in-house research at NHSRC in

## Cincinnati, Ohio

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### Test and Evaluation Facility – Cincinnati, Ohio

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# Single Pass Simulator

- 1200 feet of 3 inch cast iron pipe
  - Flow is 1 ft/sec
- Sensors are located at 80 and 1100 ft from the injection point
- Sensors only see the contaminants once
  - Spatial differences can be observed
- Contaminants injected with a pump


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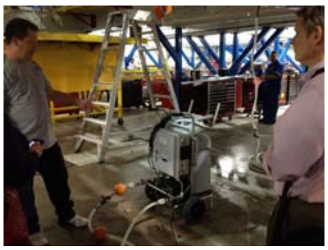
# Distribution System Simulator

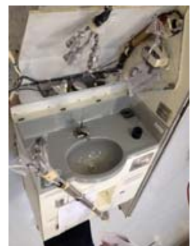
Clear PVC pipe with sampling ports and fire hydrant connection.

Removable coupons of different pipe materials for decontamination studies

## Mock Aircraft Water System

- Being constructed--modeled after a Boeing 737 water system, with an actual Boeing water tank
- The mock system will be contaminated with the isolated coliforms and persistence/colonization observed
- Various decontamination techniques will be attempted







**Some unique facilities for in-house research at NHSRC in**

## Idaho Fall, Idaho

**(See 10:40 talk in this session by Stephen Reese)**

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# The Water Security Test Bed (WSTB)

- Located at Idaho National Lab (INL)
  - Idaho Falls, Idaho (SE portion of state)
- Above ground drinking water pipe system with a 40,000 gallon lagoon, high rate groundwater pump, and storage tanks
- The WSTB can support research on distribution system decontamination, sensors, cyber security, and wash/flush water treatment
  - Construction underway
  - Decontamination and flush water treatment will be the initial focus (Sept. 2014)
- Located near adjacent office building with plumbing
- CBR agents or simulants

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# Project Goals

- Construct a full scale pipe simulator connected to a treated water supply with functioning fire hydrants
- Field deploy and test potential water security technologies and methods to detect contamination events and decontaminate drinking water infrastructure

## Why is WSTB important

- Realistic and representative water distribution system contamination events
- Remedial technologies and methods can be applied
- Best performing technologies and methods can be made available to help improve community water system resilience.



## Thank you!

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**http://www.epa.gov/nhrsc**

# The Water Security Test Bed:

***A Large Scale Test Bed for Water Infrastructure Decontamination in collaboration with the USEPA National Homeland Security Research Center***

Stephen Reese
May 6, 2015

www.inl.gov

## *Background*

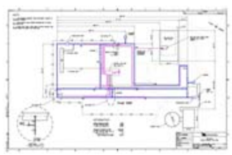
US EPA and INL partnership to create a unique water security center for research, development, and testing related to national water security and other drinking water distribution issues.

- Addresses biological, chemical, radiological, and cyber vulnerabilities due to natural, accidental, or malicious acts
- Supports testing and demonstration of full size or near full size components
- Enables development and testing of methods for monitoring and decontaminating water infrastructure
- Leverages INL's supporting infrastructure:
  - Remote, accessible location
  - Cyber security program
  - Radiological support
  - Full range of facility services support

## Current Status & Future Objectives

- EPA funded Phase I of the WSTB in FY2013-2014
- First experiments conducted in September – October 2014
- EPA & INL planning for additional experiments in 2015 using current configuration
- Completion of WSTB in FY2015 not feasible due to lack of funding
- Reaching out to other stakeholders for partnering opportunities to enable completion of the system
- Complete build out of the system and associated infrastructure
- Develop multi-agency national user facility
  - Potential collaborators include DHS, DOD, AWWA

Concept

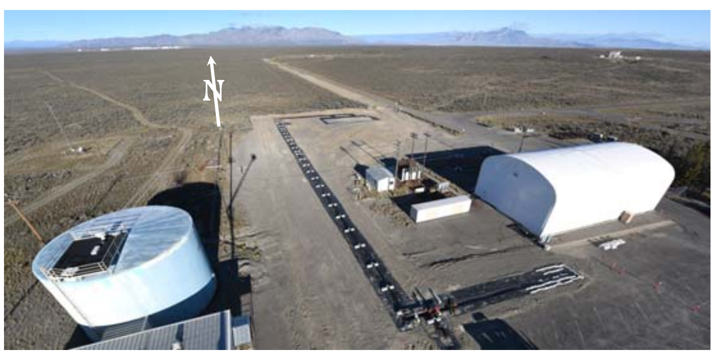


Design

Build

Test & Operate

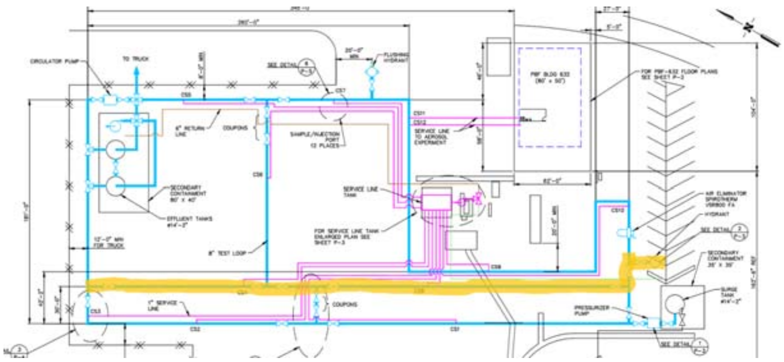
## Present Configuration




Phase I of the test bed is a once through system

- ~445' of 8" cement mortar lined, ductile iron pipe (water main)
- 6 × 1" service connections/sample ports, 2 hydrants
- 15' pipe material coupon section for sampling the interior of the pipe surface
- 2 water quality monitoring stations measuring chlorine and TOC levels
- Above ground system, underlined by secondary containment

## Complete Loop Plan

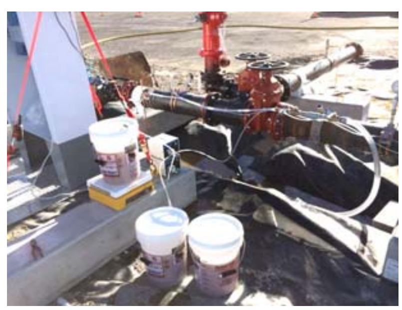


When completed the test bed will consist of a recirculating main pipe loop with four sub loops, each of which can be isolated from the rest of the system.

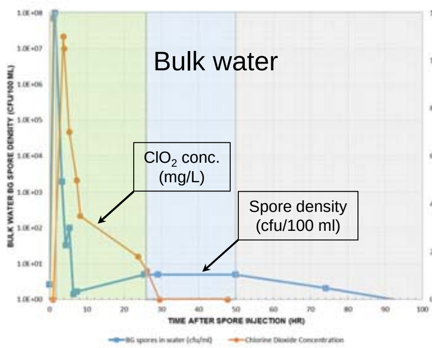
- Cover ~2 acres on the INL desert site.
- ~2100' of 8" ductile iron pipe (water main) + ~2800' of 1" Cu line (individual service connections).
- Pipe loop volume of ~5500 gallons + 3 × 12,000 gallon storage tanks and pumps to pressurize and circulate water in the loop.

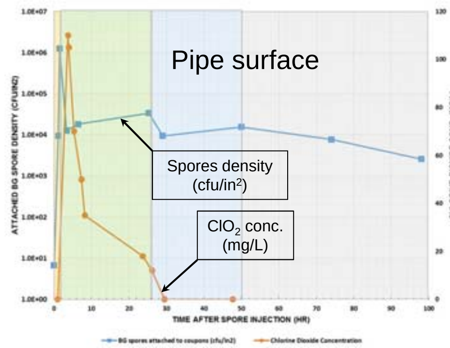
## 2014 Experiments

- A dye test (tracer) to evaluate travel times and system flows
- Sodium thiosulfate ($Na_2S_2O_3$) injection to remove free chlorine from the pipe – successfully triggered automated fire hydrant flushing device
  - Residual sodium thiosulfate in pipe dead legs released with subsequent hydraulic changes.



## 2014 Experiments cont.



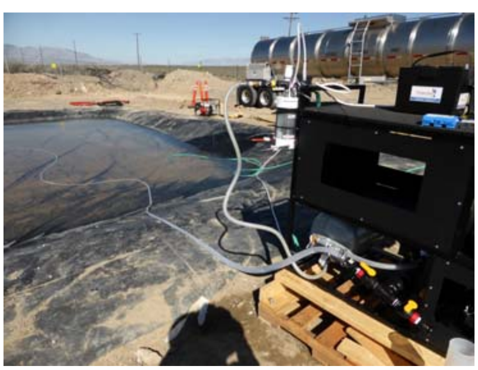




- Contamination with *B. globigii* and $ClO_2$ decontamination
  - Effective (5-8 $\log_{10}$) removal of *B. globigii* in bulk water
    - Decontamination with $ClO_2$ for 24 hours (110 mg/L initial concentration; 12 mg/L $ClO_2$ after 24 hours)
  - Less effective removal (~2 $\log_{10}$) from the pipe surface

Idaho National Laboratory

## 2014 Experiments cont.

- WaterStep® Portable Water Treatment System treated effluent lagoon water to disinfect spores flushed from the WSTB pipe.
  - System is designed to disinfect water (by on-site chlorine generation) for human consumption or discharge.
  - Chlorine generation and disinfection efficacy were evaluated.



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## 2015 Experiments

- Additional $ClO_2$ decontamination and flushing of system
- Biofilm growth in the water main
- Effluent lagoon treatment using $Cl_2$, UV, and/or UV+$O_3$
- Crude oil contamination and decontamination - simulating a refinery/rail transport accident
- Cyber attack on system instrumentation and communications

Idaho National Laboratory

## Experiment Concepts Beyond 2015

Future studies may focus on:

- Aerosolization of biological agent via a shower head
- SCADA vulnerabilities in water infrastructure
- Chem/rad/bio contamination due to natural, accidental, or intentional acts
- Testing and validation of water system components
- Household appliance decontamination
- First responder training exercises

## Challenges & Opportunities

Challenge

- Current scale and capability of WSTB not adequate to sustain a diverse research portfolio
- Additional funding is needed to enable infrastructure build out and operation of the WSTB
  - Additional research partners required to develop program

Opportunity

- National research asset for water security and the Water Energy Nexus
- Address gaps in threat identification and response (chem/rad/bio/cyber) in water infrastructure protection – through large scale, applied research and demonstration at a remotely located, dedicated facility

## Questions?

Contacts

Idaho National Laboratory

- Steve Reese (stephen.reese@inl.gov)
- Mike Carpenter (michael.carpenter@inl.gov)

US EPA

- Jim Goodrich (goodrich.james@epa.gov)

Disclaimer: The U.S. Environmental Protection Agency through its Office of Research and Development funded and managed the research described here. It has been subjected to the Agency's review and has been approved for publication. Note that approval does not signify that the contents necessarily reflect the views of the Agency. Mention of trade names, products, or services does not convey official EPA approval, endorsement, or recommendation.

# Persistence of Simulated Radionuclides on Drinking Pipes

*Ryan James, Elizabeth Hanft, Battelle*
*Jeff Szabo, Matthew Magnuson, John Hall*
*EPA National Homeland Security Research Center*

*2015 EPA International Decontamination*
*Research and Development Conference*
*Research Triangle Park, NC*
*May 6, 2015*

Office of Research and Development
Homeland Security Research Program

## Water System Decontamination

- Possibility of attacks on water systems is coupled by reality of decontamination
  - Treatment plants
  - Distribution systems
- What decontamination approaches would be used?
- How effective are they?
- What levels need to be achieved?

# Project Overview

- Testing of the pipe decontamination experimental design with a simulated radiological contaminant
  - –Determine adsorption of contaminant to drinking water pipe materials
  - –Testing of methods for decontaminating affected pipe surfaces if contaminant persists
  - –Testing of the pipe decontamination experimental design with a simulated radiological contaminant

# Technical Approach

- Pipe Selection
  - – Cement-lined and PVC annular reactor coupons
- Contaminant Selection
  - – cesium, cobalt, and strontium
- Contamination Method
  - – Biofilm growth in dark
  - – Equilibration with contaminated solution
- Contaminant Detection Methodology
  - – ICP-MS

## Experimental Design

- Step 1: Contaminant Extraction
  - Five drops (7.5 µg each contaminant) added directly to biofilm covering coupon surface at concentration of ~$10^6$ CFU/mL
  - Extraction of contaminant from PVC surface using nitric acid and concrete is digested
- Step 2: Surface Contamination
  - Equilibrate coupons in 1 L of contaminated deionized water for 2 hours
    - 100 mg/L contaminant
    - Annular reactor rotating at 100 rpm

## Step 1 - Surface Contamination Extraction Results

| | Concrete (% Recovery) | | PVC (%Recovery) | |
|---|---|---|---|---|
| | **Avg** | **SD** | **Avg** | **SD** |
| **cobalt** | 11 | 6 | 62 | 4 |
| **cesium** | 18 | 4 | 95 | 17 |
| **strontium** | BG | BG | 101 | 15 |

- Strontium contamination level did not exceed the background in the concrete
- Concrete coupon backing was not extracted

## Step 2 - Surface Contamination Results

| Step 2 - contamination (factor above blank) | | | | |
|---|---|---|---|---|
| | Concrete | | PVC | |
| | Avg | SD | Avg | SD |
| **cobalt** | 41 | 29 | 152 | 20 |
| **cesium** | 31 | 9 | 63 | 8 |
| **strontium** | 7 | 4 | 26 | 5 |

- Cobalt and cesium contaminated well above blank levels for both surfaces while strontium was less different
- Strontium contamination performed with higher concentration
- 0.003% – 0.03% of available contaminant absorbed

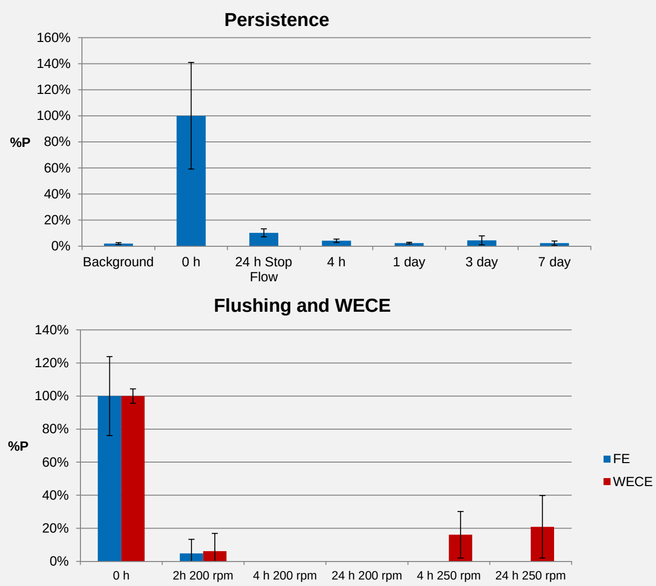
## Persistence Evaluation Experimental Design

- Equilibrated coupons in 1 L of contaminated deionized water for 2 hours
  - 100 mg/L contaminant (10g/L for strontium)
  - Annular reactor rotating at 100 rpm with no flow
- Removed three coupons as control coupons
- Filled AR with tap water and had no flow or rotation for 24 hours (removed three coupons)
- Flow water set at 0.2 L/min and rotating AR at 100 RPM and removed three coupons after 4 hr, 1 day, 3 days, and 7 days.

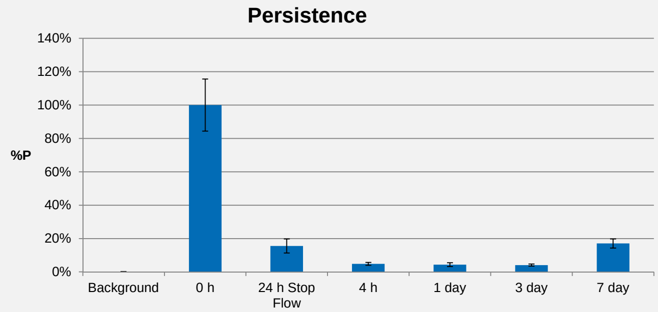
## Flushing Evaluation Experimental Design

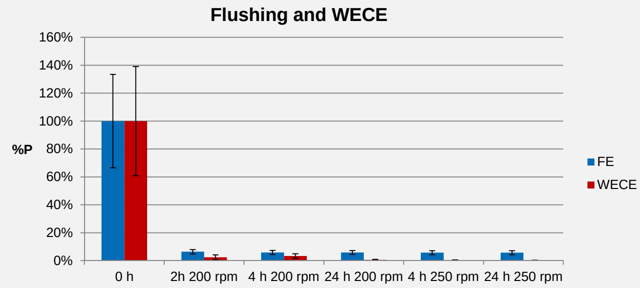
- Same as persistence evaluation except
  - No 24 hr stopped flow
  - Flow water set at 0.2 L/min and rotating AR at 200 RPM and removed three coupons after 2 hr, 4 hr, and 1 day
  - Increased AR to 250 RPM and removed three coupons after 4 hr and 1 day
- Results compared directly to Water Exposure Control Experiment (WECE) results

## Cesium on Concrete

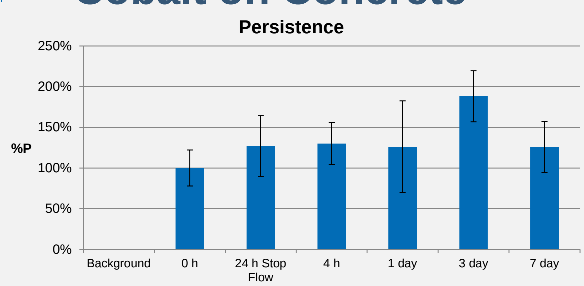


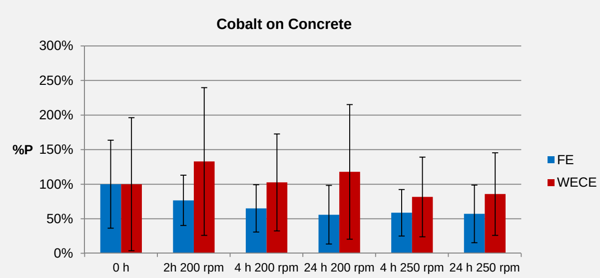
# Cesium on PVC

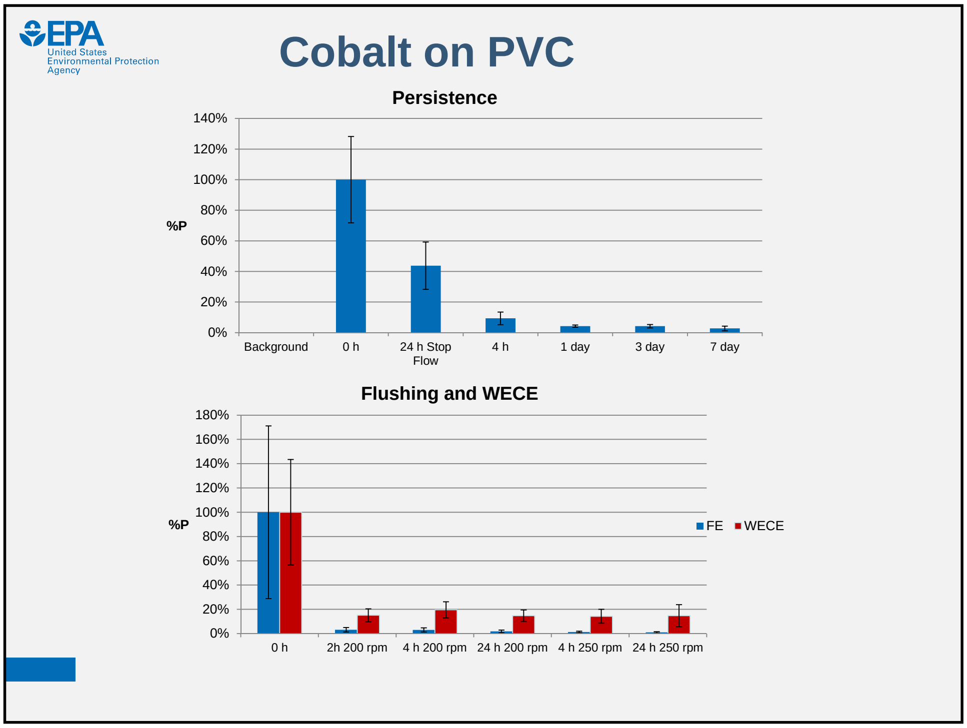



# Cobalt on Concrete

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United States Environmental Protection Agency
Cobalt on PVC
Persistence
%P
Background
0 h
24 h Stop Flow
4 h
1 day
3 day
7 day
Flushing and WECE
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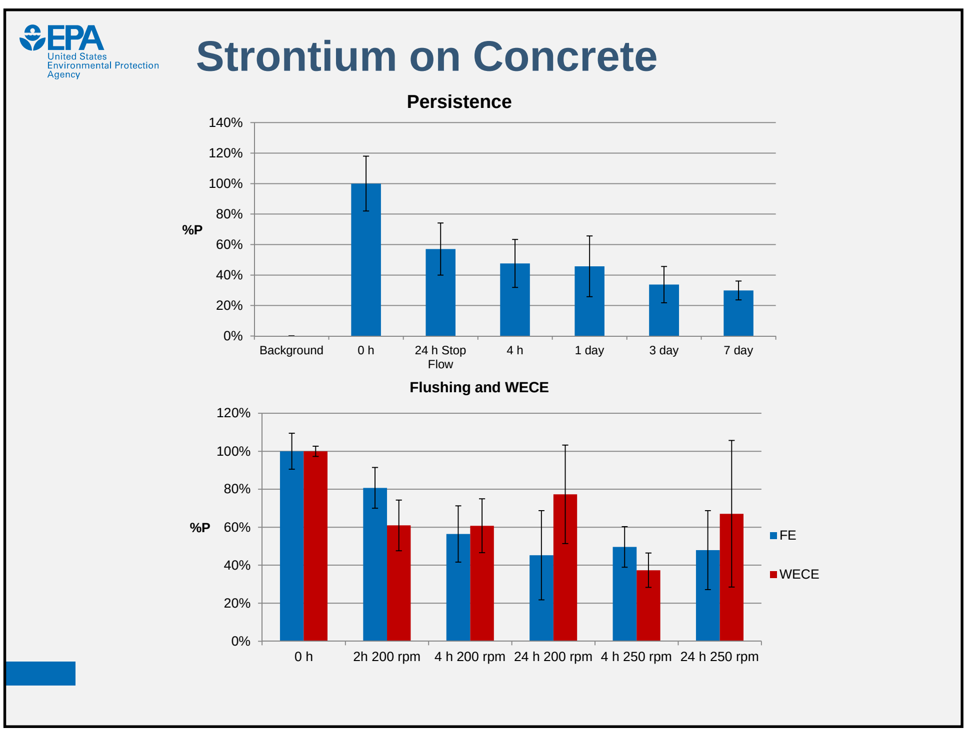
0 h
2h 200 rpm
4 h 200 rpm
24 h 200 rpm
4 h 250 rpm
24 h 250 rpm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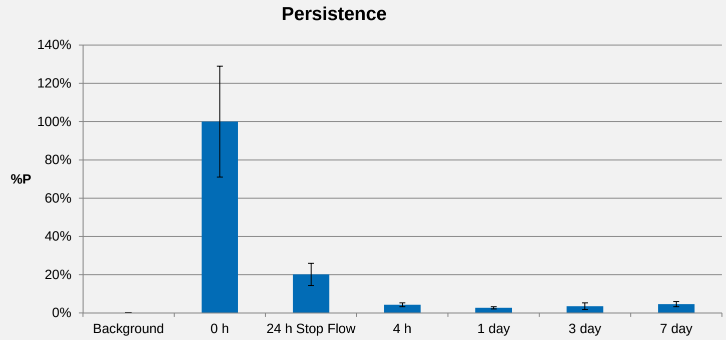
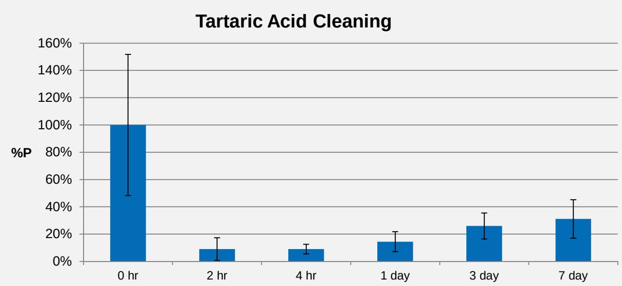
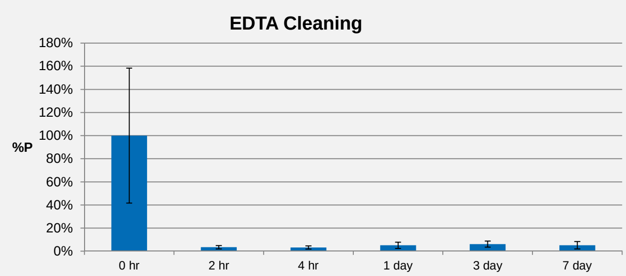
## Strontium on PVC

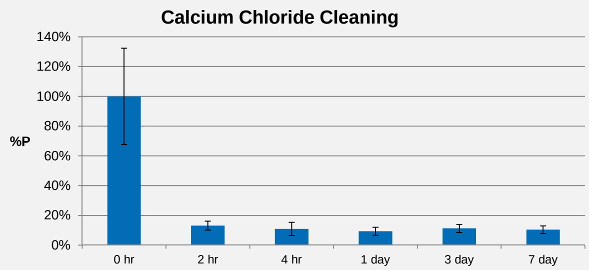


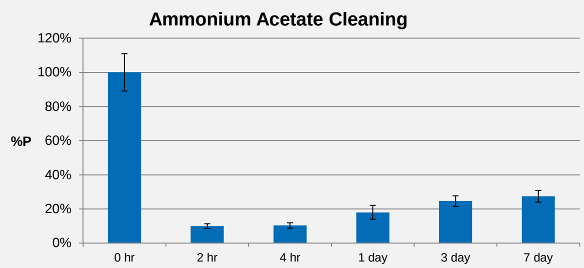

## Cobalt on Concrete



## Strontium on Concrete




## Results Summary

- Cesium not persistent on concrete or PVC pipe materials
- Cobalt was persistent on concrete, but less persistent on PVC
- Strontium was persistent on concrete, but not on PVC.
- Flushing not an effective chemical cleaning agent (CCA) for cobalt or strontium on concrete
- EDTA was an effective CCA for cobalt on concrete.
- Tartaric acid was an effective CCA for cobalt on concrete, but it formed a yellow precipitate on the surface of the coupons.
- Ammonium acetate and calcium chloride were both moderately effective as CCA for strontium on concrete.
- None of the contaminants were persistent on PVC pipe materials so CCAs were not evaluated on PVC.
- Future Research Needs
  - Study importance of biofilm on contaminant adsorption
  - Expanding contaminant list for persistence testing
  - Use of additional pipe materials
  - Scale-up of experience into pipe loop
  - Consider simpler experimental setup without flow

EPA United States Environmental Protection Agency

# Adherence of Contaminants to Drinking Water Storage Tank Sediments

Scott Minamyer, Ryan James, Jeff Szabo, John Hall and Matthew Magnuson
EPA's Homeland Security Research Program
May 6, 2015

**Office of Research and Development**
National Homeland Security Research Center

www.epa.gov/nhsrc

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EPA United States Environmental Protection Agency

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## Introduction

- EPA's HSRP conducts research to improve the security of water systems and recover from CBR contamination incidents
- This study investigates the adsorption of selected contaminants onto drinking water storage tank sediments
  - If contamination partitions into sediment, this could be another route of exposure which could impact human health
- Beyond issues related to security, data from this project may be of interest to the broader community

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## Overview

- Twenty-five sediment samples were received over approximately two years (utilities remain anonymous)
  - Eight samples were useable (a ninth was recently received)
- Sediments were characterized
- Sediment samples were suspended in tap water from the tank and put in contact with four contaminants separately
- A data report was produced summarizing the methodology and percent adherence results
  - The report and tech brief are currently available

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## How were sediment samples acquired?

- Utility Service Group: Tank cleaning crews were asked to let their managers know when they came across a tank with sediments
  - Five useable sediment samples
- AWWA: A request for sediments was included in a regular email that AWWA sends to 4,000+ utilities (thanks to Kevin Morley)
  - We received samples, but they weren't usable
- ASDWA: Requests for sediment samples were sent to each state
  - One useable sample received recently (not included here)
- Personal contacts with utilities and discussions at conferences
  - Three useable sediment samples



## Sediment and Water Sampling

- Targeted tanks that have not been cleaned recently
  - We became less picky as time went on
- When we received word that a sample was available, two coolers were sent to the tank samplers
  - Ice, sterile gloves and bottles, chain of custody forms, prepaid overnight shipping labels, ruler, scoop
- A written sampling protocol was included in the coolers, but we always spoke to the samplers on the phone before sampling

## Sediment and Water Sampling

- The sediment-water interface and sediment samples were scooped from four to five locations in the tank
  - Sediment mass required: ~1 kg dry weight
  - Sediment-water interface samples were used for another project
- Sterile sampling containers for biological measurements
- Water samples from the tank were collected at a fire hydrant or tap immediately downstream from the tank
  - Hydrants or taps were flushed before sampling
  - 4 L of water was collected
- Samples were shipped to Battelle in Columbus, OH and stored at 4º C until use

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## Sediments and Characterization

- Sediment samples can vary greatly from tank to tank (% moisture, particle size, debris, etc.)

- Characterization
  - Total organic carbon, organic matter, sand, silt, and clay content (grain size), pH, cation and anion exchange capacity

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## Results: Sediment Characterization

| Tank Location | Particle Size % Clay (<0.005 mm) | % Silt (0.005-0.74 mm) | % Sand (0.075-2 mm) | pH | Total Exchange Capacity ((mmol/L)/100g) | Total Organic Carbon (%TOC) | Organic Matter (%) |
|---|---|---|---|---|---|---|---|
| Tennessee | 0.4 | 1.06 | 98.54 | 8.2 | 3 | 0.42 | 0.43 |
| North Carolina | 7.63 | 23.39 | 68.98 | 7.6 | 110.8 | 3.11 | 5.45 |
| Ohio 1 | 1.36 | 6.7 | 91.94 | 7.1 | 26.7 | 0.25 | 0.89 |
| Alabama | 2.73 | 2.33 | 94.94 | 7.8 | 12.2 | 0.42 | 0.88 |
| Arkansas | 3.91 | 14.44 | 81.65 | 6.7 | 12.17 | 2.78 | 11.45 |
| Ohio 4 | 1.68 | 21.67 | 76.65 | 6.6 | 57.34 | 2.09 | 5.9 |
| Arizona | 7.35 | 34.34 | 58.31 | 6.7 | 154.14 | 9.42 | 4.08 |
| Illinois | 41.68 | 21.39 | 36.93 | 7.6 | 9.66 | 1.69 | 16.52 |

- Only one target contaminant was detected in the sediments



## Contaminants

- Four agents were selected to represent a broad range of chemical, biological and radiological contaminants
- Cesium chloride: non-radioactive surrogate for Cs-137
- Lindane: organic chemical
- *E. coli*: coliform and a vegetative bacteria
- *B. anthracis* Sterne spores: surrogate for pathogenic *B. anthracis* (the causative agent of anthrax)

## Sediment Adherence Protocol

- Drinking water (at pH 7.5 and 8.5) was contaminated and placed in test tubes containing 1 g sediment/50 mL drinking water
- Adherence experiments performed in triplicate with 6 or 18 hour sediment/ drinking water equilibration time
- Contaminant disappearance from water was used to determine adherence to sediments
- The mixing in this protocol was not intended to represent the mixing that would occur in a tank

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## Data Analyses, Controls and Background

- Results are shown as percent adherence
  - Samples analyzed in triplicate and experiments conducted in triplicate
- Two controls were run along with the adherence samples
  - Sediment and water
  - Contaminant and water
- Background contaminant levels
  - No lindane detected
  - Some sediments did contain cesium (4 out of 8)
- Viable *E. coli* and *B. anthracis* Sterne were not detected in the sediments
  - Sediments were not sterilized
  - *E. coli* and BA Sterne were not detected in control samples during tests

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## Data and reporting considerations

- In the project report (and in this presentation), data is reported on contaminant adherence to sediments
  - Correlation between percent adherence and sediment characteristics was not conducted
- Only eight useable sediment samples were collected, and care should be used when drawing broad conclusions from a small data set
- Data is presented in such a way that the reader can conduct their own analyses of the data if they choose

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## Example: Cesium Results pH 7.5

| Replicate | Description | Result (µg/L) | Avg. | SD | p-value | Sed Adh | % Adherence Sediment | % Adherence SD |
|---|---|---|---|---|---|---|---|---|
| A | Sediment and contaminated water | 0.104 | 0.104 | 0.002 | 7.6E-09 | 68% | 69% | 0% |
| B | Sediment and contaminated water | 0.105 | | | | 68% | | |
| C | Sediment and contaminated water | 0.102 | | | | 69% | | |
| A | Sediment and contaminated water | 0.100 | 0.095 | 0.005 | 8.4E-08 | 70% | 71% | 1% |
| B | Sediment and contaminated water | 0.091 | | | | 72% | | |
| C | Sediment and contaminated water | 0.093 | | | | 72% | | |
| A | Sediment and contaminated water | 0.130 | 0.128 | 0.002 | 1.2E-08 | 61% | 61% | 0% |
| B | Sediment and contaminated water | 0.128 | | | | 61% | | |
| C | Sediment and contaminated water | 0.127 | | | | 61% | | |
| A | Control - contaminated water, no sediment | 0.328 | 0.329 | 0.002 | | Average +/-SD | 67% +/- 5% | |
| B | Control - contaminated water, no sediment | 0.328 | | | | | | |
| C | Control - contaminated water, no sediment | 0.332 | | | | | | |
| A | Blank - sediment and uncontaminated tank wa | ND | NA | NA | | | | |
| B | Blank - sediment and uncontaminated tank wa | ND | | | | | | |
| C | Blank - sediment and uncontaminated tank wa | ND | | | | | | |

- 67% +/- 5% adherence
- Adherence was determined in all three replicates

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# Results: Cesium and Lindane

## Cesium

| Sediment | pH | Average % A | % SD |
|---|---|---|---|
| Tennessee | 7.5 | 5 | 5 |
| | 8.5 | 9 | 1 |
| North Carolina | 7.5 | 20 | 1 |
| | 8.5 | 21 | 2 |
| Ohio 1 | 7.5 | 67 | 5 |
| | 8.5 | 60 | 8 |
| Alabama | 7.5 | 38 | 5 |
| | 8.5 | 32 | 6 |
| Arkansas | 7.5 | 88 | 3 |
| | 8.5 | 82 | 2 |
| Ohio 4 | 7.5 | 28 | 6 |
| | 8.5 | 11 | 5 |
| Arizona | 7.5 | 58 | 6 |
| | 8.5 | 57 | 6 |
| Illinois | 7.5 | 20 | 11 |

## Lindane

| Sediment | pH | Average % A | % SD |
|---|---|---|---|
| Tennessee | 7.5 | 7 | 1 |
| | 8.5 | 7 | 2 |
| North Carolina | 7.5 | 40 | 7 |
| | 8.5 | 27 | 12 |
| Ohio 1 | 7.5 | 87 | 0 |
| | 8.5 | 88 | 0 |
| Alabama | 7.5 | 37 | 1 |
| | 8.5 | 31 | 6 |
| Arkansas | 7.5 | 41 | 2 |
| | 8.5 | 43 | 10 |
| Ohio 4 | 7.5 | 39 | 3 |
| | 8.5 | 44 | 2 |
| Arizona | 7.5 | 86 | 2 |
| | 8.5 | 83 | 1 |
| Illinois | 7.5 | 27 | 3 |



# Results: *BA Sterne* spores and *E. coli*

## *E. coli*

| Sediment | pH | Average %A | Δ%A |
|---|---|---|---|
| Tennessee | 7.5 | 54 | 6 |
| | 8.5 | 54 | 2 |
| North Carolina | 7.5 | 66 | 39 |
| | 8.5 | 78 | 21 |
| Ohio 1 | 7.5 | 72 | 36 |
| | 8.5 | 27 | 3 |
| Alabama | 7.5 | 76 | 4 |
| | 8.5 | 72 | 27 |
| Arkansas | 7.5 | 100 | 20 |
| | 8.5 | 99 | 121 |
| Ohio 4 | 7.5 | 85 | 27 |
| | 8.5 | 88 | 28 |
| Arizona | 7.5 | 79 | 17 |
| | 8.5 | 77 | 18 |
| Illinois | 7.5 | 42 | 18 |

## *B. anthracis* Sterne spores

| Sediment | pH | Average %A | Δ%A |
|---|---|---|---|
| Tennessee | 7.5 | 86 | 11 |
| | 8.5 | 82 | 20 |
| North Carolina | 7.5 | 31 | 5 |
| | 8.5 | 49 | 9 |
| Ohio 1 | 7.5 | 93 | 72 |
| | 8.5 | 99 | 28 |
| Alabama | 7.5 | 91 | 32 |
| | 8.5 | 92 | 13 |
| Arkansas | 7.5 | 100 | 18 |
| | 8.5 | 100 | 22 |
| Ohio 4 | 7.5 | 99 | 23 |
| | 8.5 | 99 | 33 |
| Arizona | 7.5 | 98 | 17 |
| | 8.5 | 98 | 15 |
| Illinois | 7.5 | 98 | 33 |

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## Observations

- All contaminants adhered to all sediments samples to some degree
- In general, the *E. coli* and *B. anthracis* Sterne adhered more readily than cesium and lindane
  - *B. anthracis* Sterne > *E. coli* > Lindane > Cesium
- pH did not appear to impact the adherence of contaminants to sediment
  - *E. coli* (OH 1), *B. anthracis* Sterne (NC), Cesium (OH 4)



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## Summary

- This project has come to an end, but there is potential for future work
  - *Legionella* has been proposed as a microbial contaminant
- The report summarizing this work can be found at:
  http://www.epa.gov/nhsrc/pubs.html
- A technical brief has also been published which condenses the report data into a few pages
- If you can't find the report or tech brief, contact me:
  Jeff Szabo
  513-487-2823
  szabo.jeff@epa.gov

# 2015 U.S. EPA International Decontamination Research and Development Conference

## Wednesday, May 6, 2015

## Concurrent Sessions 3

### Biological Agent Sampling





# Efficient Sampling Strategies to Minimize Number of Samples Needed for Clearance

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Pacific Northwest National Laboratory

2015 EPA International Decontamination Research and Development Conference

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## Overview

- VSP (Visual Sample Plan) Software
- Reducing the numbers of samples via:
  - Sampling Plans
    - Judgmental Only
    - Simple Random Sampling using prior belief
    - Combined Judgmental and Random Sampling
    - Stratified Compliance Sampling
    - Multiple Lines of Evidence
  - Composite Sampling
- Conclusions

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# Visual Sample Plan

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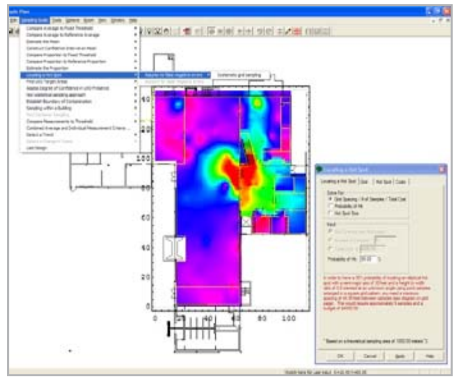
- VSP is systematic planning software for environmental sampling
- VSP helps answer:
  - How many samples do we need?
  - Where should we take samples?
  - What decisions do the data support?
  - What confidence can I have in those decisions?



- **Free VSP Download**: **vsp.pnnl.gov**

# Judgmental Sampling

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- When our objective is to:
  - Find contamination if it's present
  - Demonstrate that a decision area is clean

  **It only makes sense to look for contamination where it is most likely to be**

- The sampling process shouldn't ***throw away*** what we know about:
  - Incident details
  - Epidemiological findings
  - Industrial Hygienist expertise, etc.


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## Issues with Judgmental Sampling

- GAO:
  "Probability sampling would have allowed agencies to determine, with some defined level of confidence, when all results are negative, whether a building is contaminated."
- Judgment can be wrong: we don't always know where contamination may be
- Our knowledge about incident details is probably incomplete

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## Simple Random Sampling

- Supports the mathematical assumption of independent observations
- Random Sampling is appropriate when:
  - We wish to estimate the mean of a population (but this is not usually the need in clearance sampling)
  - Population is homogeneous (distribution of contaminant is somewhat uniform)
  - We have NO information regarding locations that are likely to be contaminated, or other factors that may influence the existence of the contamination

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## What is Probabilistic Sampling?

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**Probabilistic ≠ Random**

- "Probabilistic" sampling is often (mistakenly) associated with strictly random sampling (random sample locations)
- A definition of Probabilistic Sampling:
  - A sampling design based on a probability (statistical) model
  - Provides a quantifiable level of confidence in the results

**Probability statements CAN be made when some, many, or all sample locations are determined judgmentally**

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## Combined Judgment and Random Compliance Sampling (CJR)

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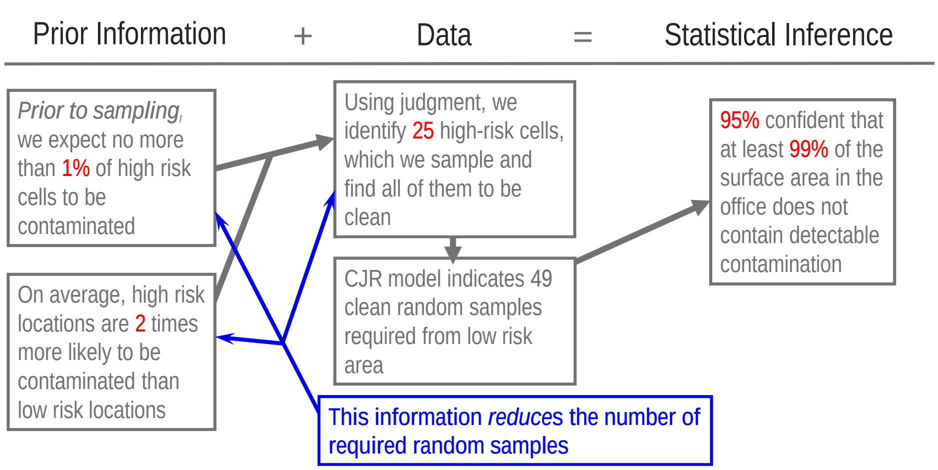


Parameters controlled by the investigator are highlighted

(Numbers in this example are based on sampling from 100 $cm^2$ grid cells in an 15x15.5x10 ft office, where all floor, walls, and ceiling surfaces are available for sampling. This gives ~10,000 possible samples)

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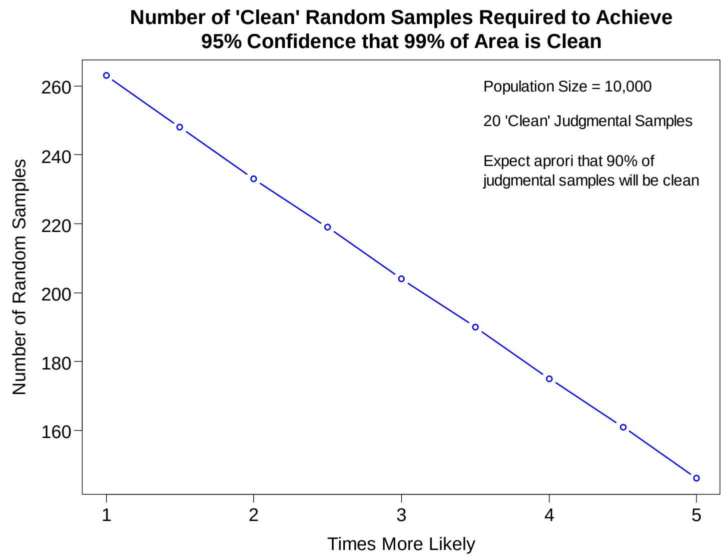
## Reduction of Numbers of Samples when using CJR Sampling




Available in VSP Visual Sample Plan

* We expect that judgmental samples are taken from areas that are x 'times more likely' to be contaminated than areas that are randomly sampled

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## Stratified Compliance Sampling

- A Bayesian inference model that uses a combination of data and SME (subject matter expert) knowledge.
- Stratification is used to separate your decision area into regions of varying probability of finding an unacceptable item.
- SME must determine relative risk parameters and the prior probability of finding an unacceptable item in the highest-risk stratum.

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## Stratified Compliance Sampling Example

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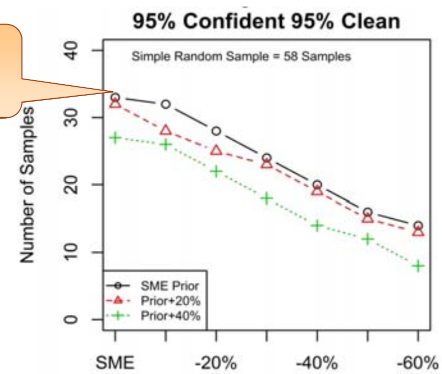
**Example building had 5000 sq ft with 4 strata defined by the surface materials**

Available in VSP Visual Sample Plan

**Based on actual SME conservative estimates**

**Number of samples needed was reduced by 43%**




A PNNL Technical report and subsequent journal article discussing the methodology with examples will be released soon



## Multiple Lines of Evidence (LOE)

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**Identify LOE Factors**
(Amount of Contamination
Air Sampling Information
Decontamination Information
Surface Material, etc)

**Use Experimental Design principals to determine which LOE factor combinations to focus on**

**SME provides insight into likelihood of contamination given combinations of LOE factors**

**Use SME input in the Stratified Compliance Sampling Method**

A PNNL Technical report discussing the methodology with examples will be released soon

## Composite Sampling Overview



- PNNL lab study looked at the efficacy of composite sampling in cases of low level contamination
  (5, 10, 25, 50, 100 CFU per coupon)
- Study focused on the factors:
  - **Compositing methodology**
  - **Surface material**
  - **Number of locations to composite**
  - **Contaminant location**

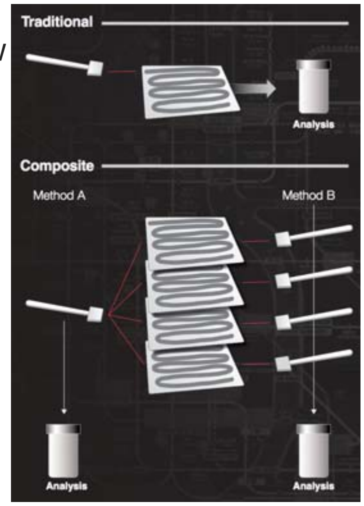


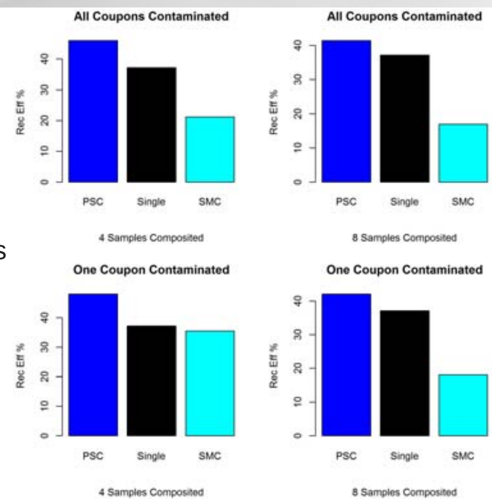

Image courtesy of MIT Lincoln Labs



## Composite Sampling
## Composite Methodology



- Two methods tested –
  - **SMC**: Single sample medium across many locations (Single Media Composite)
  - **PSC**: Single sample medium for each location, combined after sampling, before analysis (Post Sample Composite)
- **PSC** had significantly better recovery than SMC (Single Media Composite)
  (p-val < 0.0001)




Single = Traditional Single Sample Controls

## Composite Sampling
## Surface Materials

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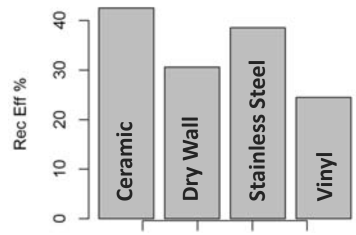
- Four materials tested:
  - Ceramic tile
  - Vinyl tile
  - Stainless steel
  - Painted drywall




- Surface materials were significantly different (p-val = 0.0008)
- Surface material effects were consistent across the other factors



## Composite Sampling
## Other Factors

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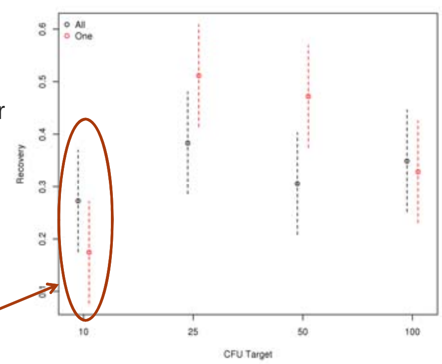
- **Number of locations composited**
  - 4 locations vs 8 locations
  - No significant differences between 4 or 8 locations composited
    (p-val = 0.2059)
- **Location of contaminant**
  - Present on all coupons vs present on only one coupon (random placement)
  - No significant differences between locations of contaminant
    (p-val = 0.1045)
- Significant interaction between CFU target amount and location of contaminant
  (p-val = 0.0256)



## Composite Sampling Results

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- Post Sample Compositing is recommended, especially for clearance sampling (low contamination levels are expected). Recovery efficiency is as good, if not a little better, than traditional single media / single location sampling.
- Composite sampling lab study results will be published in an upcoming PNNL technical report and will be submitted as a journal article.
- Composite sampling functionality will be added to VSP.
- Later this year, PNNL will be conducting another composite sampling lab study looking at dirty samples.

Please visit our Poster – **Evaluation of a Composite Sampling Method for Bacillus Spores on Clean Surfaces**, Hutchison et al.

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## Conclusions

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- Probabilistic sampling designs exist (and can be developed) which blend judgmental and random sampling strategies
- When justified, we can (and should) account for prior information (Bayesian approaches)
- Statistical sampling should leverage all available information
- Post Sample Compositing is a great way to minimize the number of analyses.


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## Acknowledgements

Pacific Northwest NATIONAL LABORATORY
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  - Chemical and Biological Research and Development Branch of the Chemical and Biological Division in the Science and Technology Directorate of the Department of Homeland Security (DHS)
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  - Representatives from DHS, EPA, CDC

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PNNL is a multi-program national laboratory operated for the U.S. Department of Energy by Battelle under Contract DE-AC05-76RL01830.

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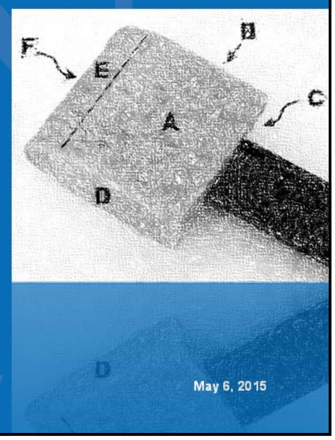
# Composite-Based Surface Sampling of a *Ba* surrogate with Cellulose Sponge Samplers

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*Sang Don Lee (EPA)*

**Office of Research and Development**
National Homeland Security Research Center

May 6, 2015

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## Wide-Area Incident Recovery Requirements

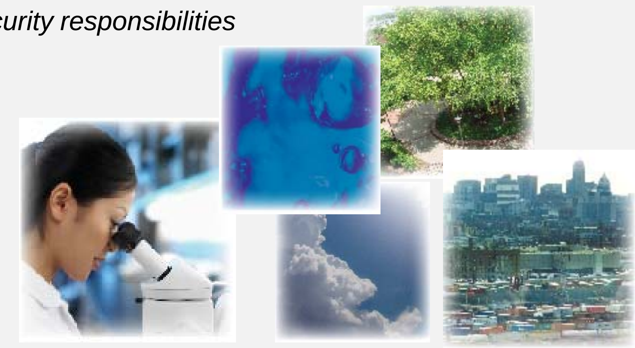



## Wide-Area Incident: Timeline

| | Respond and Recover | | | | | |
|---|---|---|---|---|---|---|
| | Crisis Management | | Consequence Management | | | Restoration/ Reoccupancy |
| Prepare | Notification | First Response | Characterization | Remediation | Clearance | |
| Plan<br>Organize, train, and equip<br>Exercise<br>Evaluate and improve | Receive and assess information<br>Identify release sites<br>Relay key information and potential risks to appropriate agencies | Hazardous materials (HAZMAT) and emergency actions<br>Forensic investigation<br>Public health actions<br>Screening and sampling<br>Initial threat assessment<br>Determination of agent type, concentration, and viability<br>Risk communication | Detailed agent characterization<br>Characterization of affected site<br>Site containment<br>Continuation of risk communication<br>Characterization of environmental sampling and analysis<br>Initial risk assessment<br>Clearance goals | Source reduction<br>Decontamination strategy<br>Remediation action plan<br>Worker health and safety<br>Site preparation<br>Decontamination of sites, items, or both<br>Waste disposal<br>Verification of decontamination parameters | Clearance sampling and analyses<br>Clearance decision | Renovation<br>Reoccupation decision<br>Potential environmental and public health monitoring |

# U.S. EPA's Homeland Security Research Program

*Mission: to conduct research and develop scientific products that improve the capability of the Agency to carry out its homeland security responsibilities*



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# EPA's HSRP Research Foci

**Securing and Sustaining Water Systems**

Supporting WSi (sensors, software tools, technical assistance)

Infrastructure decontamination

Water treatment

Innovative system designs and management

**Characterizing Contamination and Determining Risk**

Sampling, analytical methods

Sampling strategies

Determining risk, clean up goals

Microbial risk assessment methodologies

**Remediating Indoor and Outdoor Environments**

Efficacy, optimization of cleanup technologies

Fate of contamination, resuspension

Sampling to success of decon

Wide area cleanup

Waste management

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## Current HSRP Sampling Research
### Summary of Benefits

- Characterize currently-available techniques
- Develop rapid, cost-effective, representative methods
- Reduce laboratory burden following wide-area incident
- Development of field-ready methods



## Current HSRP Sampling Research

- Response to an urban biological release would pose considerable challenges due to spatial scale and complex surfaces.
- Need to enhance our ability to characterize contaminants in a wide-area (pre- and post-decon), with less time and resources, and increased representativeness and/or confidence.

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## Current HSRP Sampling Research

- Vacuum sampling method evaluation
  - Complex and porous surfaces
- Sponge Wipe composite sampling
  - Nonporous surfaces, 3M sponge samplers
- Robotic surface sampling
  - Using off-the-shelf robotic vacuum cleaners
- Aggressive Air Sampling
  - Based on asbestos sampling methods

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## Current HSRP Sampling Research

- Vacuum sampling method evaluation
  - Complex and porous surfaces
- **Sponge Wipe composite sampling**
  - **Nonporous surfaces, 3M sponge samplers**
- Robotic surface sampling
  - Using off-the-shelf robotic vacuum cleaners
- Aggressive Air Sampling
  - Based on asbestos sampling methods

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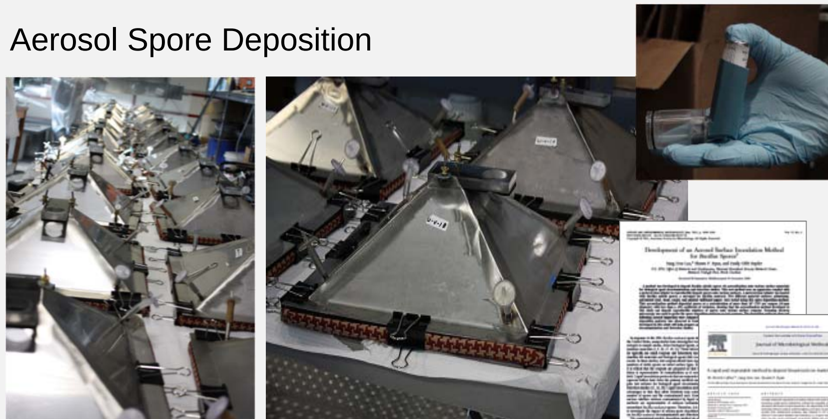
# Current HSRP Sampling Research

## Aerosol Spore Deposition



Calfee MW, Lee SD, Ryan SP. 2013. J. Microbiol. Meth. 92: 375-380.
Lee SD, Ryan SP, Snyder EG. 2011. Appl. Envrion. Microbiol. 77(5):1638-45

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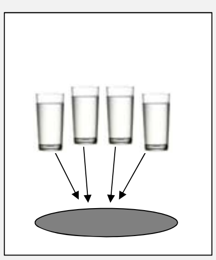
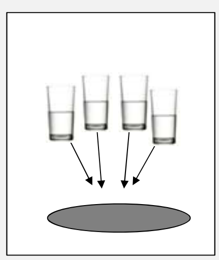
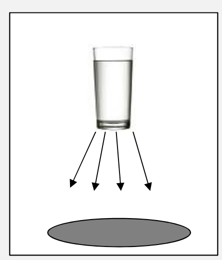
# Composite Samples and Sampling



Individual samples collected from different locations combined into one composite sample



Aliquots of individual samples collected from different locations combined into one composite sample



Individual samples collected from different locations using the same sampler, resulting in one composite sample

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# Composite-Based Surface Sampling

Cellulose Sponge Surface Sampling with Sponge-Sticks (3M)

- Base Method – Standard CDC protocol (100 in$^2$, all sides)
- Test Method 1- Standard CDC collection protocol (all sides)
- Test Method 2 - Modified protocol (one side per location)
  - Applied both to 4 x 1 ft$^2$ areas (576 in$^2$), steel surface

Factors evaluated

- Collection efficiency
- Potential for cross contamination


PLOS | ONE

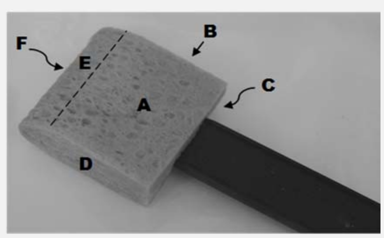
RESEARCH ARTICLE

Composite Sampling of a *Bacillus anthracis* Surrogate with Cellulose Sponge Surface Samplers from a Nonporous Surface

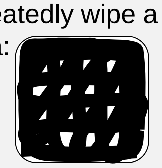
Jenia A. M. Tufts[1,2], Kathryn M. Meyer[1,2], Michael Worth Calfee[2*], Sang Don Lee[2]



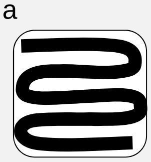
# Methods Compared




- CDC Standard Method
  - All sponge surfaces (A – F) used to repeatedly wipe a defined area:



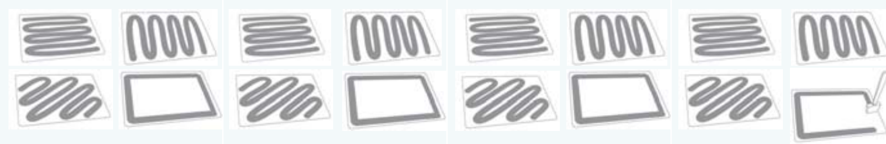
- Modified Method
  - Only one side (A, B, C, or D) used to wipe a defined area:



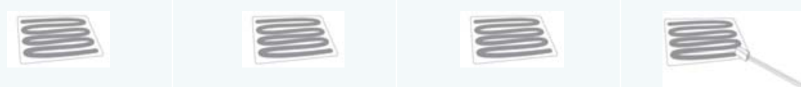
EPA United States Environmental Protection Agency

# Methods Compared

| Composite Sample Collected using the Standard CDC Method<br>All Sides of Sampler used on each Surface | | | |
|---|---|---|---|
| Surface 1 | Surface 2 | Surface 3 | Surface 4 |



| Composite Sample Collected using the Modified Method<br>One Side or Edge used on each Surface (turning sampler after each surface) | | | |
|---|---|---|---|
| Surface 1 | Surface 2 | Surface 3 | Surface 4 |





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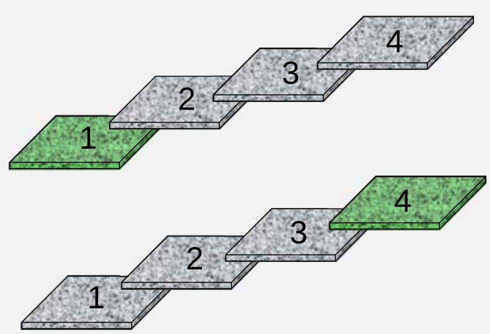
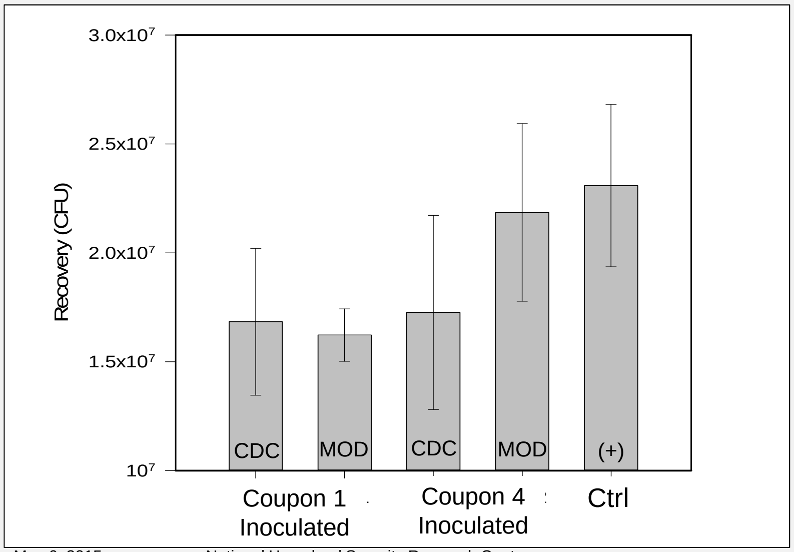
# Experimental Setup

- Four-point composites from Stainless Steel
- 2 conditions
  - Contaminant Transfer
    - Magnitude Between Methods
    - Impact on Collection Efficiency
  - Moisture Loss
    - Impact on Collection Efficiency



# Recoveries

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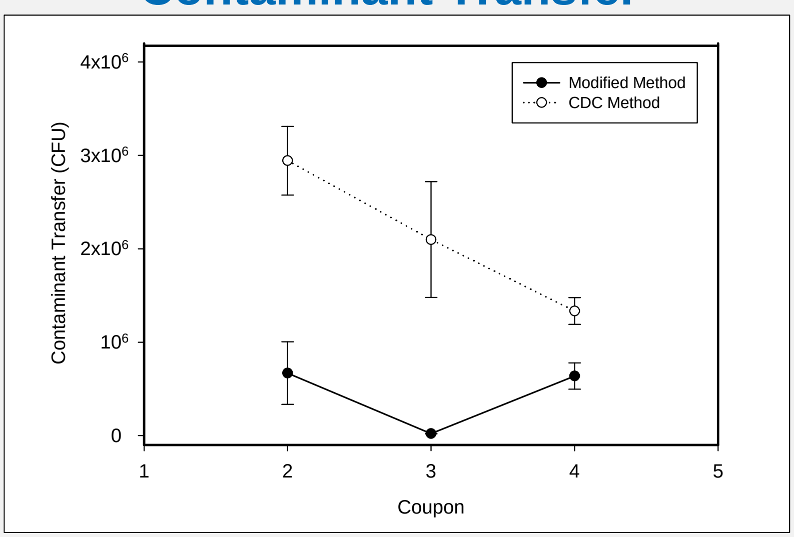
# Contaminant Transfer

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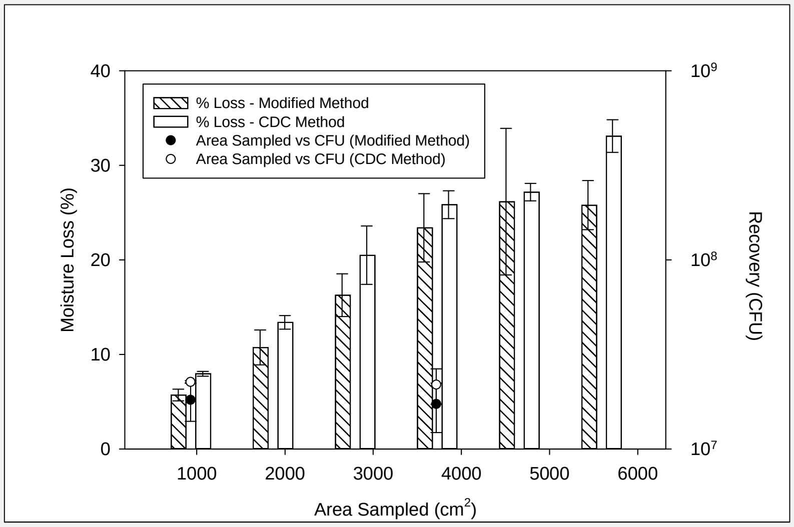
# Moisture Loss and Spore Recovery

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# Conclusions

- Promising way to increase the surface area sampled without increasing laboratory processing time, labor, and consumables.
- CDC protocol may be modified to reduce the number of passes over a single location without compromising the collection efficiency.


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# Composite-Based Surface Sampling

## Future Research Directions

- Effect of background microorganisms on collection and analysis
- Impact on collection efficiency of
  - –Additional hot spots
  - –Sponge sampler moisture
  - –Surface material type
  - –Grimed surfaces

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# Robotic Sampling and Decontamination

**The use of commercially available robots to sample and decontaminate the inhabited area**

Katy-Anne Thompson, Susan Paton, Thomas Pottage & Allan Bennett
Biosafety Investigations Unit,
Public Health England,
UK

# Background

Aim:
Assessing the Use of Commercially Available Robotic Cleaners to Sample and Decontaminate Inhabited Areas

Outcomes:

- Reduce the health impact of an incident involving biological material
- Reduce the risk to workers
- Develop ability to rapidly detect biological attack over a wide area
- Decontaminate environments affected by Biological agents
- Develop at-scene procedures

# Project overview

Task 1: Review of Technology

Task 2: Trade off selection

Task 3: Sample Efficacy Testing

Task 4: Decontamination Testing

Task 5: HVAC Feasibility Testing

Task 6: Safety Assessment

3 Robotic Sampling and Decontamination

# Previous uses of commercial robots

**Radiation[1]**

Artificially contaminated PVC flooring

Scooba floor cleaning robot 60-80% effective

**Biological**

2013[2] – 5/3 robots

Laminate flooring, 2-62% of sponge sampling efficiency

Carpet surface, 26-162% of vacuum sock efficiency

2014[3] – 2 robots

Hot spot and widely dispersed contamination

[1]Westcott E, et al. Benefits of automated surface decontamination of a radioiodine ward. Health Phys. 2012 Feb;102 Suppl 1:S4–7
[2]Lee SD, et al. Evaluation of surface sampling for Bacillus spores using commercially available cleaning robots. Environ Sci Technol. 2013 Mar 19;47(6):2595–601
[3]Lee SD, *et al*. Scenario-Based Evaluation of Commercially Available Cleaning Robots for Collection of Bacillus Spores from Environmental Surfaces. Remediat J. 2014 Mar 1;24(2):123–33

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# Robot selection

- Literature review
- Trade-off matrix for robot selection
  - HEPA filtration
  - Power (Watt)
  - Battery life (mins)
  - Capacity (ml)
  - Multifloor capability
  - Return to base function
  - Size
  - Functionality
  - Other e.g. decontamination claims
- Robot acquisition (4 types) and validation



# Robot selection

| Robot | Setting | Airflow range (L/min) | Median Speed (m/s) |
|---|---|---|---|
| Hoover RBC009 | Normal | 80 - 99 | 0.18 |
| | Turbo | 80 - 99 | 0.24 |
| Scooba 390 | N/A | 424 - 518 | 0.12 |
| Roomba 770 | N/A | 184 -212 | 0.23 |
| Moneual MR7700 | Normal | 273 - 311 | 0.16 |
| | Turbo | 377 - 452 | 0.16 |




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# Methodology

Tests performed in an environmental chamber

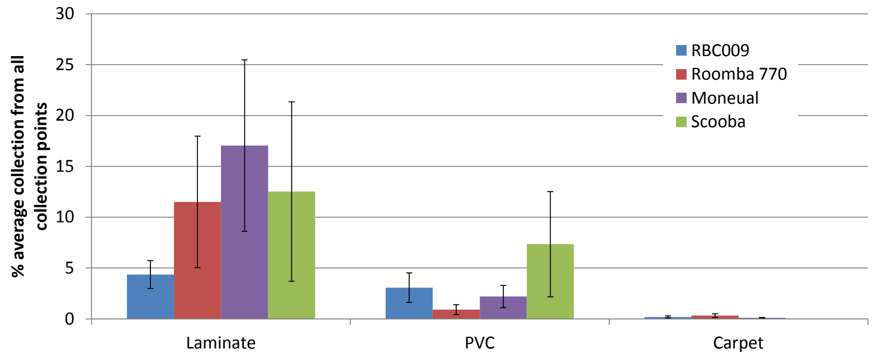
- Collection Efficiency:
  - 3 flooring types
  - Artist spray gun
  - B. atrophaeus (100% IPA)
  - 16 tiles in 4m$^2$ enclosed area
  - 1 central, contaminated tile
  - 10 minutes of robot running
  - Sample flooring and robot
- Decontamination studies:
  - 1 robot with liquid disinfectant
  - 1 flooring type

| Type | Name | Material | Size | Supplier |
|---|---|---|---|---|
| Laminate | Colours Sherzo Light Walnut Effect | High Density Fibreboard, high gloss finish | 1213mm x 125mm x 12mm planks | B&Q |
| PVC | Tarkett iD40 in Concrete Grege | PVC, textured concrete finish, PUR coating | 500mm x 500mm x 2mm tiles | Options Flooring |
| Carpet | B&Q Carpet tile Pack of 10 | Synthetic, Loop pile | 500mm x 500mm x 5.5mm tiles | B&Q |



## Results - Sampling

- Recovery efficiency: Laminate > PVC > Carpet
- Variability potentially due to sampling pattern






## Comparison to previous studies

Reduction in efficiencies in PHE study

- Laminate flooring, 2.4-61.7% efficiency, *PHE – 4.3-17.1%*
- Carpet surface, 25.8-161.5% efficiency, *PHE – 0.18-0.32%*

Lee *et al* used a vacuum collection method for carpet sampling, PHE used soluble tape

Use of deposition methods might be cause differences

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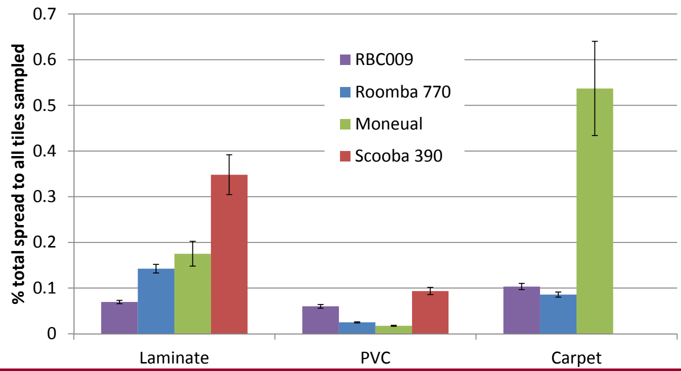
# Contamination spread

Cross-contamination to clean areas of flooring was highest on carpet (0.233%), and least on PVC (0.049%)

Moneual spread the most across the flooring types (0.243%), while the Roomba spread the least (0.075%)



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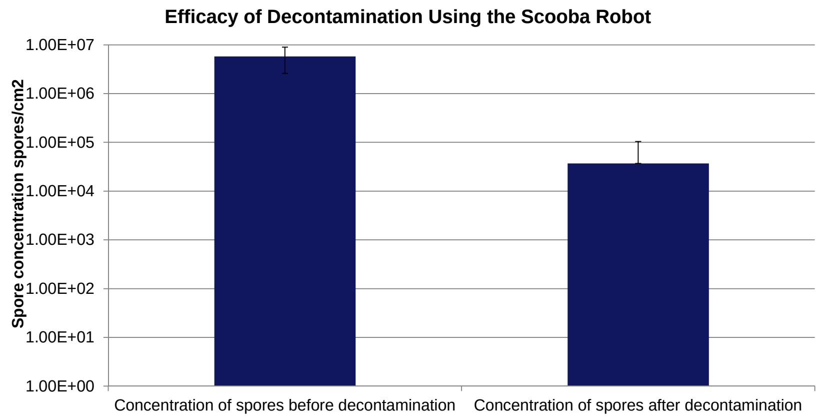
# Decontamination




There was a 99.13% (SD=1.69%) average reduction in the contamination levels on that tile from an average initial spore concentration of 5.8 x $10^6$ cfu/cm$^2$ (SD = 3.2 x $10^6$ cfu/cm$^2$)

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# Results - Safety Assessment

**Air Sampling**

The highest number of organisms detected was 5.6 spores/L (Moneual vs Laminate)

The highest number during bagging activities after a run was 0.616 spores/L (Moneual vs Carpet)

| % negative results | RBC009 | Roomba 770 | Scooba 390 | Moneual |
|---|---|---|---|---|
| During 10 min run | 0.00 | 0.00 | 33.33 | 11.11 |
| During 3 min bagging | 66.67 | 88.89 | 83.33 | 77.78 |

**Touch point sampling**

Overall the robots with handles, Roomba 770 and Scooba 390, had fewer organisms (average number of spores was 6.9 and 1, respectively) swabbed from their touch points than those without handles ($1.29 \times 10^4$ and $3.46 \times 10^3$ spores for RBC009 and Moneual, respectively)

13 Robotic Sampling and Decontamination

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# HVAC sampling in operation

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## Some difficulties



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## Summary

Collection was highest and detection limits lowest from the smoothest surface, laminate, followed by the hard but rough PVC, followed by soft, porous carpet

The Moneual MR6800-M3 had the highest collection efficiency of all at 17% from laminate flooring, the iRobot Scooba 390 collected the most from PVC (7.3%), whereas the iRobot Roomba 770 collected the most from carpet (0.2%). Therefore different robots may be suitable to different flooring types and situations

Robots both transfer hotspot contamination to other areas and aerosolise contamination during the sampling process and bagging process at low levels

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Collection efficiency appears to be proportional to airflow and inversely proportional to the speed

Collection was quicker by the robot, <11minutes for sampling $4m^2$ compared to ~15 minutes to sample 6 areas manually

A selected robot was effective at decontaminating PVC flooring hotspot contaminated with $5.8 \times 10^6$ cfu/$cm^2$ by 99.13% (SD=1.69%)

Robotic sampling devices show considerable promise as a tool for both sampling and remediation of biologically contaminated areas



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# Acknowledgements

Susan Paton

Katy-Anne Thompson

Simon Parks

Allan Bennett

# 2015 U.S. EPA International Decontamination Research and Development Conference

## Wednesday, May 6, 2015

## Concurrent Sessions 3

### Water and Waste Water Treatment





# Management and Treatment of Copious Amounts of CBR Contaminated Water And Wastewater

*Matthew Magnuson*

**2015 EPA International Decontamination Conference**
**May 6, 2015**



## Disclaimer

The U.S. Environmental Protection Agency funded, partially funded, managed, and/or collaborated in the research described in this presentation. It has been subjected to the Agency's review and has been approved for publication. Note that approval does not signify that the contents necessarily reflect the views of the Agency. Mention of trade names, products, or services does not convey official EPA approval, endorsement, or recommendation.

ADVANCING OUR NATION'S SECURITY THROUGH SCIENCE

# Outline

- **EPA Homeland Security Roles and Water Research**
- **<u>Overview</u> of management and treatment of copious amounts of CBR contaminated water and wastewater residuals**



# EPA Homeland Security Responsibilities

## Drivers

Bioterrorism Act

Presidential Directives

Executive Orders

National Response Framework

Elements of:

- Comprehensive Environmental Response, Compensation and Liability Act
- Emergency Planning and Community Right-to-Know Act
- Clean Water Act
- Safe Drinking Water Act
- Oil Pollution Act
- Clean Air Act
- Resource Conservation and Recovery Act

## Responsibilities

- **Support water systems to prepare for and recover from attacks and other disasters**
  by leading efforts to provide States and water utilities guidance, tools and strategies. ***EPA is the federal government Sector Specific Agency (SSA) lead for water infrastructure***.
- **Clean up buildings and outdoor areas**
  impacted by a terrorist attack or other disaster by leading efforts to establish clearance goals and clean up.
- **Develop a nationwide laboratory network**
  with the capability and capacity to analyze for chemical, biological and radiological (CBR) agents for routine monitoring and in response to a terrorist attacks.

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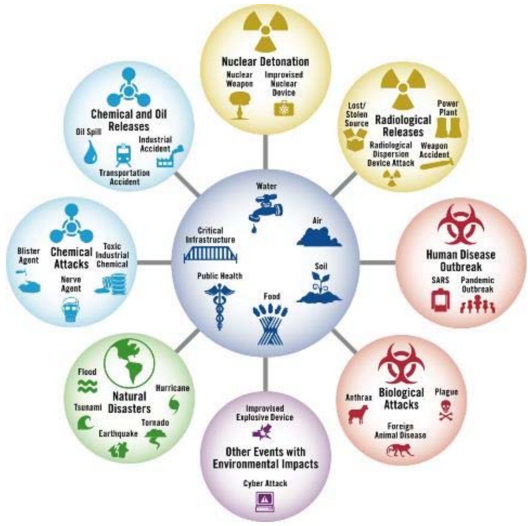
## EPA's "All Hazards" Universe




*Refining EPA's Approach to Homeland Security*, Office of Homeland Security (2011)

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## Research to Support Water Systems

- Make water systems more resilient
- Mitigate impacts of contamination
- Detect contamination
- Treat water
- Decontaminate infrastructure

## Outline

- EPA Homeland Security Roles and Water Research
- Overview of management and treatment of copious amounts of CBR contaminated water and wastewater residuals



## Selected Projects

- Inactivation of bacterial bioterrorism agents in water
- Acceptance of Bio-contaminated Waste Water
- Minimization of radiological aqueous waste from washing
- Investigation of advanced oxidation processes (AOP) for treatment and disposal of contaminated water prior to release into public sewer (collection) systems
- Fate of organophosphates (OPs) in municipal wastewater treatment systems
- Prediction of hydrolysis rates of OP compounds

## Inactivation of bacterial bioterrorism agents in water

Objectives: Study the effectiveness of inactivation methods of vegetative and spore forms of bacterial bioterrorism agents, including:

- *Bacillus anthracis* Ames and Sterne
- *Brucella melitensis*
- *Burkholderia mallei*
- *Burkholderia pseudomallei*
- *Francisella tularensis*
- *Yersinia pestis*

http://cfpub.epa.gov/si/si_public_file_download.cfm?p_download_id=511103

EPA technical BRIEF

### Inactivation of Bacterial Bioterrorism Agents in Water: Summary of Seven Studies

INTRODUCTION

In the United States, chlorine and monochloramine are the primary chemical disinfectants used to inactivate microbes in drinking water distribution systems. Although many microbes are inactivated by common water treatments, some are more resistant. Conditions for inactivating many waterborne disease-causing microbes have been established, but there are only limited data on inactivating bacterial bioterrorism agents.

U.S. EPA and the Centers for Disease Control and Prevention (CDC) have conducted seven laboratory-based inactivation studies in water using non-disease causing surrogates for *Bacillus anthracis* and microbes identified as potential bioterrorism agents. One of the studies also examined the conditions under which boiling water could inactivate microscopic resistant structures (spores) formed by surrogates.

U.S. EPA's Homeland Security Research Program (HSRP) develops products based on scientific research and technology evaluations. Our products and expertise are widely used in preventing, preparing for, and recovering from public health and environmental emergencies that arise from terrorist attacks. Our research and products address biological, radiological, or chemical contaminants that could affect indoor areas, outdoor areas, or water infrastructure. HSRP provides these products, technical assistance, and expertise to support EPA's roles and responsibilities under the National Response Framework, statutory requirements, and Homeland Security Presidential Directives.

A number of factors influence the effectiveness of chemical disinfectants in drinking water treatment systems, including:

- the type and quantity of microbes present
- whether the microbes form spores or exist primarily as vegetative cells
- the type of disinfectant and its concentration
- the amount of time the disinfectant is in contact with the microbes
- water temperature
- water acidity or alkalinity (pH)
- the type and quantity of organic and inorganic particles in the water
- water flow and pipe materials

Different species and strains of bacteria, whether bioterrorism agents or not, can have different degrees of resistance to disinfectants. If nutrients are available prior to inactivation treatments, this can increase the resistance of some species to chemical disinfection. Clumping or attachment to floating organic materials can increase resistance. Some strains produce material outside their cell wall. This extracellular material can permit attachment to other organisms or surfaces and help form biologically active layers (biofilms), which are generally more resistant to chemical disinfection than free floating (planktonic) cells.



# Selected Projects

- **Inactivation of bacterial bioterrorism agents in water**
- **Acceptance of Bio-contaminated Waste Water**
- **Minimization of radiological aqueous waste from washing**
- **Investigation of advanced oxidation processes (AOP) for treatment and disposal of contaminated water prior to release into public sewer (collection) systems**
- **Fate of organophosphates (OPs) in municipal wastewater treatment systems**
- **Prediction of hydrolysis rates of OP compounds**

## Acceptance of Bio-contaminated Waste Water

- Based on request from EPA Region 4 related to Anthrax spores
- Assist wastewater plant operators in making decisions about whether and how to accept wastewater contaminated with pathogens
- Currently planning project with stakeholders - what research is needed to address questions associated with acceptance?

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## Contaminant Persistence in Waste Water Treatment Systems

Activated sludge experimental set-up: assessing how contaminants travel through waste water treatment systems

Waste water test bed: assessing persistence of contaminants on sewer infrastructure

## Selected Projects

- Inactivation of bacterial bioterrorism agents in water
- Acceptance of Bio-contaminated Waste Water
- Minimization of radiological aqueous waste from washing
  (see Tuesday 3:50pm talk by Mike Kaminski)
- Investigation of advanced oxidation processes (AOP) for treatment and disposal of contaminated water prior to release into public sewer (collection) systems
- Fate of organophosphates (OPs) in municipal wastewater treatment systems
- Prediction of hydrolysis rates of OP compounds



## Irreversible Water Wash Aid for Cesium-137

Collaborative project with DOD/CTTSO/Technical Support Working Group

Key Points:
- State-of-the-art system reduces radiation exposure for first responders, other emergency workers, and the general population in contaminated urban environments
- Helps restore response activities and public services
- Suitable for paved surfaces, buildings, and vehicles
- Eliminates the need to dispose of potentially billions of gallons of rad-contaminated wash water
- Provides means of recycling water to reduce water demand during a crisis
- Uses COTS technology available across the U.S.

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The mobile filter skid.

## ORD's Homeland Security Research Program

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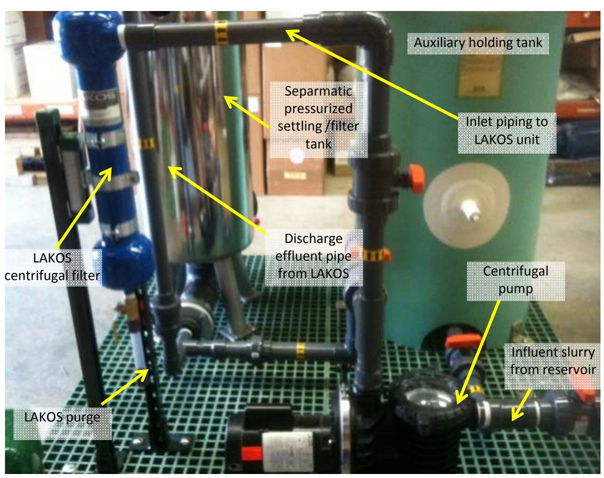


A closer look at the skid's components.

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## Selected Projects

- Inactivation of bacterial bioterrorism agents in water
- Acceptance of Bio-contaminated Waste Water
- Minimization of radiological aqueous waste from washing
- Investigation of advanced oxidation processes (AOP) for treatment and disposal of contaminated water prior to release into public sewer (collection) systems
  (see 2:00 pm talk in this session by Rebecca Phillips)
  (also see Poster by Patrick Mudimbi)
- Fate of organophosphates (OPs) in municipal wastewater treatment systems
- Prediction of hydrolysis rates of OP compounds

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## Background

- Problem: How to deal with decon waste water, which can represent significant waste management challenges
  - Incinerate water?
  - Haul thousands/millions/billions of gallons long distances to specialty facility?
  - Drain disposal to local wastewater plant?
- Objectives: Investigate Advanced Oxidation Process (AOP) for dealing with large volumes of decon wash water and contaminated water and wastewater to enable drain disposal.

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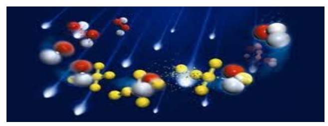
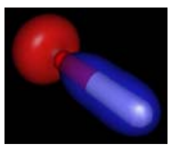
# Advanced Oxidation Process (AOP)

- Generate hydroxyl radicals with over twice the oxidizing power of chlorine.
- "Green" -- no chlorinated by-products.
- Several AOP technologies suitable for field use





hydroxyl radical

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## Technical Approach

- Investigate different AOP technologies for the treatment and disposal of drinking water contaminated with toxic chemicals into public sewer (collection) systems
- Perform toxicity tests for wastewater plant organisms and receiving waters
- Designed experiments so results will be useful in assessing impacts of an incident and selecting effective methods for handling contaminated water or wastewater.

## Selected Projects

- **Inactivation of bacterial bioterrorism agents in water**
- **Acceptance of Bio-contaminated Waste Water**
- **Minimization of radiological aqueous waste from washing**
- **Investigation of advanced oxidation processes (AOP) for treatment and disposal of contaminated water prior to release into public sewer (collection) systems**
- **Fate of organophosphates (OPs) in municipal wastewater treatment systems (see poster by Erik Rauglas)**
- **Prediction of hydrolysis rates of OP compounds**



## Background

- Problem: OPs, including pesticides and nerve agents, could enter waste water treatment plant (WWTP) during decon operations. If not degraded or removed, they may enter the environment or drinking water supplies through effluent discharge and in land applied sludge.
- Objectives: Examine experimentally the capability of municipal WWTP activated sludge to degrade and remove OP compounds in bench-scale studies

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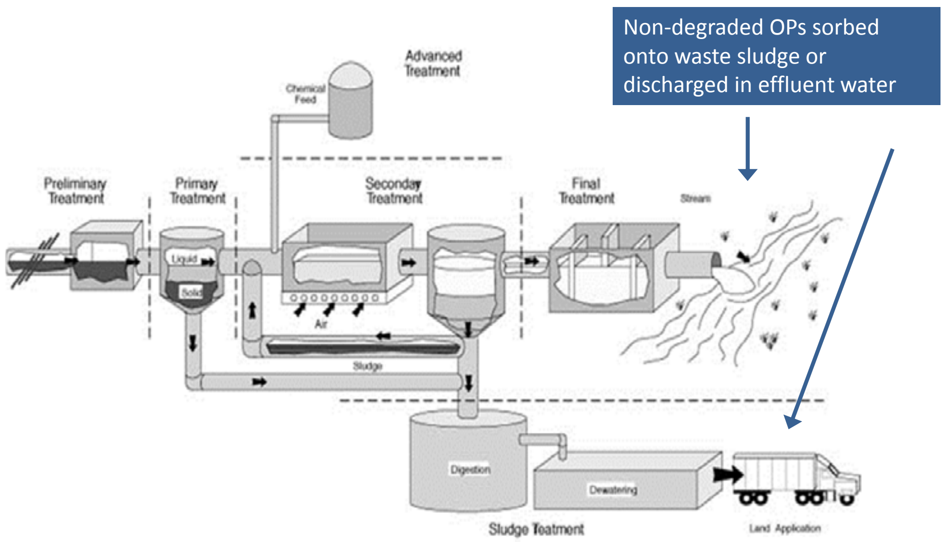


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## Research Objective

How does activated sludge respond to and recover from exposure to malathion, an organophosphate compound and VX surrogate, at various concentrations?

1. What malathion concentration inhibits activated sludge respiration?
2. Does the concentration that inhibits respiration reduce effluent quality during initial exposure?
3. What are the long term effects of malathion exposure?

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## Selected Projects

- **Inactivation of bacterial bioterrorism agents in water**
- **Acceptance of Bio-contaminated Waste Water**
- **Minimization of radiological aqueous waste from washing**
- **Investigation of advanced oxidation processes (AOP) for treatment and disposal of contaminated water prior to release into public sewer (collection) systems**
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- **Prediction of hydrolysis rates of OP compounds**

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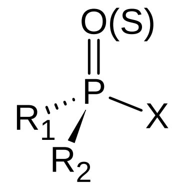
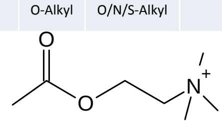
## Organophosphorus Compounds

- Organophosphorus (OP) compounds are widely employed as insecticides and/or pesticides
  - Mode of action is irreversible inhibition of acetylcholinesterase
- Potential human health risks from OP exposure
  - Chemical warfare agents such as Sarin and VX are OP compounds
- Diverse structures include variations of spectator groups (R) and leaving groups (X)




| Family | $R_1$ | $R_2$ | X |
|---|---|---|---|
| V-Agent | O-Alkyl | $CH_3$ | Thioalkylamine |
| G-Agent | O-Alkyl | $CH_3$ | F |
| Paraoxon-Like | O-Alkyl | O-Alkyl | O-Phenyl, diverse substituents |
| Other | O-Alkyl | O/N/S-Alkyl | Varied |




Acetylcholine

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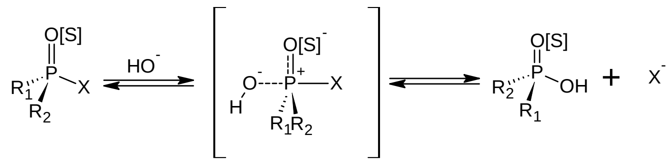
# Hydrolysis of Organophosphorus Compounds




- Hydrolysis is one of the primary decontamination pathways for OP compounds, along with oxidation
  - Not all OPs are susceptible to oxidative decontamination
- In some cases (e.g. V-agents) intermediate hydrolysis products retain toxicity
- For some species, (particularly thions) products of oxidation are more toxic

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# Objectives

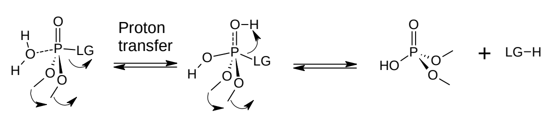
- Develop mechanistic models for hydrolysis of various classes of organophosphorus compounds
  - Explore solvent-dependence, identify key points on reaction surfaces (i.e. transition states, intermediates)
- Evaluate computational methodologies to optimize expense/output of solvent treatment
- Use these models for development of predictive tools for degradation reactions

# Theoretical Methods

- Gaussian '09 Software Suite (QM Calculations)
  - B3LYP Functional, 6-31+G**/6-311*G++ Basis Sets
  - PCM/IPCM Solvation Models
- MOE (Molecular Operating Environment) for QSPR modeling/property estimation
- UCSF Chimera for Visualization

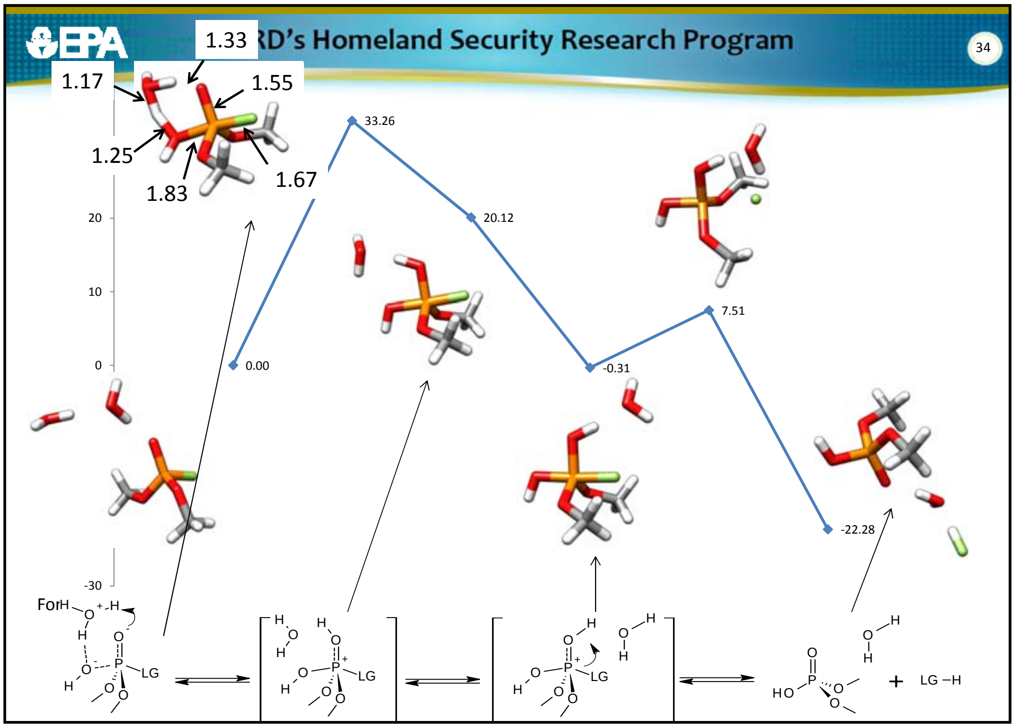


# Inclusion of Explicit Waters




Protonation of phosphoryl oxygen polarizes P to be more electrophilic

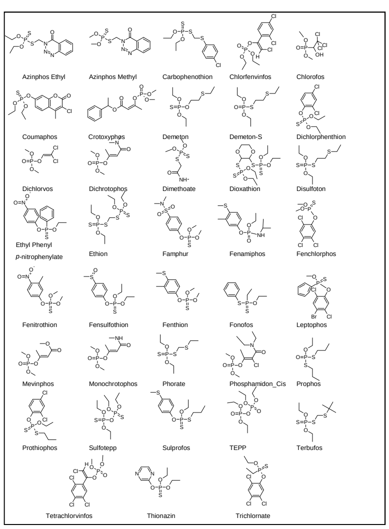
Transfer of a proton to the leaving group promotes collapse of the intermediate

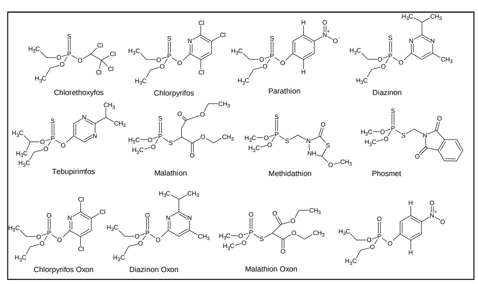







# QSPR Modeling




Two primary sets of compounds for QSPR model development and validation

Data for larger set is more questionable, taken from multiple sources

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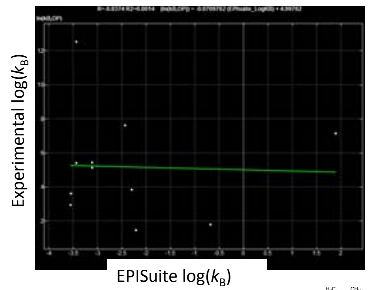
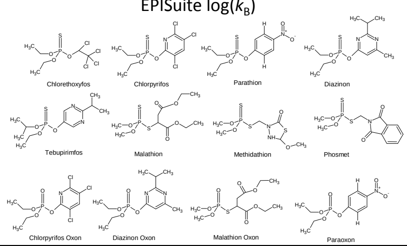
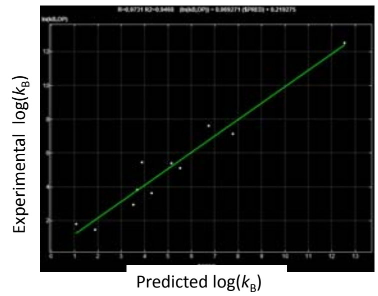
## Hydrolysis rates: Experimental vs Prediction
## EPA's EPISuite vs this QSPR work

EPISuite Predictions of Log($k_B$) for OP Hydrolysis




QSPR Model for log($k_B$) for OP Hydrolysis




Descriptors used: Thermochemistry for hydrolysis ($\Delta G_{298}$) HOMO energy, # chlorines, volume, number of sulfur atoms, # of carbons on spectator groups

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# Conclusions

- This computational approach may enable QSPR predictions
- Inclusion of explicit solvent is vital to a proper investigation of hydrolysis mechanisms for OP compounds
- Use of only one water molecule is insufficient
- Satisfactory treatment of explicit interactions appears to be obtained with between 2 and 3 waters, depending on the compound(s) of interest.

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# Thank you!

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**http://www.epa.gov/nhrsc**

# Disinfection of Vegetative Cells of *Bacillus anthracis in Drinking Water*

TECHNOLOGY DRIVEN. WARFIGHTER FOCUSED.

**Lisa Smith[1], Jeff Szabo[2], Gene Rice[2], and Vipin Rastogi[1]**
**1. U.S> Army-ECBC, R&T Directorate, MD; 2. U.S. EPA, NHSRC, WIPD, OH**

Presented at the 2015 U.S. EPA's International Decontamination Research and Development Conference May 5th-May 7th, 2015

***Approved for Public Release***

# OUTLINE

- **Project Objectives**
- **Materials and Methods**
- **Results**
  - **Vegetative Cell Preparation with Low Spore Numbers**
  - **Free Available Chlorine Disinfection**
  - **Monochloramine Disinfection**
- **Conclusions**
- **Future Directions**

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# Purpose of Study

- In the event of a bio-terrorism attack on US soil, large urban areas, including water distribution systems, are likely to be contaminated
- This poses daunting challenge for federal agencies and first-responders
- *B. anthracis* spores in drinking water are susceptible to high dosage of FAC
- Vegetative cells are assumed to be susceptible to FAC and other common disinfectants
- **Disinfection studies supporting this assumption are lacking**

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# Project Objectives

- **Collaborative Program between ECBC and US EPA**
- **To generate data on the inactivation of vegetative *Bacillus anthracis* in water using free available chlorine (FAC) and monochloramine (MC)**
- **To determine disinfection kill kinetics of FAC and MC against vegetative cells of *B. anthracis***

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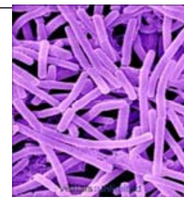
# Materials and Methods

## *Bacillus anthracis* Δ Sterne cell



*B. anthracis* ΔSterne vegetative cells

- Avirulent strain of *B. anthracis*, both pX01 and pXO2 plasmids are missing
- Primary culture
  - A single colony from a freshly-inoculated tryptic soy agar was inoculated in sterile 2xTSB media (J media) and grown at 37 +/- 2 °C for 24 hours
- Secondary culture
  - An aliquot of 100 µl of the overnight culture used to inoculate 10 ml of 2xTSB (J media)
  - Grown at 37 +/- 2° C for four hours

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# Materials and Methods

## Cell Preparation

- **The four-hour culture was centrifuged for 10 min at 3000xg,**
  - **Discard the supernatant**
  - **Pellet resuspended in 25 ml sterile CDF buffer, pH 8 (or pH 7)**
- **This was repeated 2 more times**
- **Finally, the pellet was resuspended in 20 ml of CDF buffer, placed on ice, and used as the test inoculum within 60 min**

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# Materials and Methods

## Disinfection Conditions

| Vegetative Cells | Temperature ( ºC) | pH | Disinfectant | | Time Points (minutes) | Number of test replicates/run[1] |
|---|---|---|---|---|---|---|
| | | | FAC | MC | | |
| BaDS | 5 | 7 | 2-mg/L | | 0.5, 1, 5, 10, 20 & 30 | 2 |
| BaDS | 25 | 7 | 2-mg/L | | 0.5, 1, 5, 10, 20 & 30 | 2 |
| BaDS | 5 | 8 | 2-mg/L | | 0.5, 1, 5, 10, 20 & 30 | 2 |
| BaDS | 25 | 8 | 2-mg/L | | 0.5, 1, 5, 10, 20 & 30 | 2 |
| BaDS | 5 | 8.3 | | 2-mg/L | 1, 5, 10, 20, 30 & 60 | 2 |
| BaDS | 25 | 8.3 | | 2- mg/L | 1, 5, 10, 20, 30 & 60 | 2 |

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# Materials and Methods

## Disinfectant Preparation

- All the glassware and the stirrers used were chlorine demand-free by special cleaning and rinsing with CDF buffer
- Free available chlorine
  - Made with 1:200 diluted sodium hypochlorite and chlorine demand free phosphate buffer both pH 7 and pH 8
  - Free and total chlorine concentrations were determined using a Hach pocket colorimeter II analysis system for chlorine
- Monochloramine
  - Made with 1000 mg/chlorine and 1000 mg/L ammonia nitrogen and phosphate buffer pH 8.3
  - Was calculated by subtracting the free chlorine from the total chlorine measurement

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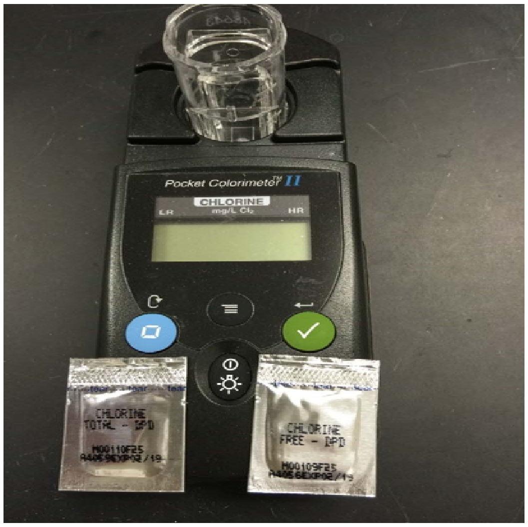
# Materials and Methods

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# Materials and Methods

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# Materials and Methods

## Holding Solutions

- Tests were conducted in two incubators, set at 5°C and 25°C
- Reaction vessels for each test consisted of four sterile, CDF borosilicate glass beakers, each containing a CDF stir bar
- An aliquot of 2 ml test inoculum was added to the 198 ml of chlorinated buffer with steady stirring
- A timer was started
- 10 ml samples were withdrawn at appropriate times and transferred to tube containing 0.1 ml of 10% sodium thiosulfate
- Chlorine samples were taken at the first and the last time point
- Samples were put on ice until serial dilutions were made and samples were plated on TSA and incubated at 37°C overnight

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# Results

## Vegetative Cell Preparation with Low Numbers

- Challenge– to find culture conditions permitting high vegetative growth (>8 – logs/ml) while keeping spore number to zero or very low (<2 logs)
- Two critical factors in controlling sporulation onset were Carbon/ Nitrogen abundance/ media type and growth temperature
- Media tested were TSB, 2xTSB, 3xTSB, 2xTSB supplemented with carbon or nitrogen, J media and a new recipe – RVLS
- Goal – zero or minimal spores

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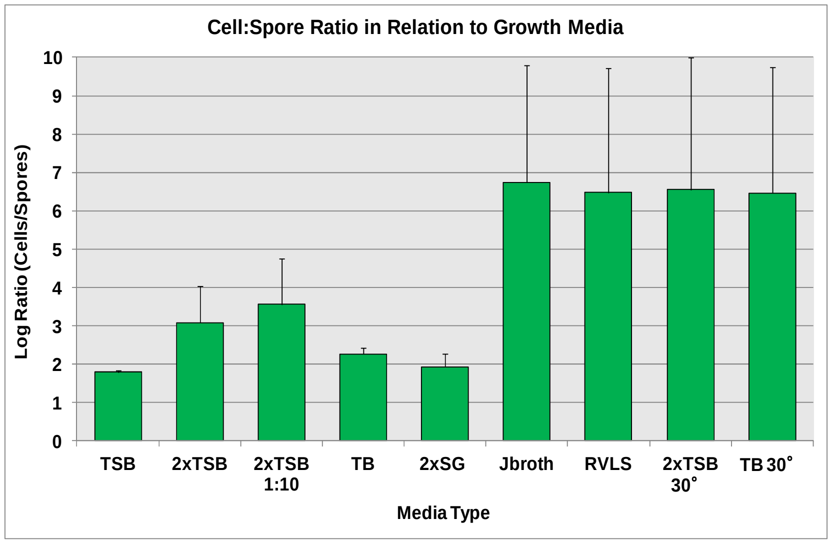
# Results – Vegetative Cells

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# Results - FAC Disinfection

## FAC Concentration at the Start and End of the Run

| | | 5 C | | 25 C | | 5 C | 25 C |
|---|---|---|---|---|---|---|---|
| Dates | pH | FAC (Start) | FAC (End) | FAC (Start) | FAC (End) | Δ FAC | Δ FAC |
| 1/30/2013 | 7 | 1.9 | 1.05 | 2.3 | 0.8 | 0.85 | 1.5 |
| 2/6/2013 | 7 | 2 | 1.5 | 2.2 | 1.15 | 0.5 | 1.05 |
| 2/13/2013 | 7 | 2.1 | 1.05 | 1.7 | 0.4 | 1.05 | 1.3 |
| 2/20/2013 | 8 | | | 1 | 0.15 | | 0.85 |
| 3/6/2013 | 8 | 0.9 | 0.3 | 1 | 0.15 | 0.6 | 0.85 |
| 3/13/2013 | 8 | 0.7 | 0.35 | 1.4 | 0.55 | 0.35 | 0.85 |
| 4/10/2013 | 8 | 0.9 | 0.55 | 1 | 0.6 | 0.35 | 0.4 |
| 4/17/2013 | 7 | 1.8 | 1.2 | 1.9 | 1.05 | 0.6 | 0.85 |
| 7/18/2013 | 7 | 1.9 | 1.4 | 1.9 | 1.4 | 0.5 | 0.5 |
| 7/23/2013 | 8 | 0.8 | 0.55 | 1 | 0.65 | 0.25 | 0.35 |

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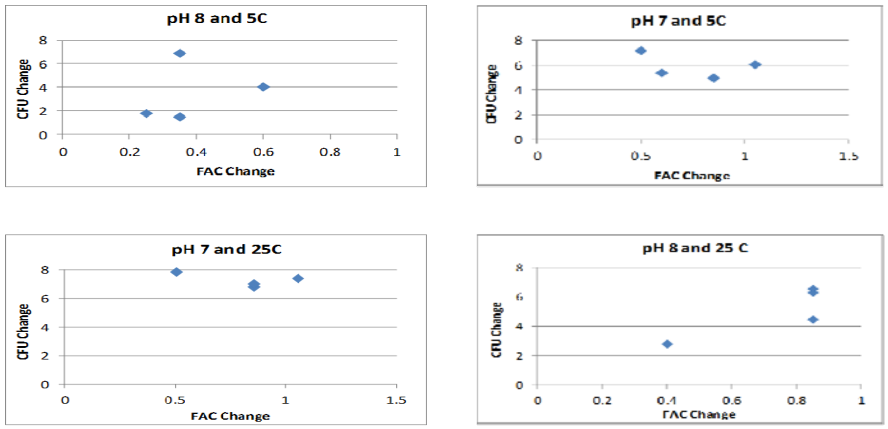
# Results – FAC Disinfection

## Correlation between ΔFAC and ΔCells

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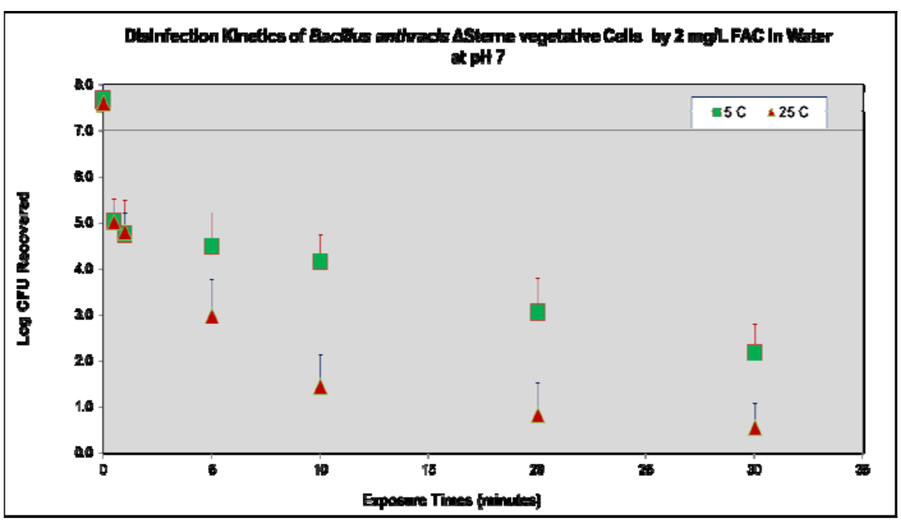
# Results - FAC Disinfection

## Free Available Chlorine Disinfection Kinetics at pH 7

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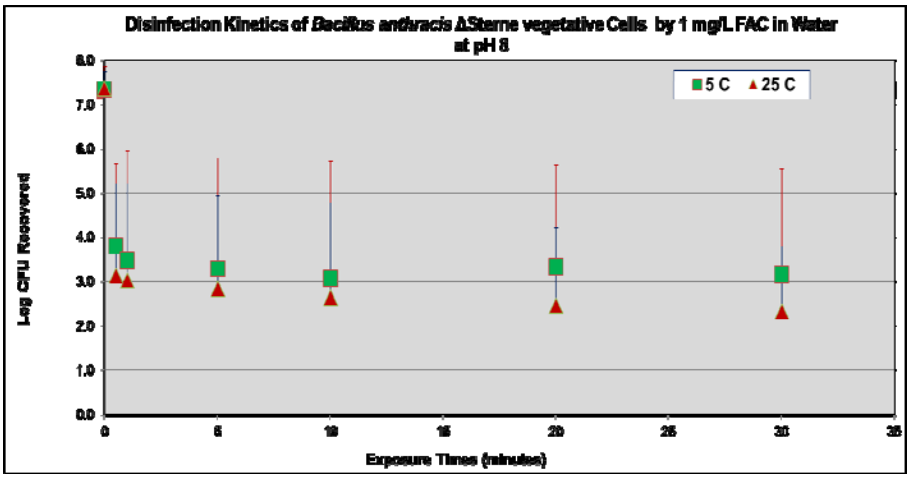
# Results – FAC Disinfection

## FAC Disinfection Kinetics at pH 8

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# Results – MC Disinfection

## MC Concentration at the Start and End of the Run and Change in Cell Numbers

| | | 5 C | | 25 C | | 5 C | 25 C | 5 C | 25 C |
|---|---|---|---|---|---|---|---|---|---|
| Dates | pH | MC (Start) | MC (End) | MC (Start) | MC (End) | Δ MC | Δ MC | Δ Log CFU (Zero-END) | Δ Log CFU (Zero-END) |
| 4/10/14 | 8.3 | 2.00 | 1.60 | 1.20 | 0.65 | 0.4 | 0.55 | 1.035 | 3.17 |
| 7/15/14 | 8.3 | 1.55 | 1.40 | 1.35 | 1.50 | 0.15 | -0.15 | 3.18 | 2.72 |
| 7/17/14 | 8.3 | 1.60 | 1.10 | 2.05 | 1.10 | 0.5 | 0.95 | 2.63 | 3.05 |
| 7/22/14 | 8.3 | 1.65 | 1.55 | 1.45 | 1.50 | 0.1 | -0.05 | 6.65 | 4.69 |

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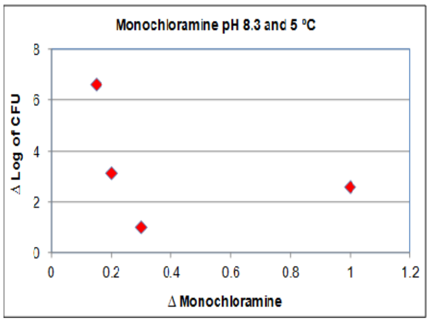
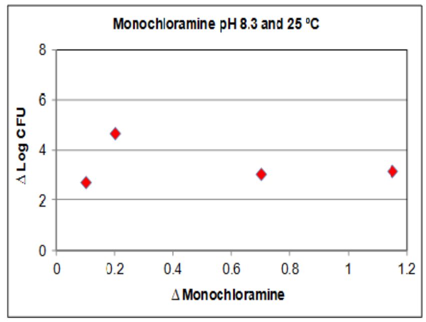
## Results – MC Disinfection

### Correlation between ΔMC and ΔCells

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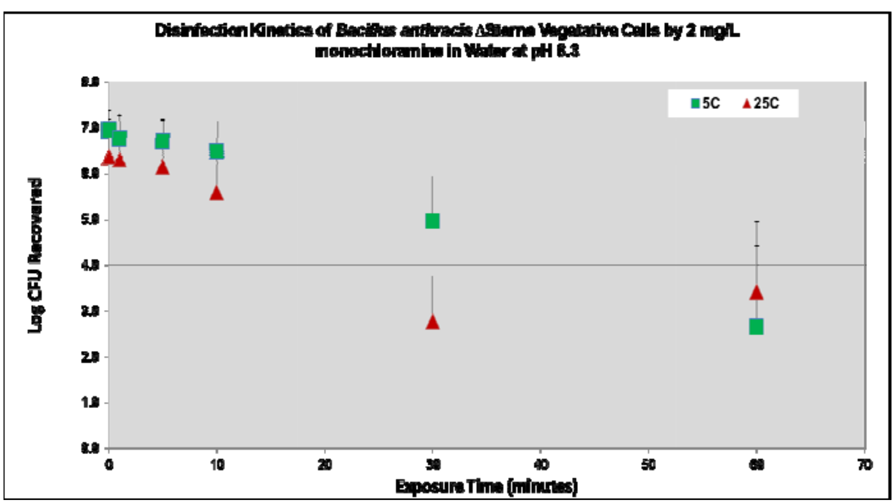
## Results – MC Disinfection

### Monochloramine Disinfection Kinetics at pH 8.3

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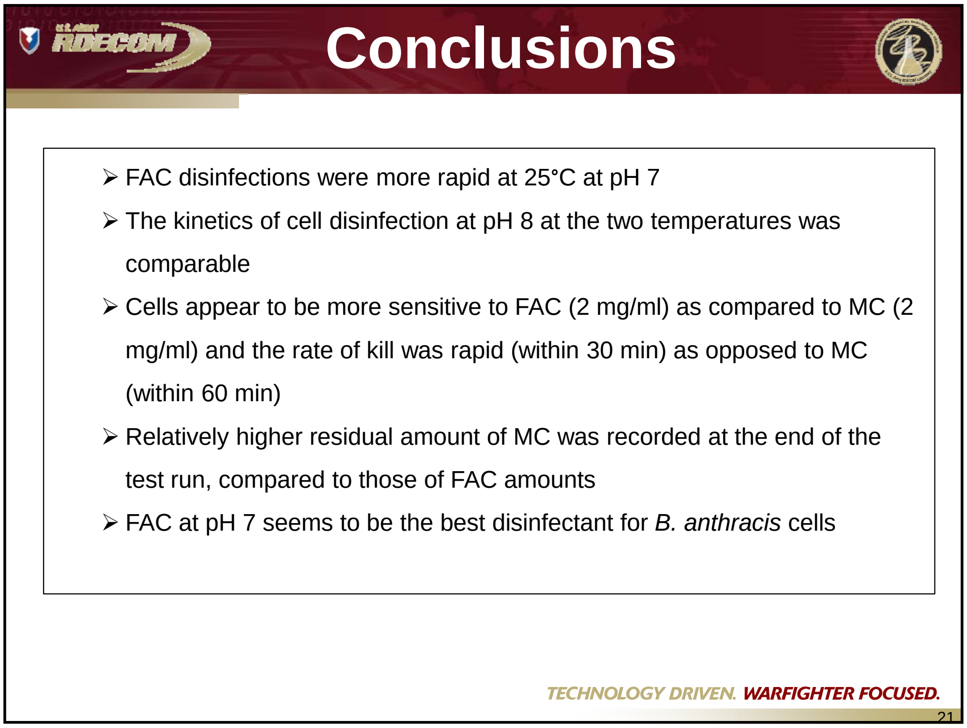
U.S. ARMY
RDECOM
Conclusions
➢ FAC disinfections were more rapid at 25°C at pH 7
➢ The kinetics of cell disinfection at pH 8 at the two temperatures was comparable
➢ Cells appear to be more sensitive to FAC (2 mg/ml) as compared to MC (2 mg/ml) and the rate of kill was rapid (within 30 min) as opposed to MC (within 60 min)
➢ Relatively higher residual amount of MC was recorded at the end of the test run, compared to those of FAC amounts
➢ FAC at pH 7 seems to be the best disinfectant for *B. anthracis* cells
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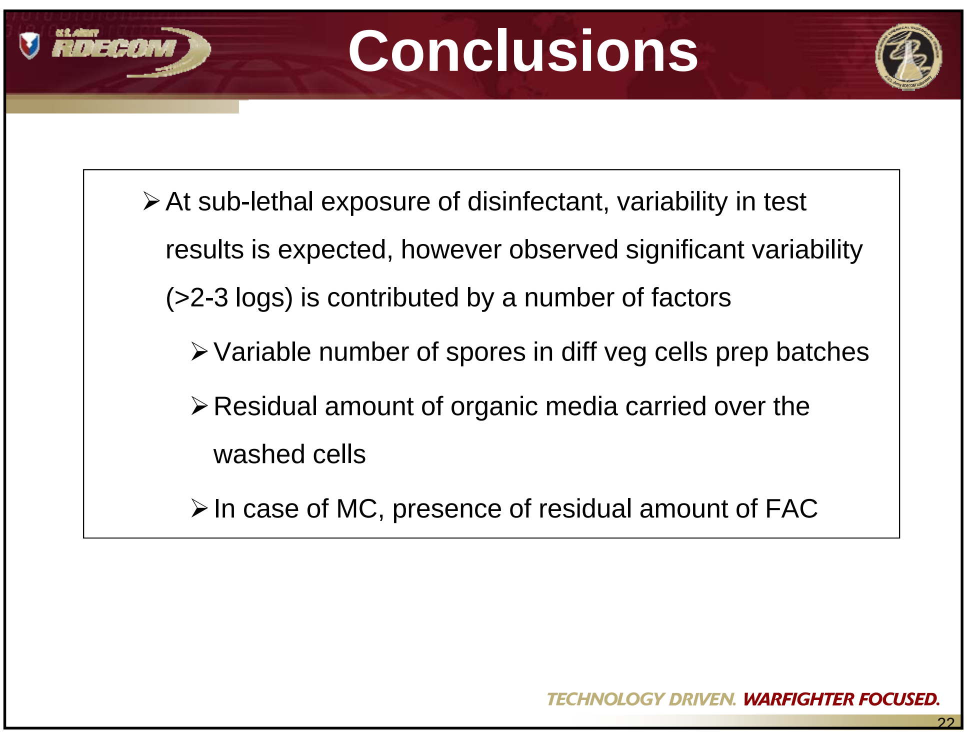
U.S. ARMY
RDECOM
Conclusions
➢ At sub-lethal exposure of disinfectant, variability in test results is expected, however observed significant variability (>2-3 logs) is contributed by a number of factors
➢ Variable number of spores in diff veg cells prep batches
➢ Residual amount of organic media carried over the washed cells
➢ In case of MC, presence of residual amount of FAC
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## Future Research

- In order to further substantiate the efficacy of disinfection of FAC and MC and generate kinetics runs with <1-log SD variability, it is recommended that the study be repeated with either use of sporulation minus strain of *B. anthracis* and or use the new growth media, RVLS
- The sporulation minus strain was procured from Dr. Steve Leppla (NIH, Bethesda, MD)
- RVLS appears to support minimal sporulation, thereby controlling the number of spores in the cell preparation batches in different runs
- A 75 min sampling time point would be recommended for MC

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## CREDITS

- **Funding**

  Dr. Jeff Szabo and Dr. Gene Rice , US EPA, NHSRC, WIPD, OH

- **ECBC Performers**

  Vipin Rastogi, Michelle Ziemski, Savannah Maggio, Laura Burton, and Amelia Stephens

**Contact Information - Lisa.s.smith.civ@mail.mil**; **410-436-3846**

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# Questions?


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# Deployable Treatment of Decontamination (DECON) Effluent

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## Challenge

**Problem:** Although the Army maintains extensive decontamination capabilities (DECON) to mitigate CBRN attacks, there is no capability to treat and/or recycle the effluent from aqueous-based decontamination operations. This effluent is still very hazardous and represents a major handling, logistical, and potentially political burden.

**Challenge: Develop a CBRN DECON effluent treatment system that will mitigate DECON water constraints, be rapidly deployed and easy to maintain, minimize the volume of water required for DECON, and minimize the volume of DECON effluent requiring management / disposal.**

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# Existing DECON Water Recycling Technology

Current DECON strategies provide physical/ chemical removal of contamination, but ***at best*** use on-site storage/containment of hazardous effluent, and often just containment.

A NIST review of 200+ commercially available DECON technologies found only ONE system that includes any treatment of effluent (a booth for tools/small equipment).

**CRITICAL TECHNOLOGY GAP**

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# Project Drivers

- FM 3-11.5 CBRN Decontamination – Appendix K
  - Large waste volumes
  - Management approaches
- 2013 Unified Quest Deep Futures Wargames – ARCIC
  - Operation in water stressed environment with a series of chemical attacks
  - Water supply heavily stressed

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# Objectives

**Develop a rapidly deployable CBRN DECON *__effluent treatment system__* for:**

1) minimization of environmental health risk
2) reduction of water supply needs associated with DECON, and
3) reduction of manpower for DECON effluent management.

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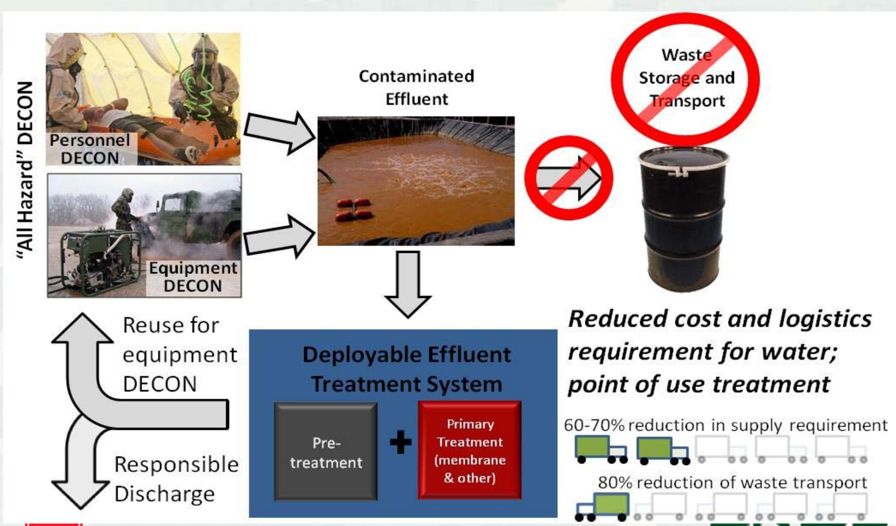
# Vision/Background

**Deployable CBRN DECON Effluent Treatment System**

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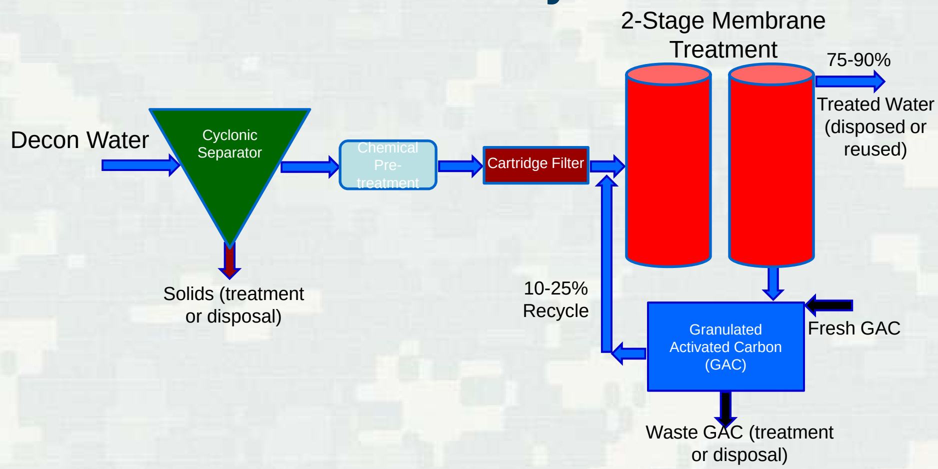
# Envisioned DECON Effluent Treatment System

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# Performance Metrics

| Metric | Current | Program Objective | Army Objective | TRL/SRL |
|---|---|---|---|---|
| Water Recovery | None | 80% reuse from system | ~60-80% reduction in water needed | Start 3<br>End 6 |
| Water Quality Standards | None | USAPHC IP 31-027 | Not Established | Start 3<br>End 6 |
| Operational Personnel | None | 1 Man Operation; < 2 hr Setup & Close | Reduction in Manpower, Water Transport | Start 3<br>End 6 |

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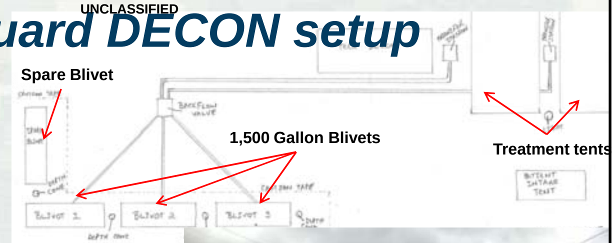
# MA National Guard DECON setup


- Green (military) Missions
  - ►Personnel and equipment/vehicle DECON
  - ►Responsible for finding water source
  - ►Collecting waste is secondary to DECON mission
  - ►System would particularly benefit water supply issues
    - Spend hours waiting on logistics (supply, delivery, treatment)
    - Securing water in hostile environments is challenging
    - Pre-treatment would be helpful-Allow use of wider variety of source waters
- White (civilian) Missions
  - ►Waste collected in 1,500 gallon blivets (3/site + 1 backup = 6,000 gallons of storage)
    - Use rate of 3,000 gallons/hour (**2-4 hours to exhaust storage capacity**) ; Incident commander responsible for removal
    - NO identified strategy once capacity is reached
  - ►Effluent Water treatment
    - They want help treating their water!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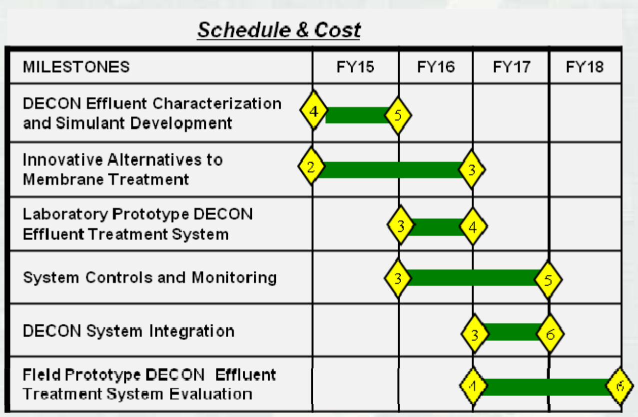
# Deployable Treatment of Decontamination Effluents

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# Results/Findings/Products To Date

- Task 1. Effluent Characterization & Simulant selection
  - ► Effluent characterization mostly completed.
  - ► Simulant selection completed
- Task 2. Novel treatment
  - ► Methods developed to produce graphene oxide (GO) filters.
  - ► Preliminary testing of GO filters with laboratory vacuum systems.
  - ► Characterization Studies on GO membranes
  - ► Development of laboratory bench test system for GO vs. conventional membrane studies.

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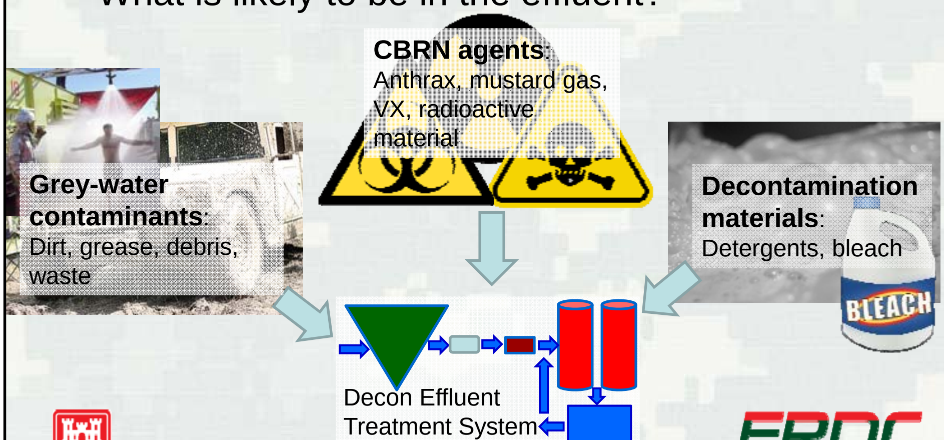
# Task 1-Effluent characterization

- What is likely to be in the effluent?

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# Task 1-Concentration estimation

## Vehicle Decontamination

| Vehicle Type | Dimensions (m) | | Approximate Surface Area (m²) | Water Volume Required to Clean (L) | Max Simulant Concentration Range in Effluent (g/L) | Effective Concentration Range in Effluent (g/L) |
|---|---|---|---|---|---|---|
| Transport (Jeep) | Length | 1.798 | 28.698 | 227 | 0.126-1.264 | 0.1134-1.1376; 0.0252-0.2528 |
| | Width | 1.615 | | | | |
| | Height | 3.353 | | | | |
| Armored vehicle (Tank) | Length | 9.43 | 153.874 | 673 | 0.229-2.286 | 0.2061-2.0574; 0.0458-0.4572 |
| | Width | 3.63 | | | | |
| | Height | 3.27 | | | | |

## Personnel Decontamination

| Patient type | Gender | Approximate Surface Area (m²) | Water Volume Required to Clean (L) | Max Concentration Range in Effluent (g/L) | Effective Concentration range in Effluent (g/L) |
|---|---|---|---|---|---|
| Ambulatory | Male | 1.9 | 35 | 0.054-0.543 | 0.049-0.486<br>0.011-0.108 |
| | Female | 1.6 | | 0.046-0.457 | 0.041-0.414<br>0.009-0.092 |
| Non-Ambulatory | Male | 1.9 | 100 | 0.019-0.190 | 0.0171-0.171<br>0.038-0.380 |
| | Female | 1.6 | | 0.016-0.160 | 0.014-0.144<br>0.003-0.032 |

- Max simulant concentration based on estimate of 1-10 g/m² coverage
- Effective simulant concentration assumes loss due to hydrolysis and other factors from 10% (top number) to 80% (bottom number)

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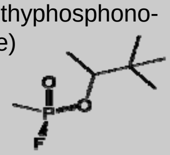
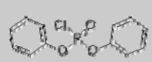
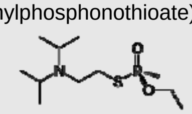
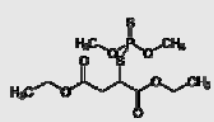
# Task 1-Simulant selection

| Agent | Simulant | Additional Info |
|---|---|---|
| Soman (Dimethyl-2-butyl methyphosphono-fluoridate)  | Diphenyl cholorophosphate  | -Available from Sigma (99% purity)<br>-Relatively inexpensive |
| VX (O-ethyl-S-[2-diisopropylamino)ethyl] methylphosphonothioate)  | Malathion  | -Available from Sigma<br>-Not as toxic as other organophosphates, still used as a pesticide and control of mosquitoes |

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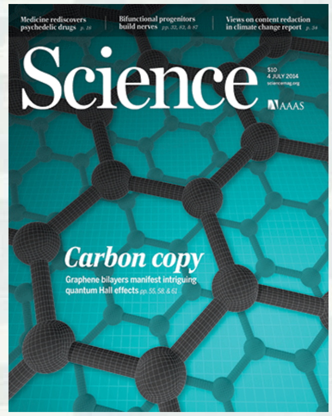
# Results/Findings/Products To Date

- Task 2. Novel treatment materials
  - ► Methods developed to produce graphene oxide (GO) filters.
  - ► Characterization Studies on GO membranes
  - ► Preliminary testing of GO filters
  - ► Development of laboratory bench test system for GO vs. conventional membrane studies.




July 2014 Cover from Science Journal Featuring Graphene Research

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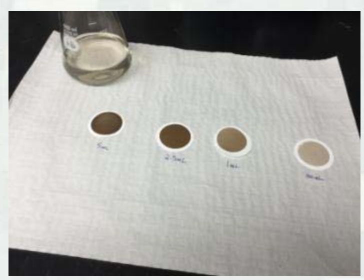
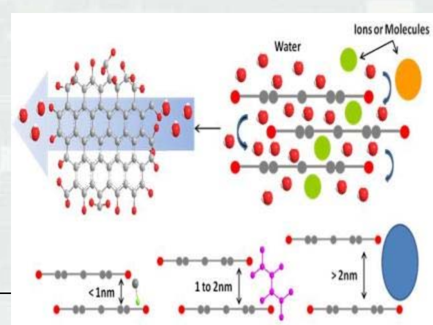
# Results/Findings/Products To Date

### Task 2 Graphene Oxide Membranes

- Potential for reverse osmosis quality treatment at much lower pressure (energy) and higher rates.
- Potential for more durability, high selectivity, & less fouling issues.
- Methods developed for preparing simple, durable filters for experimental purposes.



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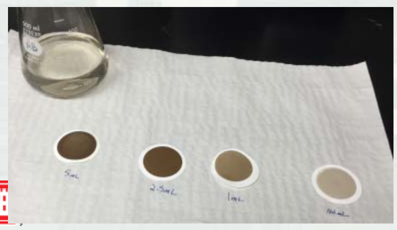
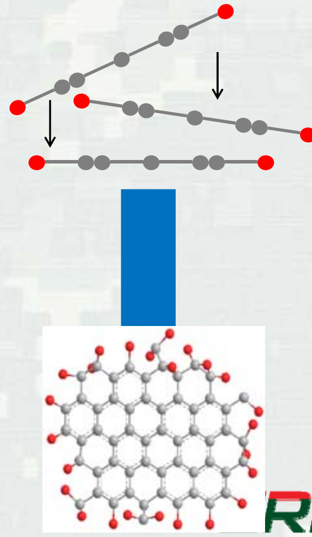
# Synthesis of GO Membrane By Vacuum Filtration





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# Results/Findings/Products To Date

### Task 2 Filtration Using GO Membranes

- Filtration of Methyl Orange Dye using a simple, vacuum-prepared GO disk on a paper, 0.45 um filter
- Filtration using a house vacuum system, about 10 times lower pressure than typical Reverse Osmosis (RO).
- Some degradation observed as the system runs.
- Constructing a high pressure system to compare GO to other membranes.

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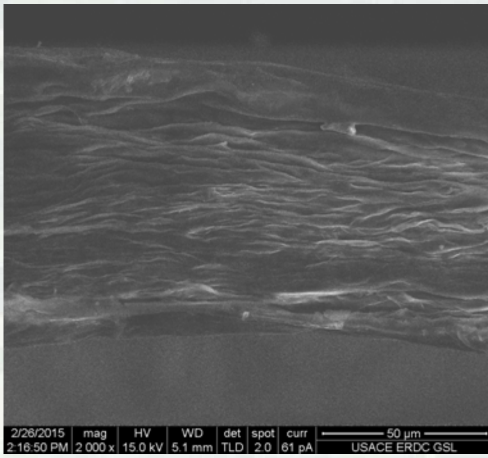
# Scanning Microscopy of GO Membrane Cross Section




Visible layers of Graphene Oxide throughout profile of membrane

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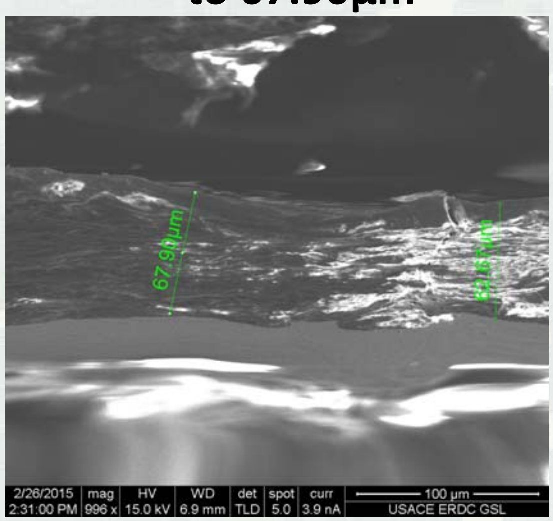
# Uniform Thickness Ranging from 62.67µm to 67.90µm

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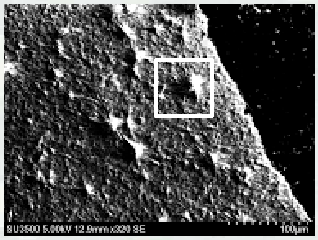
# Results/Findings/Products To Date

**Task 2. Scanning and Transmission Microscopy of GO Membranes**



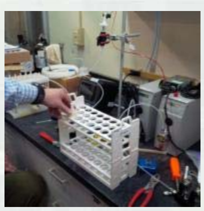

Scanning electron micrograph (SEM) of nodal growths. The lighter shade of the nodal features is indicative of higher density

Transmission electron micrograph of cross section of nodal feature on a GO membrane.





# Membrane Filtration Reactor

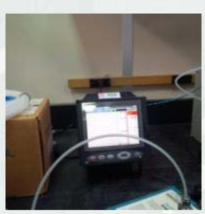


Overview - Rack allows for sample collection bottles

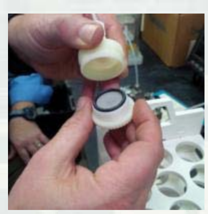
High pressure pumps

Manifold

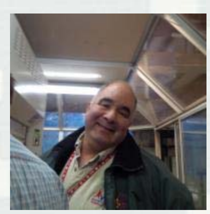
Pressure sensor



Pressure/flow recorder



Membrane cassette



Victor (Project Lead)

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# Connections/Collaborations

- Partners (to date)
  - ECBC
  - RDECOM-ARDEC
  - Sandia National Laboratory (reciprocal studies)
- Briefed organizations
  - MSCoE
  - DTRA
  - TRADOC-ARCIC
  - MIT Lincoln Labs
  - USEPA
  - USNORTHCOM
- Operational Connections
  - 272nd Chemical Brigade, MA National Guard
  - National Guard Bureau
  - ANORTH Civilian Support Training Activity (CSTA)

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# Acknowledgements

- Project Team:
  - ERDC EL:
    - Dr. Victor Medina (Project Lead)
    - Mr. John Ballard (PM)
    - Dr. Jeff Steevens (ST)
    - Mr. Scott Waisner
    - Mr. Chris Griggs
  - ERDC CERL:
    - Dr. Martin Page
    - Dr. Imee Smith
  - ERDC GSL:
    - Dr. Robert Moser
  - ERDC GRL:
    - Dr. Andromorgan Fisher
  - ECBC:
    - Dr. Lawrence Procell
  - RDECOM/ARDEC:
    - Dr. Kim Griswold

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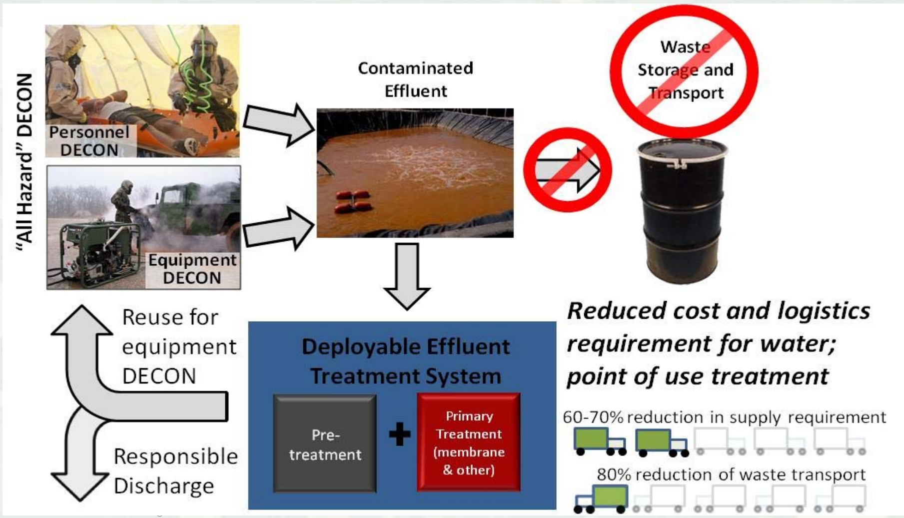
# Questions?








# Backup Material

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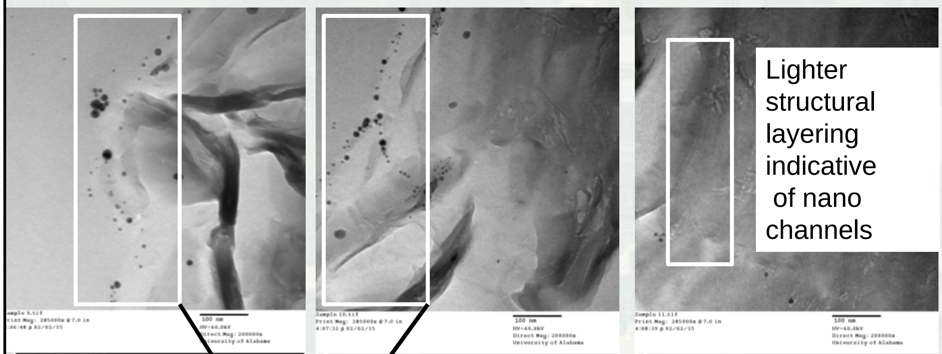
# 200,000X Transmission Microscopy of Nano-Structures



Lighter structural layering indicative of nano channels

Darker spheres on surface suspected to be higher density $Al^{3+}$ from anodized substrate

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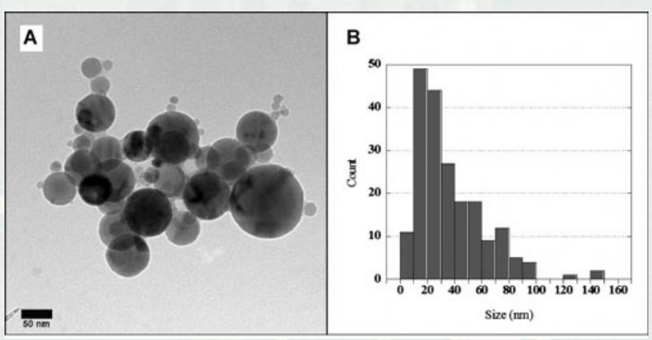
# Aluminum Nanoparticles appear to be the source of the dark, circular matter (prepared using aluminum anodisks)

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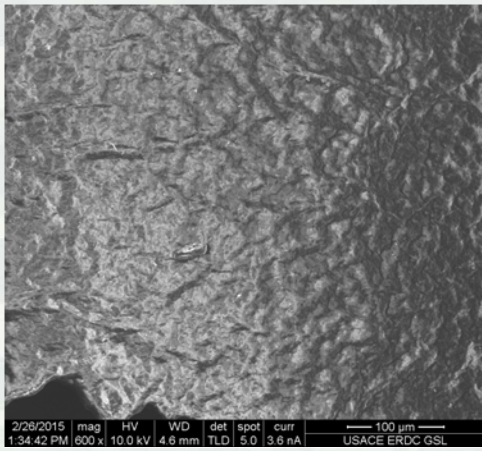
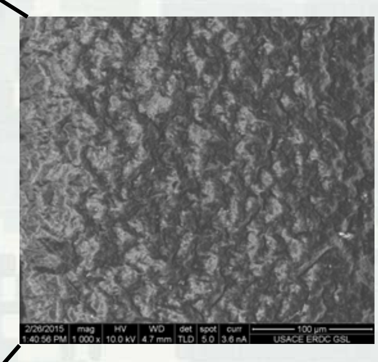
# Crumpled Topography of GO Membrane Surface




600X




1000X

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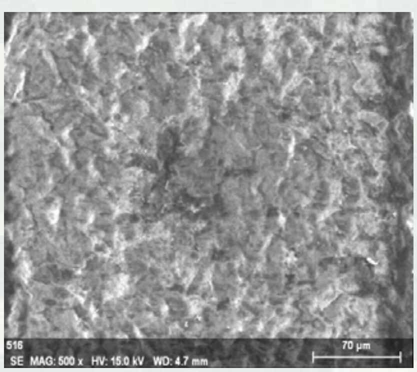
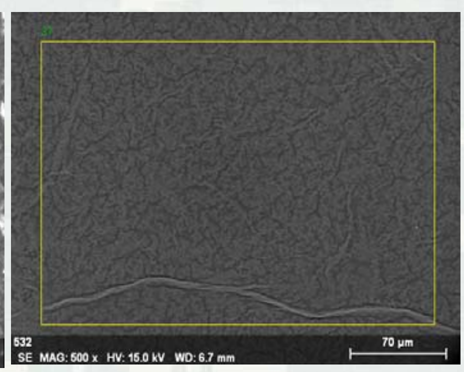
# Top/Bottom differ in Topography after Vacuum Filtration




Top




Bottom

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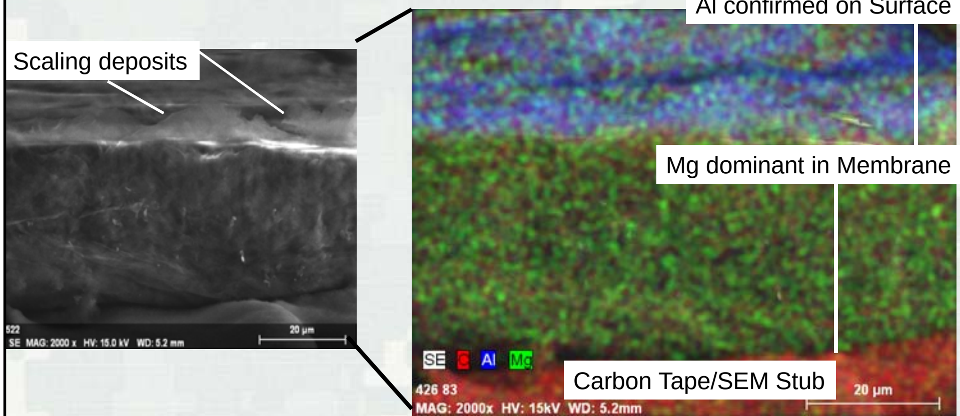
# Membrane Post $MgCl_2$ Challenge








# Comparative Scenarios

**A CBRN attack on a U.S. City stresses water sources due to firefighting and/or decontamination**

- **Scenario 1 –** Wastewater stored in water bladders.
  - Water resources are stressed.
  - Bladders take up space, could be targeted in follow on attacks, and create eventual removal management issues
- **Scenario 2 –** Wastewater is discharged into local sewers.
  - Water resources stressed
  - Sewers can become contaminated, creating a long term management issue.
  - Wastewater treatment plant may be affected by CBRN constituents & treatment chemicals.
- **Scenario 3 –** Effluent treatment leading to recycling of a portion of the waste stream
  - Reduces water stress
  - Removes liability and exposure issues.

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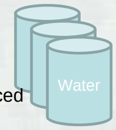
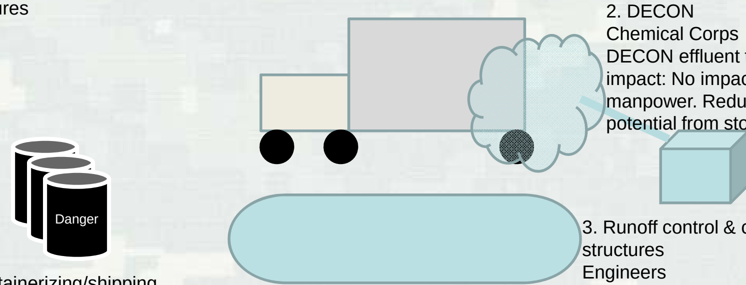
## DECON Effluent Treatment is an Army-Wide Issue

- Crosses several organizations
- Can reduce effort, costs, and manpower
- Can reduce potential for releases & toxic exposures

1. Water supply
CASCOM / LOGCAP
DECON treatment effluent impact: By recycling, water Supply needs can be reduced & manpower reduced.




2. DECON
Chemical Corps
DECON effluent treatment impact: No impact on manpower. Reduces exposure potential from stored effluent




3. Runoff control & capture structures
Engineers
DECON effluent treatment impact: Reduce size needed for capture Structures, reducing effort & manpower.

4. Containerizing/shipping
CASCOM/LOGCAP/Navy
DECON effluent treatment impact: Substantially reduce or completely eliminate, reducing effort & manpower. Potential for leaks & toxic exposures are also greatly reduced.

5. Cleanup/Remediation
Engineers/LOGCAP
DECON effluent treatment impact: Substantially reduce or completely eliminate, reducing effort & manpower. Potential toxic exposures are also greatly reduced.

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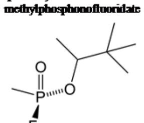
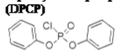
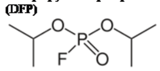
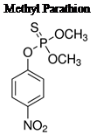
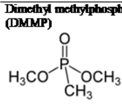
# Simulant Selection - Soman

| Agent | Simulant | Pros | Cons | Suitability Ranking |
|---|---|---|---|---|
| Soman<br>-GD<br>-Dimethyl-2-butyl methyphosphonofluoridate<br>-pinacolyl methylphosphonofluoridate<br> | Diphenyl chlorophosphate (DPCP)<br> | *Available from Sigma (99% purity) Item#D206555<br>*Inexpensive $72.80 for 100g | | 1 |
| | Diisopropyl fluorophosphate (DFP)<br> | * Available from Sigma Item# D0879<br>*Stable for 2 years | *Expensive $348.50 for 1g | 2 |
| | Methyl Parathion<br> | * Available from Sigma Item# 36187 | *Extremely toxic upon acute inhalation, oral, and dermal exposure<br>*Somewhat expensive $50.70 for 100mg | 4 |
| | Dimethyl methylphosphonate (DMMP)<br> | * Available from Sigma (97% purity) Item# D169102<br>*Inexpensive $60.40 for 500g<br>*Can also be used to mimic VX | | 3 |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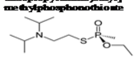
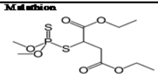
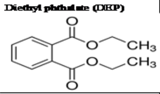
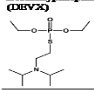
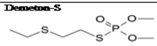
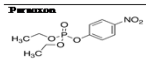
# Simulant Selection - VX

| Agent | Simulant | Pros | Cons | Suitability Ranking |
|---|---|---|---|---|
| VX<br>-O-ethyl-S-[2-diisopropylamino)ethyl] methylphosphonothioate<br> | Malathion<br> | * Available from Sigma Item# 36143<br>*Not as toxic as other organophosphates, still used as a pesticide and control of mosquitoes | *Somewhat expensive $36.70 for 100mg | 1 |
| | Diethyl phthalate (DEP)<br> | * Available from Sigma Item# W512206<br>*Very inexpensive $60.00 for 1kg<br>*Believed to have low toxic potential | | 3 |
| | Diethoxyphosphate-VX (DEVX)<br> | *Same thiolate leaving group as VX | *Not commercially available; must be synthesized<br>*Highly toxic | 5 |
| | Demeton-S<br> | *Similar chemical structure to VX, particularly at the phosphorus<br>*Discontinued by Sigma, but stock still available, Item# PS662<br>*Available from ChemService (>95% purity) Item# N-11582-100MG | *Expensive, $111.00 for 100mg (Sigma)<br>* Expensive, $100.90 for 100mg (ChemService) | 4 |
| | Paraoxon<br> | *Available from ChemService (>98% purity) Item# N-12816-100MG | * Expensive, $70.10 for 100mg | 2 |

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## Advanced Oxidative Process Treatment of Heavily Contaminated Water for Drain Disposal and POTW Acceptance


*Rebecca Phillips, Oak Ridge Institute for Science and Education Intern*
*Matthew Magnuson, US Environmental Protection Agency*
*Ryan James and Mark Benotti, Battelle*



*2015 EPA International Decontamination*
*Research and Development Conference*
*Durham, NC*
*May 6, 2015*


## Summary

Project Objectives:

- Develop a toolbox of strategies for the disposal of contaminated water from large volume contamination events
- Address concerns of wastewater utilities in accepting contaminated water pre-treated with advanced oxidation processes (AOP)

Findings:

- All AOP technologies investigated showed some degree of contaminant degradation
- Toxicity reductions were observed in the AOPs to differing extents
- Contaminant degradation is not always a good indicator of toxicity reduction.

1

## Water Contamination

- Treatment methods for large volumes of contaminated water, washwater and wastewater:
  - Incineration
  - Transportation to specialty facilities
  - Drain disposal
- Issues with drain disposal:
  - May require appropriate pre-treatment
  - Potential impact on wastewater treatment operations
  - Dischargeable effluent desired

2

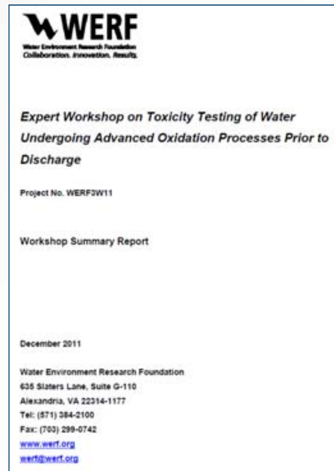
## Advantages of Advanced Oxidation Process (AOP)

- Generate hydroxyl radicals:
  - 1.5 times the oxidizing power of ozone
  - 2.1 times the oxidizing power of chlorine.
- No chlorinated by-products
- Several AOP technologies suitable for field use

3

## Development of Technical Approach

- Concerns of wastewater treatment plants on acceptance of AOP-treated water:
  - Biological treatment processes
  - Receiving waters
  - Infrastructure
- Desired tests:
  - Real-time monitoring of AOP treatment
  - Verification of contaminant degradation
  - Impact on biological treatment process
  - Impact of contaminant on receiving water organisms


WERF
Water Environment Research Foundation
Collaboration. Innovation. Results.

*Expert Workshop on Toxicity Testing of Water Undergoing Advanced Oxidation Processes Prior to Discharge*

Project No. WERF3W11

Workshop Summary Report

December 2011

Water Environment Research Foundation
635 Slaters Lane, Suite G-110
Alexandria, VA 22314-1177
Tel: (571) 384-2100
Fax: (703) 299-0742
www.werf.org
werf@werf.org

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## Technical Approach

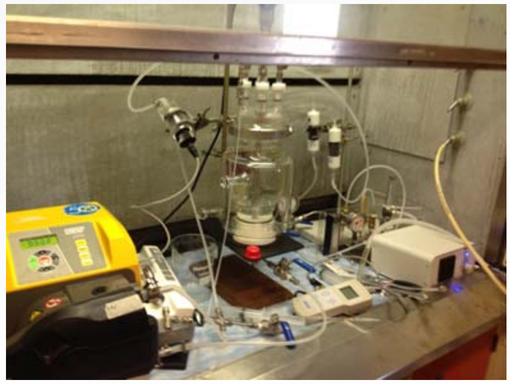
- Investigate several AOPs as pretreatments for drain disposal of contaminated drinking water
- Perform toxicity tests for:
  - Wastewater treatment plant microorganisms (Nitrification Inhibition testing)
  - Receiving waters (Microtox toxicity testing)
- Design experiments to aid in:
  - Selecting effective methods for treatment and disposal of contaminated water
  - Assessing impacts of an incident with and without treatment

5

## AOP Technologies Selected

### Ozone / peroxide

- Maximum $O_3$ concentration:
  - ~8 mg/L
- $H_2O_2$ dose:
  - 35 mg/L initially
  - 35 mg/L when Ozone concentration becomes non-zero



» Reaction: $2\ O_3 + H_2O_2 \rightarrow 2\ {\bullet}OH + 3\ O_2$

» Unit investigated: Enchem Engineering, Inc.

6

## AOP Technologies Selected

### Boron-doped diamond electrode (BDDE)

- Electrolyte concentration:
  - 0.05 M
- Electrolytes:
  - NaCl
  - $NaNO_3$

» Many reactions (including generation of •OH)

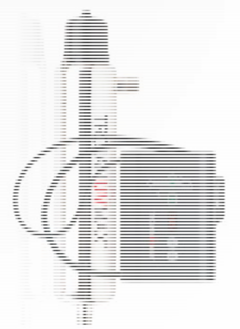
» Unit investigated: Advanced Diamond Technologies, Inc.

7

## AOP Technologies Selected

### UV / peroxide

- Constant light output
- $H_2O_2$ dose:
  - 35 mg/L initially
  - 35 mg/L when $H_2O_2$ concentration decreases below ~20 mg/L



» Reaction: $H_2O_2 \rightarrow 2\ \bullet OH$

» Unit investigated: TrojanUV - UV Max D4

8

## Target Contaminants

Attributes:

– Range of hydroxyl radical reactivity. Reaction rates of compounds not studied can be estimated via their known hydroxyl radical reactivity.

– Direct injection LC-MS/MS analysis

– Applicability to water security or water quality

| | |
|---|---|
| Propanil | Carbofuran |
| Aldicarb | Atrazine |
| Carbamazepine | Cyanazine |
| Bisphenol A (BPA) | Phenylephrine |
| Tris(2-chloroethyl) phosphate (TCEP) | Diethyl methyl phosphonate (DEMP) |

9

## Toxicity Testing

- Nitrification Inhibition Test:
  - Organism: Nitrifying bacteria in mixed liquor
  - Measures: Rate of decrease of ammonia
  - Indicates: Toxicity to wastewater biological treatment processes

- Microtox Toxicity Test:
  - Organism: Luminescent marine bacteria
  - Measures: Differences in light output
  - Indicates: Eco-toxicity for discharge to receiving waters

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## Experimental Design

- 3 AOP technologies investigated:
  - 1 contaminant at a time
  - Initial contaminant concentration: 10 mg/L
  - Reaction time: 2 hours
  - Dechlorinated drinking water matrix (~pH 7-8, ~1 mg/L total organic carbon)
- Sampling:
  - Contaminant degradation: LC-MS/MS
    - All samples
  - Toxicity testing: Microtox and Nitrification Inhibition
    - All samples adjusted to pH ~7
    - Uncontaminated Controls
    - Contaminated drinking water
    - AOP treated contaminated drinking water

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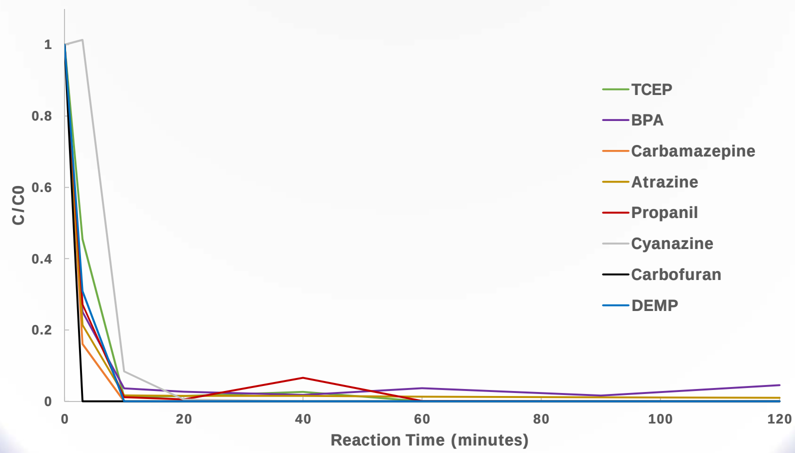
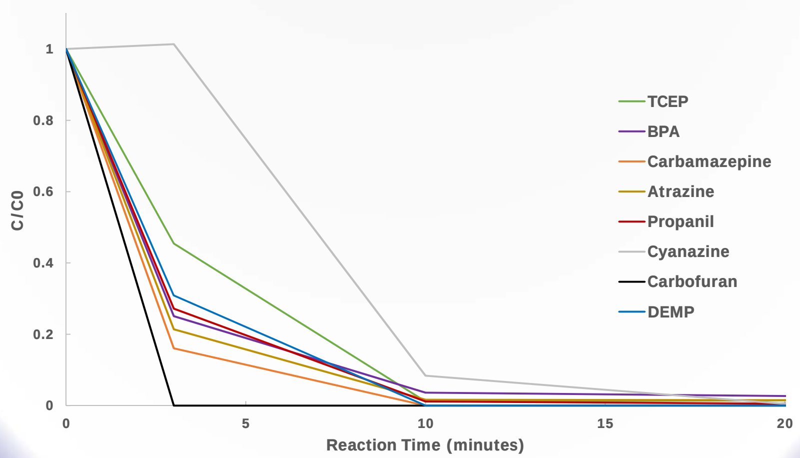
## Results: Ozone/Peroxide



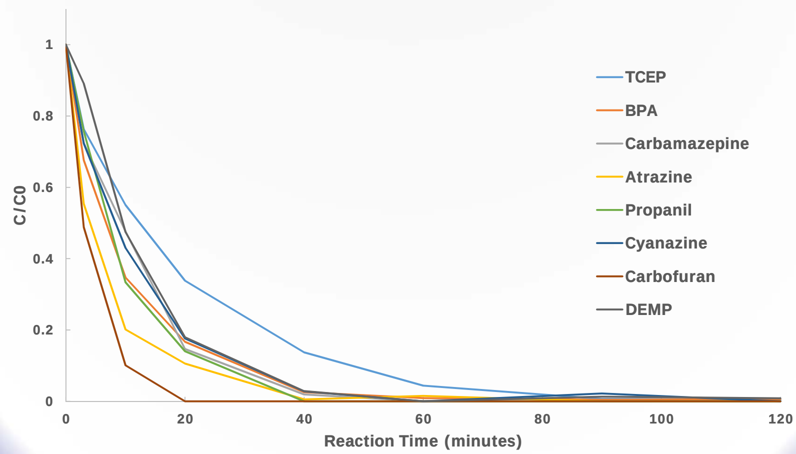

12

## Results: Ozone/Peroxide



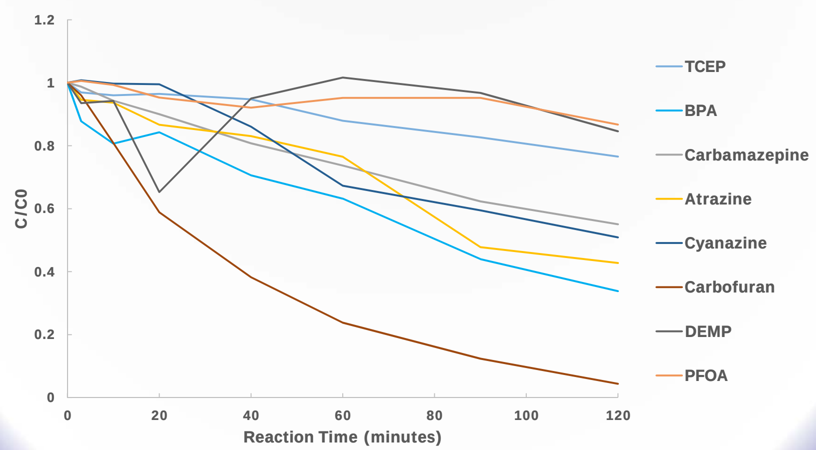

13

# Results: UV/Peroxide



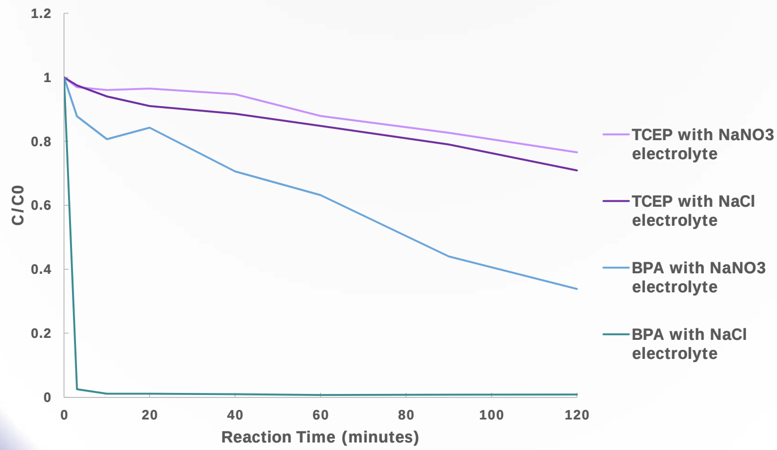

14

# Results: Boron Doped Diamond Electrode




15

# Results: Boron Doped Diamond Electrode

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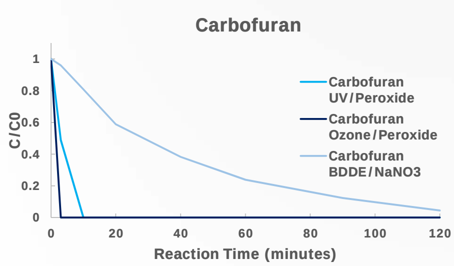
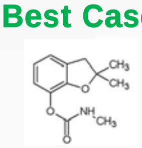
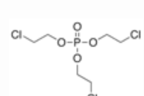
# Results: AOP Comparison

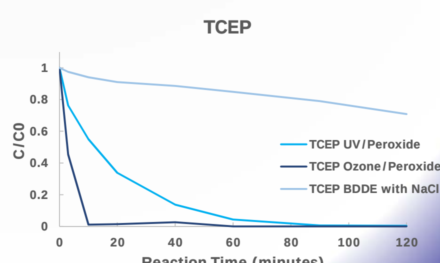



**Best Case**





**Worst Case**

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## Results: Microbial Toxicity

- Little to no initial toxicity to:
  - Microtox:
    - Carbamazepine, Atrazine, Aldicarb, DEMP, Phenylephrine
  - Nitrification Inhibition:
    - Carbamazepine, Atrazine, Aldicarb, DEMP, Phenylephrine, Carbofuran, TCEP, BPA, Cyanazine

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## Results: Microbial Toxicity

- Toxicity reductions observed in all three AOP systems
  - Variation of results based on technologies and contaminants
- Some increases in toxicity observed:
  - Microtox and Nitrification Inhibition:
    - BDDE with $NaNO_3$ electrolyte for some contaminants

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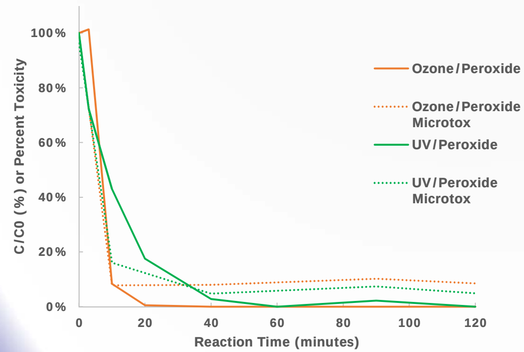
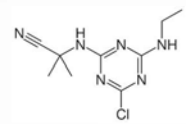
# Results: Cyanazine
## Degradation and Toxicity




| Nitrification Inhibition Toxicity | | |
|---|---|---|
| **Technology** | **Initial Toxicity** | **Final Toxicity** |
| Ozone/ Peroxide | -42% ± 17% | -25% ± 3% |
| UV/ Peroxide | -10% ± 9% | -4% ± 12% |

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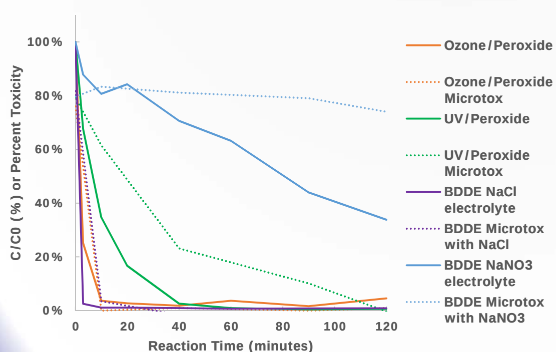
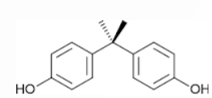
# Results: BPA
## Degradation and Toxicity




| Nitrification Inhibition Toxicity | | |
|---|---|---|
| **Technology** | **Initial Toxicity** | **Final Toxicity** |
| Ozone/ Peroxide | -21% ± 2% | -18% ± 0% |
| UV/ Peroxide | 17% ± 29% | 7% ± 21% |
| BDDE with $NaNO_3$ | 0% ± 12% | 2% ± 4% |

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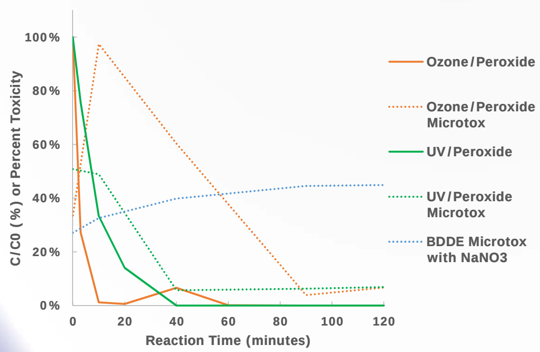
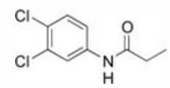
# Results: Propanil
## Degradation and Toxicity




| Nitrification Inhibition Toxicity | | |
|---|---|---|
| **Technology** | **Initial Toxicity** | **Final Toxicity** |
| Ozone/ Peroxide | 69% ± 8% | 51% ± 14% |
| UV/ Peroxide | 41% ± 15% | 13% ± 4% |

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# Conclusions

- Development of a toolbox of technologies:
  - Choice of technology based on needs and goals
- Contaminant reduction:
  - Ozone/Peroxide AOP degraded most contaminants in <20 minutes
  - UV/Peroxide AOP degraded most contaminants in <90 minutes
  - BDDE AOP performance is very dependent on the electrolyte and the contaminants
- Microbial Toxicity:
  - Toxicity does not necessarily follow contaminant degradation
  - Microtox and Nitrification Inhibition toxicity assays may yield different or conflicting results
  - Pre-treatment may be necessary even if the parent compound is not very toxic

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## Alternate Water Matrixes

- Dilute Soap Matrixes:
  - Dawn and Simple Green tested
  - 0.01% soap concentration not toxic to Microtox Toxicity test
  - Foam precluded use of the Ozone/Peroxide system
  - UV/Peroxide and BDDE systems yielded slower propanil degradation in the presence of soap
- Hardwater Matrix:
  - Reduced toxicity in the UV/Peroxide system
  - Results forthcoming
- High Total Organic Carbon (TOC) Matrix:
  - Experiments forthcoming

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## Future Work

- Investigate methods of real-time monitoring of hydroxyl radicals to verify AOP system performance
- Investigate high TOC and hardwater matrices at lab scale, including pre- and post-AOP unit processes
- Field Applications: Scale-up and reactor design, including pre- and post-AOP unit processes
- Explore prediction of AOP effectiveness via hydroxyl radical reaction rates

AOP mobile trailer, 15 ft

Water Security Test Bed
448 ft distribution system at
Idaho National Laboratory

# Thank You!

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# 2015 U.S. EPA International Decontamination Research and Development Conference

## Wednesday, May 6, 2015

## Concurrent Sessions 4

### Biological Agent Decontamination Equipment





# Equipment decontamination with disinfectants and mobile pressure washer with water containment mat

Craig Ramsey, PhD
Debra Newman
Paul Freebury
USDA-APHIS-PPQ-CPHST
Fort Collins, CO
And
Steve Newman, PhD
Colorado State University
Fort Collins, CO

## Study overview

- Equipment decontamination using a contained, mobile power washing system
- Followed by surface application of several disinfectant formulations
- Determine the sporicidal efficacy after both decontamination methods
- Samples spiked with *Bacillus subtilis* spores to simulate bio-contamination

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Mobile pressure washing system
S-K Environmental Co. (http://s-k-enviro.com/)

Waste water containment mat

Re-circulating
sump pump

# First study objectives

- Determine effects of power washing for 0, 5, and 10 seconds, with and without ElectroBiocide (EB) on *Bacillus subtilis* efficacy

- Determine effects of six EB (200 ppm) formulations on *Bacillus subtilis* efficacy

# First study objectives

- Determine the effects of EB exposure time for 5, 10, and 15 minutes on *B. subtilis* efficacy

- Determine the effects of an "organic challenge" (grease) on *B. subtilis* efficacy

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## Second study objectives

- Determine the effects of four optional disinfectant treatments on *B. subtilis* efficacy
  - Virkon-S at 1% or 10,000 ppm
  - Accel at 1:16 ratio (v/v) or 2,600 ppm
  - EB at 200 ppm + glycerol at 10% v/v
  - EB at 200 ppm + Reign at 10% v/v

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## ElectroBiocide additives

- ElectroBiocide additives tested in lab for reactivity to chlorine dioxide at 1% concentration
- Four Loveland Products additives – Tactic, Bond Max, Attach, Reign LC
- Reign - 30% polyacrylamide (polyvinyl polymer) concentrate that decreases driftable fines and improves deposition

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## Study design – Design of Experiment with JMP program

- Study designed with JMP Design of Experiment software
- Conventional full factorial study
  - total of 1,080 samples
- JMP DOE design – 340 samples

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## *B. subtilis* spore preparation

- MicroChem lab cultured *B. subtilis* in Petri dish
- *B. subtilis* cultures suspended in water and treated with isopropanol to kill off about 90+% of vegetative cells
- Spores added to steel washer at 300 ul per washer and then dried to bond to washer surface
- Washers stored at 4 C and shipped with ice packs

# Tillage equipment photo

- Soil tillage – winged harrows for mechanical weeding
- 18 ft with two foldable wings
- Sample washers placed on magnetics
- Magnetics placed on vertical surfaces back and wings of harrows

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# Sample washer photo

- *Bacillus subtilis spores* dried as white ring on washer face
- Washer labelled by JMP DOE program
- Steel washer attached by magnets to equipment

# Organic challenge or axle grease photo

- White axel grease used as the "organic" challenge
- Grease applied with a paint brush
- Grease applied just before power washing treatment

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# Power washing photo

- Power washing followed the grease application
- Power washer with 2,000 PSI water pressure about 4-6" from washer surface
- Power washing times of 0, 5, and 10 seconds
- Power washing timed with digital stop watch

# Disinfectant spray photo

- Disinfectants applied with hand spray bottle
- Four trigger pulls per washer
- Disinfectant contact times were 5,10,and 15 minutes
- Disinfectant neutralizer applied at end of contact time
- Chemical neutralizer – sodium thiosulfate mixed at 2.5% v/v
- Digital stop watch used to monitor contact time

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# Disinfectant pH and Oxidation Reduction Potential (ORP) values

| Disinfectant | pH | ORP (mV) |
|---|---|---|
| Tactic | 5.29 | 694 |
| Bond Max | 5.69 | 708 |
| EB alone | 5.88 | 726 |
| Reign | 5.95 | 720 |
| Glycerol | 5.79 | 715 |
| Attach | 5.34 | 588 |
| Accel | 2.0 | 520 |
| Virkon-S | 3.0 | 1023 |

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# Weather conditions

| Timestamp | Mean Temp (F) | Relative Humidity (%) | Wind Speed (mph) | Wind Gust (mph) | Approx. time of disinfectant application |
|---|---|---|---|---|---|
| 05-06-14 09:00 | 61.1 | 46.8 | 5 | 11.6 | |
| 05-06-14 10:00 | 61.9 | 55.2 | 7 | 11.0 | EB + Tactic |
| 05-06-14 11:00 | 63.6 | 50.6 | 7 | 10.9 | |
| 05-06-14 12:00 | 66.7 | 41.6 | 5 | 11.2 | EB + Bond Max |
| 05-06-14 13:00 | 72.6 | 21.4 | 8 | 14.2 | EB + Reign – 1% |
| 05-06-14 14:00 | 74.3 | 18.3 | 10 | 19.2 | EB + glycerol – 1% |
| 05-06-14 15:00 | 74.3 | 20.9 | 11 | 21.2 | |
| 05-06-14 16:00 | 72.9 | 20.7 | 9 | 16.7 | |
| 05-06-14 17:00 | 71.0 | 21.4 | 7 | 17.0 | |
| 05-07-14 09:00 | 52.2 | 80.2 | 5 | 8.9 | EB + Attach |
| 05-07-14 10:00 | 54.7 | 74.3 | 6 | 10.5 | EB alone |
| 05-07-14 11:00 | 56.1 | 68.4 | 6 | 10.4 | Virkon-S |
| 05-07-14 12:00 | 57.9 | 62.3 | 8 | 14.2 | |
| 05-07-14 13:00 | 54.5 | 70.0 | 8 | 17.6 | Accel |
| 05-07-14 14:00 | 49.1 | 80.2 | 11 | 17.5 | EB + Reign – 10% |
| 05-07-14 15:00 | 45.2 | 82.9 | 7 | 14.7 | EB + glycerol – 10% |
| 05-07-14 16:00 | 51.3 | 76.2 | 11 | 18.0 | |

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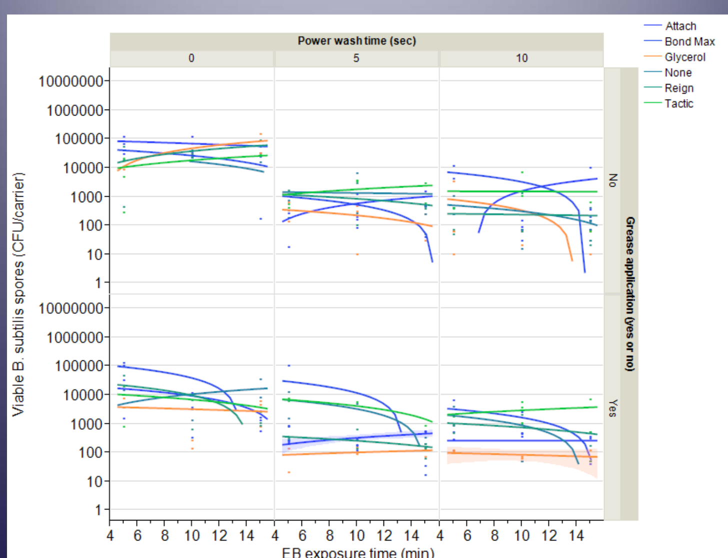
# *Bacillus subtilis* viable spore count results

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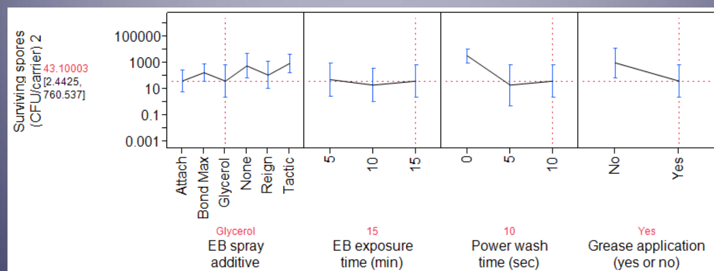
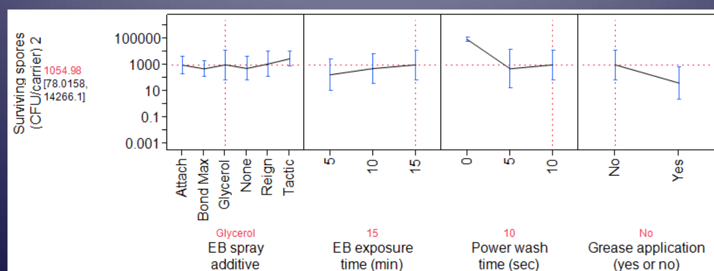
C-435

# Glycerol results for ElectroBiocide

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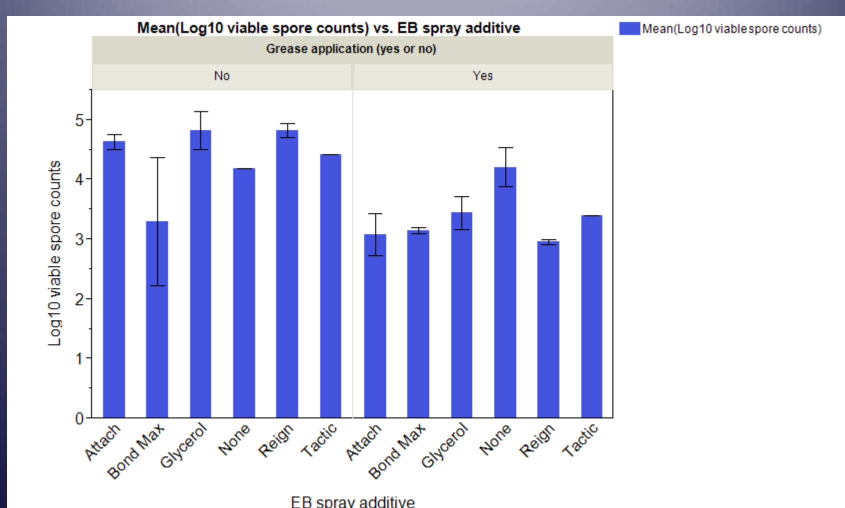
# Average viable spore counts for disinfectants without pressure washing treatment

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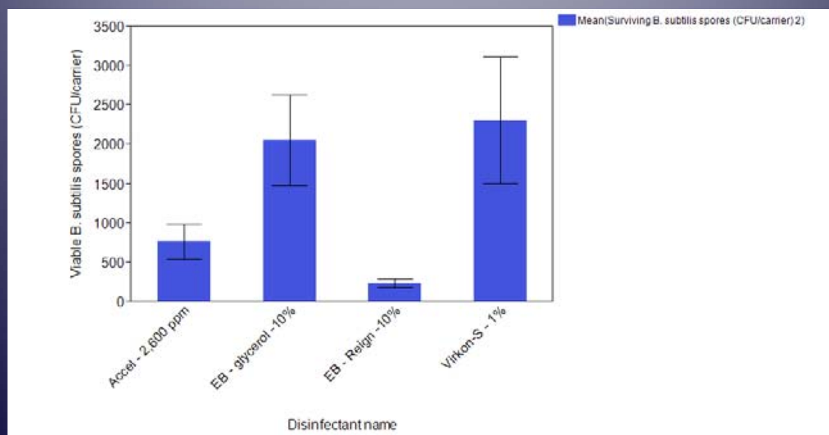
# *Bacillus subtilis* viable spore counts for optional disinfectants

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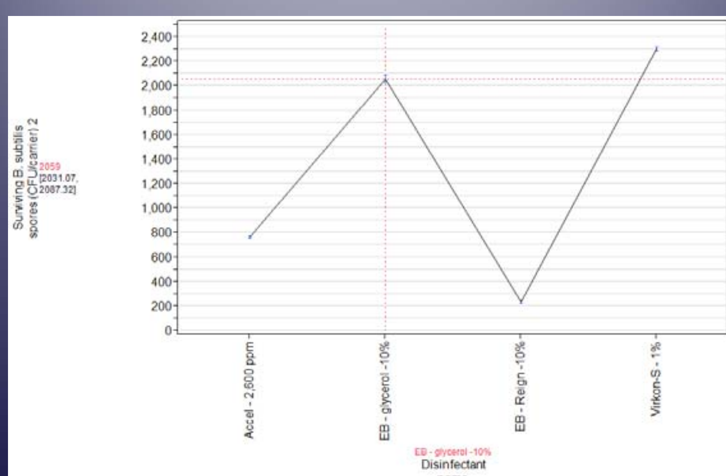
# Bacillus subtilis viable spore counts for optional disinfectants

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## Conclusions from GLM model

- Viable spore counts decreased with increasing pressure washing
- Viable spore counts decreased by mixing three additive with EB disinfectant:
  - Glycerol, Reign, and Attach
- Viable spore counts decreased by adding axel grease to Attach and glycerol samples before pressure washing

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## Conclusions from GLM model

- GLM model – highest sporicidal efficacy
  - EB + glycerol - estimated viable spore count of 43.1 CFU/washer after 10 sec power washing + 15 min disinfectant contact time and with grease treatment
  - 43.1 viable CFU/washer = 1.63 log10 viable spores
  - Log10 reduction = (7.0 -1.63) = 5.4 log10 reduction for EB + glycerol (1%)

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## Conclusions from optional treatments

- Best optional disinfectant treatments
  - Accel and EB + Reign 10%
- Increasing Reign concentration to 10% for EB improved log10 reduction
  - Log 10 reduction increased by 1.9 by increasing Reign to 10% (4.7 – 2.8 = 1.9 log10 reduction increase)

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## Conclusions from optional treatments

- Increasing glycerol concentration to 10% improved log10 spore reduction
  - Log 10 reduction increased by 0.8 by increasing glycerol to 10% (3.7 – 2.9 = 0.8)
- Increasing additive concentration needs more testing
  - Glycerol added up to 20% v/v with no negative reactivity

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## Observations of disinfectant drying time on treated sample washers

- Visual observations - disinfectant drying times was approx. 3 – 5 minutes
- Disinfectant additives didn't dramatically increase spray droplet exposure time
- Future testing options
- Compare portable steam cleaner to power washing and disinfectants

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## Options to improve pressure washing or disinfectant decon efficacy

- Increase pressure washing time
- Reduce nozzle distance from surface
- Add surfactant/oils 2 - 5 min before pressure washing to improve microbial detachment from surfaces
- Increase additive concentrations to extend disinfectant surface contact time

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# Bacillus subtilis – normal and super dormant spore coat thickness at 100 nm scale


Normal spore coat


Super dormant spore coat


## Acknowledgements

- Sheilah and Jeff Kennedy
  - S-K Environmental
  - Mobile pressure washer rental
- John Breedlove and Mike Peters
  - Strategic Resource Optimization (SRO)
  - Chlorine dioxide formulations

Christopher Fryear and Jennifer Bornhoft
- Colorado State University – ARDEC farm coordinator farm
- Use of farm facilities and farm equipment

## Spray Equipment Selection for Wide Area Application of Decontaminants

Dr. Richard Derksen — **USDA ARS** Application Technology Research Unit

Dr. Erdal Ozkan
Mike Sword — **The Ohio State University** Department of Food, Agricultural and Biological Engineering

Dr. Martin Page — **USACE, U.S. Army Construction Engineering Research Laboratory**

2015 U.S. Environmental Protection Agency (EPA) International Decontamination Research and Development Conference
May 6, 2015
Raleigh, NC

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# Objectives

- Select and test nozzles for decontamination parameters
  - Germination-biocide series application
  - Target Application Rate: 535 gal/acre
  - 2-pass system (4-24 hours between applications)
  - Potential use of foaming agents for specific targets

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# Working List of Targets

Horizontal Targets

- Grass
- Soil
- Dirt Road
- Gravel
- Paved
- Steel man covers

Vertical Targets

- Fence
- Concrete Block Walls
- Posts
- Trees
- Shrubs
- Light poles
- Vehicles/Trailers
- Planes, UAV
- Buildings
- Command Center Tents
- Temporary Barracks
- Satellite Dishes

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# Test Trailer Rig

## High Flow/High Pressure Sprayer

- 3 Flood Nozzle spaced 60" apart give 15 ft of coverage directly along travel path
- Boomless nozzles on the end of the boom give an additional 33 feet of horizontal coverage or 20 feet vertical coverage
- Flexible system that can mounted on various vehicles


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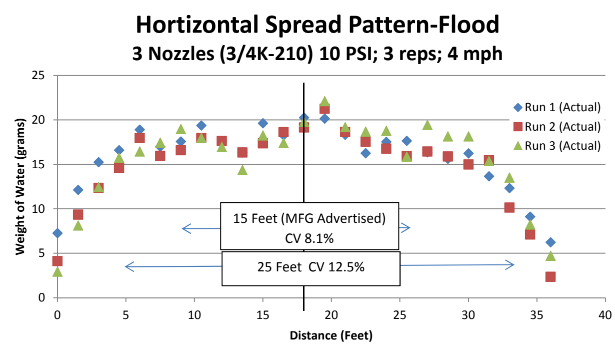
# Horizontal Testing-Flood




Flood Nozzle

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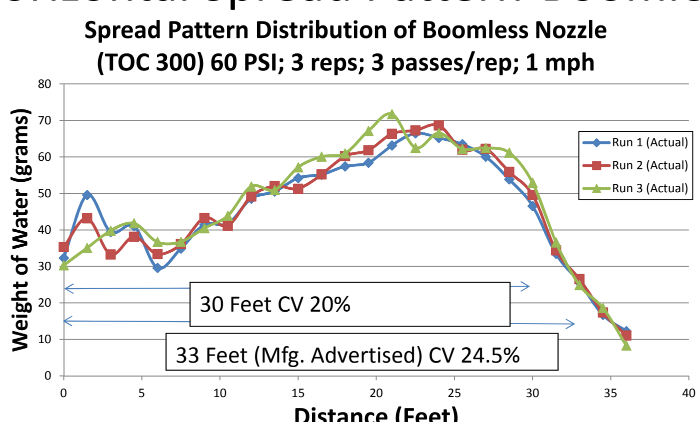
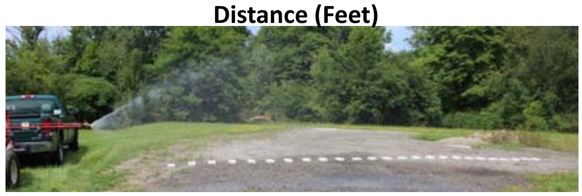
# Horizontal Spread Pattern-Boomless



Boomless Nozzle

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# Horizontal Targets

## General Nozzle Summary when considering Horizontal Targets

Flood Nozzle

Flood Nozzles on Horizontal Targets

- Utilize lower pressure (10-40 psi) to achieve coverage below a Coefficient of Variation (%CV) of 10
- Less prone to drift when compared to Boomless
- Best option for open areas such as fields

Boomless Nozzles on Horizontal Targets

- When wind is not a factor can provide coverage with a %CV of 20% on horizontal surfaces up to 30 feet from nozzle
- Requires higher pressure (60 psi) to achieve coverage
- Can cover areas, up to 30 feet, away that the flood nozzles might not be able to reach. Ravines, Other sides of fences, etc.

Boomless Nozzle

# Modified Patternator
# Vertical Spread Pattern-Boomless

- Modified Collection System
  - Large volume of solution
  - Off the shelf test system inadequate for collection
  - Data collection in process, weather delays to complete testing protocol

**Vertical Patternator modified with USDA/OSU designed collection pans**

# Modified Patternator
# Vertical Spread Pattern-Boomless

Factory Collection

OSU/USDA Modified Collection

## Changes

- Deeper Collection cavity allows for complete collection of droplets
- Factory Structural Stand utilized to provide equidistant spacing

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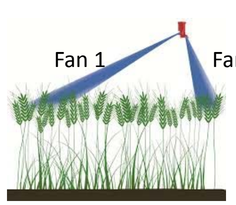
# Vertical Targets

Boomless Nozzles on Vertical Targets

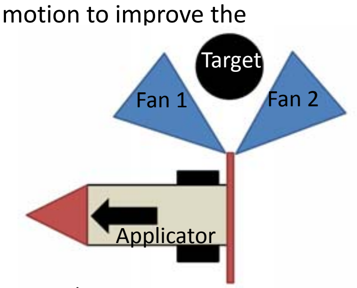
- Allow for application on targets up to 20 ft tall from one nozzle.
- Can provide for penetration into targets like trees foliage and other three dimensional targets

Twin Fan Pattern

- Working on a concept similar to that used in agriculture where a nozzles utilizes two fan patterns to improve coverage of a cylindrical target (i.e. Wheat head)
- The concept is to use two boomless nozzles one tilted forward and one backward the direction of motion to improve the coverage on targets.




TwinJet Concept for Wheat




OSU/USDA Dual Boomless Pattern

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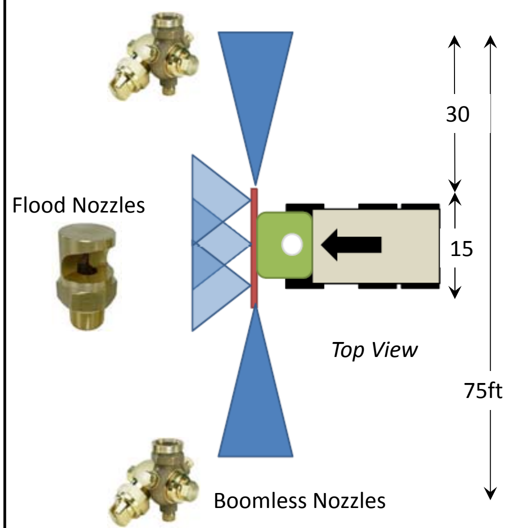
# Equipment Concepts- Horizontal




- Up to 75 feet of width in horizontal spray application
- Boomless applications to the side of vehicle
- Independent control of each nozzle grouping.

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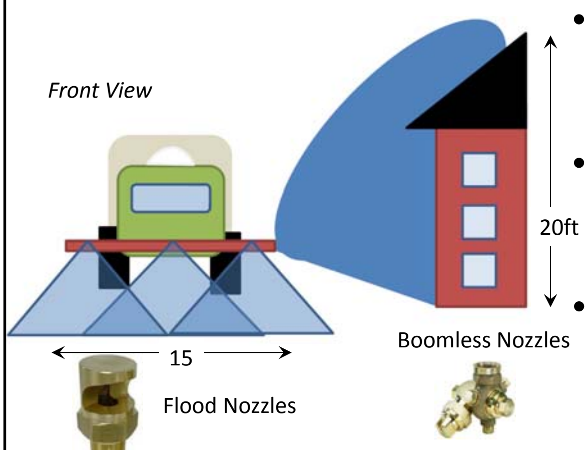
# Equipment Concepts- Vertical




- Up to 20 feet in vertical coverage with boomless nozzle
- Can allow for application of difficult targets
- Option to flood nozzles in Horizontal direction simultaneously

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# Equipment Concepts- Handgun


- Potential a need for a small rig dedicated to difficult to reach areas.
- Can allow for application of difficult, hard to reach targets

Commercially Available Solutions
*Military Systems Technology*

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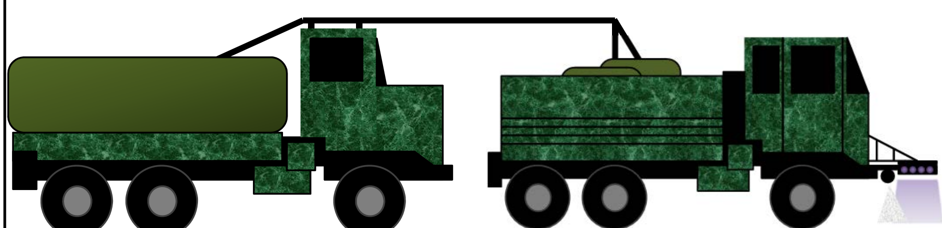
# Manual for Decontamination Refilling Concepts

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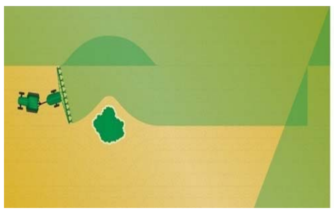
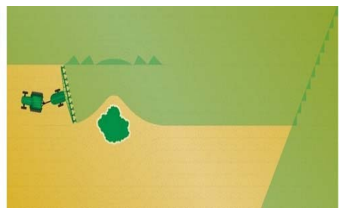
# Equipment Concepts

- Modern Control Systems to reduce skips and over application
- Utilize GPS signal and can be automated to turn nozzles on and off as the vehicle travels
- Can record application rate and coverage for reporting



*Without Boom Section Control*



*With Boom Section Control*

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USDA ARS

# Scenario Analysis


- Divide into Zones based on target types
- Characterize zones
- Size and Allocate equipment required for each zone
- Train Application Teams for specific zones

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## Summary

- System optimized for germination-biocide series application (high volume coverage desirable)
- Off-the-shelf components utilized to satisfy mission parameters
- Participation in Proof of Concept Event
  - Pilot scale field demonstration (2015?)

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# 2015 U.S. EPA International Decontamination Research and Development Conference

## Wednesday, May 6, 2015

## Concurrent Sessions 4

### Waste Treatment and Disposal





# Capture of Cesium During Biomass Combustion Using In-Furnace Sorbent Injection

P. Lemieux, S. Lee, W. Linak
U.S. EPA/Office of Research and Development
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C. Winterrowd
ARCADIS
Research Triangle Park, NC 27711

## Outline

- Radiological Dispersal Device (RDD) Scenario
- Fukushima Biomass Statistics
- Behavior of Cs in Incinerators
- Goals of This Study
- Experimental Approach
- Results
- Conclusions
- Next Steps

## RDD Scenario

## Fukushima Biomass (Estimated)

| Category of Land use | Combustible Material (million $m^3$) |
|---|---|
| Housing, Facilities, etc | 0.38 – 0.47 |
| Rice Field | 1.3 – 1.7 |
| Field | |
| Pasture, Orchards, etc | |
| Forest | 1.6 – 5.4 |
| Other | 0.1 |
| Total | 3.3 – 7.7 |

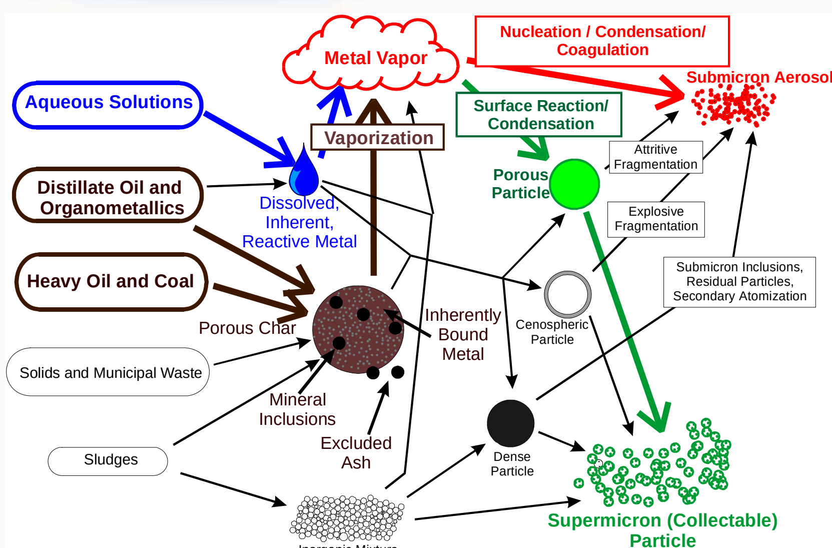
Note: Hurricane Katrina produced approximately 75 million $m^3$ of debris

Interim Storage Facility Safety Review Committee Report: http://josen.env.go.jp/area/processing/pdf/safety_measure_02.pdf

## Behavior of Cs in Incinerators

- Cs as an alkali metal, behaves similarly to Na and K
- Vaporizes readily within combustion environment
- Nucleates and condenses downstream into ultrafine particulate matter (PM)
- Submicron aerosol $d_p \approx 100 – 200$ nm

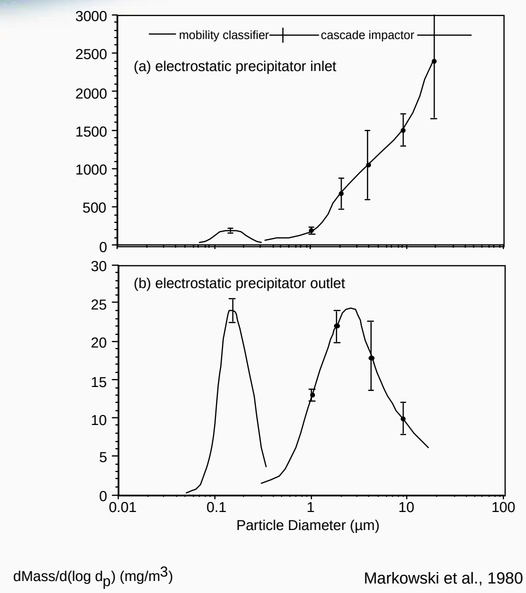
## Mechanisms




Source: Fernandez et al., 2003

# Electrostatic Precipitator (ESP) PM Partitioning

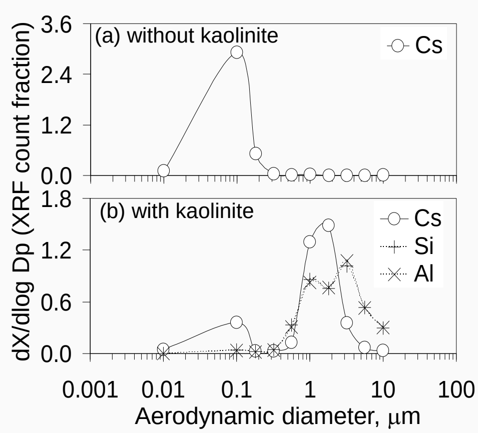
- Control technologies remove large PM preferentially
  - >99% 10 µm
  - <90% 0.2 µm
- Large fraction of emissions composed of accumulation mode aerosol
- Enriched in volatile and semi-volatile metals




Markowski et al., 1980

# Past Results (Yoo et. al)

- Cs-doped natural gas flame
- Injection of kaolinite sorbent at point in furnace where T ≈ 1400-1500 K
- Up to 80% capture of Cs on sorbent particles ($d_p$ ≈ 2 – 10 µm)



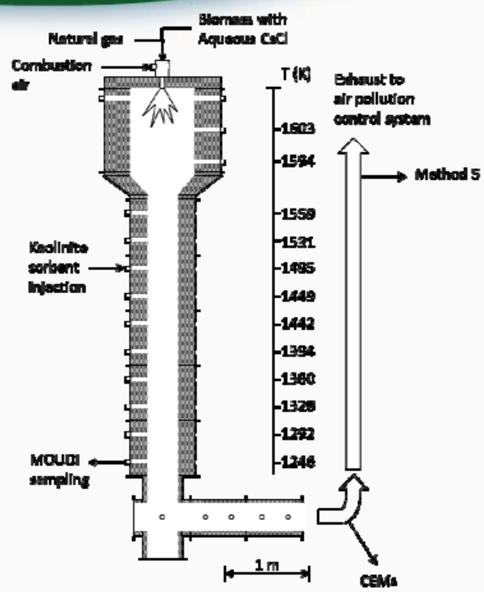
## Goals of This Study

- Examine biomass-bound Cs behavior and transformations in incinerator environment
- Determine whether alumina silicate sorbent injection could capture Cs into supermicron particle fraction in a biomass combustion system
  - Potential competition for active sorbent sites between Cs, K, and Na
  - K and Na present in concentrations >> Cs

## Experimental Approach

- Vertically-fired tunnel combustor
- Co-firing natural gas + biomass
  - Biomass flour (corncob, pine)
  - Doped with CsCl
- Reproduce optimal temperature profile from Yoo et. al (1246 K)
- Micro-Orifice Uniform Deposition Impactors™ (MOUDI) impactor sampling to determine particle size distribution
- XRF analysis of MOUDI plates to determine partitioning of Cs between particle size fractions

# Rainbow Tunnel Furnace




# Biomass Elemental Composition

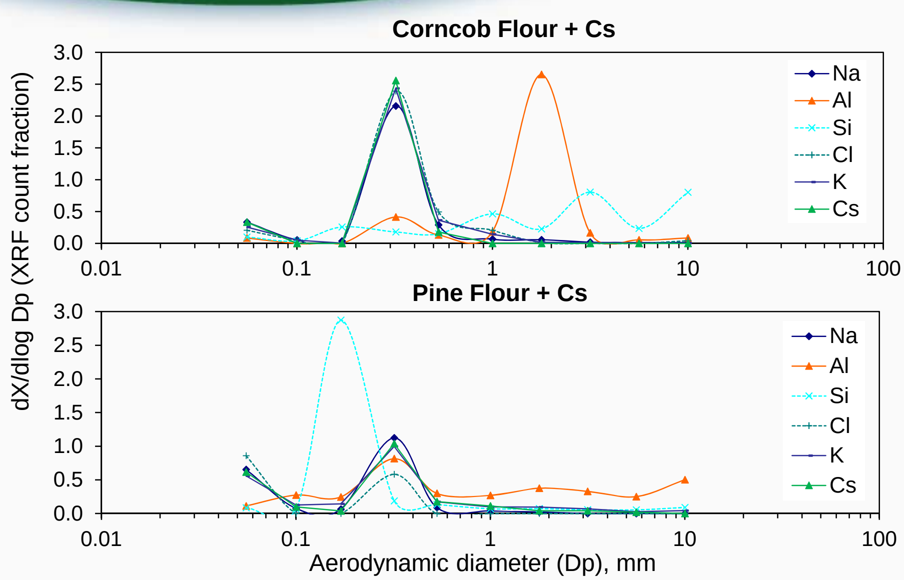
| WD-XRF Analysis | Softwood Flour | #100 Corncob Flour |
|---|---|---|
| Cellulose | 99.815% | 98.436% |
| Hydrogen (H) | 6.205% | 6.119% |
| Carbon (C) | 44.364% | 43.751% |
| Oxygen (O) | 49.246% | 48.566% |
| Sodium (Na) | - | - |
| Magnesium (Mg) | 0.017% | 0.036% |
| Aluminum (Al) | - | 0.008% |
| Silicon (Si) | 0.005% | 0.101% |
| Phosphorous (P) | 0.001% | 0.047% |
| Sulfur (S) | 0.005% | 0.030% |
| Chlorine (Cl) | 0.036% | 0.3635 |
| Potassium (K) | 0.032% | 0.950% |
| Calcium (Ca) | 0.077% | 0.021% |
| Iron (Fe) | - | 0.005% |
| Manganese (Mn) | 0.007% | - |
| Zinc (Zn) | 0.001% | 0.001% |
| Bromine (Br) | - | 0.001% |
| Strontium (Sr) | 0.001% | - |
| Barium (Ba) | - | - |

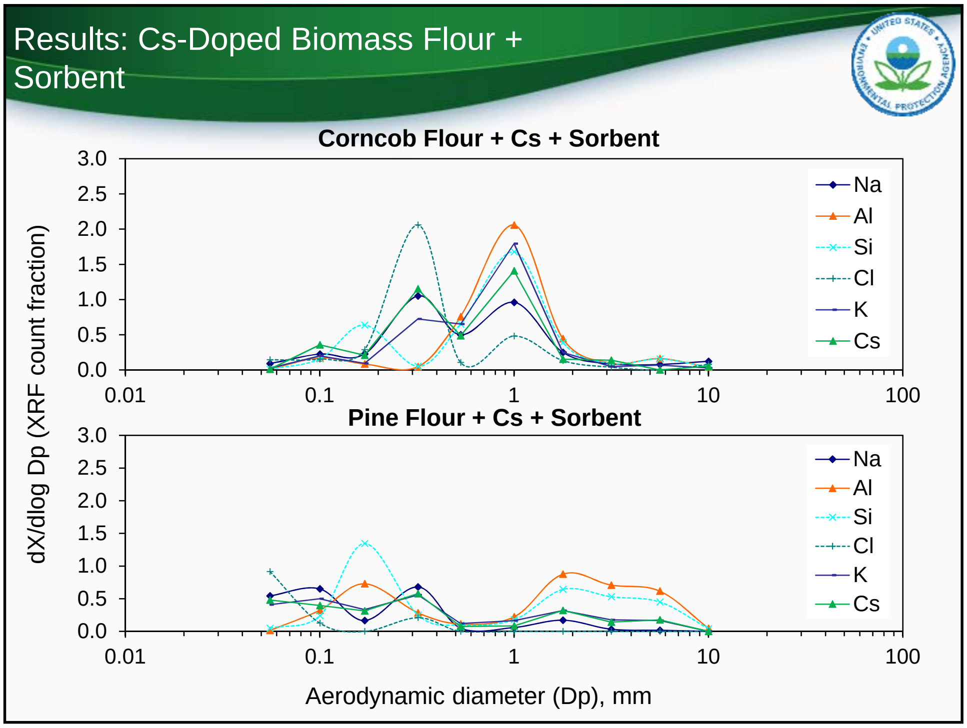
## Test Matrix

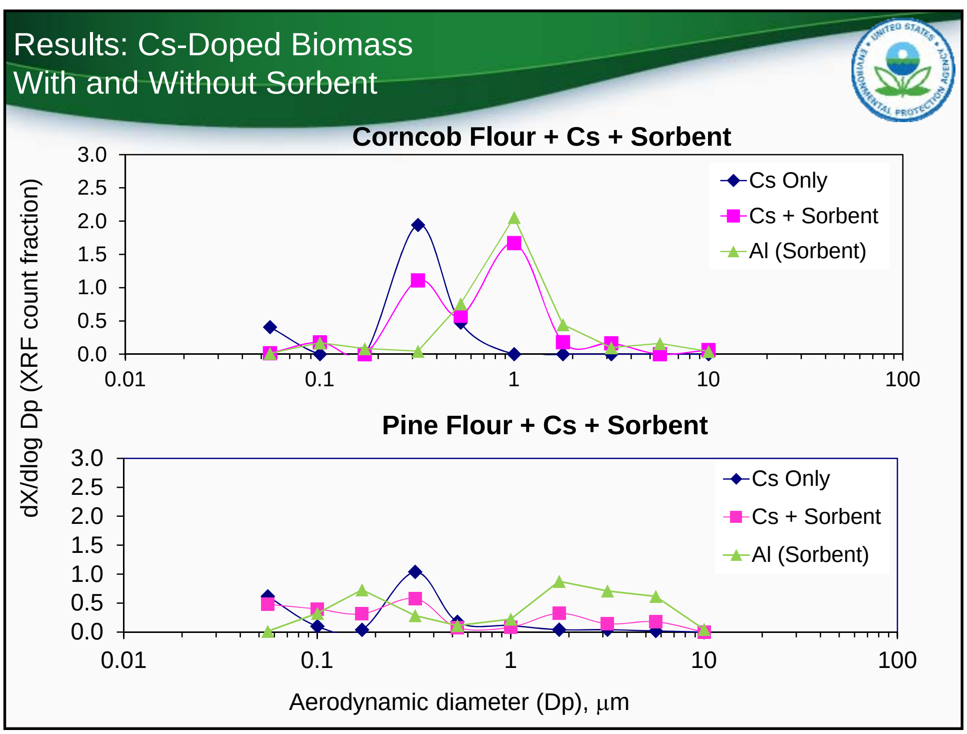
| Test Condition # | Natural Gas | Biomass Feed | Cs Doping | Sorbent Feeding | Gas Species Concentrations | Particle Analysis |
|---|---|---|---|---|---|---|
| 1 | On | Off | Off | Off | CEMs | NA |
| 2 | On | On | Off | Off | CEMs | MOUDI |
| 3 | On | On | On | Off | CEMs | MOUDI |
| 4 | On | On | On | On | CEMs | MOUDI |

Still haven't completed test with pine flour and sorbent only

## Results: Cs-Doped Biomass Flour




Results: Cs-Doped Biomass Flour + Sorbent
Corncob Flour + Cs + Sorbent
Pine Flour + Cs + Sorbent
dX/dlog Dp (XRF count fraction)
Aerodynamic diameter (Dp), mm
Na
Al
Si
Cl
K
Cs


Results: Cs-Doped Biomass With and Without Sorbent
Corncob Flour + Cs + Sorbent
Pine Flour + Cs + Sorbent
dX/dlog Dp (XRF count fraction)
Aerodynamic diameter (Dp), µm
Cs Only
Cs + Sorbent
Al (Sorbent)

## Conclusions

- With sorbent addition, Cs was successfully shifted towards the larger particle sizes associated with the sorbent
- Capture Results (based on fraction of Cs moved to the > 1µm size cut)
  - Corncob flour 65% capture
  - Pine flour 41% capture
- Increased feed rate of sorbent may overcome interferences from Cl, K, Na
- Native Al in biomass or residual in furnace may compete with sorbent
- Pine flour presented feeding difficulties
- Both suggest that kaolinite sorbent injection may be a useful combustion modification that could be used in practical-scale combustion systems while burning Cs-contaminated biomass, especially in systems with fabric filters

## Next Steps

- Previous work showed up to 85% capture in a natural gas-only system. It may be possible to enhance this process with biomass further to achieve greater degrees of capture
- Evaluate the effect of the presence of biomass Cl, Na, K to assess the viability of this process on a variety of different biomass materials
- Perform experiments using bulk solid biomass in a mass-burn type system with fabric filter
- Assess the Cs solubility and leachability once captured on the sorbent

## Disclaimer

- Reference herein to any specific commercial products, process, or service by trade name, trademark, manufacturer, or otherwise, does not necessarily constitute or imply its endorsement, recommendation, or favoring by the United States Government. The views and opinions of authors expressed herein do not necessarily state or reflect those of the United States Government, and shall not be used for advertising or product endorsement purposes.

# 2015 U.S. EPA International Decontamination Research and Development Conference

## Thursday, May 7, 2015

## General Session 3

### Biological Agent Reaerosolization





# Understanding Reaerosolization and Exposure: What Happened to “SPORE”?

CAPT Marshall S. Gray, Jr, CIH
7 May 2015

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## Disclaimer

Reference herein to any specific commercial products, process, or service by trade name, trademark, manufacturer, or otherwise, does not necessarily constitute or imply its endorsement, recommendation, or favoring by the United States Government. The views and opinions of authors expressed herein do not necessarily state or reflect those of the United States Government and shall not be used for advertising or product endorsement purposes.

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## What if…

An outdoor airborne release of *Bacillus anthracis* occurred last night in a major metropolitan area….

3

## What if…


4

# What if…

24–96 hours later the “dots are connected”….



# What if…

YOU are in charge of the overall response and recovery.

In one hour you have to brief….

# What if…

**You are asked:**

- What is the extent of the contamination?
- Should the city be evacuated?
- Do we decontaminate people, vehicles, buildings, pets, etc?
- How do we manage housing, hospitals, nursing homes, etc?
- How do we best respond and get back to business as quickly and inexpensively as possible?
- When can we get back to business as usual?

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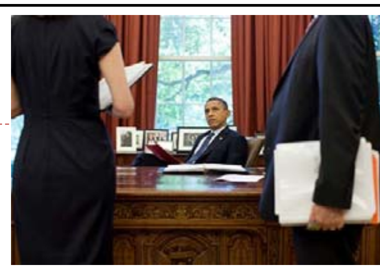

**What do I need to know?**

- How much was released?
- How virulent and hardy are the spores?
- **What was the area of their distribution and dispersion?**
- **Will the spores have entered buildings?**
- **How much additional exposure and dispersion is likely to occur post release due to reaerosolization from natural and anthropogenic events?**
- What's the status and efficacy of medical countermeasures?
- **How long will the population need to administer them?**

8

## Based on…

the current understanding of reaerosolization to inform response and recovery decisions….

How much confidence do we have in what we know, and don't know?

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## Scientific Program on Reaerosolization and Exposure (SPORE) – May 2011

**Purpose:** Understand reaerosolization to inform decisions to reduce risk

**Focus:** Outdoor release

**Partners:** DHS S&T, HHS ASPR, DoD DTRA, EPA NHSRC

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## Scientific Program on Reaerosolization and Exposure (SPORE)

- **Is spore reaerosolization an issue?**
  - **Literature review**
- **Are there useful surrogates for *Ba*?**
  - ***Bg*, *Btk*, inert materials**
- **Do variables matter?**
  - **Surfaces, spore prep, forces, humidity, conductivity, deposition, etc**

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## Scientific Program on Reaerosolization and Exposure (SPORE)

**Significant Gaps:**

- Lack of empirical data
- Models
- Surrogates
- Detection sensitivity

**Initial Goals:**

- Surrogate selection
- Surface variability
- Spore dissemination variability
- Non-dimensional analysis

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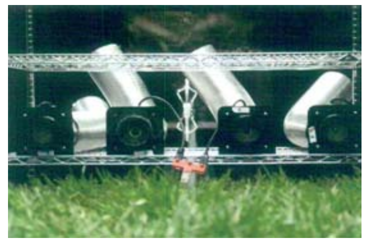
# Sod Studies at EPA (2010–2011)

**Pre-dates the SPORE collaboration:** Sprayed liquid *Bacillus thuringiensis* var *kurstaki* (*Btk*) solution with an agricultural sprayer onto a sod matrix and measured reaerosolization over an extended time period.

**Findings for *Btk* sprayed on fescue sod:**

- Very low percentage of spores were reaerosolized (0.001% to 0.1%)
- Fraction reaerosolized at 30% RH (0.013%) was an order of magnitude higher than at 70% RH (0.002%) for the same wind speed
- Reaerosolization continued over 72 hours



*Evaluation of Reaerosolization of Bacillus Spores from a Sod Matrix*, Report EPA/600/R-12/064, December 2012

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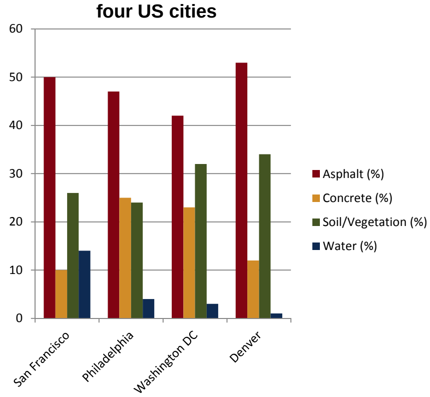
# Distribution of Urban Surfaces

**Purpose:** Understand reaerosolization to inform decisions to reduce risk.

**Comparison of urban areas in four US cities**




**Washington, DC**

Analysis of satellite imagery using surface recognition module in WEST tool (P. Lemieux, T. Boe, EPA NHSRC).

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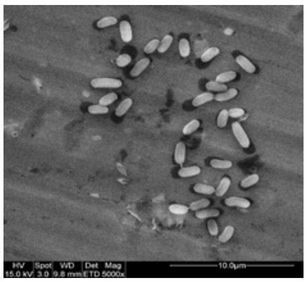
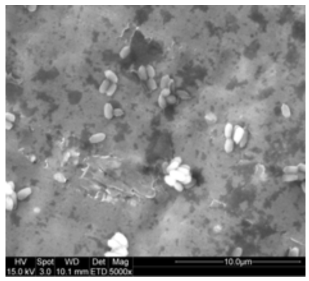
## Test Spores and Surrogates

Reaerosolization data for three surrogates—two types of nonpathogenic bacterial spores and one inert particle—were compared with data for *Bacillus anthracis* Ames strain (*Ba*-Ames).

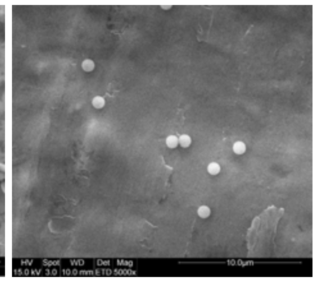
**Bar-coded *Btk* spores**



***Bg* spores**



**Polystyrene latex (PSL) spheres**



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## Initial Approach

- Controlled wind tunnel experiments for surrogate selection
- *IF* surrogate selection successful, execute program plan

**Wind tunnel in biosafety level 3 chamber at DPG**

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## Results

**Dry > Wet**

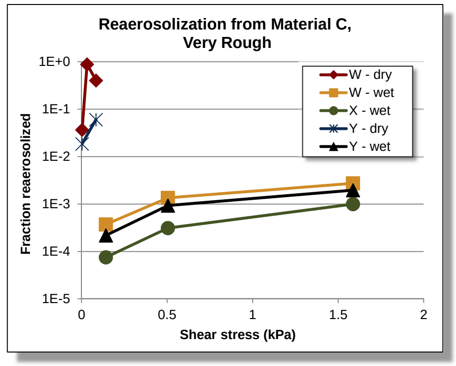
Dry-deposited spores reaerosolized more and with less applied force than wet-deposited spores

***Ba = Btk***

Results for *Btk* and *Ba* were not significantly different from each other (dry and wet deposition)

***Bg ≠***

Results for spore X were significantly different from spore W and spore Y




**The numbers:**

- 635 test runs generating 3,175 test samples completed in 2 laboratories
- 1,030 additional reference and quality control samples generated
- 22 full and 11 partial replicates of the experimental matrix completed

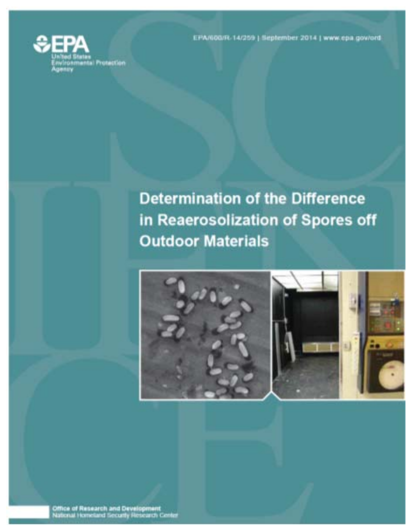


## Details in

- EPA/600/R-14/259, Sept 2014
- Eisner presentation – methods and results

***Key points:***

- Success with non-dimensional analysis
- Surface variability, sampling
- Wet vs. dry deposition and exposure



# The Issue Revisited

- ☑ **Is spore reaerosolization an issue?**
- ☑ **Are there useful surrogates for *Ba*?**
- ☑ **Do variables matter?**

**Applications**

**Non-biological particulates**

**Risk assessment**

**Response priority**

**Prediction**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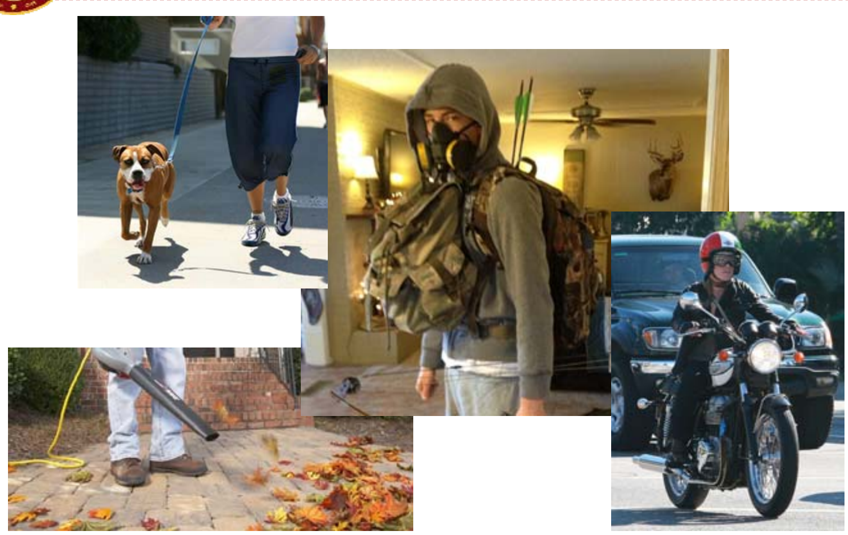
# Human Activity after Event?



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# SPORE Program Plan/Current Status

| Gap | Potential Project(s) | Status |
|---|---|---|
| Identify detachment force from urban surfaces and surrogates for *Ba* | Existing RWT projects among EPA, DHS, DPG | Complete (DHS,EPA, DoD funded) |
| Surface treatment methods to mitigate reaerosolization | Modification of RWT projects to introduce surface treatment | Underway (EPA funded) |
| Develop predictive tools | Use of data for RWT projects | Underway (EPA funded) |
| "Translation Guide" for forces that cause reaerosolization | Evaluate forces caused by human activity vs RWT | FY-16 (EPA funded) |
| Temporal decay – how long will reaerosolization occur? | Scale up from RWT | FY-16/17 |
| Washdown transport / pooling / "hot spot" ID | TBD | TBD |
| Fomite transport (how spores transport on dirt and debris) | Modify RWT projects and scale up | TBD |
| Outdoor test and evaluation (BOTE 2) | TBD (limited by detection sensitivity for reaerosolization outdoors) | TBD |

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# 2015 U.S. EPA International Decontamination Research and Development Conference

## Thursday, May 7, 2015

### Concurrent Sessions 5

Biological Agent Aerosols and Morphology of Spores





# Comparison of Reaerosolization of *Bacillus anthracis* Spores and Surrogates from Common Outdoor Surfaces

Alfred Eisner, Ph.D.
Alion Science and Technology

## Disclaimer

The United States Environmental Protection Agency through its Office of Research and Development funded and managed the research described here under Contract EP-D-10-070 to Alion Science and Technology. It has been subjected to the Agency's administrative review and approved for publication. The views expressed in this presentation are those of the authors and do not necessarily reflect the views or policies of the Agency. Mention of trade names or commercial products does not constitute endorsement or recommendation for use.

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# Method

**The method was designed to minimize common errors in reaerosolization studies.**

**Key aspects of the method:**

- Small wind tunnel with a relatively large reaerosolization surface
- Two-dimensional slotted air jet traversing the surface to eliminate the need for uniform surface loading
- Large range of air jet speeds
- Entire volume filtered to maximize spore collection
- Reaerosolization of both wet- and dry-deposited spores from a range of surface types
- Tests conducted at two independent laboratories using identical methods and equipment

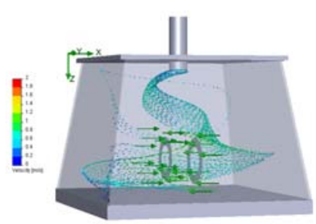
3

# Wet Deposition Chamber

The wet deposition chamber was designed to provide a reproducible single layer of spores on the test coupon surface.

- Ultrasonic nozzle—provides effective deagglomeration
- Syringe pump—provides well-controlled dispensing rate
- Two mixing fans—provide immediate dispersion of atomized liquid and a relatively uniform coating on the coupon

**Wet deposition chamber**

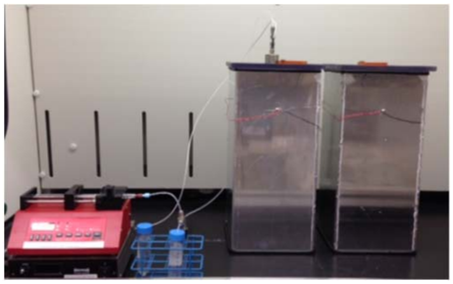


**CFD modeling of wet spore deposition**

4

# Dry Deposition Chamber

- Disperses spores suspended in 90% ethanol in a tall stack
- Uses the same ultrasonic nozzle, syringe pump, and mixing fans as the wet deposition chamber
- The spores are dry when they settle on the test coupon



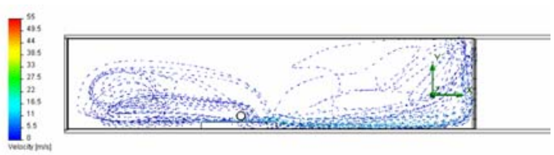
**Spray-drying system for dry spore deposition**

5

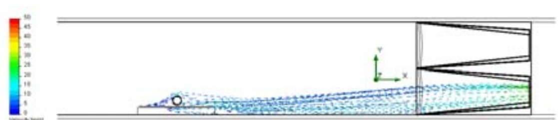
# RWT Computational Fluid Dynamics (CFD) Assisted Design

CFD was used to simulate particle trajectories that were used to finalize the specifications of RWT components.

Simulated trajectories in the initial RWT design resulted in a calculated spore collection efficiency of approximately 20%.



The RWT was redesigned to change the impingement angle of the air jet and add a filter transition unit, resulting in a calculated spore transmission efficiency approaching 80% at a maximum jet speed of approximately 80 m/s.



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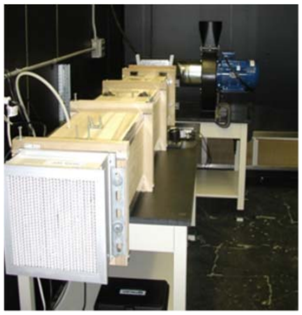
# RWT Design (cont.)

The RWT was designed to provide a test apparatus in which reaerosolization experiments can be performed rapidly and with a high degree of reproducibility. The RWT is contained in an environmental test chamber that provides temperature and humidity control.



Wind tunnel in environmental chamber at EPA

Wind tunnel in biosafety level 3 chamber at DPG

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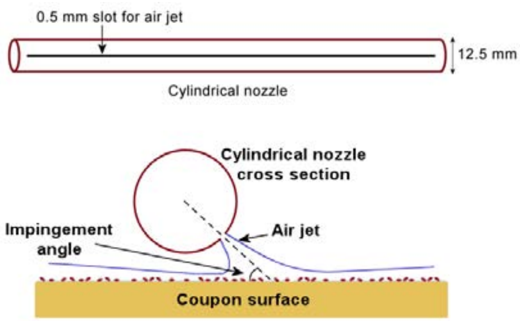
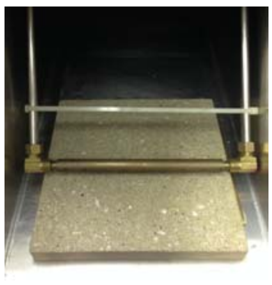
# Spore Detachment

- The detachment force applied to the deposited spores is generated by an air jet that traverses over the surface of the test coupon.
- The air jet is produced by a slotted nozzle connected to a compressed air supply.
- The air velocity can be related to a detachment force that can be translated to activities in the environment that could cause spore reaerosolization (e.g., wind, foot traffic, vehicle traffic).



Air jet traversing over coupon surface

8

# Variables Selected for Testing

- **Spore type:** *Ba*-Ames, *Btk*, *Bg*
- **Deposition method:** Wet, dry
- **Surface material:** Asphalt, concrete, glass
- **Roughness level:** Smooth, rough, very rough
- **Jet velocity:** Low, medium, high
- **Temperature:** Fixed at 20 °C
- **Relative humidity:** Fixed at 30% RH

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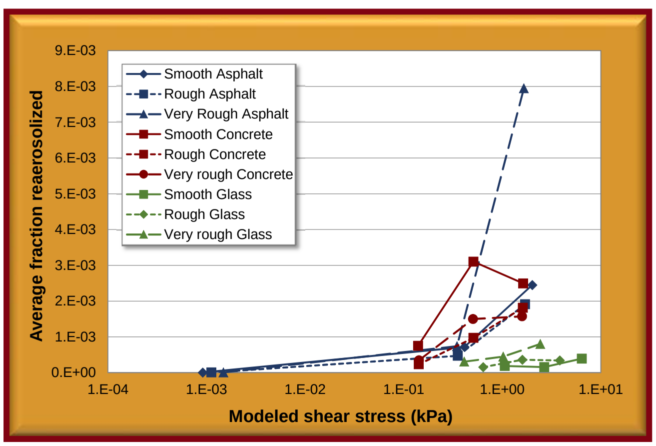
# Results by Surface Type

**Reaerosolization Efficiency vs. Shear Stress**
**for Wet-Deposited Bar-Coded *Btk***

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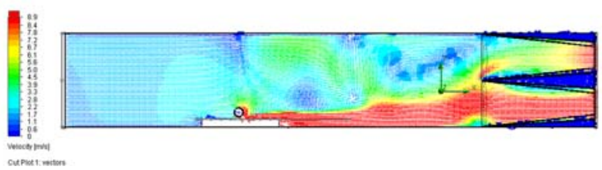
# Air Flow Patterns Inside RWT at High Air Jet Velocities

**Modeled air flow patterns with air jet at 130 m/s**



**Modeled particle trajectories with air jet at 160 m/s**

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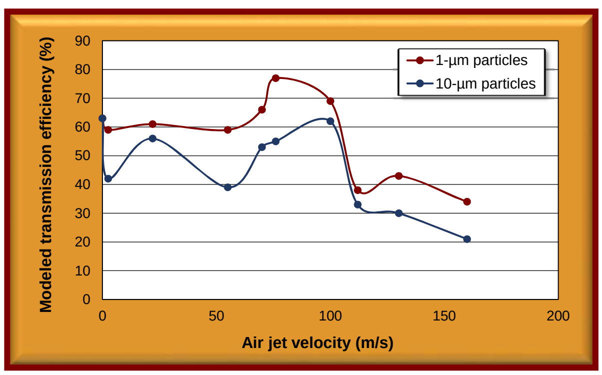
# RWT Transmission Efficiency

**Modeled RWT Transmission Efficiency**




RWT transmission efficiency depends on the particle size distribution.
A correction factor is recommended for jet velocities over 100 m/s.

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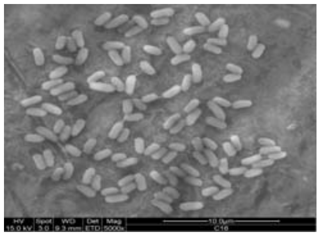
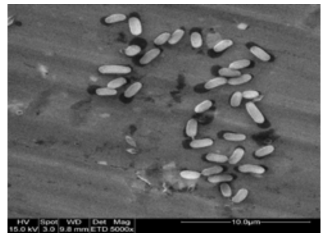
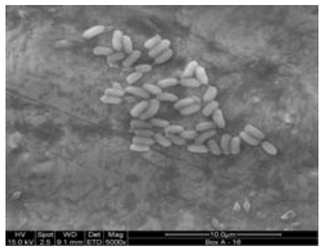
# Wet Deposition



Bar-coded *Btk* spores





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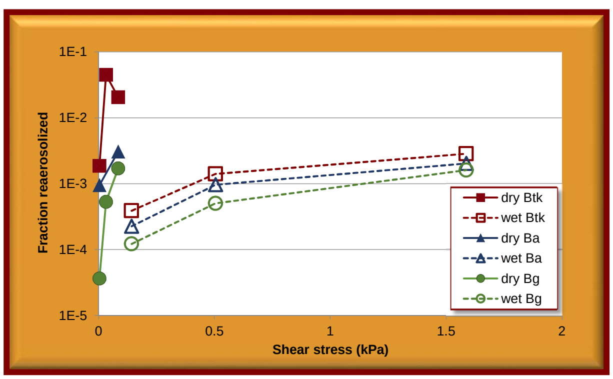
# Results by Spore Type

**Reaerosolization Efficiency vs. Shear Stress for Very Rough Concrete Surfaces**

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## Data Interpretation

- Material characterization data showed that asphalt coupons were the least hydrophilic, while glass coupons were the most hydrophilic.
- Adhesion strength of deposited spores, as measured by resistance to detachment in turbulent flow, is greatest on more hydrophilic surfaces (J.A. Finlay et al., *Integr. Comp. Biol.*, 2002).
- Data showed that microscopic surface roughness, as determined from scanning electron microscope (SEM) images, was significantly larger for asphalt (16 to 21 µm) and concrete (21 to 24 µm) than for glass ($3 \times 10^{-4}$ to 3 µm).
- Adhesion strength of deposited spores, as measured by resistance to detachment in turbulent flow, was highest for glass and lowest for asphalt.
- SEM data showed that wet-deposited spores settled in flat agglomerates.

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## Findings

**Dry > Wet**

Dry-deposited spores reaerosolized more and with less applied force than wet-deposited spores.

***Btk* = *Ba***

Results for *Btk* and *Ba* spores were not significantly different from each other for both dry and wet deposition.

***Bg* ≠ *Btk* and *Bg* ≠ *Ba***

Results for wet-deposited *Bg* spores were significantly different from *Btk* and *Ba* spores. The overall average *Bg* spore reaerosolization was 79% lower than the overall average for *Btk* and *Ba*-Ames.

**For most experimental conditions, reaerosolization was greatest from concrete surfaces and least from glass surfaces.**

**Reaerosolization was not significantly different from surfaces of different roughness levels within each material category.**

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## Summary

**The numbers:**

- 635 test runs generating 3,175 test samples completed in 2 laboratories
- 1,030 additional reference and quality control samples generated
- 22 full and 11 partial replicates of the experimental matrix completed

**Current testing to evaluate impact of additional test variables:**

- Duration of application of reaerosolization force
- Relative humidity
- Surface wetting

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## Acknowledgments

The authors would like to acknowledge the funding support of the Department of Homeland Security Science and Technology Directorate and the contributions of ARCADIS U.S., Inc. for microbiological support and Booz Allen Hamilton Inc. for program support.

The contributions of the interagency SPORE team members listed below are also acknowledged:

**EPA:** Marshall Gray, Russ Wiener, Shawn Ryan, Worth Calfee, Sang Don Lee, and Sara Taft

**DHS:** Donald Bansleben and Matthew Moe

**DOD:** K. Wing Tsang, Jeffrey Hogan, Angelo Madonna, and Nicholas Hogan

**DHHS:** John Koerner and Angela Weber

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# Evaporation and Transport of Bodily Fluid Aerosol Droplets

Jonathan Thornburg, Quentin Malloy, James Hanley, Jerome Gilberry, and Howard J. Walls

**Unclassified**



www.rti.org

RTI International

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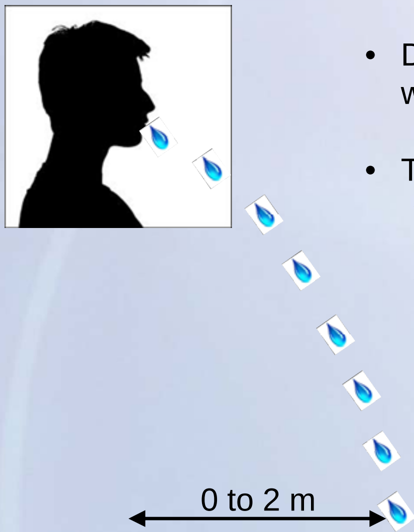
## Ebola Outbreak

2

**Unclassified**

Source: Google Images

## Bodily Fluid Transport – Common Assumption




- Droplets will fall to the ground within a few meters of the source
- True for largest drops (> 300 $\mu$m)
  - Limited evaporation
  - Gravitational settling
  - Room ventilation cannot overcome inertia of the drop





## Bodily Fluid Transport – Reality

- Cough aerosol
  - Mass Median Diameter ~ 80 µm
  - Count Median Diameter < 10 µm
    - Morawska et al., *J. Aerosol Sci*, 2009; Yang et al., *J. Aerosol Med*, 2007; Lindsley et al, *JOEH*, 2012)
- Temp/RH conditions influence drop evaporation
- Room ventilation can keep smaller particles airborne

## Droplet Evaporation Theory

$$d_{p,f}=\sqrt{2\frac{\left(\frac{\rho_a R}{4D_{a,b}M_a\left(\frac{P_\infty}{T_\infty}-\frac{P_d}{T_d}\right)}\frac{d_p^2}{2}-\Delta t\right)}{\frac{\rho_a R}{4D_{a,b}M_a\left(\frac{P_\infty}{T_\infty}-\frac{P_d}{T_d}\right)}}}$$

- Critical parameters
  - Vapor pressures (P) determined by %RH
  - Initial droplet size ($d_p$)
  - Evaporative cooling of the droplet influences diffusion ($D_{a,b}$)
- Assumptions
  - Water droplet
  - One virion per droplet





## Droplet Position

X Velocity: $v_x = u_o + (v_{xi} - u_o)e^{-t/\tau}$

X Position: $x = u_o t + \tau(v_{xi} - u_o)\left(1 - e^{-t/\tau}\right)$

Y Velocity: $v_y = v_{yi}e^{-t/\tau}$

Y position: y= $v_{yi}\tau\left(1 - e^{-t/\tau}\right)$

- These four equations describe the position and trajectory of a particle, provided the particle motion is laminar

## Modelling Effort

**Key Question:**

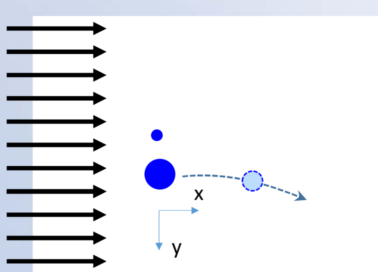
- How does evaporation influence the fate and transport?
  - How far does the bodily fluid travel?
  - Do the droplets deposit or evaporate?
- Model the influence of:
  - Initial droplet size (26 µm to 155 µm)
  - Air velocity (250 cm/s or 12 cm/s)





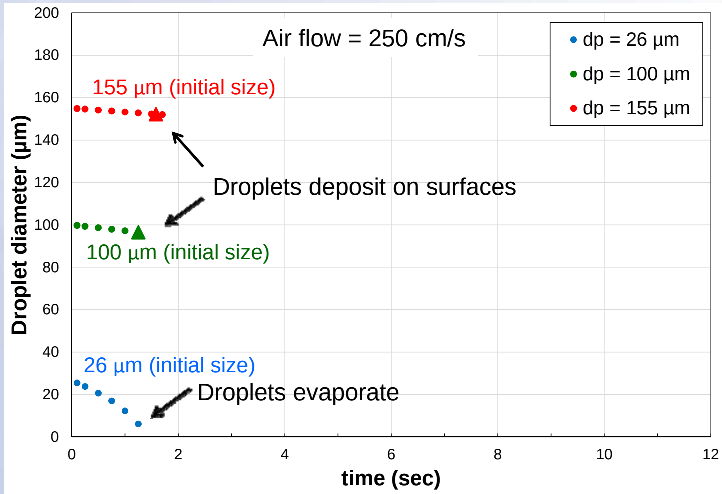
## Model Assumptions

- Room relative humidity (RH) constant at 50%
  - Note: evaporation rate ↓ as RH ↑
- Room is empty
  - Note: raised surfaces decrease time needed for deposition
  - Note: furniture may induce air turbulence, this may increase or decrease airborne time



# Evaporation Time – High Air Velocity

- Droplets ≤ 26 µm evaporate before depositing a surface (< 2 sec)
- Large particles:
  - Shrink < 10%
  - Deposit on a surface at 3 m

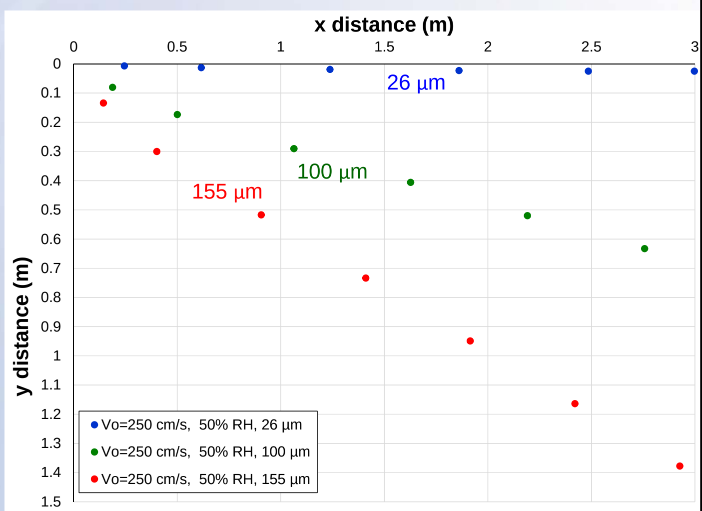







# Droplet Travel Distance – High Air Velocity

- 26 µm: evaporation within 3 m laterally
- 155 µm: smallest size that deposits on floor within 3 m laterally
- 100 µm: example maximum horizontal travel



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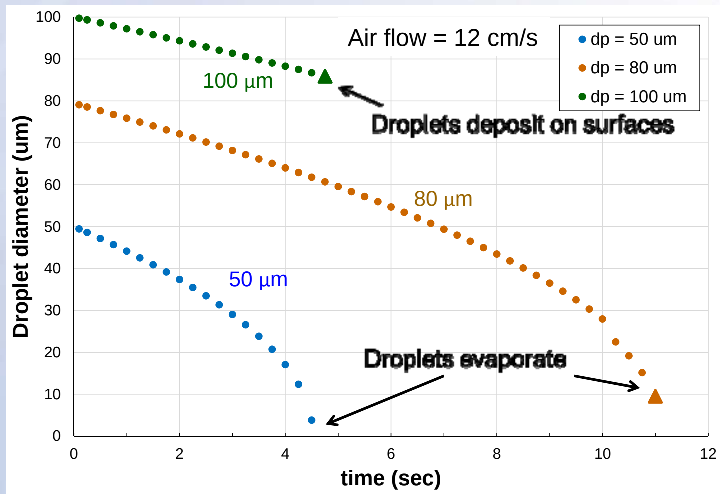
# Evaporation Time – Low Air Velocity

- 80 µm is max size for evaporating before deposition
- Large particles:
  - Shrink < 20%
  - Deposit on floor

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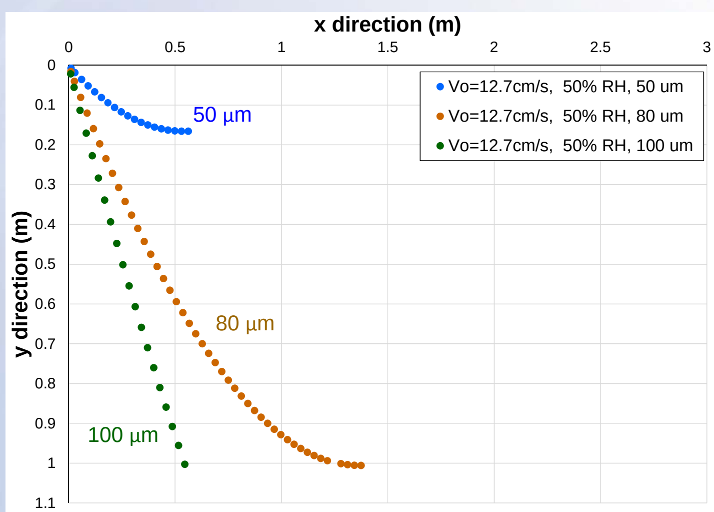
# Droplet Travel Distance – Low Air Velocity

- Limited horizontal travel distance (~1.4 m)
- 80 µm is max size to evaporate and remain airborne

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Unclassified

## Summary

- Cough aerosol size distribution is broad
  - Majority of drops, by count, are < 10 µm
  - Droplets by mass count are > 80 µm
- Bodily-fluid droplets may evaporate and provide for airborne pathogens (under the right conditions)
  - Initial droplet diameter, fluid composition, air velocity, temperature and relative humidity are determining factors
  - Evaporation times can vary from < 2 s to > 10 s
  - Even visible, 80 µm particles can evaporate and travel
- Droplet evaporation allows pathogens to travel > 2 m from the source





## Implications

- Protective room and shelter designs should consider:
  - Pathogens found in evaporating bodily fluids
  - Potential exfiltration/infiltration mechanisms and pathways
  - Air cleaning mechanisms and surface decontamination
- Procedures for personnel safety should account for:
  - Increased inhalation risk from pathogens due to bodily fluid evaporation
  - Larger than expected lateral transport of bodily fluid droplets containing pathogens

## Acknowledgements


- RTI performed this research under subcontract to Production Products with funding from DTRA
- Statements made in this document are solely the opinion of RTI and do not reflect the opinion of Production Products or the DTRA

# High-Resolution Spore Coat Architecture, Assembly, and Morphology of *Bacillus* Spores

Alexander J. Malkin

*Biosciences and Biotechnology Division, Physical and Life Sciences Directorate, Lawrence Livermore National Laboratory, Livermore, CA 94551*

I. Introduction and Motivation

II. High Resolution *Bacillus* Spore Coat Structures and Assembly.

III. Species/Formulation-Dependent Assembly of the Spore Coat Structure and Spore Morphology: Implications to the Microbial Forensics.

IV. *In vitro* High-Resolution Structural Dynamics of Single Pathogen during its Replication Cycle: Spore Germination.

V. Environmental Samples and Decontamination.

VI. Discussion on Potential AFM Applications for the Development of Decontamination Strategies.

*Contact information: A.J. Malkin: malkin1@llnl.gov; Tel: 925-423-7817*

This work performed under the auspices of the U.S. Department of Energy by Lawrence Livermore National Laboratory under Contract DE-AC52-07NA27344

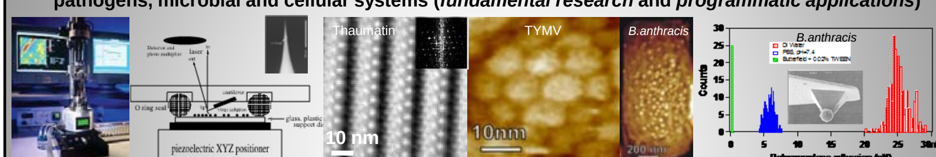
LLNL-PRES-562772

2015 EPA International Decontamination R&D Conference, Triangle Park, NC, May 5-7, 2015

## AFM Fills the Pathogen Architecture-Function Analytical Gap

A.J. Malkin, M.Plomp and A.McPherson (2005), *In: "DNA Viruses."* Humana Press , 85-108
A.J. Malkin, (2011). In: *Life at the Nanoscale: Atomic Force Microscopy of Live Cells.* Pan Stanford Publishing, *71-99.*

**LLNL team is developing *in vitro* AFM for studies of structure-function relationships of single pathogens, microbial and cellular systems (*fundamental research* and *programmatic applications*)**




**Architecture/Surface structure/physico-chemical properties of microbial, viral and cellular systems: pressing importance in medicine and biodefense, great present S&T challenge**

- Current Techniques: Limitations for characterization of large pathogens*: **AFM fills the analytical gap***.
- Rapid imaging (**Fast scanning AFM**: less than 1sec); high-resolution(spatial/height resolution of ~ 2 nm/0.1 nm).
- Covers the size range (10 nm -150 μm**)** of most biothreat agents.
- Crude, environmental samples, powder, air-dried, fully hydrated samples, environmental dynamics (e.g. decon).
- Micro quantities of samples: trace quantities of the agent, surface and internal structures.
- Small footprint/low cost: ideally suited for installation in BSL-3;4.
- Could be developed into portable device for field/clinical characterization/identification.
- Eliminates structural modifications generated during sample preparation.

*<u>Programmatic applications</u>: detection/attribution/forensics/decontamination responses*

**<u>Pathogen Structure and physico-chem properties</u>*: essential for improved understanding of reaerosolization potential and successful implementation of the decontamination strategies*.**

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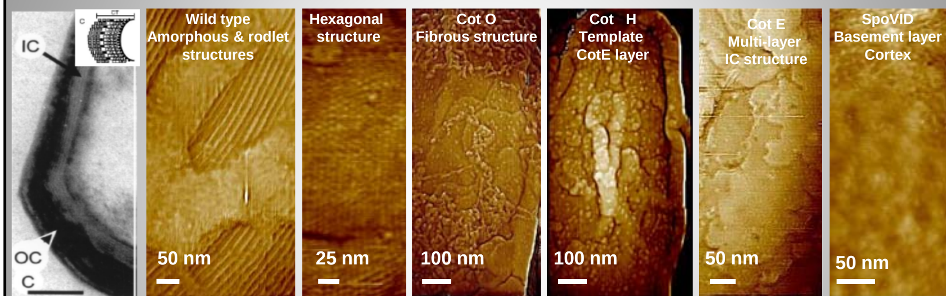
# Unraveling of the Spore Coat Assembly and High-Resolution Structure

C. Monroe, M. Plomp, A.J. Malkin and P. Setlow (2008). *Applied and Environmental Microbiology*, 74, 5875-5581.
S. Ghoshi, B. Setlow, P.G. Wahone, A.E. Cowan, M.Plomp, A. J. Malkin and P. Setlow (2008).*J. Bacteriology* 190, 6741-6748.
M. Plomp, A. Monroe, P. Setlow and A.J. Malkin (2014), *PLoS ONE* 9(9): e108560.

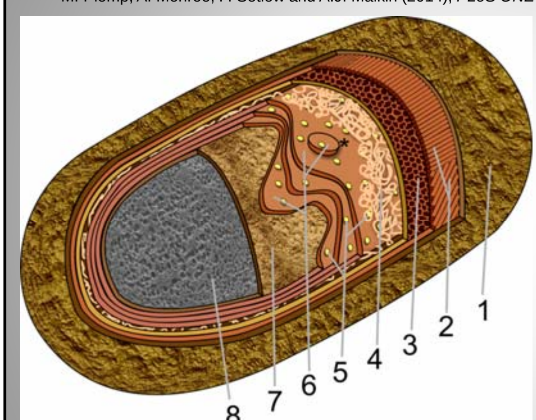



- AFM Analysis of *B. subtilis* mutants allows unraveling of the spore coat architecture and identifying ***morphogenetic*** proteins, which could be critical in directing the spore coat assembly
- First direct characterization of the spore coat assembly (cotA, cotB, cotE,cotH, cotO, spoVID, etc.).
- **CotO:** 8-20 nm thick fibrous structure –**OC**; critical role in the assembly of amorphous/rodlet layers, but not OC.
- **Cot H**: high densities of nanodot particles (smallest: 2.5-3.5 nm), critical for formation of OC fibrous structures.
- **CotE**: multi-layer (3-5) ~ 6 nm thick crystalline structure, rough steps (impurity action) –**IC** consistent with EM. No nanodots, MW CotE = 21KDa, consistent with the size of nanodot particles. CotE template?

2015 EPA International Decontamination R&D Conference, Triangle Park, NC, May 5-7, 2015

# Model of the spore coat architecture of a single *B. subtilis* spore.

M. Plomp, A. Monroe, P. Setlow and A.J. Malkin (2014), *PLoS ONE* 9(9): e108560.




- ✓ Insight into the function of specific coat proteins
- ✓ Unreported spore coat structures
- ✓ Detailed model of spore coat architecture

(1) an outermost amorphous layer (the crust);
(2) the rodlet layer;
(3) the honeycomb layer;
(4) the fibrous/granular layer;
(5) the nanodot layer;
(6) the multilayer structure;
(7) the basement layer;
(8) the cortex's outer pitted surface.

Analysis of spore mutants allows unraveling of the spore coat architecture: critical for the comprehensive understanding of formulation-dependent coat structures/signatures, establishing a baseline for decontamination structural inputs, and probing structure-function relationships

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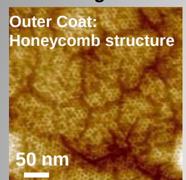
## High-Resolution Native Species-Specific Structures of *Bacillus* Spores/ Proteomic Mapping of Spore Structures

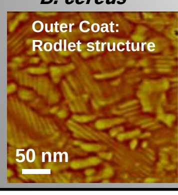
M. Plomp, T.J. Leighton, K. A. Wheeler and A.J. Malkin (2005), *Biophys. J.* 88, 603
M. Plomp, T.J. Leighton, K. A. Wheeler and A.J. Malkin (2005), *Langmuir*, *28,7892*
M. Plomp and A.J. Malkin (2009), *Langmuir*, 25, 403-409

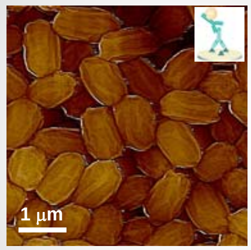
***B. thuringiensis***

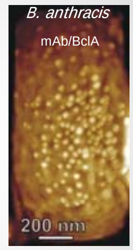




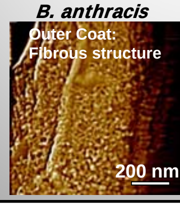
***B. cereus***



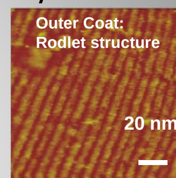




***B. anthracis***




***B. atrophaeus/subtilus***





**<u>Baseline Findings for:</u>**

- **Proteomic Mapping**
- **Molecular-Scale Structure-Function Relationships**
- **Forensic/Attribution Structural and Proteomic Attributes**
- ***Decontamination/viability Attributes***

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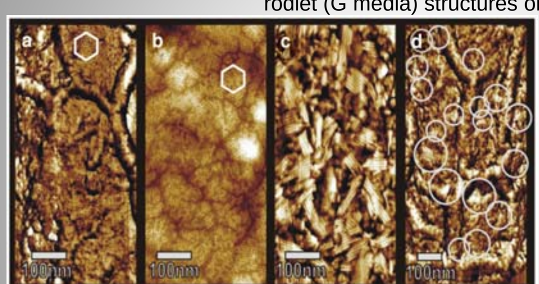
## Formulation-Specific Self-Assembly of the Outer Coat of *B. thuringiensis* Spores

A.J. Malkin and M.Plomp (2010). In: *Scanning Probe Microscopy of Functional Materials: Nanoscale Imaging and Spectroscopy*. Springer, 39-68.

Preparation-dependent formation of either extrasporal (NB media) or intact rodlet (G media) structures on the spore coat




***<u>Systematic</u> sampling: Formulation signature***

***Demonstrated, for the first time, that the assembly of the spore coat is controlled by nucleation/crystallization conditions***

**The macromolecular arrangement and topology of spore coat structures are determined by:**

- **The chemical environment during spore coat formation**
- **Thermodynamic parameters which control the formation of a new crystalline phase**

| *Pathogen Function* | ⟺ | *Physics of crystallization* | ⟺ | *Microbial Forensics* |
|---|---|---|---|---|
| ⇩ | | ⇩ | | ⇩ |
| **structure & germination/virulence competency** | | **fundamental/applied crystallization concepts** | | **reconstructing environmental conditions** |

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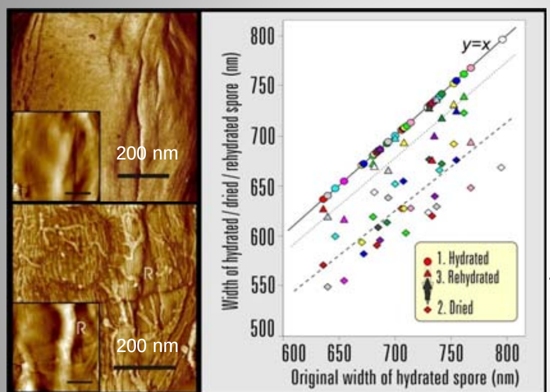
## Direct Measurements of Morphological and Structural Dynamics of Individual *Bacillus atrophaeus* Spores in Response to Changes in the Environment




***wide variety of spore surface topography***

**<u>For the first time</u>: a side-by-side comparison of fully hydrated and dehydrated *individual* spores (~200 spores)**

**The dormant spore is: a *dynamic physical structure***

**This provides an *experimental platform* for investigating spore structural dynamics, germination & *response to decontamination regimes***

- **The width of fully hydrated dormant spores was found to decrease by 12% in response to a change in the environment from aqueous to aerial milieu**
- **Spore shrinkage is reversible upon re-hydration (after 2 hours: 97% of their original size )**
- **Spore coat compensates the decrease of the internal volume / decrease of the surface area by folding**

M. Plomp, T.J. Leighton, K. A. Wheeler and A.J. Malkin (2005), *Biophys. J.* 88, 603-608

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## High-Resolution Structural Dynamics of Single Germinating Bacterial Spores

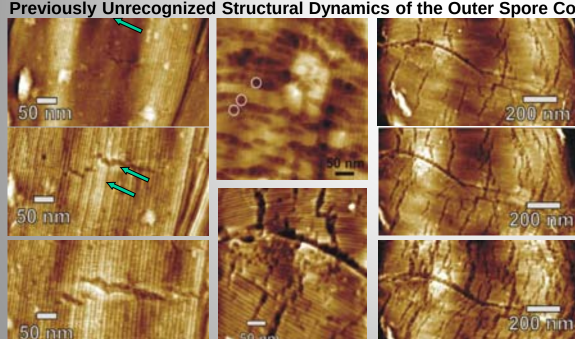
M. Plomp, T.J. Leighton, K. A. Wheeler, H.D. Hill and A.J. Malkin (2007), *PNAS*, 104, 9644-9449

**Direct *in vitro* high-resolution visualization of *individual* germinating spores in real time is required in order to probe molecular-scale structural transformation and establish direct correlations for a complete cytological sequence of the germination process**

**<u>Current Progress</u>:** biochemical & genetic aspects

*The role of spore coat is currently unclear: Investigation of the structural dynamics coupled with biochemical and genetic studies is required for a comprehensive understanding of the germination process*

**Previously Unrecognized Structural Dynamics of the Outer Spore Coat**




**<u>Initial Stages of the Germination Process</u>:**

I. Formation of ~ 2-3 nm *etch pits*

*No such pores present in the dormant spore coat*

*Etch pits could provide openings for the penetration of germinant molecules into the spore*

II. Highly directional etching perpendicular to the rodlets

III. Etch pits form *fissures* perpendicular to the rodlets

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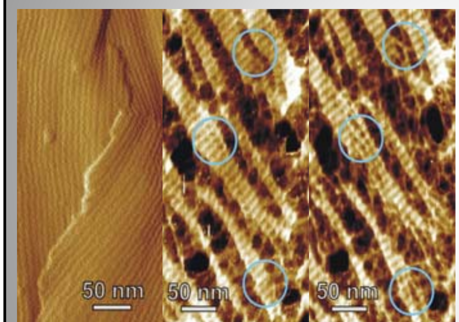
## Rodlet Structures – Functional Microbial Amyloids?

M. Plomp, T.J. Leighton, K. A. Wheeler, H.D. Hill and A.J. Malkin (2007), *PNAS*, 104, 9644-9449




Proteomic structure of rodlets is unknown
Recent studies: amyloid formation provides biologically functional molecules on the surfaces of fungi and bacteria

Mediation of mechanical invasion in human/animal infections: Protective coat enabling pathogens to evade the immune system

Amyloids – filamentous protein structures (10 nm wide; up to 10 mm long),having a cross b-structure (neurodegenerative diseases i.e. Alzheimer's).

Parameters of *Bacillus* rodlets and hydrophobicity:
*most likely amyloid structure*
*Evolutionary forces have captured the rigidity of amyloid self-assembled biomaterial to structure the protective coat (strength of steel: Young's modulus/(stiffness: silk)*

- Disassembly: final product 2-3 nm in diameter ~300 nm long fibrils, perpendicular to the rodlet direction.
- Disintegration of stable/insoluble rodlets: enzymatic action?

***Identification of Germination Enzymes for a Potential Usage for Therapeutic Purposes***

***Platform for the assessment, improved fundamental understanding , and optimization for germ-lysis or enzymatic attacks on the spore based decontamination strategies.***

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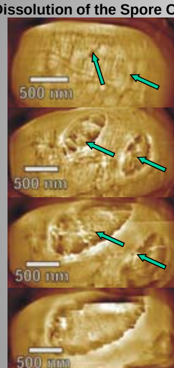
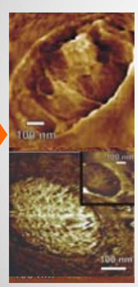
## Unraveling of High-Resolution Native Single Microbial Cell Surfaces

M. Plomp, T.J. Leighton, K. A. Wheeler, H.D. Hill and A.J. Malkin (2007), *PNAS*, 104, 9644.
M.Plomp, J.M. McCaffey, I. Cheong, X. Huang, C. Bettegowda, K.W. Kinzler, S. Zhou, B. Vogelstein and A.J. Malkin (2007). *J. Bacteriology*, 189, 6457

**Late Stages of Spore Germination: Dissolution of the Spore Coat**

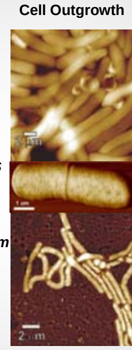


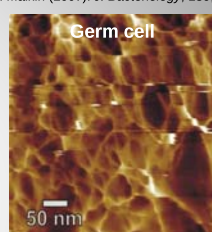



***Bacillus***

***Clostridium***

**Cell Outgrowth**






More dense "**mature**" cell wall/crosslinking

Germination conditions – dependent different pathways of the dissolution of the spore coat.

***Molecular-Scale Mechanisms of Cellular Processes***
***Environmental Resistance & Biotransformation***
***Impact of Therapeutics: Direct Probing***
***Mechanisms/Viability Studies for Germination-lysis or enzymatic attacks decontamination strategies***

- The cell wall is formed by the porous network of 1-6 nm fibers, with numerous 10-70 nm depressions
- This corresponds to the peptidoglycan layer (major function to allow bacteria to withstand the high internal osmotic pressure, critical in cell division and interactions with antibiotics)
- Currently, there are no experimental techniques available to resolve the peptidoglycan architecture (planar vs scaffold models)

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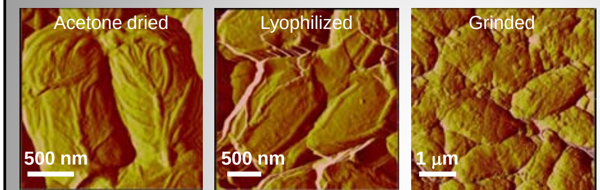
## AFM Characterization of Bacterial Spores in the Environmental Clutter and Spore Powder

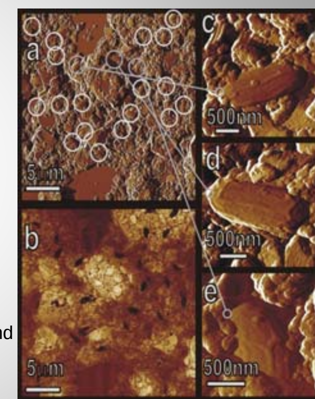
**Direct probing of spore powder samples**




*B. thuringiensis spores*

- Direct probing of powder samples of spores
- Pronounced morphological changes for lyophilized, acetone dried, and grinded/"formulated" spores
- Potentially different adhesion/reaerolization properties

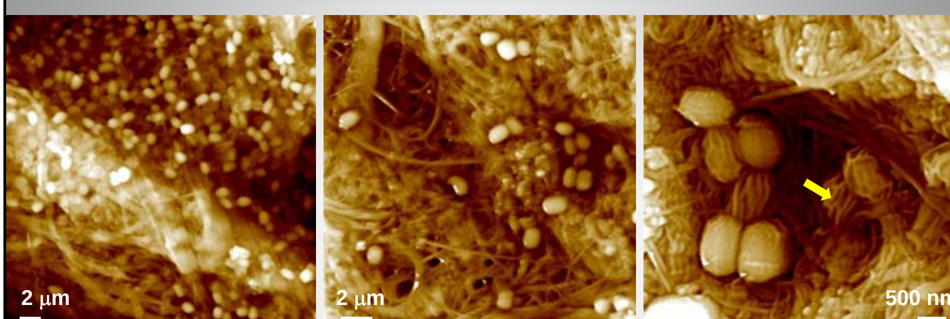
**Direct probing of *B. thuringiensis* spores in sand**




Mixture with silica aerogel (DoD environmental "common" sand model)
Amplitude and Phase AFM imaging:
*Morphological & Viscoelastic Attributes*

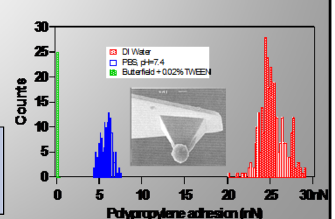
2015 EPA International Decontamination R&D Conference, Triangle Park, NC, May 5-7, 2015

## *B. anthracis* Sterne spores in fibrous materials and proof-of-concept adhesion measurements



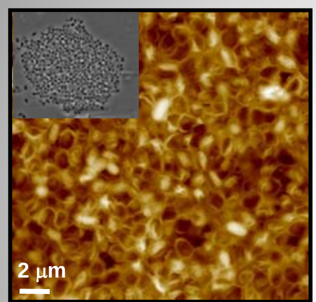

**Evaluation of adhesion and decontamination procedures/fibrous matrices**

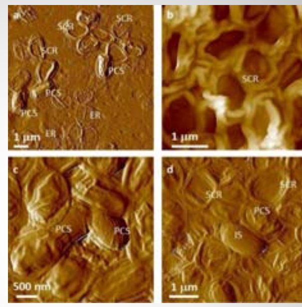
**Adhesion of single *B. anthracis* spores**: Pronounced differences in three different liquids




AFM: Enables characterization of decontamination inputs and adhesion properties for *B. anthracis* spores in various matrices including environmental samples and "formulated" samples

## Characterization of $\gamma$-irradiated *B. anthracis* spores



- Sterilizing $\gamma$-irradiation of *B. anthracis* (Ames) and *Bti* spores: profound structural changes.
- Irradiation/overheating damaged spore internal structural integrity and caused evacuation of the spore core.
- Upon dehydration of spores suspended in liquid the spores collapse. The majority of spores are partially collapsed spores (PCS) and spore coat remnants (SCR) with a few intact spores (IC). The vast majority of spores were phase dark.
- It is likely that in the hydrated sample, internal spore components have partially/or completely diffused from the spore core into the bulk liquid phase.

***The leakage of spore core contents into bulk media could also adversely affect biochemical and chemical analytical techniques***.

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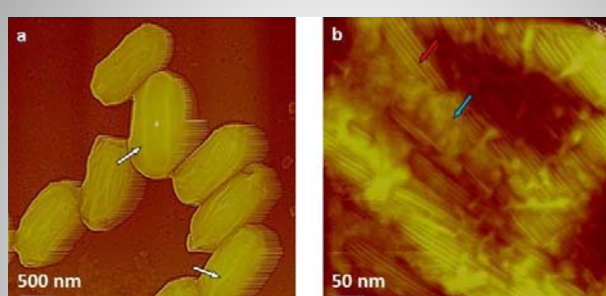
## Characterization of chlorine dioxide treated *B. subtilis* spores




- Treated spores are intact and do not collapse upon air drying
- High-resolution spore coat architecture and topology are unaltered
- AFM imaging characterization procedures for the processing and treatment of forensic samples containing virulent spores.

AFM: Enables characterization of high-resolution and morphological decontamination attributes of *B. anthracis* spores

## The Areas where AFM could be Useful for the Development of Decontamination Strategies

**This effort builds on:**

- Extensive work on AFM studies of architecture, assembly and function of pathogens/microbial systems, and activities in the area of AFM-based microbial forensics (*B. anthracis* spores).
- Prior AFM work has established statistical measures for characterization of the morphological and structural formulation-dependent attributes in single *B. anthracis* spores.
- Extensive CFM studies of adhesion and hydrophobicity of a wide range of materials.

**Probe-microscopy Relevant Potential R&D Decontamination Topics:**

I. Probing adhesion, individual spore characteristics (*e.g*., size distributions, surface charge, hydrophobicity), propensity of spores to aggregate, aerolization/re-aerosolization potential, and transport properties: input parameters for fate and transport modeling, assessment of formulation and decontamination inputs, and selection of appropriate surrogates.

II. Unraveling/testing of the decon/viability structural/morphological signatures by means of physical characteristics can have high orthogonal probative value in a decontamination context if proper validation studies are performed

III. Development of novel germination-lysis decontamination approaches/enzymatic attacks on the spore

AFM orthogonal data could significantly improve fundamental understanding of the decontamination mechanisms of pathogens in general and *B. anthracis* spores in particular and efficacy studies of multifunctional formulations required to advance these technologies to wide area applications.

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## Summary and Acknowledgements

**High-resolution biophysical analysis: Direct insights into molecular architecture and structural variability of viral, microbial and cellular systems as a function of spatial, temporal, developmental and environmental organizational scales**

M. Plomp, S. Elhadj, P. Weber, N. Montgomery, A. Noy and S. Velsko (LLNL)
P. Setlow (U. of Connecticut) T.J. Leighton (CHORI), A. Aronson (Purdue U),
B. Vogelstein' group (Kimmel Cancer Research Center, the John Hopkins U)

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# 2015 U.S. EPA International Decontamination Research and Development Conference

## Thursday, May 7, 2015

## Concurrent Sessions 5

### Chemical Agent Decontamination





2015 U.S. Environmental Protection Agency (EPA) International Decontamination Research and Development Conference

May 5-7, 2015
EPA's Research Triangle Park, NC, Campus

# *Site remediation of a 282,000 cu ft. (7,985 cu m) penicillin production facility using chlorine dioxide gas*


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**Director of Technology**
ClorDiSys

**Brett Cole**
**Director**
BioSafety


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# *Overview*

1. **Background**
2. **Cost / Equipment / Time Line**
3. **Facility Setup**
4. **Pictures of Setup**
5. **Readings**
6. **Conclusions**

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## Reasons for Decontamination

- Allergic reactions to beta-lactams are the most common cause of adverse drug reactions mediated by specific immunological mechanisms (Torres et al., 2003)
- 3%-10% of all adults in the US have experienced an allergic response to penicillin (CDC, 2006)
- Reactions to these allergies can range from simple rashes to life-threatening anaphylaxis (Romano et al., 2002)
- Another possible reaction is blood pressure dropping to life-threatening levels, causing lightheadedness and loss of consciousness (Barza, 1985)

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## Reasons for Decontamination

- Production of Amoxicillin or Penicillin-V in facility
- Facility is remote from main production campus
- Production of Amoxicillin or Penicillin-V was ceased 2009
- **Customer wants to sell the Building**

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# Preliminary Work

- 3 log reduction of 6 different beta lactams
  - Lorcheim, K. (2011). Chlorine Dioxide Gas Inactivation of Beta-Lactams. Applied Biosafety, Vol. 16(1); pp. 34-43.
- Gaseous decontamination of a production facility
  - Lorcheim, K., Lorcheim, P., & Czarneski, M. (2009). Decontamination of Beta-Lactams in a production facility using Chlorine dioxide gas. Pharmaceutical Processing, 44-46.
- An Australian verification study was conducted and analyzed by a third-party ISO17025, NATA and TGA (Australian FDA) certified facility

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# Requirements

- Less than 50ppb residuals for both Penicillin-V and Amoxicillin
- Verification of process was done using chemical indicators (CI) coupons of 3 materials
  - polycarbonate plastic (Lexan), 316L stainless steel (passivated), and aluminum. These materials represented the common surfaces inside a production facility
  - The coupons were 100mm x 100mm x 5-6mm
- Minimum chlorine dioxide gas exposure of 7240 ppm-hrs

| Detection Levels | Amoxicillin | Penicillin-V |
|---|---|---|
| LOD | 0.05ppb | 0.01ppb |
| LOQ (instrument) | 0.20ppb | 0.05ppb |

LOD – Level of Detection
LOQ – Level of Quantification

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## Equipment and Costs

- 282,000 cu ft (7,985 cu m)
- 40 generators
- 120 chlorine cylinders
- 65 Fans
- 30 steam generators
- 2 Automatic EMS CD Gas Sensor Module
- 1/4” gas inject tubing (red)
- 1/4” gas sample tubing (green)
- 50 Extension Cords
- Duct Tape
- 2 ft Wide Tape
- Plastic Sheeting
- 7 people
- 4 Days setup
- 1 day gassing

**Total Decontamination Cost**
***$350,000 AUD***
***Approx: $327,000 USD***

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## CD Gas Generation Technology

$Cl_{2(g)} + 2NaClO_{2(s)} \longrightarrow 2ClO_{2(g)} + 2NaCl_{(s)}$

- Performed in solid phase (no liquids)
- Gas generated on demand
- Gas generated at 100mg/L (36,200 ppm)
- Use concentration 0.1mg/L – 100mg/L
- Easily scalable to ANY volume
- Simple to replace consumables
- Small, Medium and Large portable generators


- Photometric measurement of concentration at multiple points
- Real Time
- Repeatable
- Accurate

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## *Time Line (How Long is the whole Process?)*

- Prior to arrival facility was cleaned of all visible residues
- Day 1 - 4
  - Uncrate generators & sensors
  - Place Fans & Humidifiers
  - Run injection tubing
  - Run sample tubing
  - Seal all entry / exit areas
  - Place signage
- Day 5 arrive in morning
  - Start RH humidification 9:00am
  - Start CD gassing 10:30am
  - Reach minimum target (3mg/L) 1:00 pm
  - Maintain / increase / hold ------------
  - Aerate start 7:30 pm
- Day 6 finish
  - Finish Aeration, Safe to enter 7:30 am
  - Remove Equipment 12:00 pm

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## *CI Locations (80)*

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## Gas Injection (80) and Sample (20) Locations

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## Fan Locations (65)

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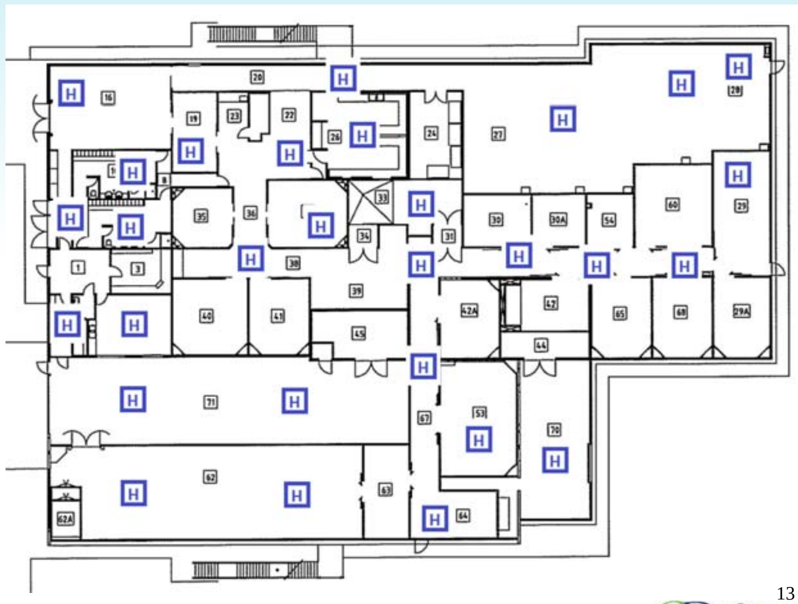
## Humidity Generator Locations (30)



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## Seal Doorways and Openings

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## Seal Roof Vents and Stacks

## Run Tubing, Place Fans & Humidifiers

## Setup Generators


## Setup EMS Sensors

## Setup Chemical Indicators

## Setup Exhaust

## Place Signage


## Gassing

## Exhaust

## Clean Up

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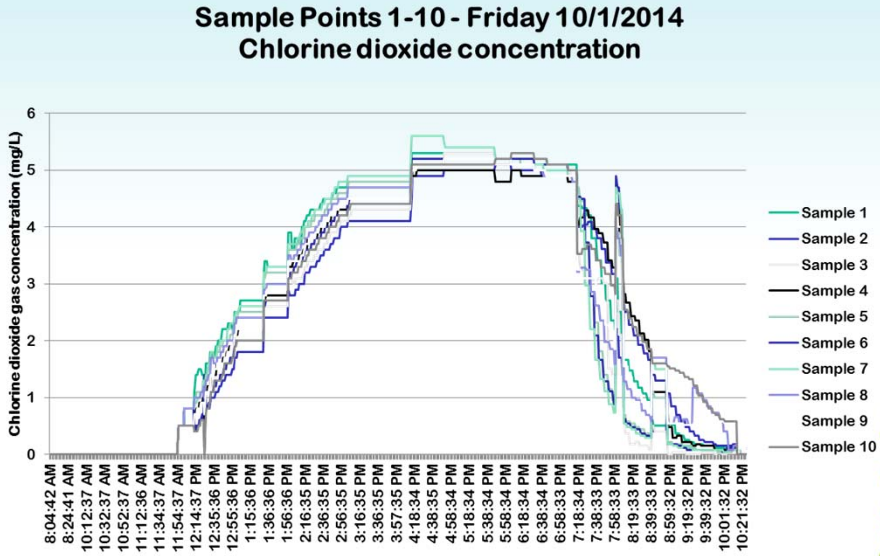
# Concentration Readings (Samples 1-10)

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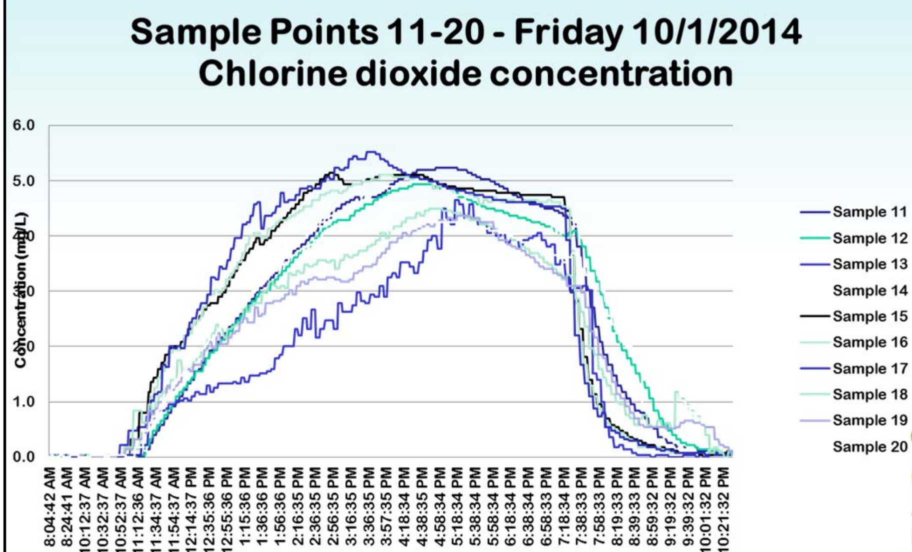
# Concentration Readings (Samples 11-20)

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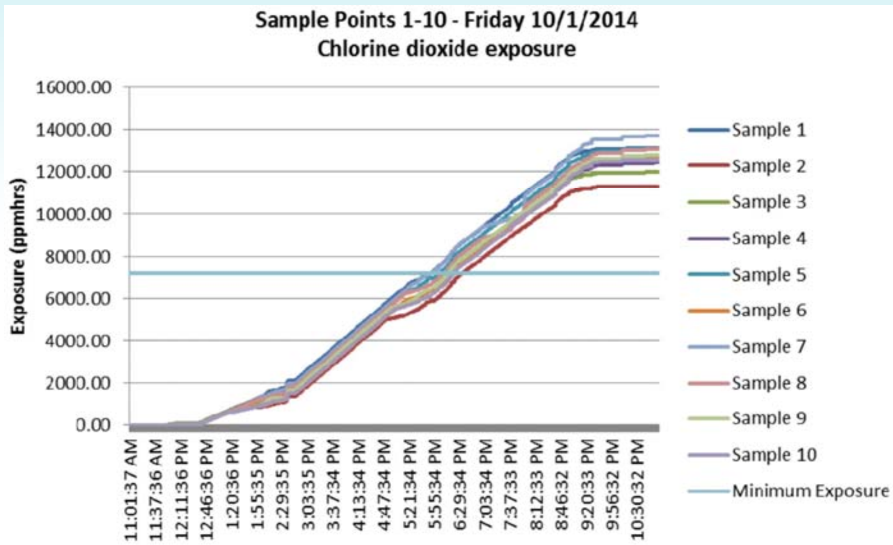
# PPM-Hrs Cycle Chart (Samples 1-10)

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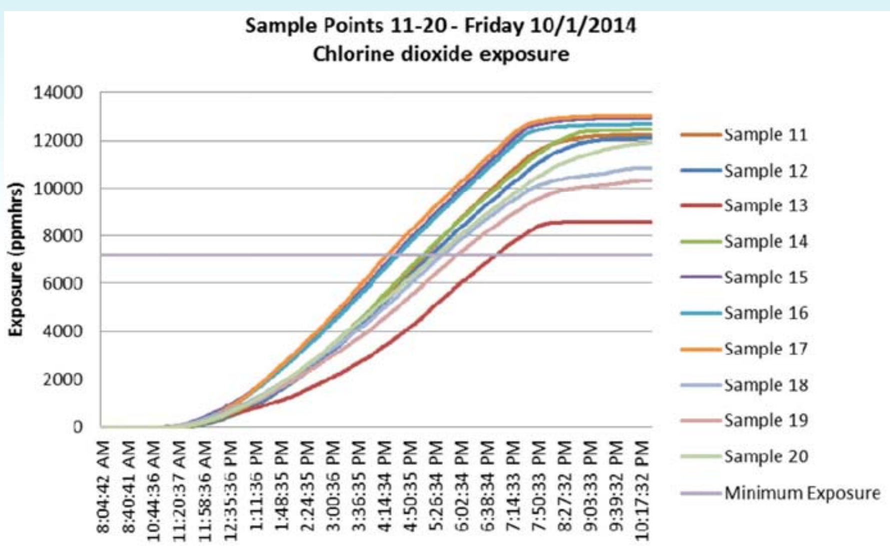
Minimum chlorine dioxide gas exposure of 7240 ppm-hrs

# PPM-Hrs Cycle Chart (Samples 11-20)




Minimum chlorine dioxide gas exposure of 7240 ppm-hrs

# Results

**PASS - All reading below 50 ppb or not detected**

| Line No | Biosafety Sample ID | Lab (CA) Sample ID | Material | Beta-Lactams: Amoxicillin (ppb) | PASS (<50ppb) FAIL (>50ppb) | Penicillin-V (ppb) | PASS (<50ppb) FAIL (>50ppb) |
|---|---|---|---|---|---|---|---|
| 1 | 1A | C20179/1 | Polycarbonate | n/d | PASS | n/d | PASS |
| 2 | 1B | C20177/31 | Stainless Steel | n/d | PASS | n/d | PASS |
| 3 | 1C | C20178/1 | Aluminium | n/d | PASS | n/d | PASS |
| 4 | 2A | C20179/2 | Polycarbonate | n/d | PASS | n/d | PASS |
| 5 | 2B | C20177/32 | Stainless Steel | n/d | PASS | n/d | PASS |
| 6 | 2C | C20178/2 | Aluminium | n/d | PASS | n/d | PASS |
| 7 | 3A | C20179/3 | Polycarbonate | <LOQ | PASS | n/d | PASS |
| 8 | 3B | C20177/33 | Stainless Steel | n/d | PASS | n/d | PASS |
| 9 | 3C | C20178/3 | Aluminium | n/d | PASS | n/d | PASS |
| 10 | 4A | C20179/4 | Polycarbonate | <LOQ | PASS | n/d | PASS |
| 11 | 4B | C20177/20 | Stainless Steel | <LOQ | PASS | n/d | PASS |
| 12 | 4C | C20178/4 | Aluminium | n/d | PASS | n/d | PASS |
| 13 | 5A | C20179/5 | Polycarbonate | <LOQ | PASS | n/d | PASS |
| 14 | 5B | C20177/34 | Stainless Steel | <LOQ | PASS | n/d | PASS |
| 15 | 5C | C20178/5 | Aluminium | n/d | PASS | n/d | PASS |
| 16 | 6A | C21079/6 | Polycarbonate | n/d | PASS | n/d | PASS |
| 17 | 6B | C20177/27 | Stainless Steel | n/d | PASS | 0.68 | PASS |
| 18 | 6C | C20178/6 | Aluminium | <LOQ | PASS | n/d | PASS |
| 19 | 7A | C20179/7 | Polycarbonate | n/d | PASS | n/d | PASS |
| 20 | 7B | C20177/29 | Stainless Steel | n/d | PASS | n/d | PASS |
| 21 | 7C | C20178/7 | Aluminium | n/d | PASS | <LOQ | PASS |
| 22 | 9A | C20179/8 | Polycarbonate | n/d | PASS | n/d | PASS |
| 23 | 9B | C20177/30 | Stainless Steel | n/d | PASS | n/d | PASS |
| 24 | 9C | C20178/8 | Aluminium | n/d | PASS | n/d | PASS |
| 25 | 10A | C20179/9 | Polycarbonate | n/d | PASS | n/d | PASS |
| 26 | 10B | C20177/35 | Stainless Steel | <LOQ | PASS | n/d | PASS |
| 27 | 10C | C20178/9 | Aluminium | <LOQ | PASS | n/d | PASS |
| 28 | 11A | C20179/10 | Polycarbonate | 1.24 | PASS | n/d | PASS |
| 29 | 11B | C20177/36 | Stainless Steel | <LOQ | PASS | n/d | PASS |
| 30 | 11C | C20178/10 | Aluminium | <LOQ | PASS | <LOQ | PASS |
| 31 | 12A | C20179/11 | Polycarbonate | n/d | PASS | n/d | PASS |
| 32 | 12B | C20177/37 | Stainless Steel | n/d | PASS | n/d | PASS |
| 33 | 12C | C20178/11 | Aluminium | 1.75 | PASS | <LOQ | PASS |
| 34 | 13A | C20179/12 | Polycarbonate | n/d | PASS | n/d | PASS |
| 35 | 13B | C20177/1 | Stainless Steel | 0.44 | PASS | 3.95 | PASS |
| 36 | 13C | C20178/12 | Aluminium | <LOQ | PASS | <LOQ | PASS |
| 37 | 14A | C20179/13 | Polycarbonate | <LOQ | PASS | n/d | PASS |
| 38 | 14B | C20177/38 | Stainless Steel | 0.44 | PASS | n/d | PASS |
| 39 | 14C | C20178/13 | Aluminium | <LOQ | PASS | <LOQ | PASS |
| 40 | 15A | C20179/14 | Polycarbonate | n/d | PASS | n/d | PASS |
| 41 | 15B | C20177/39 | Stainless Steel | n/d | PASS | n/d | PASS |
| 42 | 15C | C20178/14 | Aluminium | <LOQ | PASS | <LOQ | PASS |
| 43 | 16A | C20179/15 | Polycarbonate | <LOQ | PASS | n/d | PASS |
| | | C20177/2 | Stainless Steel | n/d | PASS | <LOQ | PASS |
| | | C20178/15 | Aluminium | 0.17 | PASS | <LOQ | PASS |
| | | C20179/16 | Polycarbonate | n/d | PASS | n/d | PASS |
| | | C20177/3 | Stainless Steel | 1.29 | PASS | n/d | PASS |
| | | C20178/16 | Aluminium | <LOQ | PASS | <LOQ | PASS |
| | | C20179/17 | Polycarbonate | n/d | PASS | n/d | PASS |
| | | C20177/4 | Stainless Steel | <LOQ | PASS | 0.24 | PASS |
| | | C20178/17 | Aluminium | 0.17 | PASS | <LOQ | PASS |
| | | C20179/18 | Polycarbonate | <LOQ | PASS | n/d | PASS |
| | | C20177/5 | Stainless Steel | n/d | PASS | <LOQ | PASS |
| | | C20178/18 | Aluminium | 0.64 | PASS | <LOQ | PASS |
| 55 | 20A | C20179/19 | Polycarbonate | n/d | PASS | n/d | PASS |
| 56 | 20B | C20177/6 | Stainless Steel | n/d | PASS | 0.26 | PASS |
| 57 | 20C | C20178/19 | Aluminium | n/d | PASS | <LOQ | PASS |
| 58 | 21A | C20179/20 | Polycarbonate | 36.65 | PASS | n/d | PASS |
| 59 | 21B | C20177/40 | Stainless Steel | <LOQ | PASS | n/d | PASS |
| 60 | 21C | C20178/20 | Aluminium | n/d | PASS | n/d | PASS |

| Detection Levels | Amoxicillin | Penicillin-V |
|---|---|---|
| LOD | 0.05ppb | 0.01ppb |
| LOQ (instrument) | 0.20ppb | 0.05ppb |

**LOD – Level of Detection**
**LOQ – Level of Quantification**
**n/d – Not Detected**

# Results

***Lost Sample***

| | | | | | | | |
|---|---|---|---|---|---|---|---|
| 61 | 22A | C20179/21 | Polycarbonate | 0.21 | PASS | 0.37 | PASS |
| 62 | 22B | C20177/41 | Stainless Steel | n/d | PASS | n/d | PASS |
| 63 | 22C | C20178/21 | Aluminium | n/d | PASS | n/d | PASS |
| 64 | 23A | C20179/22 | Polycarbonate | 0.16 | PASS | n/d | PASS |
| 65 | 23B | C20177/42 | Stainless Steel | <LOQ | PASS | n/d | PASS |
| 66 | 23C | C20178/22 | Aluminium | n/d | PASS | n/d | PASS |
| 67 | 24A | C20179/23 | Polycarbonate | <LOQ | PASS | n/d | PASS |
| 68 | 24B | C20177/43 | Stainless Steel | n/d | PASS | n/d | PASS |
| 69 | 24C | C20178/23 | Aluminium | <LOQ | PASS | n/d | PASS |
| 70 | 25A | MISSING SAMPLE | Polycarbonate | - | - | - | - |
| 71 | 25B | C20177/44 | Stainless Steel | <LOQ | PASS | n/d | PASS |
| 72 | 25C | C20178/24 | Aluminium | n/d | PASS | n/d | PASS |
| 73 | 26A | C20179/24 | Polycarbonate | <LOQ | PASS | n/d | PASS |
| 74 | 26B | C20177/45 | Stainless Steel | <LOQ | PASS | 0.42 | PASS |
| 75 | 26C | C20178/25 | Aluminium | n/d | PASS | <LOQ | PASS |
| 76 | 27A | C20179/25 | Polycarbonate | 0.2 | PASS | n/d | PASS |
| 77 | 27B | C20177/46 | Stainless Steel | <LOQ | PASS | n/d | PASS |
| 78 | 27C | C20178/26 | Aluminium | <LOQ | PASS | n/d | PASS |
| 79 | 28A | C20179/26 | Polycarbonate | <LOQ | PASS | n/d | PASS |
| 80 | 28B | C20177/7 | Stainless Steel | <LOQ | PASS | <LOQ | PASS |
| 81 | 28C | C20178/27 | Aluminium | <LOQ | PASS | n/d | PASS |
| 82 | 29A | C20179/27 | Polycarbonate | 0.34 | PASS | 0.2 | PASS |
| 83 | 29B | C20177/47 | Stainless Steel | n/d | PASS | n/d | PASS |
| 84 | 29C | C20178/28 | Aluminium | n/d | PASS | n/d | PASS |
| 85 | 29AA | C20179/28 | Polycarbonate | 0.59 | PASS | 0.3 | PASS |
| 86 | 29AB | C20177/8 | Stainless Steel | n/d | PASS | n/d | PASS |
| 87 | 29AC | C21078/29 | Aluminium | <LOQ | PASS | n/d | PASS |
| 88 | 30A | C20179/29 | Polycarbonate | 0.28 | PASS | 0.13 | PASS |
| 89 | 30B | C20177/9 | Stainless Steel | <LOQ | PASS | n/d | PASS |
| 90 | 30C | C20178/30 | Aluminium | n/d | PASS | n/d | PASS |
| 91 | 30AA | C20179/30 | Polycarbonate | <LOQ | PASS | <LOQ | PASS |
| 92 | 30AB | C20177/48 | Stainless Steel | n/d | PASS | n/d | PASS |
| 93 | 30AC | C20178/79 | Aluminium | <LOQ | PASS | n/d | PASS |
| 94 | 31A | C20179/31 | Polycarbonate | 0.26 | PASS | 0.63 | PASS |
| 95 | 31B | C20177/49 | Stainless Steel | <LOQ | PASS | n/d | PASS |
| 96 | 31C | C20178/31 | Aluminium | <LOQ | PASS | n/d | PASS |
| 97 | 32A | C20179/32 | Polycarbonate | 1.97 | PASS | <LOQ | PASS |
| 98 | 32B | C20177/49 | Stainless Steel | <LOQ | PASS | n/d | PASS |
| 99 | 32C | C20178/32 | Aluminium | <LOQ | PASS | n/d | PASS |
| 100 | 33A | C20179/33 | Polycarbonate | 0.3 | PASS | n/d | PASS |
| 101 | 33B | C20177/10 | Stainless Steel | <LOQ | PASS | n/d | PASS |
| 102 | 33C | C20178/33 | Aluminium | <LOQ | PASS | <LOQ | PASS |
| 103 | 34A | C20179/34 | Polycarbonate | 2.04 | PASS | n/d | PASS |
| 104 | 34B | C20177/11 | Stainless Steel | 0.39 | PASS | n/d | PASS |
| 105 | 34C | C20178/34 | Aluminium | <LOQ | PASS | 0.19 | PASS |
| 106 | 35A | C20179/35 | Polycarbonate | <LOQ | PASS | n/d | PASS |
| 107 | 35B | C20177/12 | Stainless Steel | <LOQ | PASS | n/d | PASS |
| 108 | 35C | C20178/35 | Aluminium | n/d | PASS | n/d | PASS |
| 109 | 36A | C20179/36 | Polycarbonate | 0.24 | PASS | n/d | PASS |
| 110 | 36B | C20177/50 | Stainless Steel | <LOQ | PASS | <LOQ | PASS |
| 111 | 36C | C20178/36 | Aluminium | <LOQ | PASS | 0.49 | PASS |
| 112 | 37A | C20179/37 | Polycarbonate | <LOQ | PASS | 0.3 | PASS |
| 113 | 37B | C20177/13 | Stainless Steel | <LOQ | PASS | n/d | PASS |
| 114 | 37C | C20178/37 | Aluminium | <LOQ | PASS | n/d | PASS |
| 115 | 38A | C20179/38 | Polycarbonate | n/d | PASS | n/d | PASS |
| 116 | 38B | C20177/51 | Stainless Steel | <LOQ | PASS | n/d | PASS |
| 117 | 38C | C20178/38 | Aluminium | n/d | PASS | n/d | PASS |
| 118 | 39A | C20179/39 | Polycarbonate | <LOQ | PASS | n/d | PASS |
| 119 | 39B | C20177/14 | Stainless Steel | n/d | PASS | n/d | PASS |
| 120 | 39C | C20178/39 | Aluminium | <LOQ | PASS | <LOQ | PASS |
| 121 | 40A | C20179/40 | Polycarbonate | 0.23 | PASS | n/d | PASS |
| 122 | 40B | C20177/16 | Stainless Steel | n/d | PASS | n/d | PASS |
| 123 | 40C | C20178/40 | Aluminium | <LOQ | PASS | <LOQ | PASS |
| 124 | 41A | C20179/41 | Polycarbonate | n/d | PASS | n/d | PASS |
| 125 | 41B | C20177/52 | Stainless Steel | n/d | PASS | n/d | PASS |
| 126 | 41C | C20178/41 | Aluminium | 0.52 | PASS | 0.21 | PASS |
| 127 | 42A | C20179/42 | Polycarbonate | n/d | PASS | n/d | PASS |
| 128 | 42B | C20177/53 | Stainless Steel | <LOQ | PASS | n/d | PASS |
| 129 | 42C | C20178/42 | Aluminium | <LOQ | PASS | <LOQ | PASS |
| 130 | 42AA | C20179/43 | Polycarbonate | n/d | PASS | n/d | PASS |
| 131 | 42AB | C20177/17 | Stainless Steel | n/d | PASS | n/d | PASS |
| 132 | 42AC | C20178/43 | Aluminium | <LOQ | PASS | <LOQ | PASS |
| 133 | 43A | C20179/44 | Polycarbonate | n/d | PASS | n/d | PASS |
| 134 | 43B | C20177/54 | Stainless Steel | <LOQ | PASS | n/d | PASS |
| 135 | 43C | C20178/44 | Aluminium | <LOQ | PASS | n/d | PASS |
| 136 | 44A | C20179/45 | Polycarbonate | <LOQ | PASS | n/d | PASS |
| 137 | 44B | C20177/18 | Stainless Steel | n/d | PASS | n/d | PASS |
| 138 | 44C | C20178/45 | Aluminium | <LOQ | PASS | <LOQ | PASS |
| 139 | 45A | C20179/46 | Polycarbonate | n/d | PASS | n/d | PASS |
| 140 | 45B | C20177/55 | Stainless Steel | n/d | PASS | n/d | PASS |
| 141 | 45C | C20178/46 | Aluminium | n/d | PASS | n/d | PASS |
| 142 | 46A | C20179/47 | Polycarbonate | n/d | PASS | n/d | PASS |
| 143 | 46B | C20177/19 | Stainless Steel | n/d | PASS | n/d | PASS |
| 144 | 46C | C20178/47 | Aluminium | <LOQ | PASS | n/d | PASS |
| 145 | 47A | C20179/48 | Polycarbonate | n/d | PASS | n/d | PASS |
| 146 | 47B | C20177/56 | Stainless Steel | <LOQ | PASS | n/d | PASS |
| 147 | 47C | C20178/48 | Aluminium | 0.38 | PASS | n/d | PASS |
| 148 | 48A | C20179/49 | Polycarbonate | <LOQ | PASS | n/d | PASS |
| 149 | 48B | C20177/57 | Stainless Steel | n/d | PASS | n/d | PASS |
| 150 | 48C | C20178/49 | Aluminium | 0.42 | PASS | <LOQ | PASS |
| 151 | 49A | C20179/50 | Polycarbonate | n/d | PASS | n/d | PASS |
| 152 | 49B | C20177/58 | Stainless Steel | <LOQ | PASS | n/d | PASS |

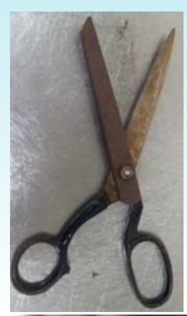
# Results

Contaminated Sample

| | | | | | | | |
|---|---|---|---|---|---|---|---|
| 153 | 49C | C20178/50 | Aluminium | n/d | PASS | <LOQ | PASS |
| 154 | 50A | C20179/51 | Polycarbonate | 0.85 | PASS | 0.3 | PASS |
| 155 | 50B | C20177/21 | Stainless Steel | 0.37 | PASS | n/d | PASS |
| 156 | 50C | C20178/51 | Aluminium | <LOQ | PASS | <LOQ | PASS |
| 157 | 51A | C20179/52 | Polycarbonate | <LOQ | PASS | <LOQ | PASS |
| 158 | 51B | C20177/59 | Stainless Steel | <LOQ | PASS | n/d | PASS |
| 159 | 51C | C20178/52 | Aluminium | <LOQ | PASS | <LOQ | PASS |
| 160 | 52A | C20179/53 | Polycarbonate | 0.6 | PASS | <LOQ | PASS |
| 161 | 52B | C20177/60 | Stainless Steel | n/d | PASS | n/d | PASS |
| 162 | 52C | C20178/53 | Aluminium | 0.47 | PASS | <LOQ | PASS |
| 163 | 53A | C20179/54 | Polycarbonate | <LOQ | PASS | 0.4 | PASS |
| 164 | 53B | C20177/61 | Stainless Steel | <LOQ | PASS | n/d | PASS |
| 165 | 53C | C20178/54 | Aluminium | <LOQ | PASS | <LOQ | PASS |
| 166 | 54A | C20179/55 | Polycarbonate | 0.23 | PASS | <LOQ | PASS |
| 167 | 54B | C20177/22 | Stainless Steel | <LOQ | PASS | n/d | PASS |
| 168 | 54C | C20178/55 | Aluminium | n/d | PASS | <LOQ | PASS |
| 169 | 55A | C20179/56 | Polycarbonate | 0.41 | PASS | 3.32 | PASS |
| 170 | 55B | C20177/80 | Stainless Steel | NT | PASS | NT | PASS |
| 171 | 55C | C20178/56 | Aluminium | 1.44 | PASS | n/d | PASS |
| 172 | 56A | C20179/57 | Polycarbonate | <LOQ | PASS | <LOQ | PASS |
| 173 | 56B | C20177/23 | Stainless Steel | 1.01 | PASS | 0.43 | PASS |
| 174 | 56C | C20178/57 | Aluminium | 1.21 | PASS | n/d | PASS |
| 175 | 58A | C20179/58 | Polycarbonate | 0.29 | PASS | <LOQ | PASS |
| 176 | 58B | C20177/24 | Stainless Steel | n/d | PASS | 0.68 | PASS |
| 177 | 58C | C20178/58 | Aluminium | 15.21 | PASS | <LOQ | PASS |
| 178 | 60A | C20179/59 | Polycarbonate | 0.28 | PASS | 0.11 | PASS |
| 179 | 60B | C20177/25 | Stainless Steel | n/d | PASS | n/d | PASS |
| 180 | 60C | C20178/59 | Aluminium | <LOQ | PASS | n/d | PASS |
| 181 | 62A | C20179/60 | Polycarbonate | <LOQ | PASS | <LOQ | PASS |
| 182 | 62B | C20177/62 | Stainless Steel | n/d | PASS | <LOQ | PASS |
| 183 | 62C | C20178/60 | Aluminium | n/d | PASS | n/d | PASS |
| 184 | 62AA | C20179/61 | Polycarbonate | 0.24 | PASS | n/d | PASS |
| 185 | 62AB | C20177/53 | Stainless Steel | <LOQ | PASS | 0.45 | PASS |
| 186 | 62AC | C20178/61 | Aluminium | n/d | PASS | n/d | PASS |
| 187 | 63A | C20179/62 | Polycarbonate | <LOQ | PASS | n/d | PASS |
| 188 | 63B | C20177/64 | Stainless Steel | 0.85 | PASS | n/d | PASS |
| 189 | 63C | C20178/62 | Aluminium | <LOQ | PASS | n/d | PASS |
| 190 | 64A | C20179/63 | Polycarbonate | <LOQ | PASS | n/d | PASS |
| 191 | 64B | C20177/65 | Stainless Steel | n/d | PASS | n/d | PASS |
| 192 | 64C | C20178/63 | Aluminium | <LOQ | PASS | n/d | PASS |
| 193 | 65A | C20179/64 | Polycarbonate | <LOQ | PASS | n/d | PASS |
| 194 | 65B | C20177/26 | Stainless Steel | n/d | PASS | n/d | PASS |
| 195 | 65C | C20178/64 | Aluminium | <LOQ | PASS | n/d | PASS |
| 196 | 66A | C20179/65 | Polycarbonate | <LOQ | PASS | n/d | PASS |
| 197 | 66B | C20177/66 | Stainless Steel | <LOQ | PASS | n/d | PASS |
| 198 | 66C | C20178/65 | Aluminium | n/d | PASS | n/d | PASS |
| 199 | 67AA | C20179/66 | Polycarbonate | 0.33 | PASS | n/d | PASS |
| 200 | 67AB | C20177/67 | Stainless Steel | n/d | PASS | n/d | PASS |
| 201 | 67AC | C20178/66 | Aluminium | n/d | PASS | n/d | PASS |
| 202 | 67BA | C20179/67 | Polycarbonate | 0.26 | PASS | n/d | PASS |
| 203 | 67BB | C20177/6[illegible] | Stainless Steel | <LOQ | PASS | 1.92 | PASS |
| 204 | 67BC | C20178/6[illegible] | Aluminium | <LOQ | PASS | n/d | PASS |
| 205 | 68A | C20179/6[illegible] | Polycarbonate | 0.29 | PASS | n/d | PASS |
| 206 | 68B | C20177/6[illegible] | Stainless Steel | <LOQ | PASS | n/d | PASS |
| 207 | 68C | C20178/6[illegible] | Aluminium | <LOQ | PASS | n/d | PASS |
| 208 | 69A | C20179/[illegible] | Polycarbonate | <LOQ | PASS | n/d | PASS |
| 209 | 69B | C20177/[illegible] | Stainless Steel | n/d | PASS | n/d | PASS |
| 210 | 69C | C20178/[illegible] | Aluminium | n/d | PASS | n/d | PASS |
| 211 | 70AA | C20179/[illegible]0 | Polycarbonate | <LOQ | PASS | <LOQ | PASS |
| 212 | 70AB | C20177/[illegible]8 | Stainless Steel | n/d | PASS | 0.68 | PASS |
| 213 | 70AC | C20178/[illegible]0 | Aluminium | 26.21 | PASS | 0.18 | PASS |
| 214 | 70BA | C2017[illegible]/71 | Polycarbonate | 0.22 | PASS | <LOQ | PASS |
| 215 | 70BB | C2017[illegible]/71 | Stainless Steel | n/d | PASS | n/d | PASS |
| 216 | 70BC | C2017[illegible]80 | Aluminium | n/d | PASS | n/d | PASS |
| 217 | 71A | C2017[illegible]/72 | Polycarbonate | <LOQ | PASS | n/d | PASS |
| 218 | 71B | C2017[illegible]/72 | Stainless Steel | n/d | PASS | n/d | PASS |
| 219 | 71C | C2017[illegible]/71 | Aluminium | 1.89 | PASS | 4.46 | PASS |
| 220 | 72A | C2017[illegible]/73 | Polycarbonate | <LOQ | PASS | n/d | PASS |
| 221 | 72B | C2017[illegible]/73 | Stainless Steel | 22.81 | PASS | 1.42 | PASS |
| 222 | 72C | C201[illegible]/72 | Aluminium | 5.95 | PASS | n/d | PASS |
| 223 | 73A | C201[illegible]/74 | Polycarbonate | <LOQ | PASS | n/d | PASS |
| 224 | 73B | C201[illegible]/74 | Stainless Steel | n/d | PASS | 11.03 | PASS |
| 225 | 73C | C201[illegible]/73 | Aluminium | <LOQ | PASS | n/d | PASS |
| 226 | 74A | C20[illegible]/75 | Polycarbonate | 1.49 | PASS | n/d | PASS |
| 227 | 74B | NOT TESTED | Stainless Steel | NT | PASS | NT | PASS |
| 228 | 74C | C20178/74 | Aluminium | <LOQ | PASS | n/d | PASS |
| 229 | 75A | C20179/76 | Polycarbonate | <LOQ | PASS | n/d | PASS |
| 230 | 75B | C20177/76 | Stainless Steel | n/d | PASS | n/d | PASS |
| 231 | 75C | C20178/75 | Aluminium | <LOQ | PASS | n/d | PASS |
| 232 | 77A | C20179/77 | Polycarbonate | n/d | PASS | n/d | PASS |
| 233 | 77B | C20177/77 | Stainless Steel | <LOQ | PASS | n/d | PASS |
| 234 | 77C | C20178/76 | Aluminium | <LOQ | PASS | n/d | PASS |
| 235 | 78A | C20178/78 | Polycarbonate | <LOQ | PASS | <LOQ | PASS |
| 236 | 78B | C20177/78 | Stainless Steel | n/d | PASS | n/d | PASS |
| 237 | 78C | C20178/77 | Aluminium | n/d | PASS | n/d | PASS |
| 238 | 79A | C20179/79 | Polycarbonate | <LOQ | PASS | n/d | PASS |
| 239 | 79B | C20177/79 | Stainless Steel | <LOQ | PASS | n/d | PASS |
| 240 | 79C | C20178/78 | Aluminium | <LOQ | PASS | n/d | PASS |

**Notes:** LOQ = Level of Quantification, n/d = not detected, NT = Not tested

# Conclusions



- **SUCCESS - All CI had less than 50 ppb of residuals**
- **SUCCESS - Building SOLD, June 2014**
- **8,253 Lowest PPM-Hrs**
- **12,253 Highest PPM-Hrs**
- **Average concentration 3-5mg/L (3200 – 1800 ppm)**
- **No physical residue observed**
- **Had leakage from few areas that had to be corrected**
- **No visible indication of material degradation on any electronics**
- **No affects to HVAC system (blowers, condenser coils, heating elements, control dampers, duct work material diffusers)**
- **Had minor corrosion of ferrous metals (scissors & hinges)**

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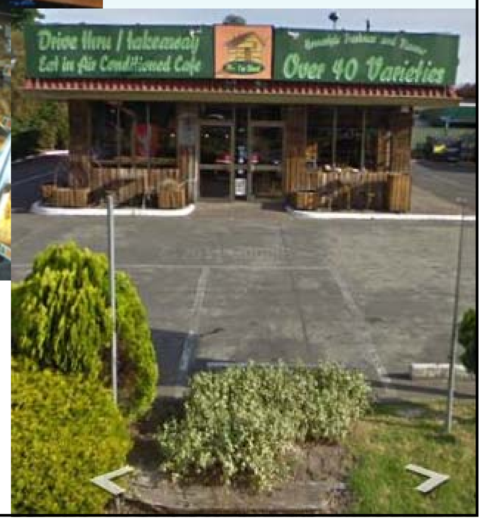
## Stop at the Pie Shed for some Aussie Meat Pies

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### Decon Team

BioSafety

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ClorDiSys

Revision Date: April 14, 2015

US ARMY RDECOM

# Hydrogen Peroxide-Based “Self-Help” and Residue-Free Decontaminants for Chemical Warfare Agents

EDGEWOOD CHEMICAL BIOLOGICAL CENTER
A U.S. Army RDECOM Laboratory

TECHNOLOGY DRIVEN. WARFIGHTER FOCUSED.

2015 EPA International Decontamination Research and Development Conference

George W. Wagner, Ph.D.

May 7, 2015

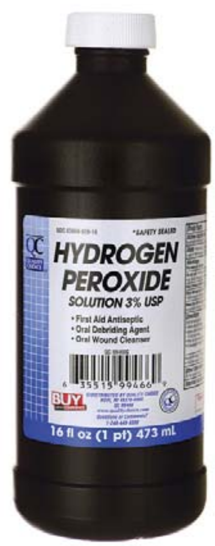
Approved for Public Release

## Why Hydrogen Peroxide?

- Decomposes to water and oxygen in the environment, leaving no residue:

  $H_2O_2 \rightarrow H_2O + ½ O_2$

- Low corrosivity/toxicity:
  - 3 % aqueous solution (drugstore, “topical” $H_2O_2$) can be used on skin and cuts/abrasions
  - 1.5 % $H_2O_2$ for oral use
- High volume industrial chemical (cheap & plentiful)
- Higher concentrations have very low freezing points, useful for low temperature decontamination
- 35 % $H_2O_2$ freezes at -33 $^{o}$C (-27 $^{o}$F)

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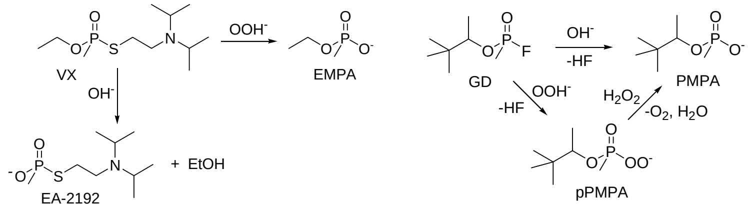
## Chemical Warfare Agent Decontamination by $H_2O_2$: Nerve Agents

- Making $H_2O_2$ basic ($NaHCO_3$) generates peroxyanion nucleophile $OOH^-$
- $OOH^-$ quickly reacts with nerve agents VX and GD:[1]




- Reaction with $OOH^-$ avoids formation of toxic EA 2192 in the case of VX
- Hydrolysis of VX with simple base ($OH^-$) forms up to 22 % EA 2192[2]

1. Wagner and Yang, IECR **2002**, *41*, 1925.
2. Yang et al. JACS **1990**, *112*, 6621.

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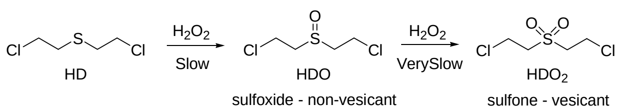
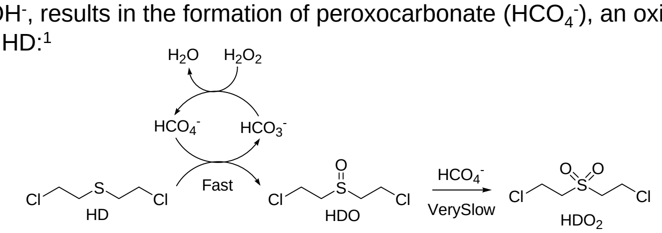
## Chemical Warfare Agent Decontamination by $H_2O_2$: Blister Agent HD

- Reaction with (un-activated) $H_2O_2$ is slow. Avoids formation of the vesicant sulfone product:[1]




- Use of bicarbonate activator, in addition to raising the pH of $H_2O_2$ to generate $OOH^-$, results in the formation of peroxocarbonate ($HCO_4^-$), an oxidation catalyst for HD:[1]




- Secondary oxidation to vesicant sulfone is still very slow with $HCO_4^-$ catalyst[1]

1. Wagner and Yang, IECR **2002**, *41*, 1925.

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## Ammonia Decontamination of GD

- Vaporized hydrogen peroxide (VHP) modified with ammonia gas (mVHP) found to be an effective fumigant gas for VX, GD, and HD[1]
- Also found that ammonia gas itself is effective for GD[1]
- Additional studies showed that ammonia-window and floor cleaners also very effective for GD:[1]

| Time (min) | Window Cleaner #1 | | Window Cleaner #1 | | Floor Cleaner | |
|---|---|---|---|---|---|---|
| | 1:50 | 1:500 | 1:50 | 1:500 | 1:50 | 1:500 |
| 2 | 81.8 | 68.5 | 86.6 | 63.0 | 20.5 | ND |
| 5 | 81.0 | 45.3 | 70.4 | 33.6 | 1.2 | |
| 15 | 75.6 | 24.0 | 57.9 | 17.4 | ND | |

1. Wagner et al., Langmuir **2007**, *23*, 1178.

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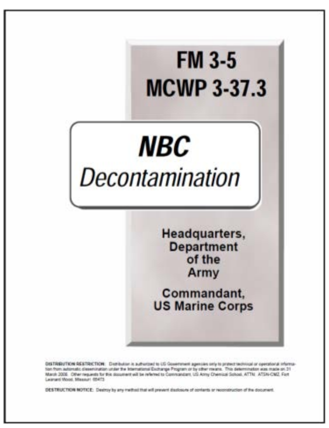
## Ammonia is a Known Decontaminant for G Agents

- Ammonia is recognized as a nonstandard decontaminant in Army Field Manual FM 3-5[1]




FM 3-5/MCWP 3-37.3

Table B-2. Nonstandard Decontaminants Available in the Supply System (Continued)

| Decontaminants | Use | Remarks | Cautions | Preparation |
|---|---|---|---|---|
| Ammonia or ammonium hydroxide (household ammonia) | Chem | Is effective against G agents. Is slower acting than sodium hydroxide or potassium hydroxide. | May require the use of a self-contained breathing apparatus or special purpose mask. | Ammonium hydroxide is a water solution of ammonia. No further mixing is required. |

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## *Self-Help* Decontamination Using $H_2O_2$ and Other Household Products

- 3 % Household Hydrogen Peroxide
- Ammonia Cleaners (Window, Floor)
- Baking Soda ($NaHCO_3$)
- Washing Soda ($Na_2CO_3$)
- Rubbing Alcohol (70 % isopropanol)



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## *Self-Help* Decon Using Household Products 1:50 Agent to Decon Challenge[1]

| VX | GD | HD | HD | HD | VX | GD | VX | GD | GD | VX |
|---|---|---|---|---|---|---|---|---|---|---|
| 50% | 50% | 50% | 50% | 50% | 50% | 50% | 100% | 100% | 100% | 100% |
| 50% | 50% | 50% | 50% | 50% | 50% | 50% | 1% | 1% | 5% | 5% |
| | | | 2% | 5% | 5% | 5% | | | | |
| ND after 6 min | ND after 1 min | 47-min half-life | 10-min half-life | 8-min half-life | 49% left 15 min | 3.5% left 15 min | ND after 4 min | ND after 15 min | ND after 4 min | 31% left 15 min |

1. Wagner, IECR **2011**, *50*, 12285.

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## Mixing *Self-Help* Decontaminants[1]

| Agent | To Mix One Gallon of Decontamination Solution: |
|---|---|
| **G**<br>GB (Sarin), GD (Soman) | Use straight ammonia window or floor cleaner (no mixing needed). |
| **V**<br>VX | Stir two (2) level tablespoons washing soda into one (1) gallon topical hydrogen peroxide (3 %) until completely dissolved. |
| **H**<br>HD (Mustard) | First stir ¾ level cup baking soda into ½ gallon topical hydrogen peroxide (3 %) until completely dissolved. Then add ½ gallon rubbing alcohol, with stirring. |
| **Universal**<br>For G, V, H agents when identity unknown | Use H solution above. |


1. Wagner, IECR **2011**, *50*, 12285.

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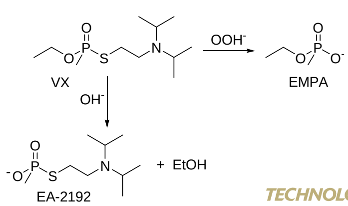
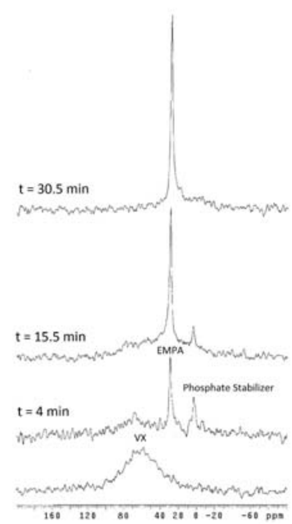
## Residue-Free $H_2O_2$-Decontamination of VX, GD, and HD on Concrete[1]

- VX applied to concrete coupon, allowed to adsorb for ca. 1 h
- 35 % $H_2O_2$ applied cover concrete coupon
- Reaction monitored in situ by $^{31}P$ NMR
- Rapid formation of non-toxic EMPA product observed in $H_2O_2$ surrounding the concrete coupon
- No leaching of VX from the concrete is observed
- No toxic EA-2192 is observed consistent with perhydrolysis, most likely enabled by surface-sorbed carbonate:




1. Wagner, ES&T **2015**, *49*, 3750.

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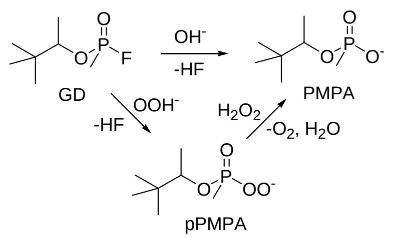
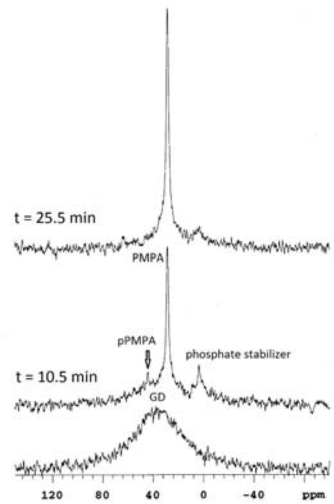
## Residue-Free $H_2O_2$-Decontamination of VX, GD, and HD on Concrete[1]

- GD also rapidly forms non-toxic product, PMPA
- No leaching of GD from the concrete is observed
- Observance of peroxy-PMPA (pPMPA) is consistent with perhydrolysis (enabled by surface-sorbed bicarbonate):




1. Wagner, ES&T **2015**, *49*, 3750.

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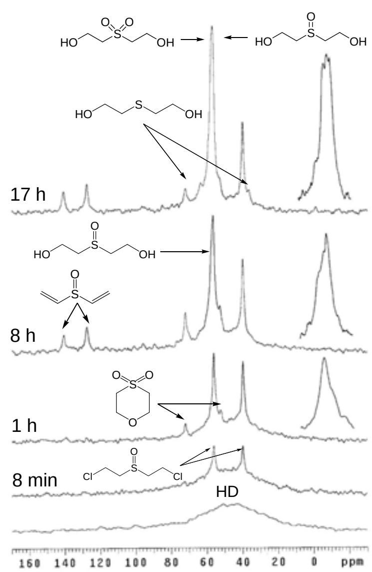
## Residue-Free $H_2O_2$-Decontamination of VX, GD, and HD on Concrete[1]

- HD ($^{13}C$-enriched; monitored by $^{13}C$ NMR) quickly forms water-soluble, non-vesicant sulfoxide product
- Oxidation probably enhanced by surface-sorbed bicarbonate
- Following the initial oxidation product, a variety of other products ensue, including those due to hydrolysis and elimination
- Acid-clyclization (HCl) of a diol product is also observed
- Eventually the hydrolysis product thiodiglycol is observed, following $H_2O_2$ depletion




1. Wagner, ES&T **2015**, *49*, 3750.

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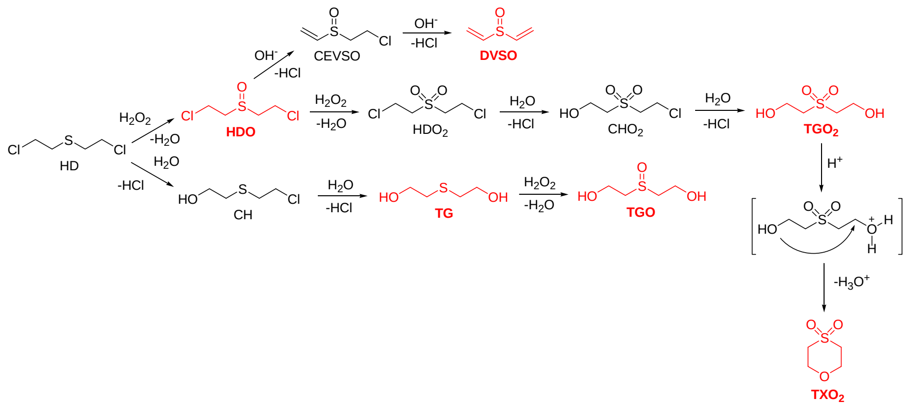
# Observed HD Reactions[1]

- Persistent products formed (shown in red) during the decontamination of HD on concrete by $H_2O_2$ are generally non-vesicant (either sulfoxides or diols)




1. Wagner, ES&T **2015**, *49*, 3750.

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# Residue-Free Decontaminant for Surfaces other than Concrete

- $H_2O_2$ can be activated with non-residue-forming ammonia ($NH_3$) and carbon dioxide ($CO_2$), generating an "HPAC" decontaminant[1]
- The HPAC decontaminant[a] was tested against VX, GD, and HD in solution:

| VX | | GD | | HD | |
|---|---|---|---|---|---|
| Time (min) | % | Time (min) | % | Time (min) | % |
| 2 | 28.6 | 2 | ND | 2 | 72.3 |
| 3 | 20.0 | | | 4 | 57.3 |
| 4 | 15.0 | | | 6 | 43.7 |
| 5 | 11.7 | | | 8 | 32.0 |
| 6 | 10.6 | | | 10 | 23.3 |
| 7 | 8.6 | | | 12 | 16.0 |
| 8 | 7.2 | | | 14 | 10.7 |
| 9 | 6.3 | | | 16 | 7.3 |
| 15 | 2.8 | | | 18 | 4.4 |
| 30 | 1.4 | | | 20 | 2.4 |
| 1 h | 0.63 | | | 22 | 1.5 |
| 2 h | ND | | | 24 | <1.0 |

[a]Decontaminant generated by bubbling $NH_3$ and $CO_2$ into water, combining with 35 % $H_2O_2$. Propylene carbonate and Triton X-100 surfactant were added to assist in dissolving HD. Propylene glycol was added to lower the freezing point.

1. Wagner, ES&T **2015**, *49*, 3750.

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## Conclusions

- Household-strength 3 % hydrogen peroxide can be combined with other common household materials (ammonia cleaners, baking soda, washing soda, rubbing alcohol) to fashion self-help decontaminants for VX, GD, and HD
- More concentrated, industrial-grade hydrogen peroxide (e.g. 35 %) is effective for residue-free decontamination of VX, GD, and HD on concrete
- High-concentration hydrogen peroxide activated using non-residue-forming $NH_3$ and $CO_2$ gases ("HPAC" decontaminant) is effective for the decontamination of VX, GD, and HD in solution
- Studies of residue-free HPAC decontaminants on surfaces of interest are needed

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## Acknowledgements

Acknowledgements: Research reported in this presentation was funded or supported by the Defense Threat Reduction Agency under project numbers BZ06DEC016 and BA06DEC052.

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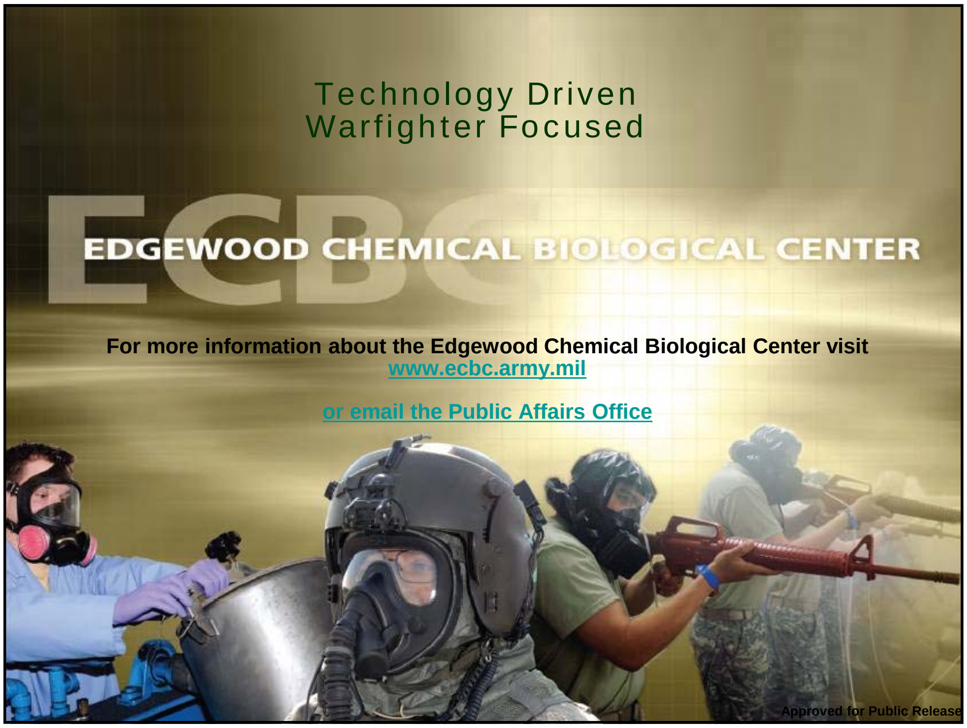
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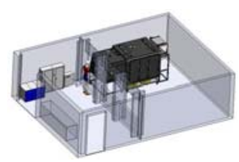
# Integrated Decontamination Test and Evaluation System (IDTES) for Evaluation of Hazard Mitigation Technologies

2015 International Decontamination Research and Development Conference
U.S. Environmental Protection Agency, Durham, NC, May 5-7, 2015

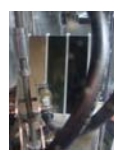
George Wrenn, Erin Lamb, Bruce Campbell,
Scott Mason, Gary Stickel, Shawn Shumaker



## System Description



The Integrated Decontamination Test and Evaluation System (IDTES) is a surety chemical test facility that enables system-level evaluation of hazard mitigation technologies and protocols in tests that combine use of full-scale apparatus and products with full-strength chemical agents or other toxic compounds. Decontamination efficacy tests are conducted using material panels, equipment items, or mock-ups as test articles.



- The IDTES treatment chamber provides capability for:
  - weathering test articles in temperature and humidity conditions
    - that simulate a range of indoor and outdoor climates
  - contaminating the test articles with neat chemical agents
    - and other toxic compounds
  - applying various decontamination products and indicator products
    - using full scale field equipment and operating protocols

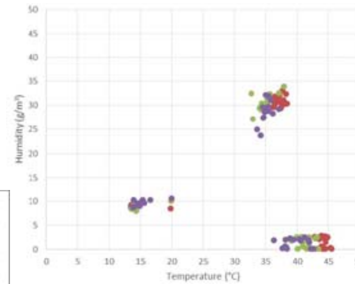
Chemical decontamination efficacy tests conducted using the IDTES provide information needed to evaluate hazard mitigation systems in laboratory conditions that support demonstration of the highest technology readiness level (TRL-6) that does not include use of actual operational environments. The IDTES can also be used to evaluate the contamination survivability of equipment and gear.

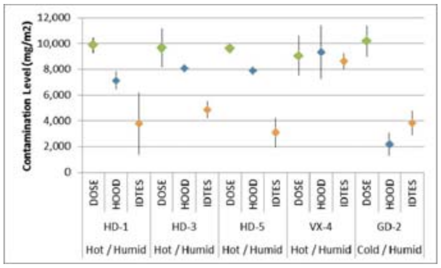
*Development of the IDTES is sponsored jointly by the Defense Threat Reduction Agency (JSTO/DTRA-CB) and the Joint Program Manager for Protection (JPEO/JPM-P)*

## Temperature and humidity inside IDTES Treatment Chamber are controlled and varied to evaluate effects of heat and moisture

### Environmental Conditions

- Hot / Humid (35±3 °C; 30±5 g/m³)
- Hot / Dry (42±3 °C; 2±2 g/m³)
- Cold / Humid (15±2 °C; 10±2 g/m³)

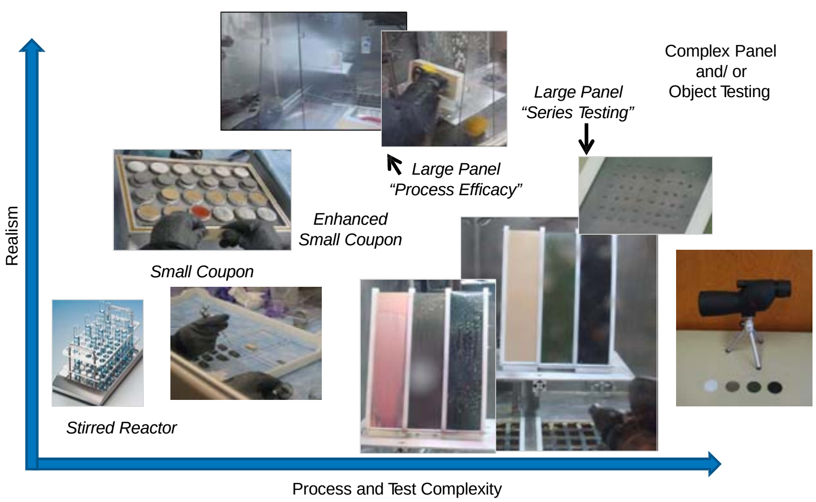



-- Agent Fate --
Evaporation losses occur as expected for various environmental conditions. Volatile agents (GD&HD) evaporate more quickly in hotter environments than cooler environments. Conversely, evaporation of VX is unaffected by changing weathering conditions.



## Scaling Factors for Decontamination Efficacy Testing



## TEST ACTIVITIES

- HaMMER-ATD Test Event (2012)
  - Hazard Mitigation for Materials and Equipment Restoration – Advanced Technology Demonstration
- SuperSoap Test Event (2013)
  - Evaluation of Surfactant Cleaners (SuperSoap / Air Force Cleaner) – Advanced Technology Demonstration
- JGPD-HME CP Test Event (2014)
  - Joint General Purpose Decontaminant for Hardened Military Equipment – Competitive Prototyping
- JGPD-HME DT Test Event (2015)
  - Joint General Purpose Decontaminant for Hardened Military Equipment – Developmental Testing

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## Multiple field treatment operations were demonstrated inside the IDTES during HaMMER-ATD Chemical Efficacy Test Event (2012)

- Field operations for HaMMER Mobile Suite and Stationary Suite hazard mitigation protocols were executed inside the IDTES in system-level tests with actual equipment components, decon products, and indicator products using full-strength chemical warfare agents (HD, VX)

Low-Pressure Rinse (similar to Merlin and JPDS)

High-Pressure Rinse (similar to M17/M26)

Soapy Water Prewash

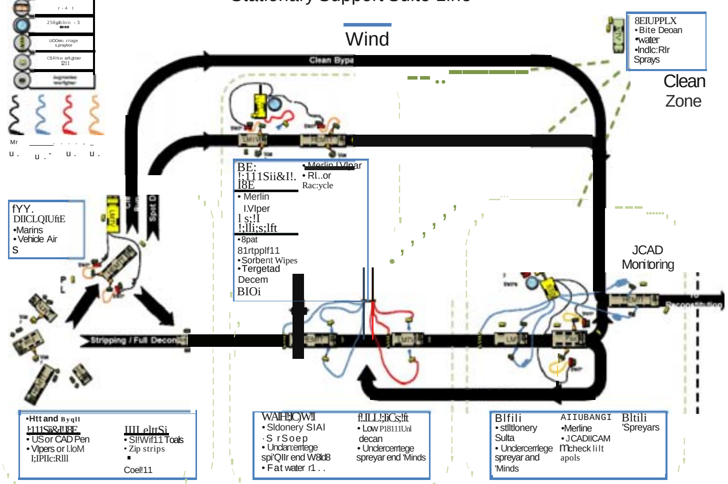
Brush Scrub

Decon Application

6

## HaMMERATD

Stationary Support Suite Line

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## *Decontamination Efficacy Comparisons for HD in HaMMER ATD*

***(Higher is Better)***

Decontaminant > Soapy Water > Water Rinse

| ***Panel Orientation*** | ***Decon Suite*** | ***CARC*** |
|---|---|---|
| Near Horizontal > Near Vertical | Stationary ≤ Mobile | CARC-S > CARC-W |

| Decon Suite | Material | HAMMER-E8-04 HD (Full Decon) (Vertical) Contamination Zone (mg/m²) | Run-off Zone (mg/m²) | Splash Zone (mg/m²) | HAMMER-E8-06 HD (Full Decon) (Horizontal) Contamination Zone (mg/m²) | Run-off Zone (mg/m²) | Splash Zone (mg/m²) |
|---|---|---|---|---|---|---|---|
| Mobile | CARC(W) | 13.10 (2.30 - 74.54) | < 1.20 | < 1.20 | 3.95 (2.79 - 5.60) | < 1.20 | < 1.20 |
| Mobile | CARC(S) | 7.62 (1.72 - 33.83) | < 1.20 | < 1.20 | 0.98 (0.37 - 2.60) | < 1.20 | < 1.20 |
| Mobile | SBR | 197.77 (114.74 - 340.87) | 24 / 70 | 2.3 / 1.5 | 126.91 (114.18 - 141.06) | 8 / 1.8 | < 1.20 |
| Stationary | CARC(W) | 8.41 (2.03 - 34.77) | < 1.20 | < 1.20 | 1.71 (1.10 – 2.76) | < 1.20 | < 1.20 |
| Stationary | CARC(S) | 11.76 (6.11 - 22.65) | < 1.20 | < 1.20 | 1.12 (1.10 – 1.48) | < 1.20 | < 1.20 |
| Stationary | SBR | 220.06 (164.12 - 295.08) | 50 / 7.6 | 5.5/1.2 | 158.31 (122.62 – 187.64) | 5.5 / 4.4 | 2.2 / 11 |

| Decon Suite | Material | HAMMER-E8-02 HD (Soapy Water, Water, and AD/DA) (No Decon) (Vertical) Contamination Zone (mg/m²) | Run-off Zone (mg/m²) | Splash Zone (mg/m²) |
|---|---|---|---|---|
| SuperSoap 5 Min | CARC(W) | 11.83 (9.18 - 15.23) | 2.7 / 1.2 | 1.3 / 1.8 |
| SuperSoap 5 Min | CARC(S) | 6.27 (4.59 - 8.56) | 8.6 / 1.2 | 1.2 / 1.5 |
| SuperSoap 5 Min | SBR | 271.74 (239 - 309) | 4.0 / 2.4 | 5.2 / 20 |
| SuperSoap 30 Min | CARC(W) | 4.61 (2.32-9.14) | 4.8 / 2.5 | 1.2 / 1.2 |
| SuperSoap 30 Min | CARC(S) | 8.59 (6.70 - 11.02) | 2.7 / 1.2 | 1.2 / 1.2 |
| SuperSoap 30 Min | SBR | 149.76 (132 - 191) | 2.7 / 1.6 | 1.7 / 1.8 |
| Water only | CARC(W) | 8.70 (4.43 - 17.08) | 2.8 / 1.7 | 1.4 / 1.2 |
| Water only | CARC(S) | 5.79 (4.36 - 7.68) | 2.1 / 1.2 | < 1.20 |
| Water only | SBR | 313.08 (266 - 368) | 15.4 / 6.2 | 2.2 / 4.6 |

Each set of results for Contamination Zone represent Geo Mean with Upper and Lower 95% Confidence Interval for four samples

Green = <100 mg/m² Blue = <15 mg/m²

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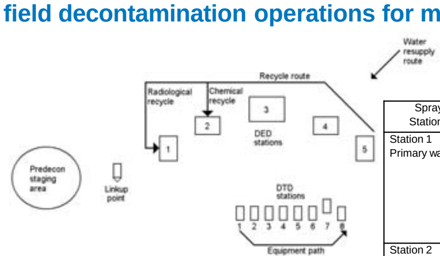
## Experimental design matrix for JGDP-HME DT Test Event includes six factors that may influence chemical decontamination efficacy

- Full design matrix is executed for three chemical agents (GD-HD-VX) in vapor emissions test activity
- Abbreviated matrix may be used with two agents (GD-HD) in contact exposure test activity
  - based on preliminary results at designated “best and worst” exposure conditions

| Decon | Pre-Wash | Agent Aging Time | Decon Pot Life | Environment | Materials | Agents |
|---|---|---|---|---|---|---|
| JGPD HME (chem) | With | 1 Hour | 1 Hour | Tropical | CARC-W | GD |
| | | 6 Hours | 6 Hours | Ambient | Lexan | HD |
| | | | | Cold | Silicone | VX |
| | | | | | Non-Skid | |
| | | | | | Stainless Steel | |



## JGPD-HME Chemical Efficacy Test Events (2014-2015) simulate field decontamination operations for military vehicles in IDTES

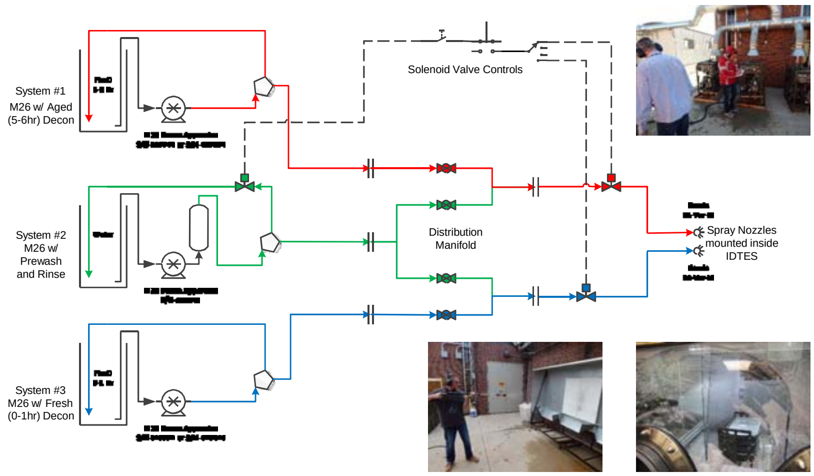



| Prewash / Rinse @ ~2,000 mL/m2 | | | Decon @ ~500 mL/m2 | |
|---|---|---|---|---|
| Equipment | M26 JSTDS-SS | | M26 w/bypass hose | |
| | Gallons | Minutes | Gallons | Minutes |
| M1 Tank | 57 | 14 | 15 | 10-12 |
| M2 BFV | 57 | 14 | 15 | 10-12 |
| M113 APC | 38 | 10 | 10 | 7-8 |
| M109A Paladin | 57 | 14 | 16 | 11-13 |
| HEMTT | 50 | 12 | 12 | 8-9 |
| 5-Ton Truck | 42 | 11 | 11 | 8-9 |
| HMMWV | 23 | 6 | 5 | 3 |

| Spray Stations | Personnel ( * Decon Platoon) | Equipment and Supplies |
|---|---|---|
| Station 1<br>Primary wash | 1 squad leader *<br>4 sprayers<br>~~4 scrubbers~~ | **2 M26 JSTDS-SSs**<br>13,000-gallon tanks<br>265-/125-GPM pumps<br>~~4 long-handled brushes~~<br>4 TAP aprons<br>1 TPU<br>~~Liquid detergent~~<br>2 flashlights |
| Station 2<br>Decontaminant application | 1squad leader *<br>4 sprayers<br>2 mixers | **2 M26 JSTDS-SSs**<br>1 3,000-gallon tank<br>2 65-/125-GPM pumps<br>~~12 long-handled brushes~~<br>~~8 mops with extra mop heads~~<br>4 30-gallon containers<br>4 TAP aprons<br>1 TPU<br>**Sufficient JGPD-HME**<br>2 flashlights |
| Station 4<br>Rinse | 1 squad leader *<br>4 sprayers | **2 M26 JSTDS-SSs**<br>1 3,000-gallon tank<br>2 65-/125-GPM pumps<br>4 TAP aprons<br>1 TPU<br>2 flashlights |

Source: CBRN Decontamination. Multiservice Tactics, Techniques, and Procedures (FM-3-11.5/MCWP-3-37.3/NTTP-3-11.26/AFTTP(I)-3-2.60)

## Systems are configured to deliver decon treatments from three M26s through two nozzles mounted inside the IDTES chamber

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## Equipment performance is characterized before and after integration with IDTES

- Performance tests are conducted to characterize key parameters of fielded systems and verify that system integration with IDTES accurately reproduces field performance metrics and desired surface coverage

Spray Force

Spray Span and Pressure

Flow Rate

12

## IDTES sprayer system sweep speed control settings are determined using treatment system integration test results

- Range of acceptable combinations of speed settings and number of sweep passes are identified for each decontamination treatment process

| Equipment Configuration | Speed Setting | Avg. Coverage per Full Sweep (mL/m$^2$) | Target Coverage for Surfaces (mL/m$^2$) | Full Sweeps | Coverage (mL/m$^2$) |
|---|---|---|---|---|---|
| Prewash Treatment and Rinse Treatment | | | | | |
| Single Lance | 20 | 1480 | 2000-2200 | 2 | **2960** |
| | 30 | 1125 | | 2 | 2250 |
| | 50 | 655 | | 3 | 1965 |
| | **60** | **540** | | **4** | **2160** |
| Decon Treatment - Single Application | | | | | |
| Lance w/ Bypass Hose | 20 | 323 | 500-600 | 2 | 646 |
| | 30 | 241 | | 2 | 482 |
| | 40 | 199 | | 3 | 597 |
| | **50** | **140** | | **4** | **560** |
| Decon Treatment - Double Application | | | | | |
| Lance w/ Bypass Hose | 20 | 323 | 250-300 | 1 | 323 |
| | 30 | 241 | | 1 | 241 |
| | 40 | 199 | | 1 / 2 | **199 / 398** |
| | **50** | **140** | | **2** | **280** |

- Speed/Sweep Combinations in Black provide acceptable coverage. Combinations in Red provide unacceptable coverage.
- Speed/Sweep combinations in Green provide optimum coverage and are selected for use in the Test Event.

- Additional tests are performed at optimum settings to confirm process parameters to be used for treatment of test articles inside the IDTES

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## Contamination and decontamination treatment processes are performed inside IDTES exposure chamber

Preconditioning test articles

Prewash treatment (4 passes)

Applying VX contamination to test articles

Decon treatment (2 passes - one of two applications)

14

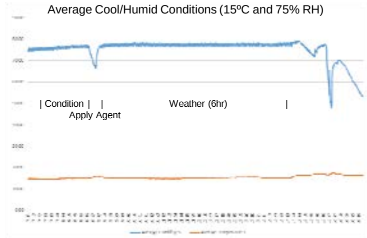
## Test events, environmental conditions, and observations were recorded during each trial

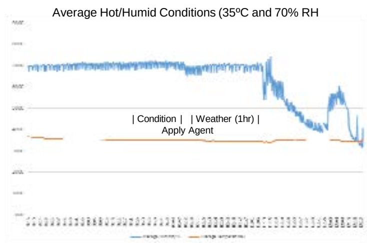
Treatment Schedules for JGPD-HME Test Event

- 1-Hr / 6-Hr Agent Age Time
- 0515 / ----- Prepare Delay Use (5-6Hr) Decon
- 0815 / 0745 Precondition in IDTES
- 0915 / 0845 Contaminate with CA
- ------ / 0945 Prepare Delay Use (5-6Hr) Decon
- 1000 / 1430 Prepare Fresh Use (0-1Hr) Decon
- 1015 / 1445 Apply Prewash (HW or CW)
- 1030 / 1500 Apply 1st Decon
- 1045 / 1515 Apply 2nd Decon
- 1100 / 1530 Apply Rinse (CW)
- 1115 / 1545 Remove Test Articles from IDTES
- 1130 / 1600 Initiate Contact Test or Vapor Test

Observations

- Agent interaction with material when applied
- Agent interaction with material after aging
- Decon interaction with agent and material
- Presence / absence of water after drying

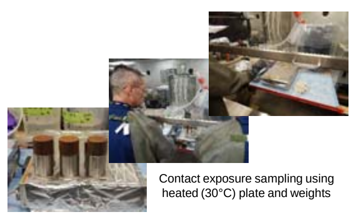


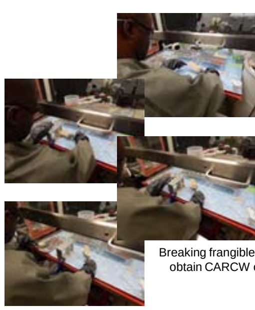



## Sampling processes for Contact Exposure Test and Vapor Emissions Test are performed in lab hoods adjacent to IDTES

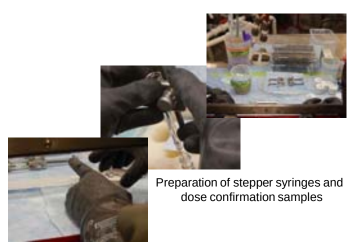
Small Item Vapor (SIV) Chamber and test cells for vapor emissions testing



Contact exposure sampling using heated (30°C) plate and weights



Breaking frangible panels to obtain CARCW coupons

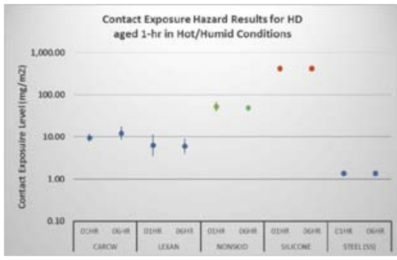


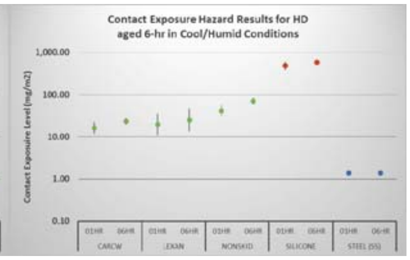
Preparation of stepper syringes and dose confirmation samples

## Decontamination Efficacy Comparisons for HD in JGPD-HME

***(Higher = Better)***

- Materials: STEEL > CARCW & LEXAN > NONSKID > SILICONE
- Exposure Environment: Hot/Humid > Cool/Humid
- Agent Age Time: Evaluation requires additional data
- Decon Age Time: 1-Hour = 6-Hour (no degradation)




Each set of results represent Geomean with Upper and Lower 90% Confidence Interval for eight samples

Green = <100 mg/m$^2$ Blue = <15 mg/m$^2$



## Chemical efficacy test is designed to evaluate field equipment, hazard mitigation processes, and products with contamination

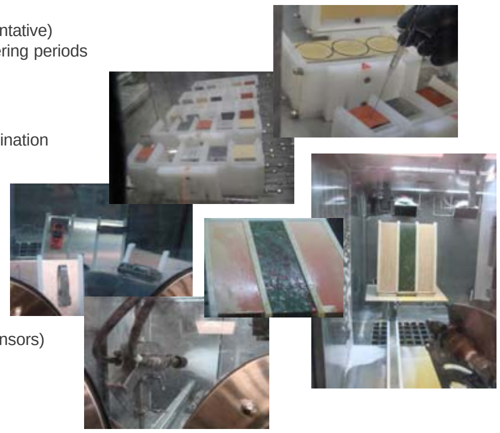
- Scenario: Decontamination and restoration of indoor spaces

Decontamination protocols and process sequences are replicated and tested safely with highly toxic chemicals inside the IDTES using actual field apparatus and decon products

- Scenario: Decontamination and recovery of transportation infrastructure

## Summary – IDTES enables system-level evaluation of methods, equipment, and products used for mitigation of chemical hazards

- Preconditioning and Weathering
  - Indoor conditions (Ambient)
  - Outdoor conditions (Representative)
  - Fate during extended weathering periods
- Contamination
  - Liquid agent droplets
  - Stepper syringe dispensers
  - Full or partial surface contamination
- Decontamination
  - Decon wipes (hasty)
  - Water prewash (hot or cold)
  - Liquid decon spray
  - Brush scrubs
  - Water rinse
- Qualitative Assessments
  - Visual observations
  - Field indicators (sprays or sensors)
- Quantitative Evaluation Methods
  - Contact exposure test
  - Vapor emission test
  - Contaminant residue test



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# Surface Decontamination for Blister Agents Lewisite, Sulfur Mustard and Agent Yellow

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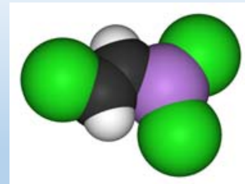
2015 US EPA International Decontamination R&D Conference, May 5-7, 2015

## Disclaimer

- *These are preliminary data that have not been through a full quality assurance review.*
- Questions concerning this presentation or its application should be addressed to Lukas Oudejans, National Homeland Security Research Center, Office of Research and Development, U.S. Environmental Protection Agency (EPA), 109 TW Alexander Dr., Research Triangle Park, NC 27711, 919-541-2973.

DISCLAIMER: The U.S. Environmental Protection Agency, through its Office of Research and Development, funded and managed this investigation through Contract No. EP-C-11-038 Task Order 0007 and EP-C-10-001 Work Assignments 4-28 and 5-28 with Battelle. This document has been subjected to the Agency's review and has been approved for presentation. Note that approval does not signify that the contents necessarily reflect the views of the Agency. Mention of trade names or commercial products, or services does not constitute EPA approval, endorsement or recommendation for use.

# Outline of Presentation



- Background
- Objectives
- Experimental Methods
- Results
- Discussion / Conclusions

# Background 1

- ➢U.S. EPA was assigned homeland security responsibilities.
  - ➢Responsible to help communities prepare for and recover from disasters including acts of terrorism
    - ➢Protect water systems
    - ➢Lead remediation of contaminated areas (indoor, outdoor, water infrastructure)
- ➢The Homeland Security Research Program (HSRP) was established to fill gaps that were identified during EPA's responses to incidents through scientific research.
- ➢One of the goals is identifying methods and equipment that can be used for decontamination following a terrorist attack using CBRN agents.

# Background 2

- Limited data exist on decontamination approaches that neutralize vesicant properties of Lewisite or chemical agent mixtures containing Lewisite.

- Research presented here investigated several decontaminants on their ability to decontaminate building materials contaminated with sulfur mustard (HD), Lewisite (L), and agent yellow (HL, a mixture of L and HD).

# Background on targeted chemicals & decon:

- Sulfur mustard (HD) is a vesicant (blister) chemical warfare agent.
  - Actually used in chemical warfare (WW I, Iraq/Iran war, Iraq)
- Lewisite (L) is an arsenical vesicant chemical warfare agent.
  - Stockpiled by several governments
- Agent yellow (HL) is the eutectic mixture (1:1 by volume) of HD and L 1.
  - Was prepared and stockpiled as "yellow shells" by Japanese in World War II
- Decontamination/neutralization data, including data on removal of residual arsenic, are lacking.
  - Decontamination data for L limited to military studies
  - Decontamination data for HD more readily available
  - No decontamination information exists for HL

# Objectives of this Study

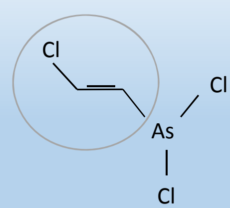
- Determine efficacy of several decontaminants applied to nonporous building materials.
  - Apply to surfaces contaminated with HD, L and HL
  - Semi-quantitative analysis to determine whether toxic byproducts are formed
- Determine whether efficacy of decontaminants applied to surfaces contaminated with a mixture of blister agents (HL) can be predicted based on the performance of these products against the individual components (HD and L) of the mixture.

# Chemicals

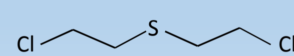
Lewisite (L)

Lewisite (L1) $C_2H_2AsCl_3$ ↔ Lewisite 3 (L3) $C_6H_6AsCl_3$ ↔ Lewisite 2 (L2) $C_4H_2AsCl_3$

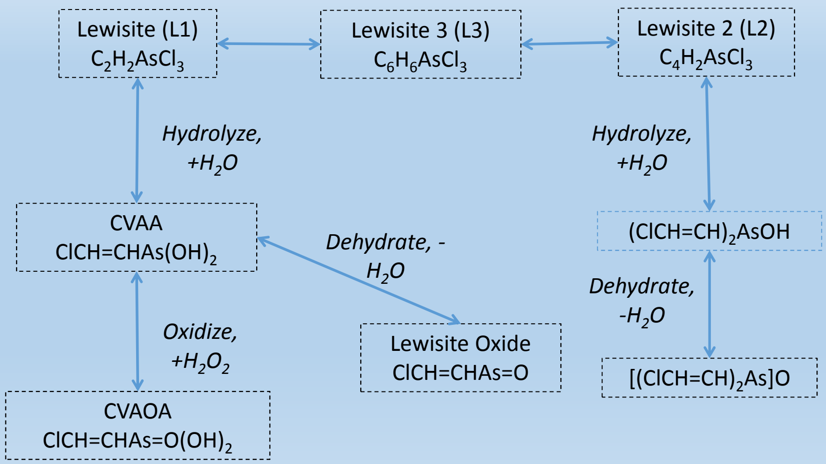
90% 1% 9%




Sulfur Mustard (HD)



# Common Known Degradation Byproducts of L



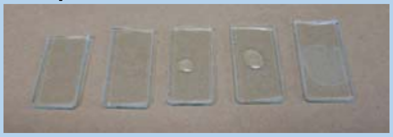

# Experimental Approach / Methods I

- Bench scale study of the decontamination of building materials using four decontaminants
- Materials: wood, metal, glass, and sealed concrete
- Decontamination solutions:
  - household bleach, full strength
  - household bleach, 10 fold diluted;
  - hydrogen peroxide 3% solution;
  - EasyDECON® DF200
- Extraction of coupons to quantify residual agent
- Analyze for agent (HD and Lewisite)
  - Requires analytical methods for HD and L
  - Preference to analyze both in same experimental run
- Look for byproducts of relevance

## Experimental Approach / Methods II

t= 0 min: Apply Agent to Test Coupons and Positive Controls (1 µL drop per coupon); start of weathering

t= 30 min: Apply Decontaminant to Test Coupons



t= 60 (or 90) min:

Extract all Coupons in Hexane Solvent

10 min sonication followed by transfer of aliquot to GC vial (with derivatization agent) for analysis

## Analytical Methods to Quantify Chemical Agents

- Detection of HD by conventional GC/MS is relatively straightforward.
- Detection of L is more complicated:
    1. Lewisite itself is a mixture of three vesicant agents: L1, L2, L3
    2. Direct injection of L onto GC column does not work (due to reactive nature of Lewisite)
    3. Cool on-column injection: Works but still requires frequent change of injection plunger
    4. Derivatization (w. butanethiol) of L is possible. This results in analysis of derivatized products for L-1 and L-2 (defined as der-L1, and der-L2)
    5. This approach cannot separate L1 from its hydrolysis product CVAA (similarly, der-L2 consists of L2 and its hydrolysis product)
    6. Since L-1 and CVAA are both vesicant, getting results for both is advantageous

- Note: Work in progress by NHSRC to use LC-MS/MS for detection of Lewisite (measurement of Lewisite oxide end product)

# Efficacy Definitions / Calculations

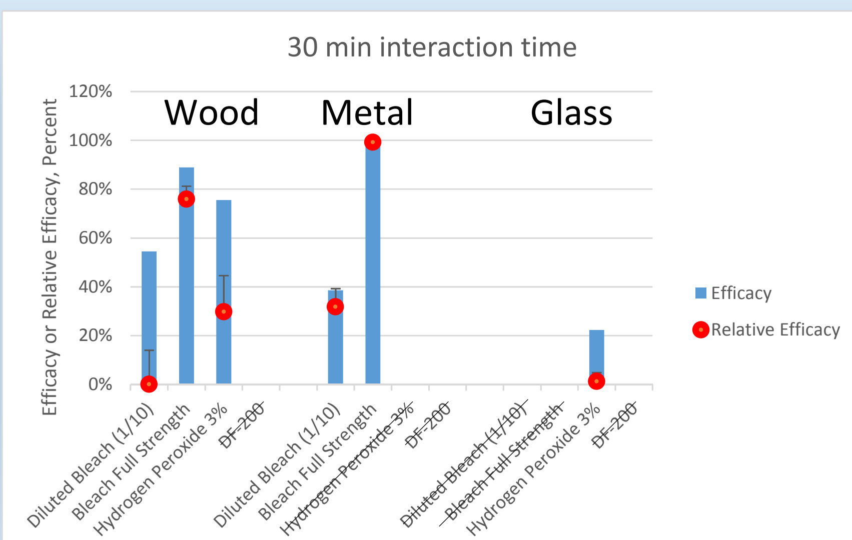
- Amounts recovered from spike controls, test coupons, and positive controls are used to calculate efficacy and relative efficacy.
  - **Efficacy**: % decrease of test coupon amount ($M_{TC}$) compared to amount applied ($M_a$):

$$\mathbf{Efficacy} = 100 \times \frac{\overline{M}_a - \overline{M}_{TC}}{\overline{M}_a}$$

  - This value includes losses due to e.g., evaporation which can be significant
  - **Relative Efficacy**: % decrease of test coupon amount ($M_{TC}$) compared to positive control amount ($M_{PC}$):

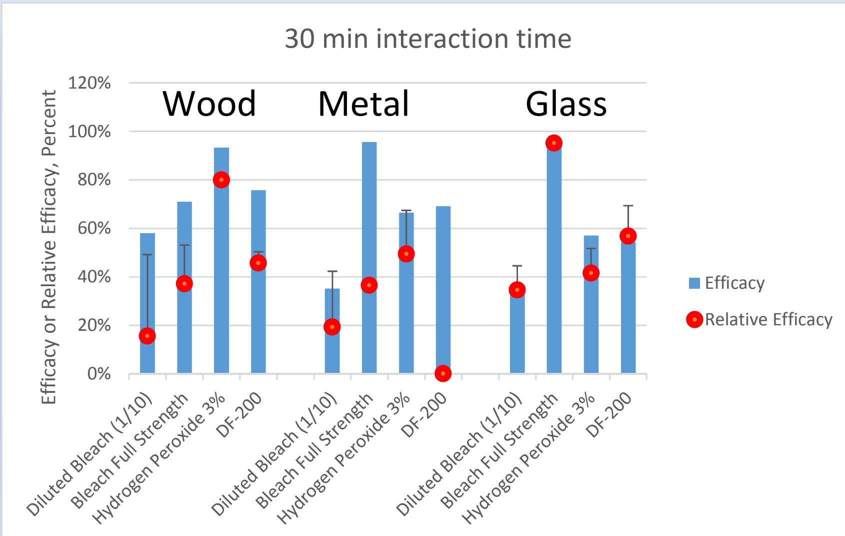
$$\mathbf{Relative\ Efficacy} = 100 \times \frac{\overline{M}_{PC} - M_{TC}}{\overline{M}_{PC}}$$

# Decontamination Results 1: Sulfur Mustard



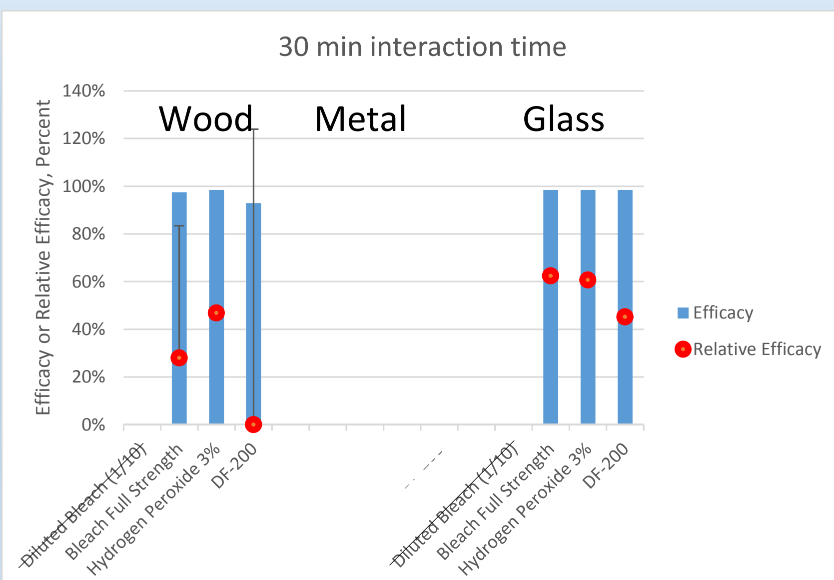

- Data is compilation of EPA data (2011) limited to wood, metal, and glass, and current study.
- Not all combinations of material and decontaminant were tested for HD.
- Bleach (Full Strength) is more efficacious than diluted Bleach.
- Hydrogen peroxide solution (3%) is not highly efficacious.

# Decon Results 2: Agent Yellow (HL); HD



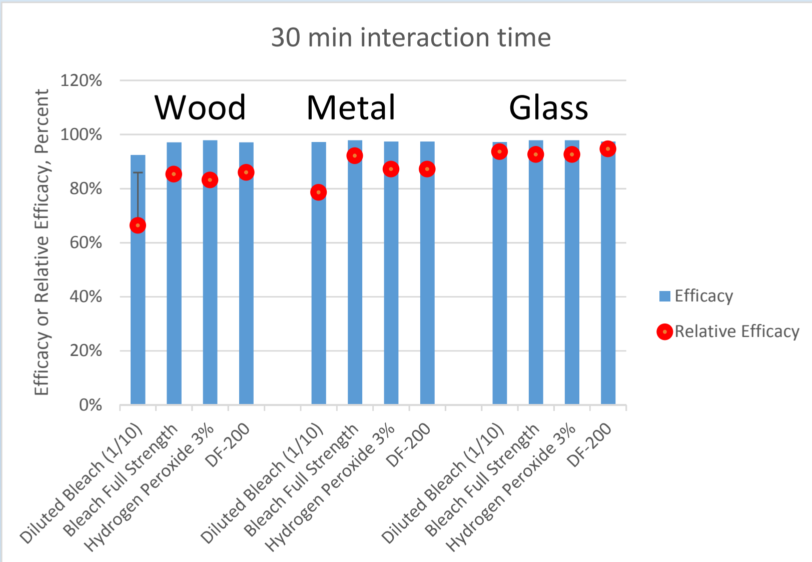

- Bleach (full strength) is more efficacious than diluted bleach.
- Not shown, relative efficacy improves appreciably for 60 min interaction with hydrogen peroxide.
- Hydrogen peroxide (3%) is efficacious when applied to decon wood; less for metal and glass.
- Vesicant HD decon byproduct (mustard sulfone) observed following decon with hydrogen peroxide (3%).

# Decontamination Results 3: Lewisite



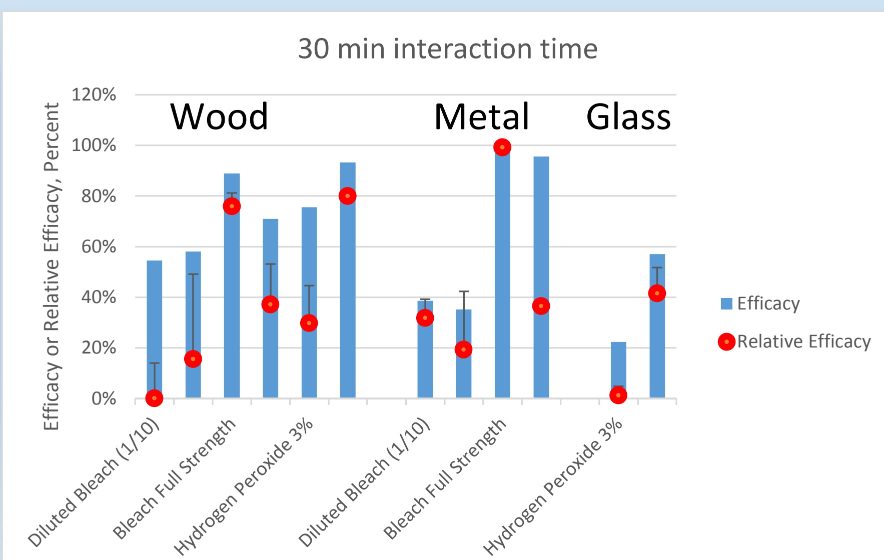

- Efficacy is >98% for three decontaminants on wood and glass (no metal data available).
- Dissipation of Lewisite (and hydrolysis of byproducts) is main driver of high efficacy.

# Decon Results 4: Agent Yellow (HL); L

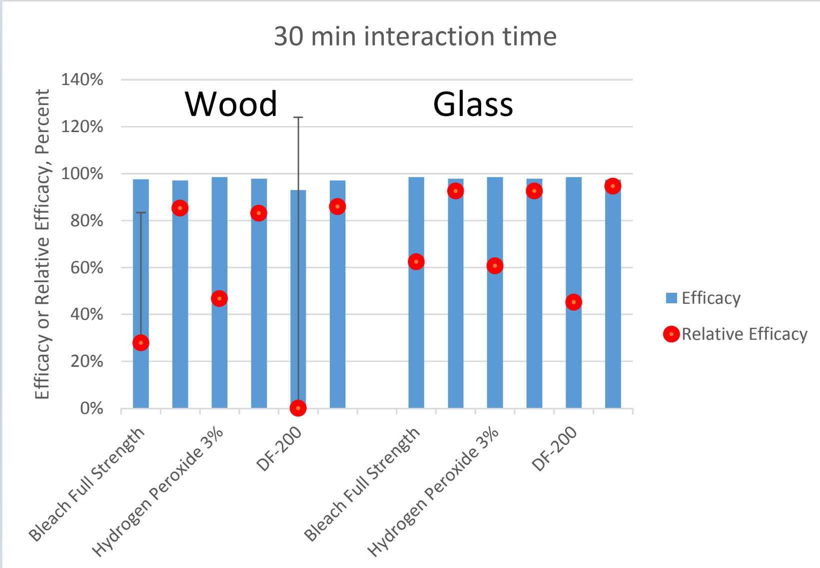



- High efficacy for all four decontaminants; bleach is more efficacious than diluted bleach.
- L hydrolyses in water; study does not decouple water efficacy from decontaminant efficacy.
- Vesicant properties may have been removed; arsenic containing decontamination (end-) products are present on coupons.

# Comparison Decontamination Results: HD as HD vs. HD as HL



# Comparison Decontamination Results: L as L vs. L as HL




# Analysis of Variance

- Agent, material, decontaminant: p-values ≤0.0001
- Contact time: p-value 0.87
- No difference in HD decontamination whether applied as HD or HL

| Contrast | p-value (Scheffe Adj) |
|---|---|
| HD v HL/H Glass HP3% 30M | 0.9981 |
| HD v HL/H Metal Bleach10% 30M | 1.0000 |
| HD v HL/H Metal Bleach10% 60M | 1.0000 |
| HD v HL/H Metal BleachFS 30M | 0.9999 |
| HD v HL/H Wood Bleach10% 30M | 1.0000 |
| HD v HL/H Wood Bleach10% 60M | 1.0000 |
| HD v HL/H Wood BleachFS% 30M | 0.9988 |
| HD v HL/H Wood HP3% 30M | 0.9778 |
| L v HL/L Glass BleachFS% 30M | 0.0066 |
| L v HL/L Glass DF200 30M | 0.0410 |
| L v HL/L Glass HP3% 30M | 0.0080 |
| L v HL/L Glass HP3% 60M | 0.0856 |
| L v HL/L Wood BleachFS 30M | 0.9058 |
| L v HL/L Wood DF200 30M | <0.0001 |
| L v HL/L Wood HP3% 30M | 1.0000 |
| L v HL/L Wood HP3% 60M | 1.0000 |

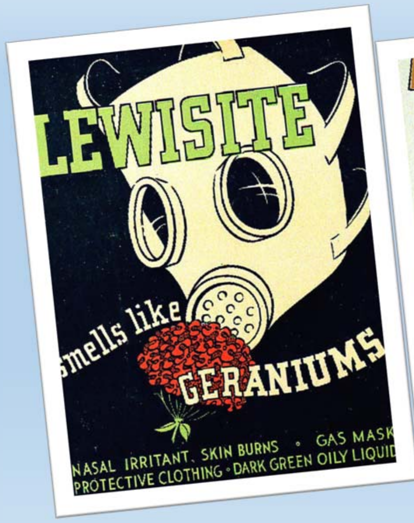
## Summary

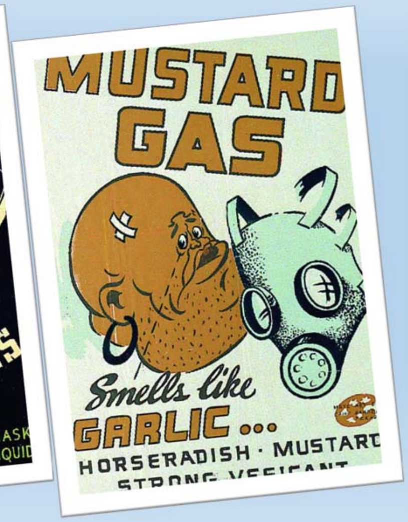
- Bleach (full strength), hydrogen peroxide (-containing products) are efficacious against L and its vesicant byproducts whether applied as L or HL.
- All four decontaminants reduced the amount of L recovered from coupons by >95% (relative efficacy differences lack practical significance).
- Non-vesicant arsenical compounds are end products of L decontamination.

## Summary (cont.)

- Application of dilute bleach showed little or no difference compared to natural attenuation in the amount of HD recovered from coupons.
- Full strength bleach was the most effective of the four decontaminants at reducing HD recoverable from coupons.
- Hydrogen peroxide 3% solution and DF200 did decrease the amount of HD recovered from coupons more than natural attenuation, but substantial HD remained on some material.
- Very low levels of toxic HD byproducts were generated by hydrogen peroxide treatment.
- ANOVA indicated no differences for decontamination of HD whether applied as HD or HL.

## Questions ?


LEWISITE
smells like
GERANIUMS
NASAL IRRITANT. SKIN BURNS • GAS MASK
PROTECTIVE CLOTHING • DARK GREEN OILY LIQUID


MUSTARD GAS
Smells like
GARLIC ...
HORSERADISH · MUSTARD

# 2015 U.S. EPA International Decontamination Research and Development Conference

## Thursday, May 7, 2015

## General Session 4

Decision Support Tools and Guidance Documents





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Sandia National Laboratories

# Estimating the Cost and Time for Recovery from WMD or FMD Events Under Resource Constraints

Robert Knowlton, Mark Tucker, Scott Olson, and Kurt Hollowell
Sandia National Laboratories

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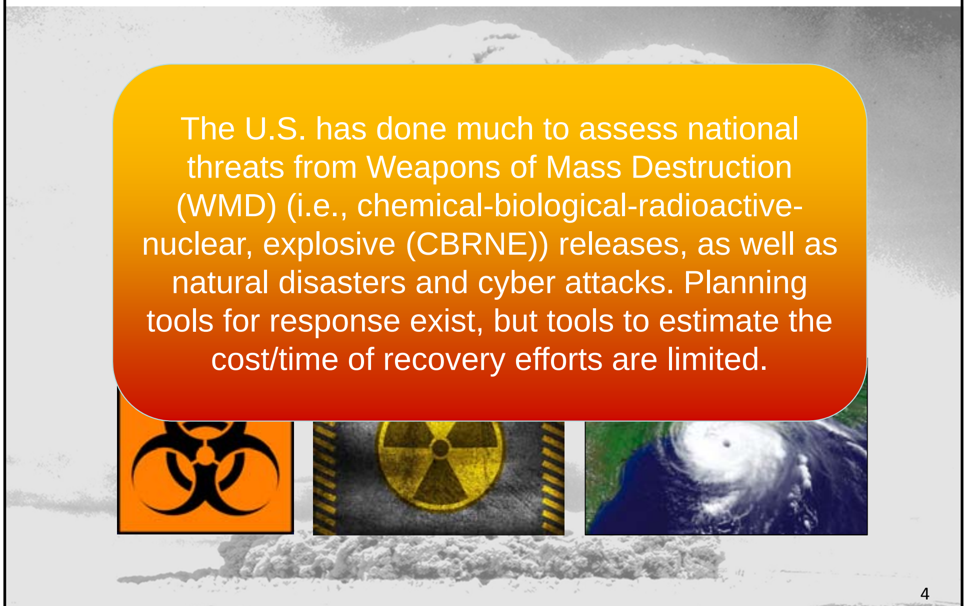
## Topics

- National Planning Scenarios
- PATH/AWARE Tool for WMD Recovery
- Resource Constraints
- Agricultural Security (AgSec) Module
- Future Plans




# National Planning Scenarios

- Scenario 1: Nuclear Detonation – 10-kiloton Improvised Nuclear Device
- Scenario 2: Biological Attack – Aerosol Anthrax
- Scenario 3: Biolog
- Scenario 4: Biol
- Scenario 5: Che
- Scenario 6: Che
- Scenario 7: Che
- Scenario 8: Che
- Scenario 9: Natu
- Scenario 10: Na
- Scenario 11: Ra
- Scenario 12: Explo ... plosive Devices
- Scenario 13: Biological Attack – Food Contamination
- Scenario 14: Biological Attack – Foreign Animal Disease (Foot-and-Mouth Disease)
- Scenario 15: Cyber Attack

5 Biological Scenarios
3 Chemical Scenarios
1 Radiological Scenario
1 Nuclear Scenario
1 Explosive Scenario
2 Natural Disaster Scenarios
1 Cyber Attack Scenario

aken from:
ttp://www.fema.gov/txt/media/f
ctsheets/2009/npd_natl_plan_
cenario.txt

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## In a wide area recovery event, multiple remediation strategies (and trade-offs) exist

- **Following a wide-area release:**
  - There will be a loss of functionality across many systems in multiple jurisdictions
  - Resources available to respond to and restore the area will be extremely limited
  - Time to complete restoration will be lengthy, possibly years
- **Decision makers will need to know:**
  - What resources are needed? Where do those resources get applied?
  - How long will the cleanup take? When will significant functions be restored?
  - Which assets have been contaminated? What functions have been impacted?
  - What are the interdependencies? How will these be factored into the restoration strategy?

Sandia National Laboratories has the capability to address these issues with several comprehensive decision support tools

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## PATH/AWARE for WMD Scenarios

- The Prioritization Analysis Tool for All-Hazards/Analyzer for Wide-Area Restoration Effectiveness (PATH/AWARE) was developed to address chem-bio-rad WMD scenarios
- PATH/AWARE is a comprehensive decision support tool, that has the following attributes:
  - A Geographical Information System (GIS) to manage spatial data
  - A comprehensive database to manage user scenario data, building density data, and critical infrastructure
  - The initial version of the tool was developed as a Windows desktop tool (i.e., thick client)
  - Recently the tool was converted to a web-based architecture (i.e., thin client) and is part of the Defense Threat Reduction Agency's (DTRA's) TaCBoaRD system

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## Zone Concepts in PATH/AWARE

- PATH/AWARE has a 2-tiered approach to zonation
  - Top level relates to the notional severity of the contamination
    - Red zone – highly contaminated
    - Yellow zone – less contaminated
    - Green zone – uncontaminated
  - Lower level (i.e., Remediation Unit [RU]) relates to the size of an area that would be remediated during a particular phase of recovery; the user can prioritize the order in which each RU is remediated

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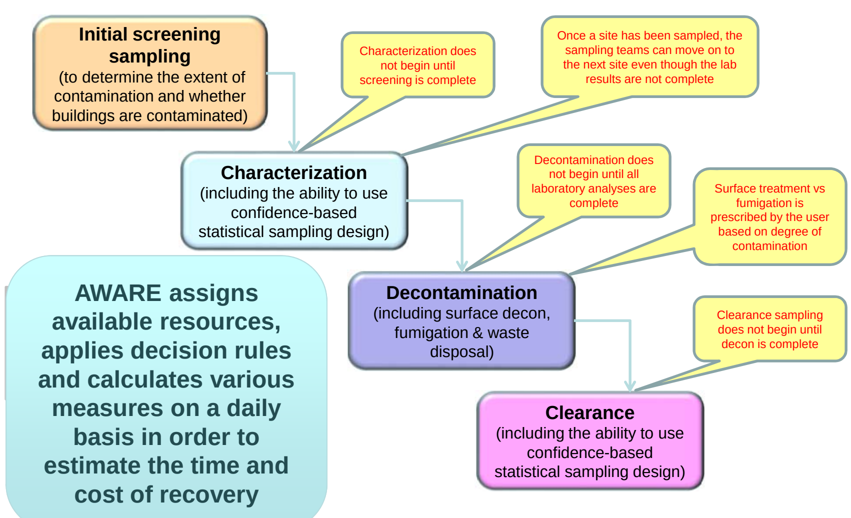
## Decision Rules in AWARE

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## PATH/AWARE Web-based Tool

- PATH/AWARE has 5 portlets to facilitate scenario analyses

- RU Tool – the Remediation Unit (RU) Tool allows the user to import spatial polygons (e.g., plume model results), to create RU polygons, to assign building densities.

- Asset Tool – the Asset Tool assembles the results of a Google search for critical infrastructure, allows the user to add assets, to calculate indoor areas of buildings, and to edit asset information

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## PATH/AWARE Web-based Tool

- PATH Tool - allows users to weight criteria for objectives and functions, to develop a prioritized list of the critical infrastructure to be remediated, while accounting for dependencies.

- AWARE Tool - allows users to input parameters for sampling, lab analysis, waste handling & disposal, decontamination options, and clearance sampling

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## PATH/AWARE Web-based Tool

- Analysis Tool - provides the results of the cost/time estimates in several formats:
  - Statistical summary of RU areas
  - Cost of recovery
  - Resource utilization on a daily basis
  - Resource utilization as a function of the overall effort
  - Schedule table
  - Schedule graphic

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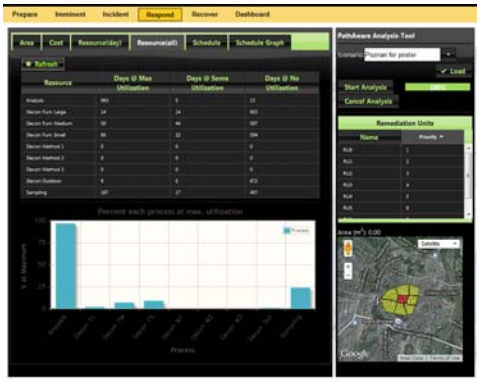
## Resource Constraints




- PATH/AWARE provides a summary of the percentage of time that critical resources are 100% utilized
- These parameters include:
  - Sampling teams
  - Lab throughput
  - Decontamination resources
- Typically, a scenario is developed with resources known to be readily available, then the results reviewed, and if utilization is an issue additional resources added, if available, to reduce chokepoints in the schedule

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## An outbreak of Foot and Mouth Disease (FMD) in livestock would be devastating

- **Historical outbreaks of livestock diseases have had significant impacts:**
  - In 2001, the UK had an FMD outbreak that resulted in the slaughter of over 4M livestock and caused over $6B in agricultural and food chain losses.
  - An FMD outbreak in Korea in 2010-2011 resulted in the slaughter of over 3M livestock and $2B in financial losses.
  - The occurrence of bovine spongiform encephalopathy (BSE) in a dairy cow in the US in 2003 resulted in over $3B in lost revenue due to export restrictions.
- **Following an FMD outbreak there will be tough decisions:**
  - Should vaccination be considered?
  - Should depopulation occur both in the infected zone and a buffer zone?
  - Several options exist for disposing of carcasses, which option, or options, are best, given time and resource constraints?



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## AgSec Module

- The Agricultural Security (AgSec) module within PATH/AWARE is also a web-based tool
- Information on FMD recovery was obtained from a variety of sources, including the US Department of Agriculture (USDA) Animal and Plant Health Inspection Service (APHIS) publication "*Foot-and-Mouth Disease Response Plan - The Red Book*"
- A set of requirements for the software were developed
- A spreadsheet application was developed that implements most of the logic for the tool to aid with the tool development and with code testing
- Reference data (e.g., cost of equipment rental, manpower rates, etc.) from the literature and the web have been documented for inclusion in the spreadsheet application and the AgSec module of PATH/AWARE

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## Key Components of the AgSec Module

- The modules that have been defined for the tool are:
  - Vaccination
  - Depopulation (including multiple options for euthanizing livestock such as captive bolt, gunshot, and injection)
  - Composting (including carbon source estimation)
  - Rendering (including transportation)

Captive Bolt

Composting

Carcass grinding

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## Key Components of the AgSec Module (continued)

- The modules that have been defined for the tool are:
  - Off-site Incineration (including transportation)
  - On-site Incineration (with portable air-curtain incinerators)
  - Off-site landfill burial (including transportation)
  - On-site trench burial
  - On-site Open Burning
- In addition, the AgSec module has a Disposal Decision Tree and check list, as well as a Decision Options Matrix to aid the decision maker

Commercial incinerator

Air curtain incinerator

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## AgSec Module Functionality

- The input parameters for developing cost/time estimates for disposal options are grouped as follows:
  - Personnel resources (e.g., veterinarian, laborer, loader operator, etc.)
  - Disposable supplies (e.g., PPE, syringes for vaccination, carbon source, etc.)
  - Equipment, purchases and rentals (e.g., loader, captive bolt, etc.)
  - Transportation options
  - Decontamination/disinfection
  - Processing rates
  - Disposal charges

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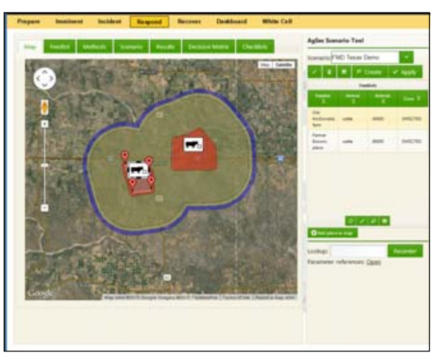
## AgSec Module Functionality (continued)



- The AgSec module has:
  - GIS spatial analysis capability
  - The ability to create feed lot polygons to represent the location and numbers of livestock infected, or suspected of being infected
  - The tool automatically generates buffer, vaccination, and surveillance zones around infected feed lots

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# AgSec Module Functionality (continued)

- The AgSec module has:
  - A database of locations for rendering facilities, incinerators, and landfills (largely taken from EPA's iWASTE tool)
  - The tool automatically calculates a straight-line distance between a feed lot and the disposal facility selected, to make it easier for the user to estimate transportation distances

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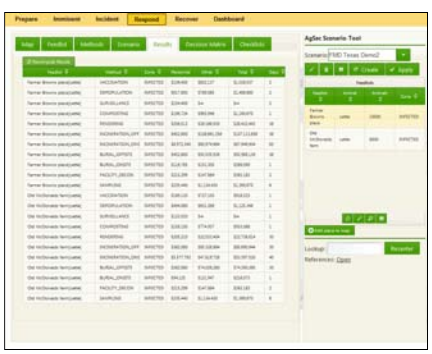
# AgSec Module Functionality (continued)



- The AgSec module has output results for each disposal option that summarize:
  - Personnel cost
  - Operations cost
  - Total cost
  - Time to complete
- If the cost or time are not acceptable due to resource constraints, the user iterates to a more desirable result
- Some States have rules about how quickly carcasses shall be disposed, and that may influence the selection of the disposal options

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## AgSec Module Functionality (continued)


- The AgSec module also has a Disposal Decision Tree and check list
- The software provides estimates of essential resources needed for the various disposal options (e.g., land needed for composting windrows, volume of carbon needed, etc.)
- The user is asked to supply available resources and the software computes a capacity estimate to determine if this is a viable option



## AgSec Module Functionality (continued)


- The AgSec module also has a Decision Options Matrix
- The Matrix provides a ranking of the various disposal options based on key criteria, such as:
  - Availability
  - Throughput
  - Volume reduction
  - Cost effectiveness
  - Public health risk
  - Public acceptance

# Future Plans

- Proposal in to the Department of Homeland Security (DHS) to add modules for the following:
  - A building demolition and disposal module that would aid with natural disaster and IND scenarios
  - A module for estimating the cost/time of rebuilding infrastructure
  - Modules to make PATH/AWARE an all-hazards analysis tool
    - Hurricanes
    - Floods
    - Earthquakes
    - IND

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# Acknowledgments


- We would like to thank the sponsors of this work, including:
  - The Department of Homeland Security, Office of Science and Technology, Chemical-Biological Directorate
  - The Department of Defense, Defense Threat Reduction Agency


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# WASTE ESTIMATION SUPPORT TOOL FOR DEVELOPING DECONTAMINATION AND WASTE MANAGEMENT STRATEGIES FOR WIDE-AREA RADIOLOGICAL INCIDENTS

United States Environmental Protection Agency


Paul Lemieux
US EPA, Office of Research and Development

Dan Schultheisz, Tom Peake
US EPA, Office of Radiation and Indoor Air

Colin Hayes, Tim Boe
Eastern Research Group
Morrisville, NC

2015 EPA International Decontamination Research and Development Conference

Office of Research and Development
National Homeland Security Research Center

United States Environmental Protection Agency

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Office of Research and Development
National Homeland Security Research Center

## Purpose

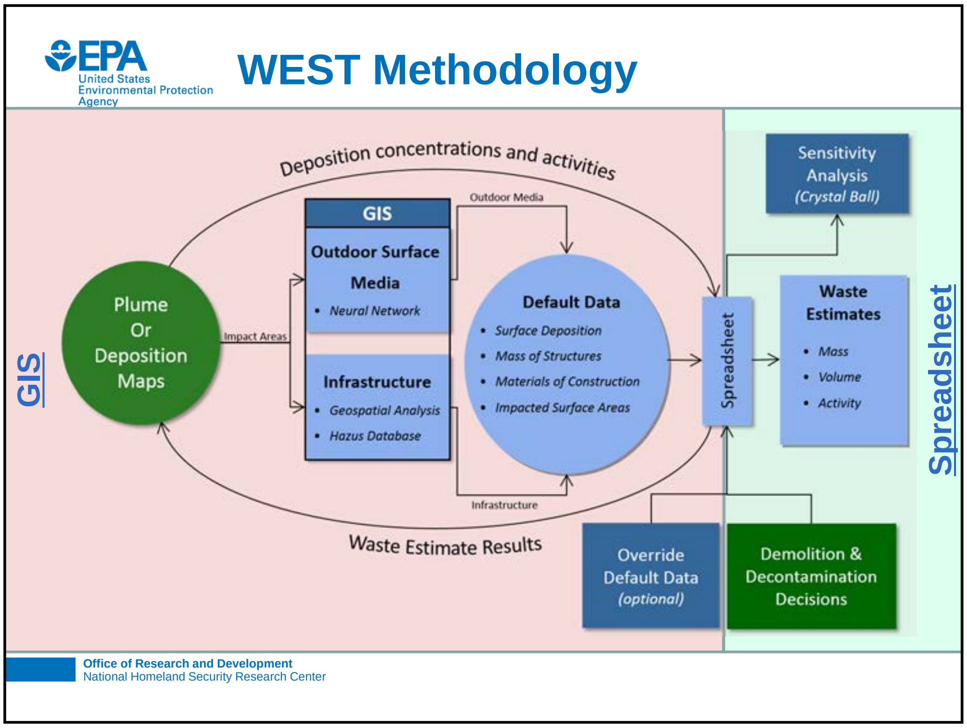
- **GIS-based tool that can assist in planning/preparedness activities at all levels of government**
  - Radiological Dispersal Device (RDD) waste management issues linked with decontamination and restoration timeline
  - Waste management decisions need to be made early
- **Waste Estimation Support Tool (WEST) Facilitates**
  - First-order estimate of waste quantity and activity
  - Pre-selection of disposal options
  - ID of potential triage/staging/storage within each zone or surrounding area
  - Assessment of impact of decontamination strategies on waste generation
  - Assessment of impact of waste management strategies on decontamination decisions
  - Identify resource limitations and response bottlenecks
  - Identify starting points for policy discussions

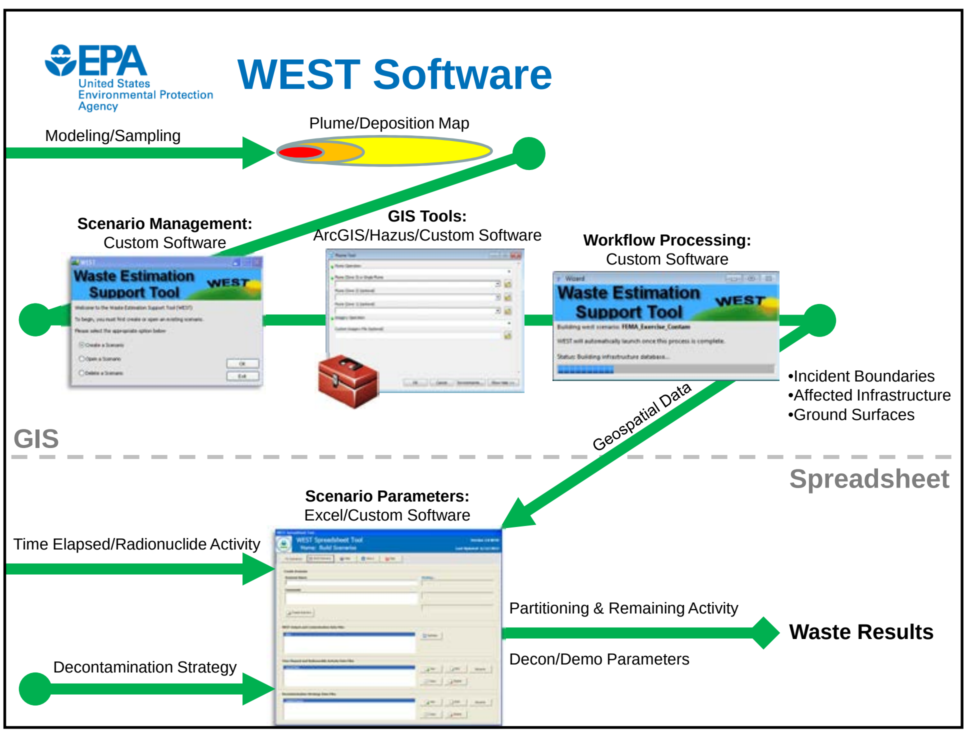
Office of Research and Development
National Homeland Security Research Center

## Adjustable Parameters

- **Demolition/decontamination decisions**
  - Default % for all buildings within each zone
  - Custom based on 28 user specific occupancy types (e.g., single family homes, industrial buildings, etc.)
- **% Distribution of decontamination technologies (includes solid/aqueous waste, removed material per unit area)**
  - Water Washing
  - Abrasive removal
  - Strippable coatings
  - 2 optional "generic" decontamination technologies
  - "No decontamination" option

Office of Research and Development
National Homeland Security Research Center


EPA
United States
Environmental Protection
Agency
WEST Methodology
GIS
Spreadsheet
Deposition concentrations and activities
Plume
Or
Deposition
Maps
Impact Areas
GIS
Outdoor Surface
Media
• Neural Network
Infrastructure
• Geospatial Analysis
• Hazus Database
Outdoor Media
Infrastructure
Default Data
• Surface Deposition
• Mass of Structures
• Materials of Construction
• Impacted Surface Areas
Spreadsheet
Sensitivity
Analysis
(Crystal Ball)
Waste
Estimates
• Mass
• Volume
• Activity
Waste Estimate Results
Override
Default Data
(optional)
Demolition &
Decontamination
Decisions
Office of Research and Development
National Homeland Security Research Center


EPA
United States
Environmental Protection
Agency
WEST Software
Modeling/Sampling
Plume/Deposition Map
Scenario Management:
Custom Software
GIS Tools:
ArcGIS/Hazus/Custom Software
Workflow Processing:
Custom Software
Waste Estimation
Support Tool
WEST
•Incident Boundaries
•Affected Infrastructure
•Ground Surfaces
Geospatial Data
GIS
Spreadsheet
Scenario Parameters:
Excel/Custom Software
Time Elapsed/Radionuclide Activity
Partitioning & Remaining Activity
Waste Results
Decon/Demo Parameters
Decontamination Strategy

United States Environmental Protection Agency

## GIS Demo


United States Environmental Protection Agency

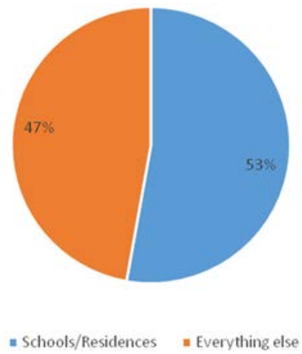
## WARRP Scenario

**Office of Research and Development**
National Homeland Security Research Center

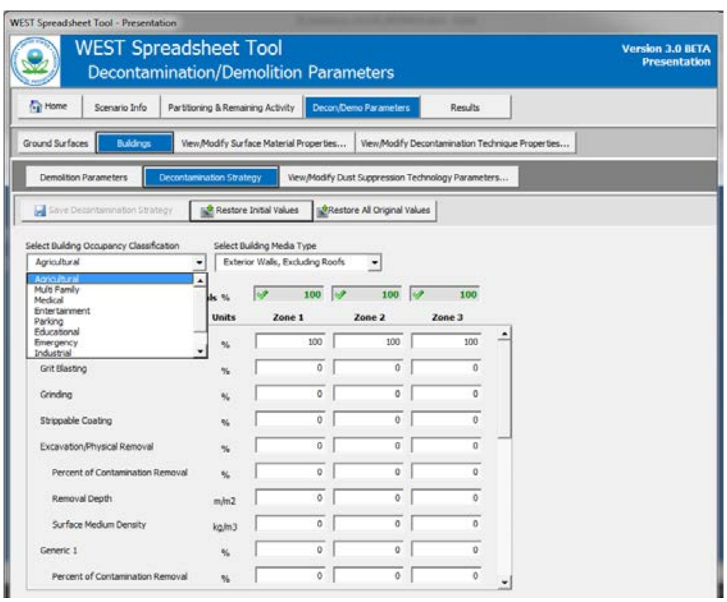
Wide Area Recovery and Resiliency Program (Denver Metro Area)

## Occupancy Type Distribution

- Target susceptible populations by specific infrastructure types (e.g., schools or residences)
- Potentially an important consideration for determining the most effective decontamination strategy
- Roughly half of infrastructure within the WARRP scenario consisted of schools and residences




## Example Input: Decon/ Demolition Parameters




C-566

## Demolition/Decon Assumptions: *Mostly Decon Approach*

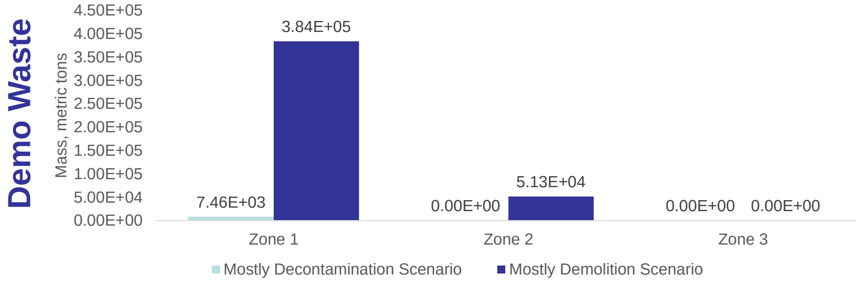
| Media | Zone 1 | Zone 2 | Zone 3 |
|---|---|---|---|
| | **Residences/education**<br>10 % demolition<br>90 % decontamination | **Residences/education**<br>0 % demolition<br>100 % decontamination | **Residences/education**<br>0 % demolition<br>100 % decontamination |
| | **Everything else**<br>0 % demolition<br>100 % decontamination | **Everything else**<br>0 % demolition<br>100 % decontamination | **Everything else**<br>0 % demolition<br>100 % decontamination |
| Asphalt | 2.5 cm removal – 50%<br>Wash – 50 % | 2.5 cm removal – 25 %<br>Wash – 75 % | 2.5 cm removal – 10 %<br>Wash – 90 % |
| Concrete | 2.5 cm removal – 50 %<br>Wash – 50 % | 2.5 cm removal – 25 %<br>Wash – 75 % | 2.5 cm removal – 10 %<br>Wash – 90 % |
| Soil | 15 cm removal – 100 % | 15 cm removal – 50 % | 15 cm removal – 25 % |
| External Walls | Wash – 100 % | Wash – 100 % | Wash – 100 % |
| Roofs | Wash – 100 % | Wash – 100 % | Wash – 100 % |
| Interior Walls | Wash – 100 % | Grinding – 50 %<br>Strippable Coating – 50 % | None |
| Floors | Mop – 100 % | Mop – 100 % | Mop – 100 % |

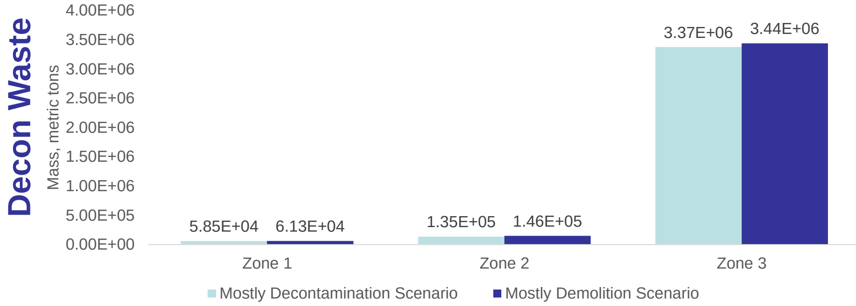
## Demolition/Decon Assumptions: *Mostly Demolition Approach*

| Media | Zone 1 | Zone 2 | Zone 3 |
|---|---|---|---|
| | **Residences/education**<br>100 % demolition<br>0 % decontamination | **Residences/education**<br>50 % demolition<br>50 % decontamination | **Residences/education**<br>0 % demolition<br>100 % decontamination |
| | **Everything else**<br>50 % demolition<br>50 % decontamination | **Everything else**<br>0 % demolition<br>100 % decontamination | **Everything else**<br>0 % demolition<br>100 % decontamination |
| Asphalt | 2.5 cm removal – 70 %<br>Wash – 30 % | 2.5 cm removal – 50 %<br>Wash – 50 % | 2.5 cm removal – 30 %<br>Wash – 70 % |
| Concrete | 2.5 cm removal – 70 %<br>Wash – 30 % | 2.5 cm removal – 50 %<br>Wash – 50 % | 2.5 cm removal – 30 %<br>Wash – 70 % |
| Soil | 15 cm removal – 100 % | 15 cm removal – 50 % | 15 cm removal – 25 % |
| External Walls | Wash – 100 % | Wash – 100 % | Wash – 50 % |
| Roofs | Wash – 100 % | Wash – 100 % | Wash – 50 % |
| Interior Walls | Wash – 100 % | Grinding – 50 %<br>Strippable Coating – 50 % | None |
| Floors | Mop – 100 % | Mop – 100 % | Mop – 100 % |

EPA United States Environmental Protection Agency

## Example of Demolition and Decon Waste from the WARRP Scenario

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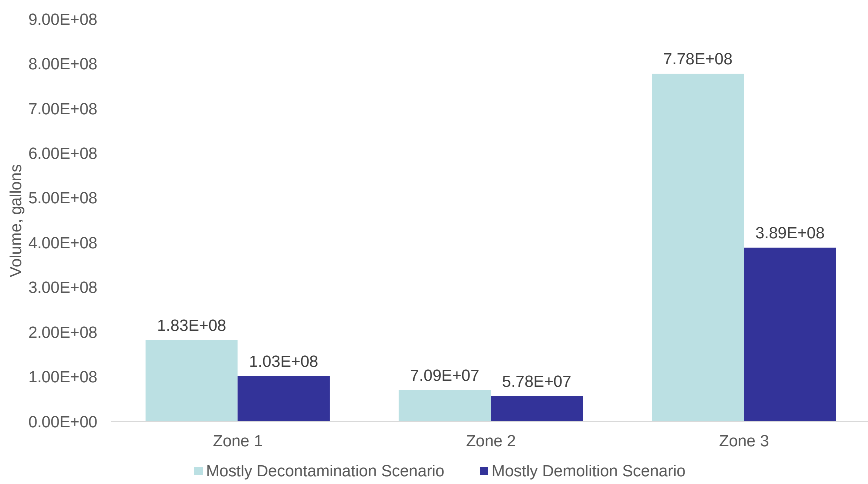
## Example of Liquid Waste from the WARRP scenario

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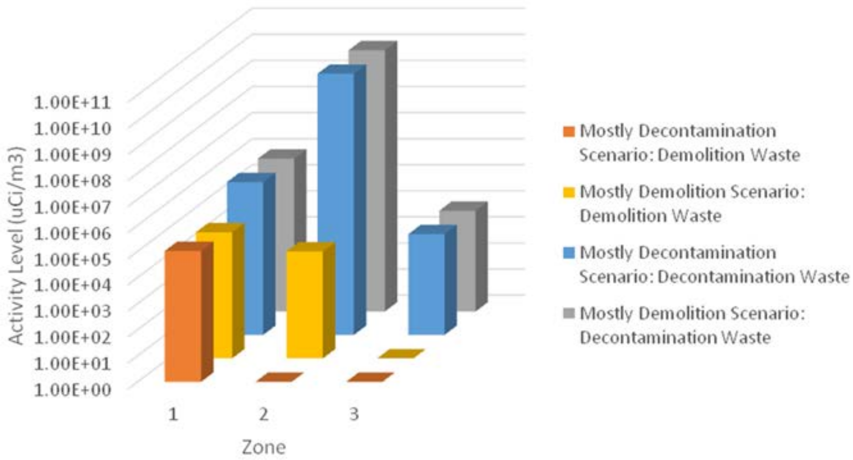
## Example Estimated Solid Waste Activity (µCi/m3)

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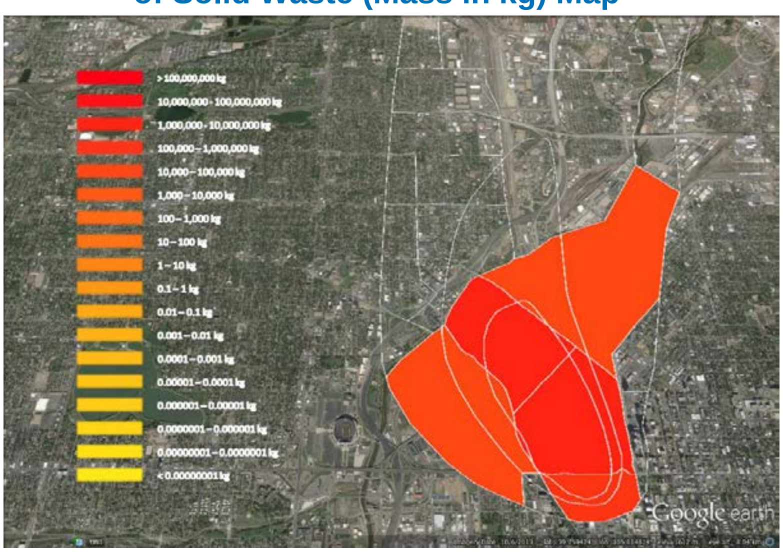
## Example Mostly Decon Scenario: Demolition of Solid Waste (Mass in kg) Map

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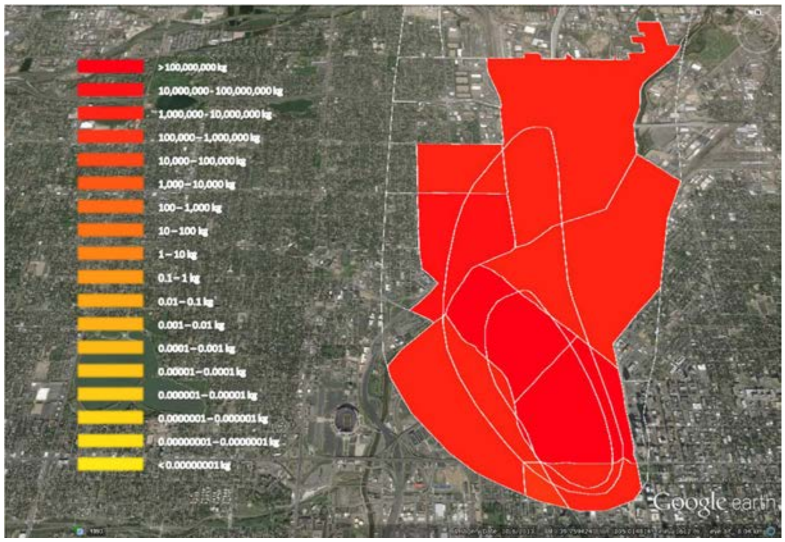
## Example Mostly Demolition Scenario: Demolition Solid Waste (Mass in kg) Map

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## Implications Identified by the Tool

- **Highlights benefits of considering waste and when selecting decontamination options**
- **Further define decontamination strategy based on infrastructure, time, & radionuclide activity**
- **Advantages of on-site treatment to reduce waste**
  - Soil is prime candidate for on-site treatment and waste minimization activities
- **Identifies starting point for policy discussions**
  - Use of conventional or haz. waste landfills for minimally-contaminated materials
  - Use of low-level radioactive waste disposal capacity for materials contaminated at higher levels

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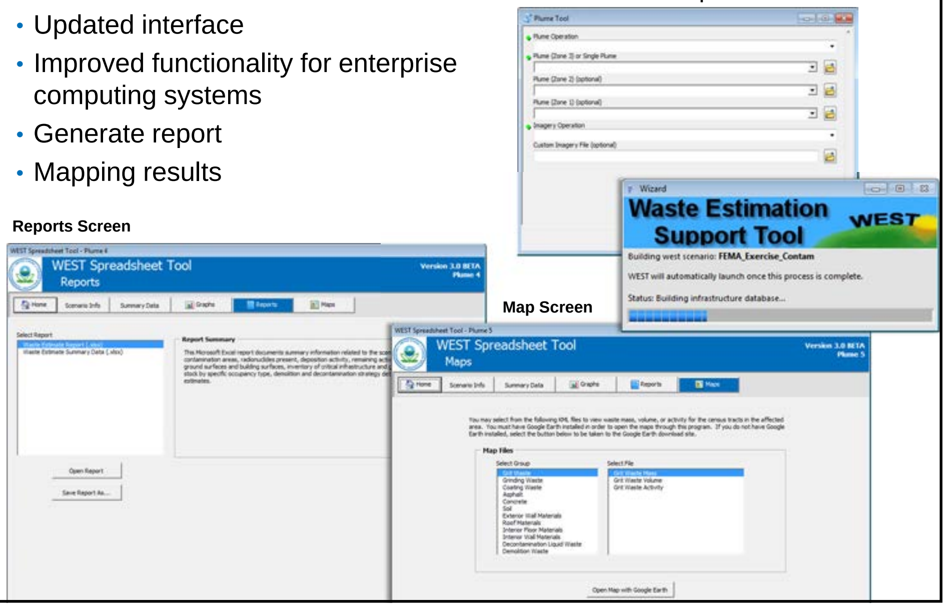
## WEST 3.0 (September '15)

- Updated interface
- Improved functionality for enterprise computing systems
- Generate report
- Mapping results

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## Future Plans

- **Short Term**
  - Biological support
  - Vehicle waste support
  - Hazus updates
- **Long Term**
  - Blast Debris Support (i.e., Improvised Nuclear Device)
  - Estimation of required resources (beginnings of cost estimation)
  - Additional waste factors
  - Documentation/training


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# Thank You

- **Contact Info:**

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# Developing Biological Operational Response and Recovery Guidance for Rapid Return to Service of Underground Transportation

**Presented: 2015 EPA International Decontamination R&D Conference**

Robert Fischer (LLNL), Scott Davison (SNL)
Ellen Raber, Dianne Gates-Anderson,
Hank Khan, Sav Mancieri
Lawrence Livermore National Laboratory

Lawrence Livermore National Laboratory
Sandia National Laboratories

May 7, 2015

LLNL-PRES-670194
This work was performed under the auspices of the U.S. Department of Energy by Lawrence Livermore National Laboratory under contract DE-AC52-07NA27344. Lawrence Livermore National Security, LLC

## A joint DHS-EPA project is underway to protect the Nation's Underground Transportation Systems

### Underground Transportation Restoration (UTR) Project Goals:

- **Deliver first comprehensive federal guidance to decrease time to return a subway system to service following a biological agent event**
- **Streamline process to map contamination levels and boundaries**
- **Field test efficacious, cost-effective, decontamination technologies, and isolation techniques for stations, tunnels, and rolling stock**
- **Improve sampling and analysis process for clearance, reducing burden on laboratory network performing sample analysis**
- **Exercise guidance with system operators and public health officials**

Translate what we know about 'clean' building recovery to a complex, 'harsh' environment

The challenge is to design a phased recovery plan that rapidly restores transit operations

## UTR Project Incorporates Technical Data with Transit Agency Needs into one Integrated Rapid Return to Service (RRS) Strategy

**Technical Data**

**Large Amounts of Technical Data Generated by Project Teams**
- Modeling
- Characterization
- Decontamination Technologies/Techniques
- Operational Technology Demonstrations
- Clearance

**User Group Needs**

**Response strategies must align and support the needs of two user groups (Transit and Responding agencies)**
- Safe and efficient shutdown of operations leveraging a rapid system restart
- Rapid system characterization to determine extent of impact
- Phased restart of transit system
- Integration of response community assets with transit operations to prioritize recovery efforts

**Return to Service Strategy**

**Technical Data, Response Strategies (Guidance), and User Group needs are then integrated into one Return to Service Strategy**
- Key decisions and actions
- Specific transit agency information
- Focus on restoring transit service in the shortest amount of time



## The project encompasses three major focus areas

**1. Identify Technologies to Expedite Timely Recovery**
- Characterization
- Decontamination
- Clearance

**2. Validate Technologies Through Field Demonstrations**
- Rolling Stock Decontamination
- Infrastructure Decontamination
- Rapid Characterization Techniques


**3. Rapid Return to Service Strategy**
- Integration of technologies
- National and Transit agency specific guidance
- Exercise guidance with transit agencies and response personnel

## LLNL is leveraging previously developed NYCT/MNR radiological response and recovery plans


- Phased return-to-service strategy (initial, interim and final) for critical operations
- System Isolation plans
- Infrastructure-specific decontamination plans
- Rolling stock characterization and recovery plans
- Guidance for waste management and minimization

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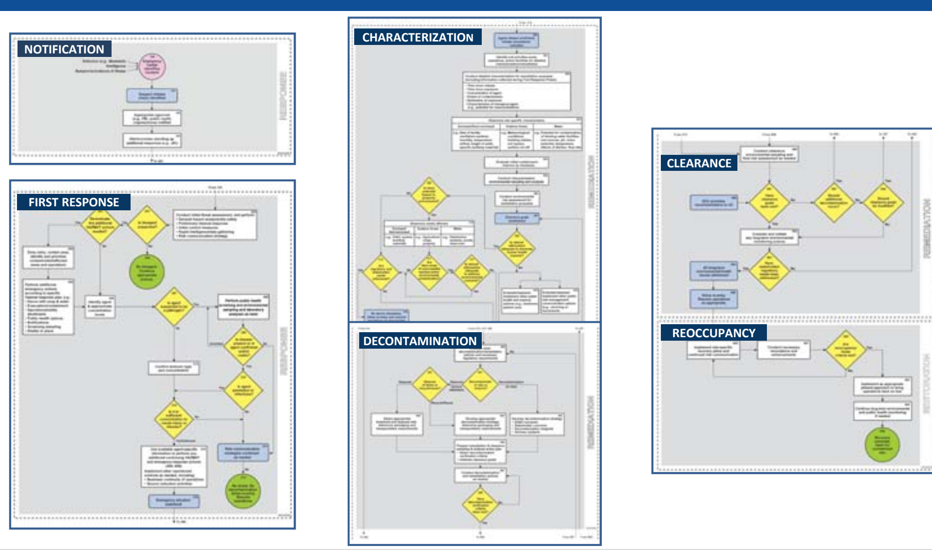
## The UTR decision process will be consistent with the six phase DHS-EPA interagency guidance (OSTP)

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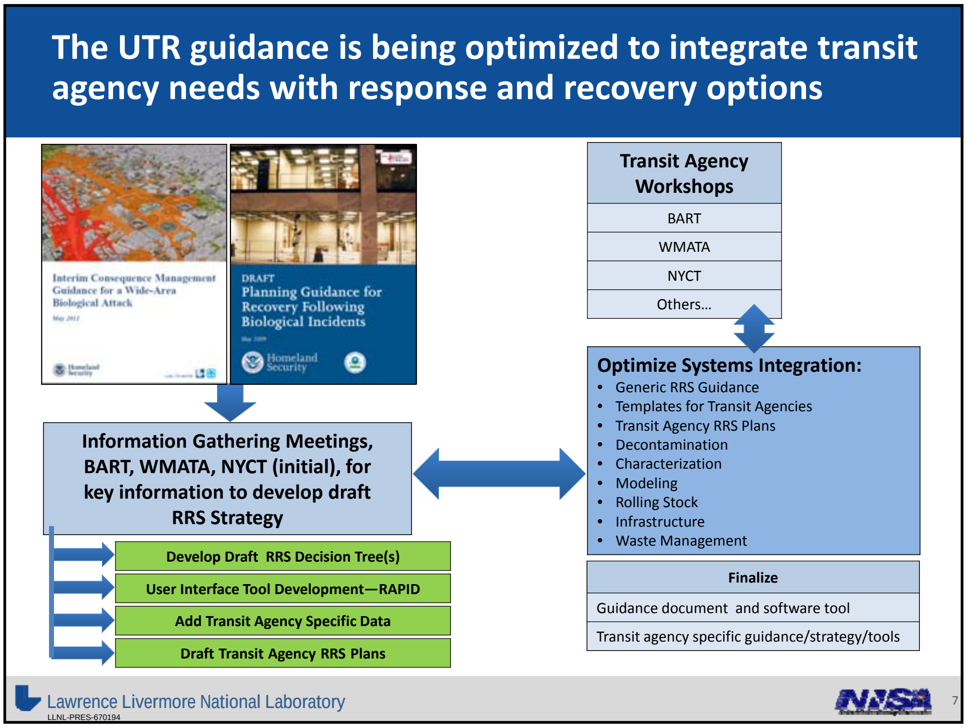
The UTR guidance is being optimized to integrate transit agency needs with response and recovery options
Interim Consequence Management Guidance for a Wide-Area Biological Attack
DRAFT
Planning Guidance for Recovery Following Biological Incidents
Homeland Security
Transit Agency Workshops
BART
WMATA
NYCT
Others…
Optimize Systems Integration:
• Generic RRS Guidance
• Templates for Transit Agencies
• Transit Agency RRS Plans
• Decontamination
• Characterization
• Modeling
• Rolling Stock
• Infrastructure
• Waste Management
Information Gathering Meetings, BART, WMATA, NYCT (initial), for key information to develop draft RRS Strategy
Develop Draft RRS Decision Tree(s)
User Interface Tool Development—RAPID
Add Transit Agency Specific Data
Draft Transit Agency RRS Plans
Finalize
Guidance document and software tool
Transit agency specific guidance/strategy/tools
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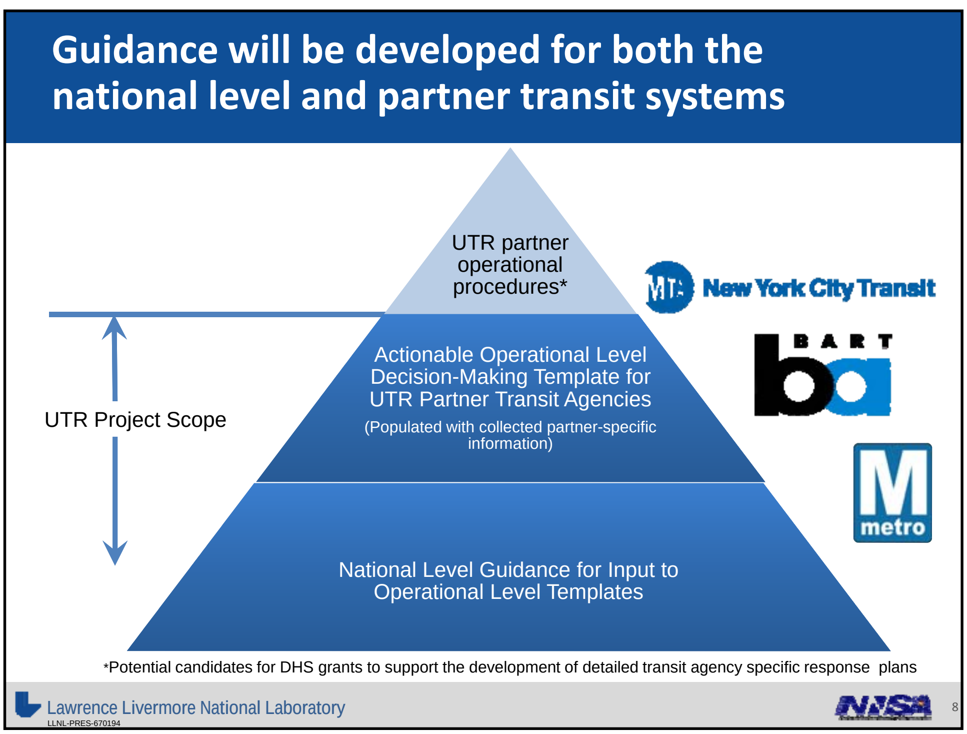
Guidance will be developed for both the national level and partner transit systems
UTR partner operational procedures*
Actionable Operational Level Decision-Making Template for UTR Partner Transit Agencies
(Populated with collected partner-specific information)
National Level Guidance for Input to Operational Level Templates
UTR Project Scope
New York City Transit
BART
metro
*Potential candidates for DHS grants to support the development of detailed transit agency specific response plans
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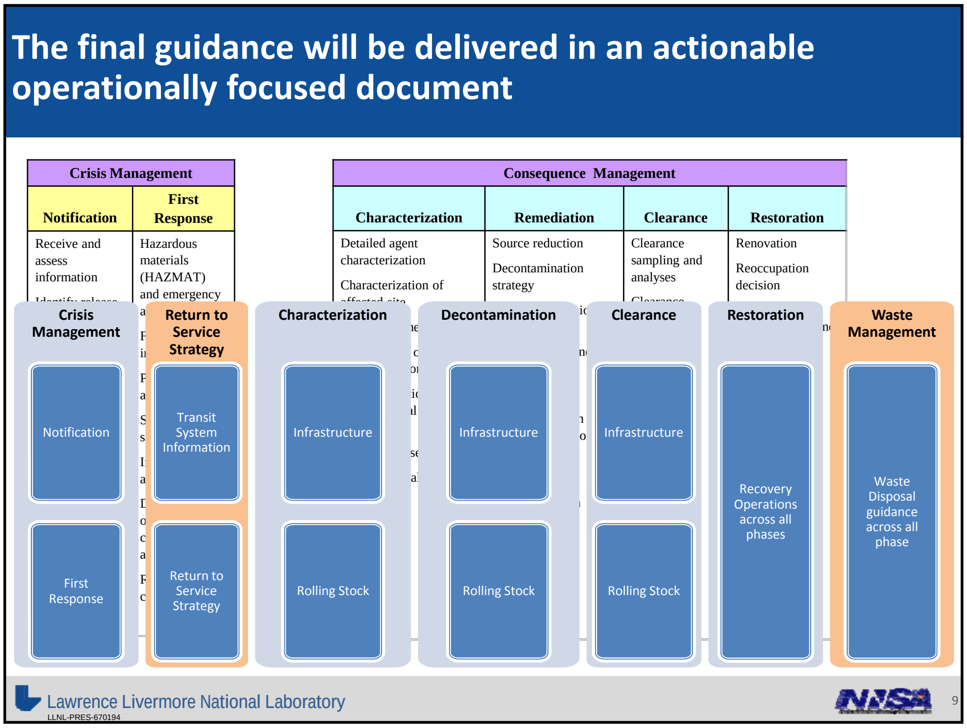
The final guidance will be delivered in an actionable operationally focused document
Crisis Management
Notification
First Response
Receive and assess information
Hazardous materials (HAZMAT) and emergency
Consequence Management
Characterization
Remediation
Clearance
Restoration
Detailed agent characterization
Characterization of
Source reduction
Decontamination strategy
Clearance sampling and analyses
Renovation
Reoccupation decision
Crisis Management
Notification
First Response
Return to Service Strategy
Transit System Information
Return to Service Strategy
Characterization
Infrastructure
Rolling Stock
Decontamination
Infrastructure
Rolling Stock
Clearance
Infrastructure
Rolling Stock
Restoration
Recovery Operations across all phases
Waste Management
Waste Disposal guidance across all phase
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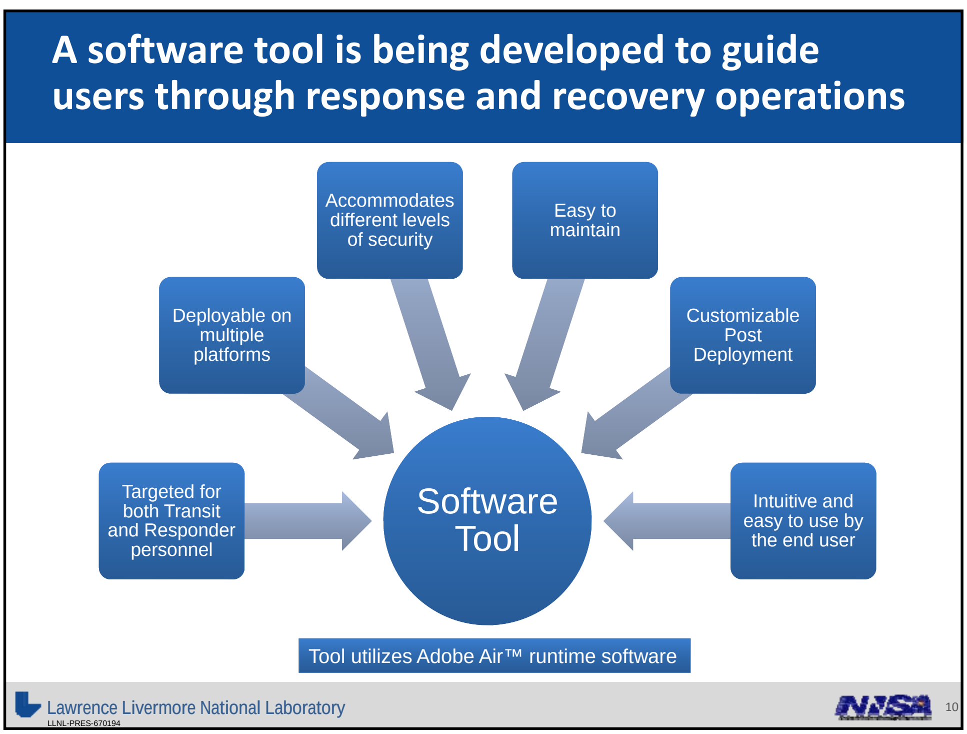
A software tool is being developed to guide users through response and recovery operations
Accommodates different levels of security
Easy to maintain
Deployable on multiple platforms
Customizable Post Deployment
Targeted for both Transit and Responder personnel
Software Tool
Intuitive and easy to use by the end user
Tool utilizes Adobe Air™ runtime software
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## Decision process incorporated into an interactive response architecture

**R**ecovery **A**ssessment **P**lanning and **I**ntegrated **D**ecision tool

**RAPID**

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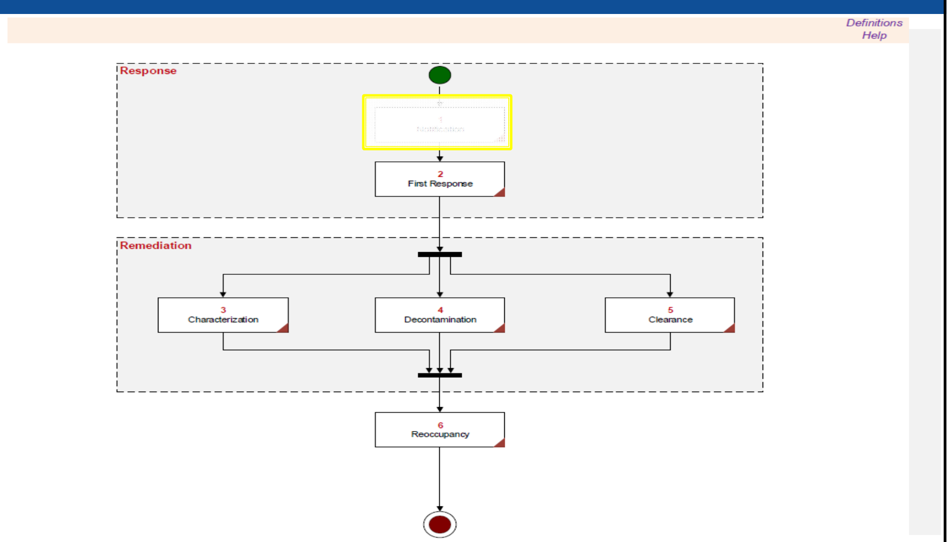
## Each response phase expands to more detail guiding the user through key actions steps

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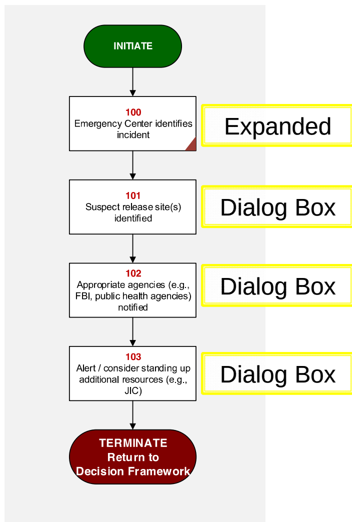
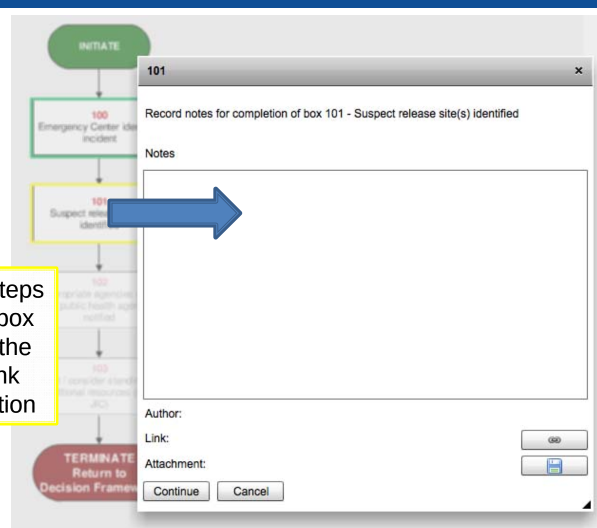
## Steps are expandable to allow additional levels of information to be provided to the user




- **Process step expansion options:**
  - Dialog Box
  - Decision Box
  - Additional expanded decision tree
  - Information Page
- **Ability to link to supporting and specific information and procedures**

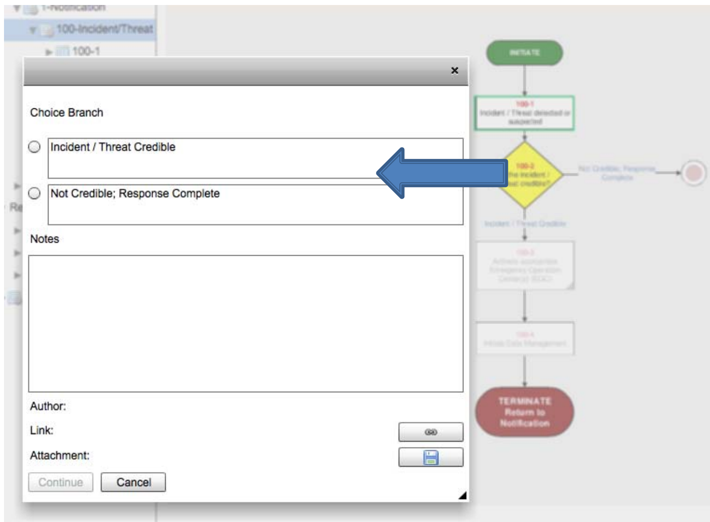


## Dialog boxes record details about actions and decisions taken during the recovery process



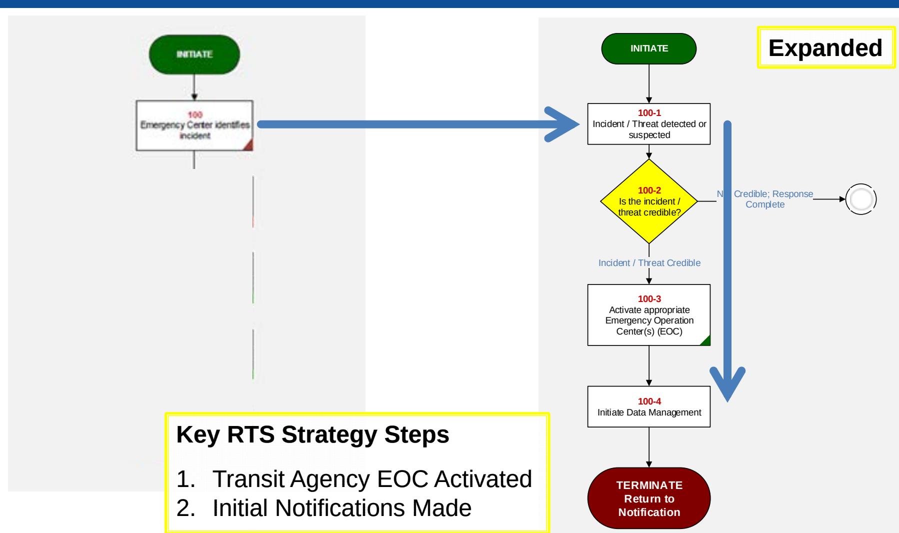

Single action process steps go directly to a dialog box to record notes about the action / decision or link supporting documentation

## Decision boxes record details about critical decisions made during the recovery process

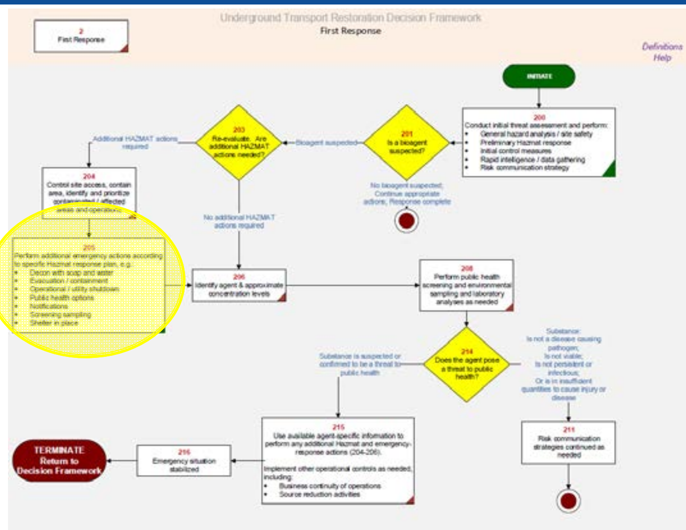





## Expansion of key steps allows for more detail and facilitates the incorporation of RRS strategy



## For steps that require additional guidance an Information Page is provided






## The Information page provides for additional expansion of guidance and identifies key actions in the form of a checklist

**UTR Decision Framework Information Page**

205 Perform additional emergency actions

**Perform Additional Emergency Actions**

**Expanded Description:**
Perform additional emergency actions according to specific hazmat response plan

**Additional Information:** *Document Link*

| Responsible Individual or Agencies | Key Actions/Decisions | Information/Data Required | Resources/Assets Needed | Supporting Information |
|---|---|---|---|---|
| Emergency Response org:<br>-Fire Department;<br>-Law Enforcement Agencies (includes transit agency law enforcement)<br>-Other response organizations i.e. EPA OSCs, Public Health Organization | ✔ Decontaminate individuals/ surfaces with soap and water, as needed<br>• Small amount of material<br>• Clearly defined contamination boundaries<br>• Readily accessible location<br>• Appropriate PPE and materials available | [redacted] | • Soap and water waste containers<br>• appropriate PPE for responding agencies<br>• Equipment and supplies for personnel decontamination | • Responding agency emergency procedures for biological response, decontamination, and evacuation (if any)<br>• Responding Agency Hazmat response plans |
| | ✔ Evaluate and implement early containment of suspected contamination area(s) as necessary<br>• Consider minimal wetting of area to prevent resuspension | • Locations of available sprinkler systems and/or water availability for key areas | [redacted] | |
| | ✔ Evaluate public health options and/or send individuals to local hospitals as needed | • Public health plans (health and safety; decontamination; evacuation)<br>• List of EMT ambulance providers<br>• List of hospitals in local area | • Ambulance and other health resources to evacuate affected personnel to local hospitals | • Public Health agency procedures for H&S, personnel decontamination, and evacuation to area hospitals |

## Transit agency actions are clearly delineated in a separate section of the information page

| Responsible Individual or Agencies | Key Actions/Decisions | Information/Data Required | Resources/Assets Needed: | Supporting Information: |
|---|---|---|---|---|
| Transit Agency | ☑ Continued support for estimation and containment of potentially contaminated area(s)<br>☑ Decision on potential station/platform shutdown | • Transit Agency Hazmat Response Plans/evacuation plans/ system shutdown plans<br>• List of emergency response and public health organizations | • Evacuation plans and procedures<br>• Emergency signs, yellow tape and cones<br>• Utility shutdown list (and locations) | • Transit Agency-specific evacuation/shutdown plans for underground and aboveground stations, railcars, tunnels/tubes, and utility systems<br>• Information regarding air flow and potential cross-contamination routes to minimize spread of material an allow for potential mitigation options.<br>• Possible containment/barrier strategies, if appropriate |
| | ☑ Train Control<br>• Stop or reroute trains | • Transit Agency Hazmat Response Plans/evacuation plans/ system shutdown plans | • Precautionary (or local) shutdown locations (entrances, gates, doors, etc.) | • Supporting plans and details as available. |
| | ☑ Initiate utilities mgt.<br>• Track power<br>• Ventilation systems | | | • List of critical Utility systems (that cannot be shutdown)<br>• Transit emergency operational plans |
| | ☑ Escort response personnel to incident site | | • Appropriate PPE as needed | |
| | ☑ Continued support for estimation and containment of potentially contaminated area(s) | | | |

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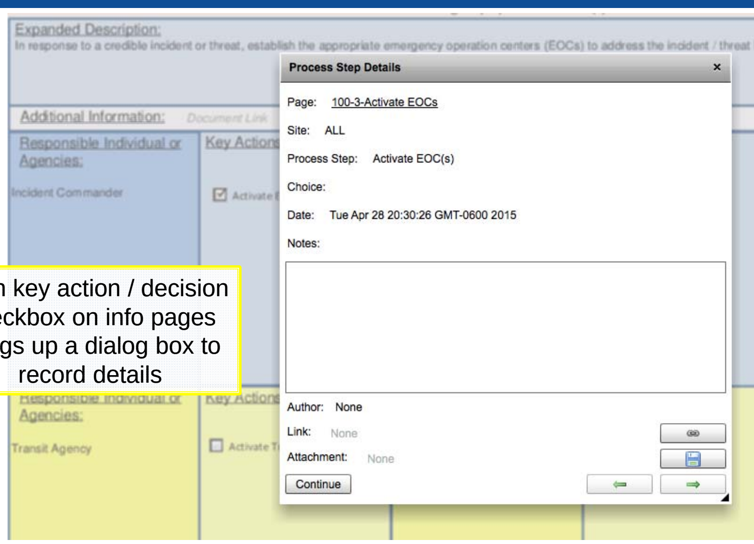
## Dialog boxes record details about actions and decisions taken during the recovery process




Each key action / decision checkbox on info pages brings up a dialog box to record details

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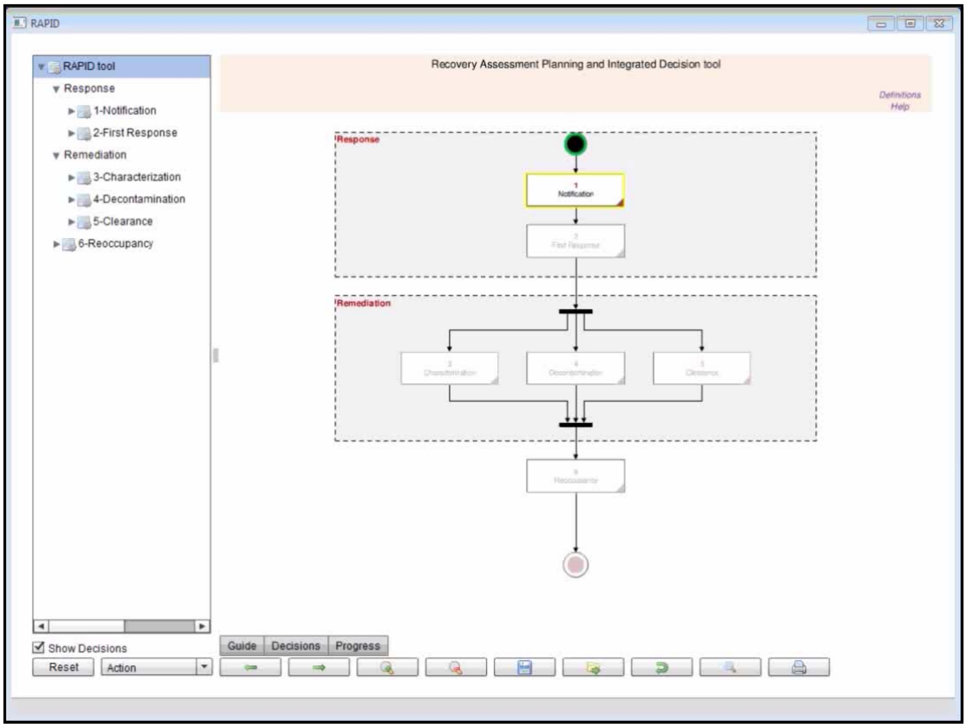


## Next steps

- Brief end-users and stakeholders to make sure planned format/information and content information is correct
- Check to ensure consistencies with other documents and guidance
- Brief transit agency partner(s) to get feedback an validate provided information/guidance
- We would like to achieve consensus by stakeholders before launching into full development of tool


**Thank you!!**

Contact Information

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# Challenges in Applying Old Data to New Paradigms in Wide-Area, Urban Radiological Response and Recovery


Michael Kaminski,[1] Sang Don Lee,[2] Matthew Magnuson[2]
[1]Nuclear Engineering Division, Argonne National Laboratory
[2]U.S. EPA National Homeland Security Research Center



## After World War II

- Nevada Test Site researchers studied the characteristics of fallout
  - radioisotope distribution patterns along the fallout path
  - characteristics of the fallout particles
- Majority of radioactivity very short-lived radioisotopes
- Two major contributors to long-lived radioisotopes (half-life greater than months or years).
  - Radioactivity associated with solid particulate (>10 μm) that condensed close to ground zero
  - Radioactivity associated with volatile isotopes that could be carried by a plume(cesium, <10 μm)
- First reports describe techniques for solid particles
  - Wait…
  - Fire hose washing, vacuum sweeping of roadways, and commercial-off-the-shelf (COTS) sand blasters, detergent scrubbers, washers, steam cleaners, and vacuums.

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## Nuclear Reactor Accidents

- Nuclear power fleet expanded in the 1970s
- U.S. NRC published first summary of decontamination methods in response to a nuclear power accident
  - Simply repeated previous slide.
- Swedes built a reactor
  - Danes published calculations of the impact of a core meltdown on Danish territory .
  - Followed up with a review of the techniques gathered by the U.S. during the 1960s.
  - Roed first identified the difficulty in removing cesium deposited onto roofing material after rain.
- The UK initiated laboratory studies on sandblasting, steam cleaning, and ammonium nitrate wash to remove cesium from new and old building materials after both wet and dry deposition.

Barsebäck nuclear power plant



## Chernobyl Accident

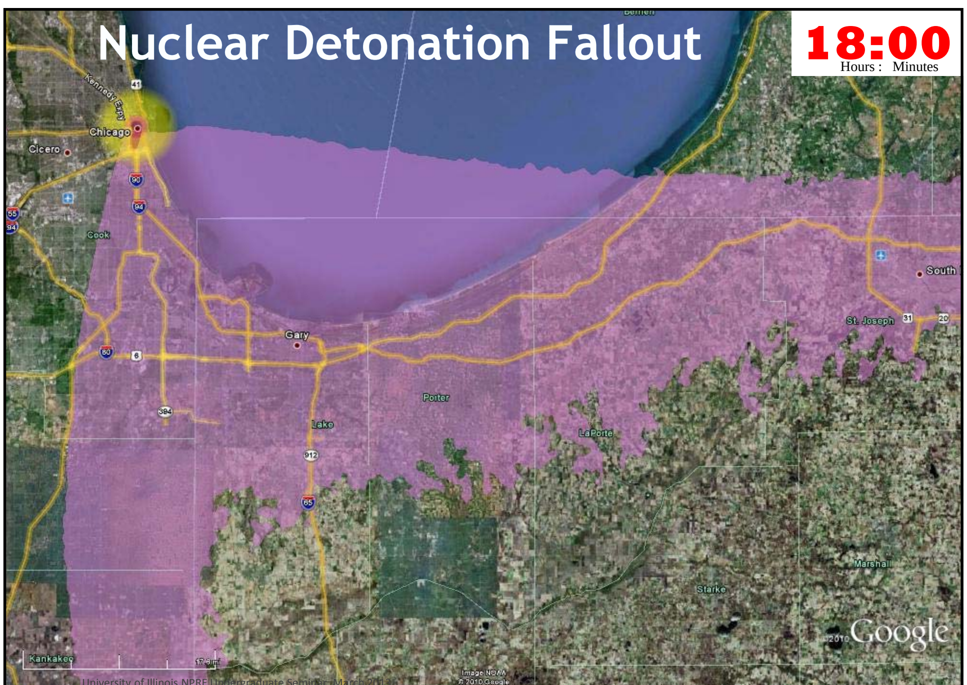
- Wake up call
- Nuclear community needs formal plan to institute large-scale remediation
- A summary publication (IAEA) on large-scale environmental decontamination methods quickly followed
  - Recognized that methods developed in areas immediately surrounding a nuclear reactor and D&D of nuclear facilities would be too expensive for large-scale use.
  - Also, methods developed for environmental cleanup concentrated on grasslands and, therefore, were more applicable to agricultural fields.
  - Wide area methods were desperately needed.

## Valuable Resources

- *EURANOS*
  - First comprehensive guide provides thorough decision trees from planning to response to training.
- *UK Recovery Handbooks for Radiation Incidents*
  - Patterned after EURANOS.
- *Decontamination Guidelines*
  - Japanese Ministry of the Environment to "explain [decontamination] processes in a concrete and straightforward manner" revised based on lessons' learned in Japan.
- Shortcomings
  - Recovery phase documents
  - Focused on nuclear detonation and reactor accident
  - Details of method (chemicals, procedures) missing
  - DF data based on limited data and is very material specific
  - Lack of process to guide decision making at every level

$$DF = \frac{\text{radioactive levels before}}{\text{radioactivity levels after}}$$



## RDD Fallout

## Summary of Methods for Urban Building Materials

- Strippable Coatings
- Clay Film Coatings
- Fire Hose Washing
- High Pressure Wash
- Ionic Wash
- Sandblasting
- Street Sweeping and Vacuum Cleaning

## Strippable Coatings

- Used extensively in the nuclear industry to control *loose*, dust-like, surface contamination
- Demmer summarized several commercially-available films during D&D at Idaho National Laboratory
  - DF values varied but were generally 4-20 from steel and lead bricks.
- Andersson investigated six film formulations for the decontamination of soils.
- Gray describes smart coatings that incorporate a color indicator to ID hotspots.
  - DF>>100 for steels, glasses, painted aluminum, and painted cement at Los Alamos National Laboratory.
- Parra et al. review strippable coatings and fixatives in response to an RDD.

WSRC-MS-98-00122

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## Clay Film Coatings

- Vovk et al. tested a Na form of bentonite clay near and further away from Chernobyl reactor
  - DF=2-20 on whitewashed brick wall, 2 for smooth concrete, 3 for roofing slate, and 10 for zinc-coated iron
- Ahn et al. used a $NH_4^+$-loaded form of montmorillonite clay
  - DF=3.4-4.5 for slate, 2 for silicate brick, and 1.3-1.6 red brick.

- Movchan et al. use "Cleadecon" clay coating to decontaminate rural houses in Vladimirovka and Chernobyl
  - DF=2-5.4 for roofs and external walls and DF = 1.8-4.0 silicate bricks .
  - Distinct trend toward lower DF values over 7 year study (DF=15 for 1987 and DF=1.4 for 1994).
- Roed and Andersson use clay paste to decontaminate in Pripyat (DF = 1.6)
- Interestingly, none of the above clay-assisted decontamination methods is included in the EURANOS or UK Handbook.

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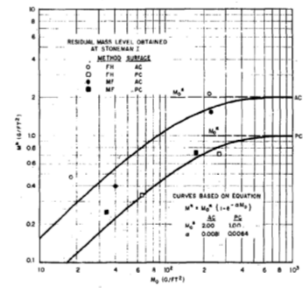
## Fire Hose Washing

- Studies in the U.S. 1960s to remove particulates associated with nuclear detonation fallout
  - Established good practices for applying water for particulate wash down from various paving and roofing materials
- Studies by Warming are the only sources we have for using a fire hose to remove soluble radioactivity from asphalt and concrete pavement
  - Fire hosed after 4 to 179 days of natural weathering outdoors in Denmark
  - The technique was generally ineffective (DF = 1.2)
  - Inconclusive data






## High Pressure Wash

- Six materials tested in several towns contaminated after Chernobyl
  - DF=1.1-1.9.
- EPA experiments on pressurized water to remove aerosolized CsCl from concrete, brick, and asphalt
  - DF=3.4 for asphalt, DF=1.85 for brick, and DF=2.2 for concrete
  - Values are markedly higher than above, reflecting particulate nature of Cs in EPA experiments

Figure 2-5: Example of decontamination of roof tiles (pressure washing)

Photo courtesy of: Fukushima City

## Ionic Wash

- Studies from Warming on Danish concrete and asphalt roadways reported no improvement using potassium fertilizer added to the wash water
- Sandalls tested $NH_4^+$ in UK lab for removal of cesium from old and aged materials
- DeWitt tested up to 1.0M $NH_4^+$ in lab and found that concentrations >0.2M gave only marginal improvement in the DF
  - Note: materials wetted before contamination were easier to decontaminate!!
- Sinnuave and Olast used successive methods that included a 0.1M $NH_4^+$ wash on tile from single story home and brick walls in Gavle
  - Not surprisingly, the $NH_4^+$ rinse did not lead to improved DF
- Roed and Andersson studied decontamination exclusive to sandstone walls near the Chernobyl reactor site (particulate contamination) as well as farther away (soluble contamination)
  - They found that 0.1M $NH_4^+$ removed the particulate (DF=3.03) better than the soluble form (DF=1.27)

2011 EPA Decontamination Research and Development Conference, Norvember 2011

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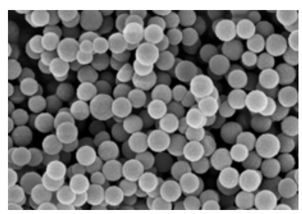
## Ionic Wash



- Claret et al. spread aerosol surrogates from a reactor meltdown explosion that contained cesium and strontium in particulate form
  - $NH_4^+$ solution in long washes (2 h, 30 min) could remove cesium and strontium activity (DF=2.5) from concrete if rain had not occurred prior to the $NH_4^+$ washes
  - Contamination on the clay tiles proved to be more tenacious (DF=1. 11)
- Idaho National Laboratory team developed a wash agent that is first applied and removed, either by vacuum, or preferably, by application of clay
  - The method was relatively effective in EPA tests for soluble contaminations with DF = 1.7-11, depending on the building materi al and radionuclide
- Argonne National Laboratory developed a hydrogel ("Argonne SuperGel")

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## Sandblasting

- The effect of sandblasting was reported in several studies but often as a step in successive methods
  - Studies on clay brick and brick walls removed most of the contamination resulting from the Chernobyl accident
- Sandalls reported complete removal with DF>10
- Dick and Baker reported that sand-blasting particulate forms of contamination was the most effective technique they tested



## Street Sweeping and Vacuum Cleaning

- Efficiency of motorized street sweepers (1960’s) investigated for nuclear fallout in particulate form
  - Questionable utility because equipment is outdated
- Sinnaeve and Olast were the first to investigate wet deposition of cesium using several techniques in succession
  - found greater difficulty in removing cesium from asphalt (DF=1.11) than concrete (DF=2.0)
- Vacuum cleaning on “two occasions” was ineffective in removing simulated soluble rubidium (surrogate for cesium) from asphalt pavement

## EPA Testing and Japanese Experience

- EPA evaluating technologies to **mitigate** an RDD to benchmark technologies available to the market
  - Well-planned studies focus on concrete decontamination of soluble radionuclides but studies on granite, marble, and limestone have been completed more recently.
  - Various mechanical and chemical techniques
- Japanese urban techniques focus on removing sediments/solids
  - Wiping important! but not part of EURANOS/UK Handbook.
  - New data is massive!



## Summary

- Techniques specific to nuclear detonation and reactor explosion
- Data
  - Inherently *very* material specific and may not be directly translated from one location to another
    - Country to country, city to city, neighborhood to neighborhood, building to building
  - Details of method (chemicals, procedures) missing
  - Room to improve/develop new methods (before a crisis!)
  - Complexity requires modeling -- basic sensitivity analyses?
  - Lack of Decision Support Process
  - Stakeholder input/buy-in
- Starting point framework is in place by adapting that of EURANOS and UK Handbook and digesting information from Japan (!).

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