United States
Environmental Protection
Agency

2016 U.S. EPA International Decontamination Research and Development Conference

Tuesday, November 1, 2016

General Session 1

Program Overviews, Responses, and Field Studies

EPA

Preparing for the (un)known

GREGORY SAYLES, PH.D.

2016 EPA INTERNATIONAL DECONTAMINATION R&D CONFERENCE

NOVEMBER 1, 2016

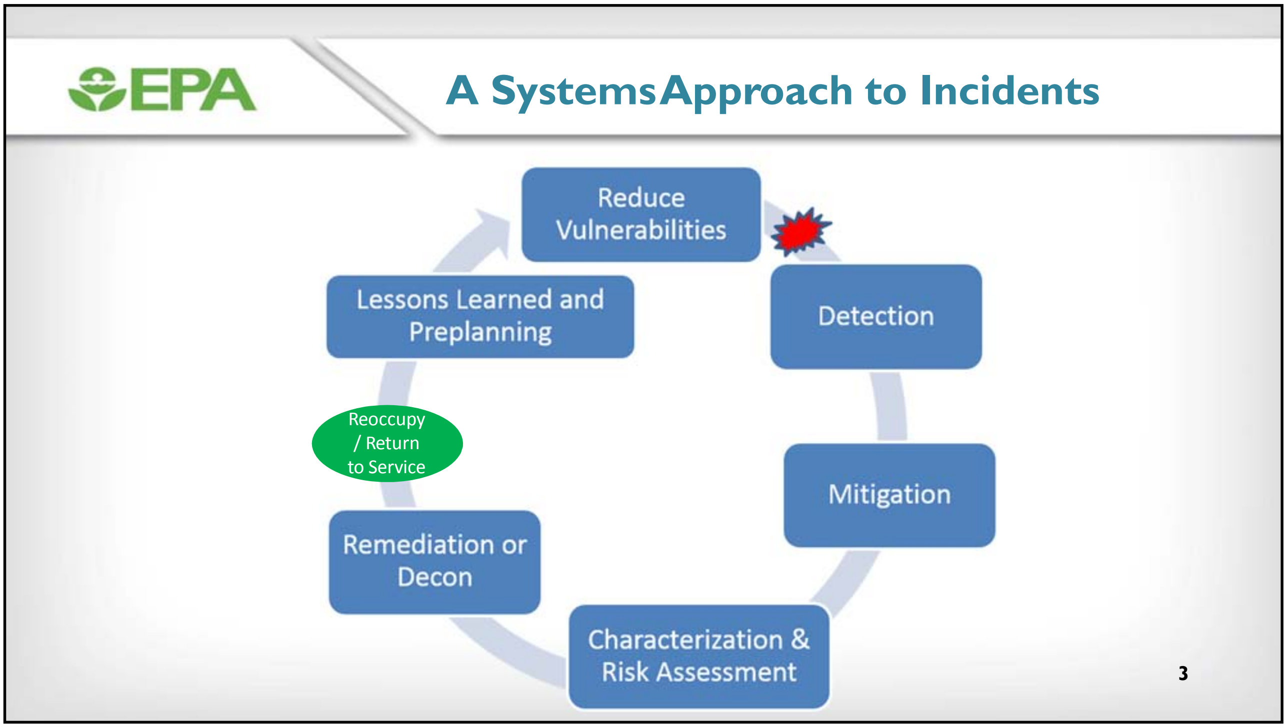
EPA

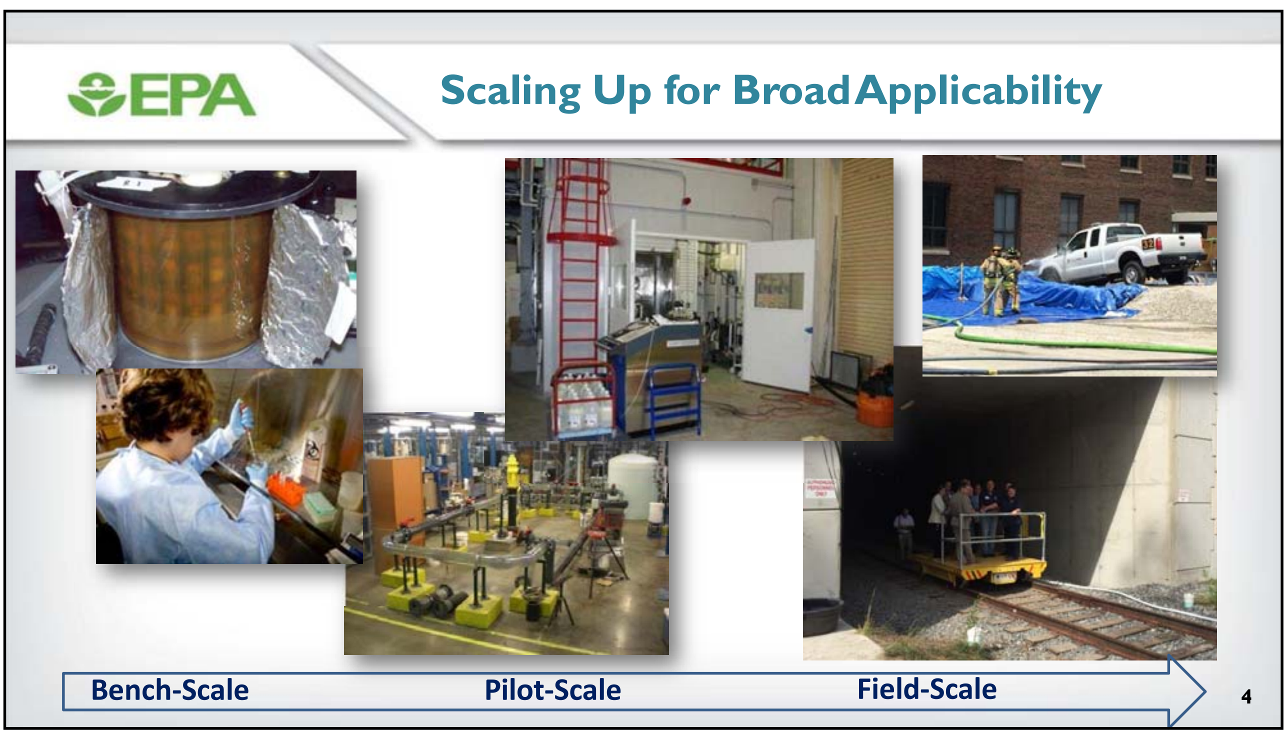
The"All Hazards" Science Challenge

How can we address the highest priority HS threats
AND
prepare for unforeseen hazards?

Aim at high priority, known science needs,
WHILE
Using a **systems view** of response,
Scale R&D incrementally, and
Researchers, end users and agencies **collaborate**

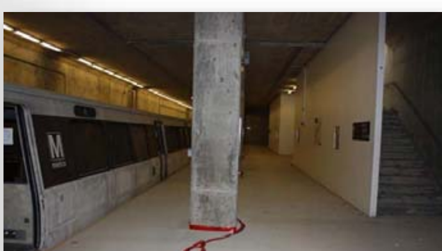
2


EPA
A Systems Approach to Incidents
Reduce Vulnerabilities
Detection
Mitigation
Characterization & Risk Assessment
Remediation or Decon
Reoccupy / Return to Service
Lessons Learned and Preplanning
3

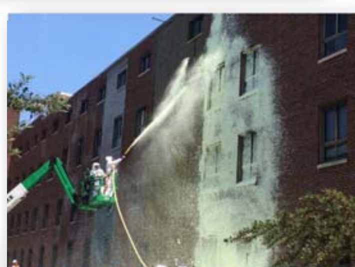

EPA
Scaling Up for Broad Applicability
Bench-Scale
Pilot-Scale
Field-Scale
4

EPA Water Security Test Bed

Researchers and End-Users:
Operational Demonstrations








6

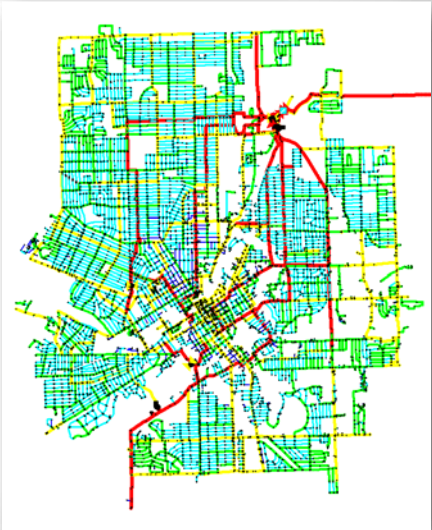
EPA

Viruses: Ebola, High-Path Avian Flu 2014-5

7

EPA

Tulane Primates 2015 and Flint 2016



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The Wide Area

Department
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Food & Rural Affairs

UK Government Decontamination Service
Science and Technology Programme

November 2016

Department
for Environment
Food & Rural Affairs

GDS Organization & Remit

- Provide advice, guidance and support to those responsible for dealing with the consequences of an accidental or deliberate release of CBRN and hazardous materials;
- Enable quick access to an Framework of specialist suppliers able to offer expert decontamination and related services in response to a CBRN or major HazMat incident;
- Advise the Government on the national capability for the decontamination of buildings, infrastructure, transport assets and the open environment.

Department for Environment Food & Rural Affairs

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Technology Mapping

Normal Business Environment		CT Environment (NRA)
Industrial chemical spills and asbestos removal	→	Deliberate releases of chemical warfare agents (Aum Shinrikyo)
Clinical sterilisation and oil extraction	→	Anthrax remediation (dispersion of *bacillus anthracis*)
Nuclear power station maintenance and decommissioning, atomic weapons	→	Radiological dispersal & improvised nuclear devices

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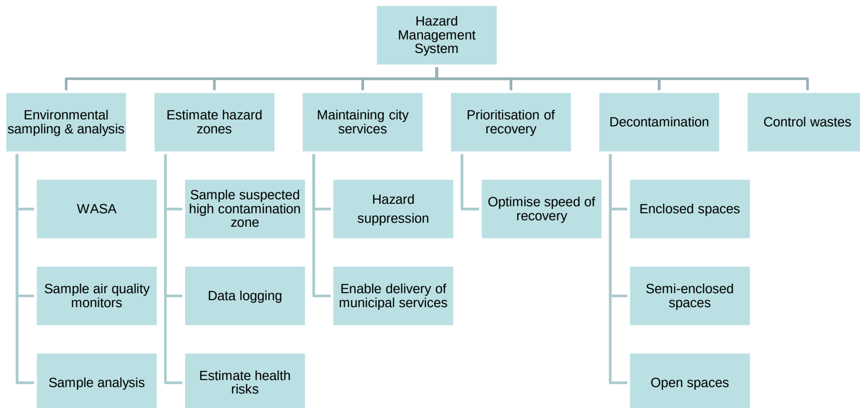
In practise – system for large wide-area releases



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Capability Matrix

Threat agent/scenario	Capability demonstrated	Level of Evidence	Closeness of fit
Sarin dissemination in urban environment affecting: • Building interiors • Building exteriors • Open ground • Tarmac roads • Water table	Health and Safety – working safely in a contaminated environment Decontamination – efficacy of approach	2 – written evidence of proven industrial capability to remediate organophosphate manufacturing plant 4 – completed simulated CBRN exercise	Similar chemical properties and toxic effects. Remediated contamination on surfaces inside and outside buildings, on open ground, tarmac roads.

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Chemical Threats Evidence Requirement

- Ability to select & deliver decontaminants for specific chemical agents:
  - Materials of interest list
  - Available decontaminants
  - Typical surfaces (offices, domestics, tube)
- Identify key factors important in the selection of decontaminants for unique combinations of surfaces and agents

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Previous Studies

- Surface interaction studies and off-gassing
- Effectiveness of decontamination during exercises
- Rapid cure sealants
- Effectiveness of fumigants on chemical agents
- Auto-assembly to trap chemical agents
- Effectiveness of peracetic acid as a decontaminant

Chemical Threats
Post deposition mathematical modelling

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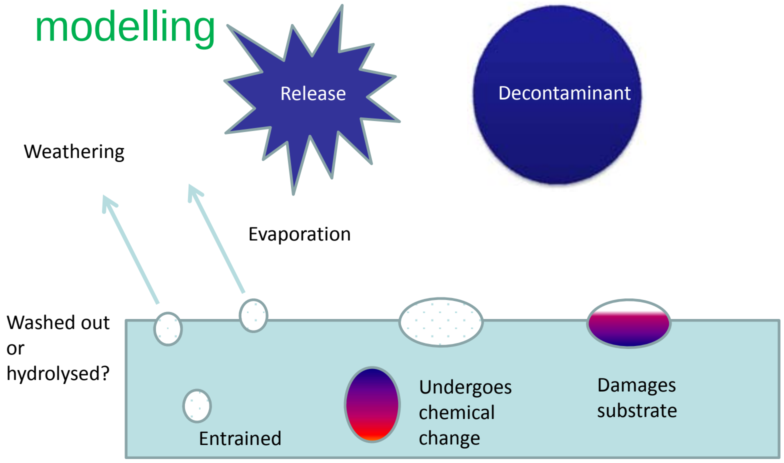

http://www.maths-in-industry.org/miis/671/1/ESGI100-UKGDS-Report.pdf

Biological Threats
Requirement

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- Ability to select & deliver decontaminants for biological agents:
  - Materials of interest list
  - Available decontaminants
  - Typical surfaces (offices, domestics, tube)
- Wide area sampling and analysis
- Practical methods for scaling up decontamination

Previous & current studies

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- Effectiveness of HCHO, ClO_2 and H_2O_2 against *B. anthracis* (Ba.)
- Surge capacity of analytical facilities
- Penetration of particles into buildings
- Standard operating procedures – formaldehyde
- Endemic Ba. and seroconversion in local populations
- Natural distribution of Ba.
- Adaptations of agricultural equipment and processes
- ***Robotic vacuum cleaners***
- ***Spore germinants***

Practical Testing of a Formaldehyde SOP

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- Development of a standard operating procedure (SOP) for a decontamination process using formaldehyde
- To test a GDS supplier using the formaldehyde SOP
- To validate the efficacy of the SOP in the hands of a GDS supplier

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Radiological Threats Requirement

- Ability to deploy industrial remediation technologies in urban environments
  - o Nuclear industry technologies
  - o Specific radionuclides
  - o Common building surfaces
- Ability to survey wide areas for radioactive contamination
- Strategy for radioactively contaminated wastes

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Previous & Current Studies

- Consequences of different RDD designs in urban settings
- Behaviour of radioisotopes on common building surfaces
- Practical volume reduction
- ***Effectiveness of strippable coatings***

Volume Reduction
Polonium 210 (London, 2006)

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Before

After

Cross-cutting Research

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- OR studies - staffing requirements
- OR studies - assessing industrial capability
- Wide area sampling and analysis (WASA)
- ***Effects of contaminated water on infrastructure***
- ***Prioritisation of recovery from wide-area incidents***

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Wide area sampling

- Visual Sampling Plan
  - o uses data quality objectives common in nuclear decommissioning
  - o Developed by Pacific Northwest National Laboratory (http://vsp.pnnl.gov/)

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Partners

- Office for Security & Counterterrorism - Home Office
- Department for Transport
- Defence Science & Technology Laboratory
- Health & Safety Laboratory
- Atomic Weapons Establishment
- National Nuclear Laboratory
- Public Health England
- Universities of Cambridge, Cardiff, Kent, Manchester Oxford, Southampton & West of England
- Smith Institute for Industrial Mathematics & System Engineering

Department for Environment Food & Rural Affairs

Further Information

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USEPA Decontamination and Technology Conference, 2016

Current Status in Fukushima and Study on Volume Reduction and Recycling

November 1st, 2016

Kiyohiko EINO
Section Chief,
International Cooperation Office for Decontamination of Radioactive Materials and Director's Office for Decontamination,
Environment Management Bureau, Ministry of the Environment, Japan

Outline

- ✓ Current Status in Fukushima
- ✓ Treatment Flow of Contaminated Soil
- ✓ Overview of Interim Storage Facility and Final Disposal
- ✓ Effects of Development of Volume Reduction Technology
- ✓ Technology Development Strategy and Study on Recycling

1

Outline

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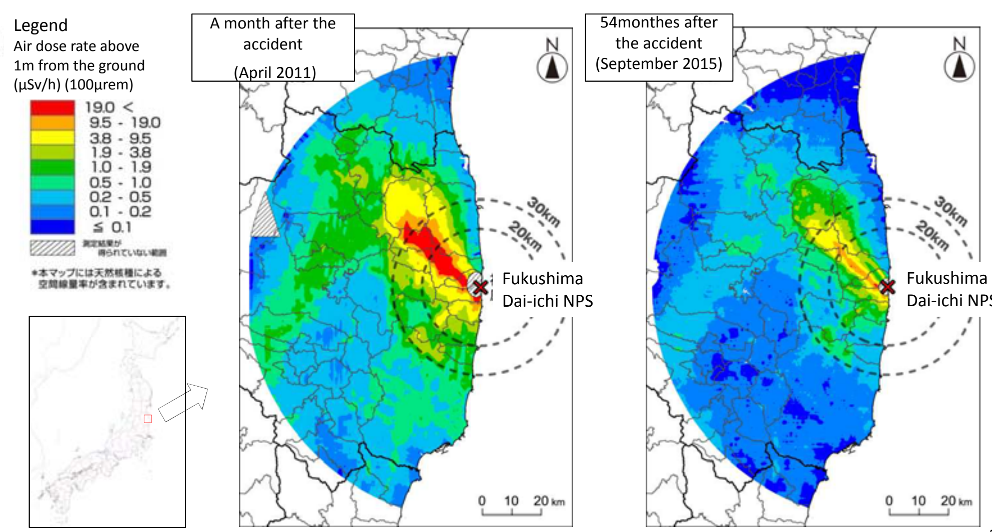
2

Conversion of Air Dose Rate (within 80km radius from Fukushima Dai-ichi NPS

- Air dose rate around Fukushima Dai-ichi NPS has been decreasing by radioactive decay, etc.



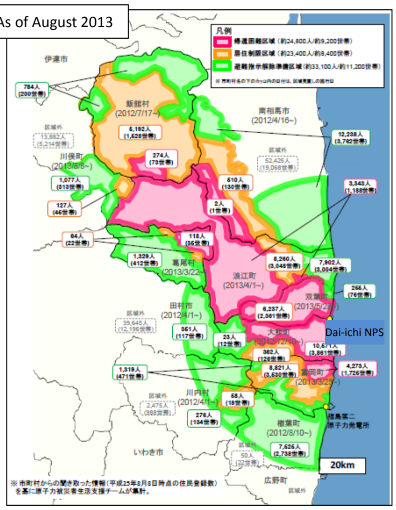
3

Ref: Nuclear Regulation Authority Result of monitoring survey by aircraft http://radioactivity.nsr.go.jp/ja/contents/12000/11624/24/160202_10th_air.pdf

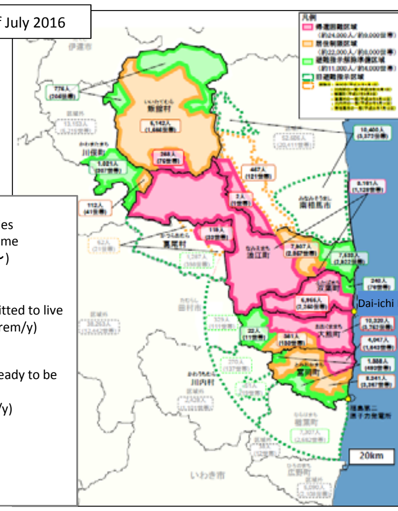
Conversion of the Evacuation Areas (Conceptual Diagram)

- Evacuation orders have been sequentially lifted in the areas where requirements for Evacuation order-lift fulfill (air dose rate, restoration of infrastructure, progress of decontamination, discussing with municipalities)
- However, there are still a long list of residents who are under constraint

As of August 2013



As of July 2016



- Residents have difficulties in returning for a long time (50mSv/y～)(=5rem/y～)
- Residents are not permitted to live (20 ～50mSv/y)(=2 ～5rem/y)
- Evacuation orders are ready to be lifted (～20mSv/y)(=～2rem/y)
- Evacuation orders were lifted

4

Ref: Nuclear Emergency Response Headquarters http://www.meti.go.jp/earthquake/nuclear/kinkyu/hinanshiji/2016/pdf/0712gainenzu02.pdf

Decontamination based on the “Act on Special Measures”

1) Special Decontamination Area

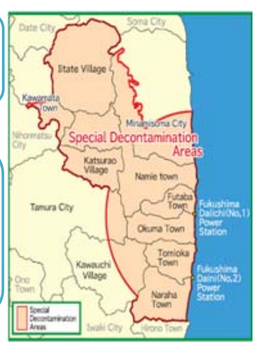
Designation of SDA by the Minister of the Environment

↓

Development of the decontamination implementation plan in the SDA by the Minister of the Environment

↓

Implementation of decontamination by the national government



2) Intensive Contamination Survey Area

Designation of ICSA by the Minister of the Environment (Areas where air dose rate is 0.23μSv/h(23μrem/h) or more)

※0.23μSv/h is a criterion for designation of ICSA and not a decontamination target

↓

Survey measurement by the mayors of the municipalities

↓

Development of the decontamination implementation plan by the mayors of the municipalities

↓

Implementation of decontamination by the municipalities, etc. (The national government allocates budgets.)

Note: The air dose rate 0.23μSv/h(23μrem/h) corresponds to a cautiously estimated individual exposure dose of 1mSv/y(100mrem/y) assuming that people spend ① 8 hours outside ② 16 hours in a wooden house with a low shielding rate in a day

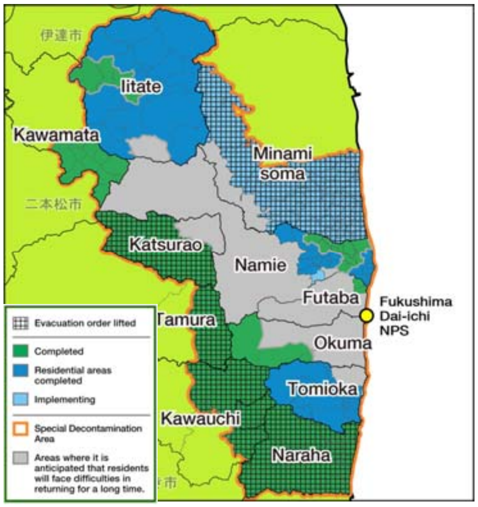
Decontamination and disposal of soil at NPS

Implemented by the nuclear power station operating company in charge (TEPCO)

5

Progress in the Special Decontamination Area (as of August 2016)

▸Decontamination is one of the measures for radiation protection*to remove radioactive materials from the inhabitation areas in order to promptly decrease impacts on human health and the environment. ＜Municipalities in which evacuation orders were lifted＞
*The national government aims at a long-term goal to reduce additional annual dose to 1 mSv/y (100mrem/y)or less by comprehensive measures for radiation risk management including not only decontamination, but also monitoring survey, food safety administration, risk communication, etc.



- ✓ Special Decontamination Area is 11 municipalities in Fukushima Pref. designated by the Minister of the Environment where evacuation order was issued by the time of the accident (Tamura, Minamisoma, Kawamata, Naraha, Tomioka, Kawauchi, Okuma, Futaba, Namie, Katsurao, Iitate)
- ✓ Aims to complete whole area decontamination by the end of March 2017, without the Area where it is expected that people have difficulties in returning for a long time

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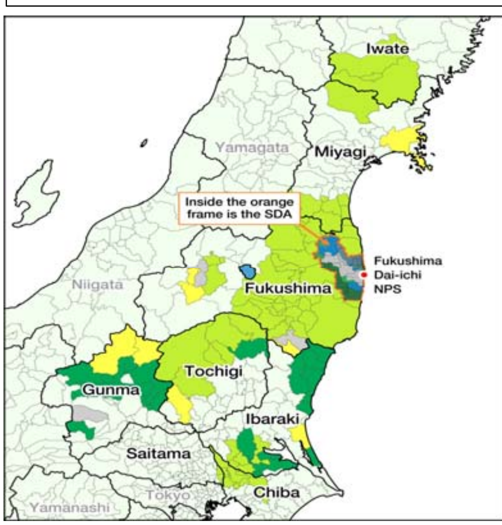
Progress in the Intensive Contamination Survey Area (as of the end of Aug.)

- ➢ Decontamination is one of the measures※ for radiation protection to eliminate radioactive materials from the inhabitation areas in order to promptly decrease impacts on human health and environment

(※) The national Government aims at a long-time goal to reduce additional annual dose to 1mSv/y(100mrem/y) or less by comprehensive measures for radiation risk management including not only decontamination, but also monitoring survey, food safety administration, risk communication, etc.



- ✓ Decontamination areas for ICSA are designated by the Minister of the Environment where air dose rate is 0.23ɥSv/h(23µrem/h) or more (96municipalities within and outside Fukushima Prefecture)
- ✓ Decontamination is planned to be completed by the end of March 2017

Municipalities for which designation of ICSA has been lifted
Municipalities that completed planned decontamination
Municipalities that have formulated decontamination plans based on the Act
Other municipalities of ICSA

7

Dissemination and Sharing of Lessons Learned through Decontamination

- After the NPS accident, MOE summarized knowledge and decontamination technologies, conditions, effects, basic policy, and framework based on the actual decontamination works as the "Decontamination Report" in order to disseminate off-site information home and abroad on knowledge and lessons learned


FY2014 Decontamination Report
- A compilation of experiences to date on decontamination for the living environment conducted by the Ministry of the Environment -
(Tentative Translation)
March 2015
Ministry of the Environment




http://josen.env.go.jp/en/cooperation/

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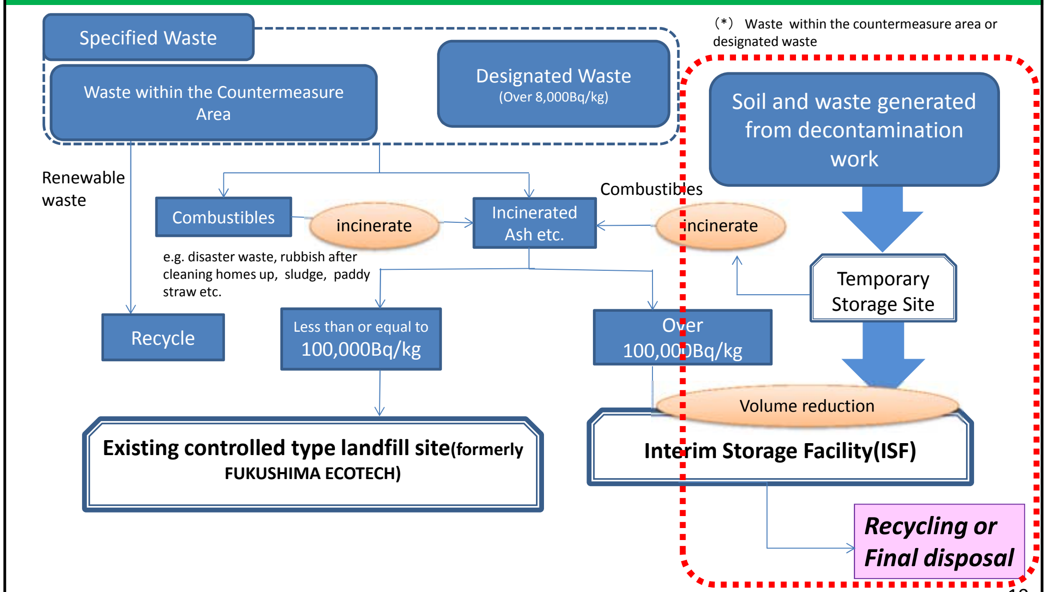
Flow Diagram for Treatment of Specified Waste(*), Soil and Waste Generated from Decontamination（Fukushima Pref.)



Note: Volume of specified waste generated was estimated to be near 1.16 million tons. Out of them, around 140 and 350 thousand tons have already been incinerated and recycled, respectively. (As of June 30, 2016)

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What is an Interim Storage Facility (ISF)?

- Removed soil and waste in Large amount being generated in Fukushima
- Currently, difficult to specify how to dispose of such removed soil and waste.
- Interim Storage Facilities (ISF) needed for safe management and storage of removed soil and waste before final disposal

Following materials generated in Fukushima Prefecture will be stored in the ISF.

1. Removed soil and waste (such as fallen leaves and branches) generated from decontamination activities and stored at the Temporary Storage Facilities.

* In principle, combustible materials shall be as ash after incineration.

2. Incineration ash with radioactivity concentration more than 100,000 Bq/kg.

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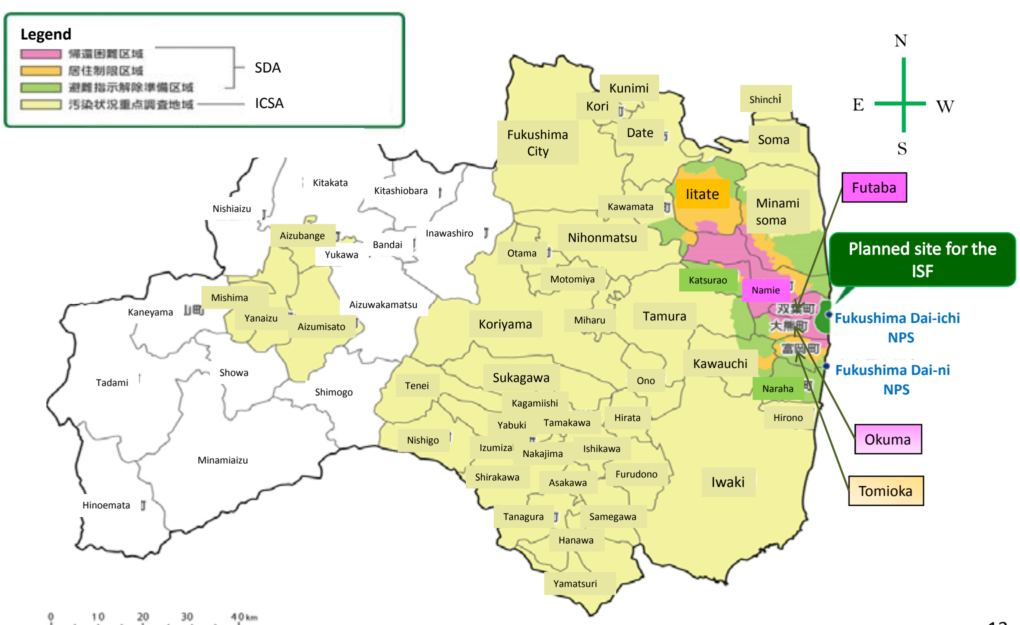
Planned Site for the Interim Storage Facility



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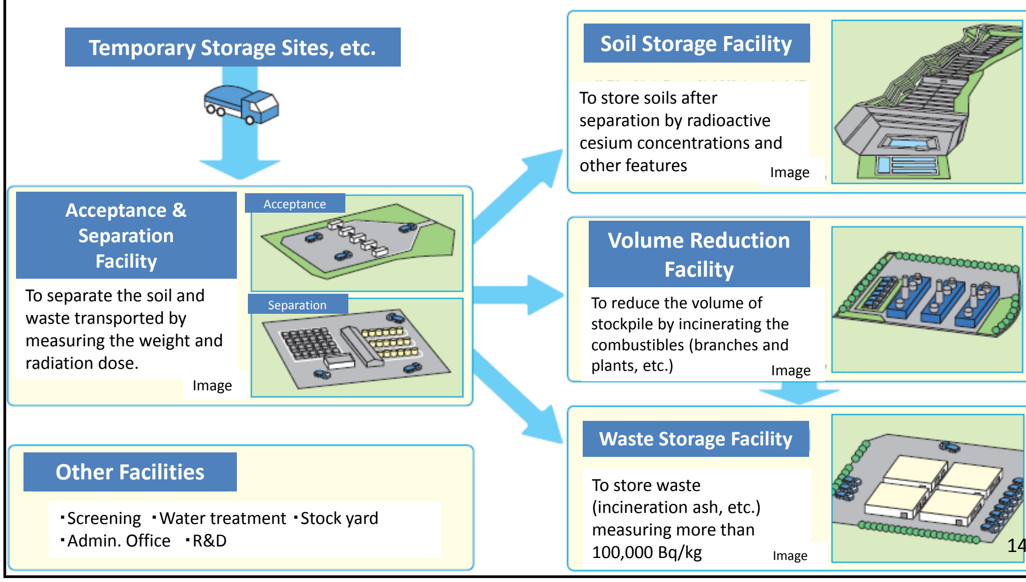
Facilities and Disposal Process at the Interim Storage Facility

➢ The Interim Storage Facility will consist of several facilities with various functions.



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Status of Candidate Site for the ISF

As of the end of September 2016

Whole Area Approx. 1,600ha(4,000acre)	**Item**	**Whole area**	**Ratio to the whole area**	**Registration record detail (2,360pers.)**
Private Land Approx. 1270ha (3,140acre)	Landowners with contact information	Approx. 1,180ha (2,920 acre)	approx. 74% ※1	1,640 pers.
	Property investigations accepted	Approx. 1,060ha (2,620 acre)	Approx. 66%	1,410 pers.
	Property already investigated	Approx. 980ha (2,420 acre)	Approx. 61%	1,260 pers.
	Contracted	Approx. 144ha (360 acre)	Approx. 9.0%	379 pers. (approx. 16.1%) ※2
National/ Municipality Land etc. Approx. 330ha (820 acre)	Town owned -land	Approx. 165ha (410 acre)	Approx. 10.3 ※1	
	National/ Municipality land/ Land without address	Approx. 165ha (410 acre)	Approx. 10.3 ※1	

※1 Areas with owners' contact information occupies approx. 94% to the total area including private/national lands

※2 The ratio is to the record of 2,360 pers. with family registration and residence certificate

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Transportation to Stock Yards

- In order to confirm safe and secure delivery towards the transportation of a large amount of contaminated soil, MOE implemented the transportation approx. 1,000m^3 (1300yd^3)each from 43 municipalities in Fukushima Prefecture from 2015-2016

<Actual achievement in FY2016>
As of August 31, 2016

◆ **Stored volume: 20,326m^3 <26,585 yd^3>**
(65,708m^3 <85,942 yd^3> in total)

Stock Yards in Okuma: 9,448 m^3 <12,358 yd^3>
Stock Yards in Futaba: 10,878 m^3 <14,228 yd^3>
* Calculated on the assumption that the volume of a large bag is 1 m^3

◆ **Total number of trucks used: 3,482 (11,011 in total)**

Stock yards in Okuma: 1,592 trucks
Stockyards in Futaba: 1,890 trucks


Facilitation of bags at Stock Yards


Operation of a truck screening

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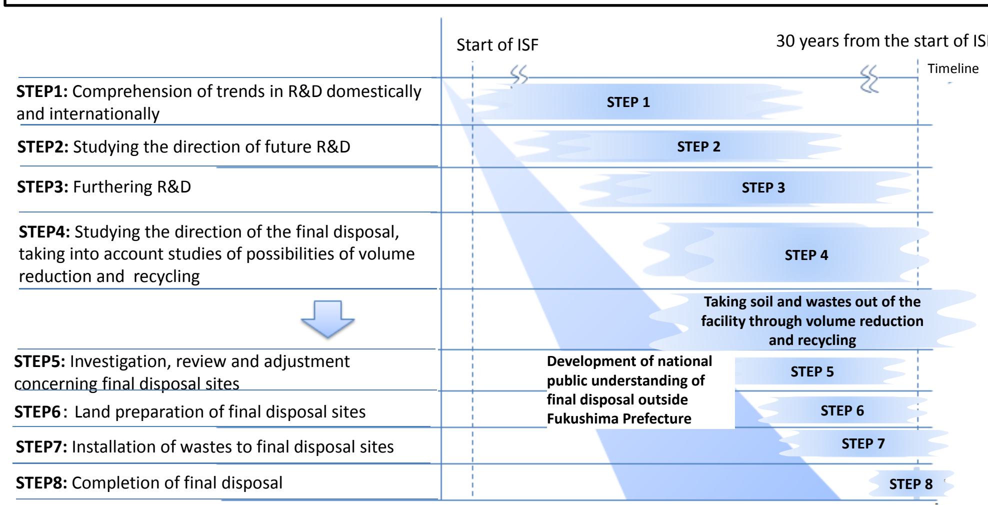
8 Steps towards the Final Disposal outside Fukushima Prefecture within 30 years from the Start of the ISF

- MOE conducts R&D and examines a direction of the final disposal, taking into account radioactive decay and possibilities of volume reduction and recycling
- MOE will also develop national public understanding through dissemination of information concerning the reuse of low radioactive materials and the final disposal outside Fukushima Prefecture



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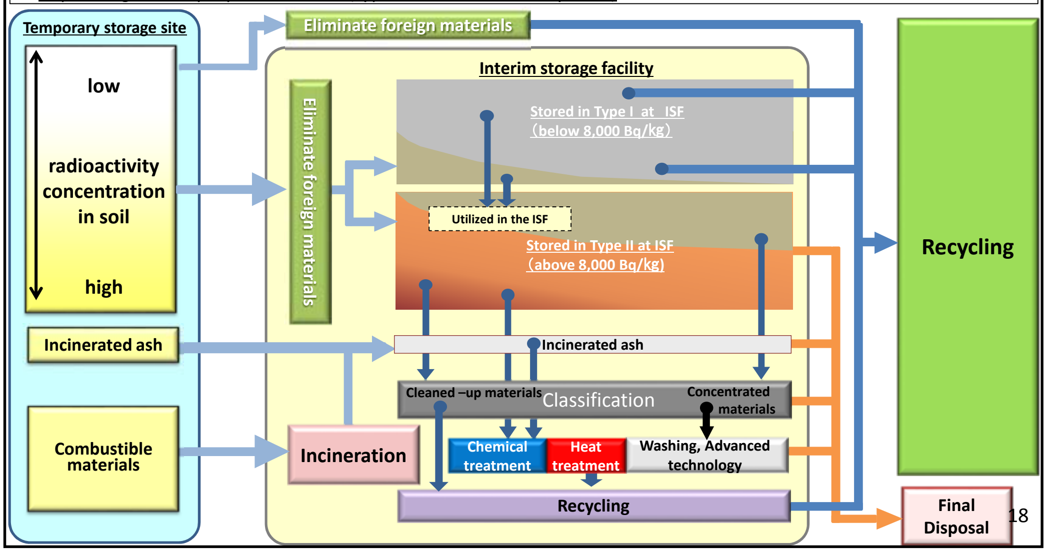
Scenario of Volume Reduction, Recycling and Final Disposal of the Removed Soil (Image)

- Removed soil and waste will be classified upon radioactivity level and stored temporarily in the ISF. After volume reduction, cleaned-up materials will be recycled. Radioactive concentrated fractions will be disposed at final disposal sites.
- Various technologies (classification, chemical and heat treatment, etc.) will be combined for volume-reduction depending on the properties of soil (type of soil/radioactivity level)



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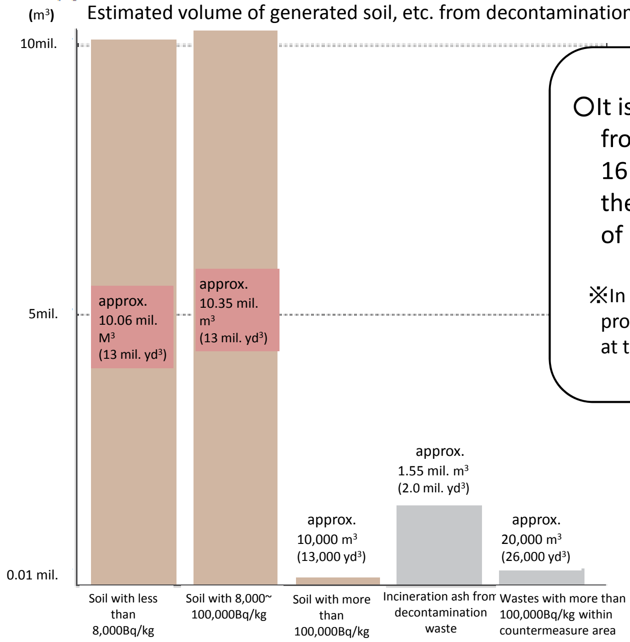
Estimated Volume in the Interim Storage Facility

Estimated volume of generated soil, etc. from decontamination work (in case of 22 million m^3)(=29 million yd^3)



○It is estimated that generated soil from decontamination will be approx. 16 ~22 mil. m^3 (21~29mil.yd^3) after the volume reduction (incineration of combustibles)

※In considering the plan for the ISF, storage of products whose volume is difficult to estimate at this moment is taken into account.

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Profile of Removed Soil (Estimated as of 2015)

- Estimated profile of soil based on radioactivity concentration level as of 2015
- Radioactivity is relatively low in large portion of soil. Highly contaminated soil mainly consists of cohesive soil.
- As for incineration ash, radioactivity data from future full-scale incineration treatment will be considered.

Target Object	Radioactivity Concentration (Bq/kg)	Sandy Soil (10,000 m^3) <10,000yd^3>	Cohesive soil (10,000 m^3) <10,000yd^3>	Total Volume (10,000 m^3) <10,000yd^3>	Volume Fraction (%)
Soil	≦3,000	335 <440>	156<200>	491<640>	23.1
	3,000 ＜～≦8,000	260 <340>	222<290>	482<630>	22.7
	8,000 ＜～≦30,000	303<400>	532<700>	835<1,100>	39.2
	30,000 ＜～≦100,000	12 <20>	152<200>	164<220>	7.7
	＞ 100,000	0	1<1>	1<1>	0.0
Incinerated Ash	Future data will be reflected	—	—	155	7.3
Total		910 <1,190>	1,063 <1,390>	2,128 <2,780>	100

3,000 Bq/kg: Level to allow disaster waste to be recycled (to be buried in the depth below 30cm)

8,000 Bq/kg: Classification levels of Type I and Type II at ISF

30,000 Bq/kg: Highest radioactivity level that can be reduced to 8,000Bq/kg thorough classification of sandy soil with the latest technologies (*)

*classification and grinding

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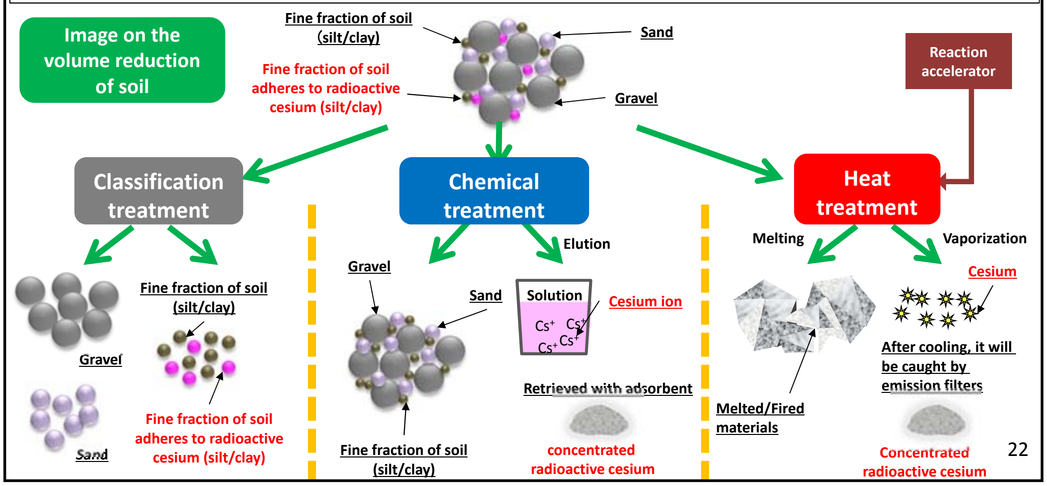
Volume Reduction Technologies for Removed Soil

- For reduction of volume of soil and wastes for final disposal, there are various technologies to classify soil and incinerated ash with low and high radioactivity.
- The main volume reduction technologies for contaminated soil are;
  - a) Classification (to classify and separate the fine soil particles to which cesium is mainly adhered)
  - b) Chemical treatment (to elute and separate cesium produced by solvents such as strong acids)
  - c) Heat treatment (to melt, cool, solidify, and collect cesium by heat)



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Outcomes of the Demonstration Model Projects

	JFY2011 Cabinet Office	JFY2011 MOE	jFY2012 MOE	JFY2013 MOE	JFY2014 MOE	JFY2015 MOE	JFY2016 MOE	TOTAL
Number of Application	305	295	173	136	64	37	23	1033
Number of Selection	25	22	15	11	10	9	9	101

Technology Category	Number of completed projects	Technology Category	Number of completed projects
Decontamination-related (including wastewater treatment)	22	Waste disposal (Combustibles)	19
Volume reduction of removed soil (including classification of removed soil & vegetation mixture and volume reduction of organic materials)	28	Incinerated ash treatment	6
Measures for reservoirs	4	Monitoring	2
Measures for debris (incombustible mixture, wasted cars, and wasted electronics, etc.)	11	ISF-related	9

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Examples of Model Demonstration and Evaluation on Volume Reduction Technologies of Contaminated Soil

Theme of demonstration	Affiliation
Development of Technique for Decontamination and Volume Reduction of Fine Soil Particles Contaminated with Radioactive Cesium and Reuse of the Resulting Cleaned Soils	Osaka University
Demonstration / verification tests on radiation-contaminated soil of high moisture content and viscosity for (1) soil quality improvement effects of mingled organic materials separation, (2) volume reduction effects of sieving and (3) reusability in agriculture	Kajima Corporation
Decontamination and Volume Reduction of Fine-grained Soil by Semi-continuous Subcritical Hydrothermal Blasting Treatment	CDM Consulting Corporation
Demonstration of classifying and washing the contaminated soil by movable system on the truck, and the validation for reusing the cleaned soil	Hitachi Kikai Corporation
Demonstration test of a contaminated soil sorting system	AREVA NC Japan Project
Volume reduction through adsorption and condensation of Cs elution or eluted Cs from a fraction of soil particles at ordinary temperatures and pressures	Swing Corporation
Soil Removing Technology from Mixture of Grass and Soil by Dry Separation	Obayashi Corporation

Results of respective model demonstration can be checked on following link (not only volume reduction technology of soil, but volume reduction of incinerated ash included)

2013 http://fukushima.jaea.go.jp/initiatives/cat01/entry07_25.html
2014 http://www.nustec.or.jp/etc/josen.html
2015 http://www.nustec.or.jp/etc/josen.html

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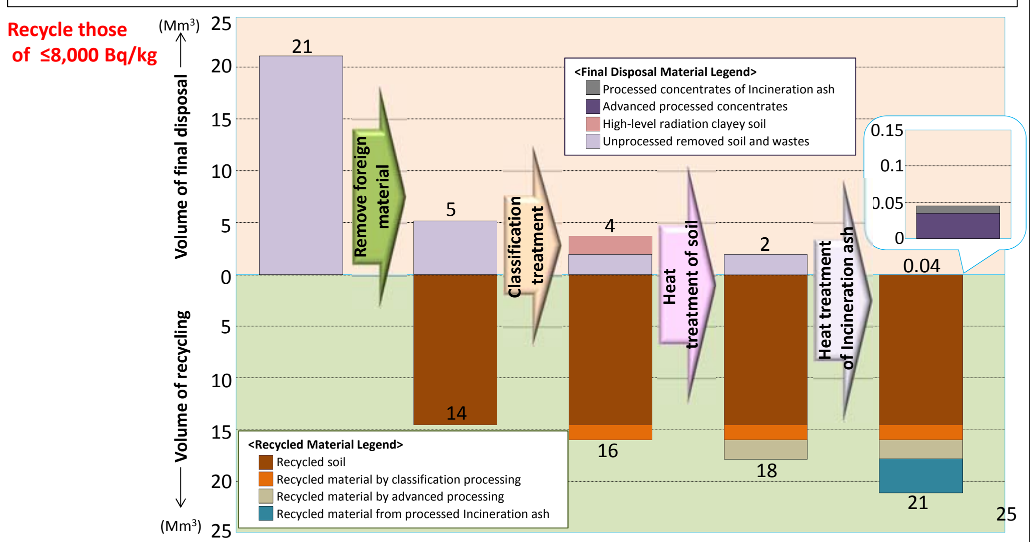
Effects of development of Volume Reduction Technology

- Combining various volume-reduction techniques could reduce greatly the volume of the final disposal compared with the initial volume.
- It is necessary to apply a technological development strategy considering the availability of final disposal sites, receivers of recycled material, and the total cost of the volume reduction and final disposal.



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Outline

- ✓ Current Status in Fukushima
- ✓ Treatment Flow of Contaminated Soil
- ✓ Overview of Interim Storage Facility and Final Disposal
- ✓ Effects of Development of Volume Reduction Technology
- ✓ **Technology Development Strategy and Study on Recycling**

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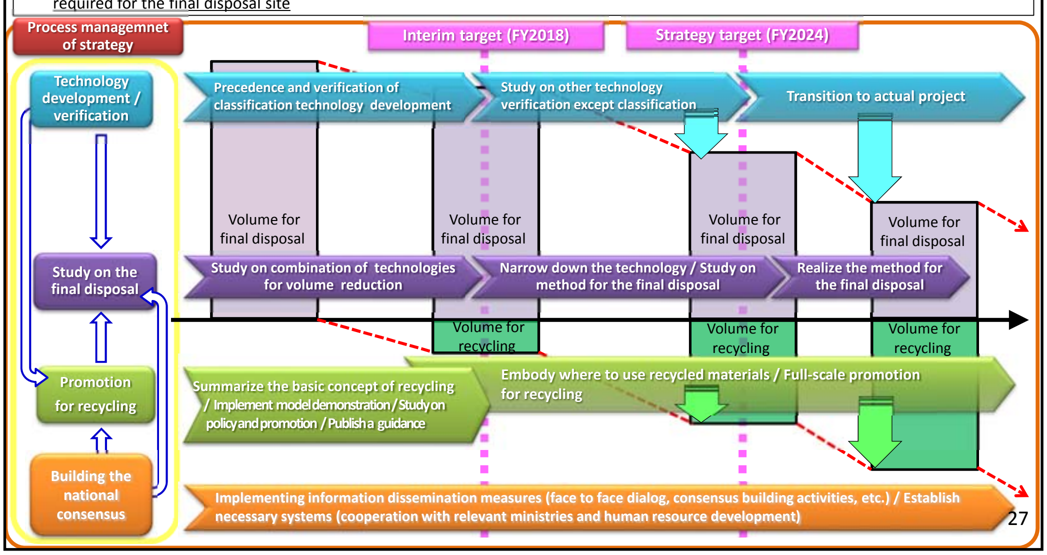
Technology Development Strategy for Volume Reduction & Recycling of Contaminated Soil

- Towards the final disposal of contaminated soil outside Fukushima Pref., MOE will promote recycling of the soil treated by volume reduction technology as much as possible, which consequently would lead to reduce the volume of soil for the final disposal
- To clarify the objectives and priority of technology development and volume reduction & recycling, basic technology development is planned to be completed within 10 years, then move onto a phase of treatment
- On the premise of securing safety, MOE will try to realize the recycling from the possible field, building public consensus for the safety
- Based on technology development and prospect of recycling in future, MOE would propose some technical options for structure and area required for the final disposal site



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Goals of Technology Development Strategy

Treatment Technology	Interim Target (JFY 2018)	Strategy Target (JFY 2024)
①Recycling by elimination of only foreign materials ensuring quality control	•To establish classification technology for low cost treatment in large scale and stability •To establish radiation management technology by recycling	–
②Recycling by classification treatment		
③Recycling by advanced treatment	•To specify treatment technologies as candidate technologies for demonstration under the government direct jurisdiction	•To establish system technologies to steadily obtain cleaned-up substances recyclable in public projects •To establish process technologies for highly concentrated radioactive materials towards final disposal
④Recycling incinerated ash	•To accumulate technological information with respect to incinerated ash by verification tests at existing facilities and to specify treatment technologies as candidates for demonstration by the government	
⑤Recycling	•To clarify the policy (guidelines) for recycling •To implement demonstration tests to confirm safety on radiation influence •To establish a guideline for practical recycling of each use	•Prepare for early full-scale practical recycling with safety first on radiation influence, and with public understanding.
⑥Final disposal	•To coordinate requirements (surface area, structures, etc.)for the final disposal	• To propose viable options as the final disposal sites

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Gradual Approaches towards Recycling of Soil

■ **Gradual approaches towards Stakeholders' Understanding and social acceptance**

Towards full-scale recycling of soil, MOE will promote

- Model projects it assume using materials derived contaminated soil, to make residents and constructors understanding , and to compile working methods
- Actual measures to experience, communicate, enlighten and to share knowledge on recycling necessity and radiation safety broadly with the public and stakeholders
- To publish a guideline to arrange management precaution, recycling method including environmental regulations related to existing public projects according to each use
- To study on promotion policy to use and implementation policy including social and economical incentives

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Basic Concepts to safely Use Recycled Contaminated Soil (June 2016)

【Basic Concepts】

After physically treated contaminated soil with preliminary treatment and classification, it is to limitedly use recycled materials (less than 8,000Bq/kg in principle but for suitable use) and to be adjusted for conditions in a certain public project, which shall be managed by public entity

【Limited Use】

It will be limitedly used for base structure materials of coastal levees, seaside protection forests, freeway roads or cover materials for wastes disposal sites which will not be artificially changed for a long time

【Management by Public Entity】

- A criteria and so on based on the Act on Special Measures will be established and be managed by MOE and public management entity (municipality)
- To be specific, in order not to exceed additional exposure dose of 1mSv/y(100mrem/y) during the construction and 0.01mSv/y (1mrem/y)after the construction, the entity shall conduct radioactive concentration monitoring, soil covering, scattering and leak prevention, record keeping, and managing landform change

【Procedure for Recycling】

As for environmental facilitation towards full-scale recycling, MOE shall implement model projects, safety check on radiation, verification for specific management method, and fostering understandings and trust of stakeholders according to above basic concepts

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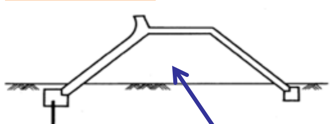
Image of uses of recycled materials under the public management

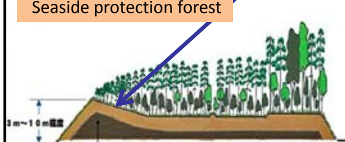
Uses of recycled materials

Coastal levee



Limited recycle for subbase materials under the public management

Seaside protection forest

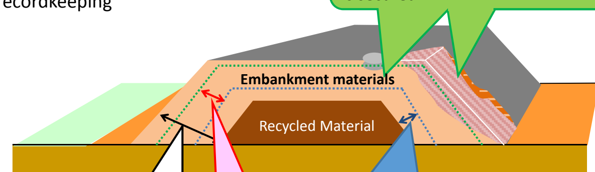


Other uses
Roads
Railway banks,
Cover soil at waste disposal areas etc.

Contents of the management

- ✓ The concentration management in consideration of isotopic ratio ($^{134}Cs/^{137}Cs$) of recycled materials are managed not to exceed additional exposure,
  - 1mSv/year(=100mrem/year) (construction)
  - 0.01mSv/year (=1mrem/year) (use of the structures)
- ✓ Concrete measures
  - Shielding by cover soil
  - Prevention of scattering and outflow of recycled materials
  - Maintenance of records and recordkeeping

Even if there is a embankment failure, the thickness of shielding is secured.



Safety margin

The thickness of shielding necessary to limit the exposure dose

The thickness of cover soil is designed so that the shielding thickness for limiting the exposure is ensured, even when the normal maintenance of the soil structures is made

The radioactive cesium conc. in the recycled materials

Use application		Shielding conditions	The radioactive cesium conc. in the recycled materials (Bq/kg)※1	The thickness of shielding necessary to reduce the additional exposure (cm)
Soil Structure (Embankment)		Covered with soil or asphalt(e.g. roads and railway banks)	≤ 6000	≥ 50cm
		Covered with concrete (e.g. Coastal levee)	≤ 6000	≥ 50cm※2
		Covered with plant (e.g. seaside protection forest)	≤ 5000	≥ 100cm※2
waste disposal areas	intermediate covers	Cover soil	≤ 8000	≥ 10cm
	Final covers		≤ 5000	≥ 30cm※2
	Embankment		≤ 8000	≥ 30cm

*1 : The radioactive cesium conc. equivalent to 1 mSv/year(100 mrem/year), which was calculated by the evaluation of exposed dose for each use application, was rounded down to 1000 Bq/kg. The recyclable conc. was calculated based on the ratio of ^{134}Cs and ^{137}Cs on March 2016, would be change with the lapse of time, because ^{137}Cs which made a small contribution to the air dose rate, would be dominantly. Furthermore the additional exposure will decrease with time by decaying radioactive cesium in the recycled materials.

*2 : The thickness of the soil (concrete) cover involves the required that of the soil (concrete) structure.

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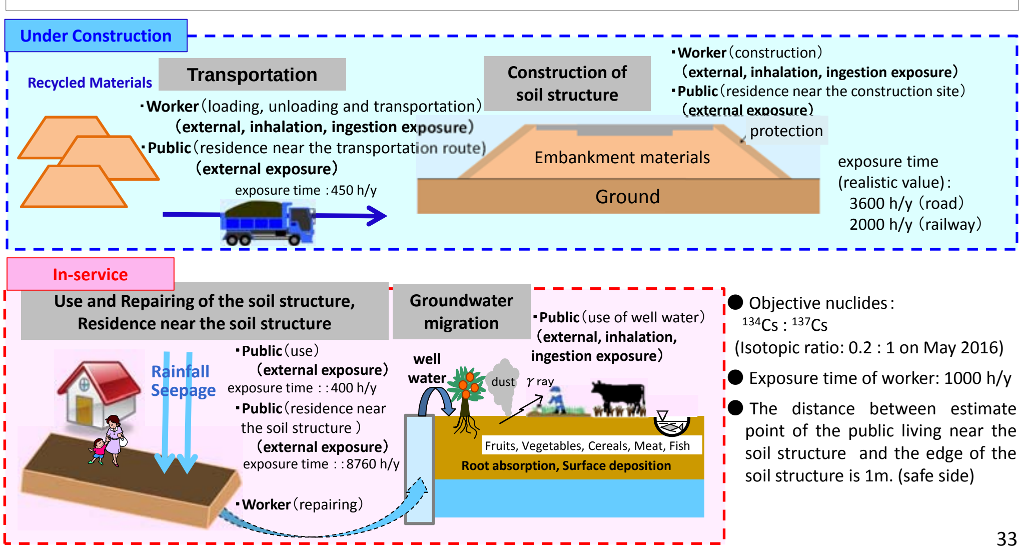
(Reference) Exposure pathways for the embankment covered with soil or asphalt

- Exposure pathways in case of recycling as the embankment is set up considering exposed individual and their action, and category of exposure (external, inhalation, ingestion exposure)



- Objective nuclides : ^{134}Cs : ^{137}Cs (Isotopic ratio: 0.2 : 1 on May 2016)
- Exposure time of worker: 1000 h/y
- The distance between estimate point of the public living near the soil structure and the edge of the soil structure is 1m. (safe side)

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Ref: MOE http://josen.env.go.jp/chukanchozou/facility/effort/investigative_commission/pdf/proceedings_160607_05.pdf (Japanese only)

(Reference) Description of the exposure pathways for the road embankment

No.	Description		Radioactive source	Exposed individual	Category of exposure
1	Transportation	Loading and unloading	Recycled materials	Worker	External
2					Inhalation
3					Ingestion
4		Transportation		Worker	External
5		Residence near the transportation route		Public (child)	External
6	Construction	Embankment construction	Embankment materials	Worker	External
7					Inhalation
8					Ingestion
9		Protection construction		Worker	External
10	Residence near the construction site	Residence near the construction site		Public (adult)	External
11					Inhalation
12				Public (child)	External
13					Inhalation
14	Pavement construction	Construction		Worker	External
15	After pavement completion	Residence near the pavement		Public (child)	External
16		Use of the pavement		Public (child)	External
17		Repairing of the pavement		Worker	External
18		Repairing of The beached bank		Worker	External
19	Groundwater migration	Ingestion of water	Well water	Public (adult)	Ingestion
20				Public (child)	Ingestion
21		Agriculture	Soil irrigated with well water	Worker	External
22					Inhalation
23		Ingestion of crops	Crops grown with the feeds cultivated with well water	Public (adult)	Ingestion
24				Public (child)	Ingestion
25		Ingestion of livestock	Livestock grown with the feeds cultivated with well water	Public (adult)	Ingestion
26				Public (child)	Ingestion
27		Ingestion of livestock	Livestock grown with well water	Public (adult)	Ingestion
28				Public (child)	Ingestion
29		Ingestion of fishery products	Fishery products farmed with well water	Public (adult)	Ingestion
30				Public (child)	Ingestion

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(Reference) Estimation of additional exposure dose on disaster and recovery

- Additional exposure dose of the public and worker is less than 1 mSv/y(100 mrem/y) if disaster such as tsunami or fire, etc. occurs.
- In a planning and designing stage, to prevent a major damage of soil structure contained recycled materials, it is necessary to consider local characteristics such as geographical and geological features, hydrology, and disaster information generated in the past.

Soil structure	Causes of a disaster	Calculated results of additional exposure in case of use of recycled material with 8000 Bq/kg (Critical pathway)	Remarks
Embankment covered with soil or asphalt (example: road embankment・railway embankment)	Embankment failure "Landslide, Slop face collapse", "Crack/Fissure, Settlement" caused by earthquake or heavy rainfall	**Worker: 0.64 mSv/y (64mrem/y)** (Crack/Fissure and Settlement, Recovery worker - External) **Public: 0.21 mSv/y (21mrem/y)** (Embankment failure, Residence near the site(child) - External)	・Collected soil contained recycled materials for restoration from disaster such as earthquake and heavy rainfall ・Recycled materials in an embankment, which become exposed due to embankment failure, crack/fissure and settlement.
Embankment covered with concrete (example: Coastal levee)	"Collapse, Flow out", "Embankment failure" caused by Tsunami	**Worker: 0.81 mSv/y (81mrem/y)** (Height of embankment: 8 m) (Embankment failure, Recovery worker -External) **Public: 0.0020 mSv/y (0.2mrem/y)** (Height of embankment: 8 m) (Collapse and Flow out, Ingestion of seafood (adult))	・Recycled materials in an embankment, which become exposed due to tsunami ・Recycled materials flowed out extensively, seafood contaminated by recycled materials
Embankment covered with planting (example: seaside protection forest)	Tsunami Fire	**Worker: 0.47 mSv/y (47mrem/y)** (Tsunami, Recovery worker -External) **Public: 0.0036 mSv/y (0.36mrem/y)** (Tsunami, Ingestion of seafood (adult))	・Recycled materials flowed out extensively, seafood contaminated by recycled materials ・Cs deposited on the earth's surface and re-floating Cs from plume caused by fire

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Study on Recycling of Contaminated Soil with Low Level Radioactive Concentration

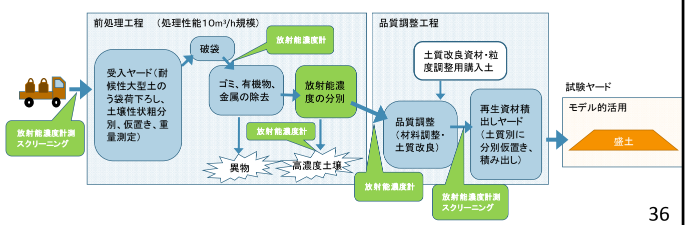
- Model demonstration on recycling and model use of contaminated soil is planned to be implemented within Minamisoma city, Fukushima
- MOE will conduct to confirm the radiation safety, to review on management measures, to foster understandings for recycling through model demonstrations

◆Model demonstration contents (draft)

1. A thousand impermeable large sandbags (1,000m^3(1,300yd^3), approx. 1,800tons) of contaminated soil will be used within temporary storage sites
2. By the preliminary treatment, radioactive concentration of contaminated soil will be decreased and run a model demonstration test for recycling materials
3. By the test construction, securement of safety (to prevent leaking radioactive materials to the underground water with water shielding sheets, to prevent scattering and leaking, and to shield contaminated soil appropriately with clean soil) will be the top priority
4. After the test, the facility will be demolished and the soil will be repacked into impermeable large sandbags

Ref: Minamisoma, Fukushima

Ref: Image of model demonstration



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Budget for R&D on Volume Reduction and Recycling of Removed Soil, etc.

Budget plan in FY2016: JPY 14.28 bil. (0.93 bil)
(※Requested amount is a part of budget for ISF's facilitation)

Background / Objectives

Volume reduction of removed soil and recycling and prepare for final disposal outside Fukushima within 30 years after the start of the ISF

Project target / Overview

Overview of the project

(1) Investigation to formulate R&D strategy (JPY 100 mil.)
①Current situation, issues, and measures for volume reduction,
②Issues on recycling,
③R&D strategy for volume reduction and recycling

(2) R&D and model demonstration projects (JPY 1 bil.)
①Function evaluation of devices for volume reduction and recycling,
②Tests on soil properties and concentration reduction,
③Model utilization as construction materials

(3) R&D to promote recycling (JPY 100 mil.)
①Where to recycle, ②Quality of recycling materials, ③Policy on radiation safety concept

(4) Demonstration of relevant technologies (JPY 230 mil.)
Small-scaled model demonstration of prospective technologies

Image

Plant for removed soil classification

(※)Classification: A technology used to separate removed soil by sifting according to particle size based on the cesium character tend to adhere to small particles

Examples for recycling
Left: Roadbed materials
Right: Core of breakwater

Project Scheme

Application

MOE ⇄ Private enterprise

Contract after advertising, etc.

Expected effect

Reflect the R&D to study towards final disposal of the removed soil outside Fukushima Prefecture

< 5year plan for technology development FY2015 – 2020 >

Item		FY2015	FY2016	FY2017	FY2018	FY2019	After 2020
Strategic plan for technical development		Study on overall strategy	Refinement of overall strategy, review on progress, and revise of the strategy (FY2016 – FY2020)				
R&D verification	Directly managed by the government	Various evaluation on classification technology and modeled material utilization for low radioactive concentrated products More advanced technology for classification, chemical & heat treatment of soil, volume reduction, volume reduction of incinerated ash will sequentially be implemented (FY2015 – FY2020)					
	Open bidding	Demonstration model project for volume reduction and decontamination (bench-scaled model demonstration and evaluation will be implemented possible for future use) (FY2015 – FY2020)					
R&D to promote recycling		Study on quality demand and safety evaluation method for recycling Establish a guideline for recycling (FY2015 – FY2016)					
			Summarize and review measures for recycling promotion Demonstration model project for quality demand and safety evaluation (FY2016 – FY2020)				

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Thank you for your attention！
ありがとう

Measures of MOEJ are shown on the web-site below and are revised time to time:

http://josen.env.go.jp/en/decontamination/

http://josen.env.go.jp/en/storage/

If you have any questions, please contact me at following address:

KIYOHIKO_EINO@env.go.jp

環境省
Ministry of the Environment

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Office of Research and Development

Homeland Security Research Program

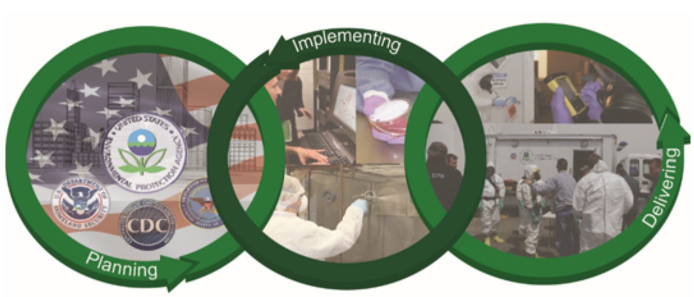
Research Supporting the Development of Capabilities for Environmental Remediation for Chemical, Biological, and Radiological Contaminants

Shawn P. Ryan, Ph.D.
National Homeland Security Research Center

EPA ORD's Homeland Security Research Program 2

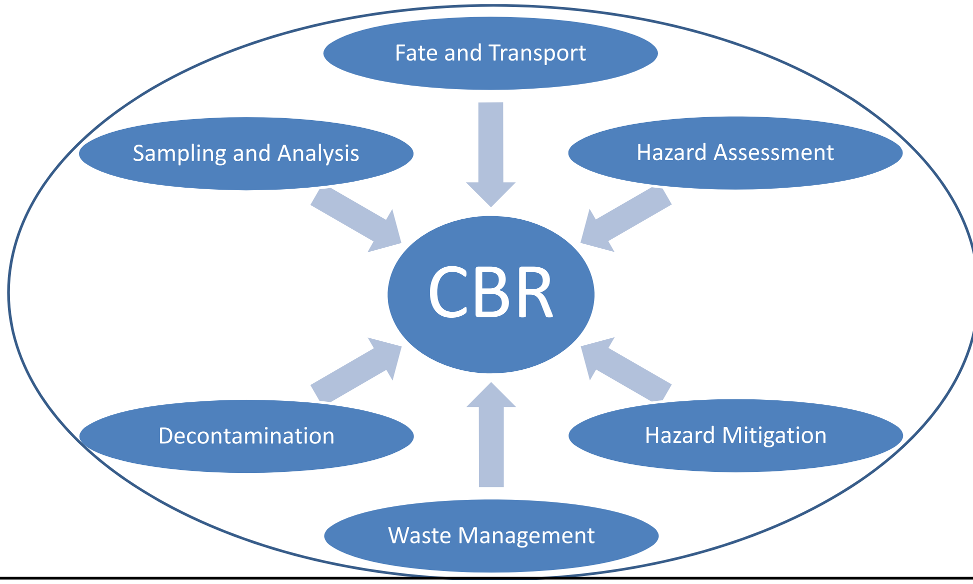
Homeland Security Research Objectives

- ***Mission: to conduct research and develop scientific products that improve the capability of the Agency to carry out its homeland security responsibilities***
- Advance EPA's capabilities to respond to wide-area contamination incidents
- Improve water utilities' abilities to prepare for and respond to incidents that threaten public health



EPA ORD's Homeland Security Research Program 3

HSRP Core Mission



EPA ORD's Homeland Security Research Program 4

Fate and Transport Research

- Fate - Interactions with environment?
- Transport - Movement in the environment?
- Based upon the current understanding of fate and transport of biological contaminants, including reaerosolization – **how much confidence do we have in what we know and don't know?**
- **Research on chemical, biological, and radiological contaminants to inform mitigation and clean-up decisions**

EPA ORD's Homeland Security Research Program 5

Fate and Transport Research: Biological Agents

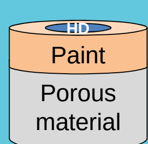
- Suitable surrogates
- Impact of temperature, humidity, sunlight, etc.
- Transport from surfaces (air and water)

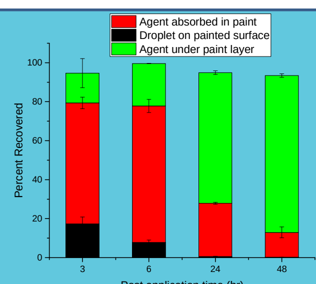
- Reaerosolization differs as a function of outdoor surface types
- Results vary greatly on how spores are deposited and spore type
- Humidity is expected to play a big role (research in progress)
- Significant data gaps identified related to human activity forces on reaerosolization

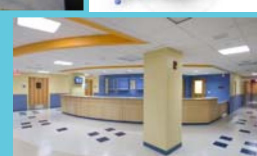
EPA ORD's Homeland Security Research Program 6

Fate and Transport Research: Chemical Agents

- Persistence on surfaces
- Penetration into materials







- Chemical agent can be absorbed into paint layer
- Chemical agent can transfer into porous material below paint
- Absorption and transfer rates are chemical agent and paint specific
- Data gaps identified related to decontamination of painted surfaces

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Fate and Transport Research: Radiological Agents

- Behavior with materials and environmental conditions
- Containment methods

- Literature review on radionuclides particle transport
- RDD particle morphology
- Laboratory studies to assess Cs subsurface penetration, sorption, and wash off by weathering
  - Study Materials: asphalt, brick, concrete, limestone, and granite
  - Cs penetrates 0.2 to 3.5 mm in a month depending on material type and RH
  - Weathering, as simulated rain, was observed to remove some Cs from the materials

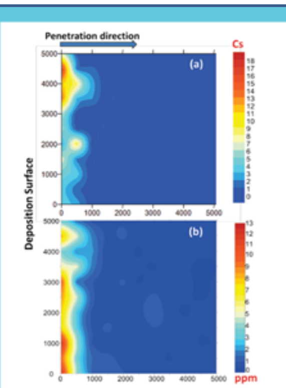

Figure 13. Concrete rain test example samples: (a) water solution sample and (b) methanol solution sample

EPA ORD's Homeland Security Research Program 8

Sampling and Analysis Research

Objective:

- Enhance our ability to characterize contaminants in a wide-area (pre- and post-decon), with less time and resources, and increased accuracy and/or confidence.




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Sampling and Analysis Research

- For large incidents, current discrete sampling approaches may be too costly, time-consuming, and large sample loads may result in laboratory bottle-necks

- Composite Sampling – A promising way to increase the surface area sampled without increasing laboratory processing time, labor, and consumables.



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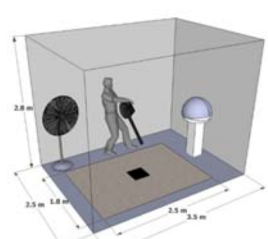
Sampling and Analysis Research

- Robotic Floor Samplers – autonomous collection of samples from large floor sections.
  - Rapid extent mapping
  - Reduced sampler personnel, reduced exposure risk to workers
  - Reduced sample numbers per area sampled

- Aggressive Air Sampling – Surface agitation coupled with air sampling
  - Estimate of inhalation exposure risk
  - Composited over large areas
  - Rapid sampling of large areas
  - Current capacity with asbestos contractors



EPA ORD's Homeland Security Research Program 11

Decontamination Research

- What clean up technologies are most effective and how are their efficacies changed by real world variations in environmental, process and agent characteristics?
- How can wide area contamination be remediated in the most cost effective and expedient way while still protecting human health and the environment?
- Research supporting understanding of:
  - Effectiveness
  - Application requirements
  - Compatibility
  - Field implementation
  - Waste management

EPA ORD's Homeland Security Research Program 12

Decontamination Research – Scale and Process

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Widely/Readily Available Solutions

- Effectiveness of commercial-off the shelf products
- Modifications or uses to improve efficacy
- Use of existing equipment, e.g., for routine cleaning
- "Self-help" methods for contamination reduction

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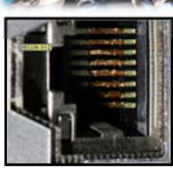
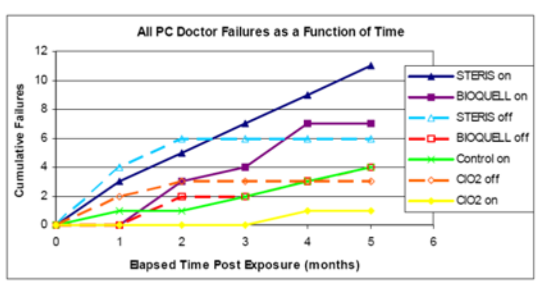
Decontamination - Material Compatibility

- Assessment of the impact of decontamination processes on materials and sensitive electronics
- Impacts waste generation and decontamination strategy development





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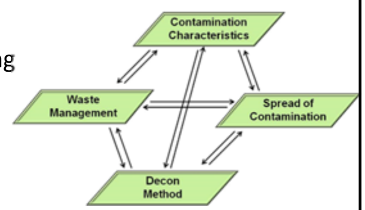
Waste Management Research: Contaminated Water and Waste

- Research to inform: Treatment, Disposal, Waste minimization, Handling
- General strategy for waste management
  - Waste management linked with decon and sampling
  - Minimize the amount of waste
  - Get waste management activities off critical path
    - *In situ* treatment
    - On-site treatment (e.g., dunking in bleach)



- Laboratory issues related to waste sampling
  - CDC's Laboratory Response Network will not take waste matrices as samples
  - No validated methods for biologicals in solid waste matrices
  - Lab capacity demands for other samples

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Waste Management Research

- Decision support tools
  - Integration of decontamination and waste management issues in a wide area response (I-WASTE & WEST)
  - Cost Estimation Tool for Wide-Area Responses (WADE)
- Ongoing R&D on persistence/ fate/ transport/ behavior of agents in treatment/ disposal processes
  - Persistence of viruses in landfill leachate (underway)
  - In situ treatment of spores in a landfill
  - Expedient approaches to on-site waste treatment (underway)
  - Best practices for waste handling and packaging
  - Developed SOP to treat *Bacillus*-contaminated wash water
  - Scalable process for on-site water treatment
  - Acceptance by Waste Water Utilities

EPA ORD's Homeland Security Research Program 17

Objective: Research to Inform Environment Response Decision Making

- **Preparation for Ebola Virus Disease Outbreak**
- **Support to Louisiana for Melioidosis cases**
- **Development of guidance and support to CDC and DoD for *B. anthracis* spores lab samples**
- Support to West Virginia in the Elk River chemical spill
- Clean-up and support of ricin incidents
- Clean-up of pesticide misuse
- US support to Japan for Fukushima clean-up

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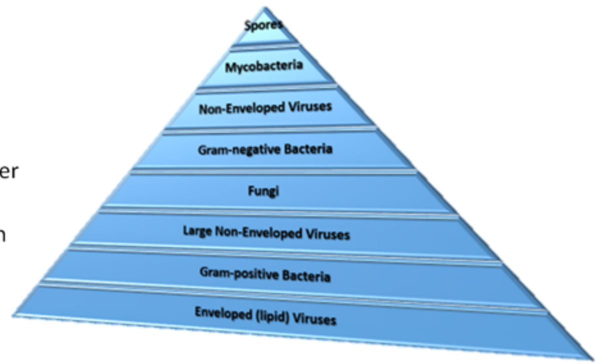
Ebola Virus Disease (EVD) Outbreak

- EVD Outbreak started in West Africa in March 2014, largest and most complex since discovery in 1976
- CDC and WHO reports 28603 cases (15216 confirmed) with 11301 deaths in Guinea, Sierra Leone, and Liberia
- Two imported cases and two locally acquired cases in the U.S.
- Heightened awareness → questions:
  - Appropriate decontamination of PPE
  - Solid and liquid waste management
  - Decontamination of environmental surfaces in patient's residence and public facilities
  - Decontamination of vehicles and equipment
- Joint EPA and CDC preparedness planning for domestic response to cases

EPA ORD's Homeland Security Research Program 19

Environmental Decontamination for Ebola Virus

- HSRP research used to develop guidance documents and training materials
  - Decontamination research on spores → other biological agents
  - Effective, but at what cost?
  - Challenge of porous materials
  - "Self help" methods
  - Reducing and treating waste
- OEM, OCSPP, NHSRC worked together to develop guidance
  - Environmental decontamination
  - PPE use and decontamination
  - Waste management
- OEM trained Regions, including NHSRC involvement



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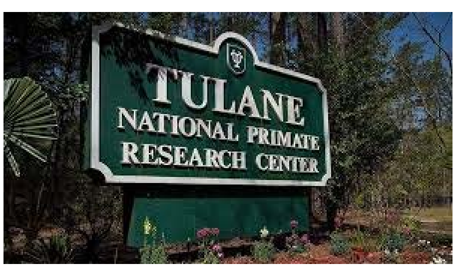
Burkholderia pseudomallei at TNPC



- Three macaques at the Tulane National Primate Center were infected with *Burkholderia pseudomallei*
- Concern for potential environmental contamination:
  - Cages including soil and gravel areas
  - Natural wetland area
- EPA consulted for advice on sampling, decontamination, and waste management plans

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HSRP Research Addressing Outdoor Remediation Applied to Burkholderia

- What are available decontamination options for outdoor areas?
- Methods for wide-scale application?
- Managing waste?
- Options to support continuity of operations?

- HSRP research on biological agents, including some work on *Burkholderia*, used to provide options
  - Soil, water, and air sampling
  - Decontamination of soil, gravel, and cages
  - On-site waste management

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DoD Anthrax Samples

- *Bacillus anthracis* samples irradiated to create killed, non-viable, "anthrax" samples
- Used by many contract, including university, labs as non-pathogenic samples (BSL-1)
- Private lab under DoD detected growth of live *B. anthracis* from an inactivated sample
- CDC consulted EPA (NHSRC) in putting together clean-up guidance for labs
  - Sensitive equipment
  - Readily and widely available methods
  - Some porous materials

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DoD Anthrax Samples

- EPA (NHSRC, OEM, OCSPP) worked with CDC to develop guidance for lab decontamination, including handling of sensitive equipment
- No suitable registered antimicrobials for use in many cases
- OCSPP granted a new/updated quarantine exemption to OSWER (OLEM) for use of antimicrobials against *B. anthracis* on environmental surfaces, citing NHSRC research publications

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Summary

- HSRP research focus on chemical, biological, radiological agents
- Responsiveness and adaptability to address challenges associated with all hazards
- Research focuses on finding solutions that are readily available and widely applicable, drastically increasing preparedness to respond

ORD's Homeland Security Research Program

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More information:

www.epa.gov/nhsrc

HSRP Leadership:

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NHSRC Division Directors:

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Tonya Nichols, Threat and Consequence Assessment, nichols.tonya@epa.gov

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EPA ORD's Homeland Security Research Program 1



DHS-EPA Toolbox of Technologies

Demonstration of Wide Area Radiological Decontamination and Mitigation Technologies for Building Structures and Vehicles

Matthew Magnuson and Sang Don Lee
National Homeland Security Research Center
Ryan James and Melissa Langton
Battelle Memorial Institute

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Wide Area, Urban Radiological Release Scenarios

- Dirty bombs, nuclear explosions, and nuclear power plant accidents can contaminate vast urban and rural areas.
- 2011 Fukushima incident contaminated an area the size of Connecticut, and the clean-up is still going on.
- If people can't get back to their homes and businesses in weeks-months, they may never return.




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Rad incident timeline

Early phase

Timeframe: less than ~72 hrs

Activities include: life safety, forensics

Personnel: mostly local responders

Cleanup phase

Timeframe: days-years

Activities include: remediation, waste management, disposition

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

Nuclear power plant accidents may be more likely, but it is important that this work apply to other rad incidents because response phases and complexities are similar.

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Need: Toolbox Technologies for Rad Response

- Many scenarios
- Response and recovery to
  - each is very different
- What happens early
  - affects what goes on later
    - Make decon harder, longer, costlier
    - End up with a lot of waste you can't easily get rid of

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Rad Response End-user Involvement

Stakeholders involved at every step through project: technology selection, research prioritization, demo design, demo observation, operational feedback

- Federal agencies: DHS (S&T, FEMA), DoS, EPA (Regions, OEM, ORCR, OSRTI, ORIA, ORD)
- State and Local responders: Ohio, New Jersey, Texas, New York, Charlotte, Columbus
- International and Tribal responders: Navajo Nation, Environment Canada, Ottawa Fire Services, UK Government Decontamination Service, Singapore, Israel
- Research institutes: national labs, universities

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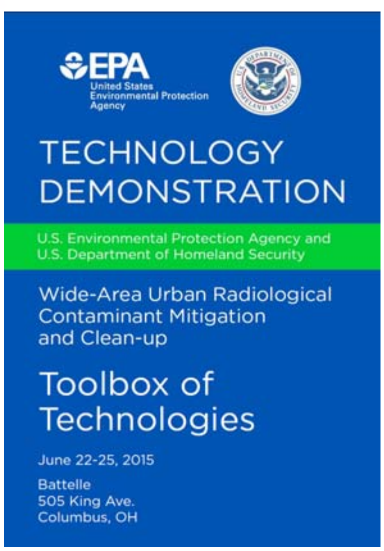

https://youtu.be/IV7N2jWm6js

- 12 technologies selected in conjunction with end-users, covering early phase to clean-up
- First demo to focus on large-scale, urban application
- Demo involved vehicles and vertical sides of buildings; also applicable to horizontal surfaces like roads, sidewalks, and tarmacs
- No live rad used. Have performance data from lab experiments with live rad

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Irreversible Wash-Aid, Treatment, and Emergency Reuse System (IWATERS)

- For both mobile and immobile radionuclides--at the same time
- Developed by DOD/TSWG, EPA, and Argonne National Lab
- Demonstrated by washing building and response vehicle inside berm
- Demonstrated system for on-site water containment treatment/reuse

https://youtu.be/_UeV4BwP_eo

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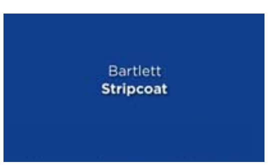
Strippable Coatings

https://youtu.be/5R0H6_X0UcE



https://youtu.be/ZXq7Q3wD6lc

Gel

https://youtu.be/tA0fwSFhWKA

Foams

https://youtu.be/D9k74P06EW0

https://youtu.be/MQnwmAvbNzU

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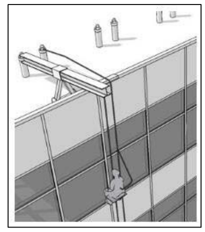
Bosan Chair Application

- Can techniques from window washing industry be applied?
- Bosan chair application is proof of concept application (not a usual method for applying these products)

https://youtu.be/NyMclLzmNv4



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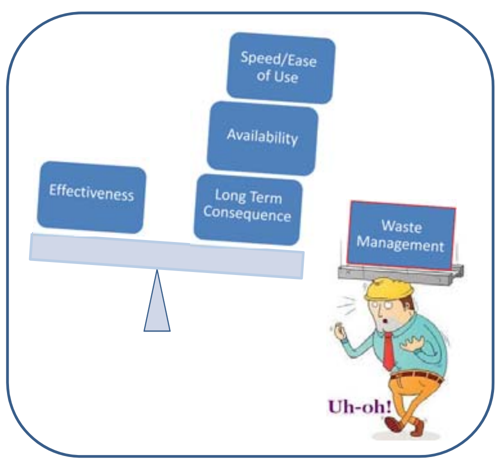
Demonstration Report

- Provides data for responders to support "balance" during planning and implementation
- Reviewed by observers of demonstration
- Includes stakeholder feedback



https://cfpub.epa.gov/si/si_public_file_download.cfm?p_download_id=527689

Research Transition: Lessons Learned

- Full-scale testing of technologies is imperative for understanding how they work at full-scale
- Involving end-users in both research and demonstration proved invaluable
- Operational demonstrations help transition research

Next Steps for Toolbox

- What about using other municipal and commercial equipment for early and later phase activities?
- For example, how can we operate street sweepers do help clean up but not spread around rad contaminants?
- Just started collaborative project with DHS to answer these questions and develop operating guides.

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Planning and research help balance factors for response strategies

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

USEPA Office of Research and Development

HOMELAND SECURITY RESEARCH PROGRAM

WATER, WATER EVERYWHERE: MANAGING CONTAMINATED WATER FROM CHEM-, BIO-, AND RAD-DECONTAMINATION

Hiba Ernst, Ph.D. and Matthew Magnuson, Ph.D.

2016 EPA International Decontamination Research and Development Conference
November 1, 2016

EPA

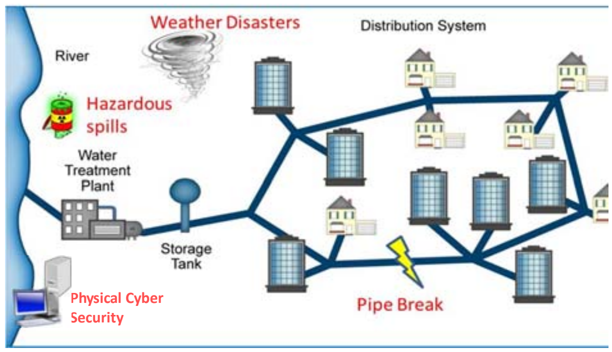
Presentation Outline

- EPA Responsibility
- How is Contaminated Water Generated?
- What to do with Contaminated Water:
  - WERF Workshops
  - Options for Treatment
- EPA Research to Support Response Capabilities

2

Water System Security and Resilience

Detection → Mitigation → Cleanup → Water Management → Resilience

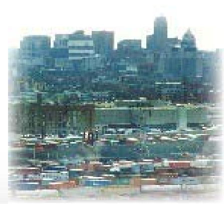
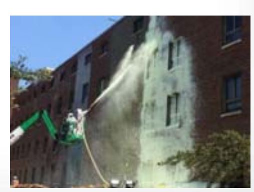


EPA is the federal government sector specific lead agency for water infrastructure protection

3

Contaminated Water: Generation

- Direct contamination of drinking water and wastewater by chemical, biological and radiological (CBR) agents
  - Intentional (e.g. terrorist attacks) and unintentional (e.g. natural disasters, industrial spills, etc.)
- Washdown activities involving CBR agents from indoor-outdoor areas
  - May include water from activities such as extinguishing industrial fires
- Runoff during precipitation events prior to or during decon activities

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Contaminated Water

How much contaminated water is generated?

Aqueous waste estimation:

- Utilize the EPA Waste Estimation Support Tool (WEST)
- Wide Area Recovery and Resiliency Program (WARRP) scenario uses the Denver Metro Area to demonstrate the WEST tool for event response
- Both scenarios (decontamination and demolition) generate significant volumes of contaminated wash water that may require special treatment or disposal.

Nearly a **Billion Gallons** of aqueous waste!

5

Contaminated Water: Example

How is contaminated water generated?

- **Recent Ebola incident**

Wash water Generation
- Contaminated water from wastewater
- Decontamination of residence, personal protective equipment, medical facilities

Risk
- Contaminated waters may pose a threat to the public through events like basement sewage backups, combined or sanitary sewer overflows
- Direct contact with contaminated waters may pose a risk for workers in wastewater collection and treatment systems

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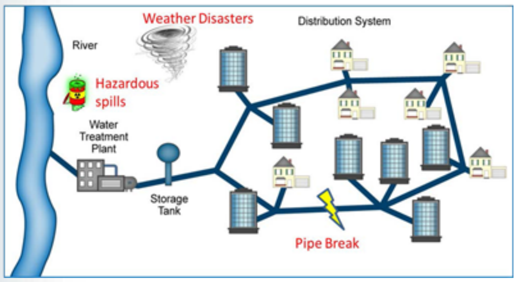
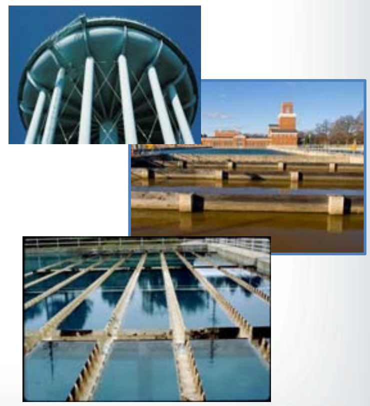
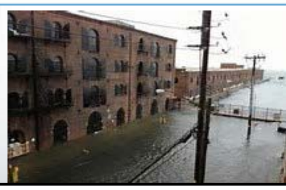
Water Contamination: Impacts

Potential Impacts of Contaminated Water

Infrastructure: drinking water plant, distribution, wastewater treatment and collection







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Contaminated Water: Impacts

- Treatment and disposal of large volumes of contaminated drinking water, wastewater and wash water
- Contaminated water may reach wastewater treatment facilities via discharge or runoff
  - Possible adverse effects on wastewater treatment processes
  - Contaminated sludge, resulting in biosolids handling and disposal issues
  - Contaminated storm water (detention/retention ponds)
- Decontamination of treatment plant infrastructure
- Safety concerns for treatment plant operators
  - Routes of transmission: inhalation/aerosols, direct contact, vectors like rats

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Contaminated Wastewater: Discharge

Discharge to Water Resource Recovery Facilities (WRRFs)

- With the WRRF's knowledge, wastewater or wash down water (treated or untreated) enters the collection system
- Direct introduction (accidentally or intentionally) into the collection system. WRRF is unaware
- Contaminants may move with wind/water for weeks, and enter collection systems/WRRFs.

http://cfpub.epa.gov/si/si_public_file_download.cfm?p_download_id=525143

It may not be a conscious decision "if" WRRFs should allow the contaminant to enter the system, but rather, what to do "now that it is in the system"

9

WERF Workshops

Workshops

- Led by WERF to understand industry concerns related to acceptance of contaminated water by Water Resource Recovery Facilities (WRRFs):
  - AOP-treated decon water
  - Radiologically contaminated decon water
  - High consequence pathogen decon water
- Simultaneous technical goals by WRRFs include:
  - Unified, sole-source guidelines
  - Contaminant characterization
  - Worker protection from contaminants
  - Monitoring and verification of contaminant treatment
  - Protecting infrastructure, treatment processes, and receiving waters

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WERF Workshop: Bio-Contamination

Bio-Contaminant Specific Technical Goals

- Assurances that workers, treatment processes and communities will not be adversely affected
- Tools/assays/surrogates to determine infectivity, persistence and fate of contaminants
  - Determine potential threats -- other than *Bacillus anthracis*
- Planning for management
  - Shared risk between utilities and regulators
  - Relationships between responders and utility personnel
- Communication and emergency toolkits for workers, operators and the public

Second of three WERF reports related to acceptance of contaminated decon water by WWRFs.

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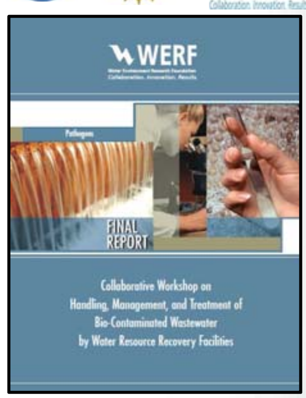
WERF Workshop: Bio-Contamination

Bio-Contaminant Specific Needed Technical Information

- Utility response planning
- State of the knowledge – *Bacillus anthracis*
- Beyond anthrax – high consequence pathogens

Research Gaps:

- Synthesis of existing data
- Survivability, persistence, fate, and viability in various media and processes
- Sampling/analysis, real time monitoring, analytical methods and technologies
- Worker exposure and risk assessments



Second of three WERF reports related to acceptance of contaminated decon water by WWRFs.

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Sampling and Analysis Research

- **Biologicals**
  - Developing methods for characterizing agents in large volumes of contaminated *wastewater*
  - Conducting single-lab verification studies of sampling and analysis protocols in *drinking water*
  - Concentration of biological agents in large volumes of contaminated wastewater
- **Chemicals**
  - Examining the applicability of drinking water methods to wastewater

31 Pathogen Analytes
25 Radiochemical Analytes
18 Biotoxin Analytes

http://www.epa.gov/sam/

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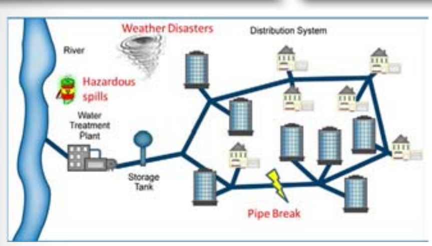
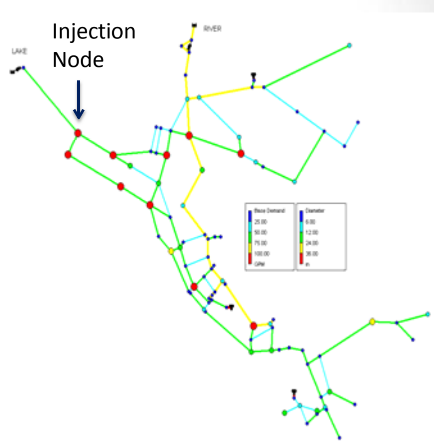
Flushing: Contaminated Water



- **WST (Water Security Toolkit)** – a hydraulic and water quality modeling, simulation and optimization software to develop response options by identifying:
  - — Possible contaminant injection locations
  - — Hydrants for flushing
  - — Locations for decontamination



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Water Management Research

NHSRC Activities

Research activities to develop and/or test:

- Chem: Toolbox of Advance Oxidation Process (AOP) pre-treatment strategies for the disposal of large volumes of contaminated water
- Rad: Integrated Wash-Aid, Treatment, and Emergency Reuse System (IWATERS) for mitigation of soluble and particulate contaminants
- Bio: Fate and transport of contaminants through activated sludge treatment plants and persistence of contaminants on infrastructure

Trailer-mounted reuse system

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Contaminated Water (Chemical): AOP Toolbox

Advanced Oxidation Processes (AOP) Toolbox of Technologies:

UV LED experiments

- Performed with methylene blue, brilliant blue FCF and tartrazine under different conditions from those utilized in other AOP experiments

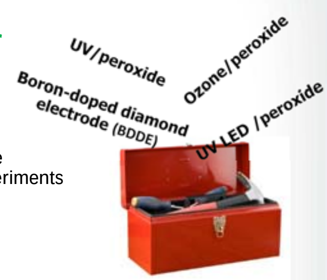
Other AOP experiments

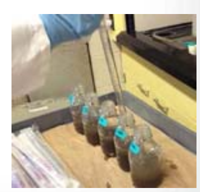
–Toxicity Tests:

- Nitrification Inhibition Test:
  - Indicates: Toxicity to wastewater biological treatment processes
- Microtox Toxicity Test:
  - Indicates: Eco-toxicity for discharge to receiving waters

–Target Contaminants (~10mg/L):

Propanil	Carbofuran
Aldicarb	Atrazine
Carbamazepine	Cyanazine
Bisphenol A (BPA)	Phenylephrine
Perfluorooctanoic Acid (PFOA)	Diethyl methyl phosphonate (DEMP)
Tris(2-chloroethyl) phosphate (TCEP)	





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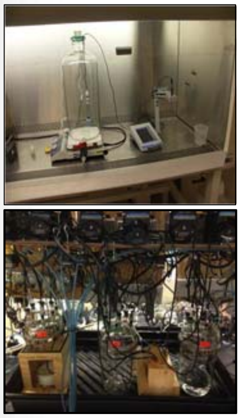
Applied Research Solutions Approach



Bench-Scale → Pilot-Scale → Full-Scale

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Treatment of Bio-contaminated Water – Bench-Scale

Bio-Contaminated Water

Developed SOP to treat *Bacillus*-contaminated wash water with chlorine bleach solutions

- *Bacillus globigii* used as a surrogate for anthrax
- Tested several wash water formulations, bleach concentrations, temperatures, pH

"Inactivation of Bacillus Spores in Decontamination Wash Down Wastewater Using Chlorine Bleach Solution," Can. J. Civ. Eng., vol. 41, 40-47, 2014.

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Wastewater Research

Bench Scale: Sequencing Batch Reactors

- Examine the effect of *Bacillus globigii* (anthrax surrogate) on the activity of activated sludge
- Examine the ability of activated sludge to remove/inactivate *Bacillus globigii*

Pilot Scale: Pilot Wastewater Treatment Plant

- Examine the fate of *Bacillus globigii* in an activated sludge treatment system
  - Fate and viability of spores once in contact with sludge (Do spores pass through the plant, stick to sludge, or settle out?)
  - Effect of spores on treatment plant processes

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Contaminated Water: Pilot Scale Research

Pilot Scale WW Collection Test Bed

- Six wastewater pipe loops to study pipe material
- Delivers 280 gpm (total) of non-chlorinated secondary effluent
- Monitor flow, pH, conductivity and persistence of *B. globigii* spores

Soil Columns for Land Applied Sludge

- Fate and transport of contaminants in the soil column below land applied sludge
- Two Columns: 30 ft tall and 10 ft tall
- 16 in diameter PVC pipe soil columns, pressurizable to 50 ft of water, with sampling ports along height

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Full-Scale: Water Security Test Bed

How will tested technologies perform in full-scale systems?

Water Security Test Bed:

- Simulates intentional and inadvertent distribution system contamination (chem, bio, rad) and disruptions (cyber-attacks)
- Supports diverse applied research
- Located at Idaho National Lab (INL) (near Idaho Falls, Idaho)

Water Security Test Bed Video: https://youtu.be/olCs_kbegBA

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; 1" Cu service line to building
- 15' pipe material coupon section for sampling the interior of the pipe surface
- Above ground system, underlined by secondary containment
- 28,000 gallon lagoon/high rate groundwater pump/storage tank

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Contaminated Water: Pilot to Full Scale

Pilot to Full-Scale Demonstration of Mobile Water and Wastewater Treatment

- *Bacillus anthracis* surrogates
- Treatment systems at wastewater lagoon at Water Security Test Bed (WSTB)
- Water from pipe and environment

- Dirty bomb contaminant mitigation technology deployable within 72 hrs.
- Allow responders to continue operations
- On-site treatment to meet water demand

22

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Decontamination: Portable Treatment Technologies

Wash Water Treatment after Pipe Decontamination

Ozone and UV AOP Mobile Trailer

Granular Activated Carbon Drums

WaterStep Mobile Emergency Water Treatment System

Solstreme UV Flow Through System

Hayward Swimming Pool Chlorinator

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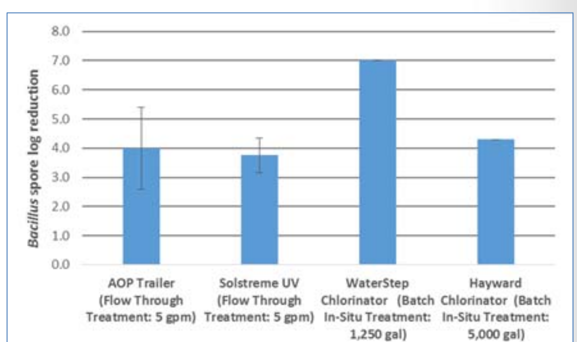
WSTB Lagoon Water Treatment

Flow Through Treatment (AOP and Solstreme)

- Disinfection began as soon as the unit was turned on
- Flow was 5 gpm for 4.5 to 5 hrs
- Variation in log reduction was observed over the course of the experiments (represented by error bars)

Batch In-Situ Treatment (WaterStep and Hayward)

- Disinfection took place in a 1,250 gal bladder (WaterStep) or 5,000 gal in the lagoon (Hayward)
- Chlorine residual increased over time in the treated volume
- Highest log reduction at the peak free chlorine concentration is reported



Search "Water Security Test Bed" at https://www.epa.gov/hsresearch for complete reports.

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Summary

- Addressing action items identified during the WERF workshops—so products are applicable to the wastewater industry and acceptable to the community
- Pilot to full-scale research for Chem, Bio, and Rad contaminated water
- Field scale demonstration of some technologies to further transition to end-users
- Continuing data/methodology development and technology demonstration
- Including cyber attacks leading to operational failure

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Thank you

EPA's Homeland Security Research Program Expands Capabilities to Treat and Dispose of Large Volumes Of CBR Contaminated Water in Ways that are Acceptable to the Community

www2.epa.gov/homeland-security-research

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NHSRC, Water Infrastructure Protection Division
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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.

Exceptional service in the national interest

Sandia National Laboratories

Fumigation of a Subway Railcar using Methyl Bromide to inactivate Bacillus anthracis Sterne

Jasper (Joe) Hardesty, PhD
Sandia National Laboratories

SAND #2016-542694

Sandia National Laboratories is a multi-mission laboratory managed and operated by Sandia Corporation, a wholly owned subsidiary of Lockheed Martin Corporation, for the U.S. Department of Energy's National Nuclear Security Administration under contract DE-AC04-94AL85000.

Sources: 1),3), "Building a Better BART: Investing in the Future of the Bay Area's Rapid Transit System, Oct. 2014; https://www.bart.gov/sites/default/files/docs/Executive%20Summary%20Building%20a%20Better%20BART.pdf ; 2) Wikimedia Commons; https://en.wikipedia.org/wiki/Washington_Metro#/media/File:Gallery_Pl-Chinatown_Upper_Level_January_28,_2010.jpg

Underground Transport Restoration (UTR) Project

- Objective:
  - Improve capabilities and 'toolset' for *faster recovery* of subway systems contaminated by a biological agent
  - *Infrastructure resilience*
- Rationale:
  - Subways are targets
  - Large regional and national impacts
  - Challenging operational environment
  - Recovery planning is uncommon

- Scope:
  - Deliver comprehensive guidance to decrease time to return a subway system to service
  - Field-test decontamination and isolation techniques
  - Reduce burden on lab network
  - Earlier start of decontamination
- Partners:
  - Multiple Transit Authorities
  - National Labs: SNL, LLNL, ANL
  - MIT Lincoln Labs
  - EPA
  - University of Florida (Rudi Scheffrahn group for railcar test)

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Rolling Stock (railcars) in Subway Systems

- Subway #s (*approximate*):
  - Los Angeles/LA Metro
    - 100 cars @ $4.3M/car ~ $0.4B
  - Atlanta/MARTA
    - 330 cars @ $3M/car ~ $1.0B
  - Boston/MBTA
    - 570 cars @ $2M/car ~ $1.14B
  - Chicago/CTA
    - 714 cars @ $2.8M/car ~ $2.0B
  - Washington DC/WMATA
    - 1,130 cars @ $2.8M/car ~ $3.2B
  - San Francisco/BART
    - 770 cars @ $4.8M/car ~ $3.7B
  - New York City/MTA
    - 6,407 cars @ $2M/car ~ $12.8B
    - One major facility ~1,000 cars

Source: Wikimedia Commons; https://commons.wikimedia.org/wiki/File:Corona_Yard_jeh.JPG

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Rolling Stock Decon Method Criteria

- Factors and Goals:
  - material compatibility, corrosion/damage
  - no damage to systems and controls
  - exposure/efficacy factors: dirt and grime, 'hidden' spaces
  - availability (decon agent, equipment, workforce, logistics)
  - cost
  - decon inside and outside of railcar
  - minimize concentration and time (rapid recovery)
  - capable of scaling up
  - capture of decon agent
  - waste minimization
- Decon Method Selection:
  - selection matrix
    - 100+ reference studies
    - 47+ applications evaluated
    - fumigants vs sprays/foams, etc.
  - match to 'goals'
  - history of use
  - availability & cost

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Rolling Stock Decon Method Selection

- Methyl Bromide selection:
  - match to 'goals'
    - material compatibility
    - systems and controls damage
    - exposure/efficacy factors
    - availability and cost
    - decon inside and outside of railcar
    - minimize concentration and time (rapid recovery)
    - capable of scaling up
    - capture of decon agent
    - waste minimization
  - history of use
    - agriculture; soil,
    - silos, buildings; hidden spaces
    - transport (trains, buses)
  - prior tests with *Ba* surrogates, e.g.:
    - combined lab/structural tests (2003)
    - Hurricane House test (2013)

University of Florida Hurricane House;
Davie, FL (2013)

Fumigation Test Parameters

• MeBr concentration (mg/L)	212
• Temperature (C)	27
• Time of fumigation (hrs)	48
• Relative Humidity (%)	≥75

Rolling Stock Decon Demonstration Team

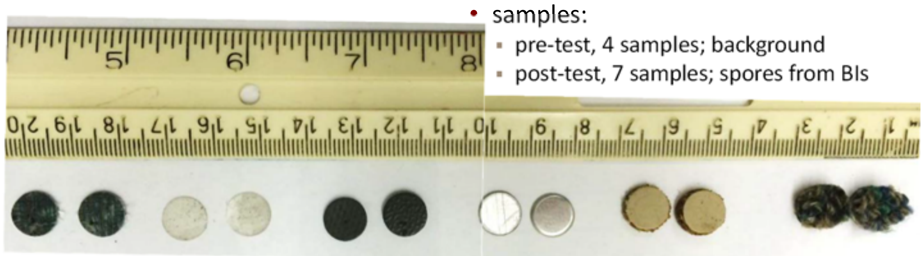
- Montreal Protocol:
  - MeBr ban since 2005; ozone depletion
  - USDA exemption for imported perishable commodities
  - Experimental Use Permit (EUP) not required:
    - proposed use is not likely to cause unreasonable adverse effects to humans or the environment

- MeBr Test Team:
  - DHS-UTR project team guidance
  - Environmental Protection Agency
  - Sandia National Laboratories
  - Lawrence Livermore National Laboratory
  - University of Florida
    - Rudolf Scheffrahn, PI and team
  - Clark Pest
    - Steve Gerboth and team
  - subway authority partners
    - loan of switchgear for testing
    - loan of railcar

Sandia National Laboratories

Rolling Stock Decon Test Planning

- Sample coupons (BIs):
  - 6 materials from actual railcars
    - vinyl seat covering
    - Mylar® on polycarbonate
    - rubber flooring
    - aluminum
    - fiberglass paneling
    - nylon carpet
- Sample types:
  - spatial tests: overall efficacy
    - 20 locations within fumigated space
    - inside and outside railcar
    - duplicate samples
    - 40 samples each material; 240 total
  - temporal tests: efficacy vs time
    - extracted from within fumigated space
    - extracted every 6 hours (6-30 hrs)
    - 10 samples each material; 60 total
  - samples:
    - pre-test, 4 samples; background
    - post-test, 7 samples; spores from BIs



11/11/2016 **Image:** Serre and Mickelsen; CBRN Consequence Management Division-EPA; "Subway Rolling Stock Decontamination with Methyl Bromide DRAFT Report - Fumigation of a Subway Railcar using Methyl Bromide Fumigant on Bacillus anthracis Sterne"; March 1, 2016 7

Sandia National Laboratories

Rolling Stock Decon Test Planning

- Test Location: Sandia National Labs at Livermore, CA

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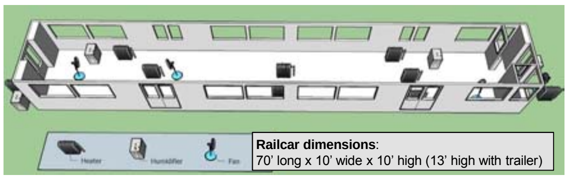
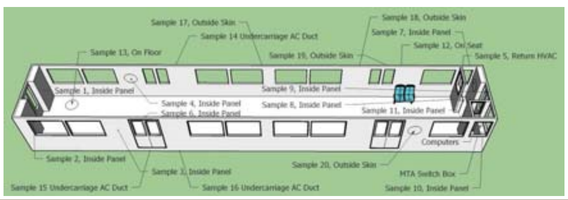
Rolling Stock Decon Test Planning

MultiRAE to monitor ambient air for MeBr leaks

Fumiscope® to Monitor Fumigation MeBr Concentrations





- Test design & layout
  - test volume ~9,750 cu.ft.
  - ethylene vinyl alcohol (EVOH) tarps
    - VIF/TIF impermeable film
  - exterior spacer
    - 4" perforated HDPE piping
  - fans and heaters
  - humidification
  - sample locations
  - monitoring:
    - temperature and RH
    - MeBr concentration
    - ambient air, exposure
  - MeBr delivery
  - displacement balloons
    - Mylar® tubes
  - MeBr capture system

11/11/2016

Images: Serre and Mickelsen; CBRN Consequence Management Division-EPA; "Subway Rolling Stock Decontamination with Methyl Bromide DRAFT Report - Fumigation of a Subway Railcar using Methyl Bromide Fumigant on Bacillus anthracis Sterne"; March 1, 2016

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Rolling Stock Decon Test

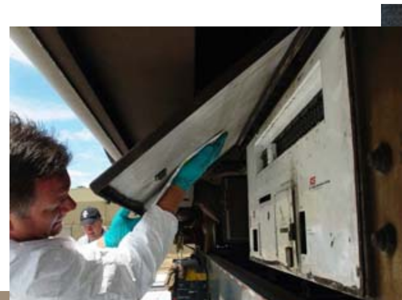
Sandia National Laboratories

- Fumigation target criteria:
  - 36 hours at:
  - 212 mg/L MeBr
  - 75 ^{o}F
  - 75% RH

- Timeline:
  - setup
  - enclosure
  - preconditioning
  - samples placement
  - fumigation
  - sample retrievals
  - capture/aeration
  - takedown
  - charcoal testing

July 2015

Sun	Mon	Tues	Wed	Thu	Fri	Sat
		Railcar Prep for Transit	1	2 Railcar Arrival to SNL	3 Railcar stored, secured	4 Independence Day
5 MeBr Team Travel	6 Mobilize at test site	7 Site Prep, Equip Setup	8	9 Tenting, VIP visit	10 Preheat, humidify; Set Samples	11 Fumigation
12 Fumi-gation	13 Scrubbing; Aeration; Retrieve Samples	14 Site Cleanup, Test Carbon; Railcar Transport Prep	15	16 Demobilize; Return Railcar	17 Travel; Temporary scrubber storage and return (~4-6 weeks)	18



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Rolling Stock Decon Test

- Time-lapse video (4 min.)

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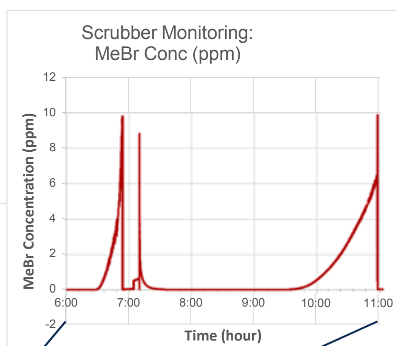
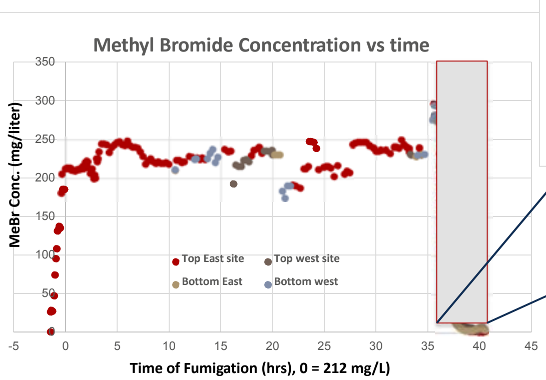
Rolling Stock Decon Test

- MeBr profiles:
  - MeBr fumigation
  - MeBr capture





11/11/2016

Source: Serre and Mickelsen; CBRN Consequence Management Division-EPA; "Subway Rolling Stock Decontamination with Methyl Bromide DRAFT Report - Fumigation of a Subway Railcar using Methyl Bromide Fumigant on Bacillus anthracis Sterne"; March 1, 2016

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Rolling Stock Decon Test: Results

Sandia National Laboratories

- **Control samples**
  - no statistically significant differences pre- and post-test

BI Coupon Type	Mean Pre-Test Spore Population	Mean Post-Test Spore Population	n
Stainless Steel	2.5×10^6	Not done	5 pre-test
Mylar®	2.3×10^6	1.6×10^6	3 pre-test, 7 post-test
Nylon Carpet	2.0×10^6	1.8×10^6	3 pre-test, 6 post-test
Rubber	2.4×10^6	2.0×10^6	3 pre-test, 7 post-test
Vinyl Seat	1.2×10^6	1.4×10^6	3 pre-test, 7 post-test
Fiberglass	1.3×10^6	1.4×10^6	3 pre-test, 7 post-test
Aluminum	2.4×10^6	2.0×10^6	3 pre-test, 5 post-test

- **Spatial controls:**
  - negative controls all no growth
  - positive controls all + growth

- **Spatial samples**

Location	Test BIs (growth-positive BIs / total BIs)						Blanks (growth+ / total BIs)
	Alum.	Carp.	Vinyl	Mylar	Rubr	Fiber	Coupons
1	0/2	0/2	0/2	0/2	0/2	0/2	0/3
2	0/2	1/2	1/2	0/2	0/2	0/2	0/3
3	0/2	0/2	0/2	0/2	0/2	0/2	0/3
4	0/2	0/2	0/2	0/2	0/2	0/2	0/3
5	0/2	0/2	0/2	0/2	0/2	0/2	0/3
6	0/2	0/2	1/2	0/2	0/2	0/2	0/3
7	0/2	0/2	1/2	0/2	0/2	0/2	0/3
8	0/2	0/2	1/2	0/2	0/2	0/2	0/3
9	0/2	0/2	0/2	0/2	0/2	0/2	0/3
10	0/2	0/2	2/2	0/2	1/2	0/2	0/3
11	0/2	0/2	0/2	0/2	0/2	0/2	0/3
12	0/2	0/2	0/2	0/2	0/2	0/2	0/3
13	0/2	0/2	0/2	0/2	0/2	0/2	0/3
14	0/2	0/2	0/2	0/2	0/2	0/2	0/3
15	0/2	0/2	1/2	0/2	0/2	0/2	0/3
16	0/2	0/2	0/2	0/2	0/2	0/2	0/3
17	0/2	0/2	0/2	0/2	0/2	0/2	0/3
18	0/2	1/2	0/2	0/2	0/2	0/2	0/3
19	0/2	0/2	0/2	1/2	0/2	0/2	0/3
20	0/2	0/2	1/2	0/2	0/2	0/2	0/3
Total	0/40	2/40	8/40	1/40	1/40	0/40	0/60
Switch Box	0/2						

Source: Serre and Mickelsen; CBRN Consequence Management Division-EPA; "Subway Rolling Stock Decontamination with Methyl Bromide DRAFT Report - Fumigation of a Subway Railcar using Methyl Bromide Fumigant on Bacillus anthracis Sterne"; March 1, 2016

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Rolling Stock Decon Test: Results

Sandia National Laboratories

Time Point (hrs)	Temporal Coupons plus Procedural Blanks Total CFU Recovered					
	Aluminum	Carpet	Vinyl	Mylar®	Rubber	Fiberglass
6	588500	603500	611000	240000	721000	532500
12	539000	494000	510500	543500	425000	347000
18	133000	186000	146000	183850	184500	164500
24	485	5300	97	1620	186	230
30	0	0	0	0	0	5

- Temporal Efficacy:
  - only fiberglass with growth after 30 hours decon treatment
    - 1 of 2 samples with 10 CFU
    - All others with no growth
  - CFU log reductions (LR):
    at 30 hours:
    - >6 LR all except fiberglass
    - ~5.5 for fiberglass
    at 24 hours:
    - >2.5 LR for all surfaces

- Swab Samples:
  - many background organisms
  - *Ba* Sterne **not** found on any of (5) pre- or (7) post-fumigation surface samples.

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Rolling Stock Decon Test: Results

- MeBr Capture System:
  - activated carbon scrubber system
  - two scrubber vessels used (1 spare required)
  - 750 pounds of activated carbon per vessel
  - blower, flexible ducting, vent stack, and fittings
- MeBr capture:
  - reduced MeBr in envelope from ~55,000 ppm to <20 ppm in 5 hours.

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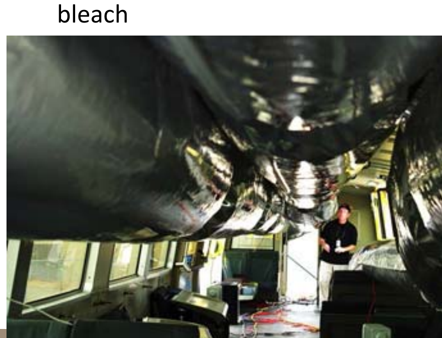
Rolling Stock Decon Test: Recommendations and Lessons

- Revised recommendations:
  - MeBr fumigation:
    - Conc = 212 mg/L MeBr
    - **Time = 48 hours**
    - Temp = 75 ^{o}F
    - RH = 75%
  - may pre-or post-treat porous surfaces (seats) with pH-amended bleach



- Lessons learned:
  - volume displacement
    - heat-seal seams of Mylar® tubing
  - EVOH enclosure performed well – can improve with better sealing at seams (~10% loss from seams)
  - have adequate backup power
  - exhaust ventilation for post-decon:
    - provide adequate makeup ventilation
    - centralize location of exhaust with vent ports at both ends of enclosure

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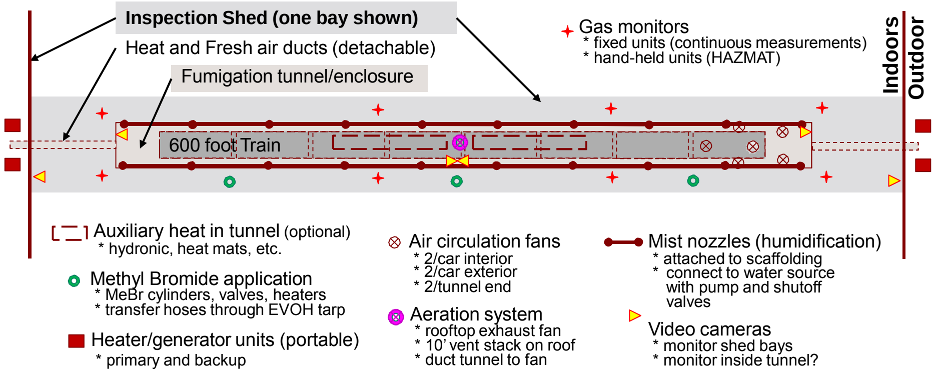
Sandia National Laboratories

Rolling Stock Decon Test: Scale-up Recommendations

- Scaling up:
  - whole train decon example
  - single bay shown, assume multiple bays in use
  - estimate ~112 hours per pre-treat/treat/aerate cycle



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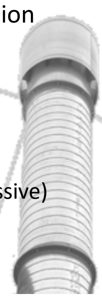
Sandia National Laboratories

Next Steps and Issues

- MeBr Buffer Zones:
  - during treatment and aeration
  - factors in calculations:
    - volume
    - MeBr application rate
    - treatment time
    - retention rate
    - aeration method (active/passive)
    - aeration time
    - vent stack type and height
    - vent/air exchange rate
  - can apply 20-60% reduction with EVOH tarps



- MeBr capture/neutralization:
  - activated carbon scrubbers?
  - catalytic neutralization/capture?

- MeBr fumigation expertise:
  - less MeBr use from Montreal Protocol = lost expertise?
- Response time & capacity:
  - erection of envelopes, humidification, heating, ventilation, capture systems?
- Transit authority facility modifications & capacity:
  - capacity to adapt existing yards and buildings?
  - decon of facilities and restoring to normal function
  - phased return to service requires functional transit facilities to maintain system

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Thank You!

- **Mark D. Tucker**; Sandia National Laboratories, Chemical & Biological Systems; Albuquerque, NM
- **Rudolf H. Scheffrahn**; University of Florida, UF/IFAS Fort Lauderdale Research and Education Center; Davie, FL
- **Shannon D. Serre and Leroy Mickelsen**;
  - US EPA Office of Land and Emergency Management/CBRN Consequence Management Advisory Division; Research Triangle Park, NC
- **Robert Fischer and Hank Khan**; Lawrence Livermore National Laboratory,

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United States Environmental Protection Agency

2016 U.S. EPA International Decontamination Research and Development Conference

Wednesday, November 2, 2016

General Session 2

Chemical, Biological, and Radiological Research Efforts

2016 EPA International Decontamination Research and Development Conference

Research Triangle Park, NC November 2, 2016

EPA's Selected Analytical Methods for Environmental Remediation and Recovery

Romy Campisano
Threat and Consequence Assessment Division
National Homeland Security Research Center

1

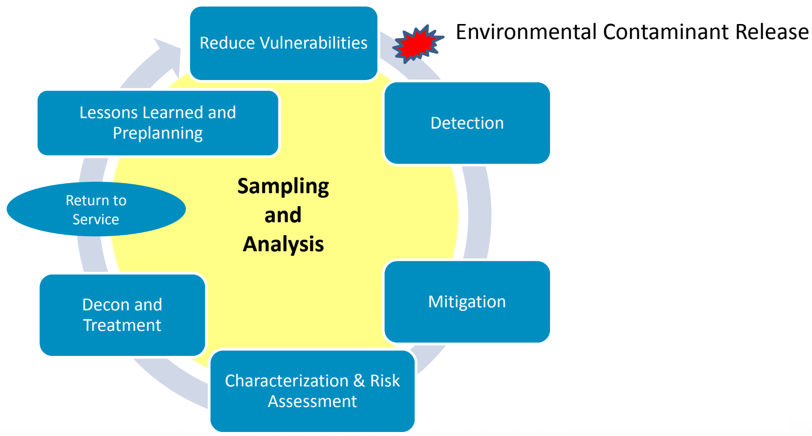
EPA

Outline

- Background and introduction
- Website demonstration
- Upcoming revision in 2017

2

Incident and Response Cycle



3

Impact of Selected Analytical Methods

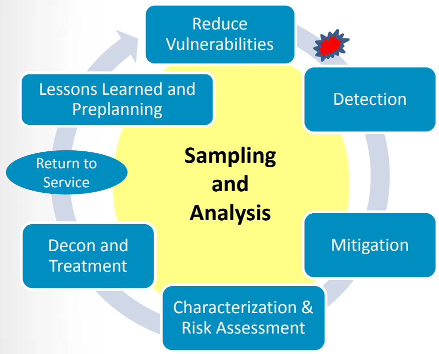
Identifies a single, selected method for each analyte/sample type pairing. Using the same set of methods would:

- Permit sharing of sample load between laboratories
- Potentially increase the speed of analysis
- Improve data comparability
- Simplify outsourcing analytical support

4

EPA

Supporting EPA laboratories



ERLN
Environmental Response Laboratory Network

WLA
Water Laboratory Alliance

NAREL
National Analytical Radiological Environmental Laboratory

5

EPA

What are the Selected Analytical Methods?

Chemicals	Radiochemicals	Pathogens	Biotoxins
• 141 analytes • 5 sample types (solids, aqueous liquids, drinking water, air and wipes)	• 25 analytes • 6 sample types (drinking water, aqueous and liquid phase, soil and sediment, surface wipes, air filters, and vegetation)	• 31 analytes • 4 sample types (aerosol, particulate, drinking water, and post decontamination waste water)	• 18 analytes • 5 sample types (aerosol, solid, particulate, liquid water, and drinking water)

>1000 analyte/sample type pairings in the 2012 revision

6

EPA

How are methods chosen?

- Is there an EPA published method for measurement of the analyte in the sample type of interest?
- Is there a method that has been published by another federal agency or Voluntary Consensus Standard Body (VCSB)?
- Is there an EPA, federal or VCSB method that has been developed for measurement of the analyte in another environmental sample type?
- Are there procedures described and supported by data in a peer-reviewed journal article?
- Are there methods that measure analytes similar to the analyte of concern?

EPA

NIOSH

ASTM

7

EPA

How to assess quality and confidence in selected methods?

Chemistry Applicability Tier I	**Analyte/sample type is a target of the method.** Multi-laboratory evaluated will allow implementation for the analyte/sample type with no modifications.
Chemistry Applicability Tier II	**Method has been used by laboratories to address the analyte/sample type, but not multi-lab validated.** (1) The analyte/sample type is a target of the method, or (2) the analyte/sample type is not a target of the method, but has been used with this method.
Chemistry Applicability Tier III	**Analyte/sample type is not a target of the method, and/or no reliable data supporting the method's fitness for its intended use are available.**

Adapted for Pathogen and Biotoxin sections in 2017.

8

Tier assignments

Analyte(s)	CAS RN	Determinative Technique	Method Type	Solid Samples		Aqueous Liquid Samples		Drinking Water Samples		Air Samples		Wipes	
Acephate	30560-19-1	LC-MS-MS	Sample Prep	Adapted from J. Chromatogr. A, (2007) 1154(1): 3-25	II	Adapted from Chromatographia, 63(5/6): 233-237	II	538 (EPA OW)	I	Adapted from J. Chromatogr. A, (2007) 1154(1): 3-25	III	Adapted from J. Chromatogr. A, (2007) 1154(1): 3-25	III
			Determinative										
Acrylamide	79-06-1	HPLC	Sample Prep	Water extraction	III	8316 (EPA SW-846)	II	8316 (EPA SW-846)	II	PV2004 (OSHA)	I	3570/8290A Appendix A (EPA SW-846)	III
			Determinative	8316 (EPA SW-846)								8316 (EPA SW-846)	
Acrylonitrile	107-13-1	HPLC / GC-MS	Sample Prep	5035A (EPA SW-846)	II	524.2 (EPA OW)	II	524.2 (EPA OW)	II	PV2004 (OSHA)	III	3570/8290A Appendix A (EPA SW-846)	III
			Determinative	8260C (EPA SW-846)								8260C (EPA SW-846)	
Aldicarb (Temik)	116-06-3	HPLC	Sample Prep	8318A (EPA SW-846)	II	D7645-10 (ASTM)	II	531.2 (EPA OW)	I	5601 (NIOSH)	I	3570/8290A Appendix A (EPA SW-846)	III
			Determinative									8318A (EPA SW-846)	
Aldicarb sulfone	1646-88-4	HPLC	Sample Prep	8318A (EPA SW-846)	II	D7645-10 (ASTM)	II	531.2 (EPA OW)	I	5601 (NIOSH)	III	3570/8290A Appendix A (EPA SW-846)	III
			Determinative									8318A (EPA SW-846)	
Aldicarb sulfoxide	1646-87-3	HPLC	Sample Prep	8318A (EPA SW-846)	III	D7645-10 (ASTM)	II	531.2 (EPA OW)	I	5601 (NIOSH)	III	3570/8290A Appendix A (EPA SW-846)	III
			Determinative									8318A (EPA SW-846)	

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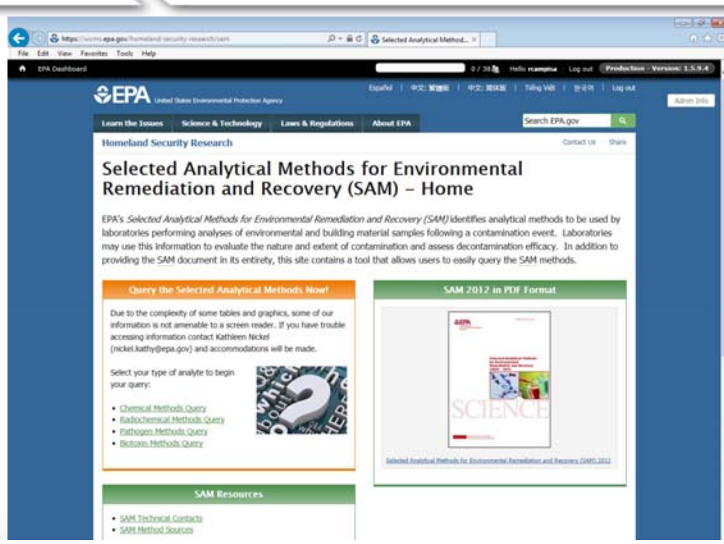
Selected Analytical Methods



http://www.epa.gov/homeland-security-research/sam/

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Search for methods on-line

Query Analyte | Query Methods

Analyte	Contains · Select an analyte
CAS RN	Exact Match · Select a CAS RN
Method	Contains · Select a Method
Method Publisher/Author	Select a Method Publisher / Author
Method Types **	☑ Include Sample Preparation ☑ Include Determinative Techniques
Determinative Techniques	Select All · Unselect All ☑ CV - Cold Vapor ☑ LC - Liquid Chromatography ☑ GC - Gas Chromatography ☑ ISE - Ion Specific Electrode ☑ GFAA - Graphite Furnace Atomic Absorption ☑ Spectrophotometry ☑ IC - Ion Chromatography ☑ TEM - Transmission Electron Microscopy ☑ ICP - Inductively Coupled Plasma
Applicable Sample Types **	Select All · Unselect All ☑ Solid Samples ☑ Aqueous Liquid Samples ☑ Drinking Water Samples ☑ Air Samples ☑ Wipe Samples

11

Query results

Chemical Analyte Query Results
(For definitions of abbreviated column headings, hold the cursor over the abbreviation.)

	Technique	Method	Prep	Det	Sol	Aq	DW	Air	Wipe
Acrylamide 79-06-1	HPLC	8316 (EPA SW-846)		✓					✓
	HPLC	8316 (EPA SW-846)	✓	✓	☑	✓	✓		
	HPLC	PV2004 (OSHA)	✓	✓				✓	
	MSE	3570 (EPA SW-846)	✓						☑
	Solvent extraction	8290A, Appendix A (EPA SW-846)	✓						☑

End of Query Results

12

Method summary

EPA Method 8316 (SW-846): Acrylamide, Acrylonitrile and Acrolein by High Performance Liquid Chromatography (HPLC)

Analyte(s)	CAS RN
Acrylamide	79-06-1

Analysis Purpose: Sample preparation and/or analyte determination and measurement

Sample Preparation Technique: Direct injection (aqueous liquid and drinking water samples), water extraction (solid), and MSE / solvent extraction by EPA SW-846 Method 3570/8290A Appendix A (wipe samples)

Determinative Technique: HPLC

Method Developed for: Acrylamide, acrylonitrile and acrolein in water samples

Method Selected for: SAM lists this method for preparation and/or analysis of solid, aqueous liquid, drinking water and wipe samples. See SAM 2012 Appendix A: Selected Chemical Methods for corresponding method usability tiers.

Detection and Quantitation: Acrylamide has an MDL of 10 µg/L; acrylonitrile has an MDL of 20 µg/L.

Method Description: Samples are analyzed by HPLC. A 200-µL aliquot is injected onto a C_{18} reverse-phase column, and compounds in the effluent are detected with a UV detector. Solid samples should be water extracted prior to injection. Aqueous liquid and drinking water samples can be directly injected.

Special Considerations: For details on method modifications allowing for the use of LC-MS-MS detection, please refer to the Points of Contact.

Source: See: EPA Method 8316 (SW-846): Acrylamide, Acrylonitrile and Acrolein by High Performance Liquid Chromatography (HPLC)

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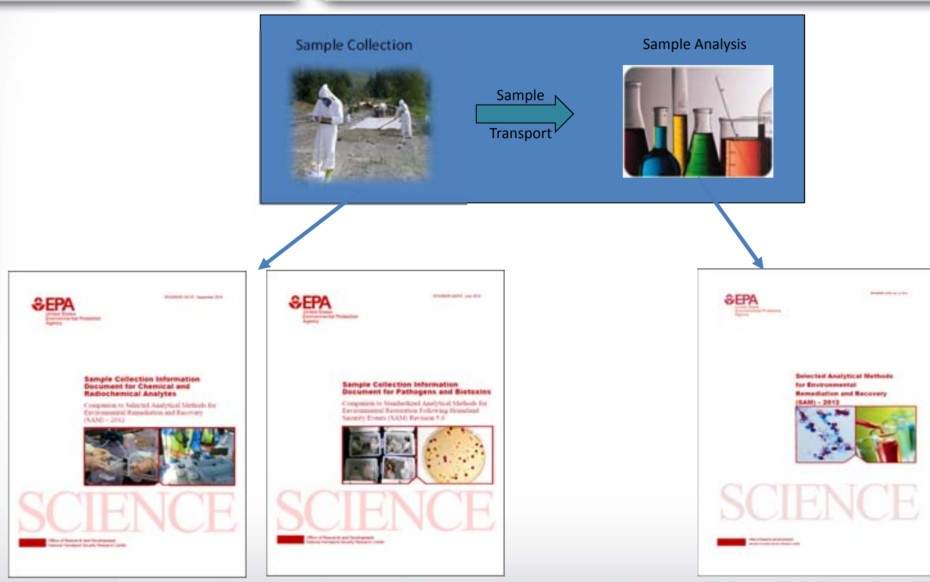
Is sample collection considered?



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Sample Collection Information Document

- **Developed to facilitate transfer of samples taken in the field to the analytical laboratory**

- **Gives details for each analyte and sample type pairing.**

Solid Samples							
Analyte	**Sample Size[1]**	**Sample Container**	**Holding Time**	**Sample Preservation or Preparation**	**Packaging Requirements**	**Shipping Label[2]**	**Source/SAM Method[3]**
Chlorfenvinphos	1 – 4 g	Wide mouth glass or PTFE container with PTFE-lined septum or lid. When PTFE-lined septa or lids are not available, solvent rinsed aluminum foil may be used as a liner.	Extract samples within 14 days of collection; analyze within 40 days of extraction.	Cool samples to ≤ 6°C and store extracts at negative (-) 10°C in the dark.	Wipe outside of each container clean using a damp, then dry cloth. Seal the container with non-reactive tape or film. Wrap glass containers with bubble wrap. Pack samples as described in Footnote (4).	Standard carrier shipping label AND Organophosphorus pesticides, solid, 6.1, Poison, UN2783	Ch. 4 / 3541 / 3545A / 8270D (EPA SW-846) [SAM Tier I]

15

Other companion documents

- **Rapid Screening and Preliminary Identification Techniques and Methods (2010)**
  - **EPA recognized that there may be situations in which laboratories receive large numbers of samples or when rapid analyses are needed to support decision making. This document partially addresses these situations by providing summary information regarding techniques, instruments, and/or methods that can be used for rapid laboratory screening of samples**

- **Laboratory Environmental Sample Disposal Information Document (2010)**
  - **This sample disposal information document provides general guidelines for use by EPA and EPA-contracted laboratories when disposing of samples and associated analytical waste following use of the analytical methods.**

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EPA

Interim updates

Updates to Selected Analytical Methods for Environmental Remediation and Recovery (SAM)

September 2014 Update:

In April 2014, EPA published five rapid methods for analysis of building materials, one rapid method for analysis of concrete and brick matrices and one rapid method for analysis of radioisotope thermoelectric generator materials. The methods should be used for qualitative analysis as follows:

Radioisotope Thermoelectric Generator Materials:

- plutonium-238
- plutonium-239

Building Materials and/or Concrete and Brick Matrices:

- americium-241
- plutonium-238
- plutonium-239
- radium-226
- strontium-89
- strontium-90
- uranium-234
- uranium-235
- uranium-238

The rapid methods are provided and summarized in the following:

1. Addendum for: Rapid Method for Sodium Hydroxide/Sodium Peroxide Fusion of Radioisotope Thermoelectric Generator Materials in Water and Air Filter Matrices Prior to Plutonium Analyses for Environmental Remediation Following Radiological Incidents
2. Addendum for: Rapid Radiochemical Method for Plutonium-238 and Plutonium-239/240 in Building Materials for Environmental Remediation Following Radiological Incidents

Related SAM Information

- SAM Home
- SAM Methods Query
- SAM Companion Documents
- SAM Updates
- SAM Abbreviations and Acronyms

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EPA

2017 revision in progress

Workgroup Leads:

Chemistry: Steve Reimer & Stuart Willison

Pathogen: Eric Rhodes & Laura Boczek

Biotoxins: Matthew Magnuson & Heath Mash

Radiochemistry: John Griggs & Kathy Hall

2017 Leads: Romy Campisano & Kathy Hall

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EPA

2017 updates

- Chemistry
  - New chemicals
  - Method updates due to new revisions of EPA methods
  - CWA included in the SCID
- Pathogens
  - New pathogens
  - Adding solids as a sample type
  - Adding method usability tiers
  - Updates for almost all methods
  - SCID updates
- Radiochemistry
  - New radiochemicals (medical uses)
  - Adding building materials as sample types
  - Building materials included in SCID
- Biotoxins
  - Adding method usability tiers
  - Updates for almost all methods
  - SCID updates

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EPA

Homeland Security Research Program

For more information:

http://www.epa.gov/homeland-security-research/sam

Romy Campisano
campisano.romy@epa.gov

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

ADVANCING OUR NATION'S SECURITY THROUGH SCIENCE

The U.S. Environmental Protection Agency through its Office of Research and Development funded collaborated in the research described here under EP-C-15-012 to CSRA. 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.

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U.S. ARMY RDECOM ARL

Basic Research for Next-Generation Decontamination Technologies

2016 EPA International Decontamination Research and Development Conference

02 November 2016

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919-549-4235

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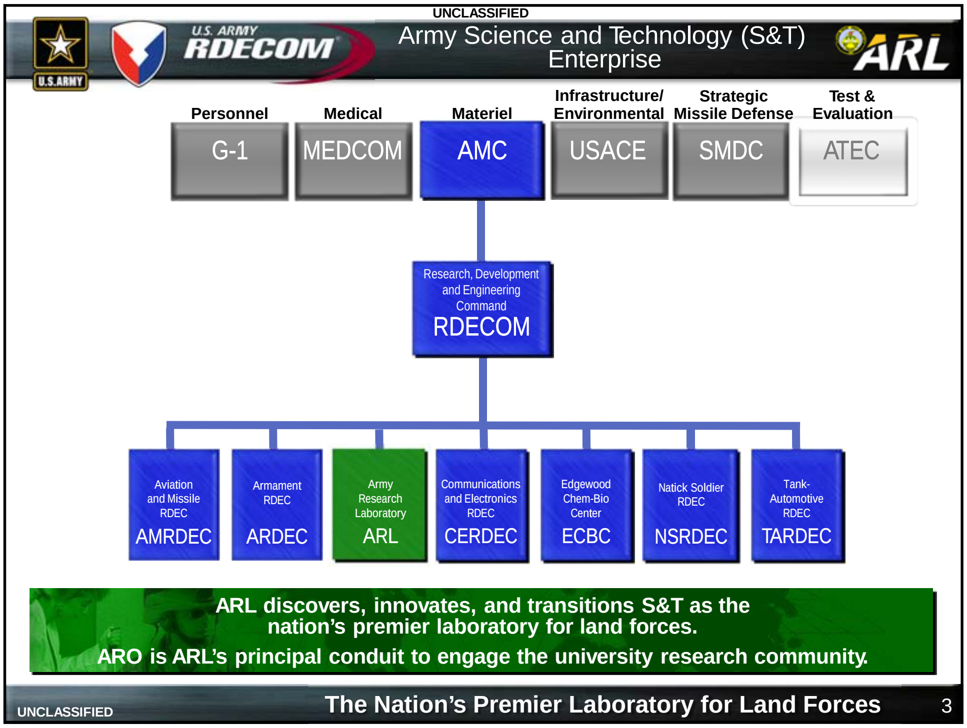
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U.S. ARMY
RDECOM
Army Science and Technology (S&T) Enterprise
ARL
Personnel
G-1
Medical
MEDCOM
Materiel
AMC
Infrastructure/ Environmental
USACE
Strategic Missile Defense
SMDC
Test & Evaluation
ATEC
Research, Development and Engineering Command
RDECOM
Aviation and Missile RDEC
AMRDEC
Armament RDEC
ARDEC
Army Research Laboratory
ARL
Communications and Electronics RDEC
CERDEC
Edgewood Chem-Bio Center
ECBC
Natick Soldier RDEC
NSRDEC
Tank-Automotive RDEC
TARDEC
ARL discovers, innovates, and transitions S&T as the nation's premier laboratory for land forces.
ARO is ARL's principal conduit to engage the university research community.
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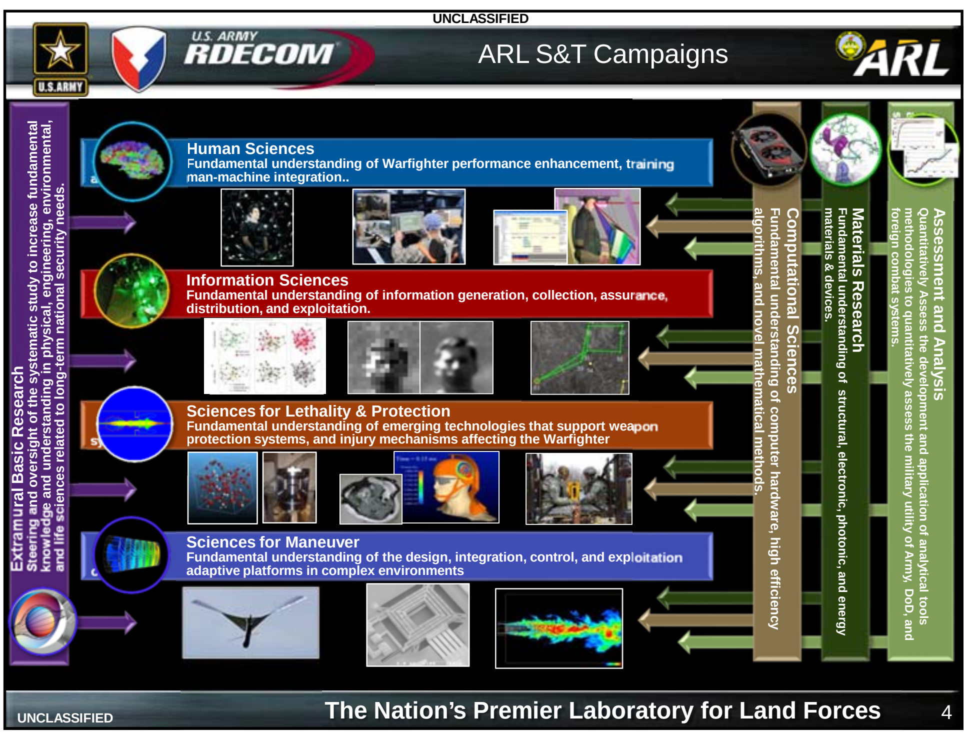
3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U.S. ARMY
RDECOM
ARL S&T Campaigns
ARL
Extramural Basic Research
Steering and oversight of the systematic study to increase fundamental knowledge and understanding in physical, engineering, environmental, and life sciences related to long-term national security needs.
Human Sciences
Fundamental understanding of Warfighter performance enhancement, training man-machine integration..
Information Sciences
Fundamental understanding of information generation, collection, assurance, distribution, and exploitation.
Sciences for Lethality & Protection
Fundamental understanding of emerging technologies that support weapon protection systems, and injury mechanisms affecting the Warfighter
Sciences for Maneuver
Fundamental understanding of the design, integration, control, and exploitation adaptive platforms in complex environments
Computational Sciences
Fundamental understanding of computer hardware, high efficiency algorithms, and novel mathematical methods.
Materials Research
Fundamental understanding of structural, electronic, photonic, and energy materials & devices.
Assessment and Analysis
Quantitatively Assess the development and application of analytical tools methodologies to quantitatively assess the military utility of Army, DoD, and foreign combat systems.
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U.S. ARMY RDECOM — ARL Open Campus — ARL

Open Campus

- Establishes a new world-class R&D and education campus for the Army
- Leverages Army resources for greater mission benefit
- Improves ARL performance by onsite R&D collaborations
  - More opportunity for technology advancement and transfer of research knowledge
  - Pursues Army education and outreach goals
  - Provides workforce development opportunities for high-tech careers
  - Attracts new staff and enhances staff retention
- Increases public involvement and understanding of defense science technology and exploration

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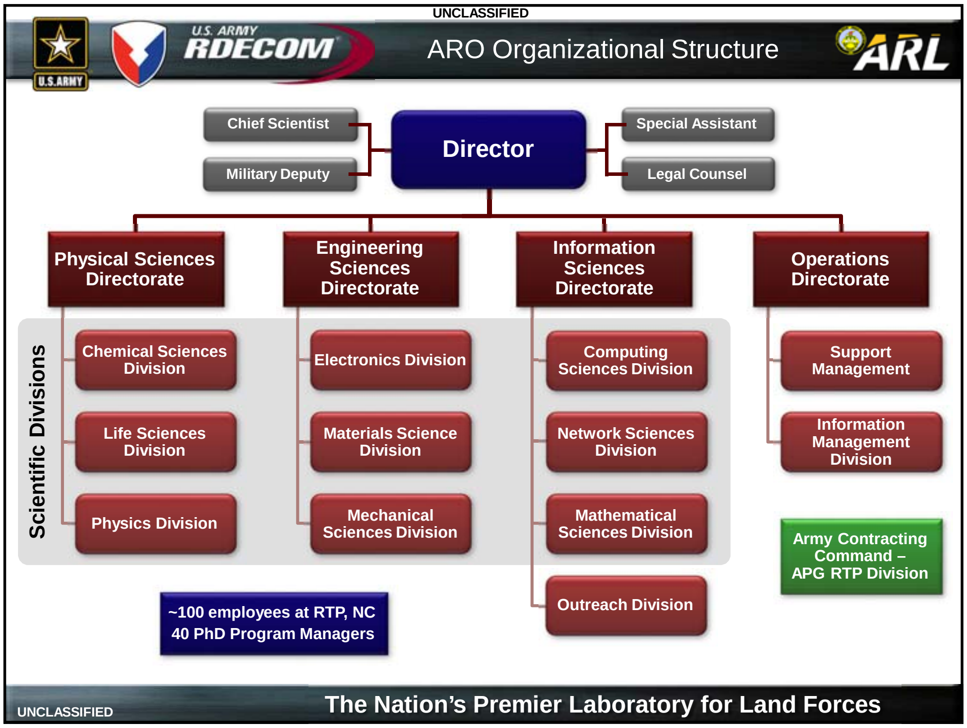
U.S. ARMY RDECOM — ARO Strategy — ARL

- 270+ Institutes of Higher Learning
- 1121 Individual Investigators
- 47 Research Centers

Utilize the vast intellectual capital of the world's universities to:

- Conceive of and exploit scientific opportunities for unimagined Army capabilities
- Drive science to develop solutions to existing Army technology needs
- Accelerate the transition of basic research
- Leverage S&T
- Create and strengthen university, industry, and government partnerships
- Prevent technological surprise
- Provide unbiased expert assessments
- Educate and train the future S&E workforce for the Army and DoD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ARO Organizational Structure
ARL
Chief Scientist
Military Deputy
Director
Special Assistant
Legal Counsel
Physical Sciences Directorate
Engineering Sciences Directorate
Information Sciences Directorate
Operations Directorate
Scientific Divisions
Chemical Sciences Division
Life Sciences Division
Physics Division
Electronics Division
Materials Science Division
Mechanical Sciences Division
Computing Sciences Division
Network Sciences Division
Mathematical Sciences Division
Outreach Division
Support Management
Information Management Division
Army Contracting Command – APG RTP Division
~100 employees at RTP, NC
40 PhD Program Managers
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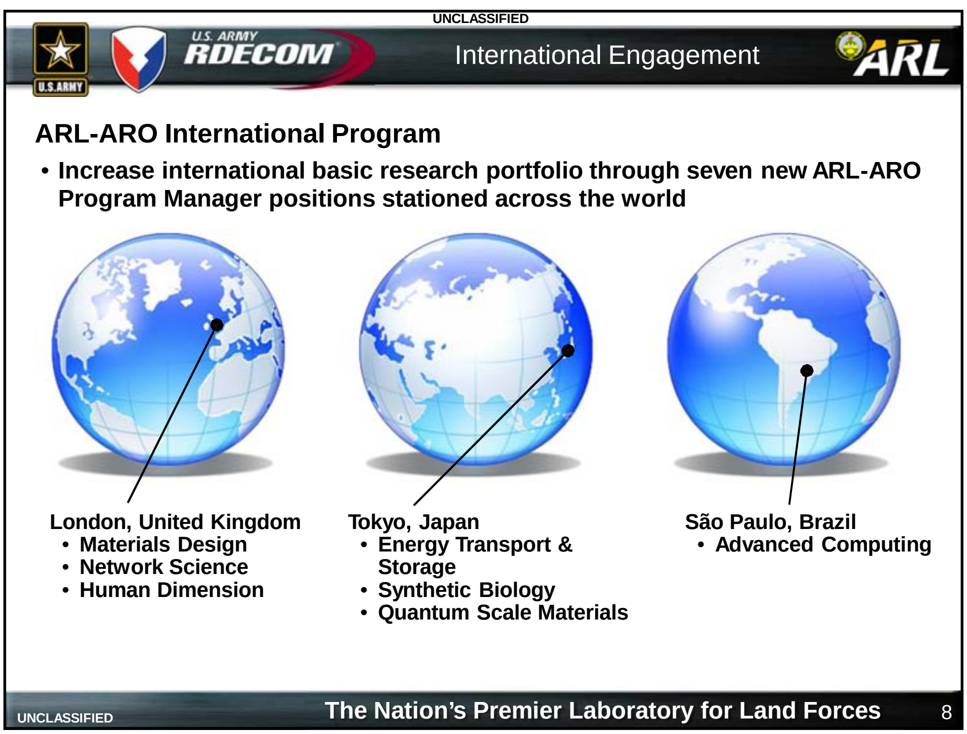
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RDECOM
International Engagement
ARL
ARL-ARO International Program
• Increase international basic research portfolio through seven new ARL-ARO Program Manager positions stationed across the world
London, United Kingdom
• Materials Design
• Network Science
• Human Dimension
Tokyo, Japan
• Energy Transport & Storage
• Synthetic Biology
• Quantum Scale Materials
São Paulo, Brazil
• Advanced Computing
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ARO and Other Broad Agency Announcements

Award Type	Target	Funding
Single Investigator (SI)	Single-laboratory projects	~$130K/year for 3 years
Short Term Innovative Research (STIR)	Very high-risk pilot projects	$50K for 9 months
Young Investigator Program (YIP)	Projects for early-career PIs	$120K/year for 3 years
Conference and Symposia	Conference, workshop and symposium support	$5-30K per award
Presidential Early Career Award for Scientists and Engineers (PECASE)	Promising future leaders	$200K/year for 5 years
Defense University Research Instrumentation Program (DURIP)	Instrumentation	~$150K per award
Multidisciplinary University Research Initiative (MURI)	Large multidisciplinary programs	~$1.25M/year for 5 years
Historically Black College/University and Minority Institution (HBCU/MI)	Minority institutions	~$120K/year for 3 years
Small Business Technology Transfer (STTR)	Multi-phase awards bridging academia and industry	$150K (6 mo.) to $1M (24 mo.)
Small Business Innovative Research (SBIR)	Multi-phase research for industry transition	$150K (6 mo) to $1M (24 mo.)

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ARO Reactive Chemical Systems Program

Dr. Dawanne Poree, Program Manager (A)

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Reactive Chemical Systems Program Vision

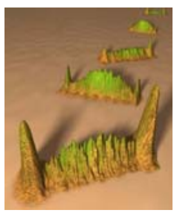
ARL

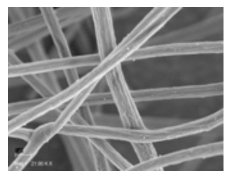
Program Vision

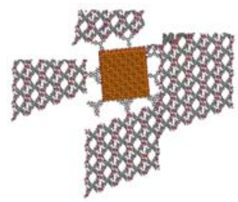
To obtain a molecular level understanding of interfacial activity and dynamic nanostructured and self-assembled chemical systems to provide unprecedented hazardous materials management capabilities and soldier survivability

Research Thrusts

- Interfacial Activity
- Synthetic Molecular Systems







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Reactive Chemical Systems Research Thrusts

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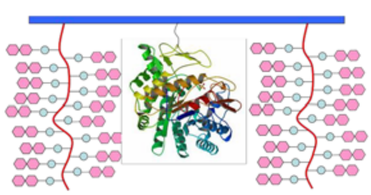
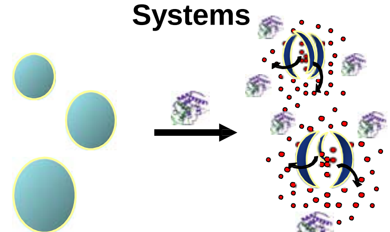
Interfacial Activity



Synthetic Molecular Systems



Kinetics and mechanisms of reactions on surfaces and at interfaces

Organization and functionality of self-assembled and supramolecular structures

Novel Materials and Processes that Enable Unprecedented Hazardous Materials Management Capabilities

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Reactive Chemical Systems Army Impact and Relevance

- Reactive materials for Solider protection
- Catalysts for hazardous materials degradation
- Multifunctional and smart materials
- Stabilization and controlled release of reactive species for hazardous material destruction
- Chemical sensors for hazardous materials

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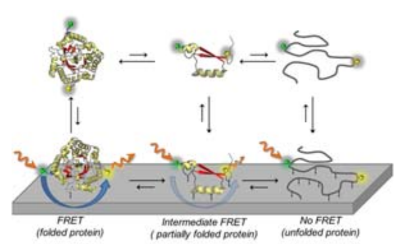
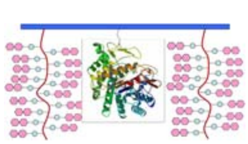
Structure/Function of Immobilized Species on Surfaces

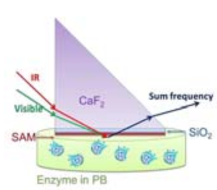
Probing Enzyme-Surface Interactions

Joel Kaar, U Colorado

Develop a novel approach to probe the structure of proteins in near-surface environments, based on site-specific labeling of enzymes with single-molecule Förster resonance energy transfer (FRET) probes







Abiotic/Biotic Interface (MURI)

Zhan Chen, U Michigan

Develop a systematic understanding of biotic/abiotic interfaces and develop design rules for "water-free" biologics

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Reactivity on Surfaces and at Interfaces

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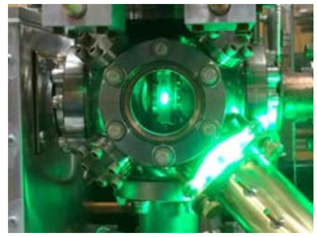
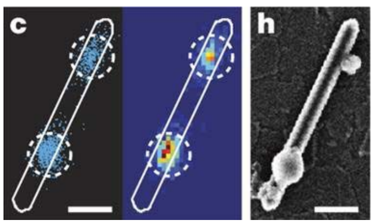
Metal Oxide Catalysts
John Morris, Virginia Tech

Develop a mechanistic understanding of activation and charge transfer that control thermal- and photocatalytic chemistry on Au/TiO_2 nanoparticles





Catalytic Behavior of Metal-Metal Interfaces
Peng Chen, Cornell

Understand interface reactivity and interface structure/composition in bimetallic nanocatalysts

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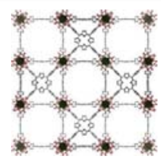
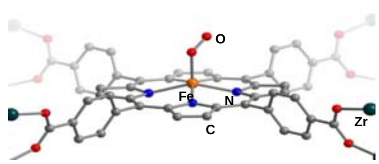
Stable, Multifunctional Catalytic Systems

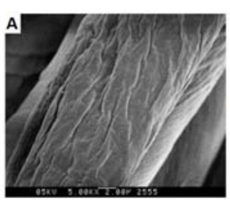
ARL

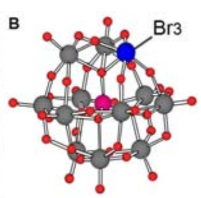
Stabilization of Reactive Species in MOFs
Dave Harris, Northwestern

Design and study porphyrin-containing MOFs for enhancing stability of highly reactive species









Highly Active Oxidation Catalysts
Craig Hill, Emory

Design and study multifunctional POM hybrid materials

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Stimuli Responsive Systems

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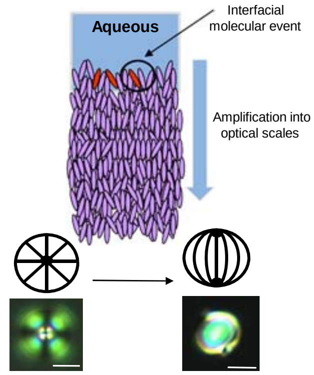
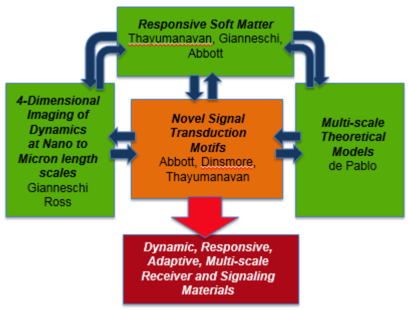
Programmable Liquid Crystal Droplets
Nathan Gianneschi, U California-San Diego
Nick Abbott, U Wisconsin

Develop principles by which targeted interfacial molecular events can trigger changes in supramolecular organization on optical scales





Triggerable Multiscale Responses in Molecular Assemblies (MURI)
Sankaran Thayumanavan, UMass-Amherst

Understand multiscale responses of adaptive systems occurring across length and time scales

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ARO Biochemistry Program

Dr. Stephanie McElhinny, Program Manager

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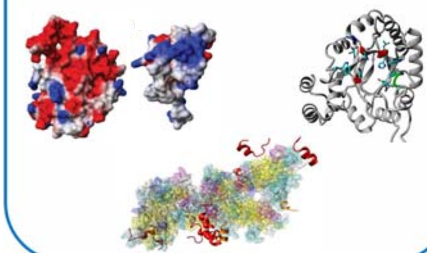
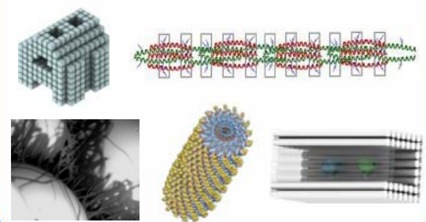
Biochemistry Research Thrusts

Biomolecular Specificity and Regulation



Characterize mechanisms of biospecificity and regulation leading to approaches to control biomolecular activity

Biomolecular Assembly and Organization



Understand how biomolecules assemble into structures/architectures that support specialized biological activity

Moving Biology Outside of the Biological Environment

Integrating biological systems with synthetic systems while maintaining or enhancing activity

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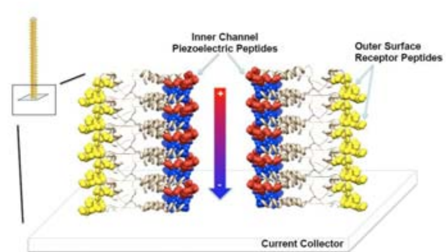
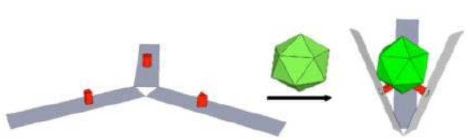
Engineering Biomolecular Assemblies for Sensing

Controlled Specificity and Assembly of Virus-Like Particles for Sensing

Jim Culver and Reza Ghodssi, U Maryland

Engineer Tobacco Mosaic Virus (TMV) virus-like particles (VLPs) as scaffolds for the display of analyte-specific receptor peptides and develop microfluidic approaches to integrate TMV VLPs into label-free transducer systems





Polyvalent, Allosteric Binding Platform for Virus Detection

Philip Lukeman, St. John's U

Synthesize and optimize a polyvalent DNA origami aptamer-displaying "claw" nanostructure that binds Norovirus with high selectivity and efficiency

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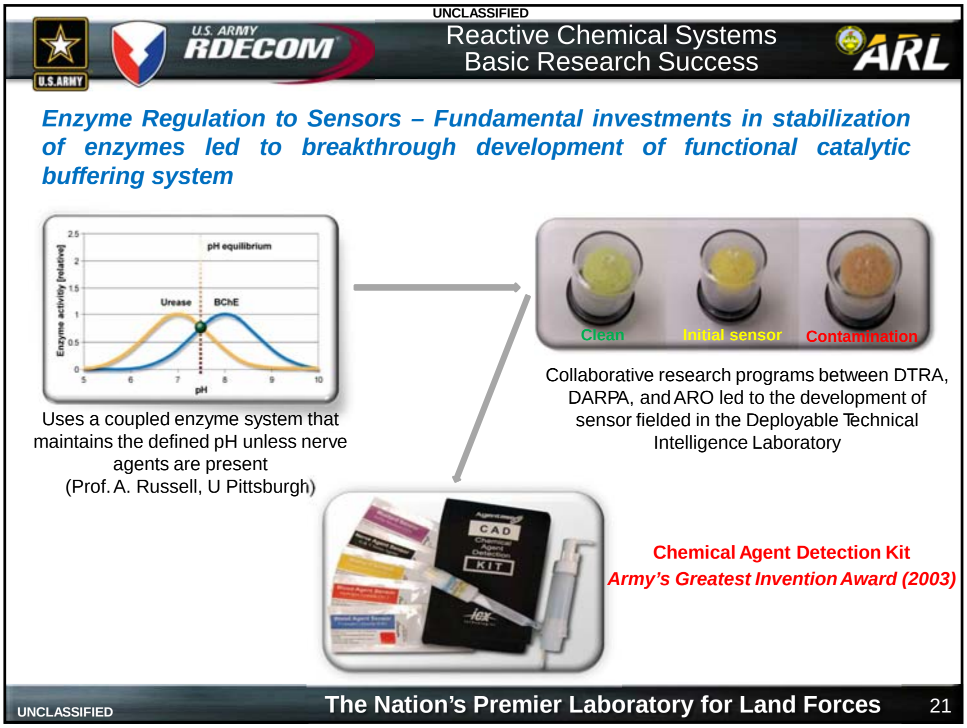
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Reactive Chemical Systems
Basic Research Success
ARL
Enzyme Regulation to Sensors – Fundamental investments in stabilization of enzymes led to breakthrough development of functional catalytic buffering system
pH equilibrium
Urease
BChE
Enzyme activity [relative]
pH
Uses a coupled enzyme system that maintains the defined pH unless nerve agents are present
(Prof. A. Russell, U Pittsburgh)
Clean
Initial sensor
Contamination
Collaborative research programs between DTRA, DARPA, and ARO led to the development of sensor fielded in the Deployable Technical Intelligence Laboratory
CAD
KIT
Chemical Agent Detection Kit
Army's Greatest Invention Award (2003)
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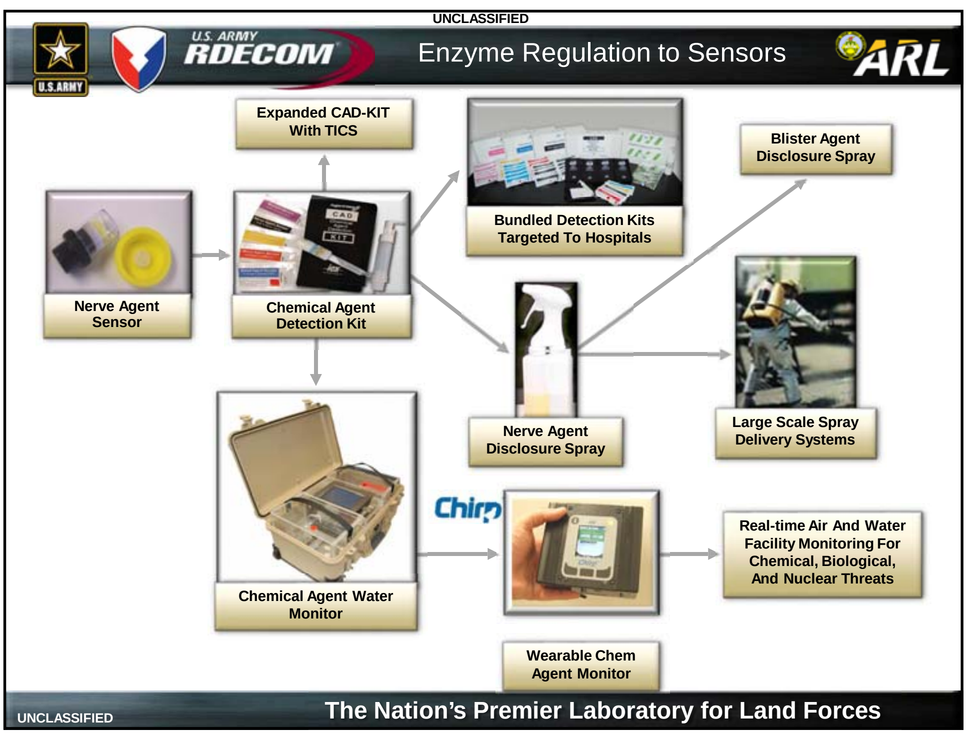
21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RDECOM
Enzyme Regulation to Sensors
ARL
Expanded CAD-KIT With TICS
Bundled Detection Kits Targeted To Hospitals
Blister Agent Disclosure Spray
Nerve Agent Sensor
Chemical Agent Detection Kit
Nerve Agent Disclosure Spray
Large Scale Spray Delivery Systems
Chemical Agent Water Monitor
Chirp
Real-time Air And Water Facility Monitoring For Chemical, Biological, And Nuclear Threats
Wearable Chem Agent Monitor
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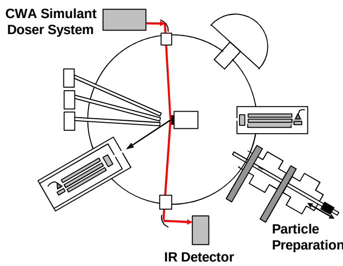
Reactive Chemical Systems Basic Research Success

ARL

Chemical Bonds to Decontaminants – Fundamental investments in chemical bonding on surfaces led to novel tools to thoroughly characterize adsorption and diffusion in new sorbents



Developed ultra-high vacuum techniques to understand reaction of simulants on surfaces (Prof. J. Yates, U Pittsburgh)

New reactive sorbent used in M295 Individual Equipment Decontamination Kit

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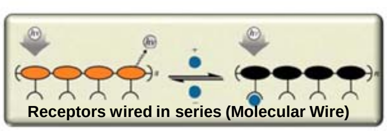
Reactive Chemical Systems Basic Research Success

ARL

Fluorescent Polymers to Sensors – Fundamental investments in amplifying fluorescent polymers led to first molecular wire with in-series receptors for signal amplification



Nitroaromatics quench AFP fluorescence in proportion to their concentration (Prof. T. Swager, MIT)

Collaborative research programs between DARPA, NVL, and ARL led to the development of an explosives detector

FIDO Explosives Detector

- **Employed in Afghanistan and Irag**
- **Army's Greatest Invention Award (2005, 2007)**
- **TSA airport version deployed (2009)**

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SBIR/STTR Program Highlights

TDA Research – Supersoap (Collaboration with P&G)

Advanced Surfactant Decontaminant, SSDX-12™

- A surfactant blend specifically designed to emulsify and lift agents from surfaces
- Non-reactive, non-corrosive, pH neutral, no-VOC, biodegradable
- High concentration (reduced shipping and storage)
- Dual use
- Commercially Available
- Non-hazardous, no DOT restrictions

Vehicle Decontaminant

Compatible with mobile vehicle decontamination platforms

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TDA Research – Supersoap (Collaboration with P&G)

ARL

Advanced Surfactant Decontaminant, SSDX-12™

Routine Aircraft Cleaner

- **Approved under:**
- U.S. Air Force MIL-PRF-87937D as a Type IV heavy duty water dilutable aerospace cleaner
- AMS 1626C Cleaner for Aircraft Exterior Surfaces
- AIRBUS AIM09-00-002 External and General Cleaners
- Boeing D6-17487 Exterior General Cleaners
- Douglas Aircraft CSD No.1 Type 1 General Cleaning of Painted and Unpainted Surfaces

Facilities Cleaner

- Industrial wastewater treatment compatible (Hill AFB)
- Prevents migration of heavy metals in aircraft maintenance facilities (Hill AFB, OSHA Expanded Standards, Cd and Cr)

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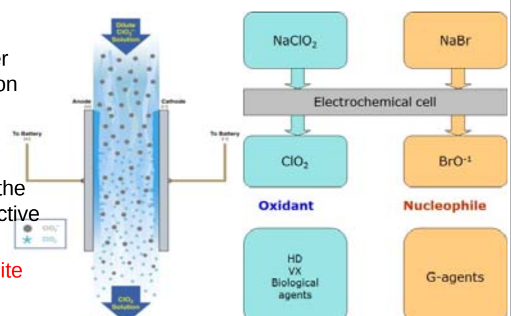
TDA Research – eClO$_2$

ARL

Immediate Chem/Bio Decontamination

- P&G brought forward a surface cleaner after the 2001 anthrax attacks for decontamination
- Potency was dialed up for chemical and biological decontamination efficacy
- Uses a miniaturized electrochemical cell in the applicator to convert a salt solution to a reactive decontaminant
  - Produces chlorine dioxide and hypobromite
- Favorable logistics
  - Solid salts are stored and shipped
  - Long shelf life
  - Combined with water on site to make starting solution
  - Decontaminant is produced as the solution is sprayed onto the contaminated surface



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U.S. ARMY RDECOM — TDA Research – $eClO_2$ — ARL

Immediate Chem/Bio Decontamination

EPA Anthrax Registration – Biological Efficacy

- The $eClO_2$ technology has been registered with the EPA under FIFRA for claims of efficacy against anthrax
- Bio-efficacy testing was performed at Dahlgren Surface Navel Warfare Center
  - **Anthrax surrogates**
  - **Virulent Anthrax**
  - **T.L. Buhr, A. Y. (2011). Decontamination of a hard surface contaminated with Bacillus anthracis delta Sterne and B. anthracis Ames spores using electrochemically generated liquid-phase chlorine dioxide (eClO2). J. App. Microbio., 111, 1057 - 1064.**
- Testing showed the ability to destroy a 7-log anthrax spore challenge within **one** minute exposure to the $eClO_2$ solution
- **U.S. EPA Reg. No. 85797-1, July 23, 2015**

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QUESTIONS / DISCUSSION

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United States
Environmental Protection
Agency

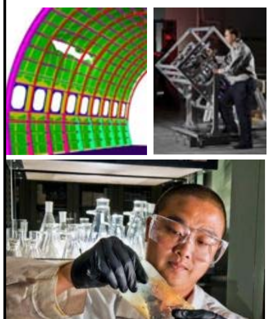
2016 U.S. EPA International Decontamination Research and Development Conference

Tuesday, November 1, 2016

Concurrent Sessions 1

Underground Transport Restoration

Sandia National Laboratories



Advances in Sampling and Situational Awareness Using Augmented and Virtual Reality Devices

Bob Knowlton, Scott Olson, &

Kurt Hollowell

U.S. DEPARTMENT OF ENERGY NNSA

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Topics

Sandia National Laboratories

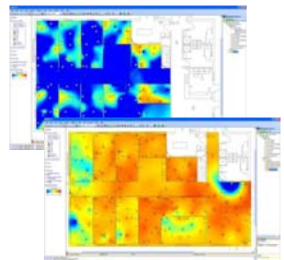
- Review of sampling practices and tools
- SESSA Capabilities
- 3D Virtual and Augmented Reality Techniques

2

Sandia National Laboratories

Sampling & Situational Awareness

- A need exists for a comprehensive decision support system to aid with sampling design, sample collection, data management, and data analysis (e.g., contamination mapping)
- This need is for chemical, biological, radiological, nuclear, explosives (CBRNE) response and recovery actions (e.g., characterization and clearance sampling), as well as forensic data gathering and sensitive site exploitation
- A comprehensive decision support system has the potential to reduce time and effort with sampling activities and data interpretation, as well as providing rapid situational awareness



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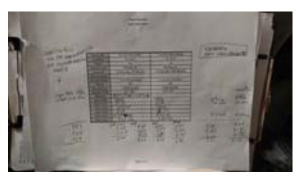
Sandia National Laboratories

Common Sampling Practices

- Traditionally, documentation of sampling activities (e.g., surface wipe sampling, air filter collection) was done with handwritten forms on a clipboard
  - Transcription errors are more prevalent with handwritten forms
  - If the sampling regime has contamination, the forms are placed in plastic sleeves and decontaminated prior to removing them from the area, possibly leading to compromises in the paper media
- More recently, the US Environmental Protection Agency (USEPA) and others have been using Apple iPads with custom forms to document the sampling process through electronic means
- With both of these protocols, the data need to be transcribed or imported into a spreadsheet or database in order to manipulate the data
- Typically, if mapping of the data is desired, a separate software package, such as a Geographical Information System, (GIS) is used



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Software for Sampling and Analysis

- As part of the Department of Homeland Security (DHS) Underground Transport Restoration (UTR) Project, the Sampling & Analysis Working Group surveyed available software to aid with sampling design, sample collection, data management and data analysis
- This summary in no way constitutes a recommendation for use of one or more of these software packages, and may not be a complete list of available systems
- In addition, each software application was evaluated against a set of need statements (e.g., WiFi enabled, GPS enabled/capable, Android/Apple/Windows operating system, mapping, GIS, SQL database, etc.)

Name of tool	Provider
Building Restoration Operations Optimization Model (BROOM)	Sandia National Laboratories (SNL)
Site Exploitation System for Situational Analysis (SESSA)	Sandia National Laboratories (SNL)
Visual Sample Plan (VSP)	Pacific Northwest National Laboratory (PNNL)
Tactical Dynamic Operational Guided Sampling (TacDOGS)	Johns Hopkins University (JHU), Applied Physics Lab (APL)
SCRIBE	U.S. Environmental Protection Agency (U.S. EPA)
EQuIS	EarthSoft
Spatial Analysis and Decision Assistance (SADA)	University of Tennessee

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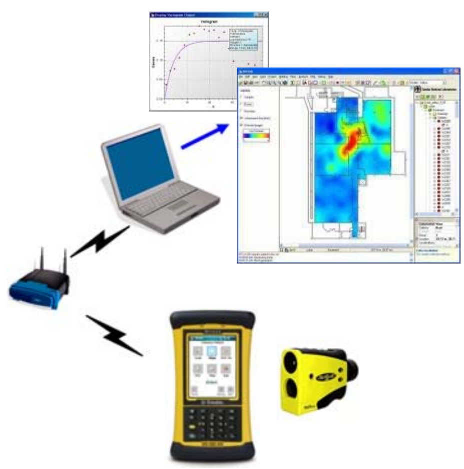
Lessons Learned From Previous Sampling Events

- Sandia National Laboratories (SNL) developed a comprehensive decision support tool called the Building Restoration Operations Optimization Model (BROOM) for the CBRNE need set, and deployed it on numerous government-sponsored release tests, logging thousands of samples
- BROOM was a comprehensive decision support tool that facilitated sampling design, data acquisition (including accurate indoor locations), real-time monitoring of personnel locations, data management, and data analysis (e.g., mapping)



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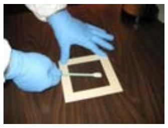
Major Projects Supporting Data Collection, Data Management, and Data Analysis

- SNL supported two separate projects at the Idaho National Laboratory (INL) for the Validated Sampling Plan Working Group (VSPWG) to address GAO (2005) concerns about sampling
  - Each of these two projects had 5 separate releases of Bg in a 2-story building, followed by characterization sampling, decontamination (with chlorine dioxide) and clearance sampling
- SNL supported the EPA's Biological Operational Test and Evaluation (BOTE) project
  - BOTE was a two-phased project, where the first phase evaluated 3 different decontamination methods and the second phase was an operational demonstration
- SNL has supported several other projects with BROOM as well
- In all, BROOM logged on the order of 8,000 samples, never losing a single sample



Surface sampling

On-site mobile lab

Sampling team

Lessons Learned From Previous Sampling Events

- Significant effort was employed on these projects to develop accurate building maps (with furniture placement) and sampling designs (with both judgmental and statistical sampling protocols)
- Accurately positioning indoor sampling locations is a significant challenge
- There was a desire to create plume maps as soon as data were available from the lab, which was done within minutes using the BROOM system
- During forensic investigations, significant effort is employed to capture scene measurements and photo documentation before any evidence is collected or samples taken
- Methods to streamline these activities are desired

SESSA

Sandia National Laboratories

- BROOM became dated, and lessons learned from it were used as the foundation for development of the SNL's Site Exploitation System for Situational Awareness (SESSA)
- SESSA's architecture has been modernized:
  - Web services module for data storage in the Cloud or a secure server, including track changes
  - Tablet computers or smart phones that facilitate scenario design, sample collection, and data analysis on Windows and Android platforms (could add iOS)
- SESSA also includes 3D Virtual Reality (VR) and Augmented Reality (AR) techniques
  - Utilizing new commercial hardware and custom software applications

SESSA (continued)

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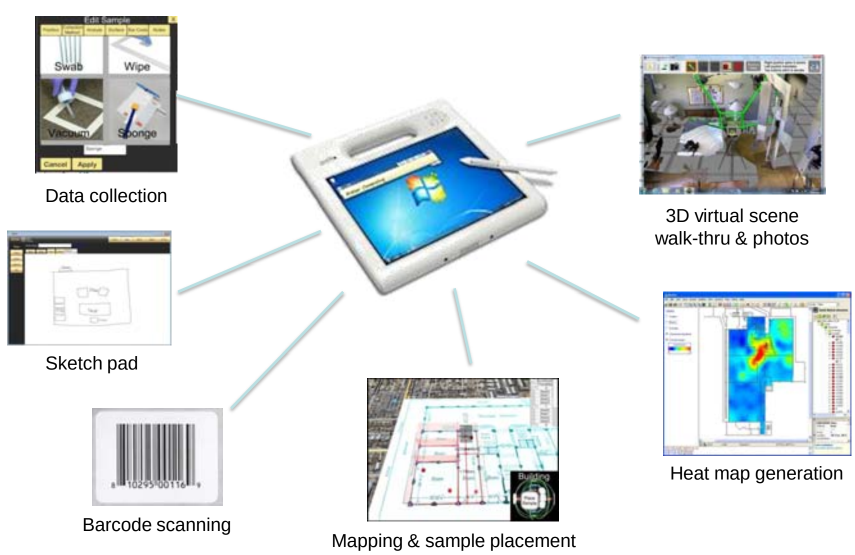
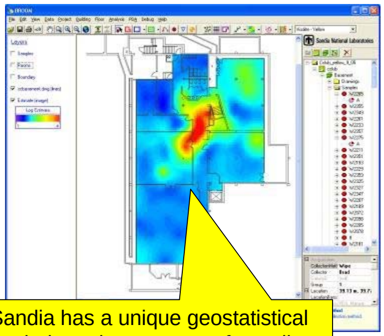


Mapping Spatial Variability

- Geostatistical methods explicitly account for spatial variability and spatial correlation of the data, traditional statistical methods do not
- These methods can quantify uncertainty and variability in the distribution of contamination
- Maps showing the probability of exceeding a specified concentration can also be made with geostatistics
- The tool can also provide contour maps using conventional contouring techniques

Expected Value Map



Sandia has a unique geostatistical technique that accounts for walls and doorways

Maps can be produced within minutes of the data uploads for real-time situational awareness

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VR & AR Capabilities

- New SESSA capabilities:
  - New hardware for virtual reality (VR) and augmented reality (AR) capabilities is truly modernizing our SESSA functionality and should revolutionize our ability to provide rapid situational awareness for first responders and decision makers
  - VR capability
    - A 3D synthetic representation of a scene (e.g., point cloud data) or computer generated imagery that can provide a virtual walk-through capability
  - AR capability
    - A wearable headset that allows the user to see his/her surroundings with holographic insertions of synthetic data

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VR Capabilities

- New VR capabilities:
  - SNL developed a prototype VR device for SESSA several years ago based around the Microsoft Kinect visual-depth sensor to capture 3D point cloud data
  - The Kinect platform provides a low-cost alternative to conventional laser-based VR scanners that cost between $45K and $100K+, and tend to be too fragile for many applications, have significant processing time, and result in large file sizes that are difficult to share remotely
  - Recently several commercial entities have developed better variants of the Kinect sensor platform
  - The DotProduct VR device was chosen for integration with SESSA, which costs ~$5,100
  - Spatial dimensioning and measurements with a 3D scan have centimeter level accuracy
  - The DotProduct device produces real-time 3D point-cloud results with manageable file sizes (e.g., 4Mb to 12Mb file for a typical office space)

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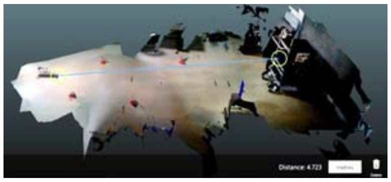
VR Capabilities

- DotProduct VR applications :
  - Mapping and measuring interior spaces, sharing that information with a Home Team or Incident Command
  - Facilitating more rapid Xray Tool Kit (XTK) explosive/radiation device scans, sharing that situational awareness with remote team members
  - Facilitating situational awareness of environmental sampling and forensic sampling, with an emphasis on sharing that information through 3D virtual walk-throughs by remote decision makers
  - Training and exercise aid



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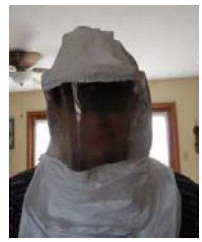
AR Capabilities

- New AR capabilities:
  - Microsoft HoloLens AR device
    - A wearable heads-up display that projects holographic information on the display
    - The headset has it's own visual-depth sensor, a CPU, data storage, Bluetooth, and WiFi
    - The device can be networked to share information with other users of HoloLens devices
    - Voice and hand-gesture controls allow users hands-free operation
    - Can be worn under Personal Protection Equipment (PPE) head gear (e.g., Powered Air Purifying Respirator (PAPR) hood)
    - Spatial dimensioning and measurements with a 3D scan have centimeter level accuracy
    - The HoloLens costs ~$3,000



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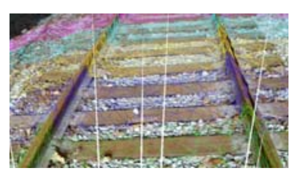
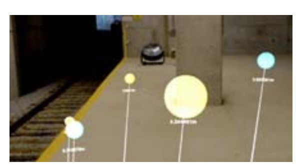
AR Capabilities

- HoloLens AR applications :
  - First responder sampling activities, including pre-defined sampling locations, documentation of sample collection, display of sampling results, sharing information in real-time between sampling teams
  - Radiation detection surveys
  - Facilitating more rapid X-ray Tool Kit (XTK) explosive/radiation device scans, sharing that situational awareness with remote team members
  - Mapping and measuring interior spaces
  - Desktop holographic display of situational awareness data (e.g., city view, building interiors, responder locations, etc.)
  - Training and exercise aid





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Indoor Geolocations

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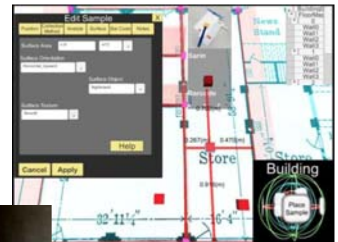
- SNL has a patented laser range finder technique that provides accurate (down to several cm) coordinates for indoor sample locations where GPS does not work
- SNL tested this method at the recent UTR Operational Test and Demonstration (OTD) venue at the Fort AP Hill mock subway
- The HoloLens and DotProduct devices were also tested at Fort AP Hill



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The Future of Sampling & Situational Analysis

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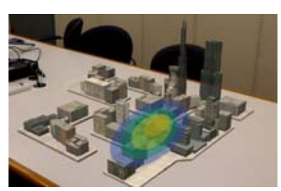
- The new VR and AR technologies offer a paradigm shift in the way we approach sampling
- One can envision the following:
  - Samplers enter a building and capture the scene with a VR device and a HoloLens, then send the scans to the Technical Working Group (TWG) and/or the Incident Command
  - A virtual walk-through is performed, sampling locations selected and input within the 3D virtual scene
  - The sampling locations are input to the HoloLens for use by the sampling teams, as well as the VR scene on tablet computers
  - Once sample results are available, plume maps are prepared and displayed in a 3D holographic projection with the HoloLens
  - The same process is proposed for clearance sampling



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Summary

- Previous experience with large-scale sampling events have shown a need for rapid situational awareness, measurement capabilities, sampling design, accurate sample locations, electronic data acquisition, data management, and data analysis
- The new VR and AR techniques have the potential to provide a paradigm shift in the way we perform these tasks by reducing time and providing greater accuracy than conventional techniques

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Sandia National Laboratories

Spray Knockdown System for Rapid Containment and Neutralization of Airborne CBW Agents

Mark D. Tucker, Andres L. Sanchez, Charles A. Brusseau, Matthew S. Tezak, Steven M. Storch, Gabriel A. Lucero, Patrick D. Burton, and Jasper O.E. Hardesty
Sandia National Laboratories

Sandia National Laboratories is a multi-program laboratory managed and operated by Sandia Corporation, a wholly owned subsidiary of Lockheed Martin Corporation, for the U.S. Department of Energy's National Nuclear Security Administration under contract DE-AC04-94AL85000.

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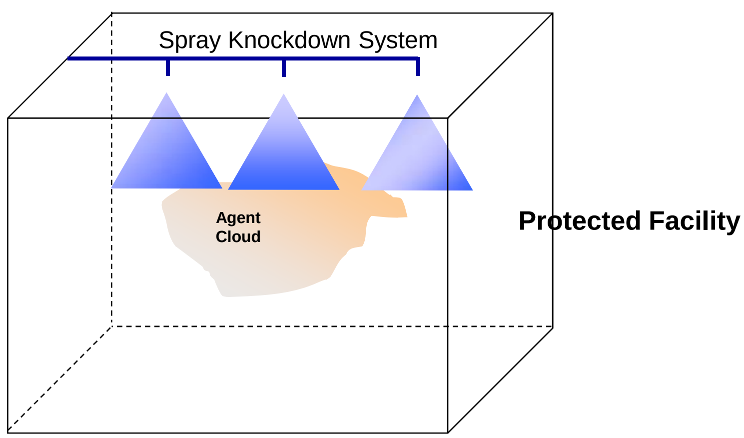
Spray Knockdown & Neutralization Concept

Interior Protection



Our objective is to investigate the use of small, charged liquid droplets to knockdown and neutralize clouds of CBW agents

2

Through a series of four projects, Sandia has developed and demonstrated a fundamental spray knockdown process

2001-2002 — DARPA Immune Building Project

- Knockdown and neutralization of CBW agents in an interior facility
- Small (~30-50µm), uncharged droplets of modified DF-200
- Prototype system developed for Anniston, AL test facility

2004-2005 — Laboratory Directed Research and Development (LDRD)

- Knockdown and neutralization of CBW agents in an outdoor setting
- Small (~30-50µm), charged droplets of modified DF-200
- Feasibility study

2008-2009 — Chemical Materials Agency (Chem Demil)

- Knockdown and neutralization of CBW agents in an interior or temporary demil facility
- Small (~30-50µm), charged droplets of modified DF-200
- Prototype system installed

2014-2017 — Underground Transport Restoration Project

- Knockdown and neutralization of CBW agents in a subway system
- Small (~30-50µm), charged droplets of modified DF-200
- Demonstration in mock subway tunnel

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3

Fundamental Requirements for Spray Knockdown & Neutralization System

Define the Threat

- Agents of Concern
- Airborne Concentrations and Exposures
- Knockdown & Neutralization Efficacy Required

Detect the Agent Cloud

- Stand-off Detection
- Direct Detection
- Particle Detectors

Knockdown efficacy requirements have been developed for each project

Knockdown and Neutralize the Agent Cloud

- Chemical Properties for Neutralization
  - Efficacy
  - Solubility
  - Safety and Environment
- Physical Properties for Efficient Collection
  - Droplet Size
  - Charge
- Deployment
  - Disperse Knockdown Spray into Agent Cloud

Our work has primarily focused on this part of the problem

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Example calculations for knockdown efficacy requirements

Toxic Material	Initial Airborne Concentration (mg/m^3)	Exposure at Initial Airborne Concentration (mg-min/m^3)[1]	LCt_{50} (mg-min/m^3)[3]	Log reduction required to reach LCt_{50}	No significant effects dosage (mg-min/m^3)[5]	Log reduction required to reach no significant effects
VX	560	300	15	1.3	0.09	3.5
GB	560[6]	300	35	0.9	0.5	2.8
HD	5600[7]	3000	900	0.5	2.0	3.2
Anthrax Spores	0.009[3]	0.0054	0.00015[4]	1.6	0.0000094	3.0
Chlorine gas	681,000[2]	408,600	52,740	0.9	150	3.4

1: Estimated from scenarios in open literature
2: From estimated maximum concentration following Graniteville, SC release
3: Data from "Immune Building Systems Technology", Kowalski, WJ, 2003
4: Assumes 10^{11} spores/g
5: Data for VX, GB, and HD from "Compilation of Existing Chemical Agent Guidelines Table as of September 1997", ORNL/TM-13649
6: Sarin attack by truck with sprayer from Davis et al. (2003, ISBN 0-8300-3473-1) 100 kg Sarin sprayed into 6 mph wind, 1 km down wind
7: Used same conditions as Davis but with 100 kg for VX and 1000 kg for HD

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Fundamental Requirements for Spray Knockdown & Neutralization System

Define the Threat → Detect the Agent Cloud → Knockdown and Neutralize the Agent Cloud

- Agents of Co
- Airborne Concentratio and Exposur
- Knockdown & Neutralization Efficacy Required

Modified Sandia DF-200 chemistry is being utilized for the knockdown and neutralization spray formulation

- Chemical Properties for Neutralization
  - Efficacy
  - Solubility
  - Safety and Environment
- Physical Properties for Efficient Collection
  - Droplet Size
  - Charge
- Deployment
  - Disperse Knockdown Spray into Agent Cloud

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Sandia Decon Formulation (DF-200)

How Does it Work?

Components

- Foam Component (Surfactants, mild solvents, buffers)
- Peroxide (7.9% Solution)
- Novel Activator

Mix →

Formulation

Synergistic formulation (multiple reactive species)

Spray, Foam, Mist, or Gel →

Multiple Uses

- Kill of BW Agents
- Kill of Bio Pathogens
- Neutralization of CW Agents
- Neutralization of TICs

Final peroxide concentration is ~3.6%

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Efficacy of Sandia DF-200 Formulation against CW Agents (US DoD Testing)

Decontaminant	GD		VX		HD	
	10 Min.	60 Min.	10 Min.	60 Min.	10 Min.	60 Min.
DS2	>99.9	>99.9	>99.9	>99.9	>99.9	>99.9
DF-200	>99.9	>99.9	97.8	>99.9	84.8	99.9

Percent decontamination from kinetic tests against CW agents (US DoD stirred reactor tests using EasyDECON™-200 Lot 3829 at 25˚C).

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Efficacy of Sandia DF-200 Formulation against BW Agents (US DoD Testing)

	B. atrophaeus		*B. anthracis* Ames		*B. anthracis* Vollum		*B. anthracis* Vollum 1B	
	MREF	Dahlgren	MREF	Dahlgren	MREF	Dahlgren	MREF	Dahlgren
	CFU	CFU	CFU	CFU	CFU	CFU	CFU	CFU
HTH (2%)	0	0	0	0	0	0	0	0
STB	0	5158 (SD=7837)	33 (SD=58)	28 (SD=48)	0	0	0	0
MDF-200	0	4	0	0	0	0	6 (SD=10)	0
EasyDECON	0	0	0	0	0	0	0	0

Residual spores following decontamination of CARC coupons (Initial surface loading: 1 x 10^7 spores; Contact time: 30 minutes; coupons rinsed in sterile de-ionized water following testing)

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Fundamental Requirements for Spray Knockdown & Neutralization System

Define the Threat → Detect the Agent Cloud → Knockdown and Neutralize the Agent Cloud

- **Agents of Concern**
- **Airborne Concentrations and Exposures**
- **Knockdown & Neutralization Efficacy Required**

- **Stand-off Detection**
- **Direct Detection**
- **Particle Detectors**

We have utilized fundamental physics and experimental work to determine the required physical properties →

- **Chemical Properties for Neutralization**
  - Efficacy
  - Solubility
  - Safety and Environment
- **Physical Properties for Efficient Collection**
  - Droplet Size
  - Charge
- **Deployment**
  - Disperse Knockdown Spray into Agent Cloud

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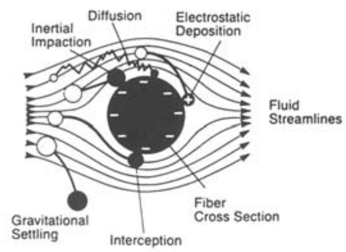
Physical properties of the knockdown spray droplets are important for optimal collection of agent vapors, liquid aerosols, and particles

- Particles may be collected by falling droplets with various mechanisms
  - Diffusion
  - Interception
  - Impaction
  - Thermal effects
  - Electrostatic effects
- Collection efficiency may be enhanced by certain physical properties of the droplets
  - Droplet size
  - Charge on the droplet
  - Concentration of the droplets
  - Surface tension (wetability)



From Spurney, "Advances in Aerosol Filtration"

The optimal properties of the knockdown spray droplet properties have been determined through modeling and experimental work

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Aerosol Test Chamber for Spray Knockdown Tests

- 8-ft wide by 16-ft long by 8-ft high chamber divided into two 8-foot cubes separated by an intervening wall (512 cu. ft.)
- The chamber was fitted with an array of nine electrostatic spray (ESS) nozzles (Maxcharge^{TM} Spray Nozzle - Agricultural Manufacturing Company, Inc.) located at the top of the test chamber
- Spray droplet sizes from the nozzles are 30-40 microns in diameter
- Required air pressure for each nozzle is 20-90 psi
- Air consumption is 2.9–10 CFM
- The liquid flow rate is 50–200 ml/min for each nozzle

Aerosol Test Chamber at Sandia National Laboratories

ESS nozzles in the chamber

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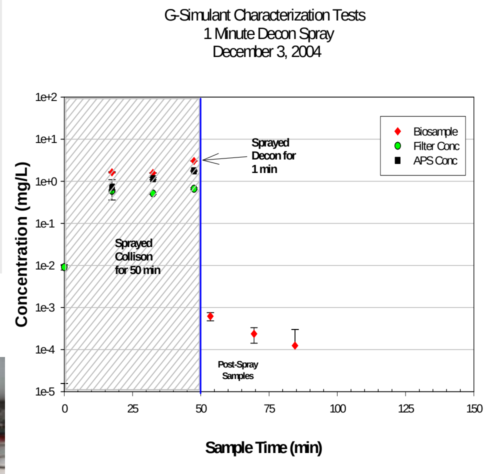
DF-200 Knockdown & Neutralization Spray

CW Agent Simulant Data

- Charged spray system
- 3.2 g/m³ G-agent simulant
- 138 g/m³ DF-200 Spray density
- Immediate decrease of nearly 4 orders of magnitude
- Knockdown/neutralization proof of concept
- Various simulant and spray densities have been evaluated



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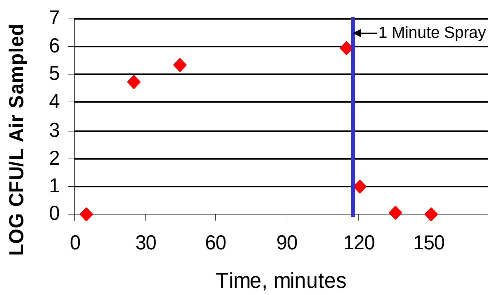
DF-200 Knockdown & Neutralization Spray

BW Agent Simulant Data

- Tests were conducted against 'weaponized-like' *Bacillus atrophaeus* spores
- Spores were introduced into the chamber at a concentration of 10⁶ log CFU/l. After 120 minutes of mixing, DF-200 spray was deployed for one minute through the ESS nozzles.
- Total spray volume deployed was 2 L and the concentration of DF-200 was approximately 138 g/m³ in the chamber.
- The simulant was collected by aerosol sampling and concentration in the chamber was determined by culturing at <1, 15, and 30 minutes after the end of the spray period.
- The results demonstrated a 5 log knockdown and kill of the simulant immediately after the spray was stopped. A 5 log knockdown and kill was also observed using a 92 g/m³ spray density and a 4 log knockdown and kill was observed using a 46 g/m³ spray density.



Results of cloud knockdown tests using a mist of DF-200 against *Bacillus atrophaeus* spores (an anthrax simulant).

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Potential Spray Knockdown Applications

- **Many applications for fundamental capability**
- **Potential applications for military use**
  - Force protection (battlefield)
  - Force protection (fixed sites)
  - Chemical demilitarization
  - Immune building
- **Potential applications for civilian use**
  - Chemical plants
  - Subways
  - Nuclear plants
  - High-profile buildings

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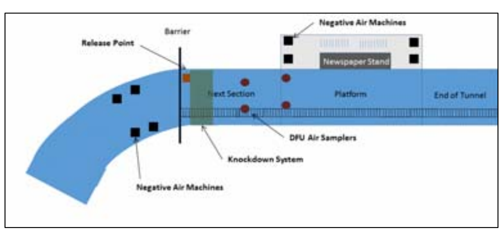
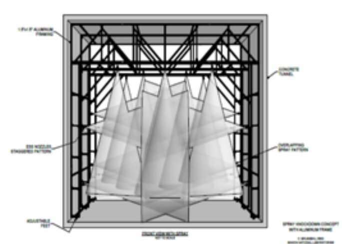
Spray Knockdown System for Containment and Neutralization of CBW Agents in Subways

Spray Knockdown Test at the OTD





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Spray Knockdown System for Containment and Neutralization of CBW Agents in Subways

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Spray Knockdown System for Containment and Neutralization of CBW Agents in Subways

Test Parameters:

- Airflow was approximately 40 ft/min
- Spray was turned on for 1 minute, 30 seconds
- B.g. spores were released (25 mg)
- Spray continued for 18 minutes, 30 seconds
- Approximately 12 gallons of modified DF-200 liquid was deployed
- 6 Liquid (pool) and 4 DFU samples were collected 15 minutes after the end of the spray
- Control (release with no spray) and background (pre-test) samples were collected

Average Spore Count (Preliminary Data)

DFU	Background	Control	Spray
1	ND	18000	ND
2	ND	24100	ND
3	ND	28900	ND
4	ND	27000	ND
5	13.3	13800	ND

Results:

- Control (i.e., no spray) resulted in ~ 4 log CFU on DFUs
- Spray Test resulted in non-detects on all DFUs
- Spray Test resulted in non-detects in all liquid (pool) samples

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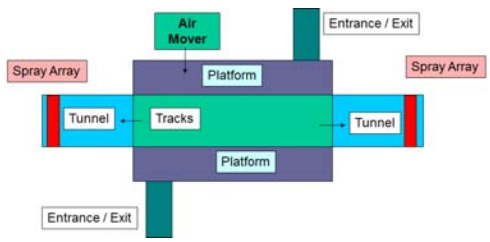
CBW Spray Knockdown & Neutralization

Subway System Concept



Advantages:

- Large order of magnitude knockdown
- Low regret action

Disadvantages:

- Depends on detection
- Must be pre-installed

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Summary of Sandia Chemical and Biological Spray Knockdown Effort

- The Sandia Decon Formulation (DF-200) can neutralize CW agents, BW agents, and many toxic industrial chemicals
- DF-200 is considered to be the "best available technology" by the US Military and was staged in Iraq
- DF-200 is commercially available in several all-liquid packaging options
- Sandia has successfully demonstrated knockdown and neutralization of agent simulant clouds
- Various deployment scenarios have also been developed
- A demonstration system was successfully tested in a mock subway system as part of the Underground Transport Restoration project

Charged spray of modified DF-200 in the Sandia Aerosol Test Chamber during a spray knockdown test.

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EPA ORD's Homeland Security Research Program 1

Homeland Security
Science and Technology

Decontamination options in a subway environment following a biological release

Lukas Oudejans and Joe Wood
National Homeland Security Research Center
Shannon Serre
Consequence Management Advisory Division

EPA ORD's Homeland Security Research Program 2

BACKGROUND ON SUITABLE DECON TECHNOLOGIES

- Very limited number of FIFRA registered products exist for *Bacillus anthracis*
  - One registered for porous materials (ClO2 fumigation)
- Impact of realistic (subway) conditions on decontamination efficacies is unknown
  - Presence of dirt and grime
  - Environmental conditions
- EPA's Homeland Security Research Program has filled many gaps
- Examples of remaining gaps pertain to:
  - Clean versus dirty surfaces
  - Capacity and logistics to deliver decontaminants

EPA ORD's Homeland Security Research Program 3

Landscape of Sporicidal Technologies:

Fumigation / Volumetric Decon

- Ethylene Oxide
- Hot, humid air
- Methyl Bromide (MB)
- Hydrogen Peroxide Vapor
- Methyl Iodide
- Formaldehyde
- Ozone
- Peracetic Acid (PAA) by fogging
- Chlorine Dioxide (ClO2)

Surface Decon

- Oxonia Active
- Peridox RTU
- Minncare
- Dichlor
- Bleach / diluted bleach
- Sodium persulfate
- EasyDecon® DF200
- Chloropicrin
- pH Amended Bleach (PAB)
- Decon Green
- CASCAD™ SDF
- Spor-Klenz® RTU
- Sodium persulfate

No universal solution exists!

EPA ORD's Homeland Security Research Program 4

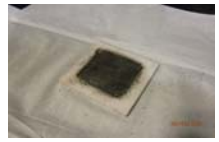
Experimental Studies

- Conducted experimental studies to bridge knowledge gaps between laboratory studies and actual subway system application
- Investigated impact of environmental conditions and dirt & grime on decontamination efficacy when considering
  - ClO2 fumigation
  - Methyl Bromide fumigation
  - Fogging of germicidal solutions

EPA ORD's Homeland Security Research Program 5

Experimental Studies

- Applied true subway car grime or artificial grime[1] to subway materials[2]

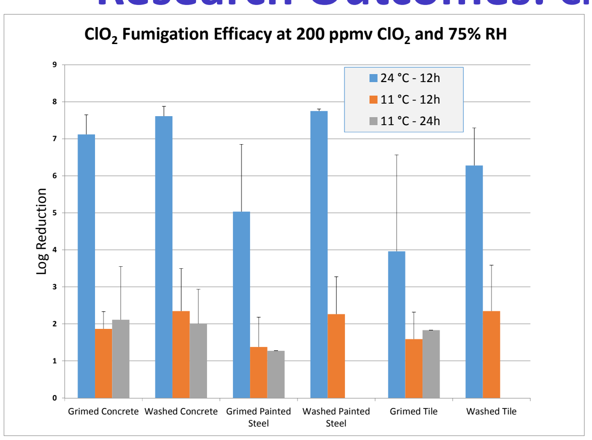
- Investigated lower (50 F) temperatures (w. 75% RH)


[1]: "Sandia Nat. Lab grime" containing Arizona fine dust (94%), soot mixture (3%), and biological materials (3%)

[2]: Materials are subway building materials: concrete, ceramic tile, painted steel; and rolling stock materials: plastic, rubber, carpet, HVAC filters. Not all materials are incorporated in every study.

EPA ORD's Homeland Security Research Program 6

Research Outcomes: ClO2 fumigation

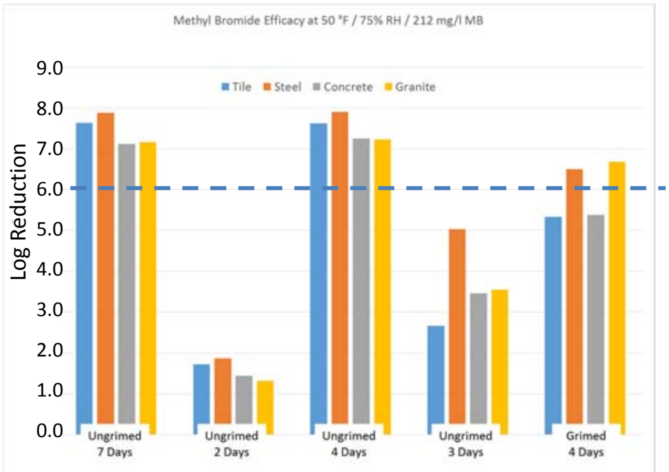


- Significant lower efficacies at 50 °F (11 °C) compared to 75 °F (24 °C)
- Occurred for low (200 ppmv) and at high (3000 ppm) ClO_2 concentrations
- Impact of dirt and grime was less noticeable and depends on material

Full report: https://www.epa.gov/homeland-security-research

EPA ORD's Homeland Security Research Program 7

Research Outcomes:
Methyl bromide fumigation (in progress)



- Significant lower efficacies at 50 °F (11 °C) compared to 75 °F (24 °C)
- Impact of grime was observed at 4 days

EPA ORD's Homeland Security Research Program 8

Research Outcomes: Fogging sporicidal solutions
Peracetic acid (PAA):

- PAA fog was effective (>6 log reduction) on several railcar materials
  - Rubber flooring, seat upholstery, Mylar glass coating, air filters
- PAA fog demonstrated lower efficacies on carpet and concrete (subway tunnel material)
- PAA was excluded from use during Operational Technology Demonstration (OTD) in (concrete) subway environment

ORD's Homeland Security Research Program

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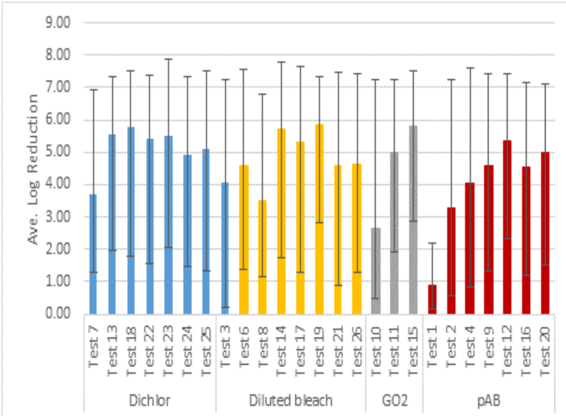
Research Outcomes: Fogging sporicidal solutions Dichlor, diluted bleach, pH amended bleach, ClO_2 liq.



Error bars reflect StDev in average LR over all tested materials

- All decontaminants were effective on most materials tested, including concrete, if using a high enough FAC or ClO_2 level, and fogging enough liquid
- Porous materials such as wood, ceiling tile, carpet and concrete (again) were most difficult materials to decon
- Pilot scale tests/results in RTP's COMMANDER were used to determine what decontaminant to use (diluted bleach), and how much, at the OTD

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EPA ORD's Homeland Security Research Program 11

Underground Transport Restoration Operational Technology Decontamination

September 12 – October 14, 2016

Homeland Security

Science and Technology

UTR Operational Technology Demonstration

OTD Planning

- Test Bed –Shannon, Mike & Lukas
  - Up fits to facility
  - Logistics/coordination
  - Contracts
  - Personnel
- Decontamination – Leroy & Joe
  - Down select to 2 decontamination technologies
  - Equipment needs
  - RAP
- Sampling – Francisco, Sarah & Worth
  - SAP
  - Analysis
- Waste – Anna, Elise & Paul
  - Solids
  - Liquids
- Cost Analysis–Paul, Jayson, & Natalie
  - Capture cost of each application
  - Capture any adverse impacts to the facility
  - Capture limitations of each approach
- Health and Safety – Marshall & John
  - HASP
  - Test Bed Safety
- R3 – Chris & Melissa

Collaborative Effort

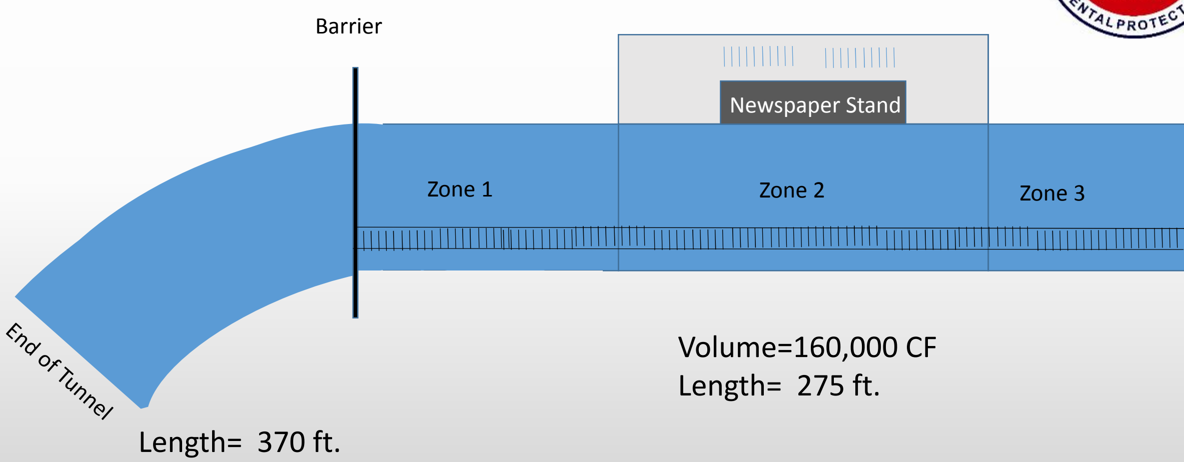
Over 250 personnel participated

- US EPA
  - OEM/CMAD
  - NHSRC
  - Regions 3, 6, 7, 9
  - ORCR
  - OSRTI/ERT
- DHS
- Sandia National Laboratory
- MIT – Lincoln Laboratory
- Lawrence Livermore National Lab
- Pacific Northwest National Lab
- Department of Defense
  - Asymmetric Warfare Group
  - Fort A.P. Hill
  - Civil Support Teams
- US Coast Guard
  - Atlantic Strike Team
- CDC/ Laboratory Response Network

Operational Technology Demonstration (OTD)

- Test and evaluate 2 options for decontamination of a subway platform and tunnel:
  - Sampling (pre-decon and post-decon)
  - Effect of grime/organic burden on decontamination
- Evaluate
  - Efficacy
  - Time and personnel required
  - Cost of each application
  - Material and waste disposal requirements

Schematic of Tunnel and Platform



Additions to Study Area

Emergency Intercom

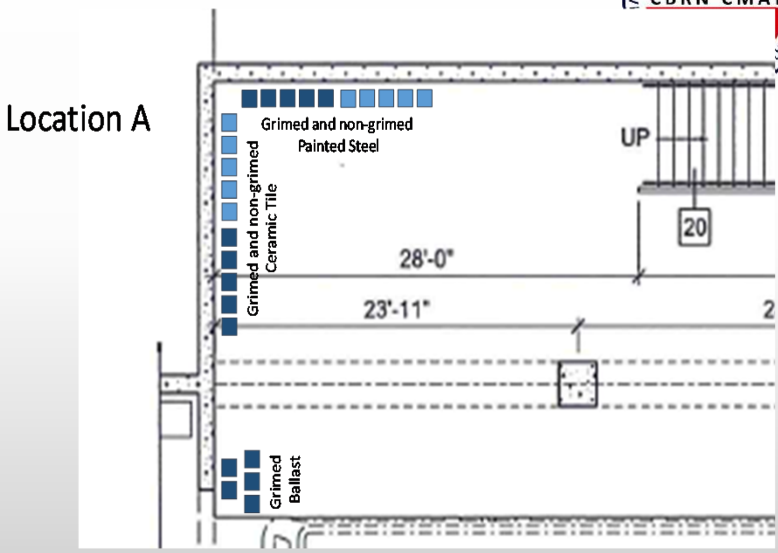
Card Reader

Electrical Circuit box

Commercial Kiosk

Grimed Coupons

- Concrete
- Painted Steel
- Ceramic Tile
- Ballast



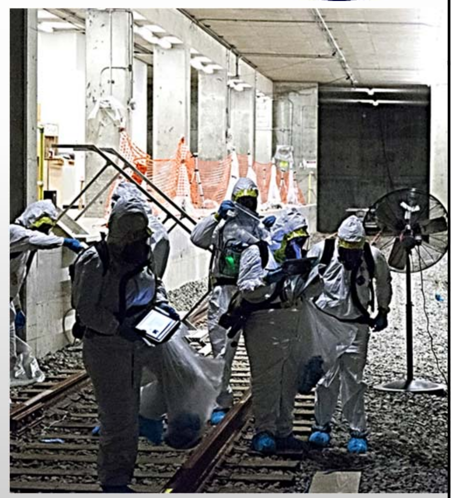
Isolation of Platform and Tunnel

Agent Dissemination

- Agent
  - Biological – *Bacillus atrophaeous, aka Bg*
    - Biosafety Level 01 (lowest level), not infectious to healthy humans/ animals
    - Same level of deposition in both tests
- Round 1 Spore Dispersion on 9/18/16 and Round 2 Spore Dispersion on 9/29/16
  - Target spore deposition concentration: $1x10^6$ cfu/ft^2
  - 800 mg spore release

Sampling

- Any background *Bg* present on tunnel/platform surfaces?
- What is the *Bg* concentration before and after decon for:
  - Grimed and ungrimed coupons
  - Wastes from kiosk
  - Sump pump water drainage
  - Decon line washwater
- Approximately 500 samples per round
- LRN, EPA/NEIC lab, and EPA/RTP microbiology lab analysis



Decontamination

- Round 1: Fogging (automated system)
  - Diluted Bleach
  - 4 units with 100 gallons diluted bleach
- Round 2: Spraying surfaces with low-pressure sprayers
  - pH amended bleach (bleach + vinegar + water)
  - Powered sprayer with 4 take-offs
  - 600 gallons

Waste Management

- Assess ability of facility decontamination operations to effectively treat *in situ* materials that would end up in waste stream
- Assess ability of *ex situ* on-site waste treatment (i.e., dunking in pH-adjusted bleach) to effectively treat materials that would end up in the waste stream
- Demonstrate effectiveness of extractive sampling approaches to characterize waste

Mold Removal


Questions

Guidance for the Rapid Return to Service of Underground Transportation Systems Following a Biological Agent Attack

Bob Fischer
Lawrence Livermore National Laboratory
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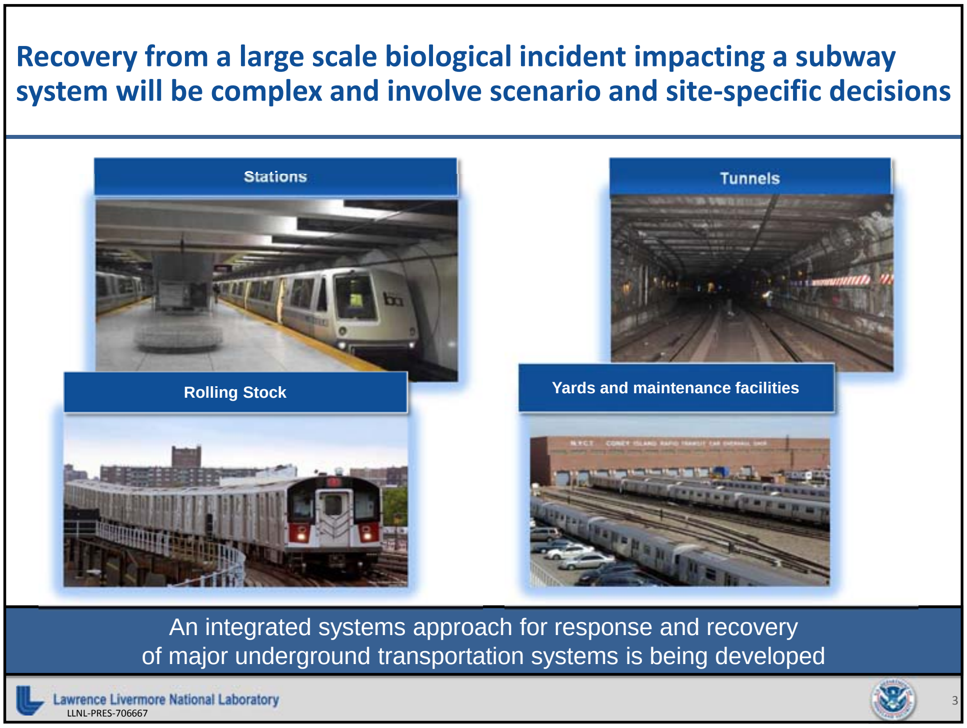
November 1, 2016

Lawrence Livermore National Laboratory
Pacific Northwest National Laboratory
EPA United States Environmental Protection Agency
Sandia National Laboratories
Argonne National Laboratory
Lincoln Laboratory Massachusetts Institute of Technology

LLNL-PRES-706667 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

Subways are complex, highly integrated systems moving large numbers of people quickly and safely over a large geographical area

- World's 7th largest system in terms of annual ridership
- First revenue service 1904
- Average daily ridership of 5.6 million
- Peak revenue service ridership of 500,000 – 600,000
- 6,400 + subway cars
- 24 service routes running over 660 miles of track (40% of which is underground)
- 469 stations
- 14 underwater crossings
- 24 rail yards
- 13 major maintenance facilities
- Operates 24/7


Recovery from a large scale biological incident impacting a subway system will be complex and involve scenario and site-specific decisions
Stations
Tunnels
Rolling Stock
Yards and maintenance facilities
An integrated systems approach for response and recovery of major underground transportation systems is being developed
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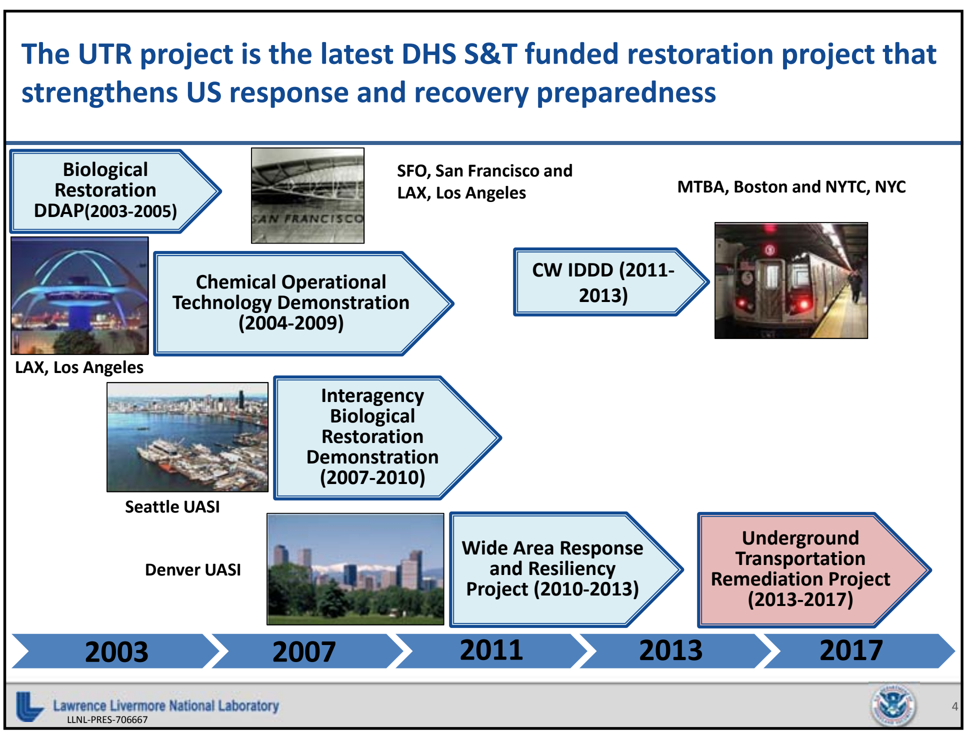
The UTR project is the latest DHS S&T funded restoration project that strengthens US response and recovery preparedness
Biological Restoration DDAP(2003-2005)
SFO, San Francisco and LAX, Los Angeles
MTBA, Boston and NYTC, NYC
Chemical Operational Technology Demonstration (2004-2009)
CW IDDD (2011-2013)
LAX, Los Angeles
Interagency Biological Restoration Demonstration (2007-2010)
Seattle UASI
Denver UASI
Wide Area Response and Resiliency Project (2010-2013)
Underground Transportation Remediation Project (2013-2017)
2003
2007
2011
2013
2017
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4

The UTR guidance development tasking specified an actionable, operationally focused rapid return to service plan

- Phased return-to-service plan
- Identification of priority components/routes
- A limited return-to-service plan designed to restore minimum service
- Preplanned countermeasures
- Optimization of service levels with ridership demand
- Integrated rolling stock remediation plans
- The role of support facilities in recovery operations

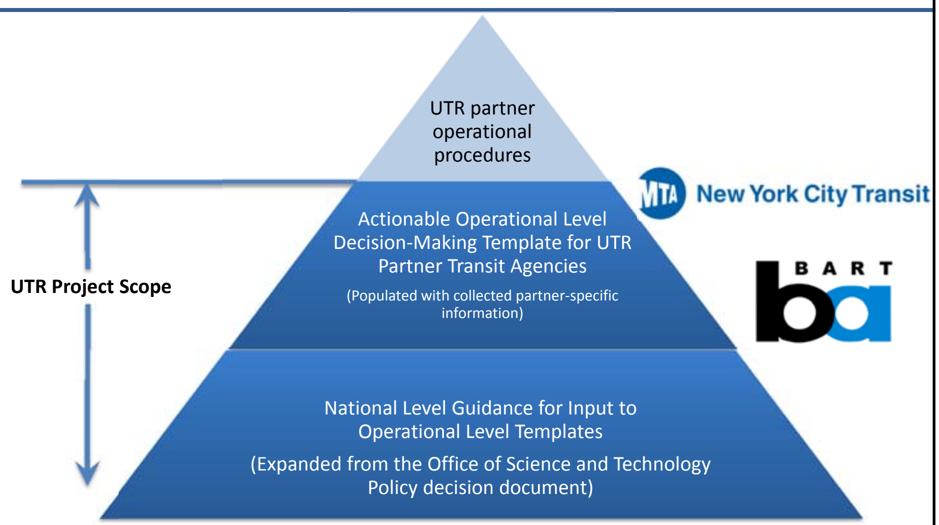
Informed from operational experience

Hurricane Sandy Recovery

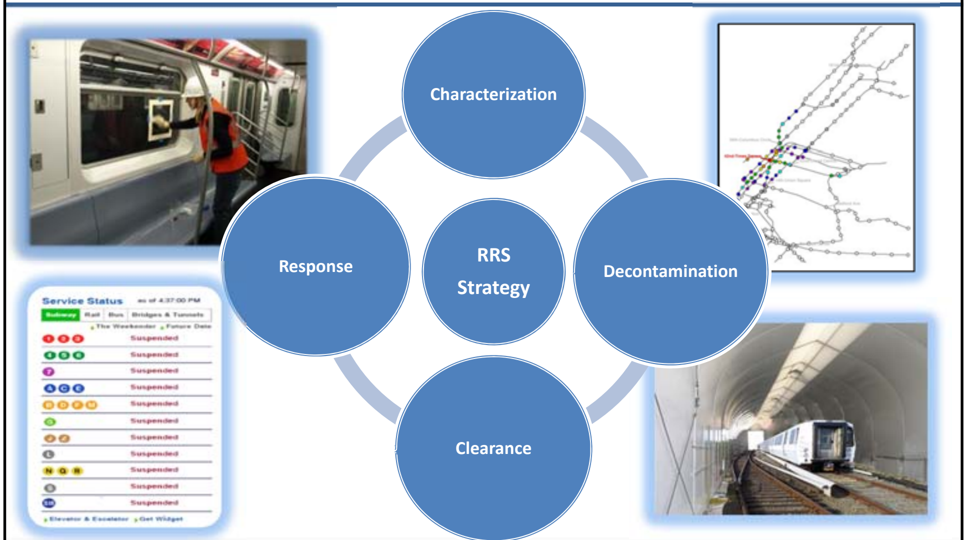
Nov. 1st	Nov. 11th
12% of Peak Capacity	93% of Peak Capacity
57% of Track Miles	96.5% of Track Miles
43% Closed	3.5 % Closed

The framework to be available in a user-friendly template format for individual systems and localities to populate, maintain, and utilize in an actual event.

An integrated guidance framework is being developed for both the national level and partner transit systems



The Rapid Return to Service (RSS) strategy is composed of four key elements



The project has identified several key return to service planning items that must be considered in strategy development

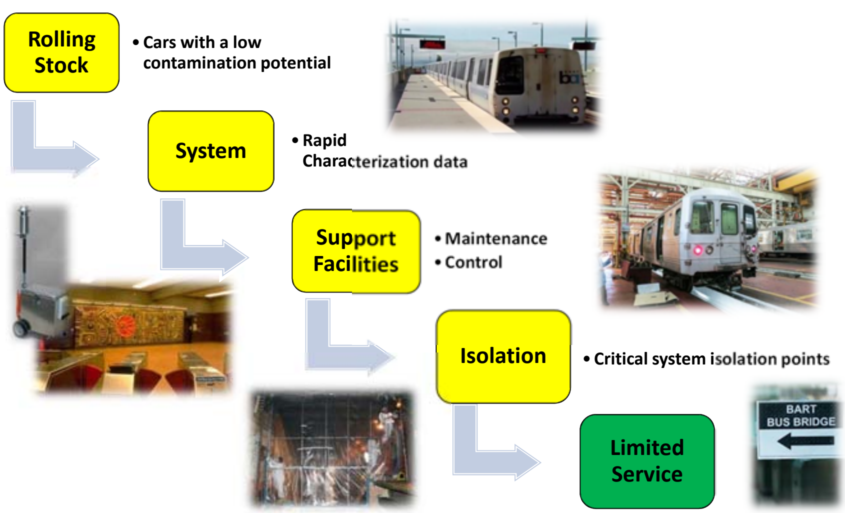
- ✓ A confirmed biological incident within a subway system and/or related transportation systems will result in the entire system being shutdown
- ✓ A criminal investigation will be initiated by law enforcement. This may restrict access to parts of the system
- ✓ Depending on how the shutdown is initiated, trains may either be sitting on tracks throughout the system or returned to storage yards
- ✓ A confirmed biological incident is unlikely to be confined solely to the transit system
- ✓ Rapid characterization of the transit system is a key component of a viable return to service strategy
- ✓ Rapid characterization supports the restoration of service in some areas while clean-up continues in the more contaminated parts of the system

A phased return to service strategy will allow for the fastest resumption of service

Optimizing key transit system elements for return to service is an essential planning strategy

- Identification of critical facilities
  - Rail and power control facilities
  - Yards and maintenance facilities
- Identification of critical routes
  - High capacity lines
  - Critical service areas
- Determine minimum service levels
  - Based on the ability to provide credible level of service
  - Integration with other forms of transit (bus bridges, ferries)
- Identification of other key transit facilities
  - Command and control facilities

Restoring limited service focuses on determining which parts of the system can quickly resume operation



Rapid system characterization is key to the RSS strategy

- Initial assessments employ a rule-in rule-out strategy
  - Using all available and relevant information
- Determines system condition with the fewest samples possible
- Prioritized areas for characterization
  - Targeted areas indicated by pre-incident modeling
- Utilizes pre-incident sampling protocols
  - Train filter sampling

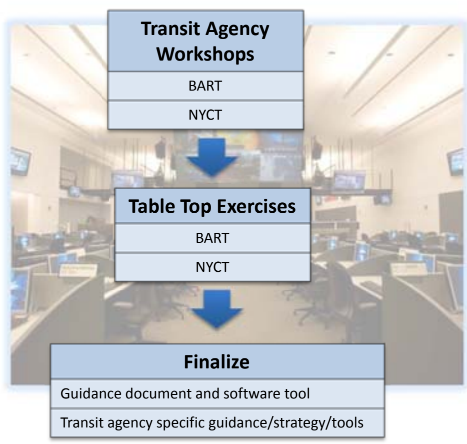
Initial assessment	Color	Definition	Supporting data
Rule in	Red	Contamination has been confirmed or is assumed	Screening sampling results (if any); visual inspections; modeling results; site of overt release
Rule out	Green	Contamination is considered highly unlikely	Distance from release site; modeling results; absence of dispersion mechanisms
Uncertain	Yellow	Contamination is unknown or uncertain	Insufficient evidence to confidently rule in or rule out

Modeling coupled with prioritized sampling locations optimizes rapid characterization efforts

The UTR guidance development process was designed to integrated input from transit agencies and stakeholders

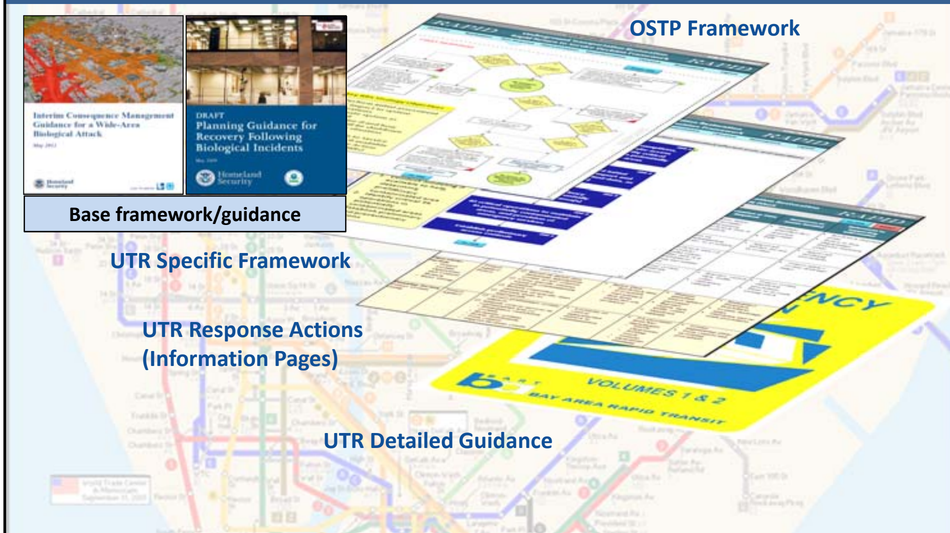
Subway Informational Meetings
key operational information to develop draft RRS Strategy

- Collect transit agency specific data/requirements
- Evaluate technical response and recovery approaches
- Develop draft RRS response framework
- Draft Transit Agency RRS Plans

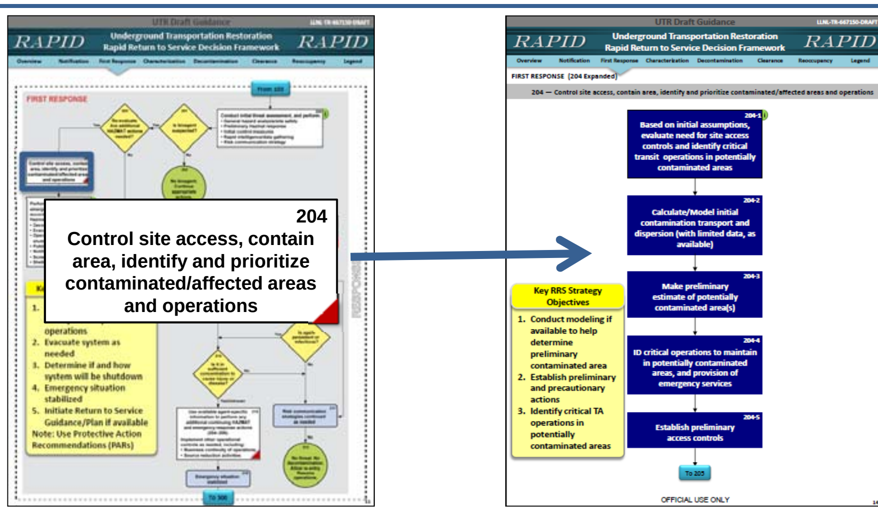


Response and recovery strategies, technical data and user needs are integrated into one optimized Return to Service Strategy

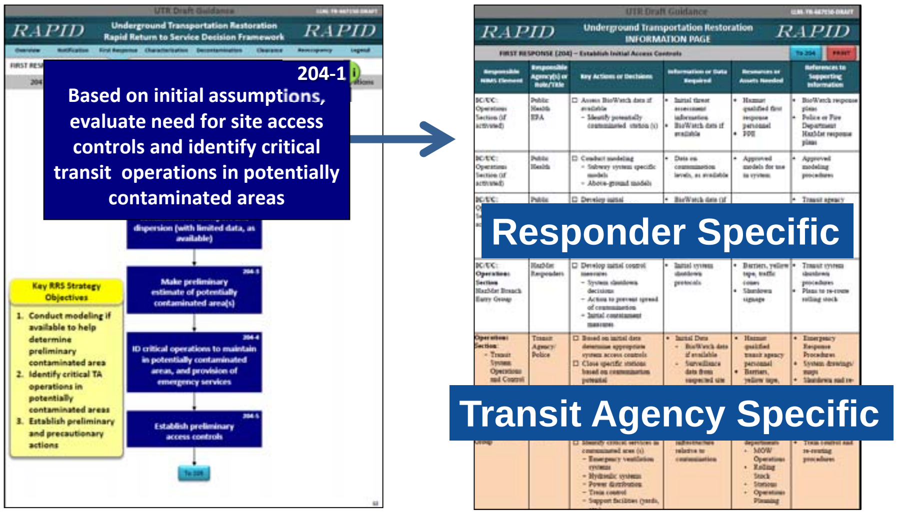
The UTR framework consists of four levels of increasingly detailed operational specific guidance



An expanded UTR specific framework is provided for key UTR action steps in each response phase

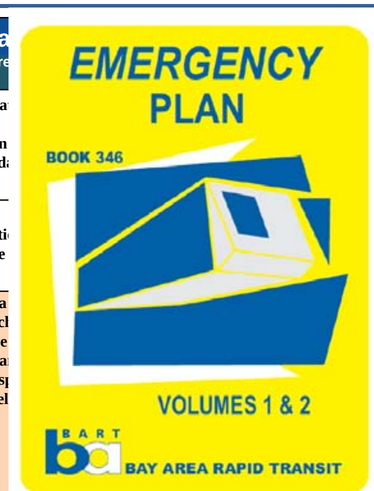


Response actions are linked to key decision and supporting information pages

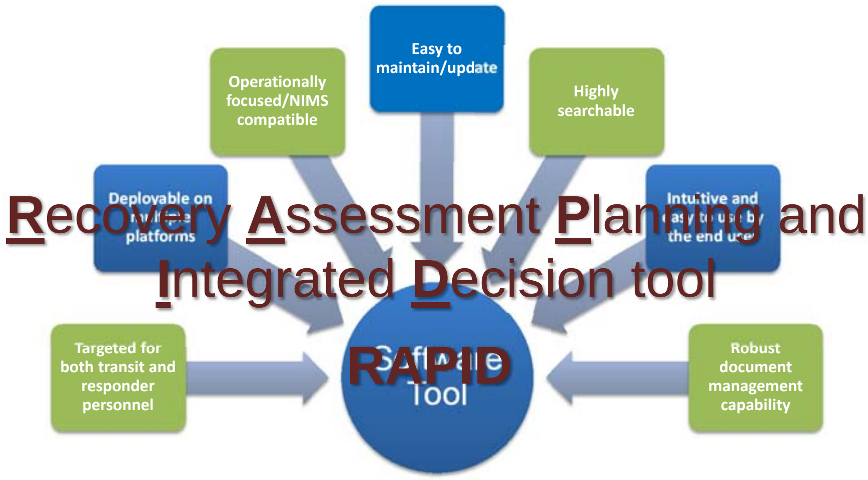


Information pages integrate responsible organizations with key actions and detailed guidance

Response Element	Agency (Role/Title)	Action	Information Required
IC/UC: Planning Section (if activated)	Public Health EPA	✓ Assess BioWatch data if available - Identify potentially contaminated station (s)	▪ Initial threat assessment information ▪ BioWatch data if available
IC/UC: Planning Section (if activated)	Public Health	✓ Conduct modeling - Subway system specific models - Above-ground models	▪ Data on contamination as available
Operations Section: - Transit System Operations and Control Branch - Entry Group	Transit Agency/ Police	✓ Based on initial data determine appropriate system access controls ☐ Close specific stations based on contamination potential ☐ Initiate controlled shutdown of specific lines ☐ Reroute trains as appropriate ☐ Determine time of release if possible	▪ Initial Data • BioWatch available • Surveillance from suspected site of release



Key features designed into the UTR users tool



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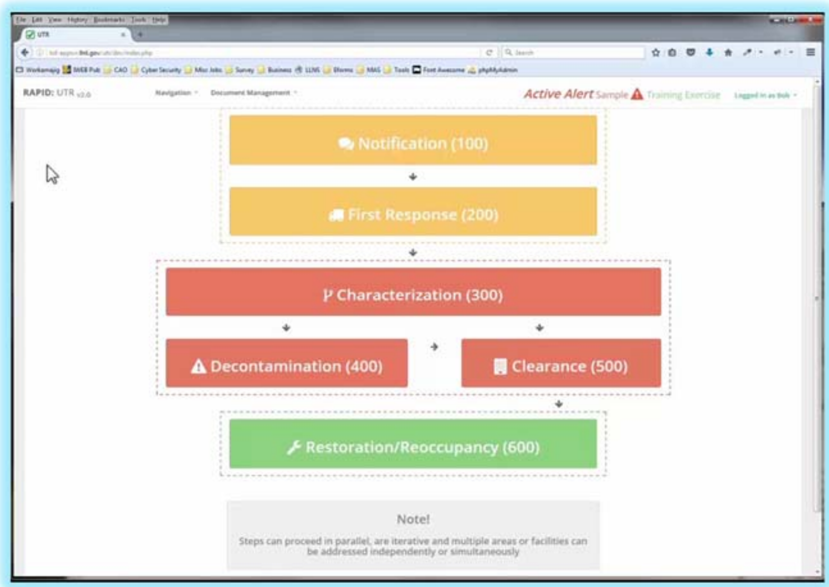

This guidance is specifically designed for response and recovery of Underground Transit Systems in the shortest amount of time possible

- **Delivers both a national level guidance and more detailed and specific tailored guidance for individual transit agencies**
- **Designed to bring all of the information together into a single actionable guidance framework which identifies key decisions/options and links to supporting information**
- **Uses the National Incident Management System (NIMS) for establishing a common linkage with response and recovery command and control systems**
- **Includes development of a user interface tool to allow for easy and timely access to information for EOC operations**

Our goal is to provide operational level guidance to be used by both the response and recovery community (first responders, EPA and public health etc.) and Transit Agencies

Lawrence Livermore National Laboratory

United States Environmental Protection Agency

2016 U.S. EPA International Decontamination Research and Development Conference

Tuesday, November 1, 2016

Concurrent Sessions 1

Water Infrastructure Protection and Decontamination

Water Utility Decontamination Preparedness Tools

Veronica Aponte-Morales
U.S. Environmental Protection Agency - Oak Ridge Institute for Science and Education (ORISE) Research Fellow; OW/OGWDW/WSD, Washington, DC
Marissa Lynch
U.S. Environmental Protection Agency; OW/OGWDW/WSD, Washington, DC

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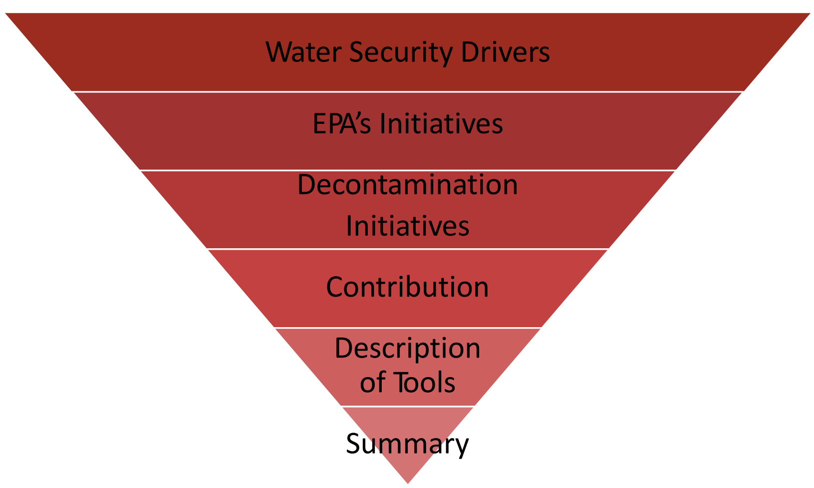
Agenda



2

Probability of an Intentional Contamination Event?

(Allgeier and Magnuson 2004)

- How to manage a contamination threat?
  - ✓ **Planning** appropriate response actions.

3

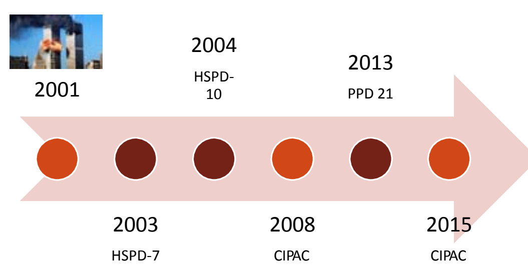
Water Security Drivers

Homeland Security Presidential Directives

- **HSPD-7 (2003)** requires EPA to "identify and prioritize US critical infrastructure and key resources and to protect them from terrorist attacks."
- **HSPD-10 (2004)** charges EPA and its partners to "developing strategies, guidelines, and plans for decontamination of person, equipment, and facilities."

Presidential Policy Directive

- **PPD 21 (2013)** is intended to ensure that the nation's critical infrastructure is "secure and able to withstand and rapidly recover from all hazards."



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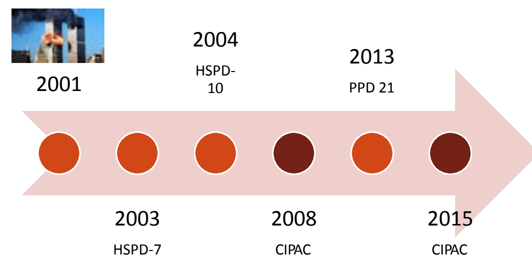
Water Security Drivers – Response

Critical Infrastructure Partnership Advisory Council (CIPAC) – Water Sector Decontamination Working Group

- In **2008**, EPA and its partners developed "CIPAC Water Sector Decontamination Working Group Recommendation and Proposed Strategic Plan, Water Sector Decontamination Priorities"
  - 35 recommendations on decontamination.
- In **2015**, EPA and its partners developed "Progress on Water Sector Decontamination Recommendations and Proposed Strategic Plan"
  - Update on the 2008 Strategic Plan.
  - 23 recommendations are in progress and 3 have been completed.



5

WSD's Decont amination Efforts

Currently addressing CIPAC's recommendations:

4.1 – Develop a decision-making framework for the decontamination of CBR agents in water systems, specifically to be used by utilities, responders, and other decision makers.

11.1 – Develop a flowchart to show progression of roles and decision making authority to be used by the utilities and responding/coordinating agencies during decontamination, treatment, and recovery.

6

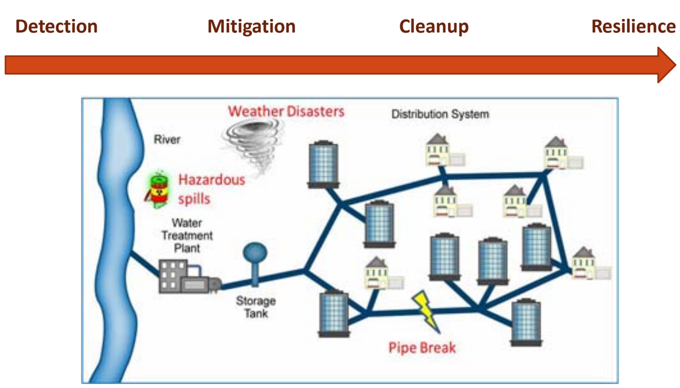
Contribution to Water Security: Emergency Response

Emergency Response

- Preparedness
  - ✓Make timely, effective, and targeted decisions on whether and how to decontaminate and recover from CBR contamination.
- Example
  - ✓Small scale problems – system outage; repair quickly (12 hours).
  - ✓Large scale unprecedented problems – intentional contamination Pittsburgh, PA; repair is uncertain (9 month)

7

Contribution to Water Security: Water System Security and Resilience



EPA is the federal government sector specific lead agency for water infrastructure protection

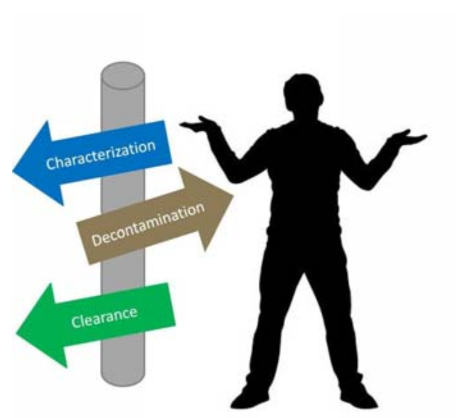
8

Decontamination Preparedness and Assessment Strategy for Water Utilities (DPAS)

Tool #1

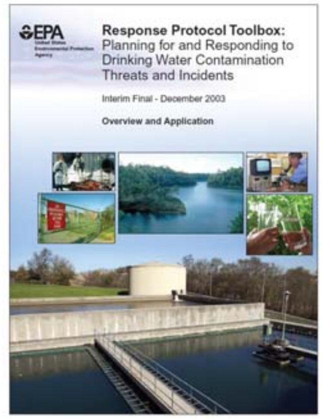
DPAS

- **Goal**: Provide guidance and information on the remediation/cleanup process to water utilities in order to enhance their preparedness in addressing decontamination.
- **Objectives**:
  - ✓ Assist water utilities to navigate the process of remediation.
  - ✓ Identify available resources that can aid utilities during the remediation process.
- **Outcomes**:
  - ✓ A strategy for the utility on how to decontaminate their system that can be incorporated in their emergency response plan.
  - ✓ Decision trees to use as an illustrative guide for remediation/cleanup decision making.
  - ✓ Worksheets/checklist that will aid in collecting information to develop SAP, WMP, and others.



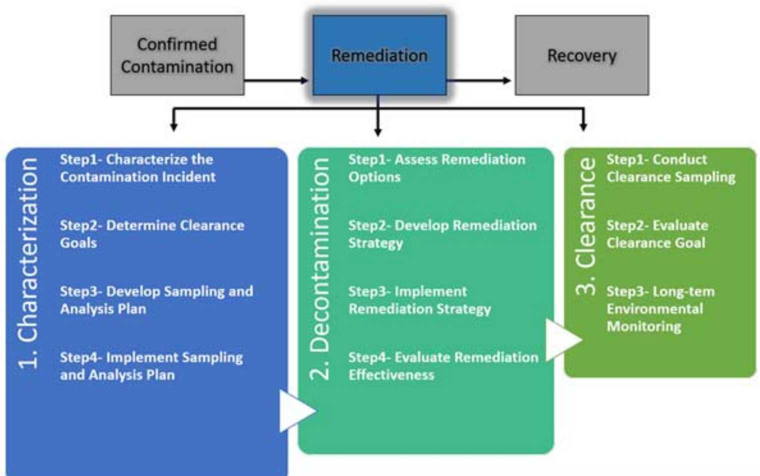
Compared with other tools… What is new?

- Doesn't replace the Response Protocol Toolbox.
  - ✓ Operationalizes Toolbox as an interactive web based tool.
  - ✓ References other tools, methods, and current science developed by EPA/NHSRC and others.
- Provides support on decontamination decisions; e.g., whether to:
  - ✓ use surface measurements or water analysis to verify that cleanup levels have been met.
  - ✓ treat and/or decontaminate infrastructure.
  - ✓ replace or decontaminate infrastructure.
  - ✓ seal and abandon in place or remove infrastructure.
  - ✓ use contaminated water for alternate use such as firefighting.
- Shows the progression of roles and decision-making authority that includes the water utility and other organization involved.



11

DPAS – Content



EPA United States Environmental Protection Agency

CONTAMINATION REMEDIATION PREPAREDNESS AND ASSESSMENT STRATEGY FOR WATER UTILITIES

Introduction

Water utilities can be contaminated by a chemical, biological (including toxins), or radiological (CBR) agent through an accidental or intentional action or a natural disaster. If CBR contamination is confirmed, utilities should be prepared to remediate the incident. Successful remediation means the public health risk and infrastructure damage caused by the contaminant(s) have been reversed or stopped. Actions following remediation include system recovery and return to normal operations.

Remediation includes three phases. Figure 1 presents an overview of the main activities for each phase of remediation. The phases are numbered based on the process described in this Strategy.

The first phase is ***characterization***. This includes characterizing the extent of contamination of the water system and how the contaminant might react with the affected infrastructure materials and sediment within the water system. It also includes assessing the public health and environmental risks of the contaminant at the concentrations present. Characterization also establishes the clearance goals—the concentration of the contaminant at or below which specific uses of the water, such as sanitary services, handwashing or showering, or drinking, can be allowed.

The second phase is ***decontamination***. This phase applies the information gained from the characterization phase. It includes identifying the appropriate methods and treatment necessary to decontaminate the water in the system and the water system infrastructure to at or below the clearance goals. Affected water system components could include source, treatment, and distribution system infrastructure. Decontamination might require treatment and disposal of contaminated water, treatment equipment, or treatment residuals. Decontamination also includes sampling and analyses to assess treatment effectiveness.

The third phase of remediation is ***clearance***. In this phase, sampling and analysis is performed to inform decisions on when the clearance goals have been met. Once the goals are met the system has completed remediation and proceeds to recovery operations and return to normal service.

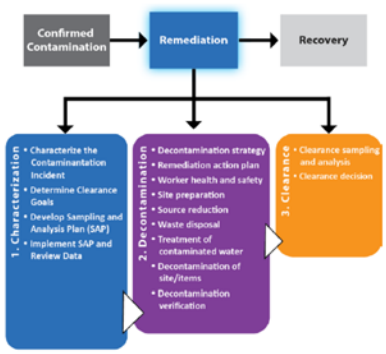
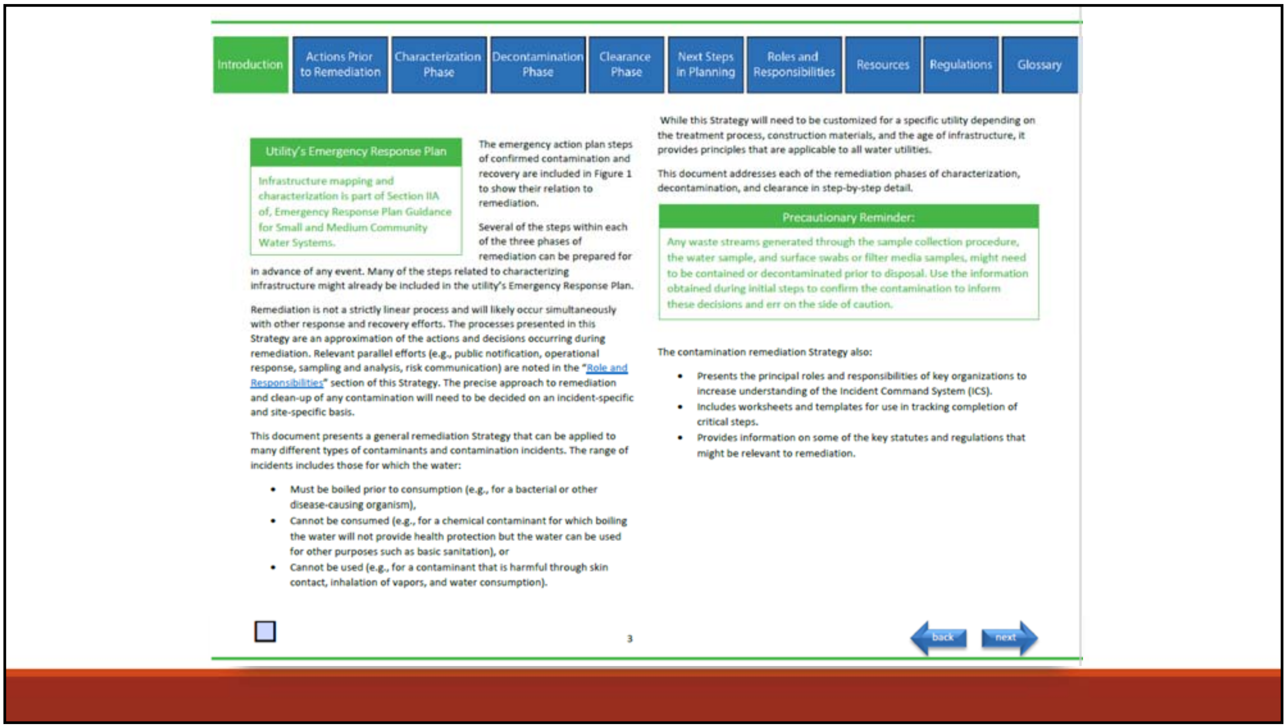
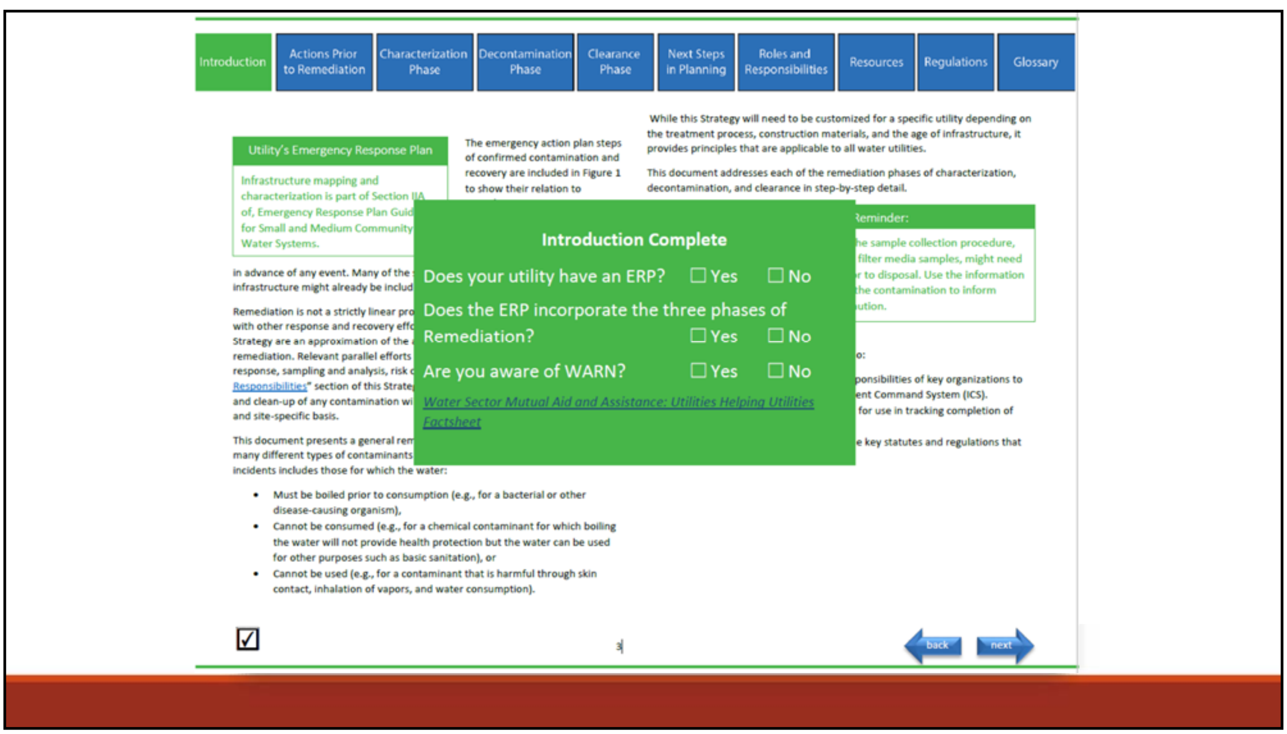
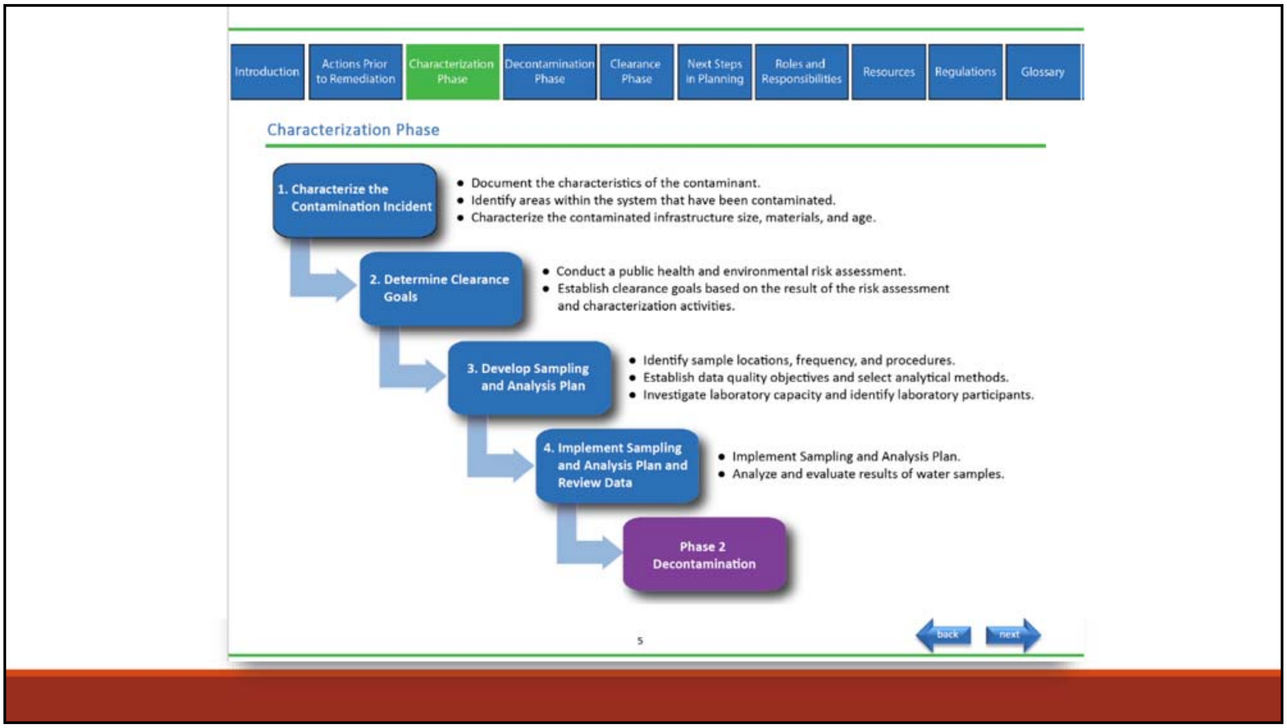


Figure 1. General overview of the three phases of the Remediation process

back next


Introduction
Actions Prior to Remediation
Characterization Phase
Decontamination Phase
Clearance Phase
Next Steps in Planning
Roles and Responsibilities
Resources
Regulations
Glossary
Utility's Emergency Response Plan
Infrastructure mapping and characterization is part of Section IIA of, Emergency Response Plan Guidance for Small and Medium Community Water Systems.
The emergency action plan steps of confirmed contamination and recovery are included in Figure 1 to show their relation to remediation.
Several of the steps within each of the three phases of remediation can be prepared for in advance of any event. Many of the steps related to characterizing infrastructure might already be included in the utility's Emergency Response Plan.
Remediation is not a strictly linear process and will likely occur simultaneously with other response and recovery efforts. The processes presented in this Strategy are an approximation of the actions and decisions occurring during remediation. Relevant parallel efforts (e.g., public notification, operational response, sampling and analysis, risk communication) are noted in the "Role and Responsibilities" section of this Strategy. The precise approach to remediation and clean-up of any contamination will need to be decided on an incident-specific and site-specific basis.
This document presents a general remediation Strategy that can be applied to many different types of contaminants and contamination incidents. The range of incidents includes those for which the water:
• Must be boiled prior to consumption (e.g., for a bacterial or other disease-causing organism),
• Cannot be consumed (e.g., for a chemical contaminant for which boiling the water will not provide health protection but the water can be used for other purposes such as basic sanitation), or
• Cannot be used (e.g., for a contaminant that is harmful through skin contact, inhalation of vapors, and water consumption).
While this Strategy will need to be customized for a specific utility depending on the treatment process, construction materials, and the age of infrastructure, it provides principles that are applicable to all water utilities.
This document addresses each of the remediation phases of characterization, decontamination, and clearance in step-by-step detail.
Precautionary Reminder:
Any waste streams generated through the sample collection procedure, the water sample, and surface swabs or filter media samples, might need to be contained or decontaminated prior to disposal. Use the information obtained during initial steps to confirm the contamination to inform these decisions and err on the side of caution.
The contamination remediation Strategy also:
• Presents the principal roles and responsibilities of key organizations to increase understanding of the Incident Command System (ICS).
• Includes worksheets and templates for use in tracking completion of critical steps.
• Provides information on some of the key statutes and regulations that might be relevant to remediation.
3
back
next


Introduction Complete
Does your utility have an ERP? ☐ Yes ☐ No
Does the ERP incorporate the three phases of Remediation? ☐ Yes ☐ No
Are you aware of WARN? ☐ Yes ☐ No
Water Sector Mutual Aid and Assistance: Utilities Helping Utilities Factsheet
back
next


Introduction
Actions Prior to Remediation
Characterization Phase
Decontamination Phase
Clearance Phase
Next Steps in Planning
Roles and Responsibilities
Resources
Regulations
Glossary
Characterization Phase
1. Characterize the Contamination Incident
Document the characteristics of the contaminant.
Identify areas within the system that have been contaminated.
Characterize the contaminated infrastructure size, materials, and age.
2. Determine Clearance Goals
Conduct a public health and environmental risk assessment.
Establish clearance goals based on the result of the risk assessment and characterization activities.
3. Develop Sampling and Analysis Plan
Identify sample locations, frequency, and procedures.
Establish data quality objectives and select analytical methods.
Investigate laboratory capacity and identify laboratory participants.
4. Implement Sampling and Analysis Plan and Review Data
Implement Sampling and Analysis Plan.
Analyze and evaluate results of water samples.
Phase 2 Decontamination
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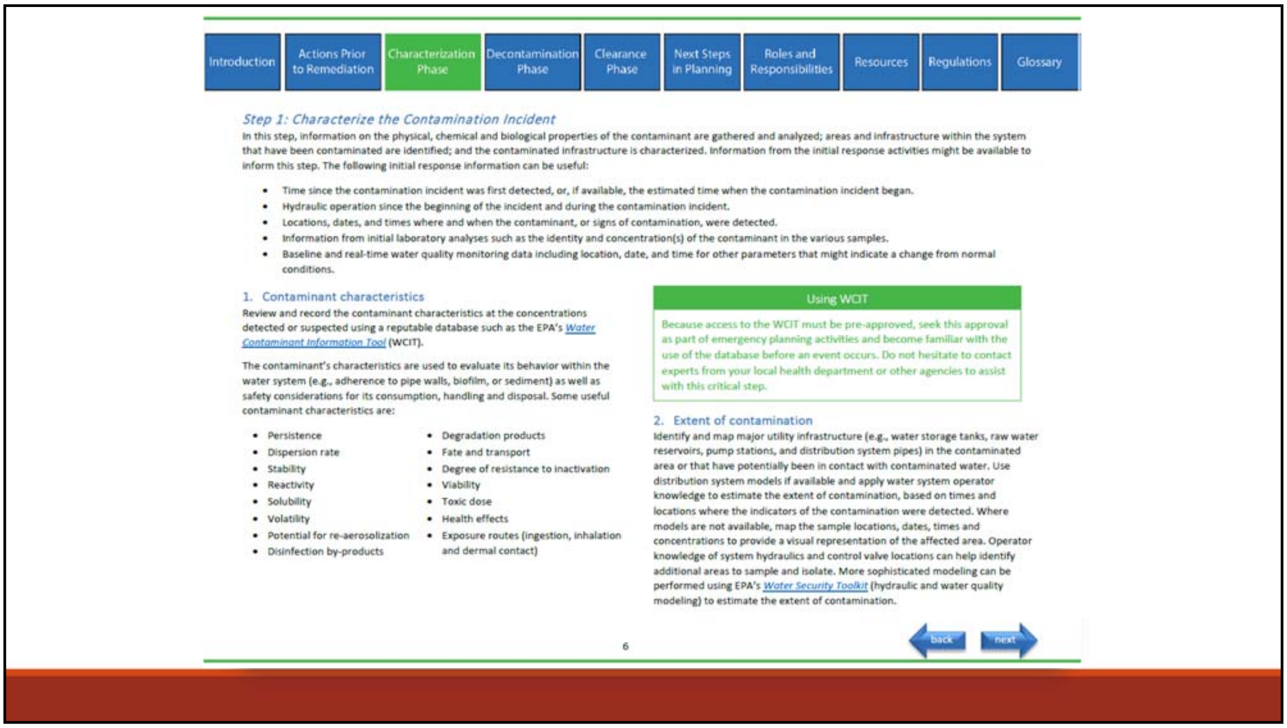
next


Introduction
Actions Prior to Remediation
Characterization Phase
Decontamination Phase
Clearance Phase
Next Steps in Planning
Roles and Responsibilities
Resources
Regulations
Glossary
Step 1: Characterize the Contamination Incident
In this step, information on the physical, chemical and biological properties of the contaminant are gathered and analyzed; areas and infrastructure within the system that have been contaminated are identified; and the contaminated infrastructure is characterized. Information from the initial response activities might be available to inform this step. The following initial response information can be useful:
Time since the contamination incident was first detected, or, if available, the estimated time when the contamination incident began.
Hydraulic operation since the beginning of the incident and during the contamination incident.
Locations, dates, and times where and when the contaminant, or signs of contamination, were detected.
Information from initial laboratory analyses such as the identity and concentration(s) of the contaminant in the various samples.
Baseline and real-time water quality monitoring data including location, date, and time for other parameters that might indicate a change from normal conditions.
1. Contaminant characteristics
Review and record the contaminant characteristics at the concentrations detected or suspected using a reputable database such as the EPA's Water Contaminant Information Tool (WCIT).
The contaminant's characteristics are used to evaluate its behavior within the water system (e.g., adherence to pipe walls, biofilm, or sediment) as well as safety considerations for its consumption, handling and disposal. Some useful contaminant characteristics are:
Persistence
Dispersion rate
Stability
Reactivity
Solubility
Volatility
Potential for re-aerosolization
Disinfection by-products
Degradation products
Fate and transport
Degree of resistance to inactivation
Viability
Toxic dose
Health effects
Exposure routes (ingestion, inhalation and dermal contact)
Using WCIT
Because access to the WCIT must be pre-approved, seek this approval as part of emergency planning activities and become familiar with the use of the database before an event occurs. Do not hesitate to contact experts from your local health department or other agencies to assist with this critical step.
2. Extent of contamination
Identify and map major utility infrastructure (e.g., water storage tanks, raw water reservoirs, pump stations, and distribution system pipes) in the contaminated area or that have potentially been in contact with contaminated water. Use distribution system models if available and apply water system operator knowledge to estimate the extent of contamination, based on times and locations where the indicators of the contamination were detected. Where models are not available, map the sample locations, dates, times and concentrations to provide a visual representation of the affected area. Operator knowledge of system hydraulics and control valve locations can help identify additional areas to sample and isolate. More sophisticated modeling can be performed using EPA's Water Security Toolkit (hydraulic and water quality modeling) to estimate the extent of contamination.
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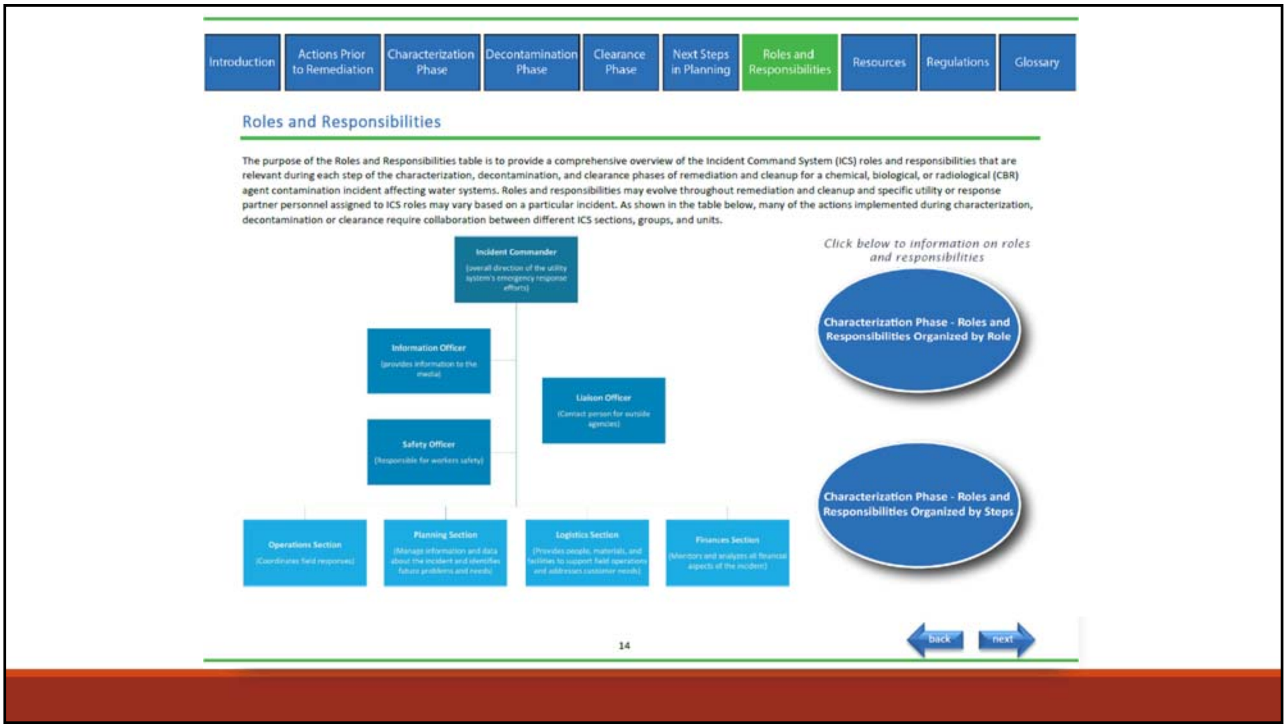

Water Utility Decontamination Tabletop Exercise (TTX) Toolkit

Tool #2

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Decontamination TTX Toolkit

- **Goal**: Provide the necessary information to plan and conduct a TTX in preparation for a water contamination incident.
- **Objective**:
  - ✓ Provide guidance and examples to water utilities and emergency responders in order to plan their own exercise.
- **Outcomes**:
  - ✓ Increase familiarity with decontamination activities.
  - ✓ Build relationships and improve coordination between and among utilities and the response partners.
  - ✓ Identify areas for improvement in their emergency response plan.
  - ✓ Familiarize with free tools and resources that can support decontamination preparedness.
  - ✓ Provide information on state of the science in decontamination practice, tools, and research.

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Decontamination TTX Toolkit – Content

Planning TTX

1. Initiate the exercise planning process
2. Identify potential participants
3. Identify objectives
4. Develop the scenario in conjunction with end-users and potential EPA participants in contamination incident response, such as Program Office, Regional, and researchers.
5. Schedule the exercise and invite participants
6. Prepare pre-exercise Webcast and exercise materials

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Decontamination TTX Toolkit – Content Continue

Conducting TTX

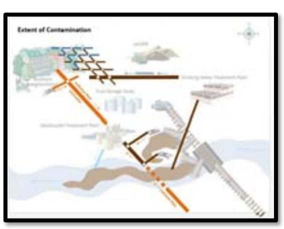
7. Conduct facilitator training and note taker training
8. Conduct pre-exercise Webcast
9. Conduct the exercise

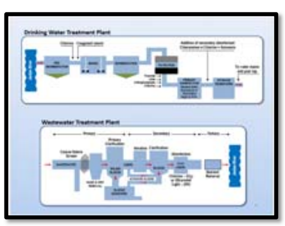
Evaluating TTX

10. Perform exercise follow-up activities

Decontamination TTX Toolkit – Structure

1. **Injects**
2. Breakout groups
3. Hot wash and participant feedback
4. Optional case study





Exercise Participants

Summary

- DPAS and Decontamination TTX Toolkit contributes to:
  - ✓ Enhance preparedness to remediate/cleanup a water utility contaminated by a intentional or accidental event.
  - ✓ Increases familiarity with decontamination activities.
  - ✓ Identify available resources that can aid during remediation/cleanup.
  - ✓ Build relationships and improve coordination between response partners.
- Expected publication date: Summer 2017.
  - ✓ Involves the water system responders, utilities, and other end-users in tool development helps ensure transition and usability of DPAS and TTX Toolkit.
- Including latest research, data, and methods from EPA/NHSRC and others help DPAS and TTX Toolkit contain best possible science.

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Acknowledgment

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Questions?

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Decontamination of Aircraft Water Systems

Jeff Szabo[1], Mark Rodgers[2], Jatin Mistry[3], John Hall[1]

[1]National Homeland Security Research Center

[2]National Risk Management Research Lab

[3]Region 6

November 1, 2016

Aircraft Drinking Water Rule

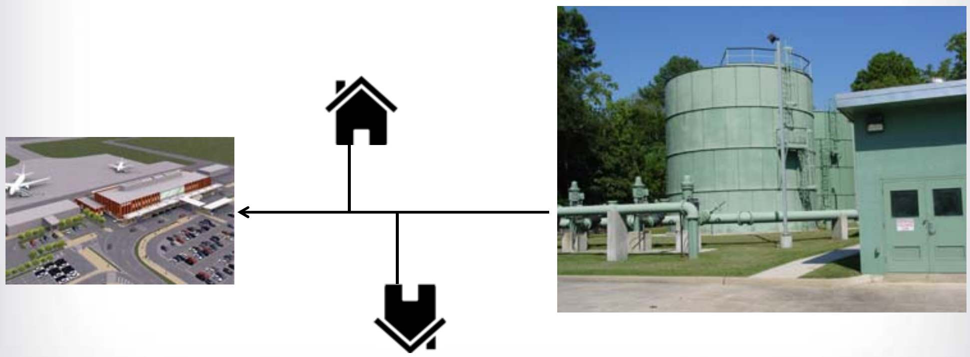
- Promulgated in October 2009 to ensure that safe and reliable drinking water is provided to passengers and crew
  - Aircraft water systems are extensions of municipal water systems
- Provides protection against disease causing organisms that may be found in onboard tap water
- Requires:
  - Coliform and *E. coli* sampling
    - 2 samples each sampling period
    - 1 lavatory and 1 galley sample
    - Monthly to yearly sampling schedule
  - Disinfection and flushing
    - Up to 4 times per year
    - Required soon after positive coliform/*E. coli* sample

TABLE IV–2—FINAL RULE REQUIREMENTS FOR ROUTINE DISINFECTION AND FLUSHING AND ROUTINE SAMPLING FREQUENCIES

Minimum routine disinfection & flushing per aircraft	Minimum frequency of routine samples per aircraft
At least 4 times per year = At least once within every three-month period (quarterly).	At least 1 time per year = At least once within every twelve-month period (annually).
At least 3 times per year = At least once within every four-month period.	At least 2 times per year = At least once within every six-month period (semi-annually).
At least 2 times per year = At least once within every six-month period (semi-annually).	At least 4 times per year = At least once within every three-month period (quarterly).
At least 1 time per year or less = At least once within every twelve-month period (annually) or less.	At least 12 times per year = At least once every month (monthly).

2

From the Plant to the Airport



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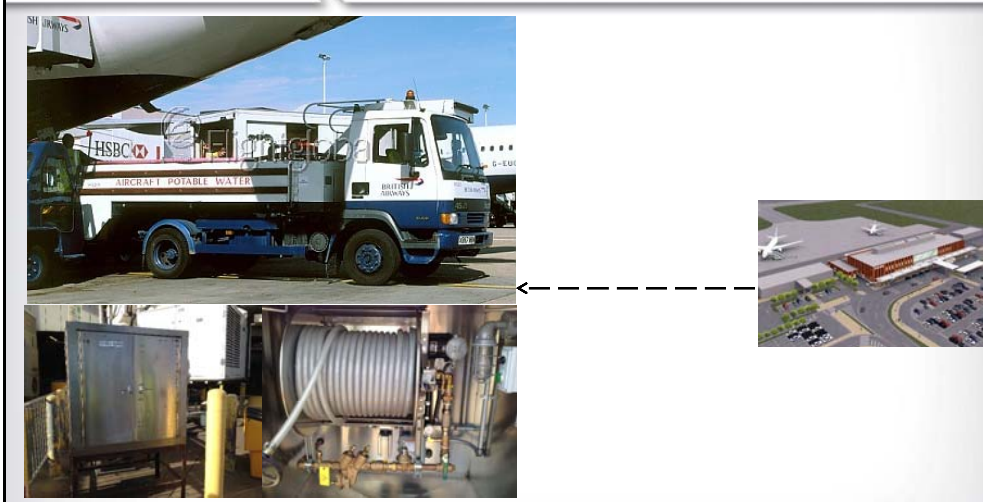
From the Airport to the Aircraft



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Aircraft Water Quality Can Be Affected By:

- Changes in water quality that occur in the airport
- Changes in water quality that occur in the water transfer facilities at the airport (hoses and water trucks or water closets)
- Changes in water quality that occur on the aircraft



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RARE Project Description

- Objective- Better understand the source of contamination in aircraft drinking water systems and to investigate effectiveness of current disinfection and flushing procedures.
- Regional Applied Research Effort
  - ORD and Region 6
  - MCRADA among ORD, Boeing Commercial Airplanes, and Region 6 Air Carriers
- Part 1 - Isolation of bacteria
  - Water samples analyzed at air carrier's contract labs
  - Positive coliform medium shipped overnight to EPA Cincinnati
  - Isolate coliform bacteria using MacConkey agar
  - Identify isolates using biochemical and molecular tests
- Part 2- Construct a mock aircraft water system in Cincinnati
  - Test selected coliform isolates for colonization of mock system
  - Test decontamination procedures for microbial and chemical contaminants

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Isolation of Coliforms

- Participation by EPA Region 6 Air Carriers
  - Samples taken from the galley and lavatory
  - Six different aircraft represented, but most are Boeing 737
- 10 contract labs submitted samples
  - Colilert® most common; also Colisure® and Colitag™
- 3 models yielded positive samples
  - 737 most common; also 757 and ERJ
- 38 total coliform water samples received from 35 different airplanes
- Our method of isolating bacteria from the medium and long holding times made it difficult to capture all bacteria that may have been in the original water samples
- But all bacterial isolates recovered were in original water samples

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Isolation of Coliforms

- Most positive samples from lavatories; one positive galley sample
- A total of 161 bacterial isolates recovered
  - *Enterobacter* and *Klebsiella* most common isolates
  - Also recovered *Citrobacter*, *Serratia*, *Hafnia*, *Kluyvera*, *Pseudomonas*, *Stenotrophomonas*, *Shigella*, *Myroides, E. coli*
  - Most common to both water and biofilm environments
  - Recovered *E. coli* from one sample (but it was the one galley sample tested!)
- Observations that support the idea of biofilm as a source of coliform bacteria:
  - 2 airplanes yielded the same bacterium from samples taken before and after disinfection and flushing procedures
  - 3 airplanes that were positive in this study (sampled in 2013) were also coliform positive in 2012
  - I set of samples, from the same lavatory faucet sampled twice on the same day, yielded the same bacterium.

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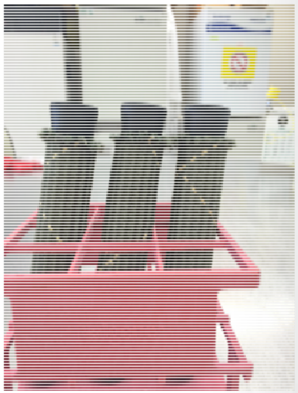
Isolation of Coliforms

- 24 isolates were tested for ability to form biofilms inside of aircraft water hose
  - Bacteria allowed to grow in broth inside hose sections overnight
  - Bacteria washed out and any remaining cells attached measured
- 12/24 were able to form a biofilm inside hose sections
- 3 colonizers were used in subsequent experiments



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Mock Aircraft Water System

- Constructed at EPA's Test and Evaluation Facility in Cincinnati, OH
- Modeled after a Boeing 737 water system
- Water tank and swivel head faucet were donated; EPA purchased the remaining parts
- The mock system was contaminated with coliforms and persistence/colonization observed
- Decontamination was examined with Purogene® (chlorine dioxide) and ozone
- The system includes six points for sampling surfaces (fittings and tubing) as well as the faucet and aerator
- Multiple faucets installed, but the swivel-head faucet was of particular interest

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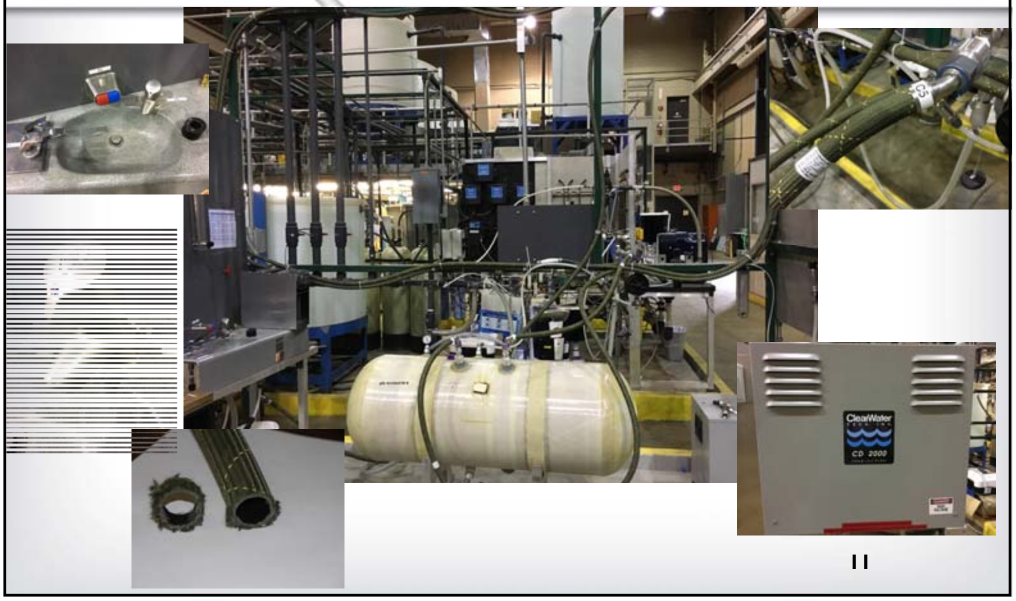
Mock Aircraft Water System



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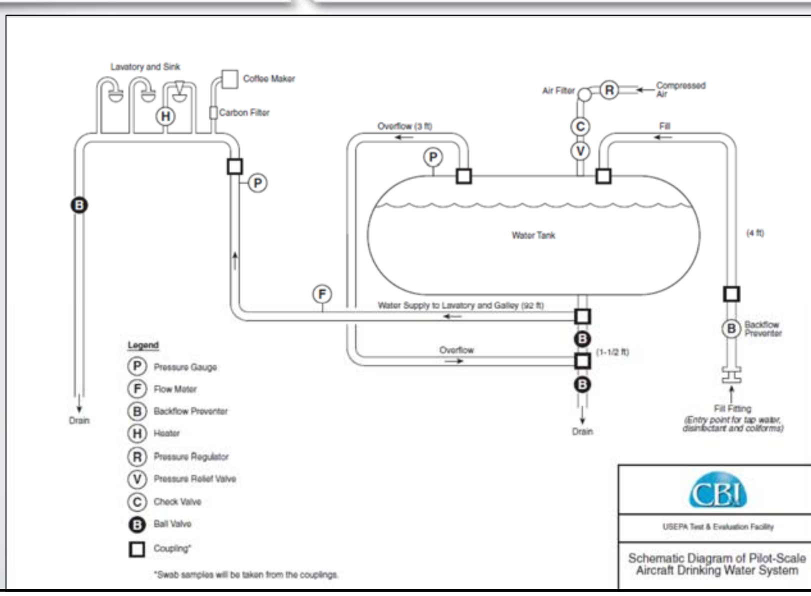
Schematic



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Experimental Procedure

- Conditioning/Biofilm Formation
  - A mixture of chlorinated and chloraminated water flowed through system
  - Free/Total Chlorine: Tank: 0.05/0.23 mg/L, Faucet: 0.02/0.04 mg/L
  - Water dispensed every 10 min, every other hour on work days
  - Conditioning occurred for 1 month
- Contamination
  - Three coliforms added to tank at ~10^5 to 10^6 MPN/100 ml (combined)
  - Flushed through the system and allowed to sit overnight
- Decontamination
  - Purogene®: 100 mg/L for 2 hours
  - Ozone: At least 1 mg/L for 5 min
  - Water sampled, tubing/fittings swabbed, aerators sampled
- All coliform analyses performed with Colilert®

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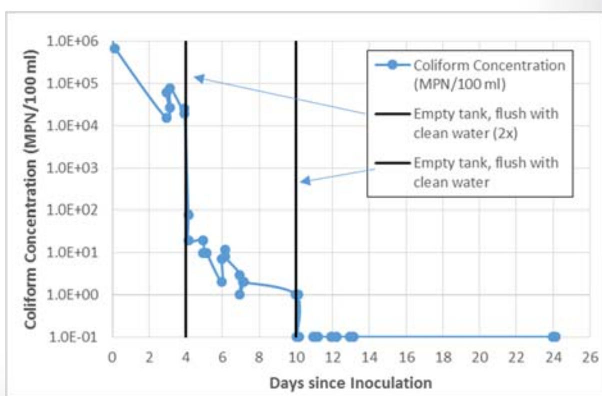
Coliform Persistence

- Coliforms inoculated into the tank at ~10^6 MPN/100 ml with dechlorinated water, flushed through the entire system and allowed to sit stagnant for three days
- Flushing on two separate periods resulted in no detectable coliforms in the water phase
- All six fitting/sampling points were negative when sampled
- HPC was measured:

Sample ID	HPC (MPN)
C1 fitting	7.0E+04
C1 hose	3.4E+02
C5 fitting	2.2E+01
C5 hose	3.0E+00
C6 fitting	2.2E+05
C6 hose	2.1E+04



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Decontamination

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Disinfection and Flushing Results

- After disinfection and flushing with Purogene® and ozone, no coliforms were detected in the water, on any fitting or tubing surface, or inside the swivel head faucet
- After ozone treatment, coliforms were detected on the aerator
- Experiments were performed in duplicate
- Purogene® concentration was not what we expected

Coliform Inoculation* (MPN/100 ml)		Disinfectant and Contact Time	Disinfectant Concentration	Fitting/Tubing Coliform Sampling (all six points**)	Inside Faucet Coliform Sampling	Aerator Coliform Sampling
Mean	St. Dev.		(mg/L)	MPN	MPN	MPN
3.7E+05	2.7E+05	Purogene/2hrs	120	ND	ND	ND
9.2E+05	2.9E+05	Purogene/2 hrs	140	ND	ND	ND
2.4E+05	2.4E+05	Purogene/2 hrs	18	ND	ND	ND
5.6E+05	4.5E+05	Ozone/5 min	1.25	ND	ND	8.5E+00
2.6E+06	3.6E+06	Ozone/5 min	1.04	ND	ND	8.8E+01

*Mean/Standard deviaiton are from eight samples from both the tap and tank

**Six fitting and six tubing sections were swabbed during each experiment. No coliforms were detected in any swab samples after disinfection

ND: None detected (detection limit 1 MPN/100ml)

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Aerator Disinfection

- Disinfection was conducted with commercially available Lysol® (dimethylbenzylammonium chloride) and Glyco-San® (L-lactic acid)
- Aerators were soaked in dechlorinated tap water with coliforms for 1 hr (~10^2 to 10^3 cfu/100 ml)
- Aerators then soaked in sterile water or disinfectant (30 min)
- After disinfection, aerators moved to sterile buffer, vortexed for 1 minute and the water analyzed for coliforms
- Half of the samples were brushed with steel wool prior to disinfection

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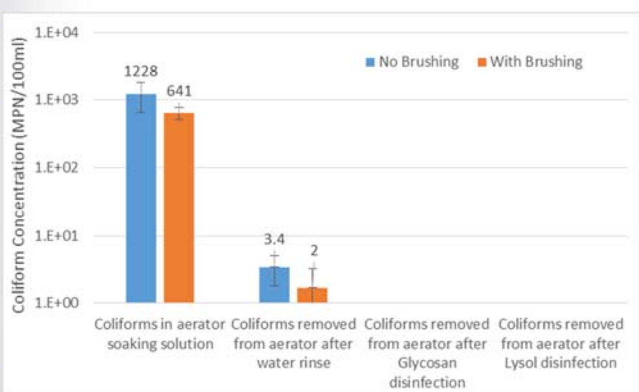
Aerator Disinfection

- Six experiments conducted: coliform contaminated aerators exposed to sterile water, Lysol® or Glyco-San®, half with and without brushing
- Coliforms were detected in sterile water, but not in Lysol® or Glyco-San®
- Brushing did not make a difference



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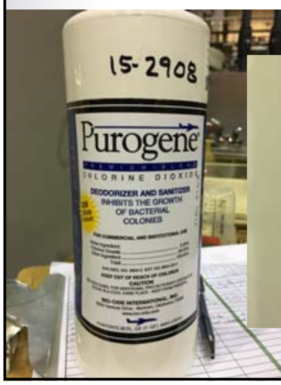
Purogene® (Chlorine Dioxide)

- Disinfection occurs by applying 100 mg/L with 2 hours of contact time
- 1 qt. of activated Purogene® produces 100 mg/L in 50 gal (more in 40 gal)
- Neat Purogene® solution is activated for 5 minutes
- Test strips are used to determine if 100 mg/L is achieved at the faucet



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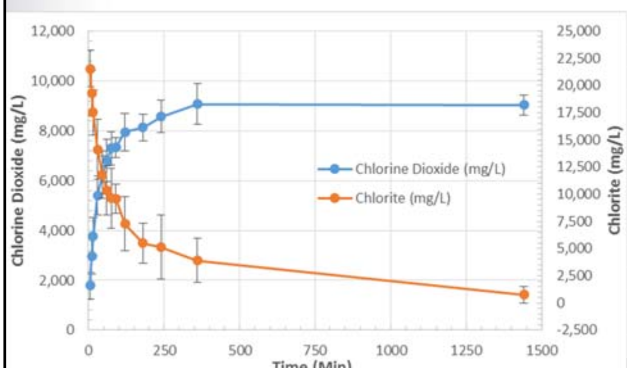
Purogene®

- Neat activated Purogene® was sampled at time intervals and the stock concentration was determined via a spectrophotometer (Hach test kit)
- Dilutions were made to approximate adding a one qt. bottle of activated Purogene® to 40 gal. of water in the aircraft tank



Time (min)	ClO_2 Concentration (mg/L)	One Purogene bottle diluted in 40 gal tank (mg/L)	Bottles Needed for 100 ppm #
5	1,787	11	9.0
10	2,960	19	5.4
15	3,760	24	4.3
30	5,407	34	3.0
45	6,233	39	2.6
60	6,807	43	2.4
75	7,293	46	2.2
90	7,327	46	2.2
120	7,940	50	2.0
180	8,133	51	2.0
240	8,573	54	1.9
360	9,073	57	1.8
1440	9,033	56	1.8

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Purogene®

- Along with spectrophotometer readings, the diluted samples were measured with the OxyStix™ test strips. All showed 100+ mg/L $Cl0_2$
- We consulted with the manufacturer of the test strips and Purogene® (Bio-Cide International), who confirmed our results
- The test strips detect chlorite as well as $Cl0_2$, and the 100 mg/L represents "potential" $Cl0_2$

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Purogene®

- As time moves forward, active $Cl0_2$ (which does the disinfecting) increases
- As $Cl0_2$ increases, chlorite is consumed
- Once the activated Purogene® is added to water, the reaction is quenched
- At 5 min, more chlorite is available to maintain the 11 mg/L in the tank
- At later time points, more active $Cl0_2$ is present (56 mg/L @ 1 day), but less chlorite is available to maintain that concentration.
- Which is better: Lower $Cl0_2$ that is better maintained, or higher active $Cl0_2$ that could decay?

Time (min)	ClO_2 Concentration (mg/L)	Chlorite Concentration (mg/L)	One Purogene bottle diluted in 40 gal tank (mg/L)
5	1,787	21,541	11
10	2,960	19,273	19
15	3,760	17,505	24
30	5,407	14,116	34
45	6,233	11,785	39
60	6,807	10,362	43
75	7,293	9,616	46
90	7,327	9,590	46
120	7,940	7,261	50
180	8,133	5,486	51
240	8,573	5,132	54
360	9,073	3,905	57
1440	9,033	755	56

Final conc. is not 100 mg/L

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Summary

- Long term coliform persistence was not observed on water system tubing and fittings in dechlorinated water
  - This finding suggests that coliforms do not readily form biofilms in airplane water systems.
- Coliforms were not detected on tubing, fittings or in the water phase after disinfection and flushing with Purogene® or ozone
  - The only exception was the swivel faucet aerator after ozone treatment
  - Overall, current disinfection and flushing procedures with Purogene® and Ozone appear adequate
- Disinfection of the aerators with Lysol® or Glyco-San® resulted in no detection of coliforms
- Purogene® concentration was expected to be 100 mg/L of active (available) $Cl0_2$, but only 10-15 mg/L was measured
  - Longer reaction of Purogene® results in more active ClO_2

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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

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Questions?

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USEPA Office of Research and Development

FIELD-SCALE WATER INFRASTRUCTURE DECONTAMINATION AND WASH WATER TREATMENT

Jim Goodrich, John Hall, and Jeff Szabo

2016 EPA International Decontamination Research and Development Conference

Durham, NC

November 1, 2016

EPA

Water Security Test Bed (WSTB)

How will these technologies perform in full-scale systems?

Water Security Test Bed:

- Simulates intentional and inadvertent distribution system contamination (chem, bio, rad) and disruptions (cyber-attacks)
- Supports diverse applied research
- Located at Idaho National Lab (INL) (near Idaho Falls, Idaho)

Water Security Test Bed Video: https://youtu.be/olCs_kbegBA

The WSTB is a once through system:

- ~445' of 8" cement mortar lined, ductile iron pipe (water main)
- ~ 200' of 1" copper service line to building; typical household appliances
- 6 × 1" service connections/sample ports, 2 hydrants
- 15' pipe material coupon section for sampling the interior of the pipe surface
- Above ground system, underlined by secondary containment
- 28,000 gallon lagoon/high rate groundwater pump/storage tank

2

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Premise Plumbing Service Line

3

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Injection Point

4

Removable Coupons and Pipe Available for Decontamination Experiments

Forty year old conveyance pipes (cement mortar lined ductile iron) servicing a decommissioned building was dug out of the ground at INL

8” ductile iron

4” cast iron

5

Chlorine and UV Sensors with Cellular Modem

6

Triggered Flushing

7

28,000 Gallon Lagoon, Tanker Truck and Treatment System

8

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WSTB Current and Future Experiments

Accomplished

- ClO_2 decontamination and flushing of system for anthrax spores surrogates (October 2014, May 2015)
- Treatment of *Bacillus* spores in the lagoon water using Cl_2, UV, and UV+O_3 (August 2015)
- Crude oil contamination and decontamination - simulating a refinery/rail transport accident (Sept. 2015)
- *Bacillus* spore decontamination using ice pigging and chlorination (May 2016)
- Decontamination of indoor plumbing and appliances (August 2016)
- Infrastructure decontamination and treatment of water containing PFOA/PFOS (September 2016)

Future

- Detection/Decontamination of radionuclides
- Aerosolization of biological agents via points of use
- Cyber attack on system instrumentation and communications
- More complex network for model validation
- First responder training exercises

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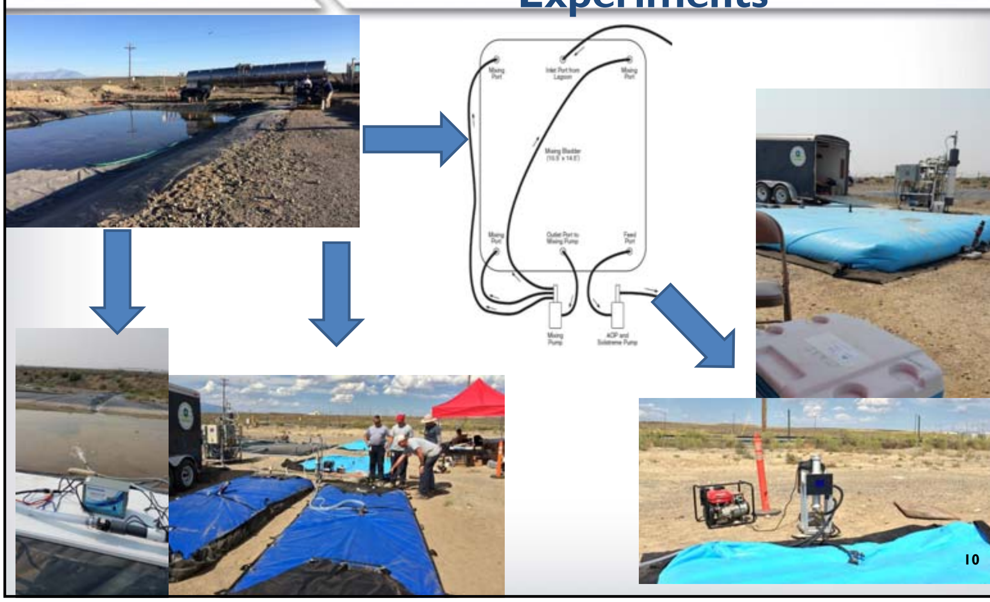
EPA

Wash Water Treatment Experiments



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Solstreme UV Flow Through System

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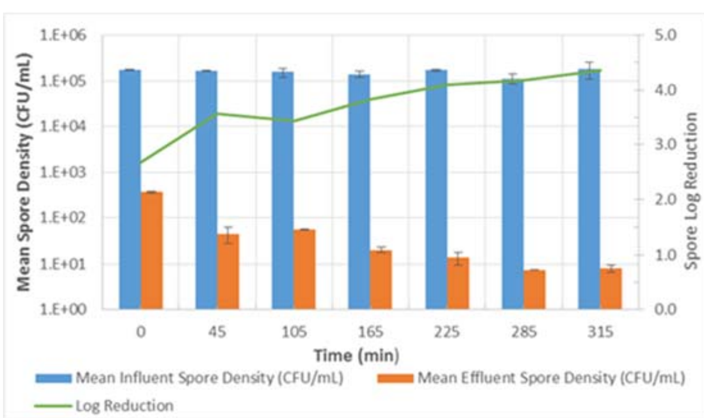
Washwater Treatment Solstreme UV Flow Through System - Lagoon



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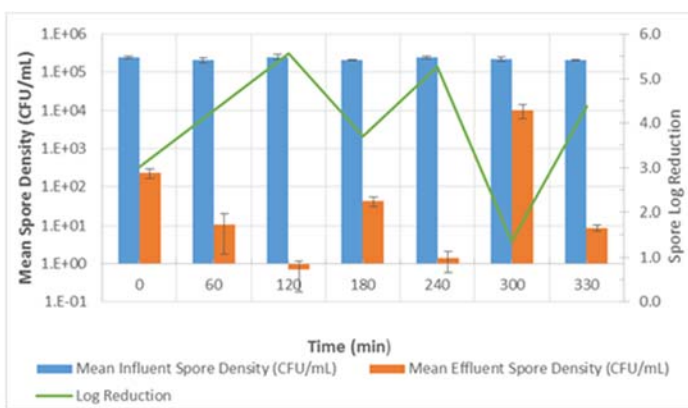
Ozone/UV Mobile Trailer

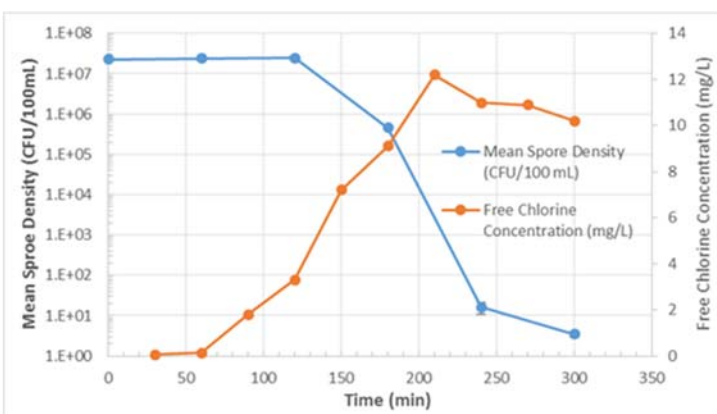
Washwater Treatment Ozone/UV Flow Through Mobile Trailer - Lagoon



WaterStep Mobile Emergency Water Treatment System

15

WaterStep Mobile On-Site Chlorine Generator – Bladder Tank



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Hayward Swimming Pool Chlorinator

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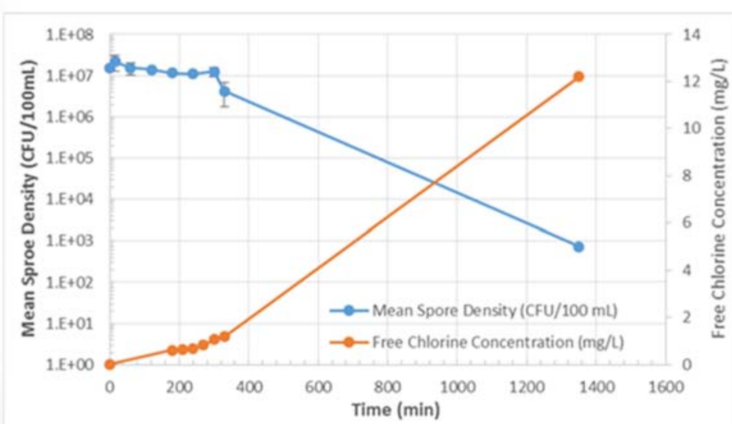
Washwater Treatment Swimming Pool Chlorinator – Lagoon Batch



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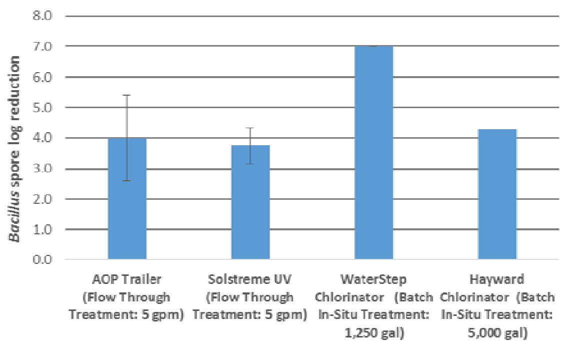
WSTB Lagoon Water Treatment

Flow Through Treatment (AOP and Solstreme)

- Disinfection began as soon as the unit was turned on
- Flow was 5 gpm for 4.5 to 5 hrs
- Variation in log reduction was observed over the course of the experiments (represented by error bars)

Batch In-Situ Treatment (WaterStep and Hayward)

- Disinfection took place in a 1,250 gal bladder (WaterStep) or 5,000 gal in the lagoon (Hayward)
- Chlorine residual increased over time in the treated volume
- Highest log reduction at the peak free chlorine concentration is reported



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Summary of Performance Data

Portable Water Treatment Device	Capital Cost	Average Log Reduction	Volume Treated (gal)	Flow (gpm)	Performance Summary
AOP Trailer (UV and Ozone)	$40,000	4.0	2,000	5	Provides immediate disinfection and 4-log removal within 1 hour.
Solstreme (UV)	$15,000	3.5 to 4.0	2,000	5	Stable, immediate 3-log disinfection, easy to transport and set up.
Water Step (Chlorinator)	$8,000	7.0	1,250	N/A	6-log reduction in 300 min, lowest total treated volume.
Hayward (Chlorinator)	$4,000	4.3	5,000	40	4-log reduction in 1,350 min, under most difficult disinfection conditions.

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Detailed Summary of Performance Data

Technology Considerations	AOP Technology
Market Availability	Low. Originally custom designed by EPA for a remediation project to provide advanced oxidation with UV and Ozone. A trailer mounted system that was re-purposed and tested for disinfection. One ozonation process component (Speece Cone diffuser) not commercially available. Other UV and Ozonation process components commercially available.
Capital Cost	High (estimated > $40,000). Custom design, process components, plumbing, trailer, etc.
Shipment to Site	Medium. Requires a tow vehicle to pull the trailer to site. Trailer may require State inspection and driver that meets the training requirements for towing the vehicle.
Setup Considerations	Medium. Requires 110 and 220 Volt AC electric or generator, the plumbing connections to the process units need to be reassembled on site. The Ozonator cone setup requires 2-3 persons onsite to assemble.
Operational Considerations	Medium. Requires operation of valves to remove air from the process units, valve adjustment to meet pressure and flow requirements. Some of the vented air may contain contaminated droplets of water that need to be contained or recirculated back through the system. There is excess ozone emissions from process unit that needs to be destroyed or vented. The catalytic destruction unit was un-operable the unit had to be vented. Flow rate needs to be less than 5 gpm (18.9 L/min).

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Decontamination Experiments






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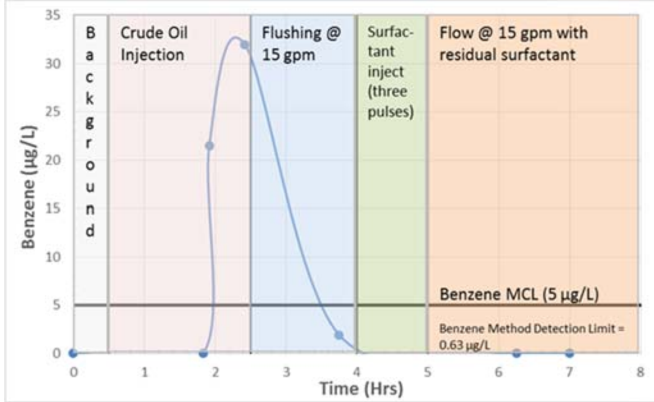
WSTB Bakken Crude Oil Results



- Crude oil components (Benzene) were not detected on the coupon surfaces
- Surfactant addition was unnecessary, and could be counterproductive as it did persist (surfactant might be needed for higher petroleum product loading)

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Future WSTB Expansion

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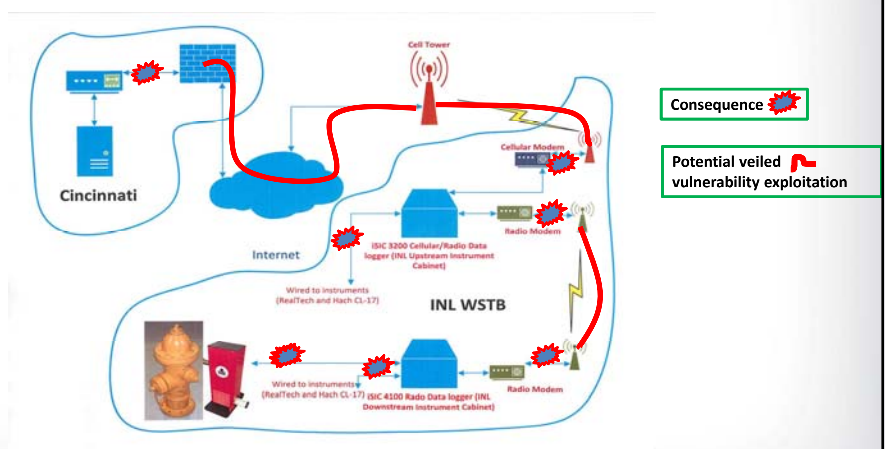
Vulnerability/Consequence Cyber Security Assessment for Water Security Test Bed



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Future Opportunities

- Capability to build the WSTB to sustain a diverse research portfolio
  - Construct and test more complex pipe networks contingent on research partners' needs and capabilities
- Address gaps in threat identification and response (chem/rad/bio/cyber)
- Collaboration with water utilities, water research organizations, state, regions, and federal agencies
- National research asset for water security and Water / Energy Nexus
- Use constructed site for training opportunities

ORD WSTB Team

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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

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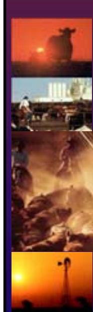
Installation of Routine and Heightened Biosecurity Equipment and Protocols at Beef Cattle Feedyard in the High Plains

Dr. Robert DeOtte – WTAMU
with credits to
Ross Wilson – TCFA
Ben Weinheimer – TCFA
Heather Manley - IIad

Photographs Courtesy of TCFA

West Texas A&M University

US Feeder/Fed Cattle Industry



Photographs Courtesy of TCFA

- Cattle industry largest U. S. agricultural sector
- 85,000 feedyards below 1000 head
- 2160 feedyards over 1000 head
- 200 feedyards in TX, NM, and OK
- 30,000 head feedyard – 840,000 pounds feed per day, seven days per week

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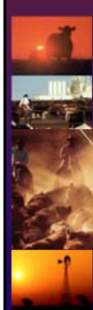
Economic Impact

- National (Wilson, 2009)
  - $30 billion per year fed cattle sales
  - $75 billion per year retail sales
- International (Wilson, 2009)
  - Beef cattle exports $3 billion per year



Photographs Courtesy of TCFA

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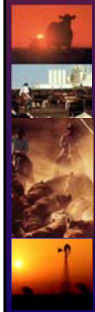
Regional Impact

- Texas, Oklahoma, New Mexico
  - 7 million fed cattle/yr
    - ~30 percent of total
  - Cattle from 29 states + Mexico + Canada
- 80 percent of US beef in 300 x 600 mile rectangle
  - TX / NM / OK / KS / NE / CO



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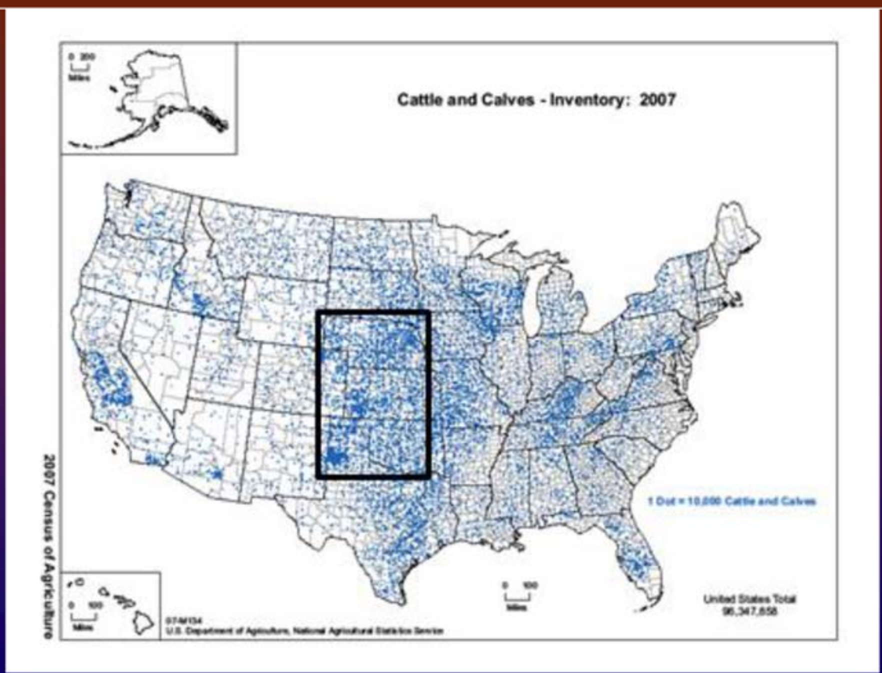


Concentrated Animal Feeding Operations

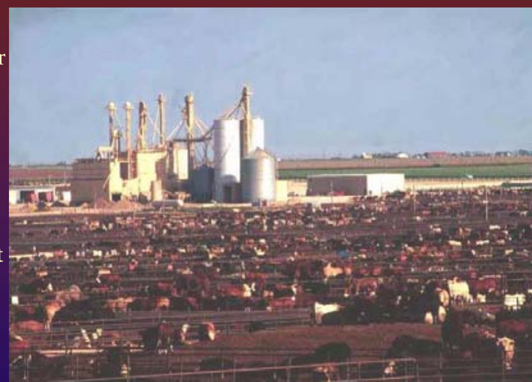
CAFOs are livestock feeding operations with 1000 animal units or more being fed in a single use facility for 45 days or more

- 1000 hd beef cattle
- 700 hd dairy cattle
- 2500 hd swine weighing more than 55 lb

Regulated under clean water act

Panhandle CAFOs

- Feedyards: 20,000 – 100,000
- Dairies: 3,000 – 40,000
- Swine farms: 6,000 – 40,000



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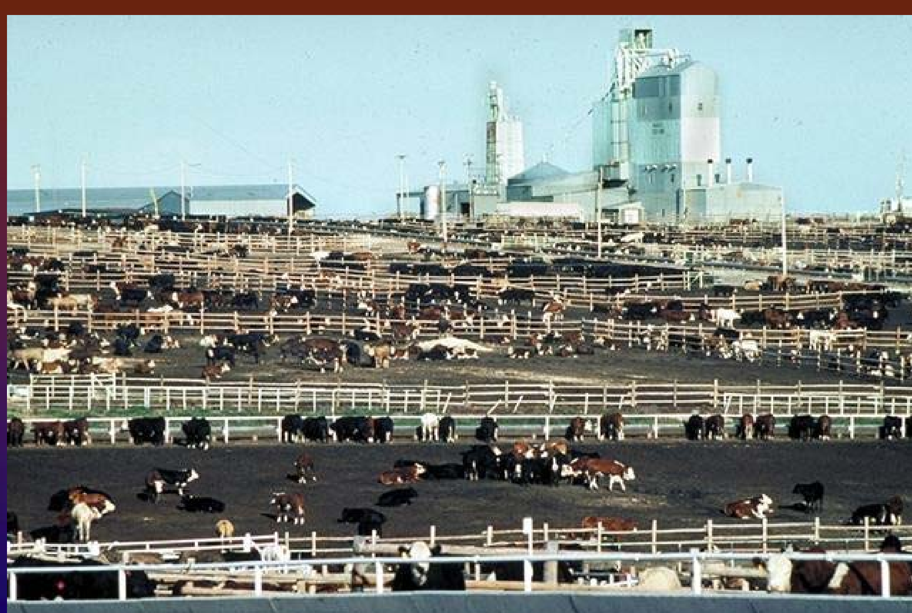
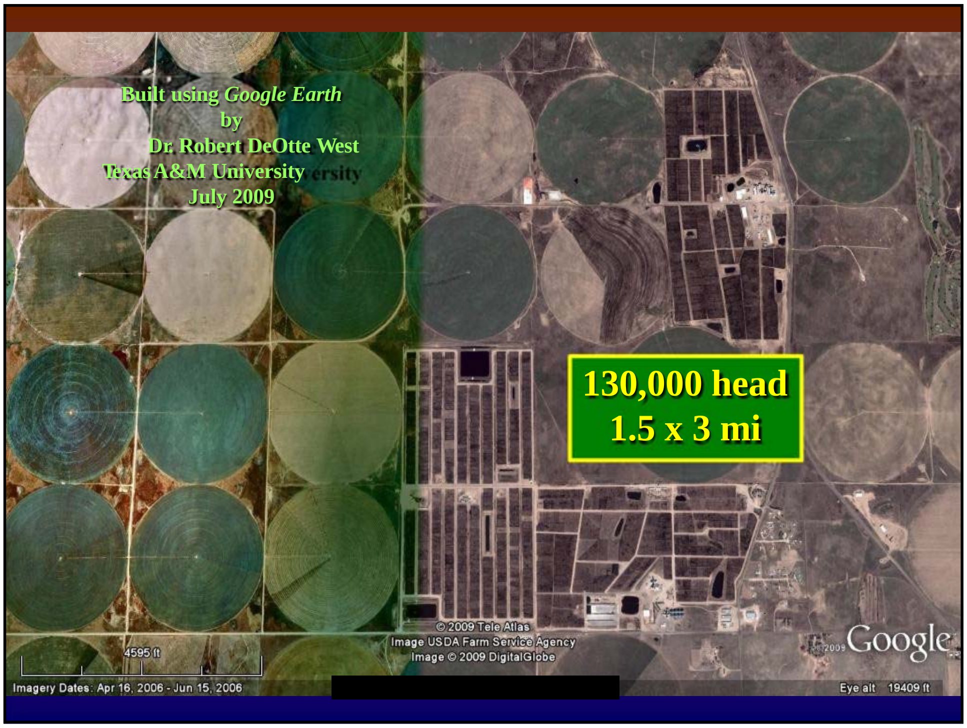
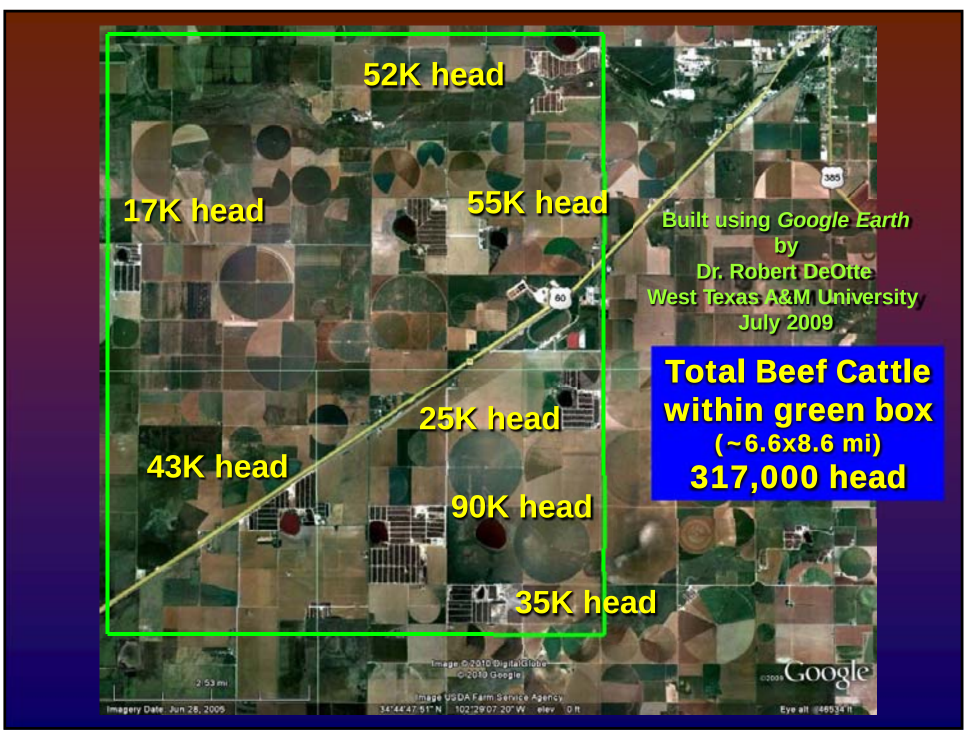



Built using Google Earth
by
Dr. Robert DeOtte West
Texas A&M University
July 2009
130,000 head
1.5 x 3 mi
Google


52K head
17K head
55K head
25K head
43K head
90K head
35K head
Built using Google Earth
by
Dr. Robert DeOtte
West Texas A&M University
July 2009
Total Beef Cattle
within green box
(~6.6x8.6 mi)
317,000 head
Google

Cattle Concentrations
Hereford, TX

Concerns

Photographs Courtesy of TCFA

- ❑ Maintain export markets
- ❑ Maintain American confidence in food supply
  - FMD is not a human health issue
    - o H1N1va – aka Swine flu
- ❑ Costs
  - Indemnity
  - Control strategies
- ❑ Psychological
- ❑ Cleaning and Disinfection
- ❑ Continuity of Business

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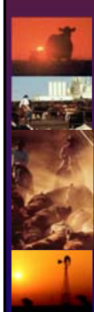
Cleaning and Disinfection



Photographs Courtesy of TCFA

- ❑ 55,000 beef cattle feedyard
  - 80 trucks per day
  - 10 min per truck = 13+ hours
- ❑ Minimize potential for disease spread by cleaning undercarriage and wheels
- ❑ Senior Design Project – WTAMU
  - Civil Engineering and Mechanical Engineering Students

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Objective

- ❑ Affordable undercarriage and wheel wash
- ❑ Use every day to maintain routine biosecurity
  - Cleaner vehicles need less maintenance
  - Want feedyards to adopt at own expense or with matching fro Natural Resources Conservation Service
- ❑ Add disinfection for heightened biosecurity

Photographs Courtesy of TCFA

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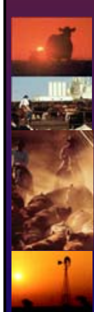
Specifications

- ❑ Able to operate in freezing conditions
  - Panhandle – added recirculation pump and 3000 gallon tank
  - Be able to retrofit with cover
  - Other locations might require antifreeze and heating
- ❑ Must make vehicle visibly cleaner
  - One to three log reduction in infectivity by washing alone
- ❑ Must be water efficient
  - Eliminate need for routine waste water treatment



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Student Design Process

- Design parameters
  - Size of vehicles
  - Number of vehicles
  - Water limited
  - Waste disposal
- Engineering economic analysis
  - Initial costs
  - Distributed maintenance costs
- Applicable regulations
  - Environmental Protection Agency
  - Texas Commission on Environmental Quality (TCEQ)
  - CAFO rules
    - NPDES
  - Vehicle washing rules
    - Water reuse
    - Waste disposal

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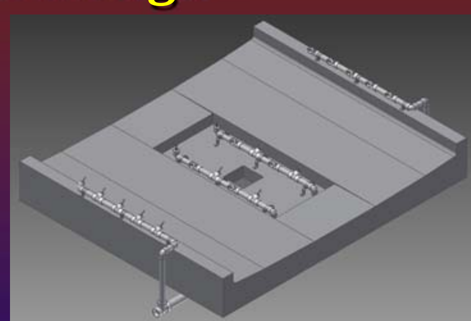
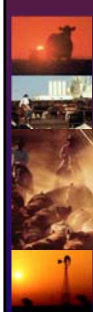
Student Design

- Evaluated soil bearing capacity
- Designed foundation
- Designed piping system
- Specified control system
- Specified water decon system



- Exceeded budget
- Overly complicated
- Good analysis but not design



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Undercarriage and Wheel Wash Construction Site

Center Channel

Three tracks for undercarriage and wheel wash

Solid Waste – 3% moisture content

Conclusion

- Affordable commercial unit
  - Modified center channel to focus on undercarriage
  - Somewhat similar to student design
- 3 gallons make-up water per vehicle
  - Polymer coagulant
  - 2% - 3% moisture content in solids
- Wash available for future research

Photographs Courtesy of TCFA

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United States Environmental Protection Agency

2016 U.S. EPA International Decontamination Research and Development Conference

Wednesday, November 2, 2016

Concurrent Sessions 2

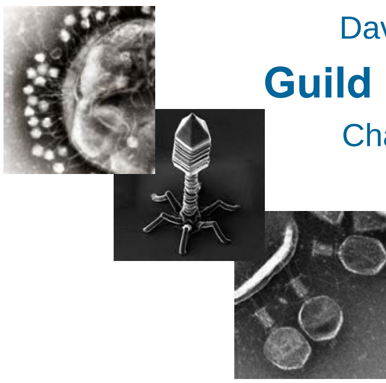
Biological Agent Detection

Bioluminescent reporter phage system for *Bacillus anthracis* detection and clearance monitoring following environmental release

David Schofield

Guild BioSciences

Charleston, SC



Why focus on *B. anthracis*?

Species	Matrix/host	Persistence (time)
B. anthracis	Soil Human remains Pond water	40 years 200 years 18 years
Y. pestis	Soil Autoclaved soil	24 days 40 weeks
F. tularensis	Water	3 weeks
B. mallei	Not specified	Weeks
B. pseudomallei	Soil Water	Years Months

- **Spores: Infectious form**
  - Stable over long periods of time
  - ‘Easy’ to produce and stockpile
  - ‘Easy’ to disseminate
  - Resistant to physical and chemical treatments

Environmental detection: Magnitude of the problem

Item	Anthrax attack
Attack method	Wide dispersion of *B. anthracis* spores in urban area
Cases/Fatalities	13,000 IA/<13,000
Incubation time	3-14 days
Secondary exposures	None
# Exposures	328,000
# Clinical tests	300,000/14 days
# Clinical tests/day	60,000
# Environmental tests	1,000,000 over months
Peak # environmental tests/day	50,000?

Adapted from DHS National Planning Scenarios, 2006

- **Wide area dispersal**
  - Dispersal of 50kg in an urban area
  - Infrastructure breakdown
  - Medical resource limitations
- **Issue: Massive number of tests**
  - >1,000,000 samples
  - ~50,000 tests/day
- **Detection & clearance monitoring**
  - Simple methodology
  - High throughput
  - Detects viable cells only
  - **Utility across all environmental matrices**

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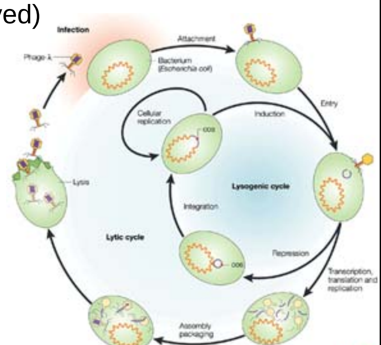
Phage-based applications

- **Phage therapy**
  - Humans, crops and/or foods
- **Phage-derived products as antimicrobial agents**
  - Killing biowarfare bacteria
- **Medical/environmental diagnostics**
  - TB, plague, anthrax & MRSA (FDA-approved)
  - Listeria (AOAC-approved)



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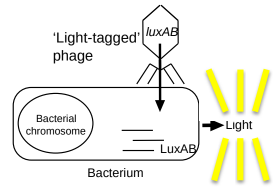
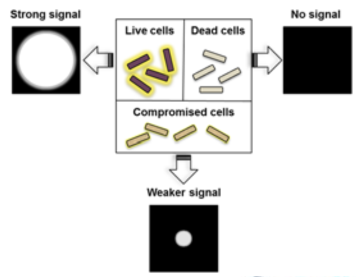
Detection platform: 'Light-tagged' reporter phage

- ***B. anthracis*** **Wβ temperate phage**
  - Parent of FDA-approved gamma 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**





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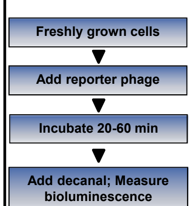
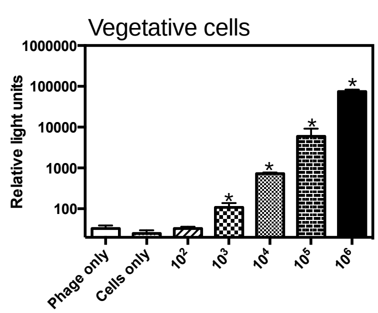
Reporter phage detection specifications





Species	# strains detected/# strains tested
B. anthracis	37/37
B. cereus	1/62
B. thuringiensis	2/45
B. mycoides	3/9
B. weihenstephanensis	0/3
Non-*Bacillus* spp.	0/38

- **Rapid vegetative cell detection (<20 min)**
- **10^3 to 10^4-fold increase in signal intensity**
- **100% inclusivity (37/37 strains)**
- **96% specificity**
- **Requires germinating spores**

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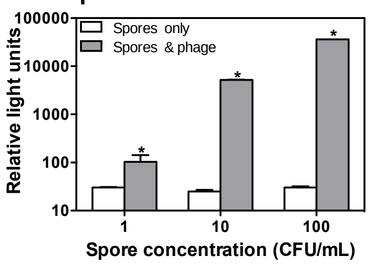
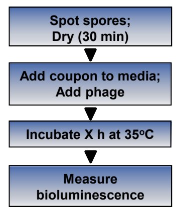
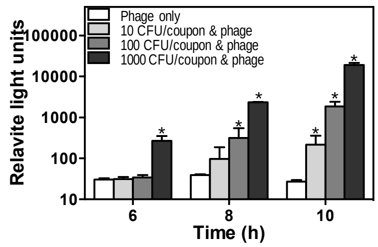
Performance in simple matrices







- **Reporter sensitivity**
  - Limit of detection 1 CFU/mL (8 h)
- **Non-porous 'clean' surface**
  - Detects 1,000 CFU/22mm^2 (6 h)
  - Detects 10 CFU/22mm^2 (10 h)
- **Transition to 'complex' samples challenging**
  - Presence of commensal flora
  - Sample matrix complexity

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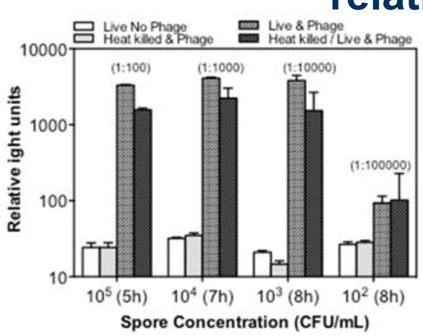
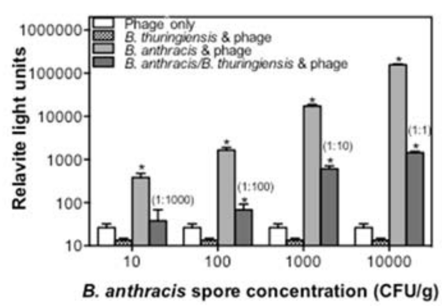
System challenges: Dead spores & close relative spp.





- **Dead spores: no signal response**
  - Detects 100 live spores in presence of 10,000,000 dead spores
- **Detection in the presence of commensal spp.**
  - Presence of *Bt* reduces *B. anthracis* signal response
  - Detects 100 *B. anthracis* in the presence of 10,000 Bt (8 h)

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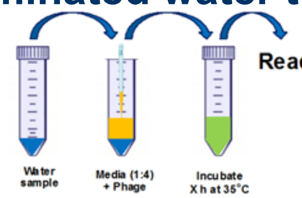
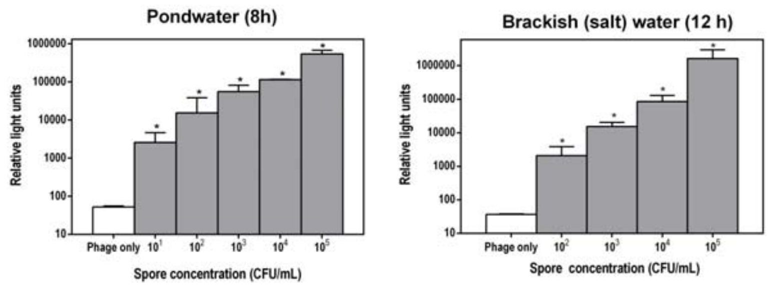
Contaminated water testing



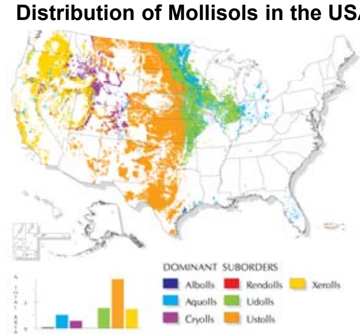


- **Spore-contaminated water:**
  - Limit of detection of 10^1 CFU/mL in pond water (8 h)
  - Limit of detection of 10^2 CFU/mL in brackish water (12 h)

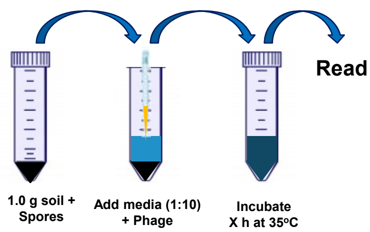
Complex environmental matrices

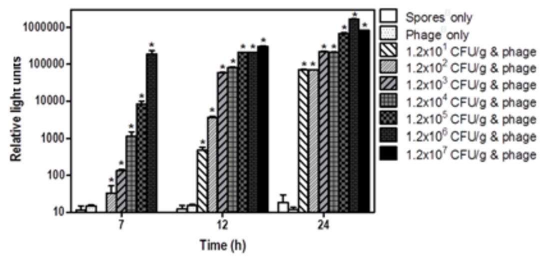
- **Mollisol**
  - Predominant soil type in USA (21%)
  - Silty clay loam (Agvise Laboratories)
    - USDA textural class
    - Top 0-6 inches; 2mm sieve
    - pH 7.8; 2.3% moisture
    - 7.5% organic matter
- **Challenges with soil matrices**
  - High number of background flora
    - $2x10^9$/g bacteria in top 1 m of soil
    - High number of closely related species
    - Low number of target bacteria

Distribution of Mollisols in the USA



Matrix challenge: Autoclaved soil





- Autoclaved mollisol soil
  - **No spore extraction/processing**
  - Add media (1:10); Add phage
  - Incubate X h at 35°C
  - Measure bioluminescence
- **Matrix does not inhibit signal (absence of viable flora)**
  - Detection of 120 CFU/g in 7 h
  - Detection of 12 CFU/g in 12 h
- **Semi-quantitative detection**

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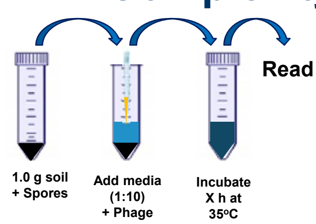
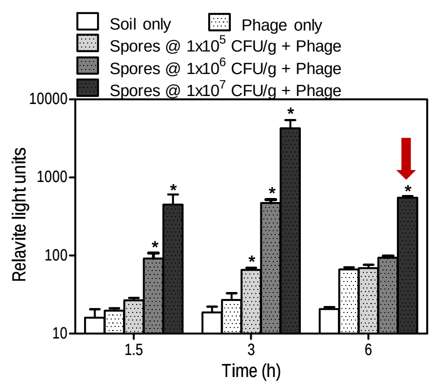
Complexity challenge: Full soil?





- **Complex soil: Challenging!**
- **Detection of 10^5 CFU/g *B. anthracis* spores in 3 h**
  - No spore extraction/processing
- **Peak in signal response at 3 h, then signal decline:**
  - *B. anthracis* viability: vegetative cell persistence in soil?
  - Predation?
  - Phage growth?

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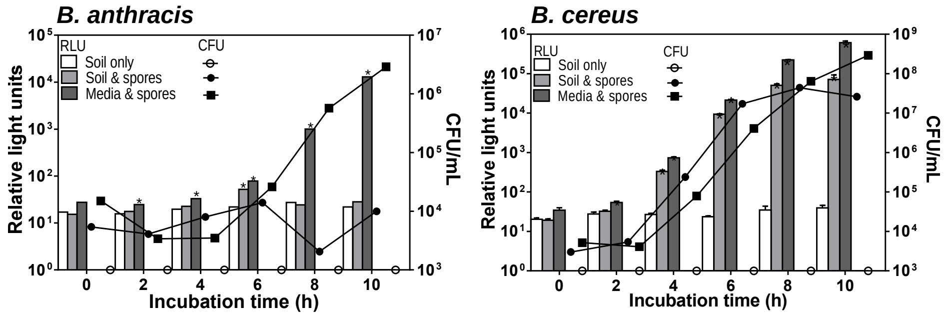
Growth of *B. anthracis* in soil?



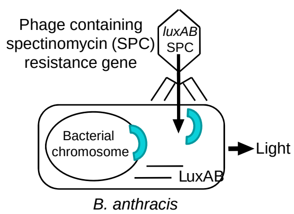
Continued challenges:

- Does *B. anthracis* grow and survive in soil?

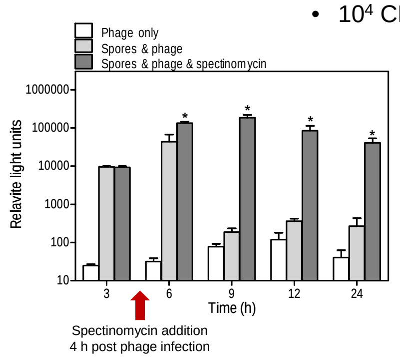
Mitigation of challenges:

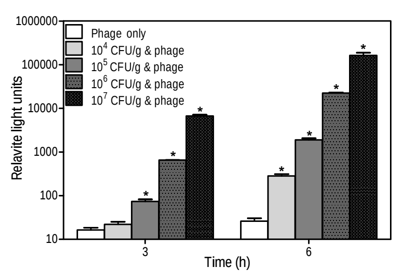
- Development of semi-selective media
- Spore extraction process

Semi-selective media

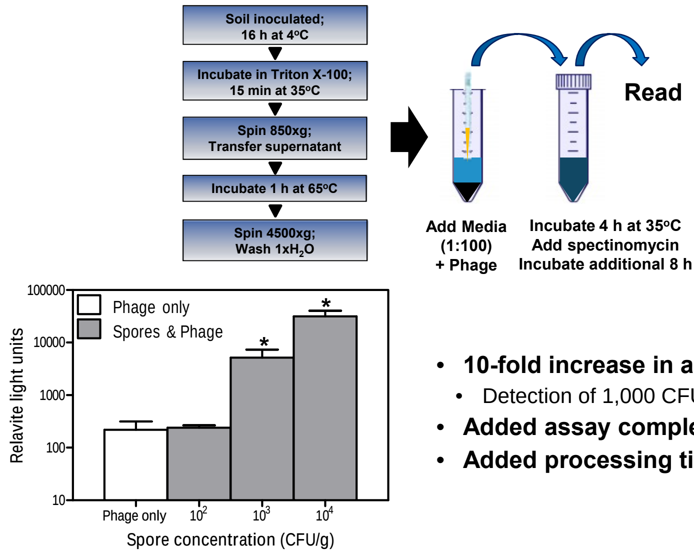


- **Spectinomycin resistance transferred to phage infected *B. anthracis***
  - Media containing SPC = competitive growth advantage
  - Increased signal stability
  - Increased signal strength
  - Sensitivity limit of detection:
    - 10^4 CFU/g in 6 h





Spore extraction



- **10-fold increase in assay sensitivity**
  - Detection of 1,000 CFU/g in 12 h
- **Added assay complexity**
- **Added processing time (2.5 h)**

Data summary

- **Displays genus specificity**
  - 96% specificity for *B. anthracis* within the *B. cereus* Group
  - 100% specificity against other pathogenic spp.
- **Viable *B. anthracis* cells only**
  - 10 CFU/mL in 8 h from contaminated water
- **Glass coupons (clean, non porous surfaces)**
  - 10 CFU in 10 h
- **Detects *B. anthracis* in soil without 'sample processing'**
  - Microbial flora adds complexity
  - 10^5 CFU/g in 3 h; 10^4 CFU/g in 6 h
- **10-fold increase in assay sensitivity following spore extraction**
  - 1,000 CFU/g in 12 h
  - Spore extraction limiting factor

Detection & clearance monitoring: Assay requirements

Item	Anthrax attack
Attack method	Wide dispersion of *B. anthracis* spores in urban area
Cases/Fatalities	13,000 IA/<13,000
# Exposures	328,000
# Clinical tests	300,000/14 days
# Clinical tests/day	60,000
# Environmental tests	1,000,000 over months
# Environmental tests/day	50,000?

- **Issue:** Massive # of tests
- **Requirements**
  - Viability (environmental tests)
  - Cost effective
  - Low complexity
  - High throughput

- **Cost effective**
  - Phage self amplifiable
    - Need 5×10^7 phage/assay: 10,000,000 assays/100 L fermentor
- **Low complexity**
  - Add phage, incubate, measure bioluminescence
- **High-throughput**
  - 94 samples in 6 h
  - Additional 94 samples every subsequent 1.5 h
  - **1248 samples in 24 h (1 technician & 1 luminometer)**

Guild BioSciences

Acknowledgements

Guild BioSciences: Dr. Natasha Sharp, Dr. Randhir Makkar, Cathy Nguyen

MUSC: Dr. Caroline Westwater

Uni. of Texas: Dr. Ian Molineux

ERDC CERL: Dr. Martin Page

DTRA: Dr. William Buechter, Dr. Charles Bass, Dr. Revell Phillips

NSWC, Dahlgren: Dr. Tony Buhr

We thank: ERDC-CERL (W9132T-12-C-0017) and DTRA (BA11PHM158)

Rapid, Quantitative Biological Indicator System with *Bacillus thuringiensis* Al Hakam Spores

Yoojeong Kim[1], John Lovaasen[1], Kristopher Daly[2], Barbara Setlow[3], Peter Setlow[3], Anant Singh[1]

[1]Triton Systems, Inc., 200 Turnpike Road, Chelmsford, MA 01824

[2] KBioSim, Worcester, MA 01606

[3]Department of Molecular Biology and Biophysics, University of Connecticut Health Center, 263 Farmington Ave, Farmington, CT 06030

Current Practice of Decontamination Assurance

- Surface sampling after decontamination - swabs
- Spore strips or coupons with a known population (biological indicators) placed before decontamination and retrieved afterward

- They are extracted, serially diluted, plated, and enumerated.
- It requires considerable labor.
- Results typically cannot be obtained before 24 – 48 hours, up to 7 days.

Commercial Biological Indicators (BIs)

Spore strips[1,2]

Up to 7 days

Self contained BIs[3] (color change)

24 – 48 hrs

Self contained BIs[4,5] (fluorescence)

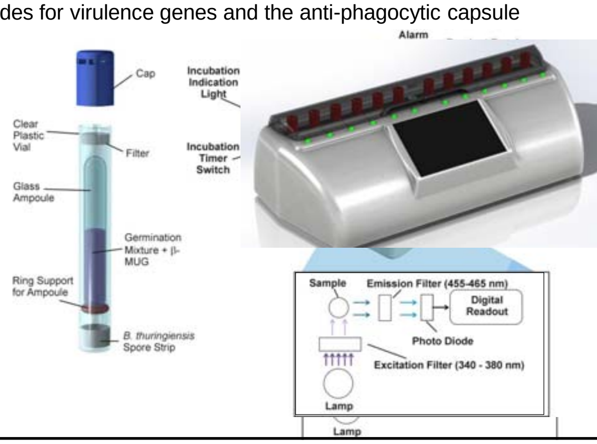
3 – 4 hrs

- *Geobacillus stearothermophilus, Bacillus atrophaeus, Bacillus pumilus*
- Qualitative results – positive/negative

1 http://biologicalindicators.mesalabs.com/spore-strips/
2http://canadawide.ca/Catalogue.aspx?c=1480&category=12581&item=797-570.1
3http://biologicalindicators.mesalabs.com/all-biological-indicators/
4 http://solutions.3m.com/wps/portal/3M/en_US/3M-Purification-Inc/3MPI-US/Products/~/3M-Attest-Rapid-Readout-Biological-Indictor-for-Steam-1292-E?N=8691596+3293240121+4294822241&rt=d
5http://multimedia.3m.com/mws/media/239489O/attest-290-290g-auto-readers.pdf

Triton's BIs and Detector

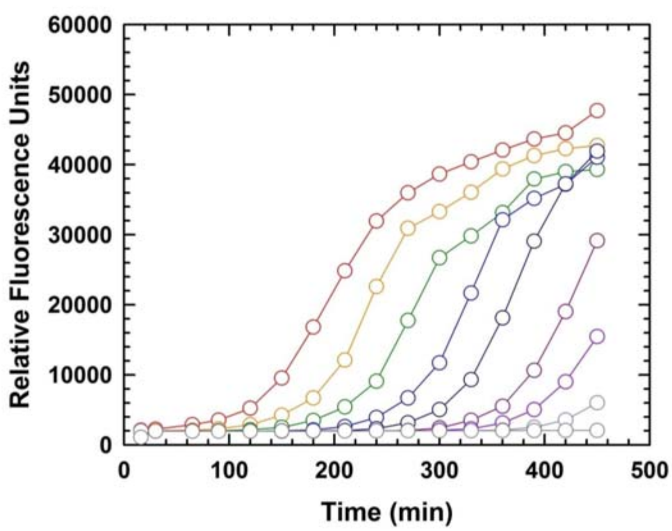
- Self-contained BIs and an incubator/detector system
- Quantitative
- *Bacillus thuringiensis* (Bt) Al Hakam
  - A close relative of *B. anthracis,* with the same growth and spore production properties
  - Without pathogenicity: do not have pXO1 or pXO2 plasmids found in *B. anthracis* that encodes for virulence genes and the anti-phagocytic capsule



Principle of Assay to Detect Spore Viability

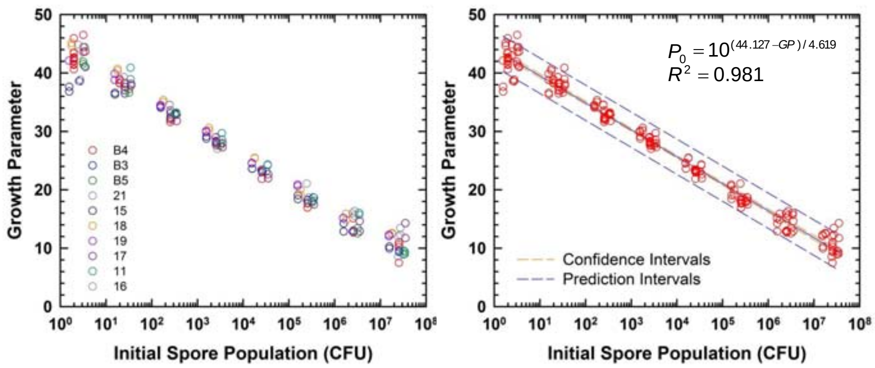
- Evaluates the ability of the spores to germinate and carry out protein synthesis as a measure of the viability of the spores
  - Based on the enzyme activity packaged in dormant spores of Bt Al Hakam
  - The enzyme is either not active or not accessible to the substrate in dormant spores.
  - When the spores germinate, the substrate is taken up by the spores and hydrolyzed into a highly fluorescent compound by the enzyme.
  - The fluorescence yield is further increased by promoting spore outgrow and vegetative growth.

Quantitative Assay



Quantitative Assay

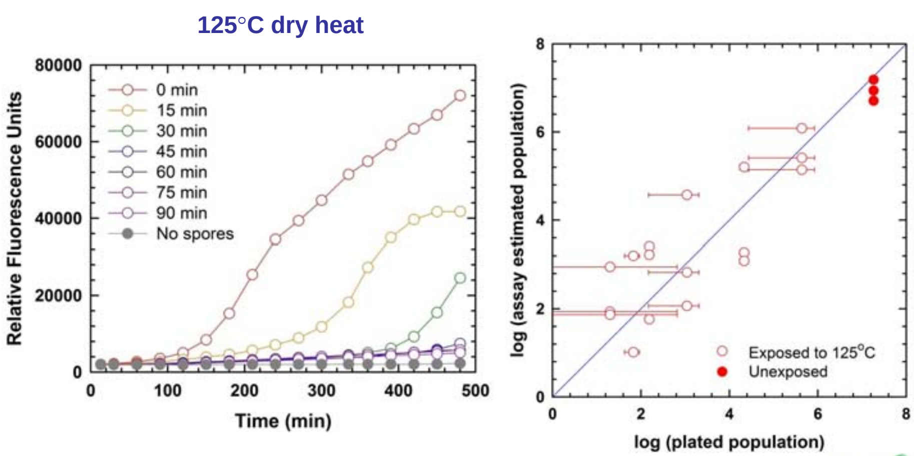
- 10 different batches were tested.



- 10^7 spores: ~1.5 hr
- 10^0 spores: 8 – 10 hrs

Validation of Quantitative Assay

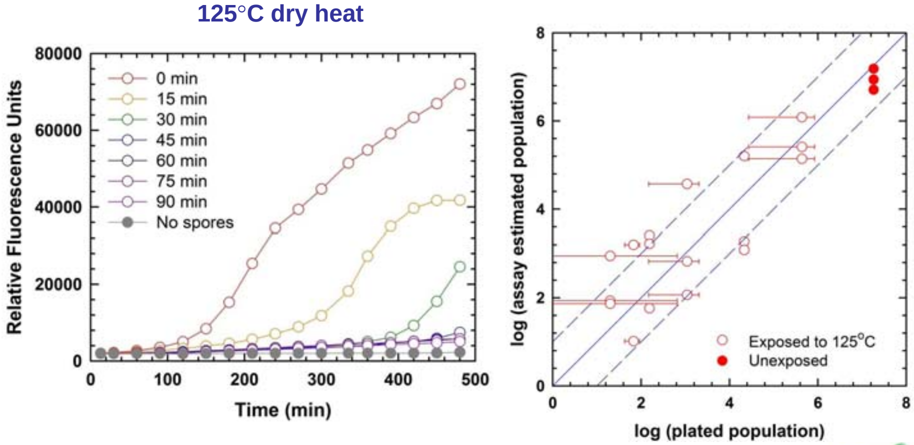
- Target: ±1 log estimation



Validation of Quantitative Assay

- Target: ±1 log estimation

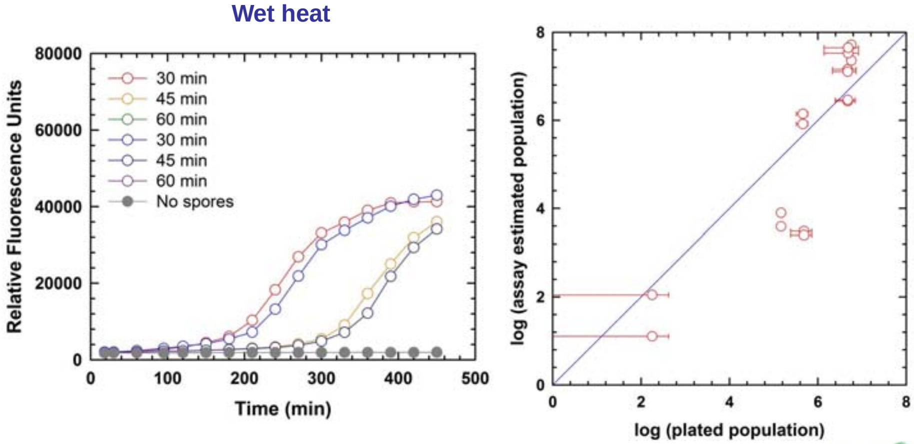
125°C dry heat



Validation of Quantitative Assay

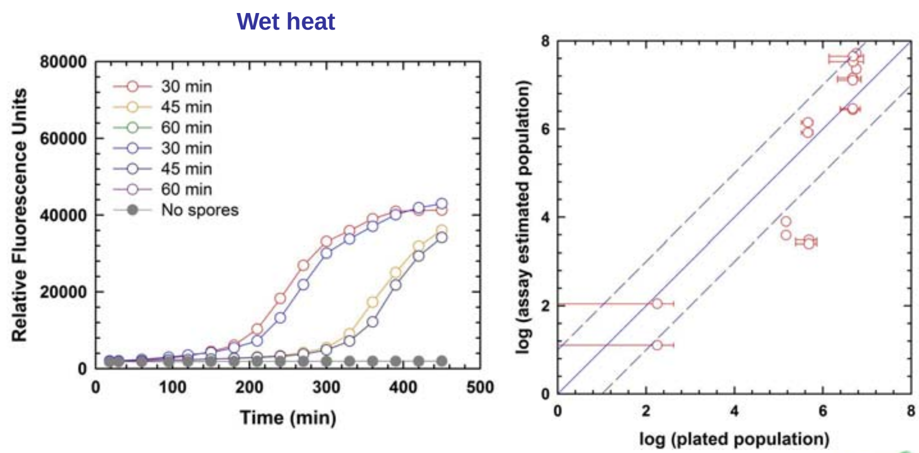
- Target: ±1 log estimation

Wet heat



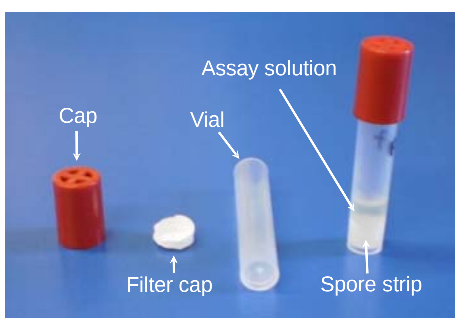
Validation of Quantitative Assay

- Target: ±1 log estimation



Triton's BIs

- Cap: injection molded, medical grade PP homopolymer
- Filter cap
- Glass ampoule: to be made
- Spore strip: inoculated with 10^7 CFU Bt Al Hakam spores
- Vial: injection molded, medical grade PP homopolymer

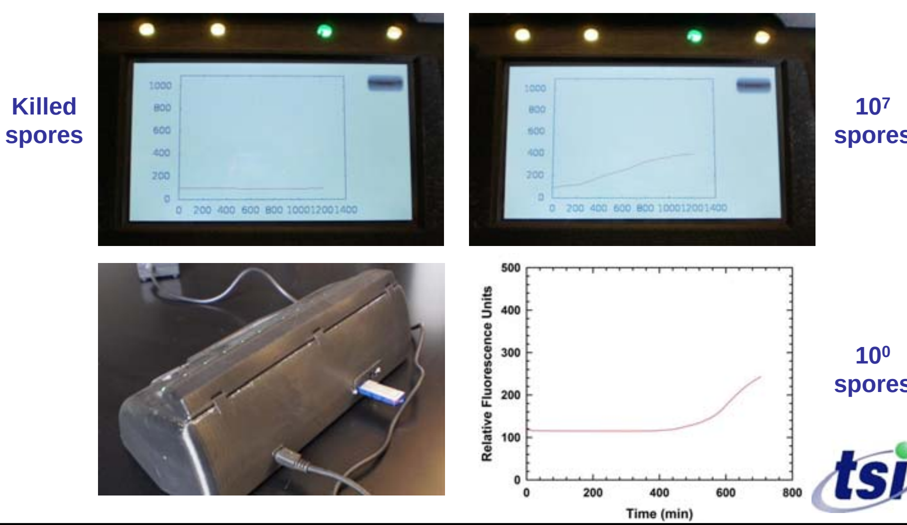


Triton's Detector

- Simultaneous incubation (37°C) and fluorescence detection of 12 BIs
- Touch screen user interface

Triton's BIs and Detector

- 8 – 10 hours to detect a single spore → 12 hour run time
- Data processing to display estimated spore population is being implemented.

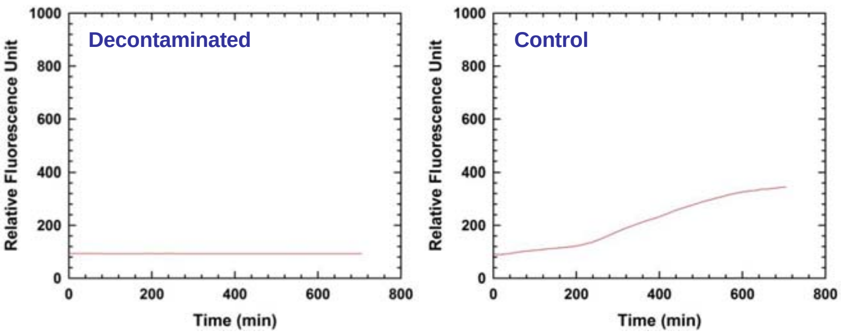


JBADS Field Demo in Orlando, FL

- Jan. 23 – Feb. 2, 2015
- 120 BIs in the C-130 aircraft
  - Distributed to 5 different locations
  - 60 BIs for controls and 60 BIs decontaminated
- 10 decontaminated BIs were processed on site by a Bio-environmental engineer from MacDill AFB in Tampa, FL (MSgt Johansen), and the rest were processed at Triton.

JBADS Field Demo in Orlando, FL

- The BI results agreed with the results by Dr. Buhr and his team at NSWCDD.



Summary

- Quantitative biological indicator system with Bt Al Hakam spores
- 8 – 10 hours to detect a single spore and ~1.5 hours for 10^7 spores
- Portable for the use in the field as decontamination assurance
- Allows determination of the decontamination kinetics for modeling to plan decontamination schemes for emergency responses or facilitate developing new decontamination systems for biological agents

- Glass ampoule production by the end of this year to make BIs self-contained
- Inclusion of data processing in the detector
- Conversion of the current prototype detector into a manufacturable form with standards compliance

Acknowledgments

- DTRA
  - Dr. Charles Bass
  - Dr. Glenn Lawson
  - Mark Morgan
  - Kelly Crigger
- Dr. Tony Buhr at NSWCDD
- ARO
  - Dr. Jennifer Becker
  - Dr. Dawanne Poree
  - Wendy Mills
- Triton
  - John Lovaasen
- KBioSim
  - Kristopher Daly
- UConn Health Center
  - Dr. Peter Setlow
  - Dr. Barbara Setlow
- Funding (JSTO-CBD)
  - DoD CBD SBIR Phase I Contract No. W911NF-11-C-0096
  - DoD CBD SBIR Phase II Contract No. W911NF-12-C-0048
  - DoD CBD SBIR Phase II Contract No. W911NF-16-C-0074

- The effort depicted here was and is supported by the U.S. Army Research Office, and that the content of the information does not necessarily reflect the position or the policy of the Government, and no official endorsement should be inferred.

US ARMY RDECOM

Detection and Identification of Environmental Microbes Contamination using Novel LC-ESI-MS/MS Method

TECHNOLOGY DRIVEN. WARFIGHTER FOCUSED.

Rabih Jabbour1, Samir Deshpande[2], Patrick F. McCubbin[3], Mary M. Wade
[1]U.S. Army Edgewood Chemical Biological Center, Aberdeen Proving Ground, MD 21010, [2]Science and Technology Corporation, Edgewood, MD 21040; [3]Optimetrics Inc. Abingdon, MD 21009.

1

What are we trying to do?

Conventional

- Rapid ID of specific threat
- Require specific reagents
- Prior sample knowledge

PD MSPM

- Rapid ID of ALL threats
- Modified, emerging threats
- No prior sample Knowledge

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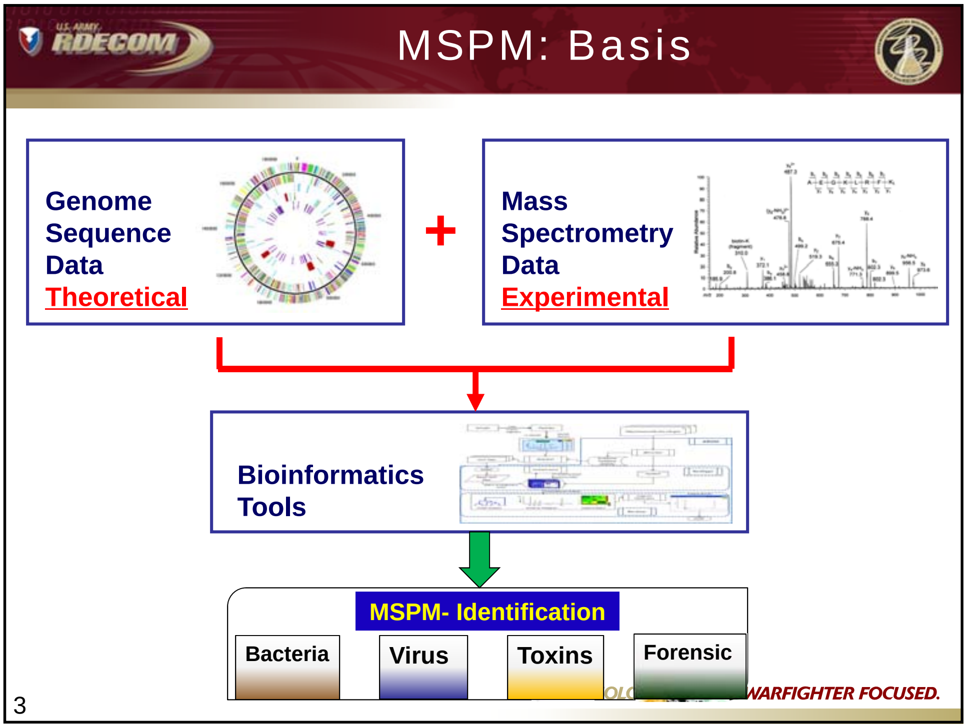
2



RDECOM
MSPM: Basis
Genome Sequence Data
Theoretical
Mass Spectrometry Data
Experimental
Bioinformatics Tools
MSPM- Identification
Bacteria
Virus
Toxins
Forensic
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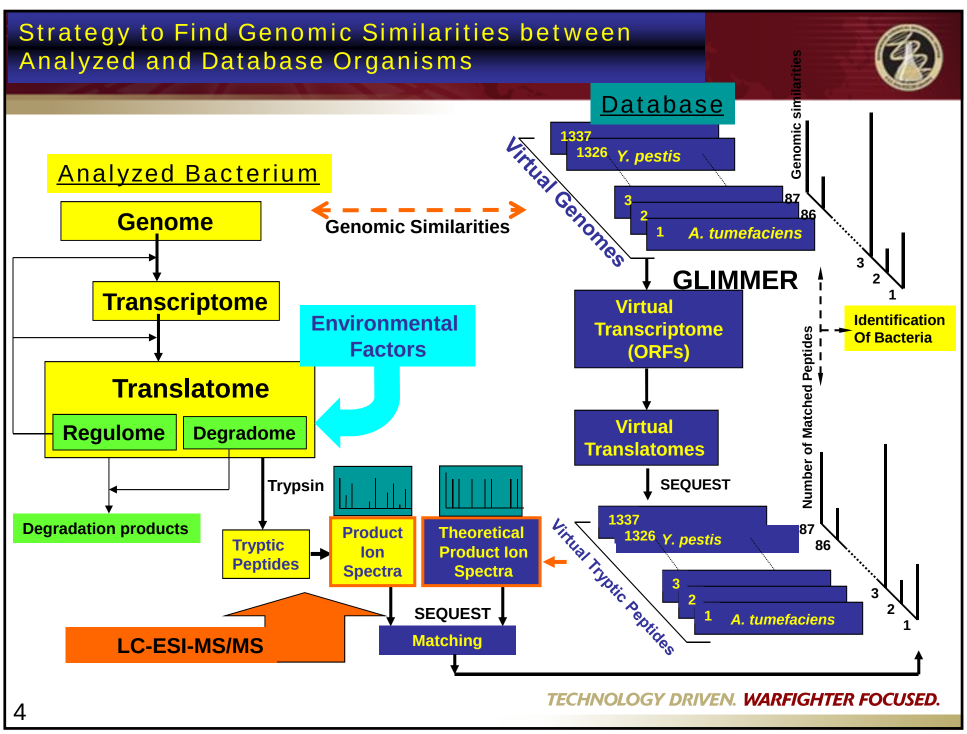
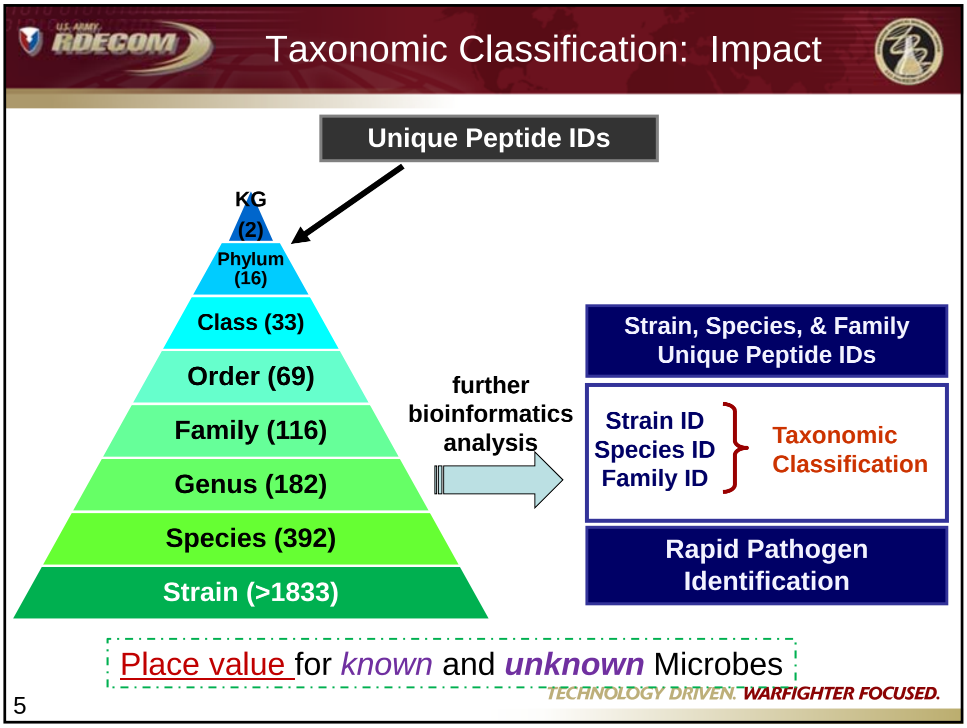
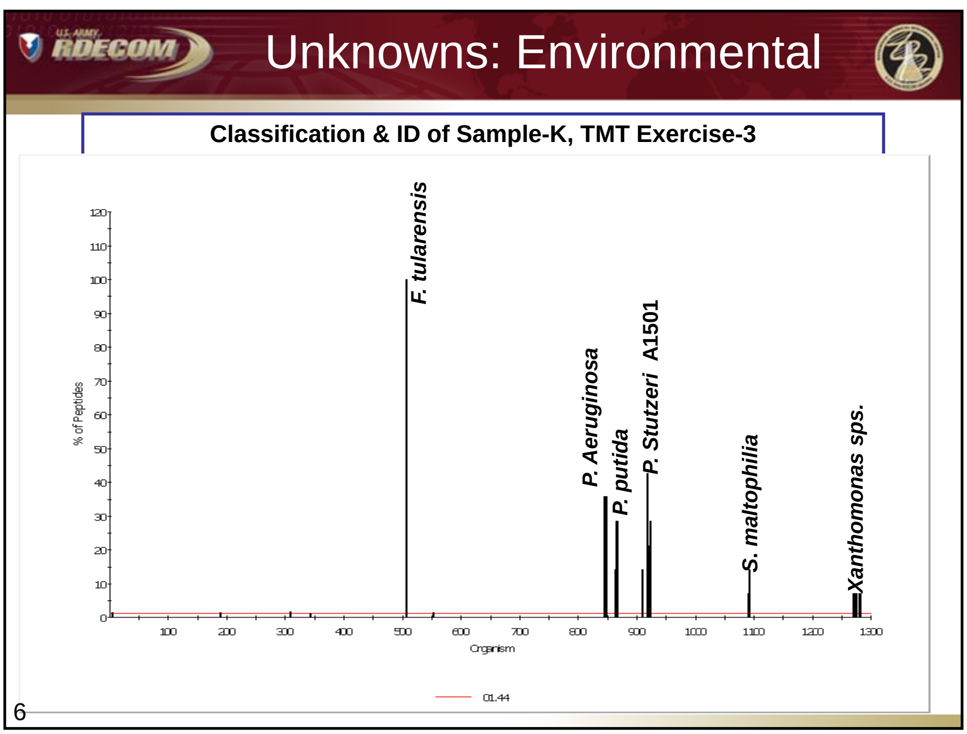
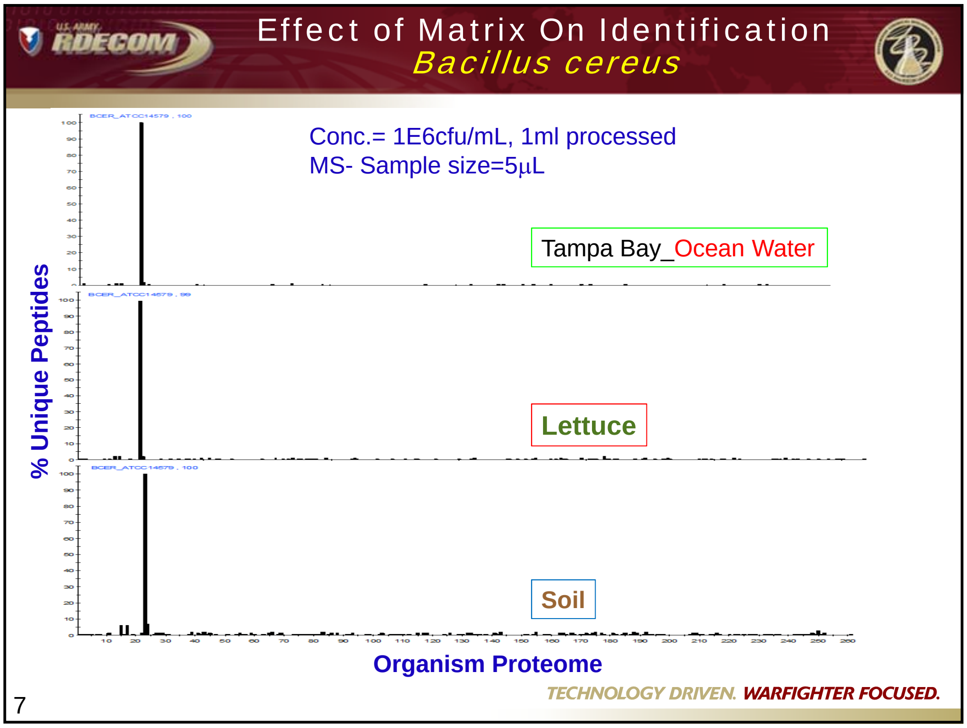
3

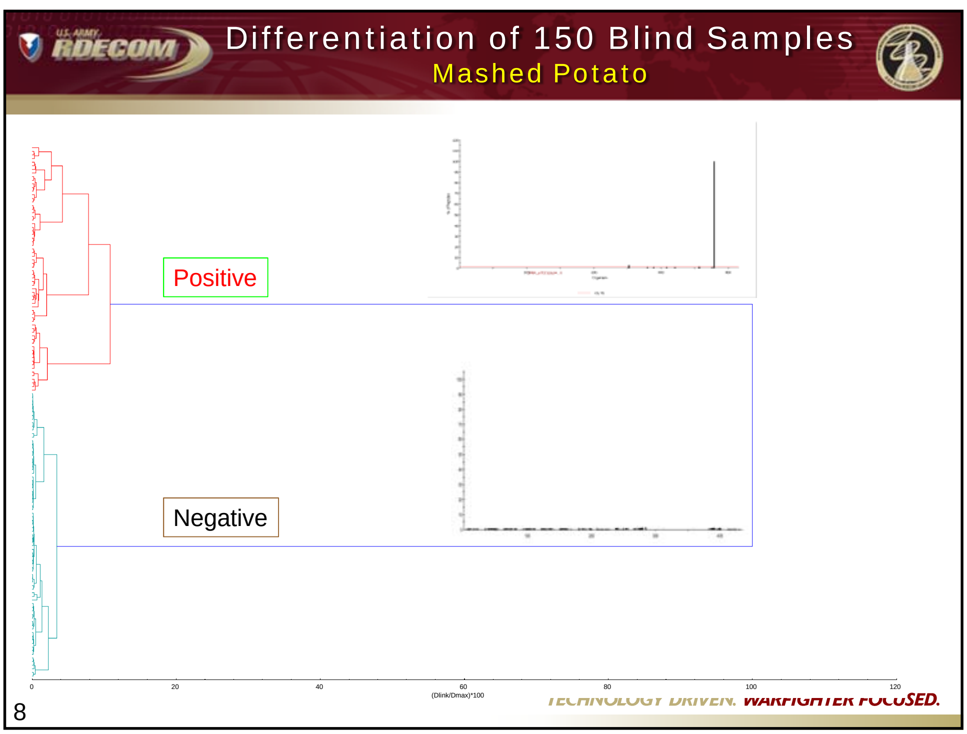


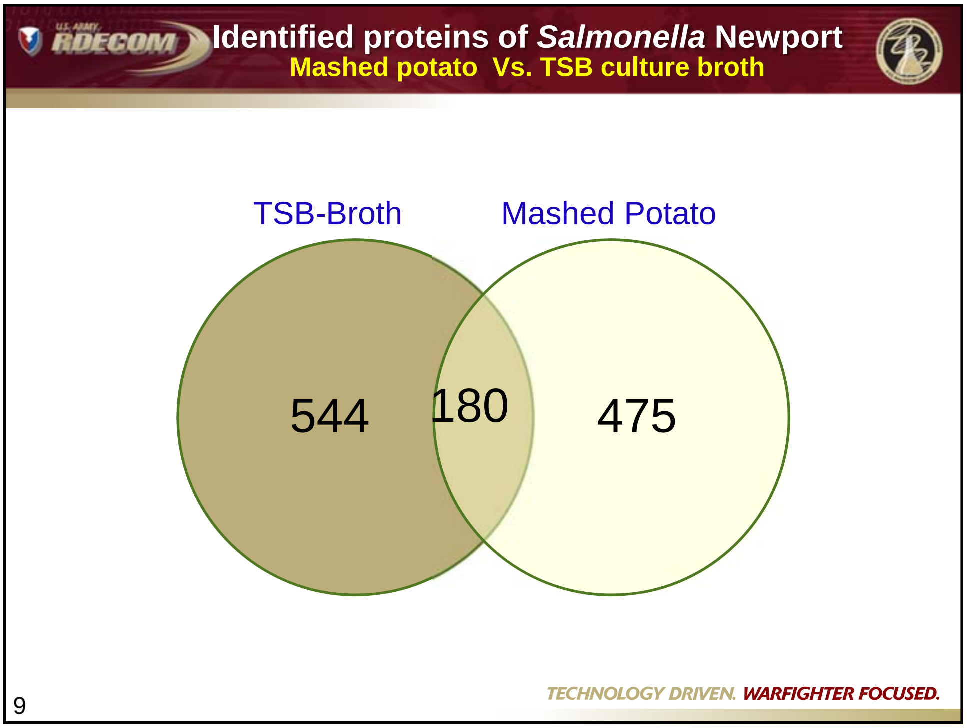
Strategy to Find Genomic Similarities between Analyzed and Database Organisms
Database
Analyzed Bacterium
Genome
Genomic Similarities
Transcriptome
Environmental Factors
Translatome
Regulome
Degradome
Degradation products
Trypsin
Tryptic Peptides
Product Ion Spectra
Theoretical Product Ion Spectra
SEQUEST
Matching
LC-ESI-MS/MS
Virtual Genomes
1337
1326 Y. pestis
A. tumefaciens
GLIMMER
Virtual Transcriptome (ORFs)
Virtual Translatomes
SEQUEST
Virtual Tryptic Peptides
Genomic similarities
Number of Matched Peptides
Identification Of Bacteria
TECHNOLOGY DRIVEN. WARFIGHTER FOCUSED.
4

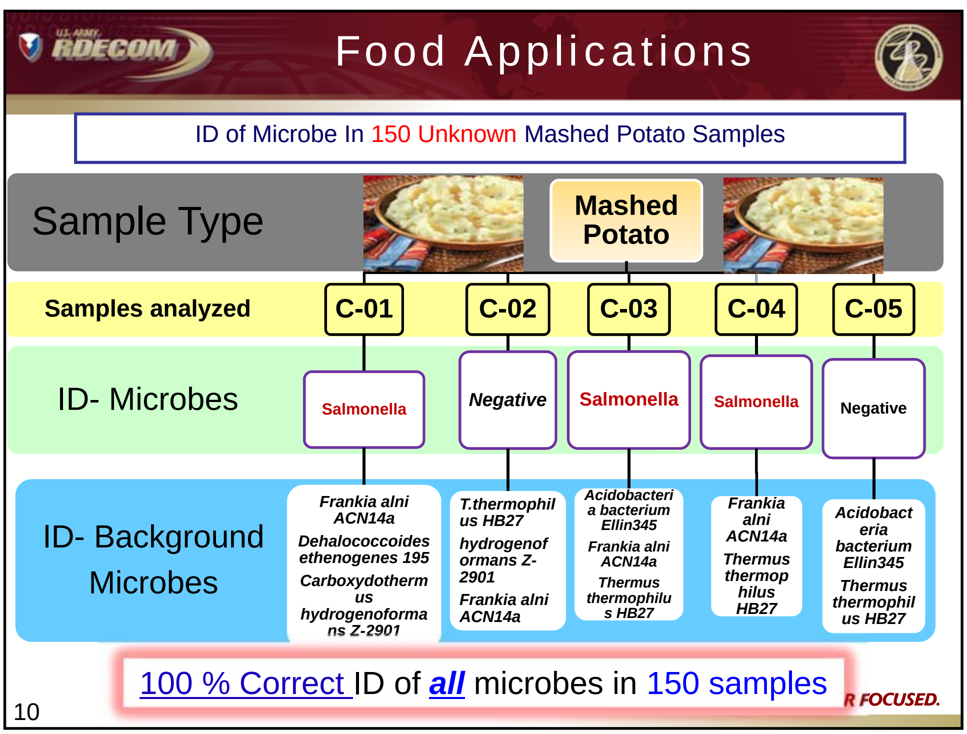

U.S. ARMY RDECOM
Taxonomic Classification: Impact
Unique Peptide IDs
KG (2)
Phylum (16)
Class (33)
Order (69)
Family (116)
Genus (182)
Species (392)
Strain (>1833)
further bioinformatics analysis
Strain, Species, & Family Unique Peptide IDs
Strain ID
Species ID
Family ID
Taxonomic Classification
Rapid Pathogen Identification
Place value for known and unknown Microbes
TECHNOLOGY DRIVEN. WARFIGHTER FOCUSED.
5


U.S. ARMY RDECOM
Unknowns: Environmental
Classification & ID of Sample-K, TMT Exercise-3
F. tularensis
P. Aeruginosa
P. putida
P. Stutzeri A1501
S. maltophilia
Xanthomonas sps.
% of Peptides
Organism
0.1.44
6

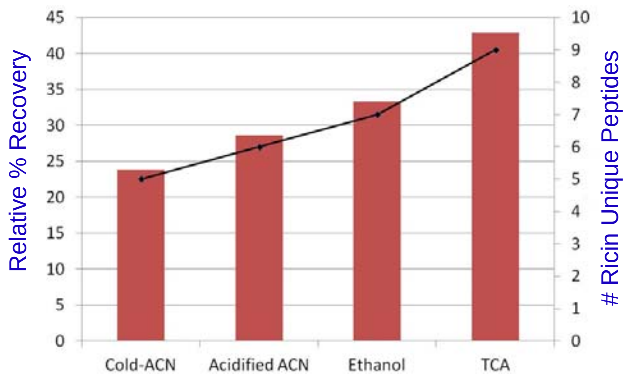

U.S. ARMY RDECOM
Effect of Matrix On Identification
Bacillus cereus
Conc.= 1E6cfu/mL, 1ml processed
MS- Sample size=5µL
Tampa Bay_Ocean Water
Lettuce
Soil
% Unique Peptides
Organism Proteome
TECHNOLOGY DRIVEN. WARFIGHTER FOCUSED.
7


U.S. ARMY RDECOM
Differentiation of 150 Blind Samples
Mashed Potato
Positive
Negative
0
20
40
60
80
100
120
(Dlink/Dmax)*100
TECHNOLOGY DRIVEN. WARFIGHTER FOCUSED.
8


U.S. ARMY RDECOM
Identified proteins of *Salmonella* Newport
Mashed potato Vs. TSB culture broth
TSB-Broth
Mashed Potato
544
180
475
TECHNOLOGY DRIVEN. WARFIGHTER FOCUSED.
9


U.S. ARMY RDECOM
Food Applications
ID of Microbe In 150 Unknown Mashed Potato Samples
Sample Type
Mashed Potato
Samples analyzed
C-01
C-02
C-03
C-04
C-05
ID- Microbes
Salmonella
Negative
Salmonella
Salmonella
Negative
ID- Background Microbes
Frankia alni ACN14a
Dehalococcoides ethenogenes 195
Carboxydothermus hydrogenoformans Z-2901
T.thermophilus HB27
hydrogenoformans Z-2901
Frankia alni ACN14a
Acidobacteria bacterium Ellin345
Frankia alni ACN14a
Thermus thermophilus HB27
Frankia alni ACN14a
Thermus thermophilus HB27
Acidobacteria bacterium Ellin345
Thermus thermophilus HB27
100 % Correct ID of *all* microbes in 150 samples
R FOCUSED.
10

Differentiation of Ricin
Mashed Potato



Samples Info:
0.5 µg Ricin(A/B)
1mL of mashed potato
N=3 samples
Enz. Cleavage=Trypsin
MS mode=Tandem MS/MS
Min. # Ricin peptide= 5

"A minimum of 2 matching peptides to the same protein are needed to ensure statistical confidence in protein assignment"

Nesvizhskii, A. I., and Aebersold, R. (2004) "Analysis, statistical validation and dissemination of large-scale proteomics datasets generated by tandem MS."
Drug Discov. Today 9, 173–181

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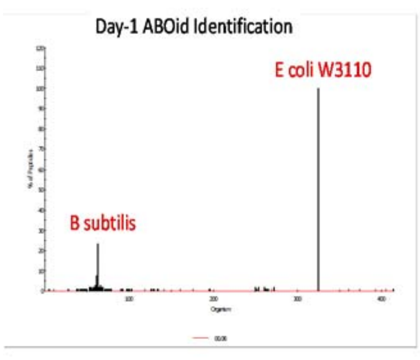
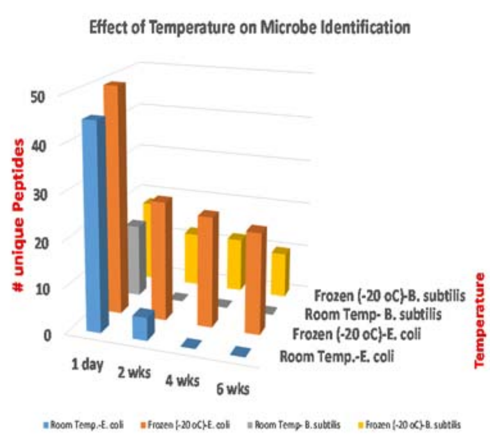
Monitoring Environmental Fate of Microbes Using ABOid





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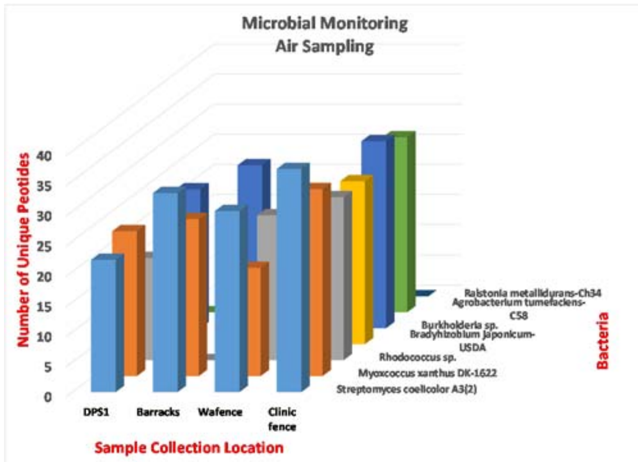
Differentiation of *E. coli* Strains



- ABOid capable of Detection of mixture of bacteria
- Bacterial type and distribution are location dependent
- Clinic Fence location showed largest number and highest Conc. Of bacterial species

13

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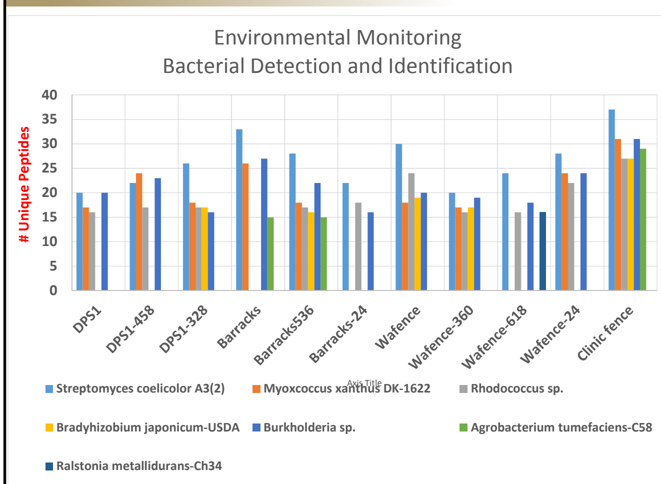
Environmental Monitoring
Bacterial Detection and Identification



- Monitoring of Bacterial changes from same and different locations
- ABOid ability to monitor changes in microbial concentration and signatures

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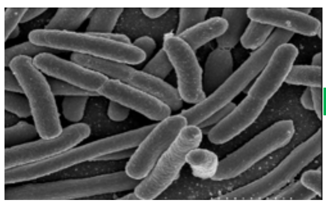
Differentiation of *E. coli* Strains

Hypothesis: The diversity of secretome proteins can be utilized to discriminate between EHEC and EPEC strains.

- Produce metaproteomic data, validate by comparison with genomic data.
- Perform metaproteomics comparison between studied *E. coli* strains to identify differentiation biomarkers.



Conventional

Emerging

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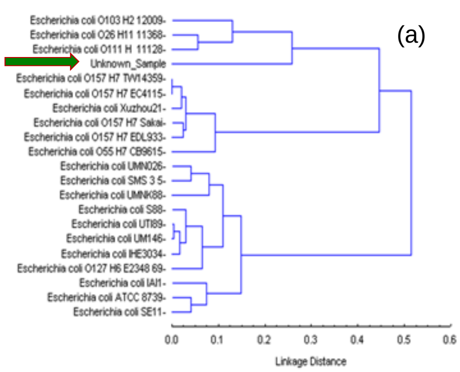
15

Differentiation of *E. coli* Strains

Mixture

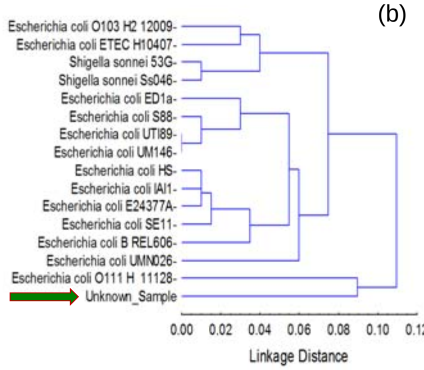
Secretome Classification of *E. coli* Strains



Single Strain

Strain Level Differentiation (O111)

OD=1.7



"Atypical EPEC and EHEC strains of **serotypes O26, O103, O111,** and O145 have been found to be similar in virulence plasmid encoded genes, *tir*-genotypes, *tccP* genes, LEE, and non-LEE encoded genes ***indicating that these are evolutionarily linked to each other***"

16 *BMC Microbiology* 2011 **11**:142

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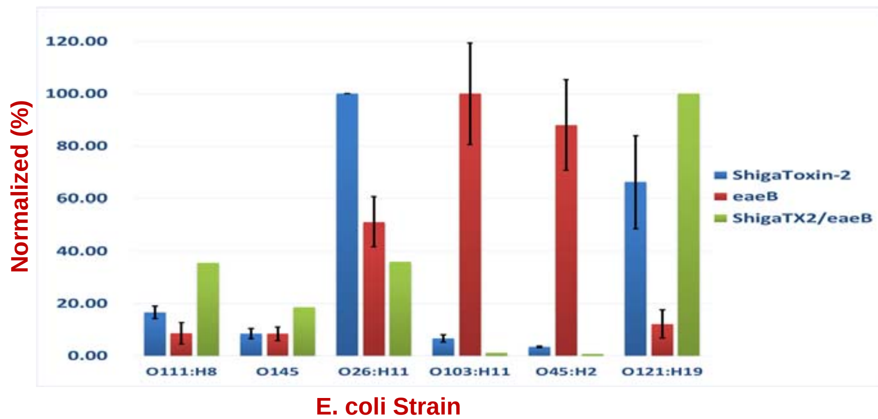
Diagnostic Potential

Differentiation of E coli Pathogenicity



"O26, O45, O103, O111, O121, and O145, causing over 70 to 83% of the total non-O157 STEC illnesses, all of these non-O157 STEC strains can cause HC, and have been shown to cause HUS (http://www.fsis.usda.gov/OPPDE/rdad/FRPubs/2010-0023PM.pdf.)"

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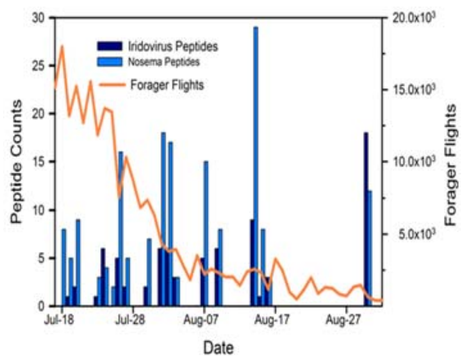
Pathogen ID

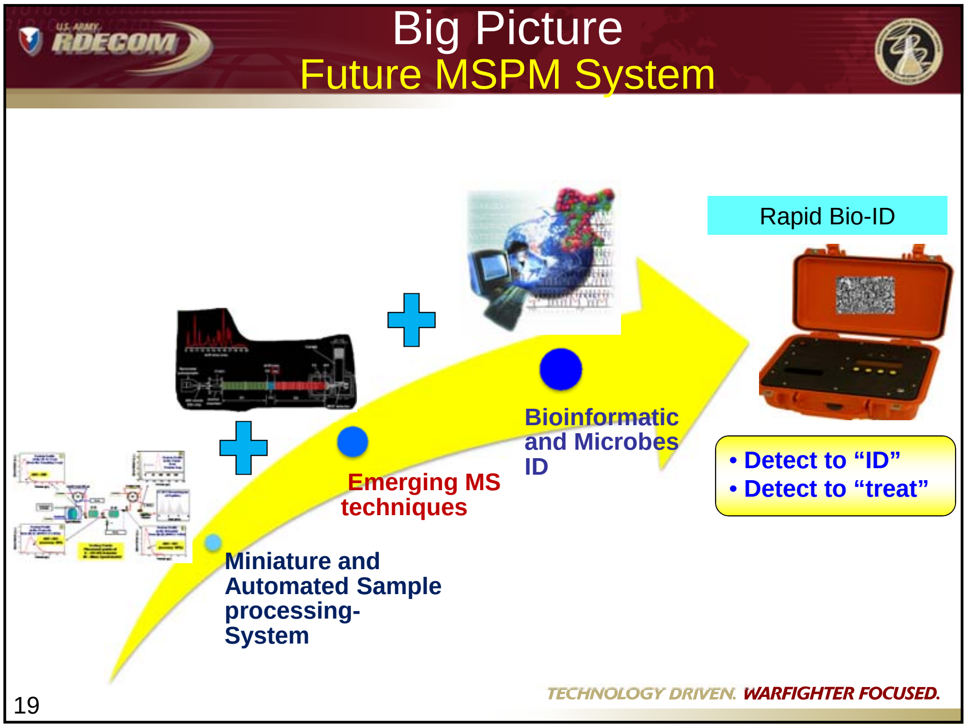
Whole Host Analysis



- Forager flights are absolute counts per day, tabulated by an automated honey bee counter.
- Peptide counts are the summed counts by day of collection for all unique IIV *Nosema* peptides in each sample.

Bromenshenk JJ et al.,"*Iridovirus and Microsporidian Linked to Honey Bee Colony Decline*" *PLoS ONE* 5(10): e13181. 2010.

18


U.S. ARMY RDECOM
Big Picture
Future MSPM System
Rapid Bio-ID
Bioinformatic and Microbes ID
• Detect to "ID"
• Detect to "treat"
Emerging MS techniques
Miniature and Automated Sample processing- System
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United States Environmental Protection Agency

2016 U.S. EPA International Decontamination Research and Development Conference

Wednesday, November 2, 2016

Concurrent Sessions 2

Chemical Agent Research

US ARMY RDECOM

Chemical Hot Air Decontamination of CWA-Contaminated Materials

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Edgewood Chemical and Biological Center (ECBC)
2016 EPA DECON Conference, Research Triangle, NC
November 1-3, 2016

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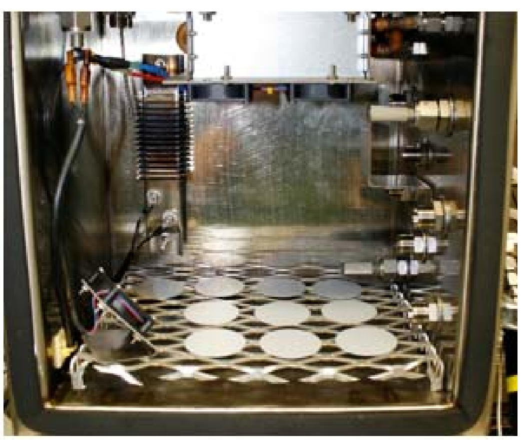
Chemical Hot Air Decontamination

Chemical Hot Air Decontamination (CHAD) is the process of using heat (76.7° C) and air flow (2 air changes/h) to remove Chemical Warfare Agents (CWA) from materials in an enclosure.


Small Item Vapor Chamber

Study Objectives:
1. To determine the feasibility of using CHAD to decontaminate HD and VX on absorptive materials
2. To determine if increased humidity in the enclosure increases the rate of decontamination ("Dry" vs. "Wet")

Benefits
- CHAD does not require harsh chemistry (Bleach, NaOH) for decontamination of CWA
  - Can be used for sensitive electronic equipment found on aircraft

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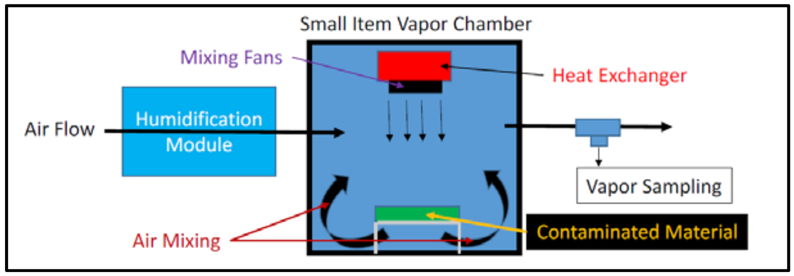
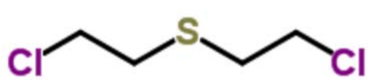
Method of Applying CHAD

Small Item Vapor Chamber

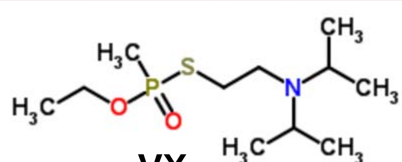


- Approximately a 1' cube
- Heat is provided by a liquid-air heat exchanger and a resistive heater (pictured)
- Mixing fans maintain a well-mixed environment
- *Optional* Vapor sampling capability on the effluent tube
- Contaminated Samples are elevated from the bottom of the chamber to allow for heated air to circulate around the materials.

Contaminants of Interest



Sulfur Mustard (HD)



VX

Molecular weight	159.1 g/mol#	267.37 g/mol^
Type	Vesicant (blister)	Nerve
Vapor Pressure	0.11 torr @ 25° C# (**Vapor Hazard**)	8.78 x10^{-4} torr @ 25° C^ (**Low Volatility**)
Water Solubility	0.0068 g/100 mL (**Hydrophobic**)	0.3 g/100 mL @ 25° C#
Toxicity (LD_{50}) liquid	20 mg/kg body mass^	0.04 mg/kg body mass*

References:
https://pubchem.ncbi.nlm.nih.gov
* https://www.nationalacademies.org/hmd/~/media/Files/Report%20Files/2007/Long-Term-Health-Effects-of-Participation-in-Project-SHAD-Shipboard-Hazard-and-Defense/VXNERVEAGENT.pdf
^ Material Safety Data Sheet

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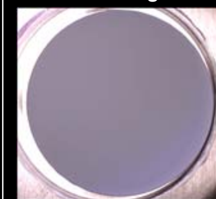
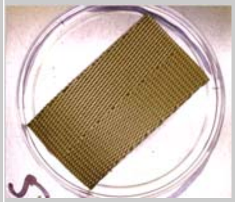
Materials

Polyurethane Coating	Fluoropolyurethane Coating	Silicone Elastomer	Stainless Steel
			
Nylon Webbing			Anti-Skid Patch on Stainless Steel

- HD and VX have been shown to absorb into all of these materials (except Stainless Steel)
- Absorbed CWAs present a significant challenge for decontamination

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Decontamination Mechanisms for CHAD

The CHAD process utilizes three primary decontamination mechanisms:

Evaporation

The heat of the CHAD causes the CWA to evaporate from the material

Thermal Degradation

The Heat of the CHAD process breaks down the contaminant by breaking chemical bonds to form smaller by-products

Hydrolysis

The contaminant reacts with water to reduce toxicity

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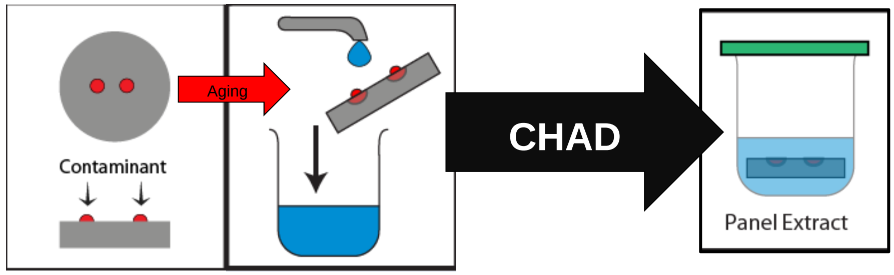
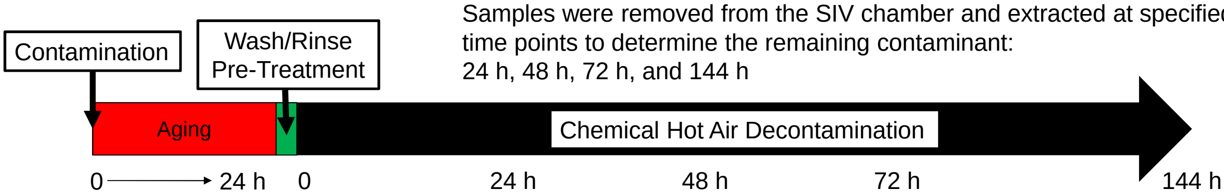
Evaluation Method

Several replicates were evaluated for each material type to determine the amount of contaminant present in the materials at time points throughout the evaluation.

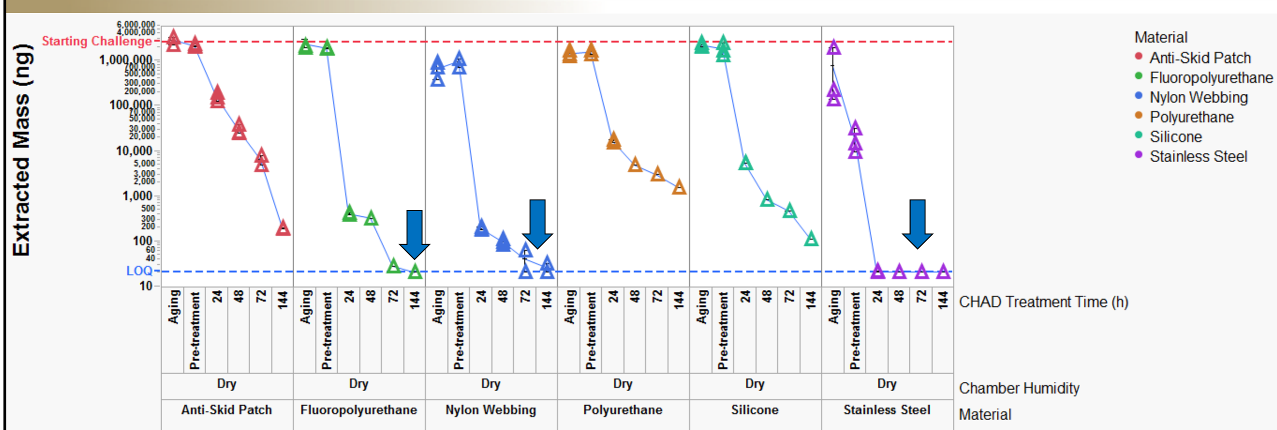
Test parameter	Value
Starting Challenge	1 g/m^2 neat contaminant
Contaminant Aging time	24 h
Wash/Rinse	Soap wash, Rinse



Samples were removed from the SIV chamber and extracted at specified time points to determine the remaining contaminant:
24 h, 48 h, 72 h, and 144 h



HD CHAD Results with Dry Air



A significant amount of HD in the materials was removed as a result of the CHAD treatment with three materials being at or near the LOQ for HD within 144 h of treatment.

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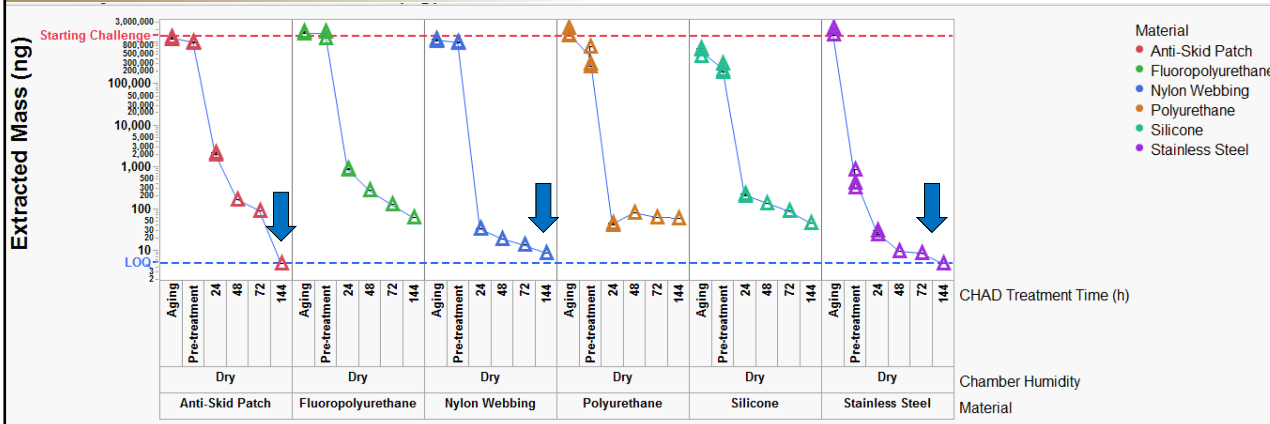
VX CHAD Results with Dry Air



A significant amount of VX in the materials was removed as a result of the CHAD treatment with three materials being at or near the LOQ for VX within 144 h of treatment.

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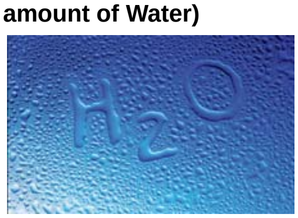
Humidification of CHAD

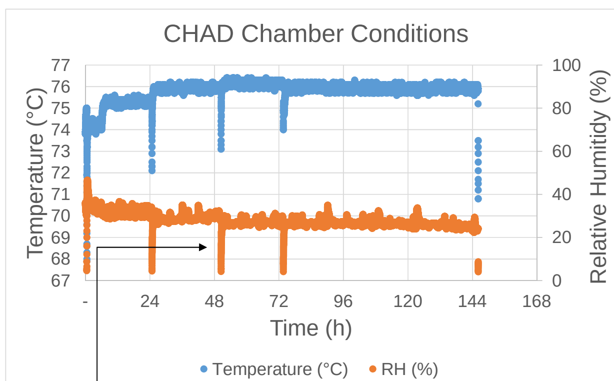
A small amount of humidity is present in “Dry” conditions due to ambient humidity in the laboratory

Humidification of the air stream was introduced to increase the amount of hydrolysis of the CWA during CHAD **(if susceptible, should result in different remaining contaminant trends during CHAD treatment)**

A target of 25% RH @ 76˚ C was determined to provide an excess amount of water for reaction with the CWA. **(Significant amount of Water)**

Hydrolysis





Temperature (76˚ C) and RH (25%) is maintained throughout the 144 h experiment with minimal variation

Drops in Temperature and RH are observed when chambers were opened to remove samples

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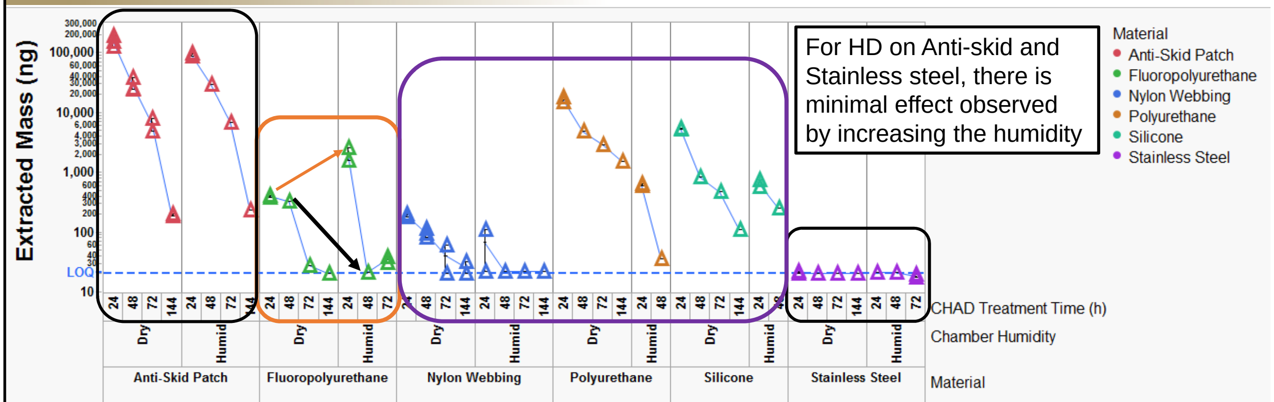
Dry v. Humid CHAD Data for HD



- For HD on Fluoropolyurethane, humidified CHAD results in a larger RES value after 24 h
  - HD may initially resist hydrolysis and have more affinity for absorption during the initial 24 h

After 48 h, a significant reduction in remaining HD is observed

Significant reduction in residual HD was observed for Polyurethane, Nylon Webbing, and Silicone

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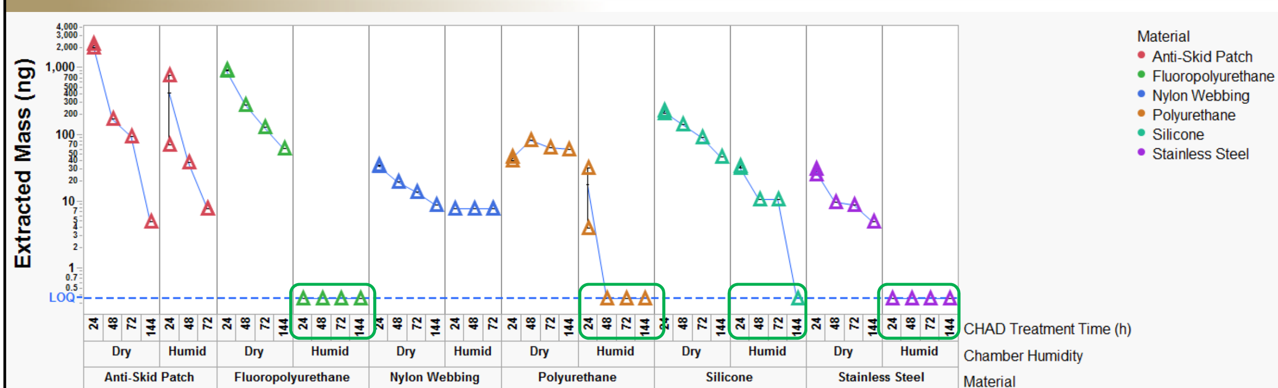
Dry v. Humid CHAD Data for VX



- Humidification of the air stream reduces the residual VX to LOQ values for 4/6 materials within 144 h
- VX is highly susceptible to hydrolysis

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Summary

- Chemical Hot Air Decontamination (CHAD) effectively removes chemical contaminants from absorptive materials.
- In general, humidification of the air stream increases the rate of removal.
- Further evaluations will be required to determine the specific mechanism for each contaminant-material combination.
- Efforts are continuing to optimize the CHAD process to reduce the time requirement for efficacy.

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Natural Attenuation of VX following Application onto Nonporous and Porous Materials

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2016 US EPA International Decontamination R&D Conference, November 1-3, 2016

Disclaimer

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- 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.

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Background

- U.S. EPA is responsible for planning for and responding to releases of chemicals into the environment.
- Includes any deliberate release of chemical warfare agents during terrorist attacks.
- EPA's National Homeland Security Research Center conducts research focused on CWA decontamination and remediation strategies.

- NHSRC determined that natural attenuation might be an effective option for decontamination of higher-volatility CWAs.
  - Structures that do not require immediate reopening/reoccupation; equipment that does not require immediate redeployment.
  - Low cost.
  - Eliminates decontaminant/material incompatibility effects.
- Further study was necessary to evaluate efficacy of natural attenuation as a decontamination option for more persistent CWAs, such as VX.

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Project Objectives

✓ Evaluate the efficacy of natural attenuation as a method of decontaminating surfaces contaminated with VX:

- ✓ Both non-porous and porous surfaces.
- ✓ Various environmental factors that could influence efficacy of attenuation and attenuation rate (including temperature, relative humidity, and air exchange).
- ✓ Redistribution of attenuated VX.
- ✓ Limited, semi-quantitative analysis to investigate presence of VX degradation products following attenuation periods.

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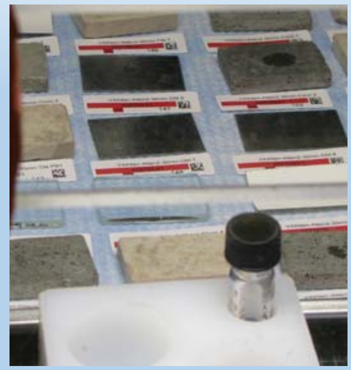
Attenuation Experimental Approach

- Bench scale studies to evaluate efficacy of natural attenuation as a decontamination option.
- Contaminate coupons of materials with VX.
- House coupons in an environmentally-controlled test chamber during set attenuation intervals.
  - VX applied at test conditions, following ≥ 60 min. coupon preconditioning.
  - Single 2 µL droplet per coupon.



- Attenuation intervals ranged from 30 minutes, up to 35 days (depending on the environmental conditions).
- Following the attenuation intervals, groups of coupons (including control coupons) were removed from the chamber and solvent extracted.
- Extracts analyzed via GC/MS to quantify residual VX.

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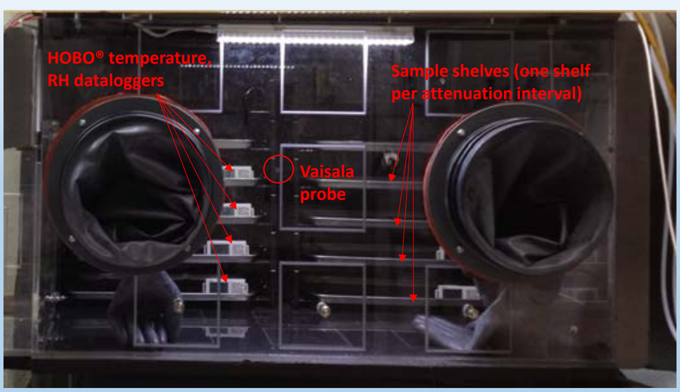
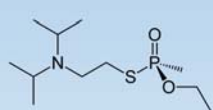


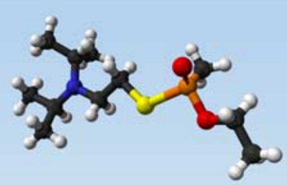
Environmentally-Controlled Test Chamber

- Acrylic chamber surrounded by 2” closed-cell insulation.
- Provisions for control, monitoring, and recording of critical test parameters (temp., RH, air exchange)
- Sample shelves in the test chamber allowed for loading of up to 288 coupons.
- Lab and test hood lights turned off when operations not taking place.
  - Minimize VX degradation due to UV.
  - LED lights used within test chamber (little to no UV).

VX

- *O*-ethyl *S*-[2-(diisopropylamino)ethyl] methylphosphonothioate
- Highly persistent nerve agent
  - Vapor pressure - 0.000084 kPa at 25°C
  - Water - 3.1690 kPa at 25°C
  - Acetone - 30 kPA at 20°C
- Organophosphate acetylcholinesterase inhibitor.





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Attenuation Test Materials

- Coupon size 2.5 cm x 4 cm. Thickness dependent upon material type (up to 1.5 cm).

- Non-porous materials
  1. Sealed Concrete
  2. Galvanized Metal Ductwork
  3. Painted Drywall Tape
  4. Glazed Ceramic Tile
  5. Silanized Glass

- Porous Materials
  1. Unsealed Concrete
  2. Pine Subfloor Plywood
  3. Rubber Escalator Handrail
  4. HDPE Plastic
  5. Acoustic Ceiling Tile
  6. Silanized Glass (inert, non-porous control)

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Attenuation Test Matrix

Test	Temperature	RH	Air Exchange (chamber volumes per hour)	Material Types	Coupon Extraction Intervals												
					30 mins	4 hrs	7 hrs	1 day	2 days	3 days	4 days	7 days	10 days	14 days	21 days	28 days	35 days
1	25°C	40%	0 (no air exchange)	All non-porous types	✓	✓		✓			✓	✓	✓	✓	✓		
2	25°C	40%	1/hour	All non-porous types	✓	✓	✓	✓	✓		✓	✓		✓			
3	10°C	40%	1/hour	All non-porous types	✓		✓	✓			✓	✓		✓	✓		✓
4	35°C	40%	1/hour	All non-porous types	✓	✓	✓	✓	✓		✓	✓	✓				
5	25°C	40%	1/hour	All porous types	✓		✓	✓	✓		✓	✓		✓		✓	
6	10°C	40%	1/hour	All porous types	✓		✓	✓			✓	✓		✓	✓		✓
7	35°C	40%	1/hour	All porous types	✓	✓	✓	✓	✓	✓		✓	✓				

- Attenuation intervals were based on anticipated differences in the persistence of VX (chosen to maximize information on the duration of VX persistence under the specific environmental condition).
- Single laboratory blank and procedural blank per combination of material type and attenuation interval.
  - Laboratory blanks – Uncontaminated (kept outside of chamber). Extracted alongside test coupons.
  - Procedural blanks – Placed in chamber with test coupons, but not challenged. Extracted alongside test coupons.

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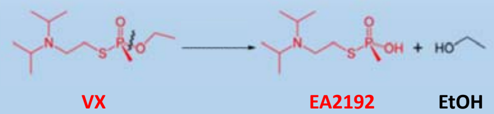
Analytical Methods and Degradation Product Analysis

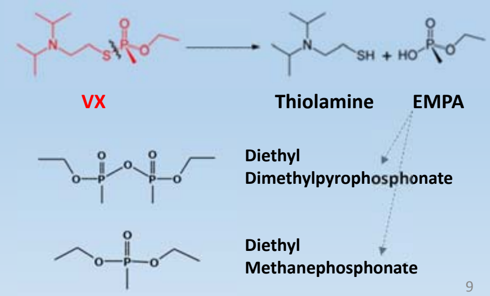
- Coupon extracts analyzed via GC/MS.
- Calibration range of 0.1 to 125 µg/mL. Nominal contamination density target of 81 µg/mL.
- Naphthalene-d8 internal standard.
- Diisopropylcarbodiimide (DIC) included as a VX stabilizer.
- VX degradation product analysis:
  - Included during porous materials attenuation testing.
  - EA2192 not amenable to analysis by the GC/MS method that was used (requires alternative methods or LC/MS analysis).
  - EMPA byproducts were detectable, and thus used to semi-quantitatively indicate the presence of VX byproducts.
    - Diethyl Dimethylpyrophosphonate
    - Diethyl Methanephosphonate

VX Hydrolysis Routes
(highly toxic compounds in red)

Cleavage at P-O bond



Cleavage at P-S bond (dominating)



Calculations

- Attenuation calculation measured **the reduction in the amount of extractable VX remaining following unaided degradation or volatilization of VX** from the spiked materials.
- Did not distinguish between VX losses attributed to volatilization, degradation, or inability to extract from the materials.

- Extract analysis results in µg/mL
  - VX exhibited a quadratic response over the calibration range
- Recovered mass in µg
  - $M_{Rep} = C_{Rep} \times Vol_{Ext}$
- Relative percent recovery from coupons
  - % Recovery = $M_{Rep} / M_{SC} \times 100\%$
  - Calculated versus control samples
- Relative percent VX attenuated
  - % Attenuated = 100% - % Recovery
  - Calculated for each material type/environmental condition/attenuation interval combination

Methods Development Results

- VX applied to test coupons and extracted in various candidate solvents to determine highest recovery.
- Target recovery criteria of 70% to 120% with < 30% coefficient of variation.
- Extraction in hexane demonstrated best recovery for all nonporous materials as well as all porous materials except pine subfloor plywood.
- Extraction in acetone demonstrated best recovery for pine subfloor plywood.
- Very poor recovery from unsealed concrete using any of the tested extraction solvents.
  - Consistent with previous studies involving recovery of VX from concrete.
  - Possibly attributed to strong adsorption and/or degradation of VX within the concrete.

Material	Mean Recovery [A]	CV
Nonporous Materials		
Silanized glass [B]	117%	5%
Painted Drywall Tape	117%	8%
Glazed Ceramic Tile	114%	2%
Sealed Concrete	79%	20%
Porous Materials		
Silanized glass [C]	104%	2%
Unsealed Concrete	17%	37%
Pine Subfloor Plywood	73%	0.7%
Rubber Escalator Handrail	76%	6%
HDPE Plastic	100%	4%
Acoustic Ceiling Tile	87%	13%

[A] Versus Control Samples

[B] Nonporous testing

[C] Porous testing

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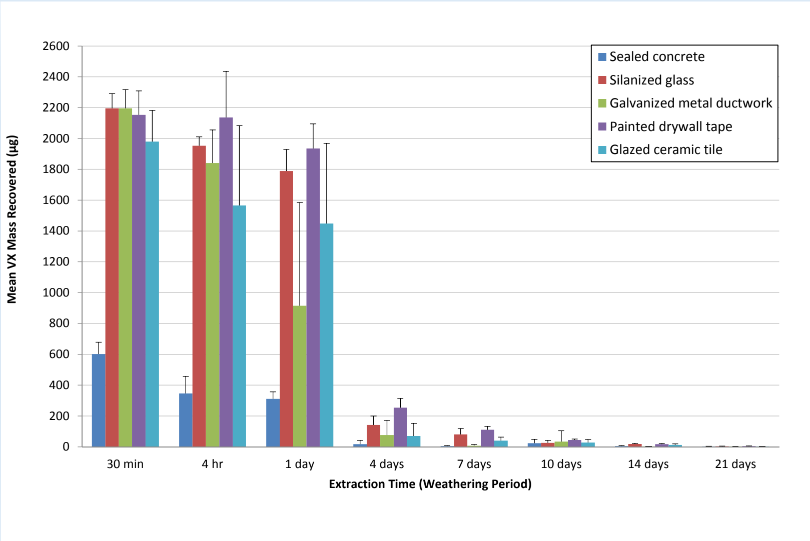
Non-Porous Materials, 25°C (no air exchange)



- 25°C, 40% RH, no air exchange.
- Mean VX recovery of 2200 µg from controls.
- Largest reduction in VX recoveries between 1 day and 4 days.
- By 21 days, VX recoveries for all materials were < 5 µg (≥ 99.8% natural attenuation).

- Error bars equal plus one standard deviation.

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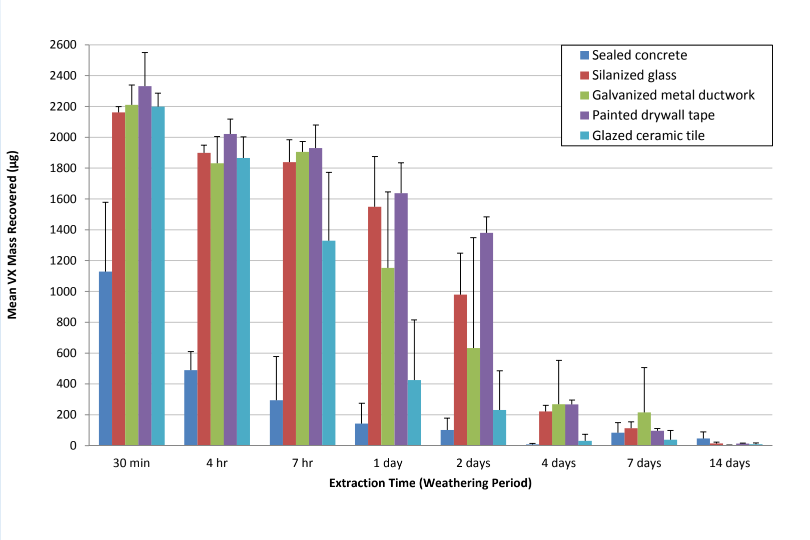
Non-Porous Materials, 25°C (air exchanged)



- 25°C, 40% RH, 1 chamber volume air exchange per hour.
- Mean VX recovery of 2300 µg from controls.
- Steadier decrease in VX recoveries. Most notable decrease between 2 and 4 days.
- After 14 days, mean recoveries < 50 µg for all materials (≥ 98.0% natural attenuation).

- Error bars equal plus one standard deviation.

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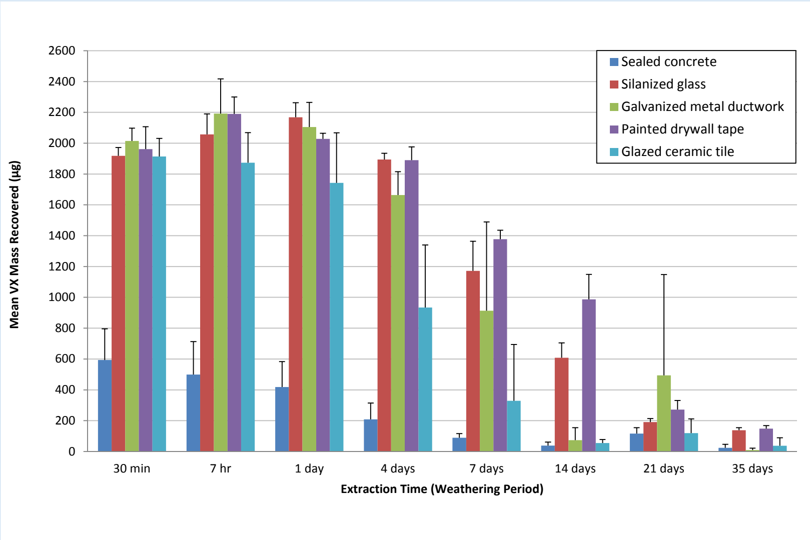
Non-Porous Materials, 10°C



- 10°C, 40% RH, 1 chamber volume air exchange per hour.
- Mean VX recovery of 2200 µg from controls.
- More VX recovered after longer periods of time at the cold condition.
- Low amounts of VX still recovered after 35 days (9.3 to 148 µg).
- Natural attenuation after 35 days ranged from 93.5% to 99.6%.

- Error bars equal plus one standard deviation.

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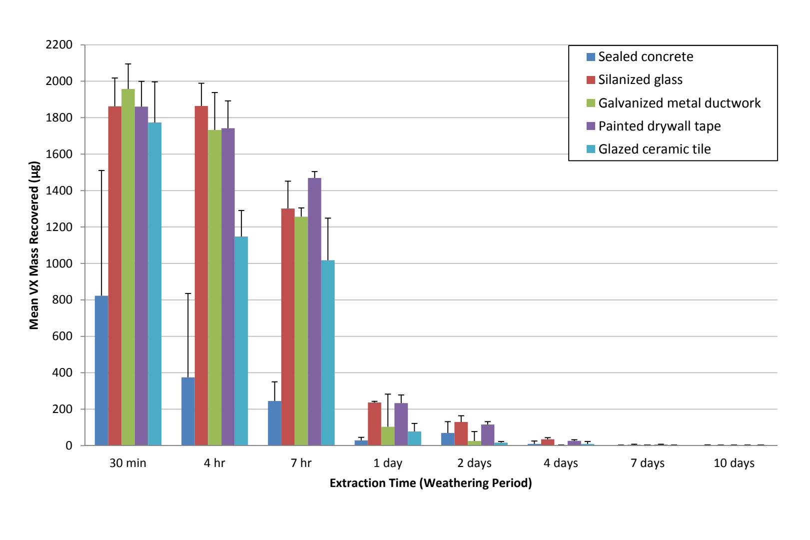
Non-Porous Materials, 35°C



- 35°C, 40% RH, 1 chamber volume air exchange per hour.
- Mean VX recovery of 1800 µg from controls.
- Attenuation occurred much faster at the warm condition.
- Significant decrease in mean recoveries between 7 hr and 1 day.
- After 10 days, mean recoveries ≤ 3.1 µg for all materials (≥ 99.8% natural attenuation).

- Error bars equal plus one standard deviation.

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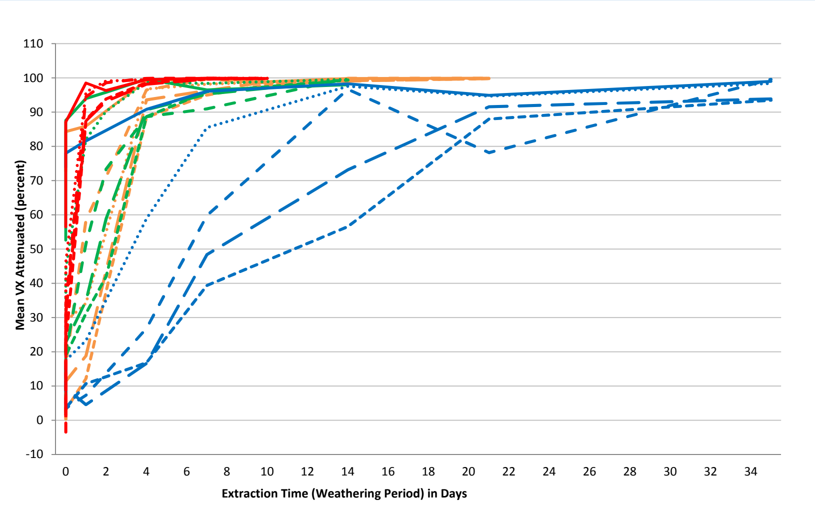
Attenuation Results, Non-Porous Materials



Orange

25°C, 40% RH
No air exchange

Green

25°C, 40% RH
1 chamber volume air exchange per hour

Blue

10°C, 40% RH
1 chamber volume air exchange per hour

Red

35°C, 40% RH
1 chamber volume air exchange per hour

Different line styles represent different materials.

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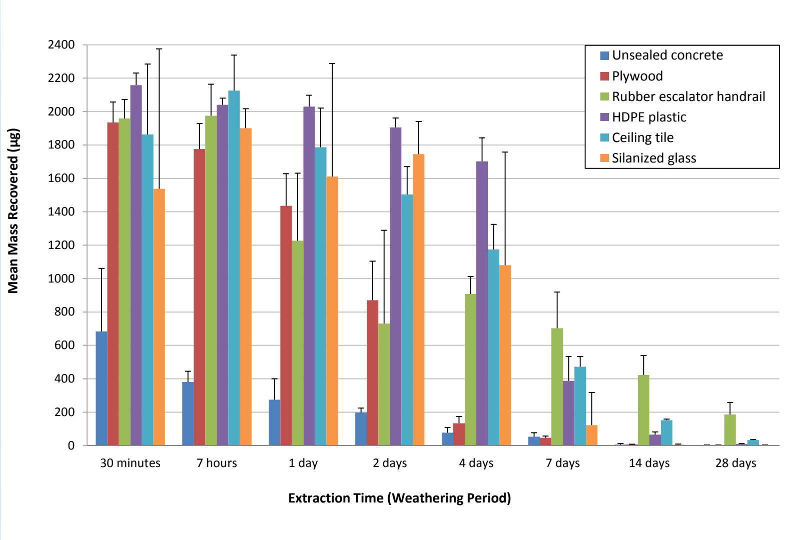
Porous Materials, 25°C



- Error bars equal plus one standard deviation.

- 25°C, 40% RH, 1 chamber volume air exchange per hour.
- Mean VX recovery from controls of 2100 µg (hexane) and 2300 µg (acetone).
- Steady decrease in recoveries; most notable decreases between 2 and 4 days or 4 and 7 days.
- ≥ 98% attenuation from all material types after 28 days, except rubber escalator handrail (91% attenuation).
- EMPA degradation products detected after:
  - Plywood - 4 days
  - HDPE, ceiling tile - 7 days
  - Glass - 14 days
  - No detections in concrete or rubber extracts.

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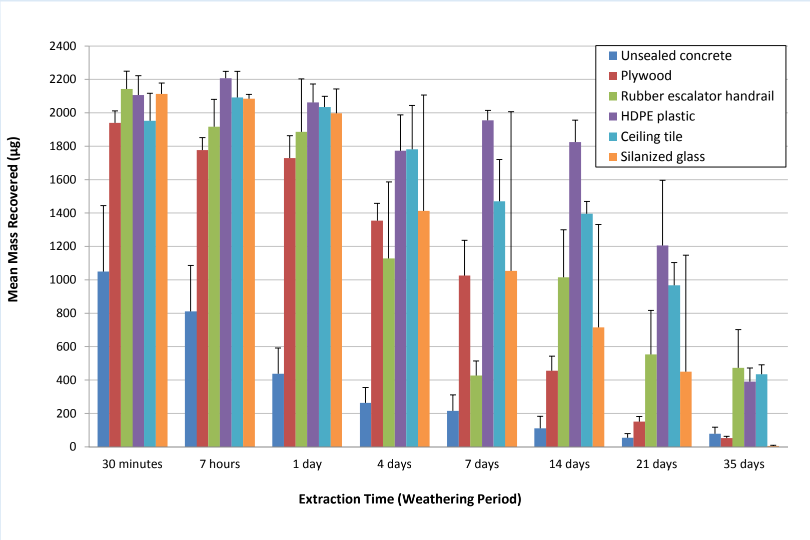
Porous Materials, 10°C



- Error bars equal plus one standard deviation.

- 10°C, 40% RH, 1 chamber volume air exchange per hour.
- Mean VX recovery from controls of 1800 µg (hexane) and 2000 µg (acetone).
- Attenuation was slower at the cold condition.
- Mean recoveries from 4 of 6 materials still above 1000 µg after 7 days (vs 25°C condition wherein all were at or below 700 µg).
- Mean recovery from 3 of 6 materials still ≥ 391 µg after 35 days (≤ 79% attenuation).
- EMPA degradation products detected after:
  - Plywood - 7 days
  - HDPE - 21 days
  - No detections in extracts of other material types.

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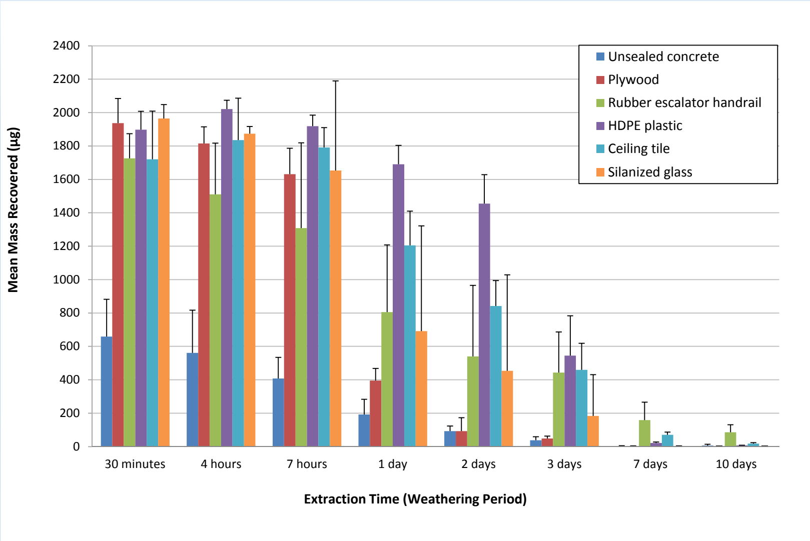
Porous Materials, 35°C



- Error bars equal plus one standard deviation.

- 35°C, 40% RH, 1 chamber volume air exchange per hour.
- Mean VX recovery from controls of 2100 µg (hexane) and 2200 µg (acetone).
- Steady and more rapid decrease in mean VX recoveries for all materials.
- Mean recoveries from all materials but HDPE < 1000 µg by 2 days. All < 600 µg by 3 days.
- 3 of 6 materials ≥ 91% attenuation by 3 days. All materials ≥ 92% by 7 days (4 of 6 were ≥ 99%).
- EMPA degradation products detected after:
  - Plywood - 1 day
  - HDPE - 2 days
  - Ceiling tile, glass - 7 days
  - No detections in rubber or concrete extracts.

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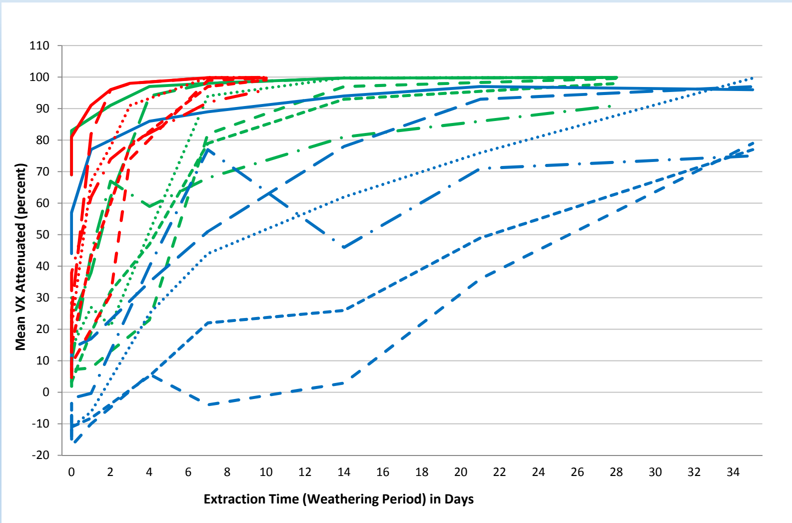
Attenuation Results, Porous Materials



Green

25°C, 40% RH
1 chamber volume air exchange per hour

Blue

10°C, 40% RH
1 chamber volume air exchange per hour

Red

35°C, 40% RH
1 chamber volume air exchange per hour

Different line styles represent different materials.

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ANOVA

- Applied to residual mass data obtained from attenuation testing with both nonporous and porous materials.
- Three hypotheses were tested:
  - Test #1: Null hypothesis: No decline occurs in mean recovered VX over time.
    Alternative hypothesis: Mean recovered VX declines over time.
  - Test #2: Null hypothesis: Mean rate of VX loss does not change between environmental conditions.
    Alternative hypothesis: Mean rate of VX loss differs between environmental conditions.
  - Test #3: Null hypothesis: Mean rate of VX loss does not vary amongst materials.
    Alternative hypothesis: Mean rate of VX loss varies amongst materials.
- In all cases, null hypotheses were rejected.
  - Residual VX mass declines over time (negative slope estimates for all conditions).
  - Mean rate of VX loss differs between environmental conditions (with the exception of the air exchange element [environmental conditions 1 and 2]).
  - Variation in mean VX loss rate amongst material types was observed (although certain groups of material types within environmental conditions may have similar rates).

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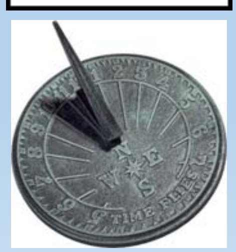
Summary/Conclusions

- Attenuation rate increases with increasing temperature. VX attenuates faster from nonporous materials.
  - ≥ 90% Attenuation, Nonporous Materials
    - 10°C – 35 Days 25°C – 7 Days 35°C – 2 Days
  - ≥ 90% Attenuation, Porous Materials
    - 10°C – >35 Days 25°C – 28 Days 35°C – 7 Days
- Given sufficient time, natural attenuation can significantly reduce VX surface contamination levels, but may not be a feasible decontamination method in many cases.
  - At the rates measured, attenuation periods of much longer than 35 days would be required to reach preliminary target cleanup levels.
  - LD50 equivalent mass for average-sized adult male would still be present in as few as 2 cm² in some cases.



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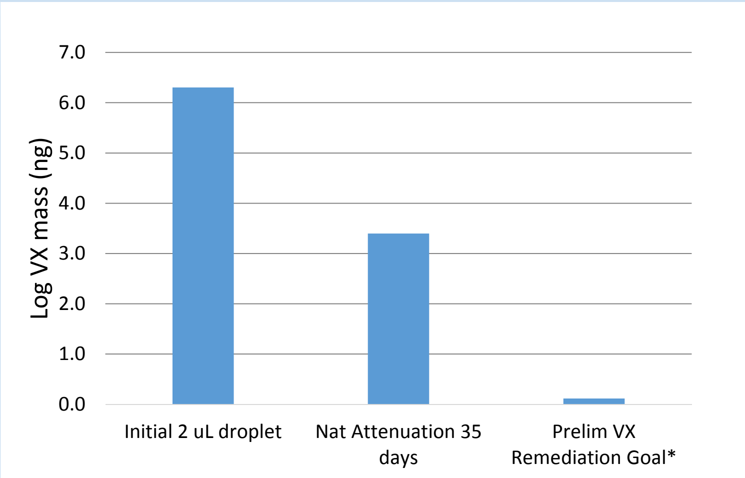
VX Clearance Values



*: Risk based goals [residential] for surfaces calculated via EPA's Risk Assessment Guide for Superfund (RAGS) methodologies

- To reach a preliminary VX cleanup goal, significantly longer periods of natural attenuation would be required.

Summary/Conclusions

- Various mechanisms contributing to measured attenuation were not explicitly investigated or quantified.
  - Evidence of chemical degradation from detection of EMPA degradation products.
  - Evidence of volatilization from redistribution test results (following slides), as well as from VX detections in procedural blank extracts.
  - Low recoveries from unsealed concrete (even at 30 minutes) suggest extraction difficulties and/or chemical degradation.

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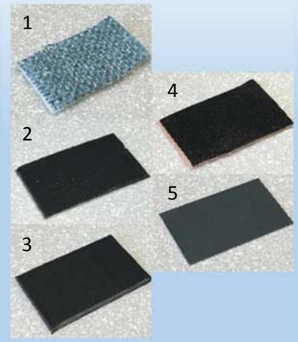
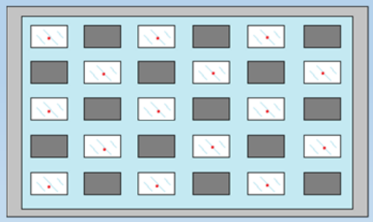
Redistribution Experimental Approach

- Redistribution of volatilized VX onto previously uncontaminated surfaces.
- Coupons of silanized glass intermingled with coupons of various materials commonly encountered in an "office" setting.
- Glass coupons challenged with 2µL of VX
- All coupons weathered in test chamber for 7 days at 25°C and 40% RH (no air exchange).
- Following weathering, all coupons removed and extracted. Extracts analyzed via GC/MS to quantify residual or redistributed VX.
- Prior to coupon removal, chamber air was sampled to measure concentration of VX in the air.
- Following coupon removal, select chamber interior surfaces were wiped to measure redistributed VX.

- "Office" setting materials
  1. Cubicle divider cloth
  2. Desktop laminate
  3. HDPE plastic
  4. Leather upholstery
  5. Painted steel (e.g. filing cabinet)
  6. Silanized glass (inert, non-porous control)





Silanized glass coupon with 2 µL VX droplet

Test material coupon (uncontaminated)

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Redistribution Results

VX Recoveries by Material after a 7-Day Weathering Period						
Material	Silanized glass (spiked)	Leather upholstery (unspiked)	HDPE (unspiked)	Painted metal (unspiked)	Desk laminate (unspiked)	Cubicle divider cloth (unspiked)
Mean (µg)	49	2.7	2.7	<2.5	<2.5	4.1
SD (µg)	24	0.12	0.17	0.00	0.00	1.0
%RSD	48%	4%	6%	0%	0%	36%
FOD	15/15	3/3	2/3	0/3	0/3	3/3

FOD = Frequency of Detection

- Mean VX recovery of 2225 µg from controls.
- VX recovered from leather, HDPE, and cubicle cloth.
- No VX recovered from painted metal or desk laminate.
- Greatest recovery (aside from glass) from cubicle divider cloth.
  - Mean recovery 4.1 µg.
  - Highest recovery from a single coupon was 5.7 µg.

- Test chamber air and wipe samples were below sampling method quantification limits.
- Ability to account for all VX is limited.
  - Large chamber volume and internal surface area coupled with detection limits of air sampling (0.0001 µg/mL) and wipe sampling (0.025 µg/cm^2).
  - Absorbent "sink" surfaces within the test chamber, including the chamber walls themselves.
  - **VX degradation over the 7-day weathering period.**

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Further Study…

- Investigation/characterization of the mechanisms contributing to attenuation.
  - Redesign redistribution test process.
  - Alternative/additional extraction/sampling methods.
  - Expand degradation product analysis capabilities. Include LC/MS analysis of extracts to investigate presence of EA2192.
- Evaluation of hazards remaining following attenuation:
  - Extended off-gas hazard testing
  - Contact hazard testing

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Questions?

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United States Environmental Protection Agency

2016 U.S. EPA International Decontamination Research and Development Conference

Wednesday, November 2, 2016

Concurrent Sessions 3

Environmental Resilience / Biological Agent Sampling and Methods

EPA National Homeland Security Research Center 1

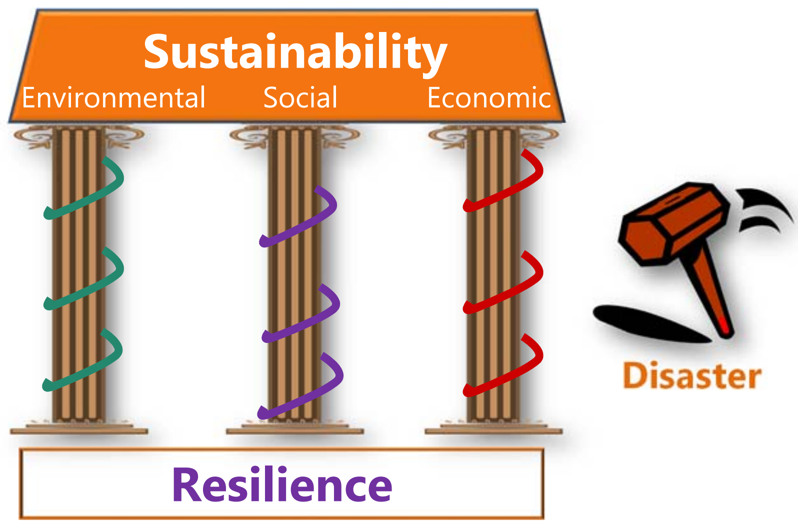
Decontamination Science & Technology and Community Resilience

EPA National Homeland Security Research Center 2

Decon S&T Supports "All-Hazards" Response & Pre-Disaster Planning

National Homeland Security Research Center 3

Resilience and Sustainability

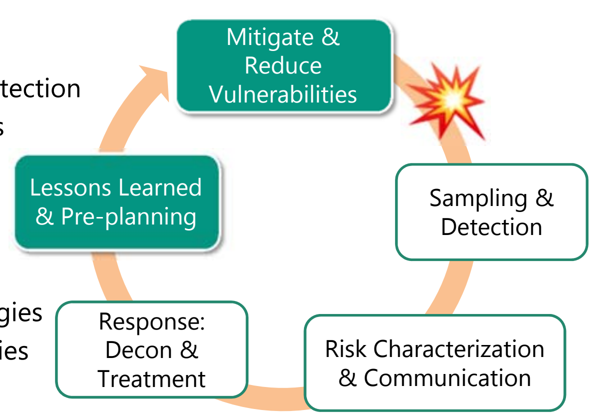


National Homeland Security Research Center 4

EPA Research Improves Community Resilience to Disasters

Relevant NHSRC research:

- Real-time contamination detection
- Water infrastructure designs
- Analytical methods
- Toxicity & risk info
- Rapid clean up methods & strategies
- Sampling methods & strategies
- Waste management strategies
- Decision support tools
- Resilience assessment tools



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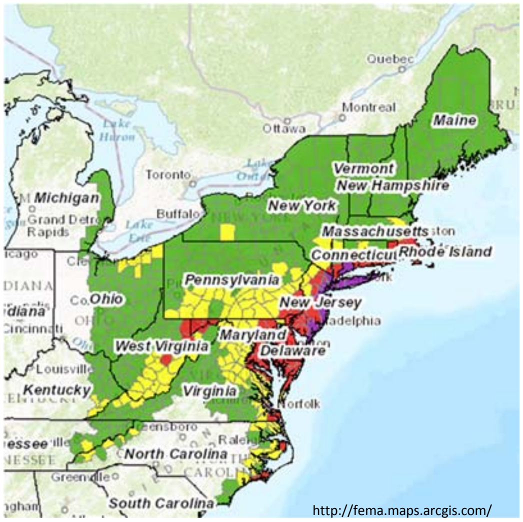
Superstorm Sandy



FEMA Map of County Impacts

Very High: Greater than 10,000 people exposed to storm surge

High: 500-10,000 people exposed to storm surge or modeled wind damages > $100M or Precipitation > 8″

Moderate: 100-500 people exposed to storm surge or modeled wind damages $10-100M or precipitation 4″- 8″

Low: no storm surge impacts or modeled wind damages < $10M or precipitation <4″

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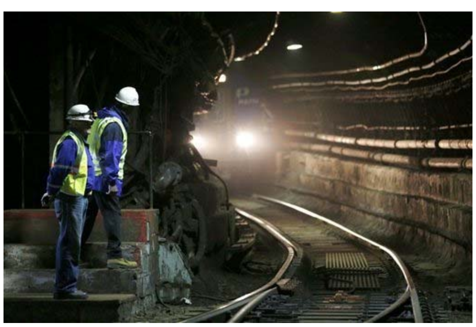
Social & Economic Damage in Hoboken, NJ



hobokennj.gov

Rebuildhoboken.org

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Environmental Damage in Hoboken, NJ

nj.com

Photo courtesy of Shane Nelson

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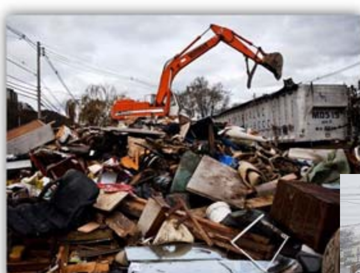
Managing Disaster Waste and Debris



www.usatoday.com/story/news/nation/2012/11/18/sandy-garbage-trash-removal/1710125/

http://www.rsvlts.com/2015/10/01/hurricane-sandy-hoboken/#22

nih.gov

What makes a waste management system resilient?

How do you properly manage vegetative debris?

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Incident Waste Decision Support Tool (I-WASTE)

Support safe and efficient removal, transport, treatment, and/or disposal of waste and debris prior to or following an incident by:

- Accessing information and guidance for incident waste treatment & disposal
- Creating records of incident planning exercises or response decisions
- Locating waste treatment and disposal facilities
- Estimating weight and volume of materials that may require disposal

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Hoboken Island?

EPA National Homeland Security Research Center 11

Rebuilding and Resilience

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Decontaminating Hamilton, NJ Mail Handling Facility

- Postal facility contaminated with *Bacillus anthracis* (anthrax) during the Amerithrax incident and closed in October, 2001
- Facility decontaminated with chlorine dioxide two years later
- Facility reopened in March, 2005 after $65 million renovation

http://www.cci-env.com/2013/02/12/anthrax-decontamination-trenton-nj-and-washington-dc/

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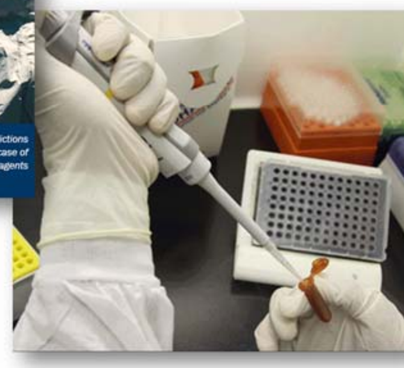
Preparing for the next Disaster



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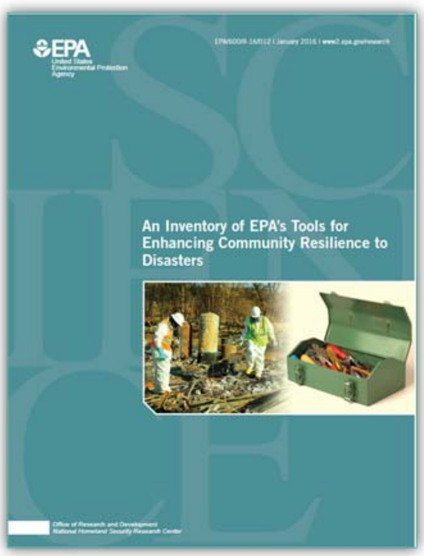
EPA Resilience Tools Inventory



Tools include:

- Guidance documents
- Modeling software
- Online applications

Potential users include:

- Utilities, emergency managers, communities, facility owners

Tools address:

- Water security, contamination, disaster response planning, waste management

Next steps:

- Interactive web wizard to match users with tools

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Resilience Research Next Steps

- Find tech transfer opportunities to test application of resilience tools to all-hazards resilience planning
- Beta test the Environmental Resilience Tools Wizard with EPA, state, and local partners

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Thank You!

Thanks to Rabi Kieber & Shane Nelson (EPA R2), Jim Manuel (NJ DEP), Glen Gilmore (former mayor of Hamilton) & Caleb Stratton (City of Hoboken) for sharing valuable information & photos

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EPA United States Environmental Protection Agency

The Application of Biological Agent Sampling Methods to a Wide-Area Incident

Colin Hayes, Eastern Research Group, Inc.

Dr. M. Worth Calfee, Dr. Sang Don Lee, Mr. Tim Boe
US EPA, Office of Research and Development

Mr. Leroy Mickelsen, Mr. Francisco J. Cruz
US EPA, Office of Land and Emergency Management

Office of Research and Development
National Homeland Security Research Center

November 2, 2016

EPA United States Environmental Protection Agency

Roadmap

- Understand the need
- Survey currently available sampling methods and research
- Use available tools to develop a hypothetical wide-area biological contamination scenario in an urban area
- Apply currently available sampling methods and resource availability estimates to the hypothetical scenario to understand impacts on overall cost and time to complete sampling and analysis activities
- Evaluate and analyze a range of possible variables and their impacts on the total cost and time to complete sampling and analysis activities
- Identify operational and technical gaps and identify areas for future work

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Background/Driver

- GAO Report
  - US needs to use validated sampling methods for *Ba* response
- Lack of understanding of wide-area demands and capabilities surrounding sampling
- Sought to understand the current situation and capability
  - Survey of available methods
  - Application to a hypothetical wide-area incident to understand impacts and any potential limitations


United States Government Accountability Office

GAO

Testimony before the Chairman, Subcommittee on National Security, Emerging Threats, and International Relations, House Committee on Government Reform, House of Representatives

ANTHRAX DETECTION

Agencies Need to Validate Sampling Activities in Order to Increase Confidence in Negative Results

Statement of Keith A. Rhodes, Chief Technologist, Center for Technology and Engineering, Applied Research and Methods

GAO Accountability * Integrity * Reliability

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Sampling Methods

- Swab sampling
- Wipe (sponge and gauze) sampling
- Vacuum sampling

Recent Work Related to Sampling

- Bench-scale studies focused on evaluations of:
  - Recovery efficiency
  - Extraction efficiency
  - False negatives
  - Numerous various surface types
  - Controlled conditions
- Field Studies

Hypothetical Wide-Area Scenario

Assumptions – Approach and Environment

- Biological attack by way of aerosolized *Ba* spores
- Dense urban area
- Dispersion across 2 square miles
- Tangible city used to derive the spatial, infrastructure, and surface media information, using a combination of EPA and geographic information system (GIS) tools and estimates
  - WEST
  - I-WASTE
- Total estimated surface area:
  - Outdoor: 2 square miles
  - Indoor: 15 square miles
  - Underground: 0.5 square miles

Hypothetical Wide-Area Scenario

Assumptions – Surface Sampling

- Indoor

Surface Type	Surface Distribution	Sample Type
Porous	90%	Vacuum
Nonporous	10%	Sponge

- Outdoor

Surface Type	Surface Distribution	Sample Type
Trees	5%	Soil sample
Grass	1%	Soil sample
Buildings	51%	Vacuum
Asphalt	22%	Vacuum
Concrete	21%	Vacuum

- Underground

Surface Type	Surface Distribution	Sample Type
Concrete	90%	Vacuum
Metal	9%	Sponge
Carpet	1%	Vacuum

Hypothetical Wide-Area Scenario

Assumptions - Resources

- Personnel
  - 500 3-man teams

Sample Medium	Time	Unit
Soil sample	0.07	team hours /sample
Sponge/gauze/wipe	0.08	team hours/sample
Vacuum	0.13	team hours/sample

- Cost

Sample Medium	Cost	Unit
Soil sample	$25	$/sample
Sponge/gauze/wipe	$20	$/sample
Vacuum	$29	$/sample

- Lab capacity
  - 250 labs

Sample Medium	Analysis Time	Unit
Soil sample	48	min/sample
Sponge/gauze/wipe	4.8	min/sample
Vacuum	48	min/sample

Hypothetical Wide-Area Scenario

VSP Sampling Strategy

- Visual Sample Plan (VSP)
  - Define area of interest
  - Define sampling goal for characterization sampling
  - "Locate hot spot"
  - Sampling design

Input	Outdoor	Indoor	Underground
Probability of detection	95%	95%	95%
Grid pattern	Square	Square	Square
Area of hot spot	10 ft^2	10 ft^2	10 ft^2
Total area to sample	5.75×10^7 ft^2	4.16×10^8 ft^2	1.92×10^6 ft^2
Spacing between samples	3 meters	3 meters	3 meters
Optimum number of samples (VSP output)	3.63×10^6	2.63×10^7	1.21×10^5

Hypothetical Wide-Area Scenario

VSP Sampling Strategy

VSP Parameter	Meaning
Sampling Area	The area of the location being sampled
Hot Spot Area	The local contiguous area that has concentrations that exceed a threshold value
Probability	Probability of a sampling location being collocated with a hot spot
False Negative Rate	Probability each contaminated sample will not be detected

Hypothetical Wide-Area Scenario

Results

Outdoor Sample Collection

Total Samples	Sample Type	Number of Samples	Sampling Cost ($)	Labor Cost ($)	Sampling Time (team hours)
3,630,000	Soil sample	219,370	5,484,260	6,449,489	15,356
	Vacuum	3,410,630	98,908,259	181,922,984	433,150

Outdoor Sample Analysis

Total Samples	Sample Type	Number of Samples	Analysis Cost ($)	Labor Cost ($)	Analysis Time (lab hours)
3,630,000	Soil sample	219,370	57,913,781	29,615,002	175,496
	Vacuum	3,410,630	982,261,329	515,005,072	2,728,504

Hypothetical Wide-Area Scenario

Results

Indoor Sample Collection

Total Samples	Sample Type	Number of Samples	Sampling Cost ($)	Labor Cost ($)	Sampling Time (team hours)
26,300,000	Sponge/gauze/wipe	2,630,000	52,600,000	90,577,200	215,660
	Vacuum	23,670,000	686,430,000	1,262,557,800	3,006,090

Indoor Sample Analysis

Total Samples	Sample Type	Number of Samples	Analysis Cost ($)	Labor Cost ($)	Analysis Time (lab hours)
26,300,000	Sponge/gauze/wipe	2,630,000	628,570,000	310,340,000	210,400
	Vacuum	23,670,000	6,816,960,000	3,574,170,000	18,936,000

Hypothetical Wide-Area Scenario

Results

Underground Sample Collection

Total Samples	Sample Type	Number of Samples	Sampling Cost ($)	Labor Cost ($)	Sampling Time (team hours)
121,000	Sponge/gauze/wipe	10,890	217,800	375,052	893
	Vacuum	110,110	3,193,190	5,873,267	13,984

Underground Sample Analysis

Total Samples	Sample Type	Number of Samples	Analysis Cost ($)	Labor Cost ($)	Analysis Time (lab hours)
121,000	Sponge/gauze/wipe	10,890	2,602,710	1,285,020	871
	Vacuum	110,110	31,711,680	16,626,610	88,088

Hypothetical Wide-Area Scenario

Results

Outdoor + Indoor + Underground Sample Collection

Total Samples	Sample Type	Number of Samples	Sampling Cost ($)	Labor Cost ($)	Sampling Time (team hours)
29,940,892	Soil	219,370	5,484,260	6,449,489	15,356
	Sponge/gauze/wipe	2,640,890	52,817,800	90,952,252	216,553
	Vacuum	27,190,740	785,338,317	1,444,480,890	3,439,240

Outdoor + Indoor + Underground Sample Analysis

Total Samples	Sample Type	Number of Samples	Analysis Cost ($)	Labor Cost ($)	Analysis Time (lab hours)
29,940,892	Soil	219,370	57,913,781	29,615,002	175,496
	Sponge/gauze/wipe	2,640,890	631,172,710	311,625,020	211,271
	Vacuum	27,190,740	7,799,221,905	4,089,175,374	21,664,505

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Hypothetical Wide-Area Scenario

Results

- Outdoor + Indoor + Underground

Sampling Plan	
Total Number of Samples	**29,940,892**
Sampling Operation	
Total Required Sampling Time (team hrs)	3,671,149
Time to Complete Sampling (days)	**1,468**
Total Sampling Labor Cost ($)	1,541,882,631
Total Sampling Material Cost ($)	843,640,376
Analysis Operation	
Total Required Analysis Time (lab hrs)	22,051,273
Time to Complete Analyses (days)	**3,675**
Total Analysis Labor Cost ($)	4,430,415,396
Total Analysis Material Cost ($)	8,488,308,397
Total Cost ($)	**15,304,246,801**
Total Time to Completion (days)	**3,675**
Limiting Time Factor	Analysis

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Wide-Area Incident Analysis

- Sampling strategies must be available for incidents of any given size, impacting any given area, and with many variable characteristics
- Extend capacity of VSP using regression modeling
- Model the number of samples needed under a range of VSP input parameters
- Evaluate the relative impact of VSP input parameters on number of samples
- Analyze potential impacts on cost and time

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Wide-Area Incident Analysis

VSP Input Parameters

- Two data sets were derived from VSP for each environment; a separate dataset for a range of false negative rates and another for a range of sampling areas

Variable	Scenario	False Negative Rate (%)	Sampling Area (ft^2)	Probability (%)	Hotspot Area (ft^2)
Sampling Area	Indoor	-	50-1,000	50-99	50-1,000
Sampling Area	Outdoor	-	50-1,000	50-99	50-1,000
Sampling Area	Underground	-	10-1,000	50-99	10-1,000
False Negative Rate	Indoor	1-8	-	50-95	55-1,000
False Negative Rate	Underground	1-10	-	50-99	4-1,000

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Wide-Area Incident Analysis

VSP Variable Sensitivities – Sampling Area

Underground

Variable	Sensitivity	% Positive	Positive Magnitude	% Negative	Negative Magnitude
Sampling Area	4.9421	0%	0	100%	4.9421
Hotspot Area	0.51549	0%	0	100%	0.51549
Probability	0.073084	100%	0.073084	0%	0

Outdoor

Variable	Sensitivity	% Positive	Positive Magnitude	% Negative	Negative Magnitude
Sampling Area	2.7538	0%	0	100%	2.7538
Hotspot Area	0.094395	0%	0	100%	0.094395
Probability	0.032768	100%	0.032768	0%	0

Indoor

Variable	Sensitivity	% Positive	Positive Magnitude	% Negative	Negative Magnitude
Sampling Area	2.7736	3%	0.011193	97%	2.8636
Hotspot Area	0.094389	0%	0	100%	0.094389
Probability	0.032678	100%	0.032678	0%	0

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Wide-Area Incident Analysis

VSP Variable Sensitivities – False Negative Rate

Underground

Variable	Sensitivity	% Positive	Positive Magnitude	% Negative	Negative Magnitude
Hotspot Area	17.085	0%	0	100%	17.085
Probability	0.38083	100%	0.38083	0%	0
False Negative Rate	0.070417	100%	0.070417	0%	0

Indoor

Variable	Sensitivity	% Positive	Positive Magnitude	% Negative	Negative Magnitude
Hot Spot Area	2.03	0%	0	100%	2.03
Probability	0.35668	100%	0.35668	0%	0
False Negative Rate	0.059827	100%	0.059827	0%	0

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Wide-Area Incident Analysis

Resource Demands

Sampling Plan

				Value
1.	False Negative Rate	%		10
2.	Probability	%		95
3.	Hotspot Area	ft2		10
4.	Sampling Area	ft2		50
				50-1000

Resource Availability and Constraints

Sampling

				Value
5.	Number of Available Teams for Sampling	teams		500
6.	Personnel per Sampling Team	person/team		3
7.	Time to Collect Samples	team hours/sample	Soil Sample	0.07
			Sponge Sample	0.08
			Gauze/Wipe Sample	0.08
			Vacuum Sample	0.13
8.	Sampling Team Hours per Shift	team hours/shift		5
	Sampling Team Shifts per Day	team shifts/day		1
	Sampling Hours per Day	sampling hours/day		2500.0
	Sampling Personnel hours per Day	person hours/day		7500.0
	Sampling Team Labor Cost	$/hour/team		420.00
	Sampling Personnel Labor Cost	$/hour/person		140.00
9.	Sampling Material Cost	$/sample	Soil Sample	25.00
			Sponge Sample	20.00
			Gauze/Wipe Sample	20.00
			Vacuum Sample	29.00

Analysis

				Value
10.	Number of Available Labs for Analysis			250
11.	Time to Analyze Samples	min/sample	Soil Sample	48.0
			Sponge Sample	4.8
			Gauze/Wipe Sample	4.8
			Vacuum Sample	48.0
12.	Analysis Lab Hours per Day	hours/day/lab		24
	Analysis Hours per Day	analysis hours/day		6000.0
13.	Analysis Labor Cost	$/sample	Soil Sample	135.00
			Sponge Sample	118.00
			Gauze/Wipe Sample	118.00
			Vacuum Sample	151.00
14.	Analysis Material Cost	$/sample	Soil Sample	264.00
			Sponge Sample	239.00
			Gauze/Wipe Sample	239.00
			Vacuum Sample	288.00

Results

Scenario	Constant	Number of Samples
Indoor	SA	8,877,950
Indoor	FNR	141,406
Outdoor	SA	N/A
Outdoor	FNR	17,359
Underground	SA	311,269
Underground	FNR	635

Sampling Plan	
Total Number of Samples	159,401
Sampling Operation	
Total Required Sampling Time (team hrs)	19,545
Time to Complete Sampling (days)	8
Total Sampling Labor Cost ($)	8,208,980
Total Sampling Material Cost ($)	4,490,644
Analysis Operation	
Total Required Analysis Time (lab hrs)	117,298
Time to Complete Analyses (days)	20
Total Analysis Labor Cost ($)	23,584,192
Total Analysis Material Cost ($)	45,186,530
Total Cost ($)	81,470,347
Total Time to Completion (days)	20
Limiting Time Factor	Analysis

Wide-Area Incident Analysis

Resource Demands

Variable Sampling Area and Sampling Teams

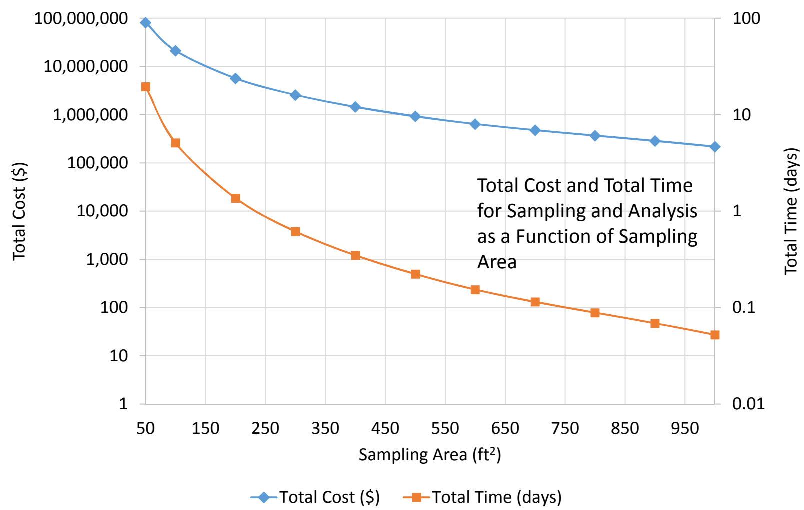
	Sampling Area = 50 ft²		Sampling Area = 500 ft²		Sampling Area = 1,000 ft²	
Sampling Teams	Total Cost ($)	Sampling Days	Total Cost ($)	Sampling Days	Total Cost ($)	Sampling Days
100	81,470,347	39	928,441	0.45	217,320	0.10
200	81,470,347	20	928,441	0.22	217,320	0.052
300	81,470,347	13	928,441	0.15	217,320	0.035
400	81,470,347	9.8	928,441	0.11	217,320	0.026
500	81,470,347	7.8	928,441	0.089	217,320	0.021

Variable Sampling Area and Analysis Laboratories

	Sampling Area = 50 ft²		Sampling Area = 500 ft²		Sampling Area = 1,000 ft²	
Analysis Labs	Total Cost ($)	Analysis Days	Total Cost ($)	Analysis Days	Total Cost ($)	Analysis Days
100	81,470,347	49	928,441	0.56	217,320	0.13
200	81,470,347	24	928,441	0.28	217,320	0.065
300	81,470,347	16	928,441	0.19	217,320	0.044
400	81,470,347	12	928,441	0.14	217,320	0.033
500	81,470,347	9.8	928,441	0.11	217,320	0.026

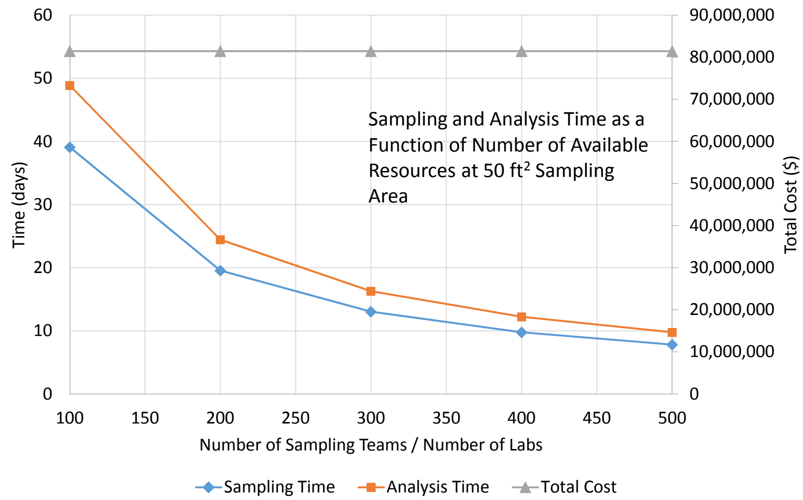
Wide-Area Incident Analysis

Resource Demands



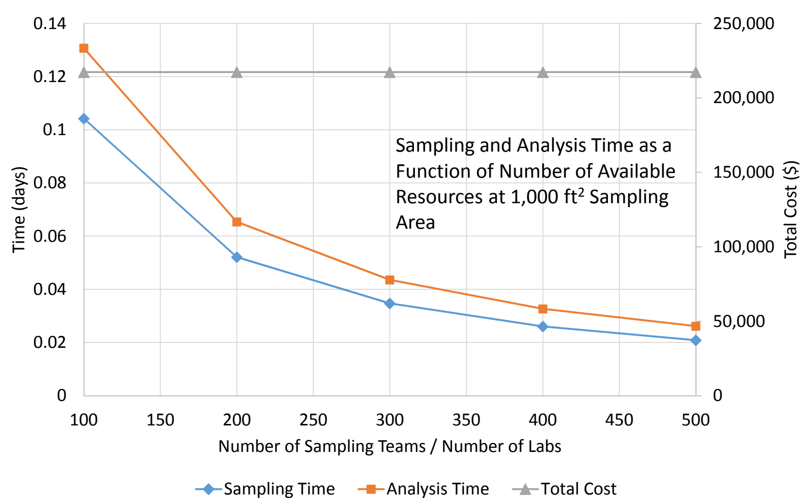
Wide-Area Incident Analysis

Resource Demands



Wide-Area Incident Analysis

Resource Demands



EPA United States Environmental Protection Agency

Observations

- VSP has limitations for application to a wide-area incident
- Many VSP inputs are poorly understood (i.e., FNR contaminated area size/shape, etc.)
- Probabilistic sampling could be too much for a wide-area incident
- Inconsistent terminology
- EPA tools (WEST and IWASTE) and GIS tools can be useful for wide area sample plan development by determining surface material types

EPA United States Environmental Protection Agency

Needs

- Consider lines-of-evidence from outset
- Need cohesive information to develop operational strategies
- Need different sampling methods
  - Larger sample area
  - Outdoor surfaces
  - Less personnel
- Need to understand fate and transport of spores over long period of time for effective sampling and remediation strategy development
- This study supports further consideration of a combined approach using probabilistic and non-probabilistic sampling, when characterizing a wide area incident. More research is needed to determine the extent.
- Decision support tools are needed to help direct sampling efforts for wide area incidents. Time and cost considerations should also be made.

Disclaimer

The U.S. Environmental Protection Agency, through its Office of Research and Development, funded and managed the research described here under Contract #EP-D-11-006 to Eastern Research Group. 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.

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US ARMY RDECOM

Comparative Efficacy of Decon Technologies for Bacillus anthracis and Bacillus atrophaeus

EDGEWOOD CHEMICAL BIOLOGICAL CENTER — A U.S. Army RDECOM Laboratory

TECHNOLOGY DRIVEN. WARFIGHTER FOCUSED.

Dr. Vipin K. Rastogi

U.S. Army - ECBC, R&T Directorate, RDECOM, APG, MD, USA

Briefing at 2016 EPA's Inter. Conference on Decon Research & Development at RTP, NC (Nov. 1-3, 2016)

OUTLINE

- ***Bacillus anthracis*** **(BW) & Surrogate *species*** -
  - ✓ Structural Complexity
  - ✓ Possible Surrogates
- **Objectives**
- **Test Conditions**
- **Sporicidal Efficacy Results**
- **Conclusions and Future Directions**

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Bacillus Spore Complexity

B. anthracis

- ✓ Genetic material is protected within multilayered coat, enclosed within the outermost layer – Exosporium
- ✓ 60-70 proteins comprise the spore coat protein
- ✓ Exosporium consists of a basal layer with a hair-like nap, with one major protein *Bcl*A, conferring hydrophobicity to the spores
- ✓ Functions of spore coat/exosporium proteins are not well understood, with the exception of *Cot*E – required for positioning of exosporium around the spore
- ✓ Role of exosporium is not well defined in spore hardiness

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Bacillus Spore Surrogates

- ***B. anthracis* Surrogates**
  - ✓ Plasmid-free *B. anthracis* (Sterne/ΔSterne) spores have proven to be one of the most appropriate surrogates
  - ✓ Genetically, *B. thuringiensis* (genetically) is most closely related to *B. anthracis*, and is the most hydrophobic spore
  - ✓ *Bt* therefore has been documented to be a suitable BSL-1 surrogate for BW agent for comparative sampling, aerosol and genetic testing
  - ✓ Antimicrobial label claims requires (as per FIFRA) that surrogate demonstrates resistance equal or slightly greater than the BW agent
  - ✓ *B. subtilis/B. atrophaeus (BG)* have been extensively used as surrogates, even though both are genetically unrelated to the BW agent

✓Why BG?

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B. globigii (BG)

B. globigii (BG)

- ✓ In has been referred as ***B. atrophaeus***, *B. subtilis* var. *subtilis*, *B. subtilis* var. *niger*, the 'red strain", *B. niger*, *B. atrophaeus* subsp. *globigii*
- ✓ Produces a brown pigment when cultured on organic nitrogen source – ease of colony identification
- ✓ BG spores lack an exosporium, and are therefore not hydrophobic
- ✓ Genetically, unrelated to the BW agent, *B. anthracis*
- ✓ Commonly has been used as a commercial sterilization biological indicators
- ✓ Widely used in biodefense research as a simulant for the BW agent, especially in detection and decontamination
- ✓ EPA has >15 years of experience using BG spores in Decon studies, and have observed comparable sensitivity of BG spores with that of BW agent
- ✓ Limited published data on any difference in the sensitivity of BG spores – relative to Ba spores - to chemical disinfectants
- ✓ About a decade ago, Sagripanti *et al* (2007) reported similar and comparable sensitivity of virulent *B. anthracis* spores to avirulent spores, including BG spores

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OBJECTIVES

- Are BG spores more sensitive than spores of *B. anthracis* (AMES) to commercial decontamination technologies, i.e. chlorine dioxide (CD) gas, vapor hydrogen peroxide (VHP) and acidified bleach?
- Are spores of *Clostridium difficile* significantly different in their sensitivities to the same technologies?

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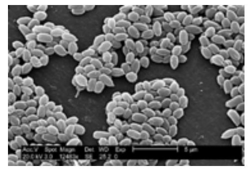
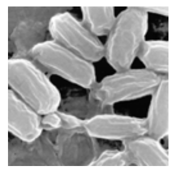
Test Spore Types



Clostridium difficile

B. anthracis Ames

B. atrophaeus

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Test Conditions

DECON TECHNOLOGIES

- Sporicidal Chemical
  - ✓ Acidified bleach (FAC) – 6000-ppm (pH 7.0)
    - Exposure for 2, 5, 10, and 20 min
- **Gases**
  - ✓ Chlorine dioxide (CD) – 3000-ppmv requiring at least 75% RH
    - Exposure for 0.5, 1, 2, and 2.5 hours
  - ✓ Vapor Hydrogen Peroxide (VHP) – 150-ppmv & requires <35% RH
    - Exposure for 0.5, 1, 2, and 3 hours

Coupons

- Glass and pinewood

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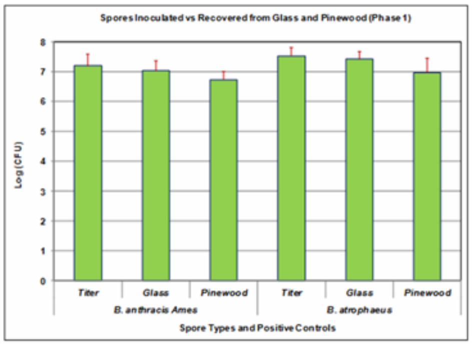
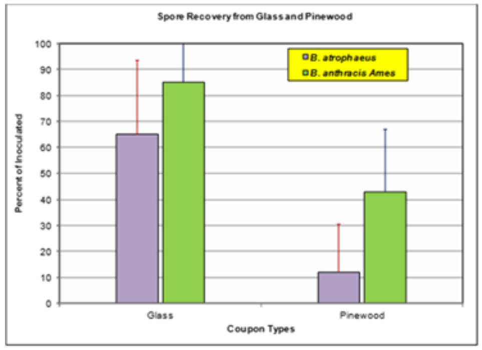
SPORE RECOVERY



- 6-logs spore recovery from glass and pinewood
- No significant difference in spore recovery between the two spore types from the two surfaces



- >10% spore recovery from both surface types
- Low (>10%) BG spore recovery from pinewood
- 60-80% spore recovery from glass

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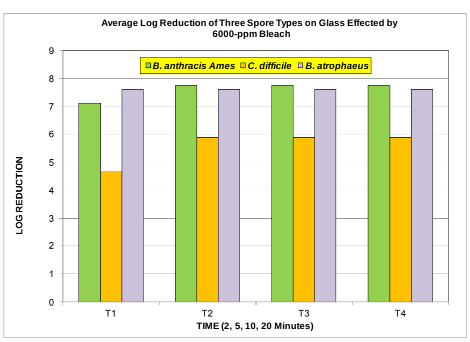
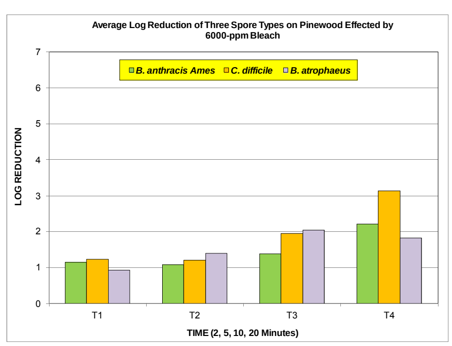
BLEACH EFFICACY

Bleach

- ✓ Three spore types – AMES, *B. atrophaeus* (Bg), and *Clostridium difficile* (unrelated)
- ✓ A significant difference between bleach efficacy on glass vs. wood
- ✓ Bg spore (surrogate) sensitivity response similar to pathogenic AMES





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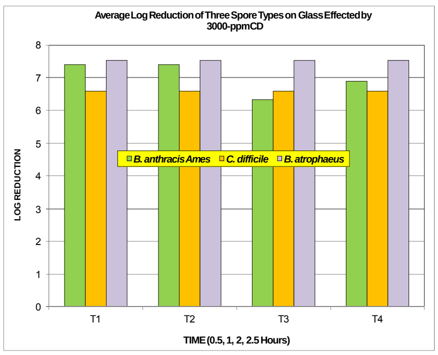
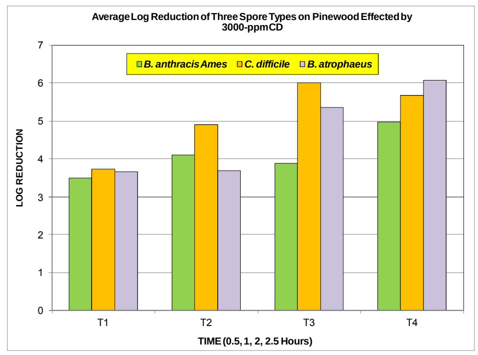
CD EFFICACY

CD Gas

- ✓ Three spore types – AMES, *B. atrophaeus* (Bg), and *C. difficile* (unrelated)
- ✓ Glass surface easier to decontaminate compared to wood
- ✓ Bg spore (surrogate) sensitivity response similar to pathogenic AMES





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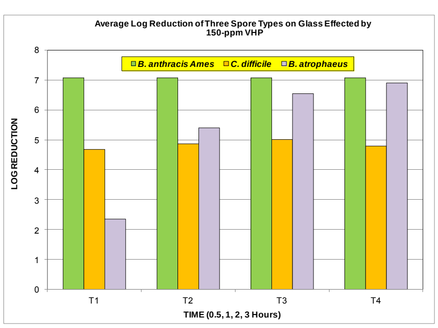
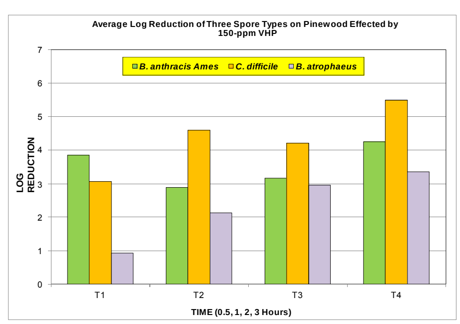
VHP EFFICACY

VHP

- ✓ Three spore types – AMES, *B. atrophaeus* (Bg), and *C. difficile* (unrelated)
- ✓ Glass surface easier to decontaminate compared to wood
- ✓ Bg spore (surrogate) sensitivity response much less than pathogenic AMES spores





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CONCLUSIONS

- Based on the fractional spore kill profile, it appears that BG spores are just as resistant as virulent BW agent spore type to the three technologies investigated in this study
- Decontamination is STRONGLY dependent upon ambient parameters and the type of material being decontaminated, i.e. pH adjusted bleach much less effective on pinewood
- Interestingly, on glass, *C. difficile* spores were found to be more resistant than *Bacillus* spore types to bleach
- As reported before, the two *Bacillus* spore types are more difficult to kill on porous pinewood surface
- Some differences and variability at fractional kill levels with VHP was evident, even though at high dosages, high spore kill was observed.
- VHP was only partially efficacious against *C. difficile* spores even at high dosage

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CONCLUSIONS

- *C. difficile* spores appear to adhere to glass surface more tightly
- Spores of *C. difficile* exhibit similar sensitivity – compared to the two *Bacillus* spore types - to CD gas and VHP
- *C. difficile* spores – compared to *Bacillus* spore types - appear to be more resistant to bleach

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FUTURE

- Spore kill kinetics should be determined at lower spore challenge levels (as opposed to 7-logs per coupon)
- Inclusion of additional porous and non-porous surfaces would be highly desirable
- Comparative efficacy with spore deposition as dry aerosolized powder
- Additional set of robust data

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Acknowledgements

Funding and Program Directions –

EPA - Dr. Worth Calfee and Dr. Shawn Ryan

Bio-Decon Group -

ECBC - Ms. Lisa Smith (now with EPA-BEAD Lab) and Ms. Michelle Ziemski

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THANKS

Thank You
&
QUESTIONS

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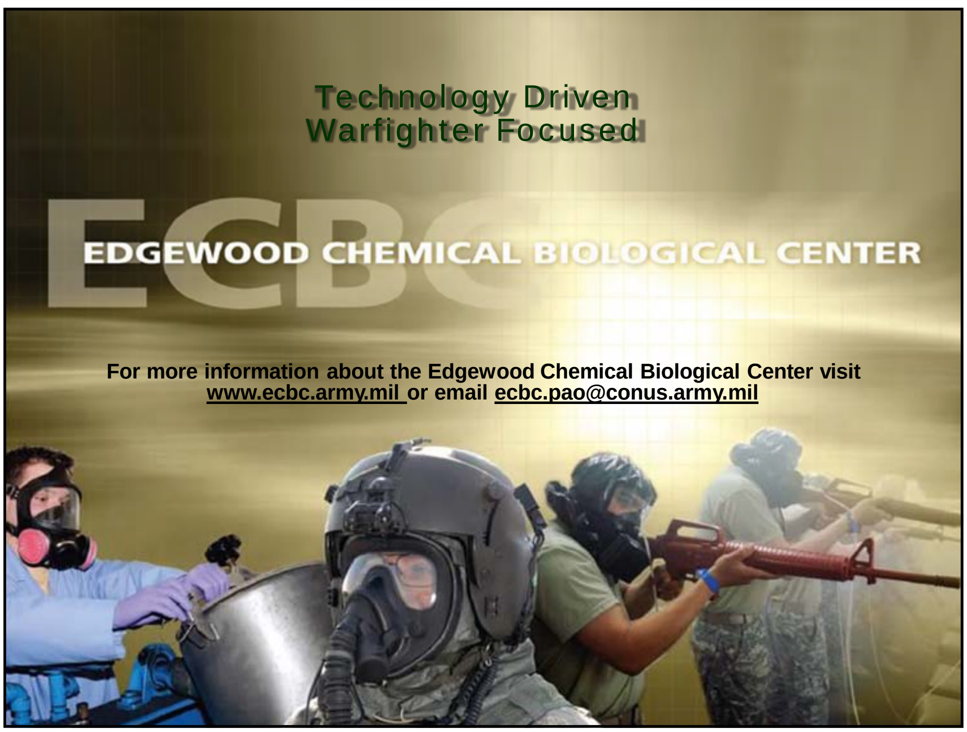

United States Environmental Protection Agency

2016 U.S. EPA International Decontamination Research and Development Conference

Wednesday, November 2, 2016

Concurrent Sessions 3

Radiological Agent Research

MODELING DECONTAMINATION STRATEGIES IN THE AFTERMATH OF A NUCLEAR DETONATION

Matthew Clay, Ph.D., Leidos
Neelima Yeddanapudi, Leidos
Timothy Adams, Gryphon Scientific
Rocco Casagrande, Ph.D., Gryphon Scientific
Jessica Appler, Ph.D., Health and Human Services

November 2, 2016

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Disclaimer

- The views presented here do not represent the official position of the United States, HHS, ASPR, BARDA, or PHEMCE.

2

Purpose of Analysis

- Is Cutaneous Radiation Injury (CRI) in the wake of a nuclear detonation a concern?
- Is the number of people who may need medical treatment for CRI high enough to warrant advanced research and development for medical countermeasures?

3

What is Cutaneous Radiation Injury?

4

CRI Overview

- Cutaneous radiation injury is a result of radiation-induced death of cells in the basal layer of the skin
- Requires high levels of exposure
  - γ radiation tends to cause lethal acute effects before CRI manifests
  - β radiation does not penetrate far enough to cause lethal effects, so high β exposure can produce survivable CRI
- Traditionally ignored in planning
  - New analysis shows it can produce significant number of injuries

5

Castle Bravo

- 1 March 1954
- Bikini Atoll
- 15 megatons
- Wind shifted and fallout hit
- Marshall Islanders
- Japanese fishing boat

Department of Energy

Asahi Graph 1954 April 7 issue

6

Injury Description

- Erythema
  - Painful reddening of the skin
  - Think 'sunburn'

Erythema

Source: Wagner L. (2007) Radiation Injury is a Potentially Serious Complication to Fluoroscopically-Guided Complex Interventions. *Biomedical Imaging Intervention Journal.* 3 (2): e22.

- Moist Desquamation
  - Loss of epithelial barrier
  - Painful, weeping skin

Moist Desquamation

Source: Rehani M, Srimahachota S. (2011) Skin Injuries in Interventional Procedures. *Radiation Protection Dosimetry.* 147 (1-2): 8-12.

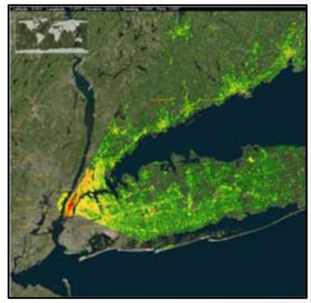
Overview of effort

8

Inputs

Lawrence Livermore National Laboratory provided scenario data:

- New York City
- Population data - daytime (Landscan)
- Prompt γ dose
- Time-specific fallout γ dose and dose rate
- Peak overpressure
- Thermal fluence

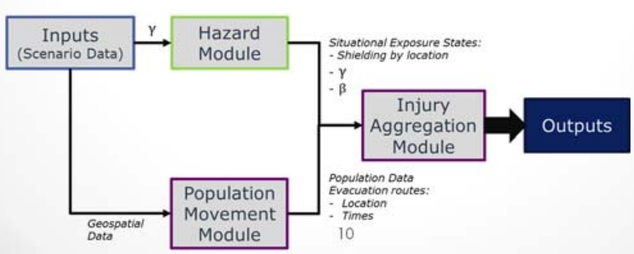


Population under fallout

9

Methodology

- Modeled prompt effects
  - Trauma, thermal burns, and γ & neutron radiation
- Modeled population movement during evacuation
  - Based on initial location and injuries
- Evacuees accumulate radiation, both γ & β, as they transit hazard zone
  - Groundshine and direct skin contamination from falling fallout



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Sensitivity analysis of fallout retention parameters

11

β Skin Contact

- Used DTRA ED04 methodology to examine β exposure due to direct skin contact by fallout
- Dose depends on:
  - Amount of fallout
  - Location on the body
  - Clothing
  - Time of exposure (affects size of particles likely to be in fallout)
- Fallout is capped by a loading factor for each location

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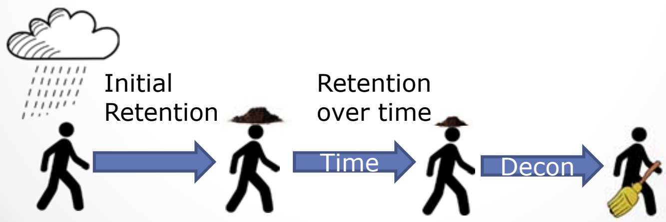
Parameters examined here

- Initial deposition of fallout on body
- Retention of fallout over time
  - Skin & clothing
- Effects of moisture on retention
- Maximum loading of fallout on body
- Effects of decontamination



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Initial Deposition of Fallout on Skin and Clothes

- Probability that a fallout particle will stick to skin or clothing.
  - Values were estimated from ash deposition on people following volcanic eruptions in Costa Rica
  - Values for clothing retention can vary by an order of magnitude

Body Region	Retention Factor (R)	Hair
Face, shoulders, back, sides of torso	0.015	Very little
Forearms and legs	0.06	Hair covered
Scalp	0.23	Very hairy
Clothes	0.06	Flat, non-wrinkled clothing
Feet	1	No hair, in contact with contaminated surface
Special Areas	1.5	Back of neck under collar, top of boot, above belt, etc.

Apostoaei, A, Kocher, D. *Radiation Doses to Skin From Dermal Contamination.* DTRA TR-09-16. 2010.

14

Effect of Moisture

- Only considered for initial retention of particles
- Straight multiplier to overall effects

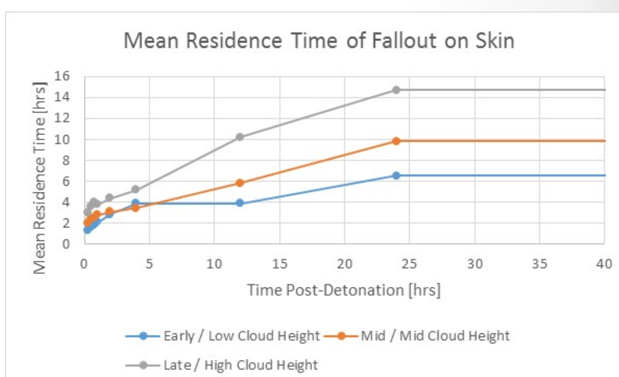
Scenario	Mean	95th Percentile
Host / Moist	1.2	1.5
"Baseline model"	1	
Dry	0.75	1

DTRA (2010) ED04 - Skin Dose from Dermal Contamination.

15

Retention on Skin over Time

- Retention of fallout on skin is driven by arriving particle size
  - Large particles arrive early, while small particles arrive later
  - Based on U.S. Naval Radiological Defense Lab studies for use of nuclear/radiological material in space
  - Single-term exponential function
- Insufficient data on how retention time might differ by type of skin (hairy vs. non-hairy)



U.S. Naval Radiological Defense Laboratory. *Rover flight safety program preliminary review. IV. Safety analysis report: radiological considerations in nuclear flight safety.* 1966.

16

Fallout on Clothing over Time

- Retention of fallout on clothing is based on analysis of glass particle retention used in criminal forensics
  - May be high, due to irregular shape of broken glass particles
- Based on this data, we found that retention follows a two-term exponential function
  - Fast component for particles that quickly fall off of clothing, including all very large particles
  - Slow component for particles trapped in fibers of clothing (or hair), and therefore retained for longer

$$R(t) = Ae^{\frac{t}{T_1}} + (1 - A)e^{\frac{t}{T_2}}$$

Hicks T *et al* (1995) Transfer and Persistence of Glass Fragments on Garments. *Science & Justice* 36: 101-107

17

Maximal Fallout Deposition on Skin and Clothing

- Only a finite amount will stick
  - Estimated skin maximal loading with data on soil contamination on skin used for estimating pesticide exposure (mg soil / cm² skin)
  - Estimated clothing maximal loading with data on retention of pottery dust on clothing
- Insufficient data to estimate for maximal loading in scalp
  - Clothing retention was used for scalp, as hairs also trap material more effectively than skin

Maximum Loading on Skin [mg/cm2]

Region	High	Mid	Low
Face, Shoulders, Back, Sides of Torso	0.08	0.06	0.04
Forearms	0.17	0.11	0.07
Legs	0.18	0.04	0.01
Scalp	22.48	6.98	2.17
Clothes	22.48	6.98	2.17
Feet	0.46	0.24	0.12
'Special Areas'	79.05	31.00	6.98
Hems of pants or shoes	79.05	31.00	6.98

Holmes KK, Jr. *et al (1999) Field measurement of dermal soil loadings in occupational and recreational activities. Environmental research 80: 148-157*

Bloor WA, Dinsdale A (1962) Protective Clothing as a Factor in the Dust Hazard of Potters. *British Journal of Industrial Medicine* 19: 229-235

18

Decontamination

- Washing skin for 90 seconds with soap and warm water is 95-99% effective in removing contamination
- Washing of clothing removes 80-90% of contamination
  - Taken as proxy for scalp
- Model presumes people decon when they reach safety (which can take a long time)
- Decon presumed to be 90% effective
  - Taken as a proxy for potential lack of water

ASPR ASSISTANT SECRETARY FOR PREPAREDNESS AND RESPONSE

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How to Decon

Office of Civil and Defense Mobilization 1961

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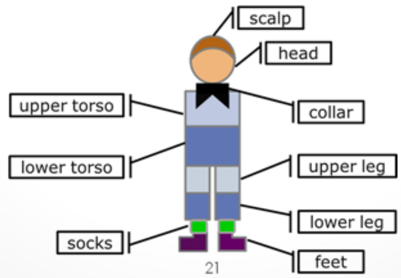
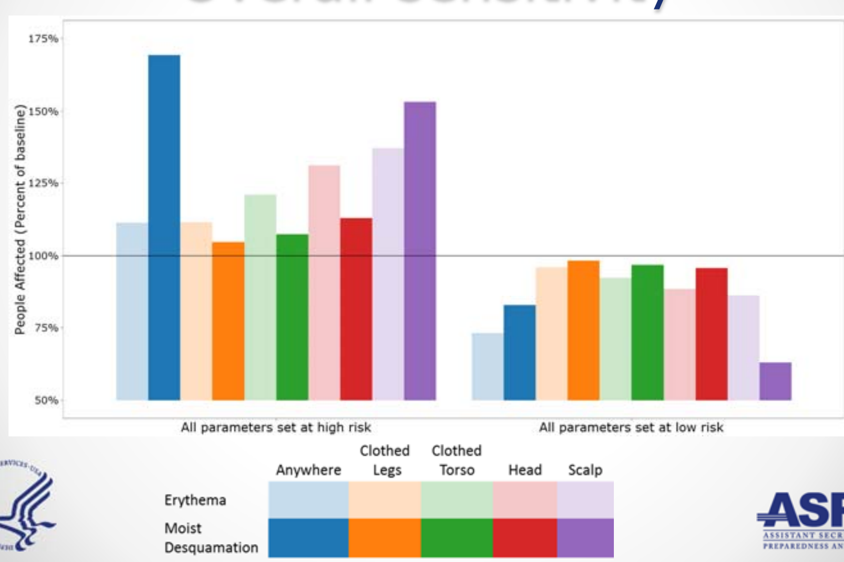
Results

- Given uncertainties in parameters, we undertook parameter sensitivity studies on key drivers
- Numbers for the overall magnitude estimates for CRI injuries are still being finalized, so all results are shown as a percentage of baseline results

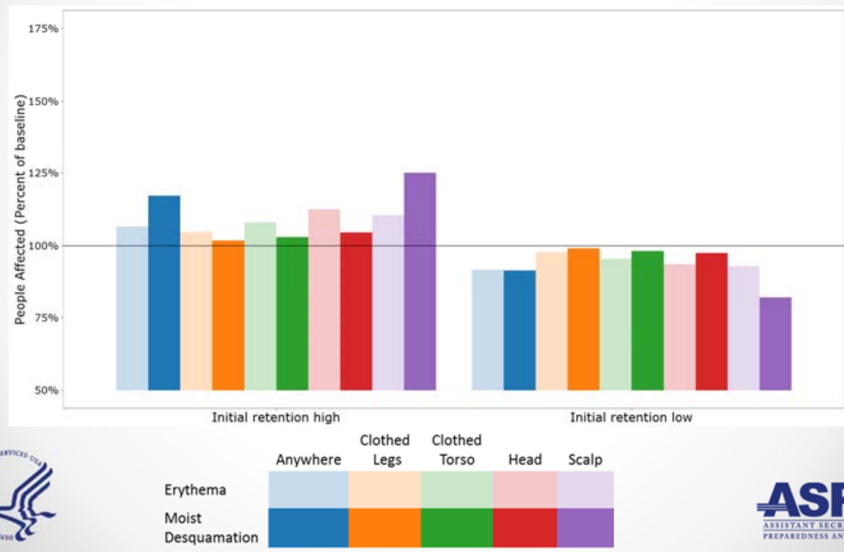


21

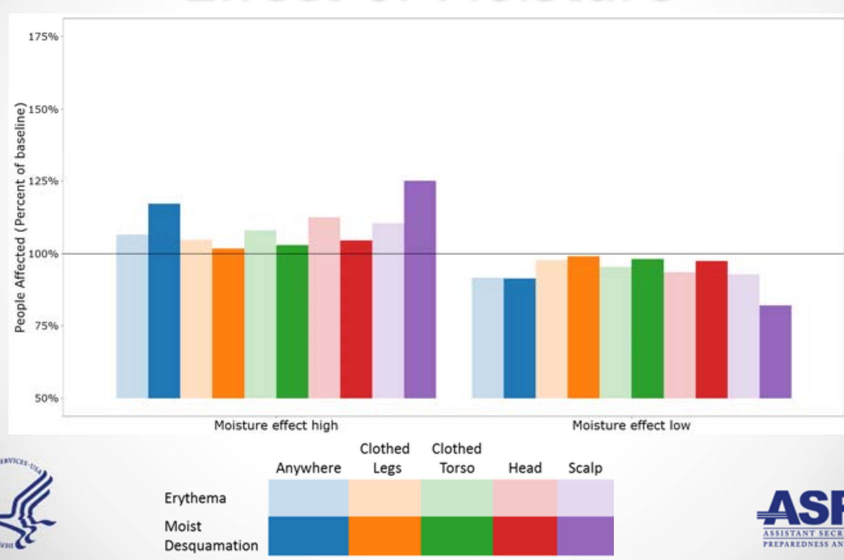
Overall sensitivity



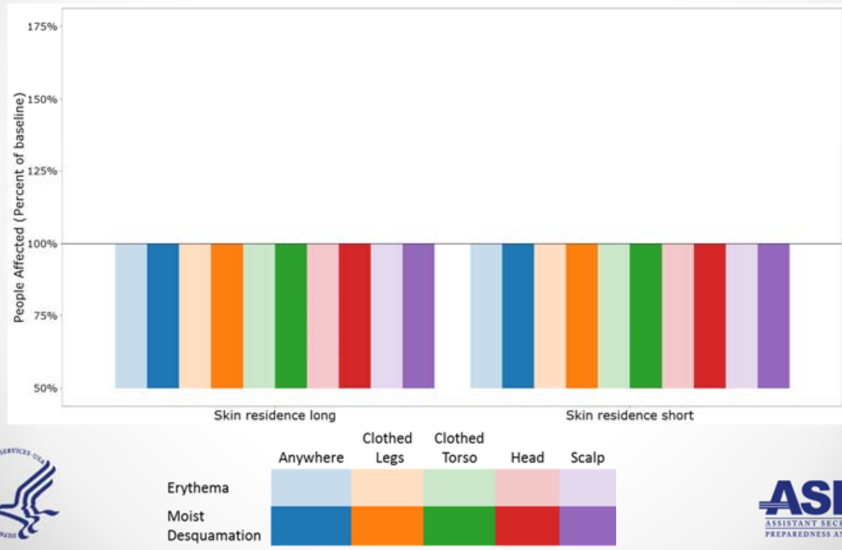
Initial Fallout Retention



Effect of Moisture

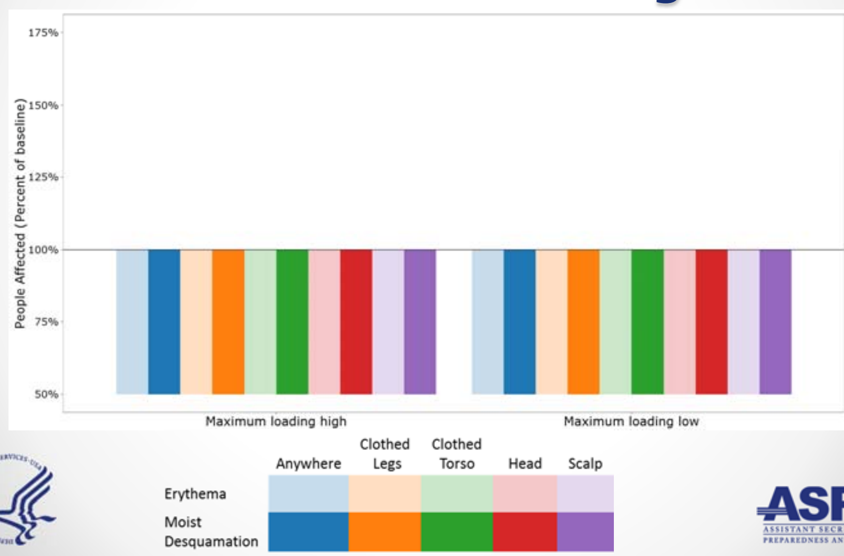


Retention on Skin



Retention on Clothing

Maximum Loading



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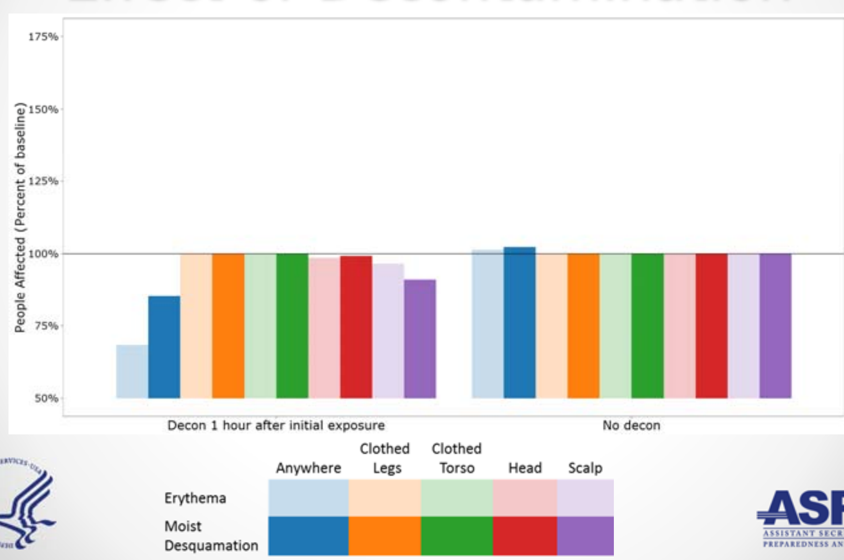
ASSISTANT SECRETARY FOR PREPAREDNESS AND RESPONSE

Effect of Decontamination



ASPR
ASSISTANT SECRETARY FOR PREPAREDNESS AND RESPONSE

Questions

- Main drivers of uncertainty
  - Effect of moisture
  - Initial retention of fallout
- Other drivers that are still uncertain
  - Maximum loading
  - Retention of fallout on skin and clothing
- Efficacy of substandard decontamination practices (brushing off)

ADSModVizHub@hhs.gov

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Sources:

- Methodology: DTRA (2010) ED04 - Skin Dose from Dermal Contamination.
- Initial Retention: Apostoaei, A, Kocher, D. *Radiation Doses to Skin From Dermal Contamination.* DTRA TR-09-16. 2010.
- Skin Retention: U.S. Naval Radiological Defense Laboratory. *Rover flight safety program preliminary review. IV. Safety analysis report: radiological considerations in nuclear flight safety.* 1966.
- Clothing over time: Hicks T *et al* (1995) Transfer and Persistence of Glass Fragments on Garments. *Science & Justice* 36**:** 101-107
- Maximum loading: Holmes KK, Jr. *et al (1999) Field measurement of dermal soil loadings in occupational and recreational activities.* Environmental research 80*: 148-157*
- Maximum loading: Bloor WA, Dinsdale A (1962) Protective Clothing as a Factor in the Dust Hazard of Potters. *British Journal of Industrial Medicine* 19**:** 229-235
- Decon: Domingueza-Gadea L, Cerezo L (2011) Decontamination of radioisotopes. Reports of Practical Oncology and Radiotherapy 16: 147-152.
- Decon: Nakazato K (2013) *Report regarding decontamination of radioisotopes by wash from polluted clothes derived from Fukushima nuclear accident and estimation of wash on radiation safety of the general public.* Radiation Safety Management 12: 61-80.

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USEPA Office of Research and Development

HOMELAND SECURITY RESEARCH PROGRAM

In Half a Half-Life of Cesium-137:
NHSRC Research for Radiological Remediation

Matthew Magnuson and Sang Don Lee

US EPA 2016 Decontamination Research and Development Conference
Research Triangle Park, NC, Nov 1-3, 2016

EPA

Presentation outline

- Why is this a problem?
- What to do about it?
- EPA responsibility and approach
- EPA research and transition
- What are the current research needs/gaps?
- How might we do rad research in the future?
- How can I be involved?

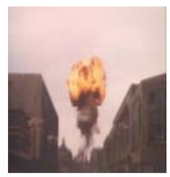
2

EPA

Why is this a problem?

Wide area, urban radiological release scenarios

- Dirty bombs, nuclear explosions, and nuclear power plant accidents can contaminate vast urban and rural areas.
- Fukushima happened 5 years ago, contaminated an area the size of Connecticut, and the clean-up is still going on.
- If people can't get back to their homes and businesses in weeks-months, they may never return.



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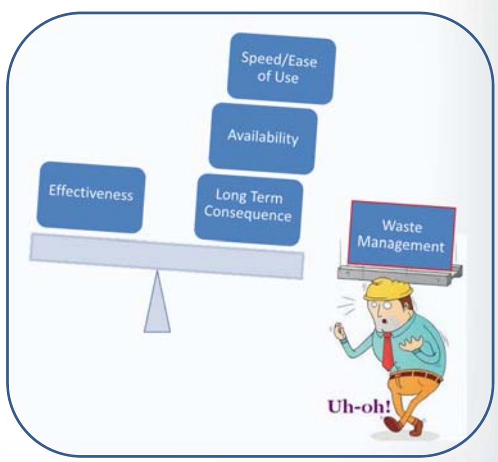
What to do about it?

Planning helps balance factors for response strategy

- ➢ Many scenarios
- ➢ Response and recovery to each is very different
- ➢ What happens early affects what goes on later



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EPA

Systems approach to wide area incidents

5

EPA

Research of increasing scale

Identify needs: methods/tools for response
- Needs assessment
- Stakeholder involvement
- Research planning

→

Technology/method identification
- Efficacy, Material impact, Material compatibility
- Literature review
- Laboratory study

→

Operational assessment
- Cost/time, Scalability, Level of effort, Resource, Waste generation
- Pilot scale test
- Field demonstration

→

Response Methods

6

EPA research

- Builds on decades of remediation work for building, power, and military applications
- Applies to wide area and water system needs
- Applies to entire timeline of response and recovery
- Involves stakeholders to enhance products and transition
- Technical Areas:
  - Fate and transport
  - Detection
  - Decontamination
  - Waste management (solid and liquid)

7

Research transition through end-user involvement

Stakeholders involved at every step through research project: technology selection, research prioritization, design, observation, operational feedback, etc.

- Federal agencies
- State and local responders
- International and tribal responders
- Research institutes: national labs, universities

8

EPA

Radiological fate and transport

- Cs, Co, and Sr transportation in urban area
  - Weathering
  - Water application
  - Prediction model
- Impacts of forest fire in contaminated area
- Fate in water and waste water collection and treatment systems

9

EPA

Radiological detection

- Laboratory methods (https://www.epa.gov/homeland-security-research/sam)
- Emerging technologies for wide area survey
- On-line water monitor at PAG levels (originated in DOD/TSWG project for MCL level detection)

Prototype on-line water monitor for alpha/beta radiation

Lab-Logic Wilma^{TM} production unit

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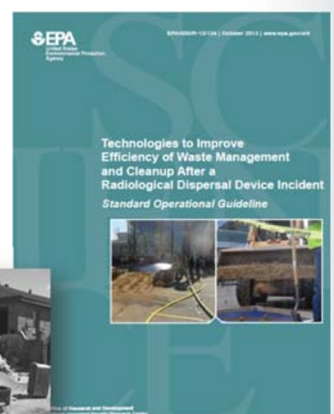
Radiological decontamination

- Cesium, cobalt, strontium, and americium
- Urban surfaces: concrete, asphalt, brick, etc
- Commercially-available chemical technologies: gels, foams, coatings, etc
- Mechanical removal methods
- Gross decon methods: fire hosing and pressure washing
- Low tech methods
- ECCC collaborative project

11

Radiological waste management: Solids

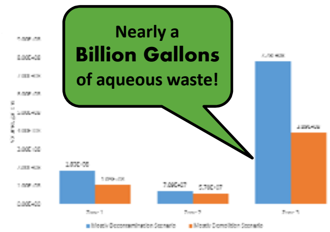
- Waste screening/segregation
- Waste volume reduction
- Waste volume and cost estimation tools
- Impact of decon on waste management
- Impact of waste management constraints on decon decisions



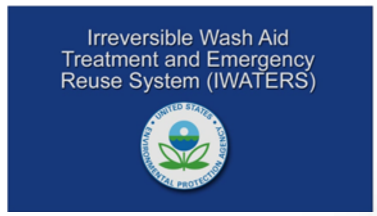
12

Radiological waste management: Aqueous

- Volume estimation tool
- Integrating decon with waste management
  - Treatment and disposal
  - Supply and reuse
- Low tech methods



Low tech barrel for water treatment



Integrated Wash, Treatment and Emergency Reuse System (IWATERS)

13

NHSRC research products

- Over 90 products at http://www.epa.gov/hsresearch
- Listed in stand-alone document
- Includes reports, analytical methods, tech briefs, review articles, technical articles, demonstration videos, etc
- Provides data, technology summaries, procedures, stakeholder feedback, etc
- Suggests research recommendations
- Leads to research transition

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Research transition: lessons learned

- Full-scale testing of technologies is imperative for understanding how they work at full-scale
- Involving end-users in both research and demonstration proved invaluable
- Compiling lessons learned from end-user observation is important.
- Operational demonstrations help transition research

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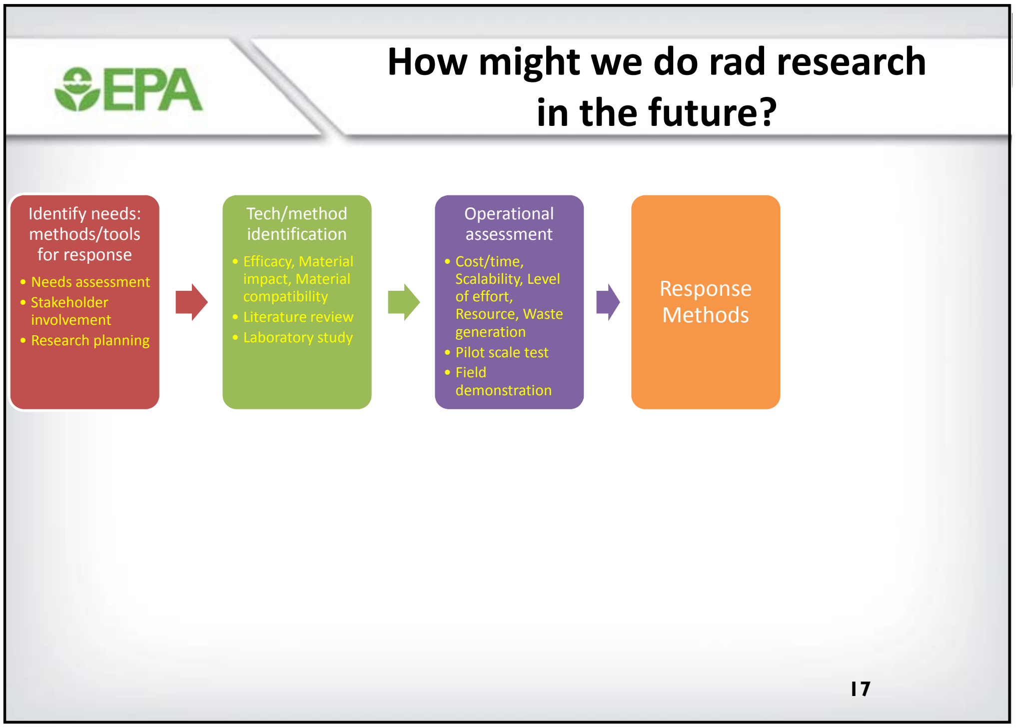
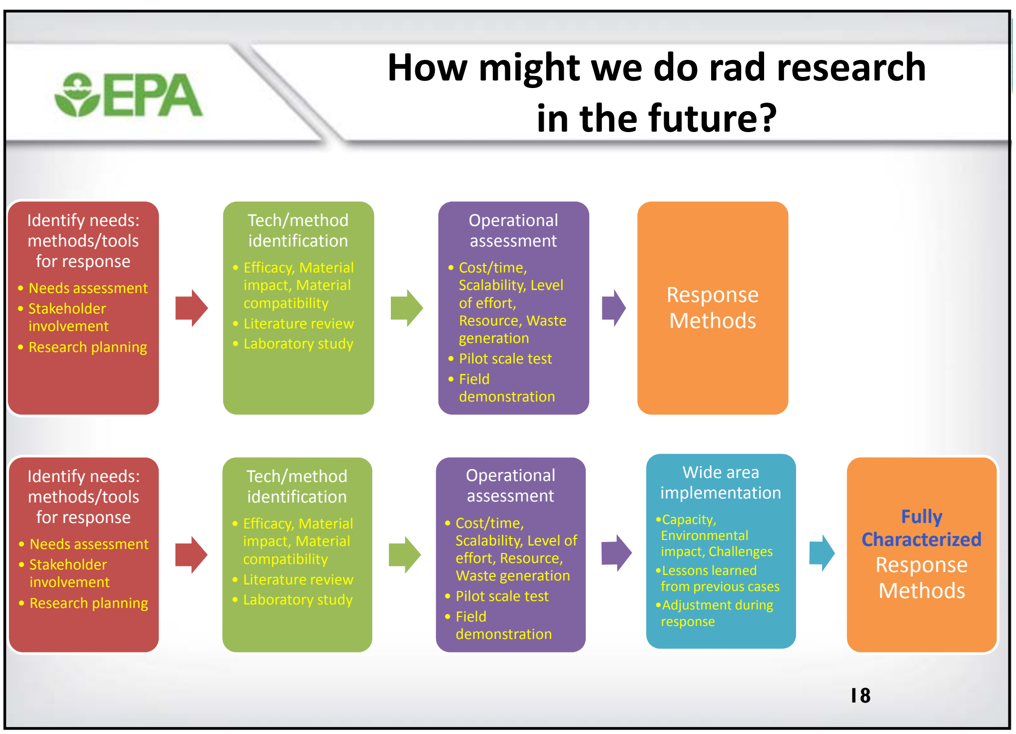
What are current research needs/gaps?

Needs/Gaps for Rad Research Identified by EPA responders and researchers
Rapid Gross Decon Methods for Rad
Rapid Min. Destructive Decon Tech for Wide Areas
Remediation Methods for Waste Volume Reduction
Low Tech Decon and/or Risk reduction Measures/Tool/Practices
Efficacy and Operational Info of Decon Tech for porous and mixed surfaces
Info on decon technologies scale-able & how to scale up for wide are app
Conduct System Evaluations
Methods and tools to conduct systems evaluations of overall implementation of response/remediation
Need for decision support tool that assists in the prioritization of remediation activities
Comprehensive resource which enables efficient, fast and accurate decision making regarding sustainable waste/debris mgmt.
Determine how to properly manage/dispose of waste ahead of time: Pre-incident waste management planning tool.
Centralized and maintained data base for monitoring, surveying, decon, mitigation, waste treatment technologies
Approaches to Reducing Resuspension, Tracking and penetration of Rad contaminants
Knowledge of Rad contaminant (RDD/IND) fate and transport to better plan sampling/monitoring/containment/decon
Guidance on Sample Plan Development for Critical Infrastructure
Verified sampling and analysis methods for RDD contaminated solid waste, waste water effluent, wastewater sludge and waste water biosolids
Sampling and analysis methods for RDD contaminated building materials
Determine how chemicals in the formulations of decontaminants will affect rapid radiochemistry methods
Detection of Radionuclides in drinking water
Sampling and analysis procedures for mixed radiological/CWA contamination
Proficiency Test Samples for Rarely analyzed alpha and beta only emitters
Ability to QA field data at a given conficence level
Certification of mobile labs
Verified sampling and analysis methods for medical isotopes in RDD contaminated matrices
Assessment of emerging technologies to enhance survey/decon/monitoring capabilities for wide area incident response
Strategies for translating science and technical info to EPA decision makers and responders
Establishment of a national policy on waste management
Persistence of radionuclides on water infrastructure
Scalable Technologies for treatment of water and waste water


EPA
How might we do rad research in the future?
Identify needs: methods/tools for response
• Needs assessment
• Stakeholder involvement
• Research planning
Tech/method identification
• Efficacy, Material impact, Material compatibility
• Literature review
• Laboratory study
Operational assessment
• Cost/time, Scalability, Level of effort, Resource, Waste generation
• Pilot scale test
• Field demonstration
Response Methods
17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• Cost/time, Scalability, Level of effort, Resource, Waste generation
• Pilot scale test
• Field demonstration
Wide area implementation
•Capacity, Environmental impact, Challenges
•Lessons learned from previous cases
•Adjustment during response
Fully Characterized Response Methods
18

EPA

Research transition: How can I be involved?

- Sign up for automatic updates from our website
  https://www.epa.gov/homeland-security-research
- Let us know your interest to observe/participate in demos
- Consider joining volunteer project teams for current and upcoming projects
  - "Municipal and commercial equipment for radiological response and recovery"
  - "low-tech remediation methods following wide area Rad/Nuc incidents of outdoor contamination"
  - "Expansion of IWATERS to other scenarios and radionuclides"
  - "low-tech methods for aqueous mitigation"
  - "Field and laboratory detection"

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EPA

Questions?

Planning and research help balance factors for response strategies

Matthew Magnuson (513-569-7321/ Magnuson.Matthew@epa.gov)

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

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Defence Research and Development Canada / Recherche et développement pour la défense Canada

RN Decontamination of Sensitive Equipment

Marc Desrosiers, DRDC Ottawa Research Centre, Radiological Nuclear and Navigational Warfare

Dr. Nikolaus Schneider, Bundeswehr Research Institute for Protective Technologies

DRDC | RDDC

Canada

Introduction

- Decontamination of Sensitive equipment
- NATO and other work

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1

Decontamination of Sensitive Equipment (DOSE) Introduction

- Decontamination of sensitive equipment has been one of the most interesting problems in the CBRN Decontamination domain
- The issue, at the extreme:
  - How do you decontaminate something that you cannot touch due to the possibility of damaging it?
- Our more realistic view:
  - How do you decontaminate something that would not survive the traditional military decontamination procedure?

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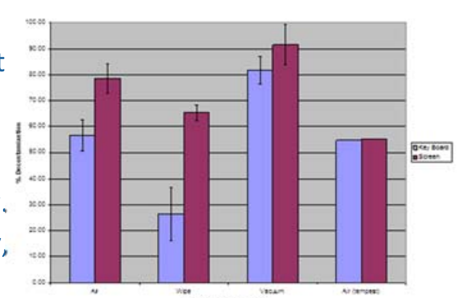
2

DRDC's Past Work

- DRDC has looked into this issue in the past:
  - First experiments were conducted back in 2007
  - Results suggested that effective decontamination could be achieved however it was highly dependent on various conditions and in some cases very difficult
  - DRDC, in collaboration with others, investigated conditions affecting the decontamination efficiency.
  - Factors such as environmental conditions (humidity, rain) in combination with different types of contaminants and surfaces were examined.
- This work provided insight into what could be possible for decontamination of sensitive equipment.



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3

DRDC's Current Project for RN Decontamination of Sensitive Equipment

- Main objectives:
  1. **Recommend field-expedient methods for decontaminating sensitive equipment for immediate implementation within the Canadian Armed Forces.**
  2. Develop appropriate decontamination processes / technology options to address capability shortfalls of COTS products and solutions for RN challenges.
  3. NATO study on current and future DOSE Solutions
- Overall delivery of the project: March 2017
- Major challenges associated with doing decontamination studies is accurately reproducing the field situation. This includes but is not limited to:
  - Contaminants (Co, Cs, Sr, Am, Ir, NF)
  - Level of contamination
  - Environmental Conditions
  - Equipment
  - Decontamination procedures

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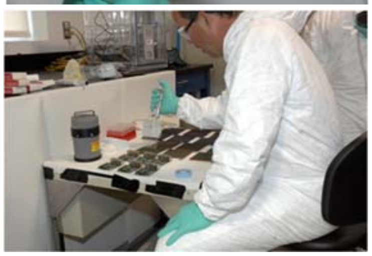
4

Experimental Design

- Experimental Endpoints:
  1. Survivability (Functionality) Testing
  2. Decontamination Efficiency
- Contaminants (and surrogates):
  - Ir-192 for Ir-192 and Co-60, pure metal, powder form
  - Na-24 ($NaNO_3$) for Cs-137 (CsCl), powder form
  - Sr-85 (SrCl) for Sr-90 ($SrTiO_3$), liquid form
  - Ce-141 (CeO_2) for Am-241 (CeO_2), powder form
  - Sand mixture with Na-24, Sr-85 and La-140 for Nuclear fallout simulant, developed in collaboration with US EPA



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5

Experimental Design (Continued)

- Environmental Conditions
  - Dry
  - Wet
  - Humid
- Sensitive Equipment being examined (Surrogates)
  - C7 rifle (using small portions from manufacturer)
  - Night Vision Goggles (outer lens and Raspberry Pi™)
  - Radios (Raspberry Pi ™)

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6

Experimental Design (Continued)

- Decontamination Methods
  - Mostly focusing on mechanical removal of particles from the surface
    - Vacuuming (standard)
    - Cyber Putty
    - Duct Tape
    - Wet Wipes
    - Compressed Air
    - Low frequency sound waves
    - RDS2000
    - Ultrasonic bath
    - Electronic Cleaning Solutions

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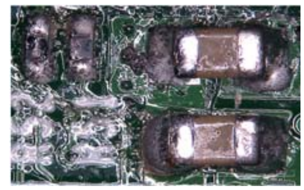
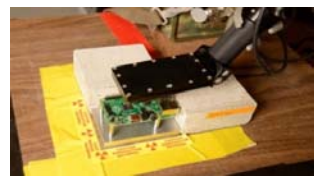
7

Experimental Set-up

- Functionality Testing
  - Visual/Microscopic inspection
  - Functional test
  - Will be repeated up to 30 days post decon, if time allows
- Decontamination Efficiency Testing
  - Performed as per MTOP from CBR MOU (US, UK, AUS and CA military science agreement).
  - Measurement with HPGe and SVG2.





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8

Experimental Matrix

Exp Plan #	Contaminant	Decontamination Method	Sensitive Equipment	Contamination Method	Enviro Condition	Dwell Time	Test Point	Notes
1	Blank	vacuum	Rasberry Pi	Shake N Bake	Ambient	min 1 hour	min 1 hour	DRY-
2	CsCl	vacuum	Rasberry Pi	Shake N Bake	Ambient	min 1 hour	min 1 hour	DRY- 7% RH
3	SrTiO3	vacuum	Rasberry Pi	Shake N Bake	Ambient	min 1 hour	min 1 hour	
3	Cobalt	vacuum	Rasberry Pi	Shake N Bake	Ambient	min 1 hour	min 1 hour	
3	Nuc Fallout	vacuum	Rasberry Pi	Shake N Bake	Ambient	min 1 hour	min 1 hour	
3	Ir-metal	vacuum	Rasberry Pi	Shake N Bake	Ambient	min 1 hour	min 1 hour	
	Blank	vacuum	Lenses	Shake N Bake	Ambient	min 1 hour	min 1 hour	
	CsCl	vacuum	Lenses	Shake N Bake	Ambient	min 1 hour	min 1 hour	
	SrTiO3	vacuum	Lenses	Shake N Bake	Ambient	min 1 hour	min 1 hour	
	Cobalt	vacuum	Lenses	Shake N Bake	Ambient	min 1 hour	min 1 hour	
	Nuc Fallout	vacuum	Lenses	Shake N Bake	Ambient	min 1 hour	min 1 hour	
	Ir-metal	vacuum	Lenses	Shake N Bake	Ambient	min 1 hour	min 1 hour	
	Blank	vacuum	Gun Parts	Shake N Bake	Ambient	min 1 hour	min 1 hour	
	CsCl	vacuum	Gun Parts	Shake N Bake	Ambient	min 1 hour	min 1 hour	
	SrTiO3	vacuum	Gun Parts	Shake N Bake	Ambient	min 1 hour	min 1 hour	
	Cobalt	vacuum	Gun Parts	Shake N Bake	Ambient	min 1 hour	min 1 hour	
	Nuc Fallout	vacuum	Gun Parts	Shake N Bake	Ambient	min 1 hour	min 1 hour	
	Ir-metal	vacuum	Gun Parts	Shake N Bake	Ambient	min 1 hour	min 1 hour	
4	Blank	water	Rasberry Pi	Shake N Bake	Humid	7 Days	7 days, 30days	
4	CsCl	water	Rasberry Pi	Shake N Bake	Humid	7 Days	7 days, 30days	
4	SrTiO3	water	Rasberry Pi	Shake N Bake	Humid	7 Days	7 days, 30days	
4	Cobalt	water	Rasberry Pi	Shake N Bake	Humid	7 Days	7 days, 30days	
4	Nuc Fallout	water	Rasberry Pi	Shake N Bake	Humid	7 Days	7 days, 30days	
4	Ir-metal	water	Rasberry Pi	Shake N Bake	Humid	7 Days	7 days, 30days	
	Blank	water	Lenses	Shake N Bake	Humid	7 Days	7 days, 30days	

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9

Preliminary Results on Functionality Testing

- RDS2000, Vacuuming, Wet Wipes, Cyber Putty and Compress Air does not seem to damage our electronic test pieces
- Duct tape had some minor damage, pieces worked but some needed to be fixed.
- Water had an effect on some USB ports.
- In Addition,
  - CsCl does seem to interact with the component (corrosion); some minor visual changes, had 1 failure out of over 30.
  - Ir shown possible corrosion, 1 piece only.

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Overview of Raspberry Pi Testing Results

Sensitive Equipment	Contamination Method	Decontamination Method	Results (The good, the bad and the ugly)	Rating	Damaged Failed
Rasberry Pi	Shake N Bake	Vacuum	bad	3	0
		Water	ugly	5	0
		Duct tape	bad	4	5 Damaged
		Cyber Putty	good	1	1 Failed
		Wet wipes	ugly	6	0
		Compressed Air	bad	2	0
	Microsprayer (Wet) & Insufflator	Vacuum	bad		
		Cyber Putty	good		1 Failed
		Compressed Air	bad		

- Notes
  - Vacuuming: Different procedure from previous experiment, included no brushing
  - Duct tape: technique may perform better on less complex surface, damaged pins and SD card holder
  - Cyber Putty: worked much better with rolling ball technique, so method of use impacts how it performs
  - Wet wipes: really not good, leaves fibers and residue behind
  - Compressed Air: Performed well, but very messy- would need to contain what gets blown off

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Overview of Gun Parts Testing Results

Sensitive Equipment	Contamination Metho	ontamination Met	Results (The good, the bad and the ugly)	Rating
Gun Parts	Shake N Bake	Vacuum	ugly	6
		Water	ugly	5
		Duct tape	bad	3
		Cyber Putty	good	1
		Wet wipes	bad	2
		Compressed Air	ugly	4

- Notes
  - Ridges on the parts seems to trap contaminants.
  - Compress air and wet wipes work ok, but requires a lot of effort and handling.
  - Cyber putty worked well with short frequent passes.

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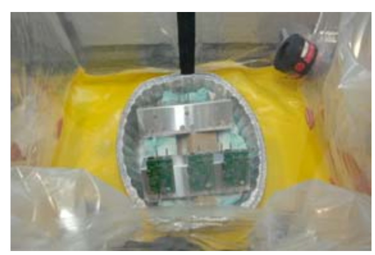
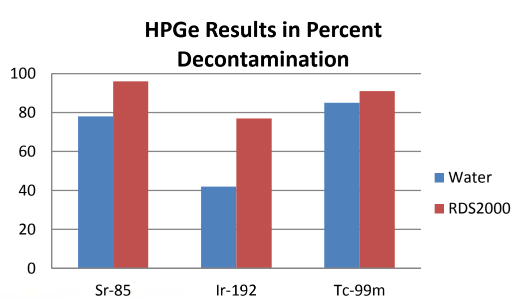
Preliminary work Decontamination Efficiency Collaboration with WIS (Germany)

- Coupon Raspberry Pie
- Decontamination Procedures
  - RDS2000
  - Water
- Contamination, all coupons were attempted to be contamination at 500 Bq/cm^2
  - Strontium-85 in a diluted solution
  - Iridium-192 in a powder from
  - Technicium-99m in a diluted solution
- Prelim Results
  - RDS2000 is more effective on Raspberry Pies than Water for Strontium, Iridium, and Technetium.
  - The prelim result could also indicate that the Raspberry Pi maybe tougher than we assumed and may not be a good surrogate.





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NATO Work

- Sensitive Equipment Decontamination Survey
- Decontamination of a few Infrastructure material

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14

NATO Sensitive Equipment Decontamination, Human Factors and Medical (HFM) Study 233

- Supported by NATO's Science and Technical Organization (STO)
- Currently at the Pre-Release stage. Final document is done and waiting for former publication
- NATO Multi Nation, Germany, France, United Kingdom, Norway, Sweden, Canada, effort (Add reference)
- Covers CBRN current and future technologies
- Approach of the study
  - Identification
  - Description
  - Technology characteristics
  - Advantages and disadvantages
  - Evaluation of the technology
  - DOTMLPF-I Rating (Military speak)
  - References
- Major findings for RN
  - Identified x number of technologies
    - Add examples
  - Very little technologies
  - Very little verification/validating of technologies
- Important Findings
  - The magic solution of a universal technical decontamination solution to decontaminate all kinds of equipment from all kinds of hazards is not available and will not be available within the next 10-15 years.
  - The results of this study lead to the conclusion that, beyond continuing to observe the market and wait for industry to develop new, innovative technologies, NATO would be quite well advised to invest in research in this area.

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15

WIS work on Infrastructure Materials

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SCIENCE, TECHNOLOGY AND KNOWLEDGE FOR CANADA'S DEFENCE AND SECURITY

SCIENCE, TECHNOLOGIE ET SAVOIR POUR LA DÉFENSE ET LA SÉCURITÉ DU CANADA

United States Environmental Protection Agency

2016 U.S. EPA International Decontamination Research and Development Conference

Wednesday, November 2, 2016

Concurrent Sessions 4

Biological Agent Research

Pacific Northwest NATIONAL LABORATORY
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Composite Sampling Efficiency for Clean and Grime Coated Surfaces

BRETT AMIDAN
JANINE HUTCHISON
BECKY HESS
KEVIN ANDERSON

Pacific Northwest National Laboratory

2016 EPA International Decontamination Research and Development Conference

January 4, 2017 1

Composite Sampling Study Overview

Factor	Test Levels
Surface materials	Ceramic tile, stainless steel, vinyl tile, and painted drywall
Contaminant surface concentrations	5, 10, 25, 50, and 100 CFU/coupon
Composite methodology	1) Single Media Single Pass Composite (SM-SPC); 2) Single Media Multi Pass Composite (SM-MPC); 3) Multi Media Multi Pass Composite (MM-MPC)
Number of locations (coupons) to composite	4, 8, and 16 (only MM_MPC)
Contaminant location	1) All composite locations contain the contaminant; 2) One random composite location contains the contaminant
Coupon Coating	1) Clean 2) Coated with grime (with and without biological component)

January 4, 2017 2

Surface Materials

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Coupon layout

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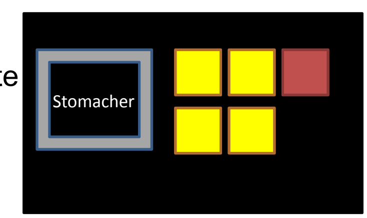
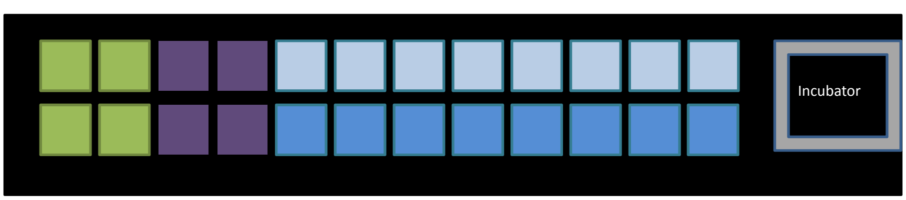
- Layout
  - Green: 4 coupons/single composite
  - Purple: 4 coupon/post composite
  - Light blue: 8 coupons single composite
  - Dark blue: 8 coupon post composite
  - Yellow: 1 coupon/single swab
  - Red: coupon negative control
  - Process control (not shown)





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Sampling

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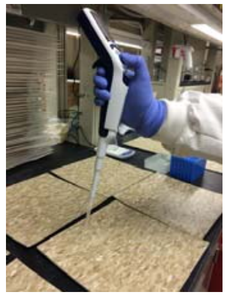
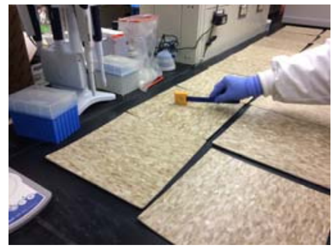
Coupon setup

Spore deposition



Sampling, 4 pass procedure



Sampling cont.

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- Sampler makes 4 passes over sampling surface: horizontal, vertical, diagonal, and perimeter of coupon

http://www.cdc.gov/niosh/topics/emres/surface-sampling-bacillus-anthracis.html

Sample Processing

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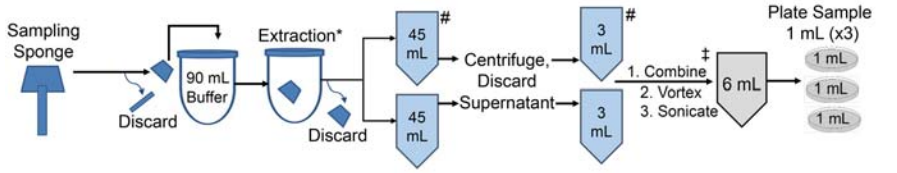
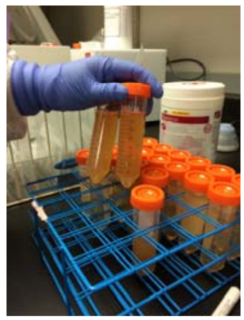
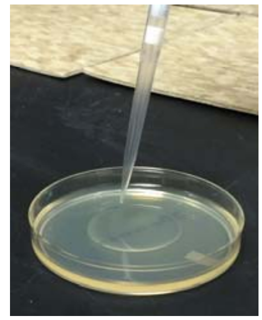


Spore extraction

Concentration



Plating done in triplicate



January 4, 2017 7

Sampling Methods Tested

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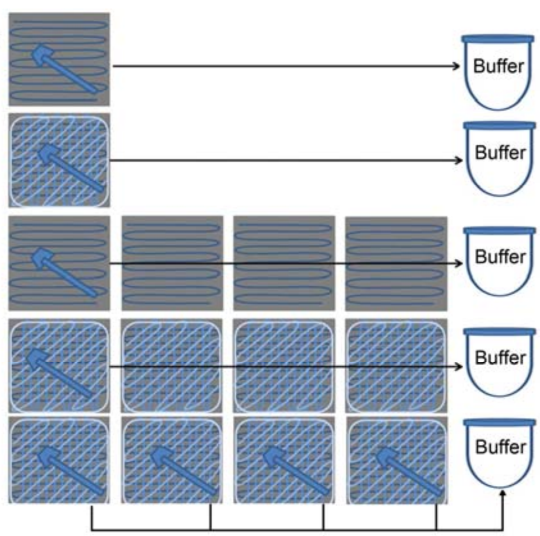
Single Medium Single Pass Discrete (SP-Discrete)

Single Medium Multi Pass Discrete (MP-Discrete)

Single Medium Single Pass Composite (SM-SPC)

Single Medium Multi Pass Composite (SM-MPC)

Multi Medium Multi Pass Composite (MM-MPC)



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SM-SPC vs SM-MPC Results

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Proudly Operated by Battelle Since 1965

- Pilot experiment run to determine which compositing method would be used in the full experiment (comparing SM-MPC to SM-SPC)
  - Tested at 100 CFU/coupon (much lower amount than many other tests)
  - 4 and 8 coupons inoculated
  - Spores deposited across all coupons or on one coupon
  - Four coupon materials
- Recovery efficiency (RE) measured for each test
- Statistical analysis showed RE was significantly higher for SM-MPC method than the SM-SPC method (p-value = 0.0063).
  - Important note: other studies have found no differences between methods for tests at significantly higher CFU targets (>10^7 spores per surface).

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Analysis of Clean Surface Data Only

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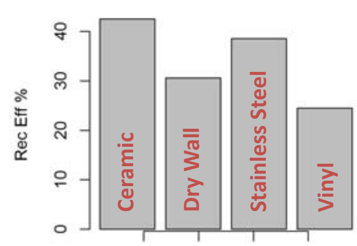
- Analysis of Variance looked for significant factors and interactions (significance level at $\alpha = 0.05$)
  - Significant differences in RE between the four coupon materials
    (p-value = 0.0006)
  - Significant differences in RE between the MM-MPC and SM-MPC compositing methods
    (p-value < 0.0001)
  - Significant interaction between CFU target and number of contaminated locations
    (p-value = 0.0271)



January 4, 2017 10

RE for Composite Methods and Material

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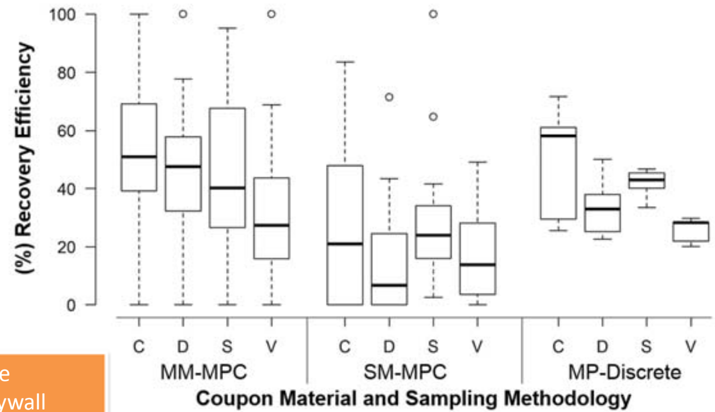

C = Ceramic Tile
D = Painted Drywall
S = Stainless Steel
V = Vinyl Tile

January 4, 2017 11

RE for Composite Method and Contamination Related Variables

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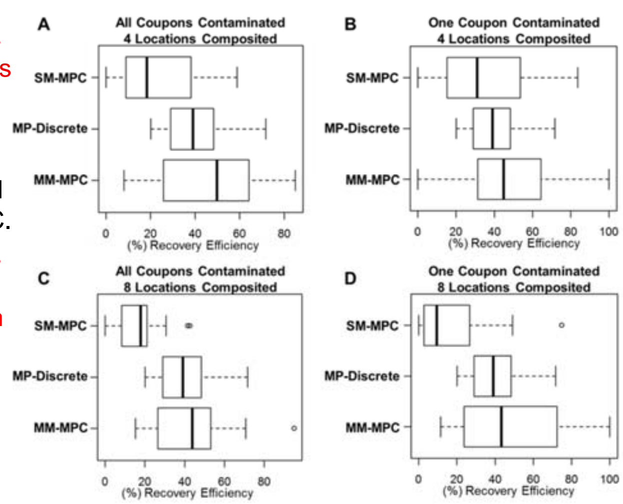
- No significant differences in RE between 4 locations composited and 8 locations composited. Additional tests show no difference between 8 and 16 locations for MM-MPC.
- No significant differences in RE between all contaminant on 1 coupon or evenly across all coupons.
- MM-MPC was very similar to MP-Discrete (single sample controls)



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Significant Interaction between CFU target amount and Number of Places Contaminated

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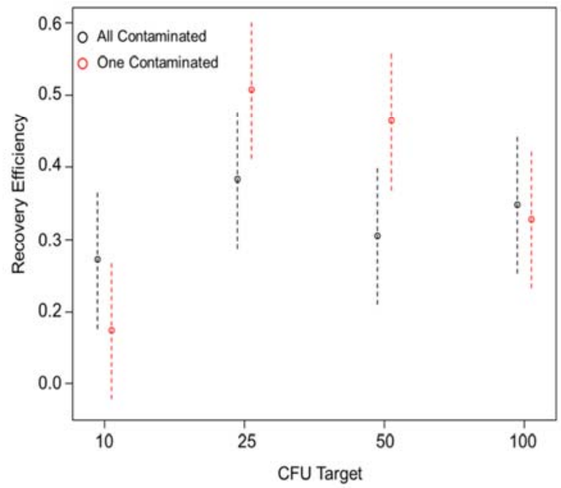
P-value = 0.0271

This interaction shows that the RE with all coupons contaminated is higher at 10 CFU target than one coupon contaminated, while one coupon contaminated is higher at 25 and 50 CFU target.



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Analysis of Clean and Grimed Surfaces

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- Additional tests done with the presence of grime
  - Coupons with grime and grime with a biological presence
  - Drywall was not included in the grimed surfaces
  - 10, 25, 50 CFU/coupon tested
  - Only MM-MPC was used
  - All other factors similar to the clean tests
- Analysis of Variance looked for significant factors and interactions (significance level at $\alpha = 0.05$)
  - Significant differences in RE between the clean and presence of grime (p-value = 0.0418)
  - Significant interaction between the presence of grime and coupon material (p-value = 0.0017)

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Significant Interaction between Presence of Grime and Surface Material

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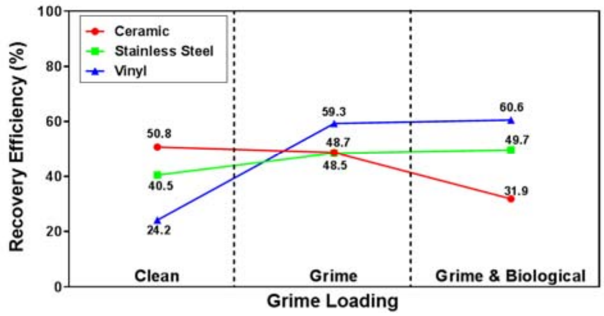

The RE for Vinyl was very low for clean surfaces (24.2%) but was very high when grime was present (approximately 60%)

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False Negative Rates

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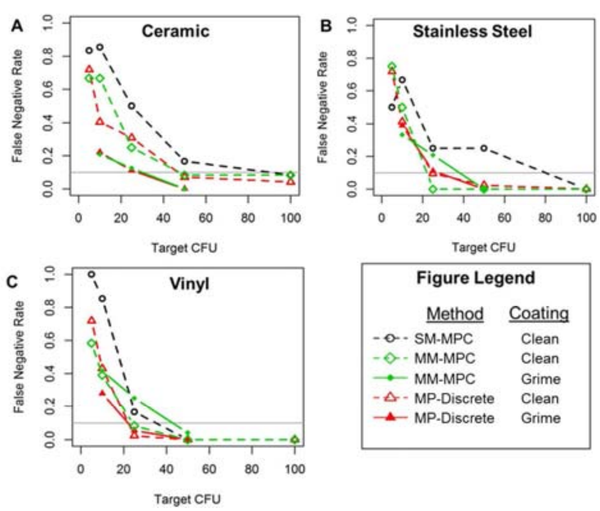

The intersection of each line and the horizontal gray line represents the LOD_{90} value

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LOD_{90} Values

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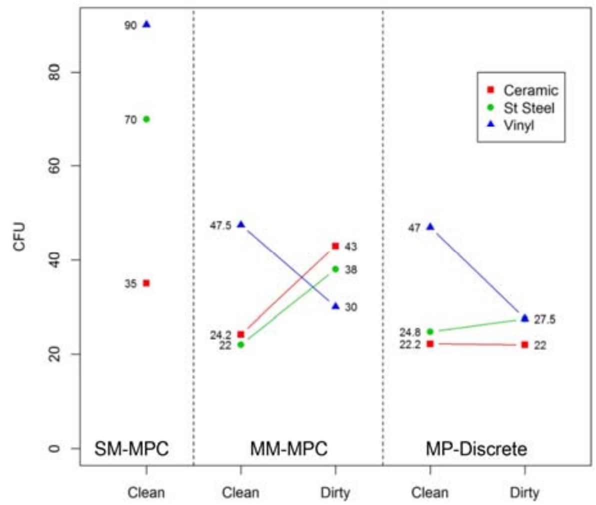
LOD_{90} is the amount of concentration in which there is 90% probability that it will be detected (10% false negative rate)



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Conclusions

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- When comparing recovery efficiency in the presence of low levels of contaminant –

  MM-MPC > SM-MPC > SM-SPC

- No significant differences in recovery efficiency when compositing 4 or 8 locations using either the MM-MPC or SM-MPC. Up to 16 locations using MM-MPC also showed no significant decrease in recovery efficiency.
- The presence of grime had a negative effect on recovery efficiency for stainless steel and ceramic tile, but had a positive effect on recovery efficiency for vinyl tile.

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Publication and Acknowledgments

Pacific Northwest NATIONAL LABORATORY
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Results published October 13, 2016 in PLOS ONE

"Evaluating Composite Sampling Methods of Bacillus Spores at Low Concentrations"

Becky M. Hess, Brett G. Amidan, Kevin K. Anderson, Janine R. Hutchison

http://journals.plos.org/plosone/article?id=10.1371/journal.pone.0164582

Work was funded by the 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).

We thank the Validated Sampling Plan Working Group (representatives from DHS, EPA, and CDC) for their input, support and review of this work.

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ERDC
Engineer Research and Development Center

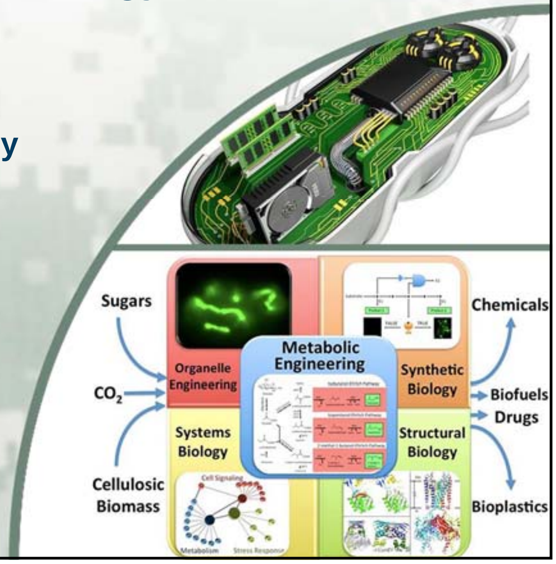
Assessing the Environmental Impact of Synthetic Biology

Chris Warner & Jed Eberly

U.S. Army Corps of Engineers

Engineering Research and Development Center

Environmental Laboratory



US Army Corps of Engineers

Syn Bio Provides Decontamination Solutions and Challenges

Definition:
Syn Bio is the design and construction of new biological parts, devices, and systems, or the re-design of existing systems

The environmental impacts associated with these new technologies are unknown.

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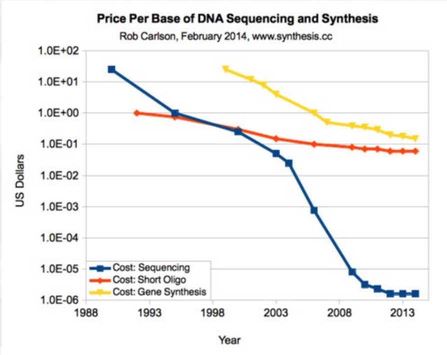
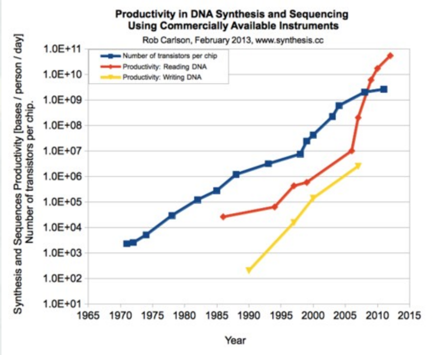
Drivers for Syn Bio Development





Read (sequencing) 2015 Projection

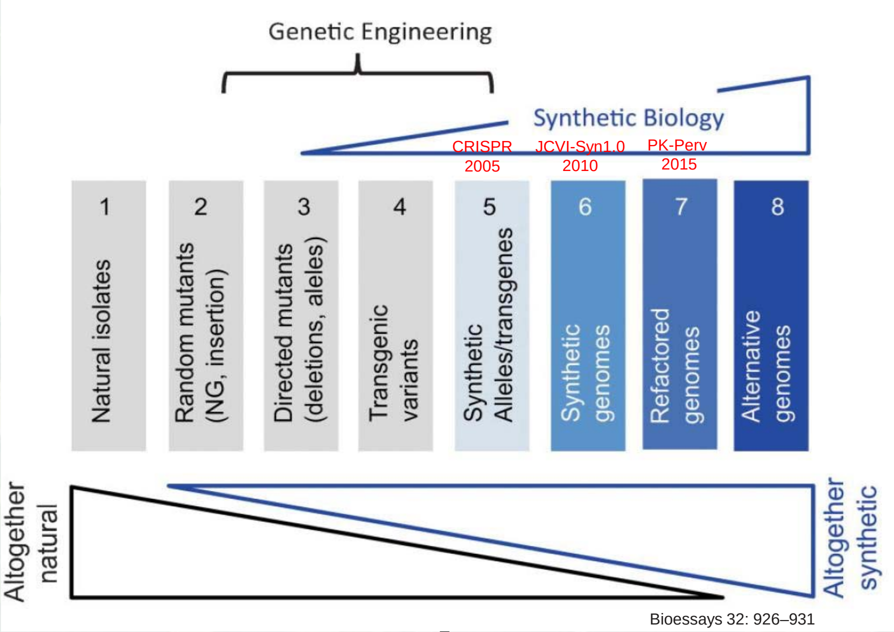
- 10^{12} bases/machine/day = 2 Trillion bases/ day
- Human Genome: 3 Billion base
- Library of Congress: 10 TB
- 10^{-6} $/Base- $3K to fully sequence a human
- genome; $40m for LoC

Write (synthesis) 2015 Projection

- 10^{7} bases/person/day = 2 Mb/ day
- 0.1 $/base: Human Genome- $300M
- 20K genes @ 1kb/gene = $20M; 1 d
- 3 orders of magnitude slower than read; 5 orders more costly

3

Syn Bio State of the Art



Bioessays 32: 926–931

4

Diverse set of Synthetic Biology Technologies

Synthetic Biology

- GMOs
- Biosensors
- Gene Drives
- Genetic Circuits
- Xenobiology
- DNA Origami
- Biofuels
- Cell Free Systems
- Genetic Barcodes
- Microbial Cell Factories
- Synthetic Chemicals
- Synthetic Materials
- Novel Enzymes
- Synthetic Materials
- Protocells

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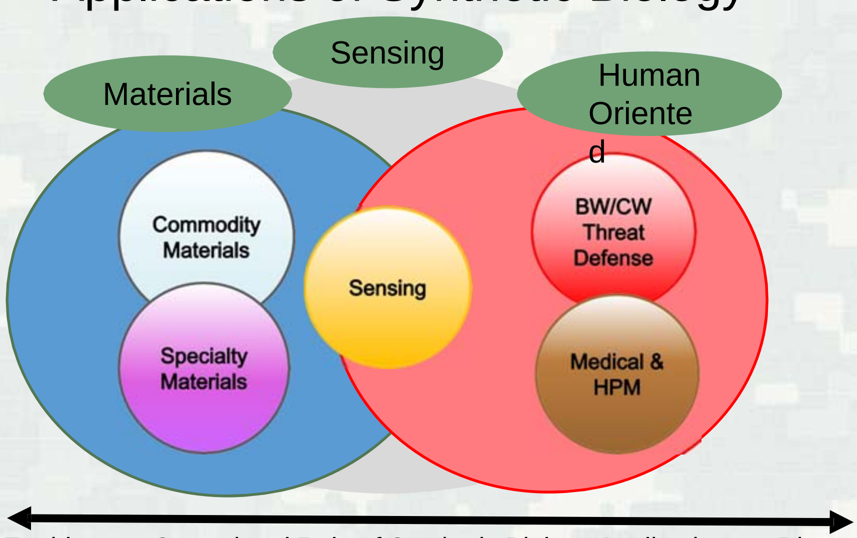
Applications of Synthetic Biology



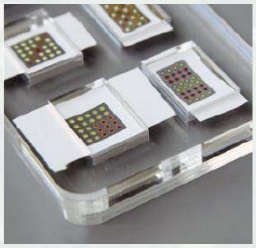
Enabler ---- Operational Role of Synthetic Biology Application ---- Direct

Department of Defense (DoD) Office of Technical Intelligence (OTI) released a Technical Assessment on the use of synthetic biology for defense applications

BW/CW: Biological Weapons/ Chemical Weapons; **HPM**; Human Performance Modification

Similarities to traditional threat agents: Activity, Transferability, Toxicology

Paper Based Sensors



BioSynthesis

Microbiome Alteration

Engineered Microbes for Remediation

1. How do we measure fate and transport?
2. What does transferability mean for a synthetic gene/protein?
3. How can we assess environmental impact?

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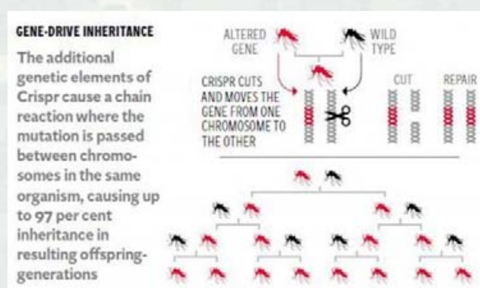
Synthetic Biology/Genetic Engineering as a potential threat



1. How will genetically engineered mosquitoes affect the ecosystem?
2. Is it possible for the Gene Drive to mutate and affect non-target organisms?

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Private biotech laboratory in a Californian garage.

Markus Schmidt, and Lei Pei Toxicol. Sci. 2011;120:S204-S224

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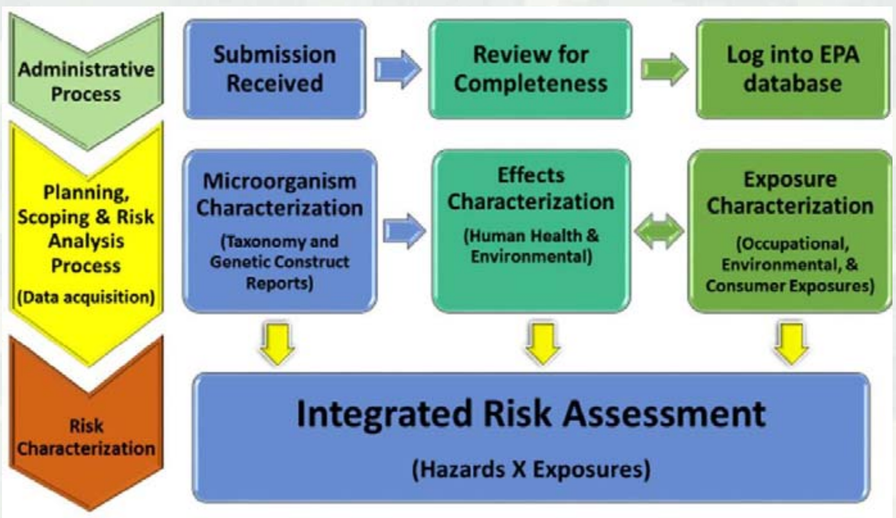
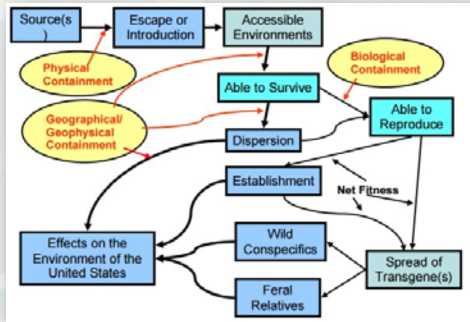
Pre and Most market monitoring of Syn Bio products and technologies



Overview of EPA's Risk Assessment Process for MCANs. **Draft Algae Guidance for the Preparation of TSCA Biotechnology Submissions**

Monitoring Efforts for Genome Editing

- Understanding transgene fitness costs
- Fate and transport models for gene flow
- Mechanisms of gene transferability



AquAdvantage Salmon Environmental Assessment

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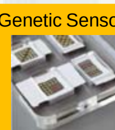
Quantification of Known- Unknown impacts. (Fill in Data Gaps)

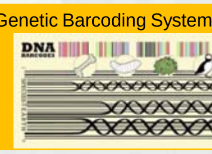
Objective: Quantify environmental impacts associated with synthetic biology technologies.

Cell Free Systems
Understand synthetic biology persistence in environment with simple non-cellular systems

Genetic Sensors

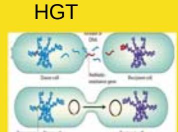


Genetic Barcoding Systems



Microbial Systems
Assess the persistence in the environment of a synthetically derived population, the potential to spread to native organisms and the subsequent impact

HGT



Interactions with other organisms

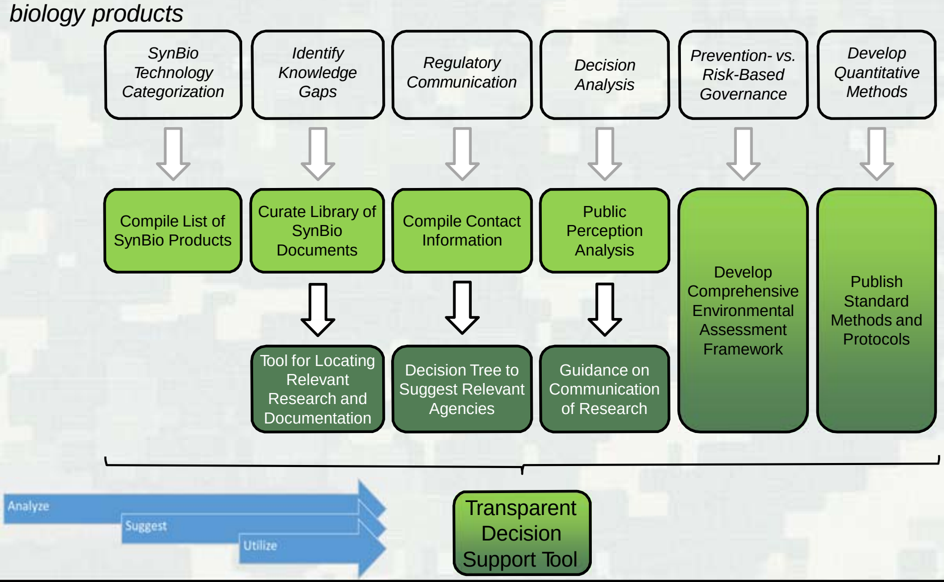
Eukaryotic Systems
Establish validated mathematical models for the spread, persistence, and mutation of gene drives

Develop "Modelscapes" for Predicting Outcomes and Risks of Self-propagating Gene Drives

12

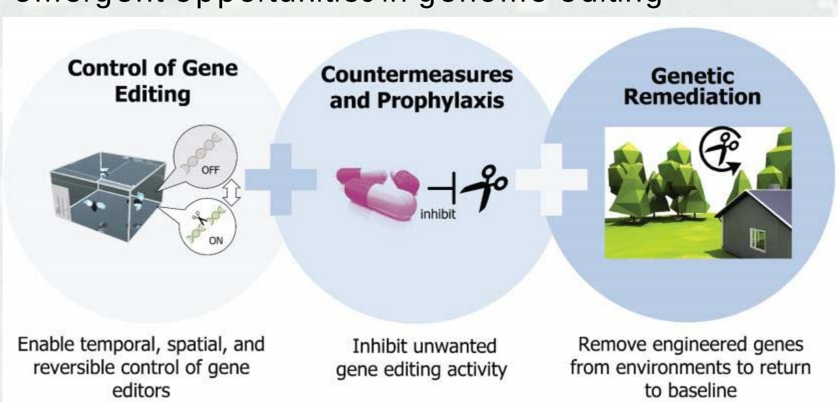
Decision Support for Environmental Impact Assessment of Syn Bio

Objective: Compile *resources to help assess the impacts associated with synthetic biology products*



DARPA Safe Genes Program

A suite of tools is needed that can be applied independently or in combination to safely pursue emergent opportunities in genome editing



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Jed Eberly, Ph.D
Email: Jed.O.Eberly@usace.army.mil

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United States Environmental Protection Agency

2016 U.S. EPA International Decontamination Research and Development Conference

Wednesday, November 2, 2016

Concurrent Sessions 4

Radiological Agent Research

Environment and Climate Change Canada | Environnement et Changement climatique Canada | Canada

A Water-Based Formulation for Rapid Response after a Radiological Incident

Wenxing Kuang, Pervez Azmi, Vladimir Blinov, Konstantin Volchek, and Carl E. Brown, Environment and Climate Change Canada, Canada

Matthew Magnuson and Sang Don Lee, US Environmental Protection Agency, USA

Jaleh Semmler, Canadian Nuclear Laboratories, Canada

Pavel Samuleev, Royal Military College, Canada

Stephen Sunquist and Ken Walton, Ottawa Fire Services, Canada

Ryan James, Battelle, USA

2016 EPA International Decontamination Research and Development Conference, Nov. 1-3, 2016 Triangle Park Campus, North Carolina

Project team

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

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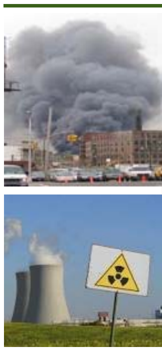
Wide area, urban radiological release scenarios

- Dirty bombs, nuclear explosions, and nuclear power plant accidents can contaminate vast urban and rural areas.
- Fukushima contaminated an area the size of Connecticut, and the clean-up is still going on.
- If people can't get back to their homes and businesses in weeks-months, they may never return.




Radiological incident timeline



Mitigate radiological contaminants as soon as possible (ASAP) and as much as possible (AMAP) at early phase by first responders

- Reduce the spread of radiation through airway and waterway
- Minimize penetration/migration

How to minimize exposure for first responders/emergency crews?

Response: 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

Objectives

Develop an early-phase technology to mitigate radiological contaminants ASAP and AMAP

- Apply across a wide area within a very short time
- Usable by first responders (firefighter) and others
- Compatible with existing commercial equipment (firefighting truck etc)
- Deployable rapidly
- Low cost, low toxicity but high efficiency
- Water-based formulation
- Applicable for multiple radionuclides
- Compatible with firefighting foam
- Minimize the waste volume
- Minimize exposure

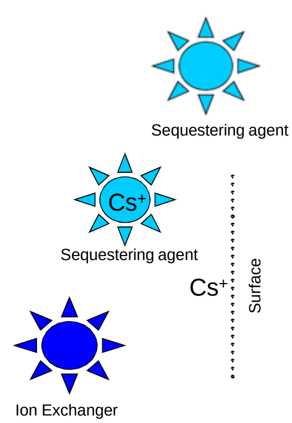
Mitigation formulation

1. Target radionuclides: Cs, Sr, Co, Am
2. Formulation contains additives that facilitate the selective removal of radionuclides
   - Water soluble
   - Isotope-binding capabilities
   - Commercial availability
   - Low toxicity
   - Low cost

Source: CPC Chemicals

Mechanism

- Displacement of cesium from surface
  – Binds preferentially to surface over cesium
- Sequestration of free cesium
  – Shifts the equilibrium towards desorption
- Combination of both types
  – Mixtures
  – Sequential



Technology approach

- Can be applied alone or as additive to firefighting foams (Class A, B, or others) when the radiological incident involves fire or flammable chemicals
- Rapidly deployable within a short time after incident by first responders (*not contractors*)
- Applicable with the existing dispensing equipment available to first responders (e.g., firefighting truck for wide area coverage)
- Minimize the exposure time of operation

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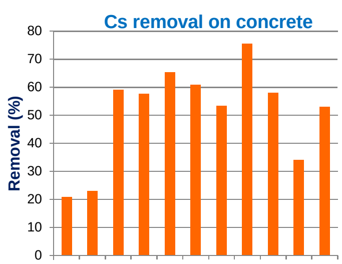
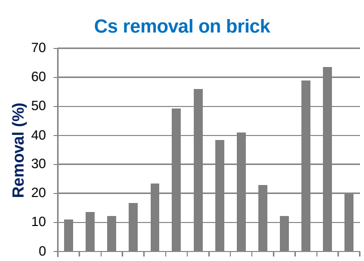
Lab-scale parameter optimization

Test parameters:

- Contaminants: non-radioactive Cs and Co;
- Materials: concrete, brick, limestone, asphalt
- Concentrations of individual components of the formulation
- Contaminants application type: spray vs. spot
- Quick wash vs. slow wash
- pH of formulation





Removal efficiency (Y axis) vs. parameters (X axis): concentration, exposure time, washing time, etc.

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Source: Environment Canada

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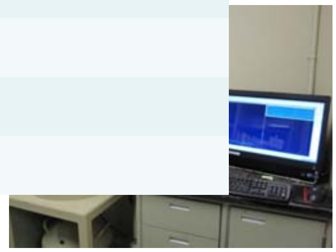
Canada

Confirmation tests on radionuclides

Removal of Cs-137

Materials	Removal (%)	Decontamination Factor
Concrete	71 ± 6	3.4
Brick (regular)	62 ± 4	2.6
Brick (glazed)	80 ± 10	5.0
Asphalt	44 ± 11	1.8



Source: Royal Military College of Canada

Formulation mixed with firefighting Class B foam

Removal of Cs-137

Materials	Removal (%)	D.F.
Concrete	68 ± 4	3.1
Brick (regular)	78 ± 5	4.5

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: 15 cm x 15 cm
- Waste collection system

Environment and Climate Change Canada / Environnement et Changement climatique Canada

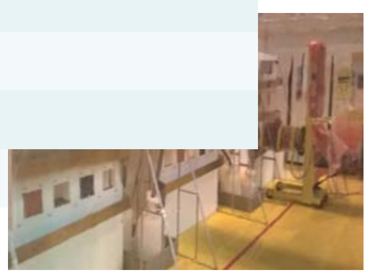
Canada

Confirmation tests on radionuclides

Removal of radionuclides from concrete

Radionuclide	Removal (%)	Decontamination Factor
Cs-137*	71 ± 6	3.4
Co-60**	63	2.7
Am-241**	94	16.7

Sources: Royal Military College of Canada* and Canadian Nuclear Laboratories (preliminary results and to be confirmed)**



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Canada

Demonstration trial
Columbus, Ohio, June 2015

Organized by
- US Environmental Protection Agency
- US Department of Homeland Security

Managed by Battelle Corp.

Focus areas
- Wide-area (e.g., Fukushima NPP accident)
- Small area (e.g.,"dirty bomb")

Toolbox of Technologies from Environment and Climate Change Canada
- **Mitigation formulation**
- **Universal Decontamination Foam**

Trial participants

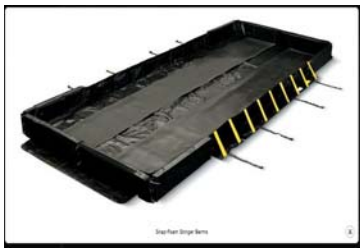
US Federal agencies: DHS (S&T, FEMA), DoS, EPA (Regions, OEM, ORCR, OSRTI, ORIA, ORD)

State and local responders: Ohio, New Jersey, Texas, New York, Charlotte, Columbus

International and tribal responders: Navajo Nation, Environment and Climate Change Canada, Ottawa Fire Services, UK Government Decontamination Service, Singapore, Israel

Research institutes: national labs, universities

Demonstration trial preparation



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Demonstration trial


The Columbus Dispatch

Battelle shows off technology to cope with terror attacks

Share this photo

LEAH KLAFCZYNSKI | THE COLUMBUS DISPATCH

Columbus firefighter K.R. Peters and S. Buchanan demonstrate how a decontaminating foam is used at Battelle

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Sources: ECCC, US EPA, Battelle

Canada

Demonstration trial vedio

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Waste management

Two tests (formulation mixed with class A and B firefighting foams) on a 100 square meter of a five-story brick building

- Approximately 800 Liters total of liquid waste consisting of (A) formulation with foams; (B) rinse water
- The time required was < 5 minutes total
- Defoamer was added to diminish foaming

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Waste management

Vehicle application (F350 pickup truck)

- Both class A and B foams
- Apply 48 L of foam and then rinse with 48 L of water
- 192 L total of foam and rinse water
- Less than 5 minutes total

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Feedback

- Easily deployed by first responders as it uses existing equipment and recycles water
- Make available to commercial market (additives are all commercially available)
- Would consider stockpiling this for scalable use by first responders
- It would assist in getting first responder equipment back in service
- Relatively low logistical effort behind application and removal, ease of transfer of knowledge from regular firefighting foam
- Better technology for first responders; easy to use with our equipment
- Higher than five floors may offer unique application problems
- Allow testing at various fire departments
- Adhesion was good for brick media
- Is it applicable for multiple radionuclides?
- **Minimize exposure time for operators**
- **No extra training required**

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Universal Decontamination Formulation- Works on all types of CBRN threats (chemical warfare, biological, and radionuclides)

Environment Canada

Universal Decontamination Foam (UDF)

EPA Technical Report describing the demonstration will be available Fall 2015.
RAD decontamination efficacy data are available in separate reports on EPA website.

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Canada

Universal Decontamination Formulation- Works on all types of CBRN threats in *wide-area*

- Cover up to 100 m^2 building
- Air Foam Dolly System (142 L or 37.5 Gal)
- Pressurized by 4500 psi SCBA air cylinder

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Urban materials: granite, quartz, marble and limestone

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Project Outcomes

Infrastructure mitigation technology was developed

Field trial confirmed its operational feasibility

Technology is ready for commercialization

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Thank you!

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

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Integrated Wash-Aid, Treatment, and Emergency Reuse System (IWATERS) for Strontium Contaminations

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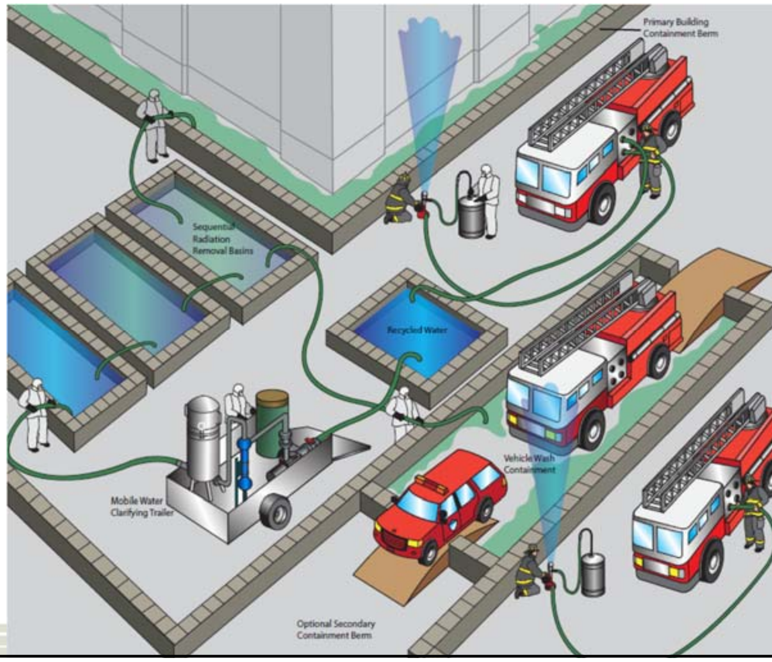
IWATERS

- In partnership with the USEPA, we have been developing a decontamination system for wide-area mitigation and remediation activities. This Integrated Wash-Aid, Treatment, and Emergency Reuse System (IWATERS) is designed for soluble and particulate contaminants.
- The components of the technology are:
  - Worker-friendly wash aid additives to tap water to promote the ion exchange of radionuclides from the surface
  - Capture and containment of the contaminated runoff
  - Use of sequestering agents to remove the dissolved radionuclides from the wash water
  - Filtration and reuse of the wash water for continued operations

IWATERS concept for buildings and vehicles



IWATERS field-scale demonstrations

- The logistics for IWATERS deployment was demonstrated first in Denver during the Wide Area Recovery and Resiliency Program (WARRP) Capstone Event held on September 13-14, 2012 in Denver, CO.
- Another demonstration was held in Columbus, OH at the "Wide-Area Urban Radiological Containment, Mitigation, and Clean-up Technology Demonstration," June 22 – 25, 2015.
- Projects were co-sponsored by the USEPA and the Department of Homeland Security.

Strontium sorption chemistry

- Sr Sequestration – Experience with Sr^{2+} sequestration is from ground waters and Na salt solutions. Various precipitation methods, solvent extractants, and engineered ion exchangers exist.
- Sr Chemistry – Strontium exists as hydrated Sr^{2+} (4.1Å) and $SrOH^+$ ions but can precipitate as $SrCO_3$, $Sr(OH)_2$ and $SrSO_4$. Strontium is chemically similar to the Ca^{2+} (4.1Å) in cements and limestones. This suggests that calcium salts might promote effective ion exchange of Sr^{2+} from contaminated building surfaces.

$Cs^+ \cdot nH_2O$=3.3Å

Salt	Formula	Solubility product (K_{sp})
Barium sulfate	$BaSO_4$	1.1×10^{-10}
Calcium sulfate	$CaSO_4$	9.1×10^{-6}
Lead(II) sulfate	$PbSO_4$	1.6×10^{-8}
Strontium carbonate	$SrCO_3$	1.1×10^{-10}
Strontium sulfate	$SrSO_4$	3.2×10^{-7}

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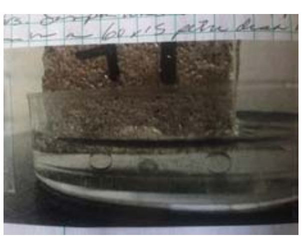
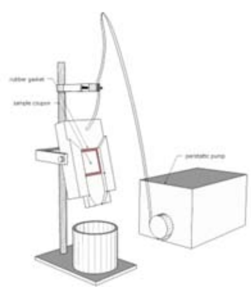
5

Test scheme

- Sorption/desorption tests to screen potential wash aid additives and sorbents (sequestering agents).
  - Sr-85, Cs-137, Eu-152 (surrogate for americium)
  - Batch tests on aggregate or crushed material to understand sorption kinetics.
  - Coupon static tests on down-selected wash additives to determine the decontamination factors.
  - Coupon low pressure flow tests to better simulate in-field conditions and determine decontamination factors.
  - Coupon high pressure flow tests to understand effect of higher pressure wash on DF.



Example concrete coupon



Schematic of flow system. A wash solution is pumped over the coupon and into a beaker.

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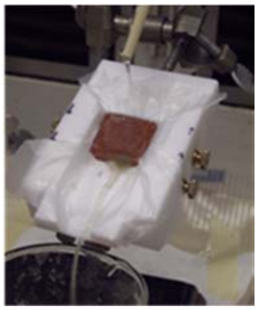
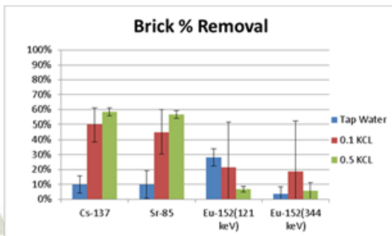
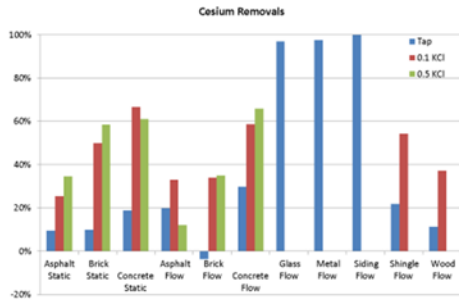
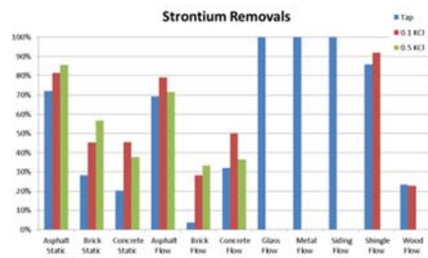
Static and low pressure flow test results







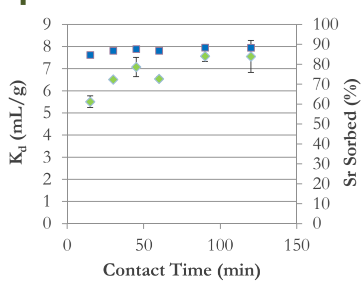
Flow studies: Removal of cesium in low pressure flow. Flow rate = 100 mL/min.



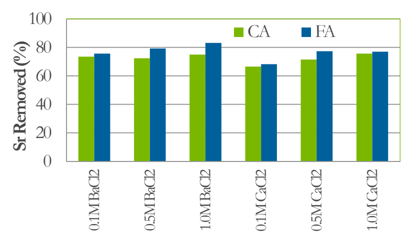
Flow studies: Removal of strontium in low pressure flow. Flow rate = 100 mL/min.

7

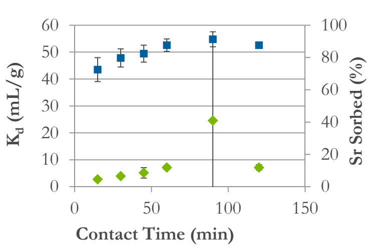
Sorption kinetics and desorption into salts



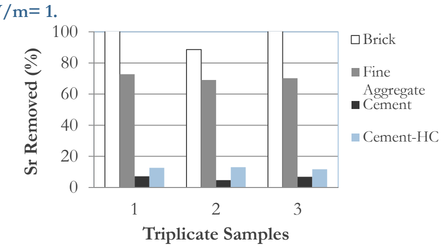
Sorption of Sr^{2+} onto fine aggregate.



Desorption of Sr^{2+} from coarse and fine aggregates (CA and FA, respectively) of concrete using Ba and Ca salts. V/m= 1.



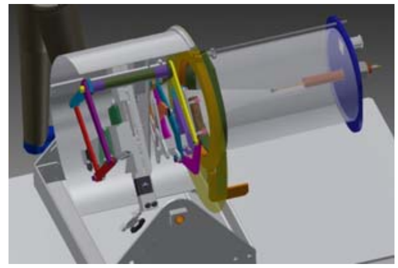
Sorption of Sr^{2+} onto crushed cement. V/m= 1.



Desorption of Sr^{2+} from fine aggregate, crushed brick, and crushed concrete using 0.1M $CaCl_2$/0.1M DTPA as pentasodium salt. V/m= 1.

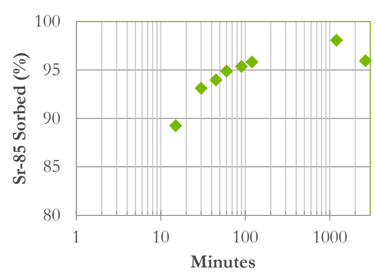
8

High pressure wash testing with tap water

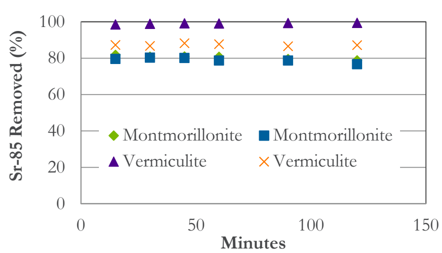


			Rate	% Removal					
Material	Wand	Nozzle (°)	(mm/sec)	**Cs-137**	std dev	**Sr-85**	std dev	**Eu-152**	std dev
Concrete	middle	15	5	**10.8**	4.2	**7.4**	7.9	**34.9**	7.7
Asphalt	middle	15	5	**6.2**	3.8	**58.8**	4.1	**21.0**	6.1
Brick	middle	15	5	**14.4**	8.0	**8.5**	4.3	**7.7**	8.5
Concrete	middle	15	25	**14.7**	0.7	**13.2**	5.4	**45.5**	15.7
Concrete	middle	15	50	**16.3**	9.3	**18.2**	7.4	**34.6**	7.2
Concrete	Long	15	5	**41**	7	**28**	7	**46**	12
Concrete	Short	15	5	**16**	13	**14**	13	**30**	13

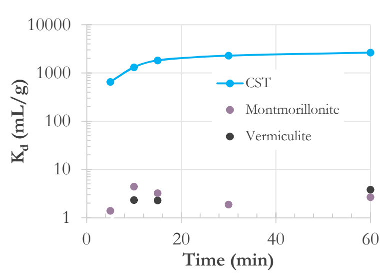
Sequestration agents for contaminated wash solution



Sorption of Sr^{2+} onto IONSIV-910 from 0.1 $CaCl_2$ solutions. V/m=100.



Sorption of Sr^{2+} onto clays from deionized water. V/m=100.

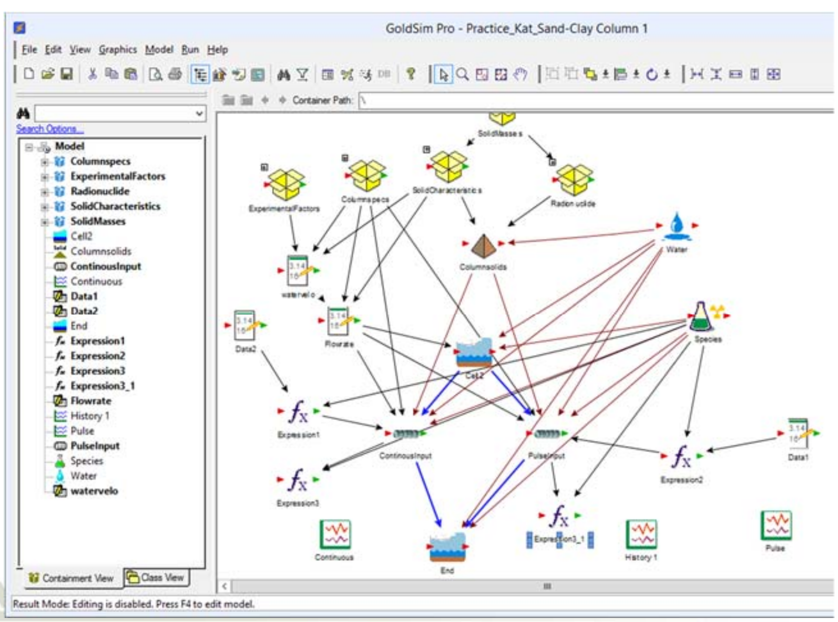


Effective K_d for separation of Sr-85 from a sea water simulant. (Similar results for 0.1M KCl).

So what do we do with this data?

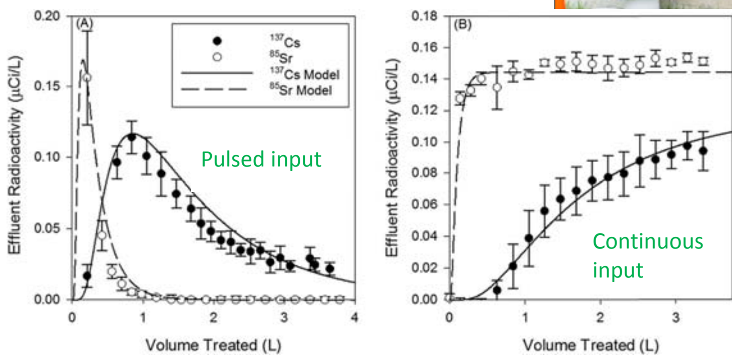
- Static and flow tests
  - Provides range of DF values for a variety of materials
    - Can be used as input into a dose model to optimize the wash down approach
  - Allows us to formulate a generic formula for the wash additive and recommendations for low-tech applications
  - Provides information on best practices (flow rate, nozzle type, wash rate)
- Sequestration material data
  - Provides K_d values to design wash water treatment options
- Systems design
  - These parameters are input into a systems design from wash down to water stabilization/treatment.
  - Modeling needed

Goldsim modeling of contaminated wash water



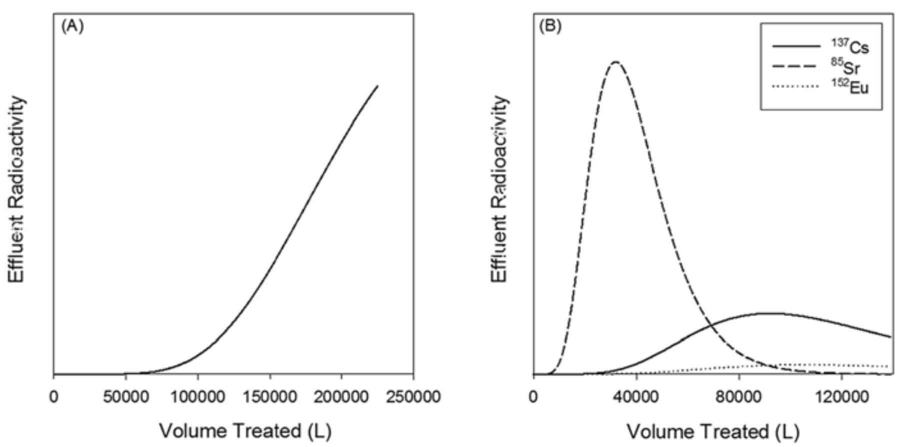
Rain barrel modeling

- Rain barrels might serve as low tech option that could be widely applied
- Conducted laboratory column experiments to measure breakthrough and validate the model



W.C. Jolin, M. Kaminski / Chemosphere 162 (2016) 165-171.

Rain barrel modeling



Predicted breakthrough for ^{137}Cs through barrel containing 1:3 mixture vermiculite to sand if concentrations are kept below 1% of the clay CEC. Flow rate was predicted to be 2.6 L/min. (B) Breakthrough curve for ^{137}Cs (solid line), ^{85}Sr (dashed line), and ^{152}Eu (dotted line) through barrel containing 1:1 mixture montmorillonite to sand. Flow rate was predicted to be 1.6 L/min.

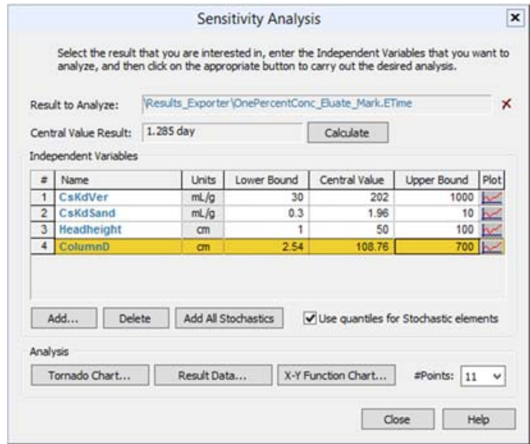
W.C. Jolin, M. Kaminski / Chemosphere 162 (2016) 165-171.

Sensitivity analyses on filtration beds

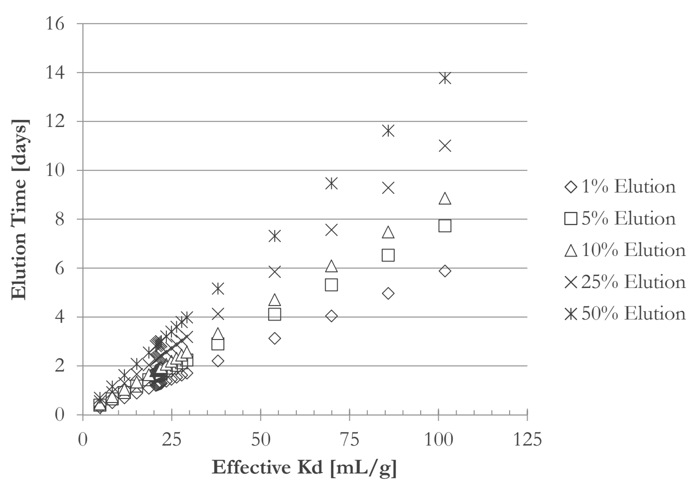
Length = 150cm

Ratio Sand to Total Mass = 0.9 (fixed)

Concentration Cs-137 = 0.0001 µCi/L



Example sensitivity analysis run



Summary

- Static and Flow Tests
  - Because of difficulty with filtering Sr from calcium-based wash waters, potassium based solutions were initially tested on a variety of coupon materials.
  - Cesium – Tap water was ineffective in decontaminating Cs except from glass, metal, and vinyl siding. 0.5M KCl was effective on concrete & composite shingle.
  - Strontium – Tap water was effective on asphalt, glass, metal, and vinyl siding. Salt was no more effective than water.
  - Europium – Eu was difficult to remove except from glass, metal, and vinyl siding (requires low pH for others). Suggests similar behavior for americium
- Modeling
  - Capability to predict breakthrough allows us to develop look up tables for a variety of applications where the K_d or effective K_d is known (CBRNE)
- Future Work
  - Evaluate Sr sorption onto sorbents in K^+ and Na^+ based wash solution
  - Complete high pressure flow tests and effect of washing on depth profile
  - Modeling to develop look up tables and help complete a systems analysis of the IWATERS for various deployment scenarios
  - Complete integration of Sr and Cs IWATERS and for other radionuclides.

Acknowledgments

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Current and Emerging Post-Fukushima Technologies and Techniques for Wide Area Radiological Survey and Remediation

Mark Sutton
Deputy Division Leader
Nuclear and Chemical Science Division

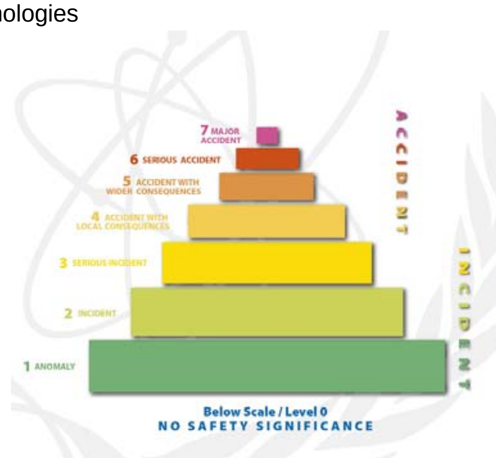
Wednesday November 2nd 2016
EPA 2016 Decontamination R&D Conference

LLNL-PRES-705914
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

Lawrence Livermore National Laboratory

Technologies for RDD response

Prior responses to radiological accidents provide information on available and developing technologies



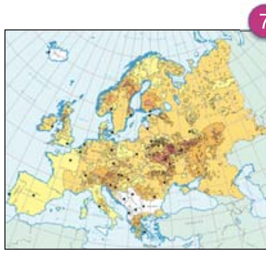
Accidental releases of Cs-137

Windscale 1957 (5)
(20 TBq, regional, 500 km^2)
180 TBq, international

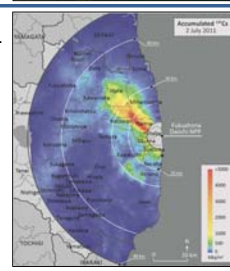
Goiania 1987 (5)
51 TBq
local ~1 km^2

Kyshtym 1957, 27 TBq (6)
regional < 23,000 km^2

Chernobyl 1986 (7)
85,000 TBq
international
> 200,000 km^2



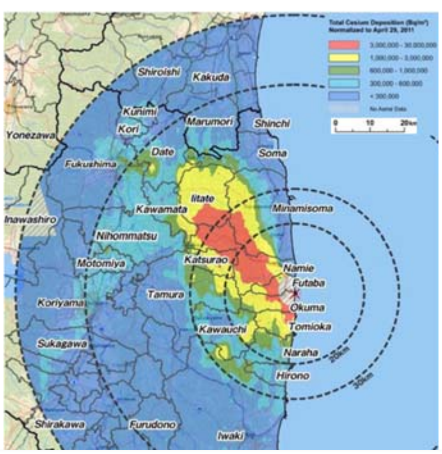
Fukushima 2011 (7)
~50,000 TBq
(regional)
13,000 km^2
international



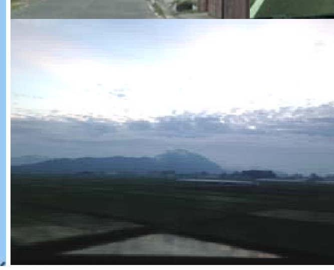
Images: BBC, IAEA, Jan Rieke

Wide Area Contamination

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







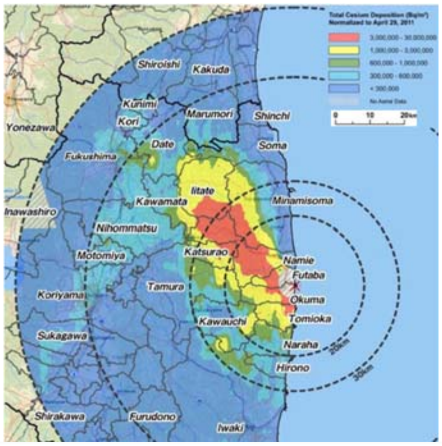
Residential
- Rural
- Urban

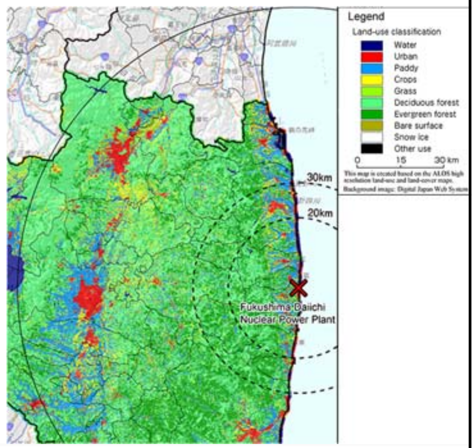
Agriculture
Water
Transportation

IAEA

Land Use

The majority of land contaminated by the Fukushima release was rural (grass, forest) and agricultural





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5

Wide Area Contamination

Urban contamination presents a complex variety of surfaces and different challenges

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Evacuated Zone Video

Communication, Education, Outreach

"Decontamination Plaza" in Fukushima City used to communicate, educate and provide outreach to the community.

(A) Reading information

(A) High-pressure roof washing

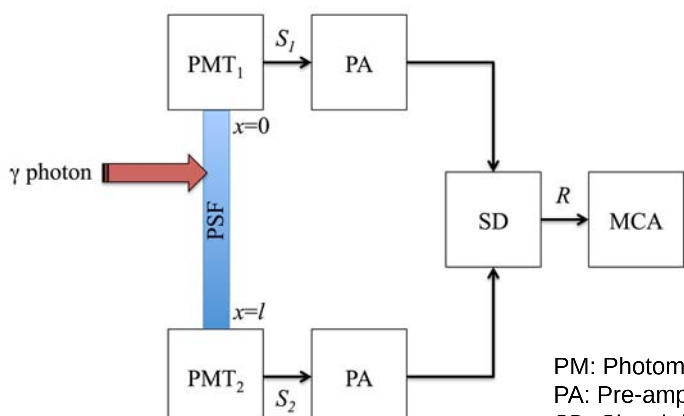
(A) Top-soil removal

Aerial Survey and Characterization in Japan

	Micro UAV	Unmanned Helicopter	Unmanned Plane	Manned Helicopter
Survey Area	**Small < 1 km^2**	**Local > 1 km^2**	**Semi-Regional > 100 km^2**	**Regional > 1000 km^2**
Option	Micro unmanned aerial vehicle (UAV)	Unmanned helicopter	Unmanned airplane	Manned helicopter
Altitude	< 10 m	~ 50 m	~ 150 m	~300 m
Features	Allow focused surveys e.g., above urban areas or in forests; under development	Higher resolution mapping available	Allows remote controlled long-time flight (e.g., 6 hours); under development	Standardized methodology available for efficient regional surveys

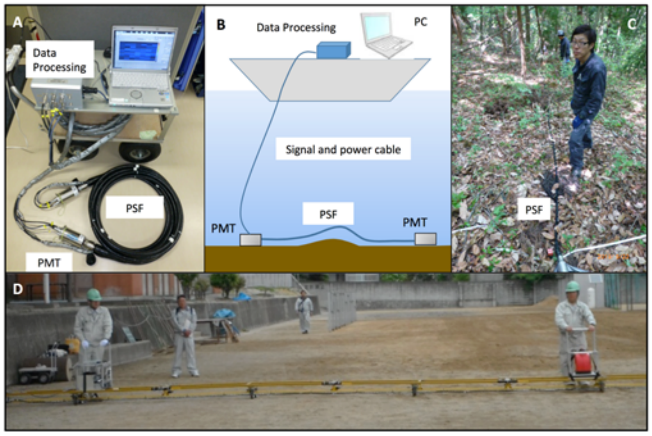
Increasing:
cost, altitude, fuel, range, maintenance, pilot qualifications, ground support

Plastic Scintillation Fibers



PM: Photomultiplier
PA: Pre-amplifier
SD: Signal divider
MCA: Multi-channel analyzer

Ground Survey and Characterization in Japan



(A) PSF apparatus used to survey:
(B) pond sediments, (C) forest soil, (D) school playground

Ground Survey and Characterization in Japan

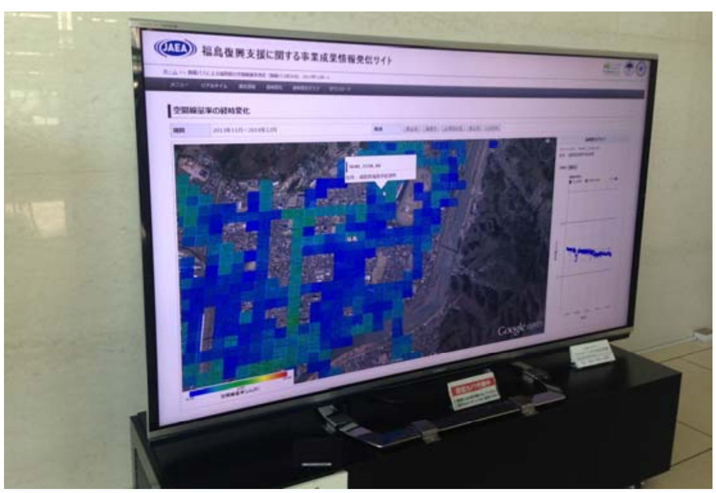
JAEA SUV with GPS, both low and high dose rate detectors, dust and gas sampling capability, fielded from the Sasakino Analytical Laboratory

Ground Survey and Characterization in Japan

The compact KURAMA II (Kyoto University RAdiation MApping) System deployed on 28 buses, 2 prefecture cars and 19 service-operated cars, data is transmitted real-time

DISPLAY IN JAEA FUKUSHIMA OFFICE

KURAMA II real-time results / interactive display in lobby of JAEA's Fukushima City office

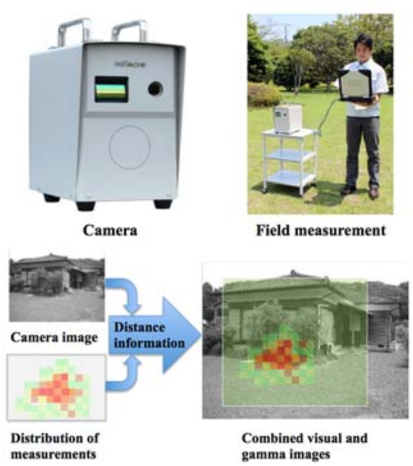


Ground Survey and Characterization in Japan

Airborne dose rate meters in urban areas and freeways to inform public

Ground Survey and Characterization in Japan

Examples of Gamma Camera applications in Japan (MOE, 2013)



Forest Decontamination in Japan

40-80% of rad distribution in evergreen forest found in leave litter,
15-50% associated with branches and leaves remaining on trees

Removal of litter, pruning of branches, pruning back foliage can significantly reduce dose

Volume reduction possible

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MOE, 2013

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Agricultural Land Decon in Japan

Mowing and plowing to remove vegetation and dilute contamination below topsoil

Studies of Cs-134 and Cs-137 depth profiling suggest that the contamination penetrates mostly within the upper 5 cm of undisturbed soil and up to 20 cm of plowed soil.

Thin layer soil stripping, reverse tillage, interchange top and subsoil are effective in reducing dose.

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MOE, 2012

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Residential Decon in Japan

Roof cleaning with high-pressure water, gutter wiping, high-pressure drain pipe (down-spout) cleaning and topsoil removal

Road Decon in Japan

(A) street sweeping, (B) ride-on sweeping, (C) water-jet vehicle,
(D) manual high-pressure water, (E) ultra-high pressure water, (F) dry-ice blasting

Road Decon in Japan

Technique	Area Decontaminated (m^2, 1 person day)	Waste Volume Generated (l/m^2)	Waste Type	Collection Type and Rate	Decon Factor; Gamma Dose Rate Reduction	Direct Implementation Cost (Yen/m^2) for Areas > 1000 m^2
Street sweeping	3,500	1 – 1.5	Soil, road dust, vegetation	N/A	1 – 2; 0 – 45%	10
Ride-on sweeping	1,750					20
Water-jet vehicle	1,000	30 – 40	Sludge	Vehicle 50 – 70%	1 – 3; 0 – 70%	150
Manual high-pressure water washing	50			Vacuum 100%	1 – 3; 0 – 65%	960
Hydro-blast ultra-high pressure water washing	80	3	Road dust, water	Vacuum absorption 100%	2 – 15; 40 – 95	1,150
Dry-ice blasting	70	2	Road dust	N/A	2.5 – 10; 60 – 90%	1,310

Road Decon in Japan

(G) sand-blasting, (H) medium-scale shot-blasting, (I) large-scale shot-blasting, (J) asphalt shaving, (K) mechanical digger asphalt removal, (L) top-soil removal

Road Decon in Japan

Technique	Area Decontaminated (m^2, 1 person day)	Waste Volume Generated (l/m^2)	Waste Type	Collection Type and Rate	Decon Factor; Gamma Dose Rate Reduction	Direct Implementation Cost (Yen/m^2) for Areas > 1000 m^2
Sand-blasting	5	20	Road dust, sand	N/A	2.5 – 10; 60 – 90%	4,190
Medium-scale shot-blasting (iron balls)	170 – 270	3	Concrete, asphalt dust, iron shot		~10; ~90%	570
Large-scale shot-blasting (iron balls)	170		Road dust, iron balls		3 – 23; 60 – 95%	480
Asphalt planing/shaving	150	8 (@5 mm thickness)	Asphalt		22; 95	390
Mechanical digger asphalt removal	26	150			3 – 10; 70 – 90%	1,620
Top-soil removal from unpaved road or soft-shoulder	90	20 – 50	Gravel, soil		1 – 13; 30 – 95%	560

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LLNL-PRES-705914

JAEA, 2015

NNSA 23

Playground/School Decon in Japan

Soil grading, artificial turf infill removal, and play-structure cleaning

Lawrence Livermore National Laboratory
LLNL-PRES-705914

MOE, 2013

NNSA 24

Waste – excavation of top-soil and vegetation

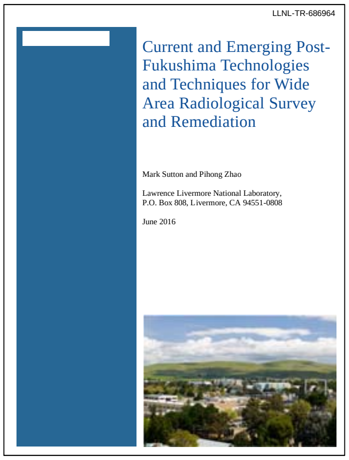
Vegetation is trimmed and the top-soil is removed using excavators

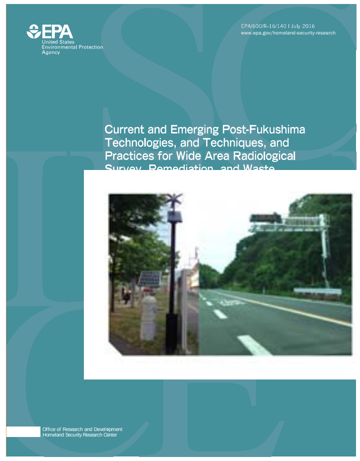
Waste – excavation of top-soil and vegetation

(A) Soil and vegetation is placed in impermeable bags
(B) sealed and labeled ("shielding")
(C) arranged in short-term storage at satellite location

Emerging Technologies Report

Additional information available from LLNL and corresponding EPA Reports





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NNSA 27

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

NNSA 28


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National Laboratory

Evaluation of Low-Tech Indoor Remediation Methods Following Wide Area Radiological/Nuclear Incidents

Ryan James, Battelle
Sang Don Lee and Matthew Magnuson EPA NHSRC

EPA International Decontamination Conference
Research Triangle Park, NC
November 2, 2016

Disclaimer

- The U.S. Environmental Protection Agency (EPA) through its Office of Research and Development (ORD) funded and managed the research described. It has been subjected to the Agency's review and has been approved for publication and distribution. 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.
- Battelle is a contractor to EPA and provided technical support for the work described.

Radiological/Nuclear Incident Response

- Dirty bombs, nuclear explosions, and nuclear power plant accidents can contaminate vast urban and rural areas.
- Fukushima contaminated an area the size of Connecticut, and the clean-up is still going on.
- If people can't get back to their homes and businesses in weeks-months, they may never return.
- What decontamination approaches would be used?
- How effective are they?

Urban Surface Decontamination

- Decontamination of urban building material surfaces using physical and chemical decontamination technologies

Decon testing using test stand at INL

EPA/DHS Wide Area Decon Demo – Battelle 2015

Example RAD decon technology (DeconGel 1108)

RAD decontamination testing of Wash Aid

Low-tech Remediation Methods

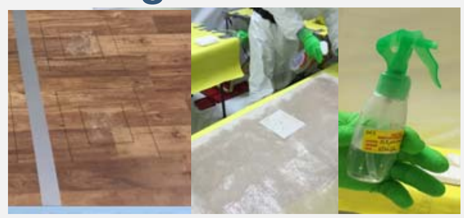
- Methods selected for availability and ease of use for personal residences, office buildings, and medical and first responder facilities
- Methods applied as they would be used by the public and workers cleaning building and facilities
- After Fukushima (and still today), Japanese public use various low tech methods

Technical Approach

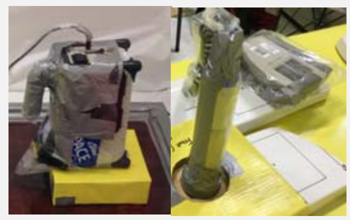
- Radiologically tagged simulated fallout material (SFM)
  - Two particle sizes (<10 µm and >250 µm) allows studying efficacy as function of particle size
  - Similar to work done by EPA / Defense Research and Development Canada
  - Each size contaminated with different contaminant: rubidium-86 (<10 µm) and cesium-137 (>250 µm)
- Contamination method
  - Spike aqueous radionuclide into sized Arizona Road Dust, mix well, dry
  - Aqueous mist onto surfaces

Experimental Design

- Contaminate indoor surfaces
  - Target activity of ≥ 2 µCi Cs-137 and 20 µCi Rb-86 (2 g of each particle size)
  - Light loading of 0.5 g AZ Road Dust
  - Aqueous mist on surfaces
- Measure pre-decontamination activities
  - 100 second measurements of contaminated samples to ensure detectability in shortest feasible time
  - 300 second (5 min) measurement of post-decon activity to measure removal in reasonable time



Application of particles and aqueous mist to surfaces

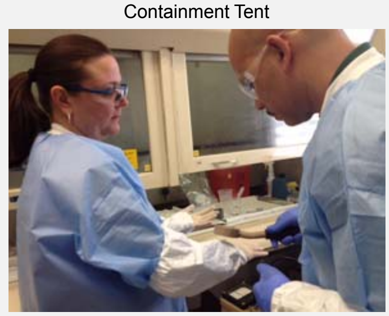


Activity measurement
ORTEC Micro-Detective
Canberra InSpector 1000

Experimental Design

- Decon performed so surface covered twice with cleaning technologies
- All steps performed in containment tent
- HEPA filtration
- 100% HP oversight
- Air sampling for technician dose estimate
- Whole body surveys for technician contamination estimate

Containment Tent

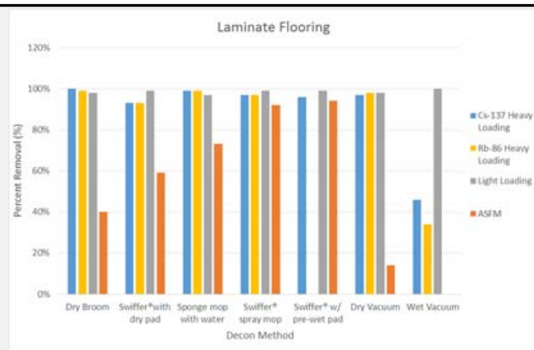


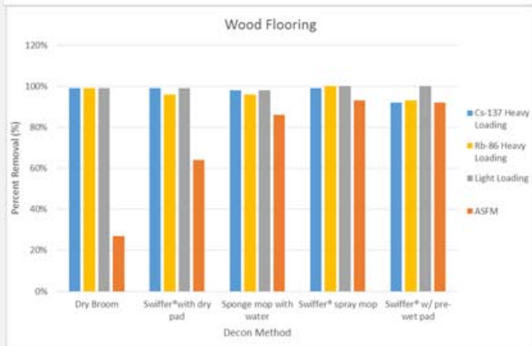
Whole Body Surveys

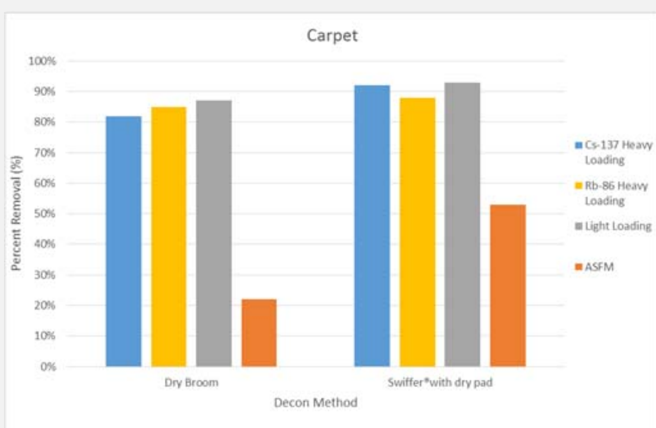
Decon Experiment Demonstration

Flooring Surfaces Results

Method	Flooring Surface	% Removal for Each Contamination Deposition Approach			
		Cs-137, > 250 µm Heavy Loading SFM	Rb-86, <10 µm Heavy Loading SFM	Cs-137, <10 µm Light Loading SFM	Cs-137 ASFM
Dry Broom	Laminate Floor	100% ± 2%	>99%	98% ± 0%	40% ± 16 %
	Wood Floor	>99%	>99%	>99%	27% ± 6%
Swiffer®with dry pad	Laminate Floor	93% ± 4%	93% ± 9%	99% ± 2%	59% ± 7%
	Wood Floor	>99%	>96%	99% ± 1%	64% ± 8%
Sponge mop with water	Laminate Floor	99% ± 0%	99% ± 1%	97% ± 1%	73% ± 3%
	Wood Floor	98% ± 3%	96% ± 3%	98% ± 0%	86% ± 1%
Swiffer® spray mop	Laminate Floor	97% ± 2%	97% ± 2%	99% ± 1%	92% ± 1%
	Wood Floor	>99%	100% ± 2%	100% ± 0%	93% ± 1%
Swiffer® w/ pre-wet pad	Laminate Floor	96% ± 6%	NA NA	99% ± 1%	94% ± 1%
	Wood Floor	92% ± 6%	93% ± 6%	100% ± 0%	92% ± 1%
Dry Vacuum	Carpet	82% ± 6%	85% ± 3%	87% ± 2%	22% ± 4%
	Laminate Floor	97% ± 1%	98% ± 1%	98% ± 0%	14% ± 6%
Wet Vacuum	Carpet	92% ± 1%	88% ± 4%	93% ± 1%	53% ± 11 %
	Laminate Floor	46% ± 12%	34% ± 8%	100% ± 0%	NA NA


Laminate Flooring
120%
100%
80%
60%
40%
20%
0%
Percent Removal (%)
Dry Broom
Swiffer®with dry pad
Sponge mop with water
Swiffer® spray mop
Swiffer® w/ pre-wet pad
Dry Vacuum
Wet Vacuum
Decon Method
Cs-137 Heavy Loading
Rb-86 Heavy Loading
Light Loading
ASFM


Wood Flooring
120%
100%
80%
60%
40%
20%
0%
Percent Removal (%)
Dry Broom
Swiffer®with dry pad
Sponge mop with water
Swiffer® spray mop
Swiffer® w/ pre-wet pad
Decon Method
Cs-137 Heavy Loading
Rb-86 Heavy Loading
Light Loading
ASFM


Carpet
100%
90%
80%
70%
60%
50%
40%
30%
20%
10%
0%
Percent Removal (%)
Dry Broom
Swiffer®with dry pad
Decon Method
Cs-137 Heavy Loading
Rb-86 Heavy Loading
Light Loading
ASFM

Flooring Observations

Heavy Loading SFM

- Efficacy independent of particles size
- Average %R less than 90% in 5 of 27 instances
- Average %R was 95% or above in 16 of 27 instances
- Largest standard deviation was 12%
- Wet-vac on laminate floor had the lowest average %R, 46% and 34%
- Dry vacuum on carpet was the next lowest average %R with 83% and 85

Light loading SFM

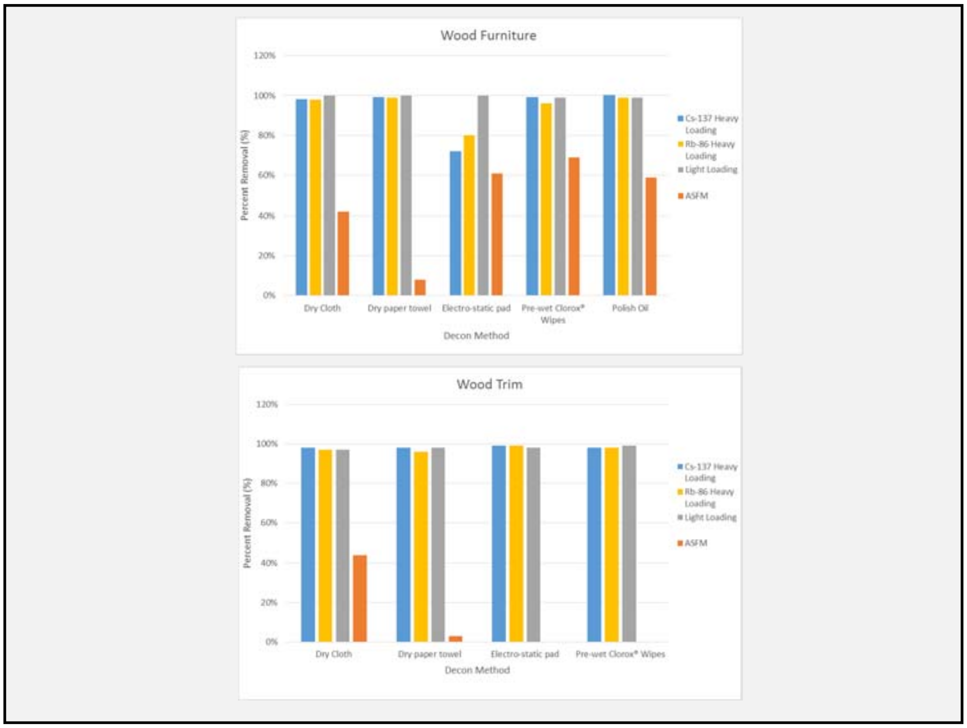
- 12 out of 14 average %R were 97% and above; dry and wet vacuum on carpet were had %R of 87% and 93%

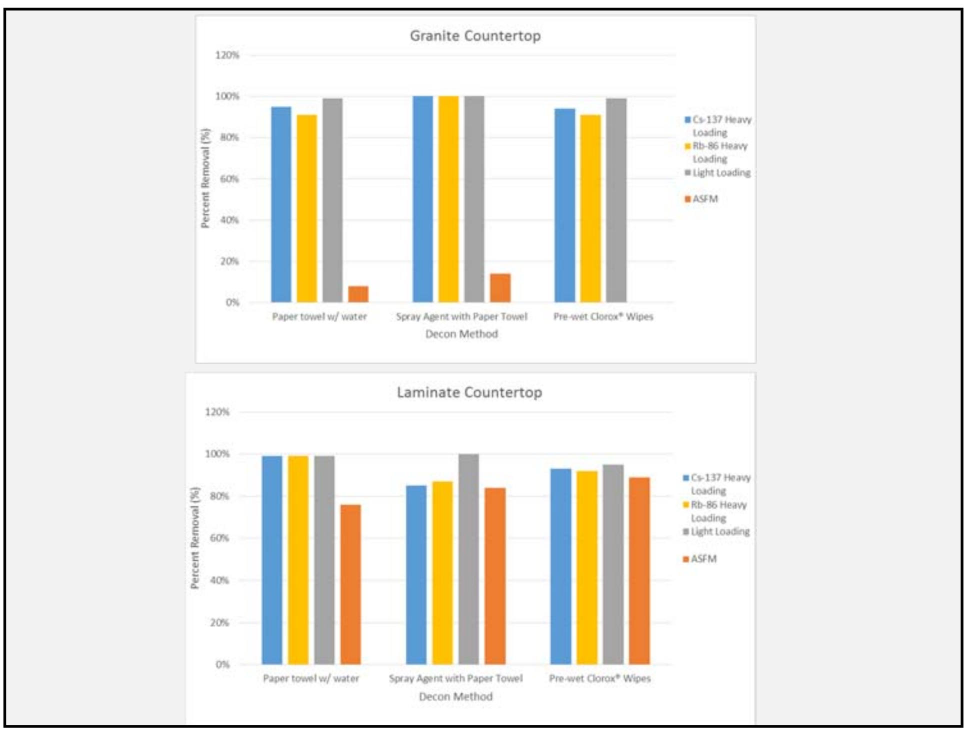
Aqueous Contaminant Application

- Average %R exceeded 90% in 4 of 13 instances; one exceeded 80%
- Dry vac on carpet and laminate floor had the low average %R of 22% and 14%
- Laminate and wood floor using wet Swiffers® had the highest average %R (92%-94%)

Non-Flooring Surfaces Results

Method	Non-Flooring Surface	% Removal for Each Contamination Deposition Approach			
		Cs-137, > 250 µm Heavy Loading SFM	Rb-86, <10 µm Heavy Loading SFM	Cs-137, <10 µm Light Loading SFM	Cs-137 ASFM
Dry Cloth	Wood furniture	>98%	>98%	100% ± 0%	42% ± 6%
	Toilet tank cover	88% ± 2%	89% ± 2%	98% ± 1%	83% ± 4%
	Wood trim	98% ± 4%	>97%	97% ± 2%	44% ± 17 %
Dry paper towel	Wood furniture	>99%	>99%	100% ± 0%	8% ± 3%
	Toilet tank cover	99% ± 1%	98% ± 1%	100% ± 0%	71% ± 6%
	Wood trim	98% ± 4%	96% ± 4%	98% ± 4%	3% ± 13 %
Electro-static pad	Wood furniture	72% ± 1%	80% ± 4%	100% ± 0%	61% ± 7%
	Toilet tank cover	>99%	98% ± 1%	99% ± 1%	39% ± 2%
	Wood trim	99% ± 2%	99% ± 2%	98% ± 3%	0% ± 18 %
Paper towel w/ water	Granite countertop	95% ± 5%	91% ± 3%	99% ± 1%	8% ± 2%
	Laminate countertop	>99%	>99%	99% ± 0%	76% ± 7%
Spray Agent with Paper Towel	Granite countertop	100% ± 0%	100% ± 0%	100% ± 0%	14% ± 2%
	Laminate countertop	85% ± 1%	87% ± 3%	100% ± 0%	84% ± 6%
Pre-wet Clorox® Wipes	Wood furniture	99% ± 3%	96% ± 7%	99% ± 0%	69% ± 11 %
	Granite countertop	94% ± 3%	91% ± 3%	99% ± 0%	0% ± 16 %
	Laminate countertop	93% ± 3%	92% ± 6%	95% ± 1%	89% ± 3%
	Toilet tank cover	99% ± 1%	100% ± 0%	100% ± 0%	95% ± 3%
	Wood trim	98% ± 3%	>98%	99% ± 0%	NA ± NA
Polish Oil	Wood furniture	100% ± 0%	>99%	99% ± 1%	59% ± 6%


Wood Furniture
Percent Removal (%)
Dry Cloth
Dry paper towel
Electro-static pad
Pre-wet Clorox® Wipes
Polish Oil
Decon Method
Cs-137 Heavy Loading
Rb-86 Heavy Loading
Light Loading
ASFM
Wood Trim
Percent Removal (%)
Dry Cloth
Dry paper towel
Electro-static pad
Pre-wet Clorox® Wipes
Decon Method


Granite Countertop
Percent Removal (%)
Paper towel w/ water
Spray Agent with Paper Towel
Pre-wet Clorox® Wipes
Decon Method
Cs-137 Heavy Loading
Rb-86 Heavy Loading
Light Loading
ASFM
Laminate Countertop
Percent Removal (%)
Paper towel w/ water
Spray Agent with Paper Towel
Pre-wet Clorox® Wipes
Decon Method

Non-Flooring Observations

Heavy Loading SFM

- Efficacy independent of particles size
- Average %R less than 90% in only 6 of 38 instances
- Average %R included 100% in 25 of 38 instances
- Largest standard deviation was 7%
- Electrostatic pad on the wood furniture had lowest average %R, 72% and 80%

Light loading SFM

- 17 out of 19 instances were 98% or above, all average %R were 95% and above

Aqueous Contaminant Application

- Average %R exceeding 90% only one of 19 instances 3 instances exceeded 80%
- %R did not exceed 10% in 5 instances
- Granite countertop had three average %R (0%, 14%, and 8%) below 20%R
- Laminate countertop and the toilet tank cover had the highest average %R

Waste Stream Estimates

Surface	Amount	Method	Number of items	Potential %R
Carpet	139 m^2	Dry vacuum	1 vacuum and SFM with 20 mg/cm^2	82%
Laminate floor	46 m^2			97%
Laminate counter	2 m^2	Formula 409® w/ paper towel	12 paper towels with 20 mg/cm^2 SFM	85%
Toilet Tank Covers	3 covers and seats	Clorox® pre-wet wipes	12 wipes with 20 mg/cm^2 SFM	99%
Tub/shower	2	Formula 409® w/ paper towel	12 paper towels with 20 mg/cm^2 SFM	99%
Wood furniture	10 m^2	Polish oil	50 dry cloths	100%

	Estimated Waste Volume		
Surface	Heavy SFM Loading	Light SFM Loading	ASFM
Carpet	1 vacuum (6 kg), 37 kg SFM	1 vacuum (6 kg), 3.7 kg SFM	1 vacuum (10 kg), 32 kg wastewater
Laminate			162 g pre-wet pads
Laminate Counter	36 g in damp paper towels; 400 g SFM	18 g in damp paper towels; 40 g SFM	18 g in damp paper towels
Toilet Tank Covers	36 g in damp wipes; 180 g SFM	24 g in damp wipes; 18 g SFM	36 g in damp wipes
Tub/shower	36 g in damp paper towels; 400 g SFM	18 g in damp paper towels; 40 g SFM	18 g in damp paper towels
Wood Furniture	3 kg dry cloths and 2 kg SFM	2 kg dry cloths and 200 g SFM	3 kg dry cloths
Estimate of total mass, volume, and activity	49 kg into 0.2 m^3 bag (if initial fallout had activity of 0.5 µCi/g, then 19 mCi)	12 kg into 0.2 m^3 bag (if initial fallout had activity of 0.5 µCi/g, then 1.9 mCi)	45 kg into 0.2 m^3 bag (if initial activity of 0.01 mCi/m^2, then 1.9 mCi)

Next Steps – Outdoor Surface Decon

- Selection of outdoor surfaces and low-tech cleaning methods
- Measuring decon efficacy, waste stream, operational factors, and operator exposure when using outdoor cleaning methods
- Roofing, siding, windows, decking, etc.
- Similar experimental approach

Additional Questions?

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

Ryan James (614-424-7954/ JamesR@battelle.org)

DISCLAIMER: The U.S. Environmental Protection Agency (EPA) through its Office of Research and Development (ORD) funded and managed the research described. It has been subjected to the Agency's review and has been approved for publication and distribution. 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.

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United States Environmental Protection Agency

2016 U.S. EPA International Decontamination Research and Development Conference

Thursday, November 3, 2016

Concurrent Sessions 5

Biological Agent Decontamination

NAVSEA WARFARE CENTERS DAHLGREN

Hot Air Decontamination of Materials Contaminated with *Bacillus anthracis* and acrystalliferous *Bacillus thuringiensis* Spores

Tony Buhr, Ph.D., Alice Young, Emily Osborn, Neil Kennihan, Zach Minter, Matt Bohmke, Erica Borgers-Klonkowski, Harold Barnette, Misty Bensman
Naval Surface Warfare Center – Dahlgren, Dahlgren, VA
October 17, 2016

NAVSEA WARFARE CENTERS DAHLGREN

History of Decontamination

Dirckx JH (1981); Sternbach G (2003)

The Roman poet Virgil (70–19 BC) gave an account of what is thought to be an anthrax plague in the eastern Alps, as well as an early description of decontamination, "The pelts of diseased animals were useless, and neither water nor fire could cleanse the taint from their flesh. The sheep men could not shear the fleece, which was riddled with disease and corruption, nor did they dare even touch the rotting strands. If anyone wore garments made from tainted wool, his limbs were soon attacked by inflamed papules and foul exudates."

1. Use of water and temperature
2. Balance decontamination efficacy and materials compatibility
3. Anthrax was the example – (causal agent - *B. anthracis*)

 2

Objective

Buhr et al. 2012, 2014, 2015; Herzberg 2012; Koch et al. 2001

Objective: Develop a technology using the synergistic action of heat, humidity and time as a biological decontaminant(s) for sensitive equipment without degradation of the functionality of that equipment. Test the limits of decontamination technology, ie. the performance envelope, using DOE, maintain both statistical and practical confidence, and then develop models to transition to end users.

Example of a Need: There are no/limited sporicidal decontaminants that can be used on aircraft interior and/or sensitive equipment.

Best current solution for contaminated aircraft – scrap or ocean floor.

U.S. Navy ships use hypochlorite despite >$1trillion annual cost due to corrosion in the U.S.

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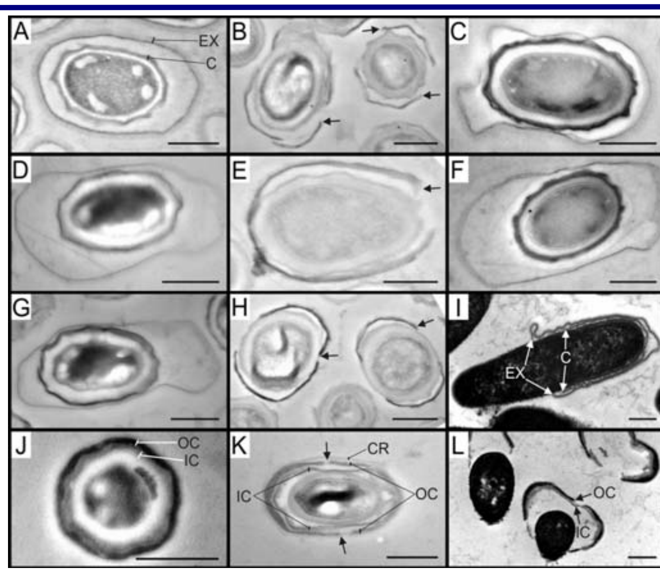
Spores – Healthy, Bleach, Heat-Killed

Buhr et al. (2012) – Derrell McPherson



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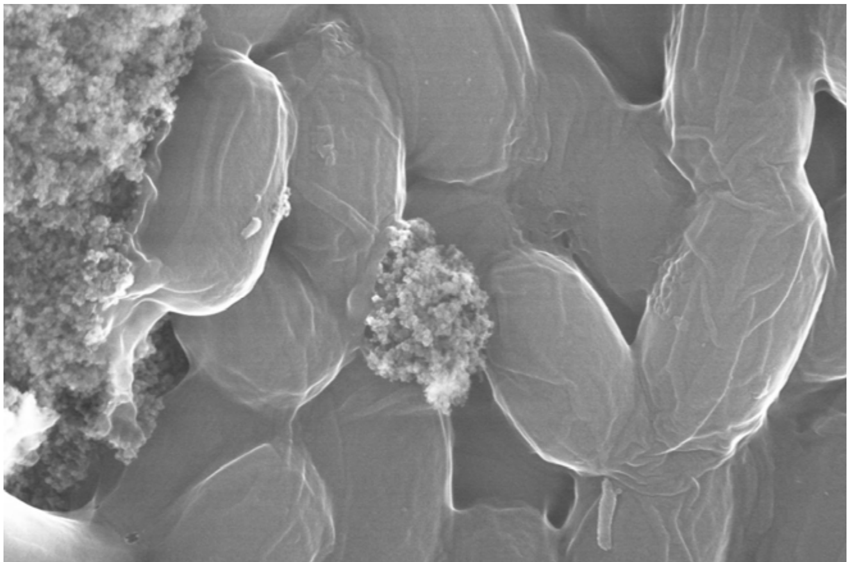
Healthy spores surface view

Buhr et al. (2015) – Derrell McPherson



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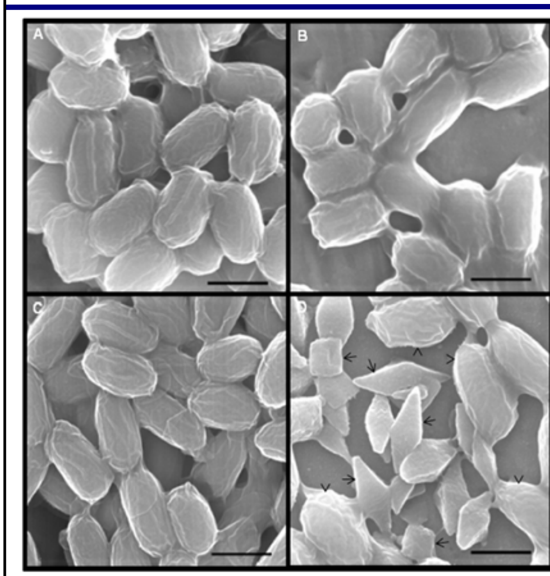
Past Present and Future of Surrogate Selection and Decontamination Development

Buhr et al. (2012) – Derrell McPherson



- *A. Bacillus anthracis* Sterne
- *B. Bacillus anthracis* ∆Sterne
- *C. Bacillus thuringiensis* Al Hakam
- D. *Bacillus thuringiensis* kurstaki

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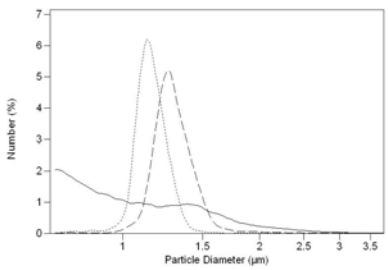
Isolation of Spores as Independent Variable

Buhr et al. (2012)



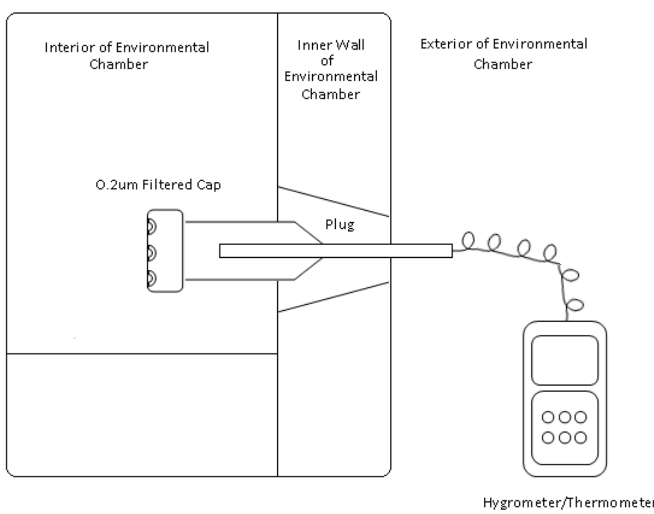
Particle size distribution of three spore preparations, representing 4,295 total particles of an in-house *B. anthracis* ΔSterne preparation (....), 5,815 total particles of an in-house *B. thuringiensis* Al Hakam preparation (– – –), and 28,834 particles of an independent laboratory's *B. thuringiensis* preparation (—). Number (%) is a normalized distribution representing the percentage of particles of the corresponding size.

Volume-equivalent spherical diameter of *B. anthracis* ΔSterne and *B. thuringiensis* Al Hakam spores from independent preparations.

	Spores	Spherical Diameter (μm)		
B. anthracis ΔSterne	Counted	Mean	Median	**Mode**
Spore Prep #1	35,157	1.10±0.14	1.09	**1.09**
Spore Prep #2	46,257	1.16±0.26	1.13	**1.12**
Spore Prep #3	30,800	1.13±0.14	1.12	**1.11**
Spore Prep #4	26,921	1.11±0.20	1.10	**1.09**
Spore Prep #5	26,345	1.12±0.19	1.11	**1.09**
Spore Prep #6	35,211	1.16±0.18	1.14	**1.13**
Spore Prep #7	41,881	1.14±0.15	1.13	**1.14**
Spore Prep #8	38,027	1.12±0.15	1.11	**1.11**
Spore Prep #9	38,408	1.14±0.15	1.13	**1.11**
Spore Prep #10	32,498	1.13±0.14	1.12	**1.11**
Spore Prep #11	30,127	1.14±0.15	1.13	**1.12**
Spore Prep #12	34,198	1.12±0.14	1.11	**1.10**
Combined	833,044	1.14±0.18	1.12	**1.12**
B. thuringiensis Al Hakam				
Spore Prep #1	76,998	1.23±0.17	1.20	**1.19**
Spore Prep #2	9,264	1.43±0.71	1.25	**1.18**
Spore Prep #3	12,468	1.45±0.71	1.26	**1.19**
Spore Prep #4	86,499	1.22±0.14	1.20	**1.19**
Spore Prep #5	101,021	1.21±0.17	1.18	**1.19**
Spore Prep #6	71,097	1.22±0.17	1.19	**1.18**
Spore Prep #7	47,690	1.53±0.11	1.29	**1.20**
Spore Prep #8	27,918	1.48±0.64	1.27	**1.19**
Spore Prep #9	24,181	1.63±0.93	1.30	**1.19**
Spore Prep #10	75,728	1.20±0.15	1.18	**1.19**
Spore Prep #11	74,948	1.21±0.16	1.19	**1.19**
Spore Prep #12	37,355	1.43±0.57	1.24	**1.19**
Spore Prep #13	85,737	1.20±0.17	1.18	**1.19**
Spore Prep #14	43,160	1.26±0.38	1.16	**1.13**
Combined	**1,560,000**	**1.28±0.38**	**1.20**	**1.19**

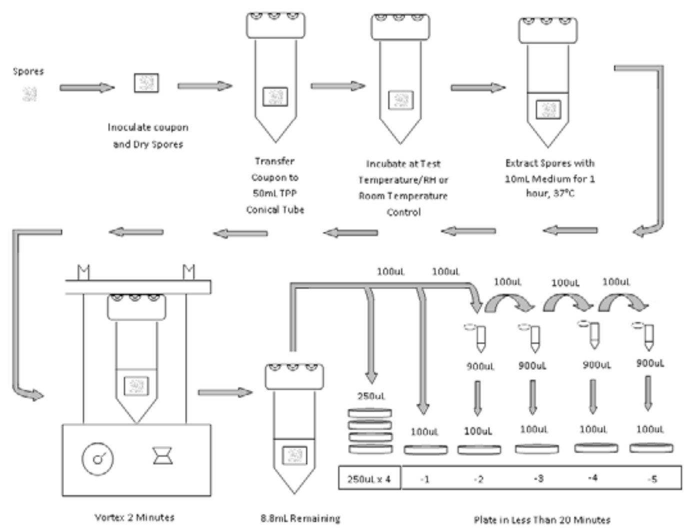
Hot Humid Air Test Method Development

Buhr et al. (2012)



Tier I, II, III – Methods

Buhr et al. (2012)



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Hot Humid Air - Tier I Summary

<u>Brooks AFB, ECBC, NSWC-Dahlgren</u>

- Spore QA and reproducibility was demonstrated
- Environmental chambers and TPP conical tubes worked
- Hot Humid Air was an effective decontaminant against *Bacillus anthracis* spore
- *Bacillus thuringiensis* Al Hakam showed promise as a fieldable simulant – number of test strains down-selected for Tier II

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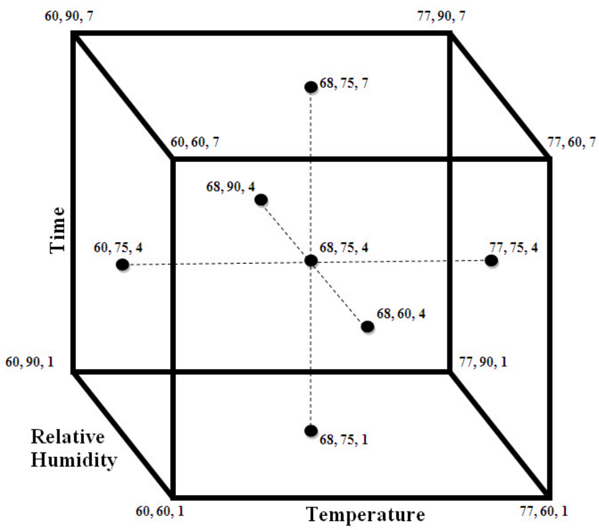
Tier II – Design of Experiments for Clean Spores

Buhr et al. (2012)



- 19 Test Runs
- 1,330 Total Test Samples
- 1,330 Total Test Controls
- 6 materials
- 2 strains
- 5 independent spore preps per strain per material for each run

Temp – 60, 68, 77° C
140, 155, 170° F
RH – 60, 75, 90%
Time – 1, 4, 7 Days

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Tier III - Design of Experiments

Buhr et al. (2015)

Tier II –
1. Clean Spores

- 19 Test Runs
- 1,330 Test Samples
- 1,330 Test Controls

Temp – 60, 68, 77° C
140, 155, 170° F
RH – 60, 75, 90%
Time – 1, 4, 7 Days

Tier III –
2. Spores + Kaolin
3. Spores + Spent Sporulation Medium + Humic Acid

- 38 Test Runs
- 2,660 Test Samples
- 2,660 Test Controls

Temp – 55, 65, 75° C
131, 149, 167° F
RH – 70, 80, 90%
Time – 1, 2, 3 Days

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Tier III – A Data Table

Spore inactivation of *B. anthracis* ΔSterne spores mixed with kaolin

Buhr et al. (2015)

B. anthracis ΔSterne; 13 independent runs; 6 independent runs; 5 independent tests per coupon per run

Log survival out of 7.1±0.1 logs of live spores inoculated (CFU) for 13 runs; and 7.2±0.2 logs of live spores inoculated (CFU) for 6 runs.

		90% RH	90% RH	90% RH	80% RH	80% RH	80% RH	70% RH	70% RH	70% RH
Material	Temp (° C)	1 day	2 days	3 days	1 day	2 days	3 days	1 day	2 days	3 days
Wiring Ins	75	0.0±0.0	NA	0.0±0.0	NA	0.0±0.0	NA	0.1±0.2	NA	0.0±0.0
Wiring Ins	65	NA	0.0±0.0	NA	2.7±1.9	0.1±0.2	0.0±0.0	NA	2.1±1.0	NA
Wiring Ins	55	6.5±0.9	NA	2.2±2.5	NA	6.6±0.3	NA	6.8±0.4	NA	6.5±0.4
APC	75	0.0±0.0	NA	0.0±0.0	NA	0.0±0.0	NA	2.0±1.8	NA	0.1±0.2
APC	65	NA	0.3±0.2	NA	6.1±0.6	4.0±1.6	1.9±2.0	NA	5.8±0.8	NA
APC	55	6.8±0.5	NA	6.2±0.9	NA	7.0±0.2	NA	6.9±0.2	NA	6.9±0.3
Anti-skid	75	0.0±0.0	NA	0.0±0.0	NA	0.0±0.0	NA	2.0±1.8	NA	0.0±0.0
Anti-skid	65	NA	0.0±0.0	NA	5.2±1.2	1.9±1.6	0.3±0.3	NA	4.0±2.3	NA
Anti-skid	55	6.8±0.4	NA	5.6±1.1	NA	6.9±0.4	NA	7.0±0.2	NA	6.8±0.2
Plastic	75	0.0±0.0	NA	0.0±0.0	NA	0.0±0.0	NA	0.0±0.0	NA	0.0±0.0
Plastic	65	NA	0.0±0.0	NA	0.9±0.6	0.1±0.2	0.0±0.0	NA	1.0±0.5	NA
Plastic	55	5.7±1.4	NA	0.2±0.3	NA	5.8±1.0	NA	6.8±0.5	NA	6.1±0.7
Nylon	75	5.9±0.1	NA	1.0±1.2	NA	5.6±0.6	NA	7.0±0.2	NA	6.9±0.2
Nylon	65	NA	6.8±0.4	NA	7.2±0.2	6.9±0.1	6.6±0.2	NA	7.1±0.2	NA
Nylon	55	7.2±0.2	NA	7.0±0.1	NA	7.1±0.4	NA	7.1±0.2	NA	7.0±0.3

APC - Aircraft Performance Coating

NA - not available, not tested for DOE

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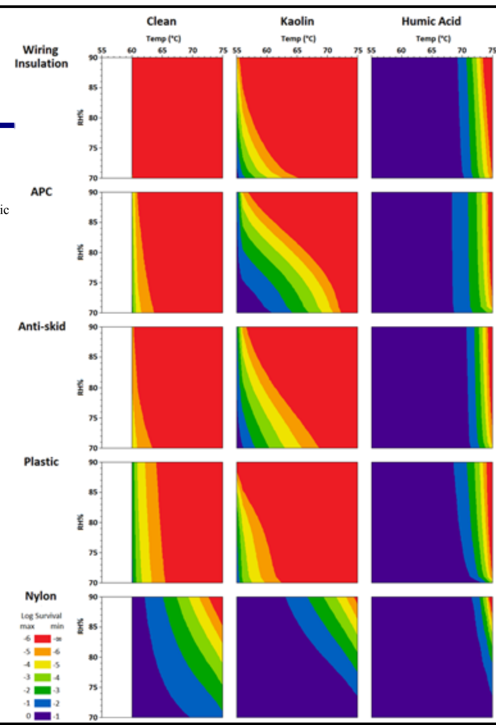
NAVSEA WARFARE CENTERS DAHLGREN

B. anthracis ΔSterne Figures. Models with a 90% statistical probability of *B. anthracis* ΔSterne spore inactivation for clean spores, spores mixed with kaolin and spores mixed with humic acid + SSM dried on to wiring insulation, APC, anti-skid, plastic and nylon after three d incubation in hot humid air. Areas are represented as > 6-$\log_{10}$ (red), 5-6 $\log_{10}$ (orange), 4-5 $\log_{10}$ (yellow), 3-4 $\log_{10}$ (green), 2-3 $\log_{10}$ (dark green), 1-2 $\log_{10}$ (blue), <1 $\log_{10}$ (dark blue) spore inactivation.

Buhr et al. (2015)



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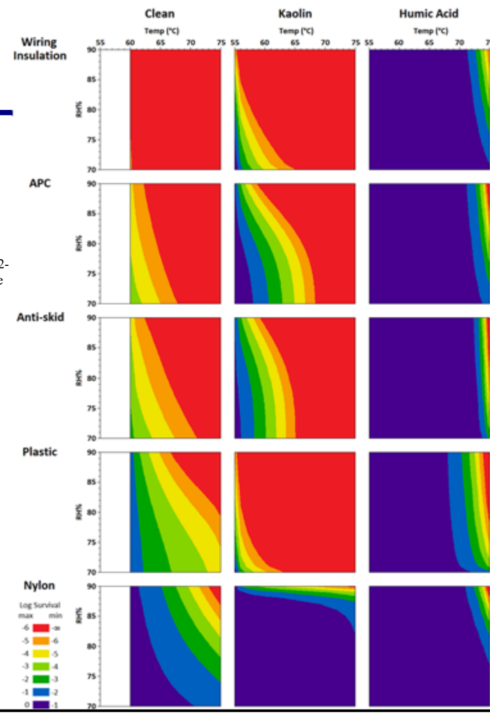
B. thuringiensis Al Hakam figures. Models with a 90% statistical probability of *B. thuringiensis* Al Hakam spore inactivation for clean spores, spores mixed with kaolin and spores mixed with humic acid + SSM dried on to wiring insulation, APC, anti-skid, plastic and nylon after three d incubation in hot humid air. Areas are represented as > 6-$\log_{10}$ (red), 5-6 $\log_{10}$ (orange), 4-5 $\log_{10}$ (yellow), 3-4 $\log_{10}$ (green), 2-3 $\log_{10}$ (dark green), 1-2 $\log_{10}$ (blue), <1 $\log_{10}$ (dark blue) spore inactivation.

Buhr et al. (2015)



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NAVSEA WARFARE CENTERS DAHLGREN

JBADS – Field Demonstration Experimental Design

Buhr et al. (2015)

Figure 1. Side view of the C-130 Cargo hold showing the sampling layout for low (L), middle (M) and high (H) sampling sites.

Front of the C-130 cargo hold — Back of the C-130 (cargo ramp)

H	A-D: 1	D: 11	D: 12	D: 13	D: 14	A-D: 4
M	D: 6	D: 7	A-D: 3 D: 8	D: 9		D: 10
L	A-D: 2	D: 15	D: 16	D: 17	D: 18	A-D: 5

A: *B. thuringiensis* Al Hakam: BIs from Triton
B: *B. thuringiensis* cry- HD-1: APC and Nylon coupons pre-inoculated with 1-2e7 spores mL^{-1}
C: APC coupons un-inoculated prior to dispersal, referred to as "blank" coupons
D: Swab of C-130 surfaces

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NAVSEA WARFARE CENTERS DAHLGREN

JBADS – Field Demonstration Experimental Design & Methods

Buhr et al. (2015)

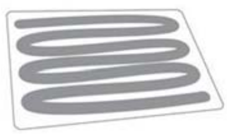
C	T	C	T
B	C	T	C
T	B	C	T

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

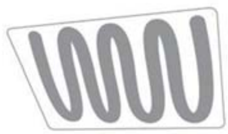
C	T
T	C

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

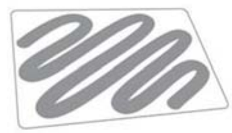
Swabbing
Step 1



Step 2



Step 3



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JBADS – Field Demonstration Methods

Buhr et al. (2015)

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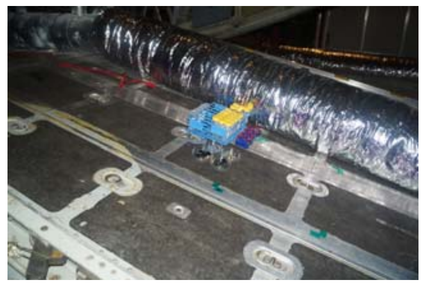
JBADS – Field Demonstration Methods

Buhr et al. (2015)



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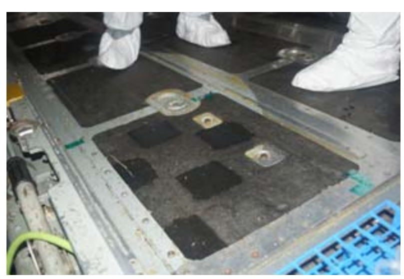
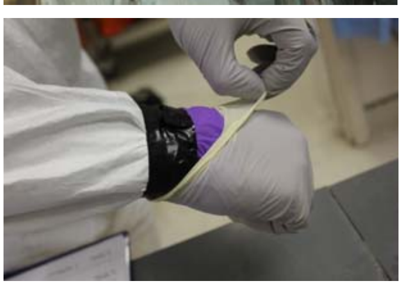
JBADS – Field Demonstration Methods

Buhr et al. (2015)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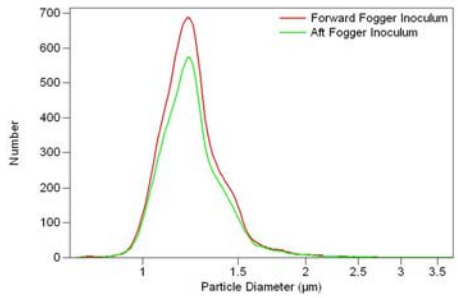
NAVSEA WARFARE CENTERS DAHLGREN

Spore Preparation Results

Buhr et al. (2015)

Forward Fogger Inoculum		Aft Fogger Inoculum	
Plate Titer	Coulter Titer	Plate Titer	Coulter Titer
1.24e8	1.33e8	1.19e8	1.09e8

Spore Inoculum	Spores Counted	Mean (μM)	Median(μM)	Mode (μM)
Forward Fogger Inoculum	16,590	1.241 ± 0.173	1.215	1.239
Aft Fogger Inoculum	13,678	1.242 ± 0.178	1.215	1.213



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Spore Dissemination Results

Buhr et al. (2015)

Dispersal ~1.6 spores per drop in the vapor, assuming all drops were equivalent in size. Actual dispersal was < 1.6 spores/drop.

Post-dispersal sampling of grids (control grids): range on all 18 grids was 8-10 logs of spores (<10 mg) per m^2. That is equivalent to ~5-6 logs on a 2cm x 2cm coupon.

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Decontamination Results

Buhr et al. (2015)

Triton BIs - All were negative

NSWCDD pre-inoculated APC - 0 CFU on 25 APC coupons with >7 logs/coupon
NSWCDD pre-inoculated nylon - 0 CFU on 25 nylon coupons with >7 logs/coupon

NSWCDD naked APC - 1 CFU on 26 APC coupons with ~6 logs/coupon
NSWCDD naked nylon - 0 CFU on 25 nylon coupons with ~6 logs/coupon

For the 18 cargo bay grids and 4 cockpit grids:
The total number of CFU on all 98 post-dissemination, pre-decontamination control swabs was 5.45e8 CFU, not accounting for any extraction efficiency. For the decontaminated samples, the plates were the detection limit since the dirt on the swabs prevented us from properly examining the tube turbidity.

Without outliers - 87/98 swabs were 0; There were a total of 47 CFU in 11 swabs over 7 grids (2, 1), 1, 1, (1,1,2), (2, 34), 1, 1 CFU (including the cargo bay and the cockpit). There was only 1 CFU from the dirty nylon seat. (7.06 logs of spore inactivation)

With outliers - 91/98 swabs were 0; There were a total of 10 CFU in 7 swabs over 4 grids (2, 1), (1,1,2), (2), 1 CFU (including the cargo bay and the cockpit). There was no CFU from the nylon seat since the outlier calculation kicked out the single CFU. (7.73 logs of spore inactivation)

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  Dr. John Crigler, Ed Prokop III, Harold Barnette – Statisticians
- Tier I Laboratories – Brooks AFB, ECBC – Dr. Johnathan Kiel
- Materials – Tim Provens and Bill Culhane at Wright-Patterson AF
- Dstl – Dr. Alistair Bishop
- ERDC – Dr. Martin Page and many other collaborators
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- International Bacillus ACT community; Dr. Paul Jackson

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Domestic Self-Help Clean-up of Biological Material in the Indoor Environment

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Alion Science & Technology, Durham, NC

2016 EPA International Decontamination
Research and Development Conference
Durham, NC; November 3, 2016

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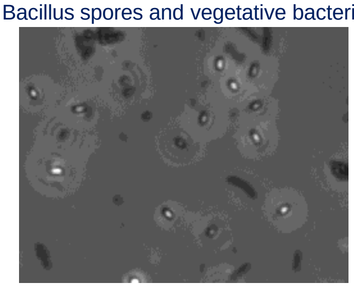
[‡] Currently at Wake County Public School System, Cary, NC

Wide Area Aerosolized Biological Attack in City

- Potential to impact 10s-of-thousands
- Agent can spread beyond initial release point
- Latency of exposure to symptom onset
  - Opportunity to reduce impact if detection and response is rapid
  - Risk of spreading agent before aware
- Exposure to initial release is well studied
- Secondary exposure risks are less understood

Shamelessly borrowed from National Geographic

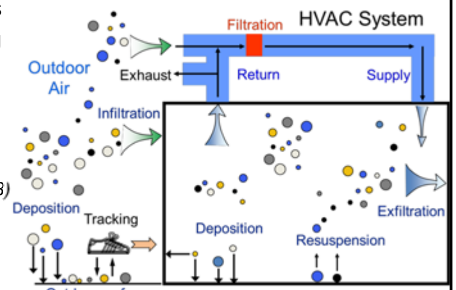
Bacillus spores and vegetative bacteria



Agent Fate and Transport Inside Buildings

- Outdoor release
  - Infiltration pressure gradients from wind and opening/closing doors & windows; aerosol passing through cracks, crevices, and openings
  - Tracking into the building on shoes and clothing
  - Building ventilation system
- Indoor release
  - Initial dispersion by the building ventilation
  - Tracking via shoes/clothing *(Thornburg et al., 2008)*
- Secondary transport
  - Shoes & clothing
  - Reaerosolization
  - HVAC
  - Decon activities

(Sextro, 2013; Thornburg, 2013)



Courtesy Rich Sextro

Self-Help Cleaning

- Areas outside main contamination/decon area will have agents due to reaerosolization/secondary transport

Risks do not stop at resident's front door

- Self-help cleaning: resident vacuuming, sweeping, mopping, wiping
- Need to study reaerosolization from indoor surfaces
  - Empower people to maintain health and safety of their homes
  - Understand what actions present the greatest risks of inhalation

Prior Clean-Up Risk Work

- Allergens and dust focus of most prior work; *Bacillus* size range, surface chemistry, and density likely different
  - 1 to 5 µm spore transport different
- Results vary significantly (Sehmel 1980; Qian 2014)
  - Ideal versus real particles and surfaces
  - Types of surfaces, test methods, data presentation
  - Sehmel showed different walking and sweeping study results vary over 6 orders of magnitude
- Reaerosolization studies
  - Walking similar to vacuuming
  - Vacuuming depends on type of vacuum
  - Resuspension fractions of 10^{-5} to 10^{-2}
- Reaerosolization due to hand wiping of surfaces not well studied

Empirical Study of Reaerosolization of Spores

Study Objectives:

1. Does wiping surfaces with Bacillus spores cause reaerosolization?
2. Is the reaerosolization more than other regular activities in the home?
3. Does the surface type and wiping method impact reaerosolization?

Design of the Empirical Study

- *Bacillus thuringiensis* var. *kurstaki* (*Btk*) as surrogate for *B. anthracis*
- Dry deposition of spores onto nonporous test surfaces
- Three common surfaces and three common wipes

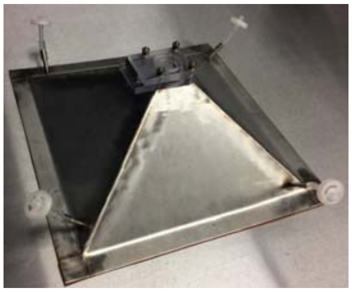
	Glass	Wood laminate	Linoleum
Dry paper towel	3	3	3
Electrostatic Swiffer	3	3	3
Lysol wet wipe	3	3	3

No endorsement of the brands is intended. Other brands may provide similar or different results.

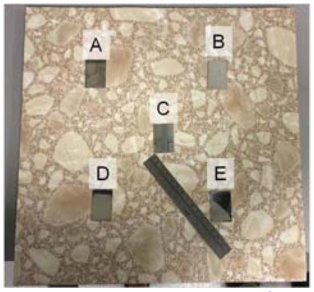
- Mechanical wiping device for consistency
- Viable spore counts of surface deposition compared to reaerosolization

Spore Deposition

- *Aerosolized Btk*
  - Spores dispersed in ethanol and Dymel 134a propellant
  - Meter-dose inhaler (MDI) canister to generate aerosol (Calfee et al., 2014)
    - Puff mass measured each time
    - CFU/Puff measured each experimental day
- Aerosol deposition pyramid on 35.5 cm (14”) square test surface
  - Puff of *Btk* spores introduced into pyramid and 18 hrs settling time
  - Sterile SS test coupons to estimate typical deposition in CFU/cm^2
    - One surface concentration test done daily



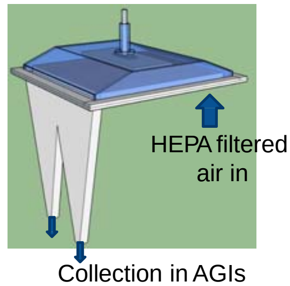
Aerosol deposition pyramid

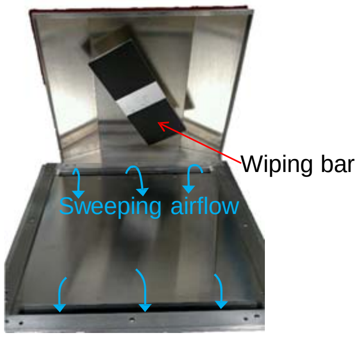


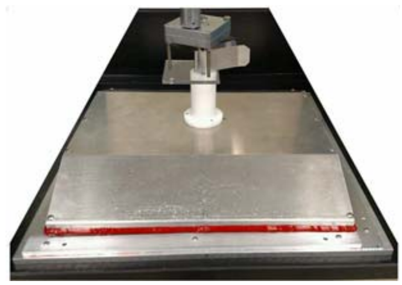
Coupons on test surface

Wiping Test Chamber Design

- Sweeping airflow to transport reaersolized spores
- Total sampling of sweeping flow
- Two direction wiping bar providing consistent force and wiping
  - 5 turns each clockwise, counter-clockwise







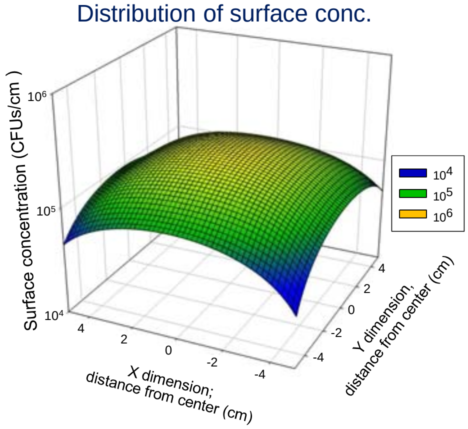
Sweeping Flow and Sampling

- Flow rate
  - 25 L/min
- Flow type and particle transport
  - Air flow: Laminar $Re_{air} \sim 148$
  - Particle transport: Stokes flow $Re_{2\ \mu m} = 0.02$, $Re_{10\ \mu m} = 0.1$
  - 2 µm particles will be collected before settling back to surface
- Spore sampling
  - Two AGI 4 mm (AGI-4); physical collection efficiency >98%
  - Sampling started 1 min before wiping and ran till 1 minute after wiping
  - Impinger buffer filtered and plated for direct counting of all spores

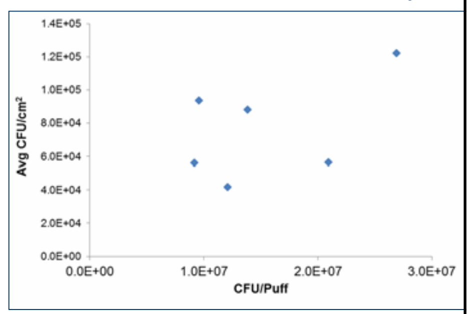
Results: Spore Deposition

- Surface concertation 7.6±3.0×10^4 CFU/cm^2
- Consistency of surface concentration per puff added uncertainty to our results

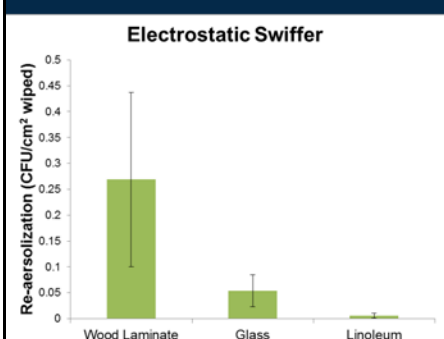
Distribution of surface conc.

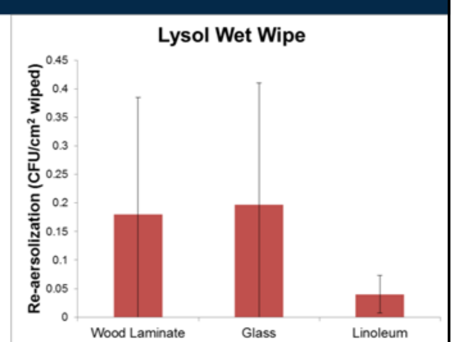


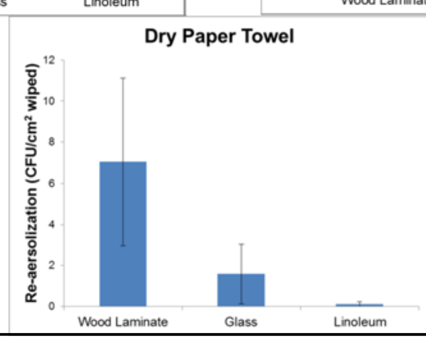
Puff and surface conc. consistency



Results: Reaerosolization Trends

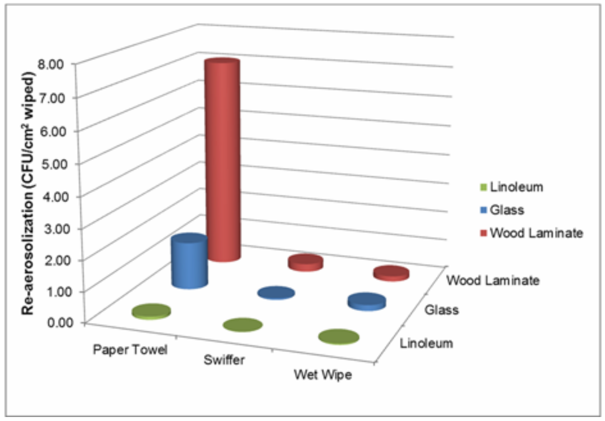






Perspective Comments on Reaerosolization Results

- Reaerosolization happens in all cases
- However, less than 0.02% of the viable spores were reaersolized
- Some indication that dry wiping has the highest risk
- *Btk* adhesion to the specific surface may play a role in reaerosolization risk



Conclusions

1. Does wiping surfaces with *Bacillus* spores cause reaerosolization?
   - Yes, *Btk* spores were reaerosolized for all surfaces and wipes tested
2. Is the reaerosolization more than other regular activities in the home?
   - Not likely
   - Results this study: ~0.02% of spores reaerosolized
   - Qian et al., 2014: 0.1% of spores reaerosolized due to walking in home
3. Does the surface type and wiping method impact reaerosolization?
   - There is some indication that dry wiping increases reaerosolization
     - Dry wiping of wood laminate reaerosolized significantly more spores
   - There is some indication that surface type influences spore adhesion
     - Linoleum had the lowest reaerosolized regardless of wipe type

Future Questions and Discussion

1. Should the public be advised to implement self-help cleaning activities?
   - Could self-help reduce burden on government agency performed cleanup?
   - Limited to specific wiping and/or vacuuming?
2. Can self-help cleaning activities reduce surface loading to “safe” levels?

Acknowledgements

Funding provided by EPA’s National Homeland Security Research Center under ORD Contract EP-D-10-070 WA4-26 to Alion Science & Technology and RTI International.

U.S. EPA has not reviewed this presentation. All content, opinions, or endorsements are strictly those of the authors and may not reflect official U.S. EPA policy.

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1

Use of the OECD Quantitative Method to Demonstrate the Susceptibility of Microbes to Sodium Hypochlorite

JORDAN ZAMBRANA, M.S. MPH

ASPPH/EPA FELLOW

2016 INTERNATIONAL DECONTAMINATION RESEARCH AND DEVELOPMENT CONFERENCE

2

Disclaimer

This information is distributed solely for the purpose of pre-dissemination peer review under applicable information quality guidelines. It does not represent and should not be construed to represent any agency determination or policy.

Presentation Outline

3

- Description of ASPPH Fellowship
- Concept of Microbial Hierarchy
  - Background
  - Study goals
  - Methodology and Experimental Design
  - Results
  - Conclusions

4

- The ASPPH/EPA Environmental Health Fellowship Program is an initiative between ASPPH and EPA designed to enhance the professional development of early career public health professionals
- Work with mentors to develop your professional skills and expertise in public health.

Background

5

- Microbial hierarchy describes the descending order of susceptibility of classes of microorganisms to a variety of factors. This study focuses on tolerance of selected microorganisms to sodium hypochlorite (NaOCl).
- While anecdotal evidence indicates the validity of the microbial hierarchy, data are needed to demonstrate the concept in a quantifiable standardized way.
- Use of the microbial hierarchy concept presents an opportunity to consolidate certain efficacy testing requirements while ensuring public health protection.
- Based on hierarchal concept described in EPA 2015 White Paper.
  - Meeting minutes for the U.S. Environmental Protection Agency (EPA) stakeholder workshop on October 7, 2015.
  - Organized list by proposed hierarchal class of EPA microbial agents has over 400 entries.

Background: Microbiological Hierarchy

6

Most Tolerant to NaOCl

- **Bacterial spores**: *Bacillus subtilis (ATCC#19659)* , *Clostridium difficile (ATCC#43598)*
- **Mycobacteria**: *Mycobacterium terrae (ATCC#15755)*
- **Small non-enveloped viruses**: eg. feline calicivirus
- **Fungi**: *Trichophyton mentagrophytes (ATCC#9533)*
- **Vegetative bacteria**:
  - **Gram-negative bacteria**: *Pseudomonas aeruginosa (ATCC#15442), Esherichia coli (ATCC#11229)*
  - **Gram-positive bacteria**: *Staphylococcus aureus*
- **Enveloped viruses**: ex. Influenza virus

Least Tolerant to NaOCl

* Organisms placed in order of data not conformance to the hierarchy

Methodology and Experimental Design

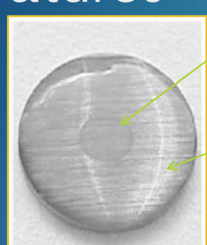
7

- The Organization for Economic Cooperation and Development (OECD) http://www.oecd.org/
- Based on test method ASTM 2197-11, the Standard Quantitative Disk Carrier Test Method.
- The OECD Quantitative Method was chosen because it can be used to test a wide range of microorganisms against antimicrobial substances.
- It is currently used for evaluating the efficacy of antimicrobial pesticides against *Clostridium difficile* and is being evaluated for efficacy testing with other microbes.
- The log reduction (LR) in viable microbes following treatment is generated and used to determine relative susceptibility of the test microorganisms to NaOCl.

OECD Quantitative Method

Key Features

8



10 µL dried inoculum

50 µL disinfectant

1 cm brushed stainless steel disk

Vial with inoculated carrier

Count colonies and determine log density for control and treated carriers.

Methodology and Experimental Design

9

- Test substance and Levels
  - Reagent grade Sodium Hypochlorite (NaOCl)
  - Each microorganism was tested starting at 200 ppm NaOCl until complete kill.
  - Complete kill is defined by no growth on membrane filters at dilutions of 10^0, 10^{-1}
  - Log Reduction - The difference in log count between control and treated carriers.
- Test Conditions
  - 5 minute contact time
  - Three part soil load
  - 375 ppm hard water as a diluent
- Target Control Counts and Replications
  - Range of 5-6 Logs of inoculum per carrier
  - 3 treated and 3 control carriers for each replicate (2-3 replicates)
- Data sources
  - Generated from current study
  - Previous collaborative studies

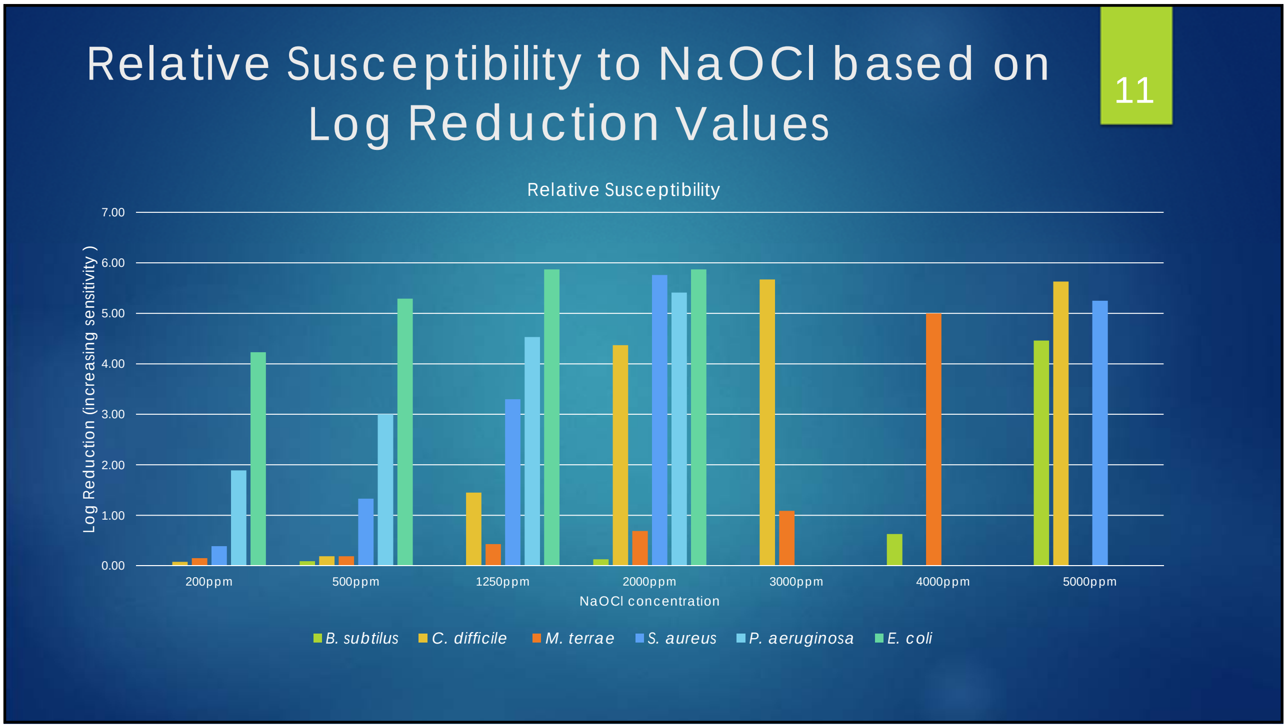
Results

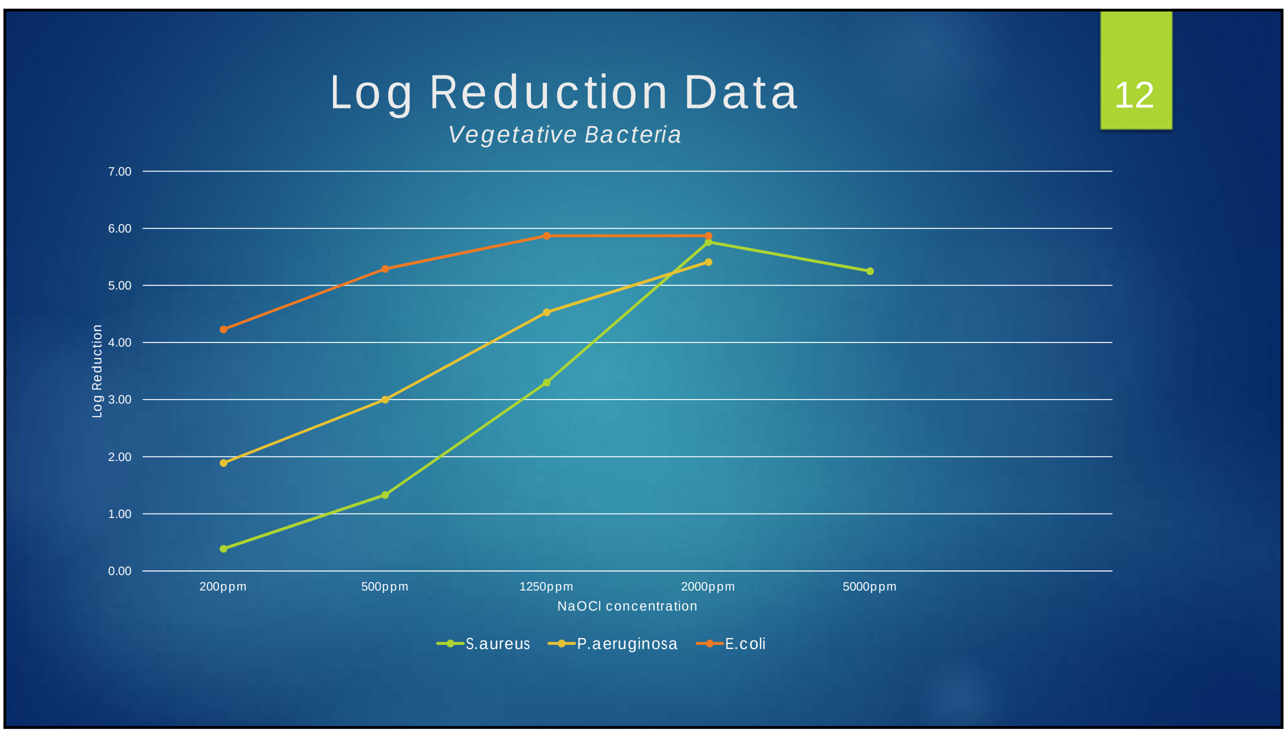
Control Carrier Counts

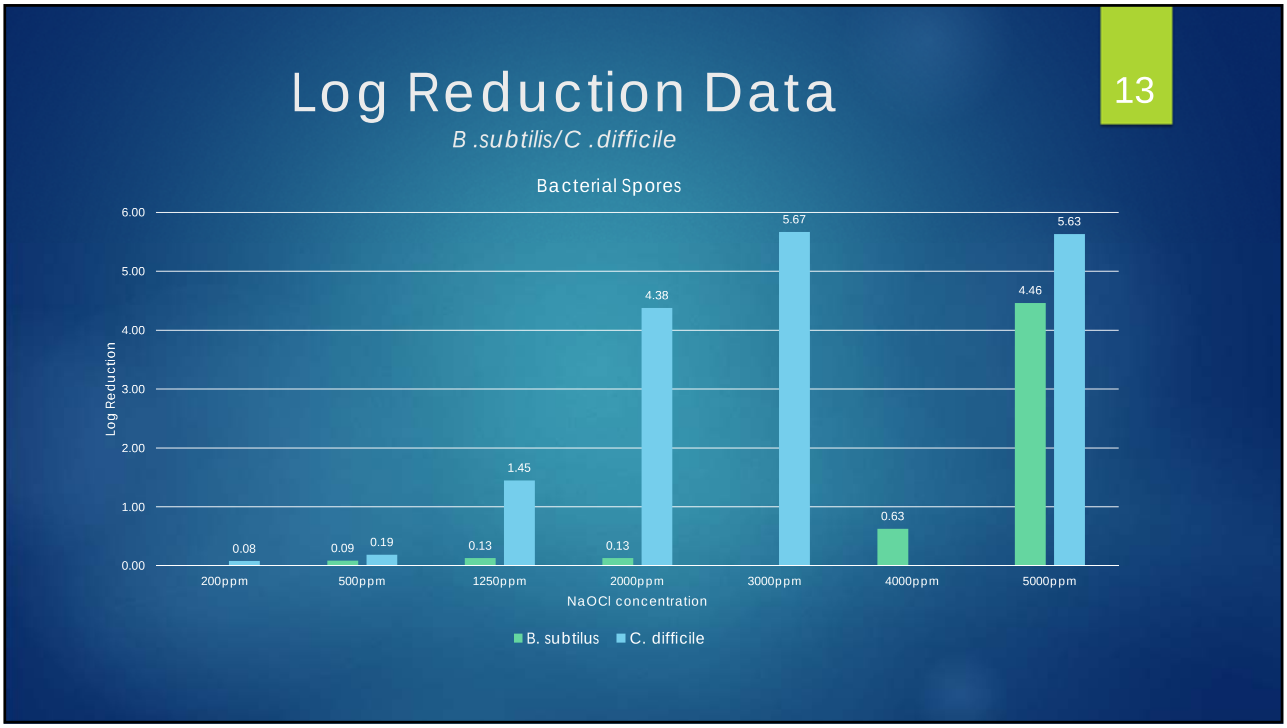
10

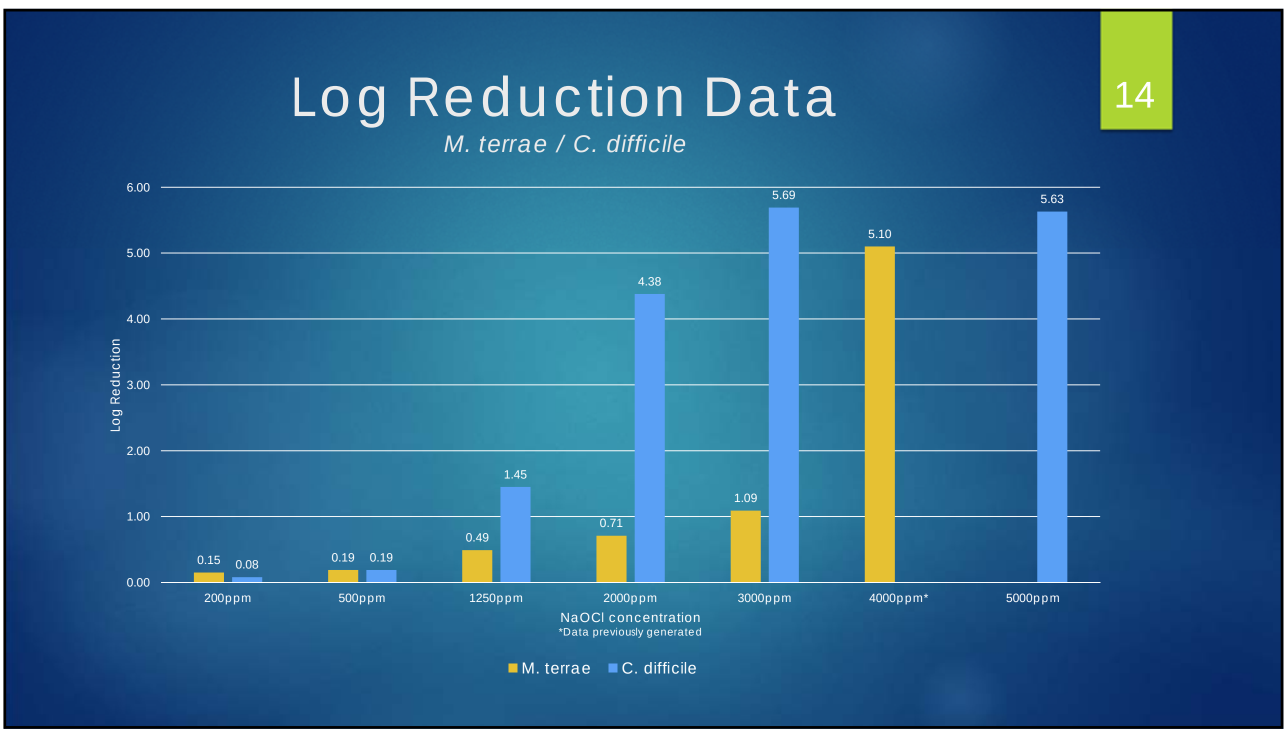
- Carrier control counts were standardized in order to normalize the log reduction assessments.
- The log reduction in the instance of complete kill would be equal to the control carrier counts.

Test Organism	Mean Control Carrier Count
B. subtilis	4.99
C. difficile	5.67
M. terrae	5.62
S. aureus	5.35
P. aeruginosa	5.24
E. coli	5.49


Relative Susceptibility to NaOCl based on Log Reduction Values
11
Relative Susceptibility
Log Reduction (increasing sensitivity)
7.00
6.00
5.00
4.00
3.00
2.00
1.00
0.00
200ppm
500ppm
1250ppm
2000ppm
3000ppm
4000ppm
5000ppm
NaOCl concentration
B. subtilus
C. difficile
M. terrae
S. aureus
P. aeruginosa
E. coli


Log Reduction Data
Vegetative Bacteria
12
Log Reduction
7.00
6.00
5.00
4.00
3.00
2.00
1.00
0.00
200ppm
500ppm
1250ppm
2000ppm
5000ppm
NaOCl concentration
S.aureus
P.aeruginosa
E.coli


13
Log Reduction Data
B .subtilis/C .difficile
Bacterial Spores
6.00
5.00
4.00
3.00
2.00
1.00
0.00
Log Reduction
0.08
0.09
0.19
0.13
1.45
0.13
4.38
5.67
0.63
4.46
5.63
200ppm
500ppm
1250ppm
2000ppm
3000ppm
4000ppm
5000ppm
NaOCl concentration
B. subtilus
C. difficile


14
Log Reduction Data
M. terrae / C. difficile
6.00
5.00
4.00
3.00
2.00
1.00
0.00
Log Reduction
0.15
0.08
0.19
0.19
0.49
1.45
0.71
4.38
1.09
5.69
5.10
5.63
200ppm
500ppm
1250ppm
2000ppm
3000ppm
4000ppm*
5000ppm
NaOCl concentration
*Data previously generated
M. terrae
C. difficile

Conclusions

15

- The control carrier counts for each of the test organisms were in the desired 5-6 log range.
- The data demonstrates the ability of the OECD Quantitative Method to elucidate the differential response of microorganisms to antimicrobial chemicals.
- In response to NaOCl, each microorganism tested appears to have a predictable LR profile which includes a point of inflection towards complete kill.
- All microorganisms test were completely susceptible to NaOCl at concentrations of 5000 ppm or above.
- In response to NaOCl, there was a general hierarchal order of susceptibility which agrees with microbial hierarchy concept.

Future Steps

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- Testing of other bacterial spores, antibiotic resistant bacteria, virus and fungi
- Testing of other antimicrobials chemicals such as quaternary ammonium compounds, phenolic compounds, hydrogen peroxide and peracetic acid.

Acknowledgments

17

- I would like to acknowledge and thank everyone at EPA Microbiology Laboratory Branch who helped with and worked on this project.
- Susan Lawrence
- Dr. Stephen Tomasino
- Rebecca Pines
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- Luisa Samalot
- Jack Deboy

United States Environmental Protection Agency

2016 U.S. EPA International Decontamination Research and Development Conference

Thursday, November 3, 2016

Concurrent Sessions 5

Livestock Remediation Options

A Field Trial of Aboveground Burial as a Tool for Managing Animal Carcasses Following a Disease Outbreak

2016 EPA International Decontamination Research and Development Conference
Durham, North Carolina
November 1 – 3, 2016

Project Team

- **Gary A. Flory**, Virginia Department of Environmental Quality
- **Robert Peer**, Virginia Department of Environmental Quality
- **Bobby Clark**, Virginia Cooperative Extension
- **Machebe Ndubuisi**, JSPS Fellow, Faculty of Agriculture, Kindai University Japan
- **Thao Le**, ORISE Fellow, USEPA

Overview:

- Purpose of the Project
- Environmental Impact of Carcass Disposal Methods
- Potential Benefits of Aboveground Burial
- Field Demonstration of Results
- Conclusions and Design Recommendations

Purpose of the Project

- Demonstrate aboveground burial
- Evaluate design variations
- Assess effectiveness
- Assess environmental impact
- Recommend final design

Environmental Impact of Existing Disposal Methods

History of Animal Carcass Disposal

Burial

Incineration

Landfilling

Rendering

Potential Benefits of Aboveground Burial

- Low cost
- Simple
- Rapid execution
- Keeps infected material on the farm
- Minimize the need for off-site resources

- Flexible
  - Temporary/Permanent
  - Vary plant species
    - Regional
    - Seasonal
- Can utilize commonly available farm equipment and resources
  - Skid steers loaders
  - Silage, bedpack, shavings, etc.

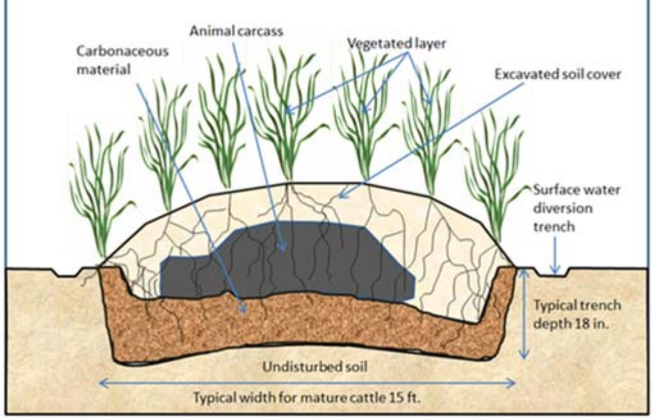
- Compact footprint
  - 45 ft^2 per cow
  - 100 mature dairy cows = 0.1 acre (12 ft. by 416 ft.)

Minimize Environmental Impact

- Shallow trench depth – greater separation from the groundwater table
- Add carbon to bind contaminants
- Vegetated layer
  - Stabilizing cap
  - Transpire moisture
  - Uptake nutrients

General Design

Figure 1. Cross Section of Aboveground Burial System



Design Variations

- Design #1
  - 18 inch depth/ woodchip base
- Design #2
  - 18 inch depth/ loose soil base
- Design #3
  - Woodchip base on ground surface
- Design #4
  - 28 inch depth/ silage base

Excavate the Trench

Add Carbon Base

Woodchips, silage, etc.

Place Carcasses on the Base

Cover Carcasses with Carbon (Optional)

Cap with Excavated Soil and Plant Vegetative Cover

Soil cap ~2 feet thick

Establish Vegetative Cover

Field Demonstration Results

Burial Assessment

2-Month	12- Month
Design 1, 2, and 3 had 90% decomposition	Soil samples were collected beneath each design and in 2 background samples

2-Month

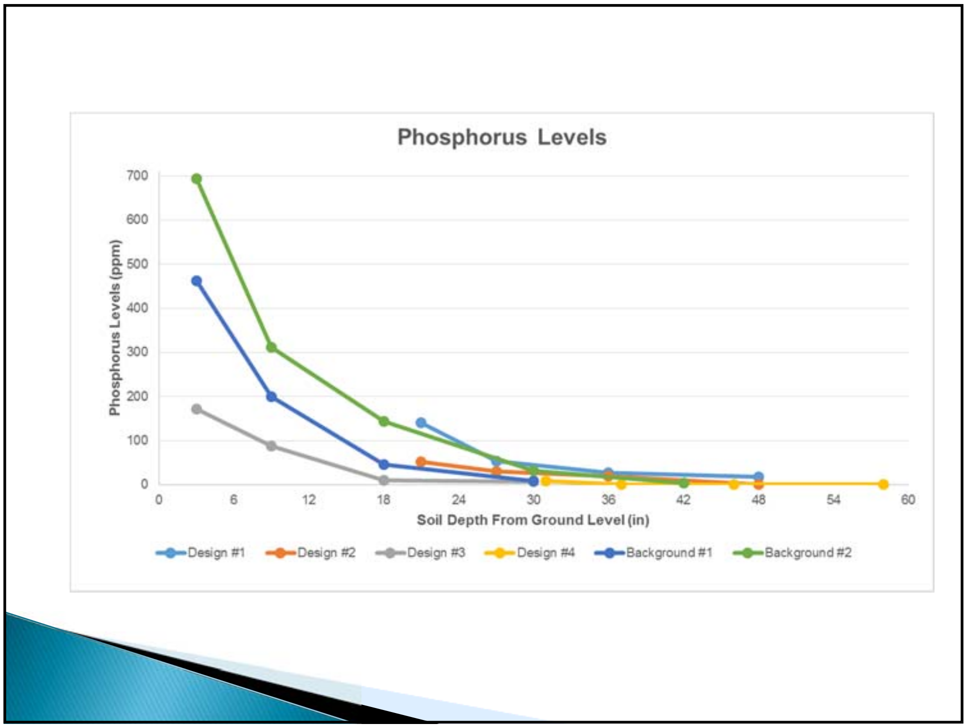
- Design 1, 2, and 3 had 90% decomposition
- Design 4 had 60% decomposition
- Vegetative cover
  - Effective for stabilization and erosion control

12- Month

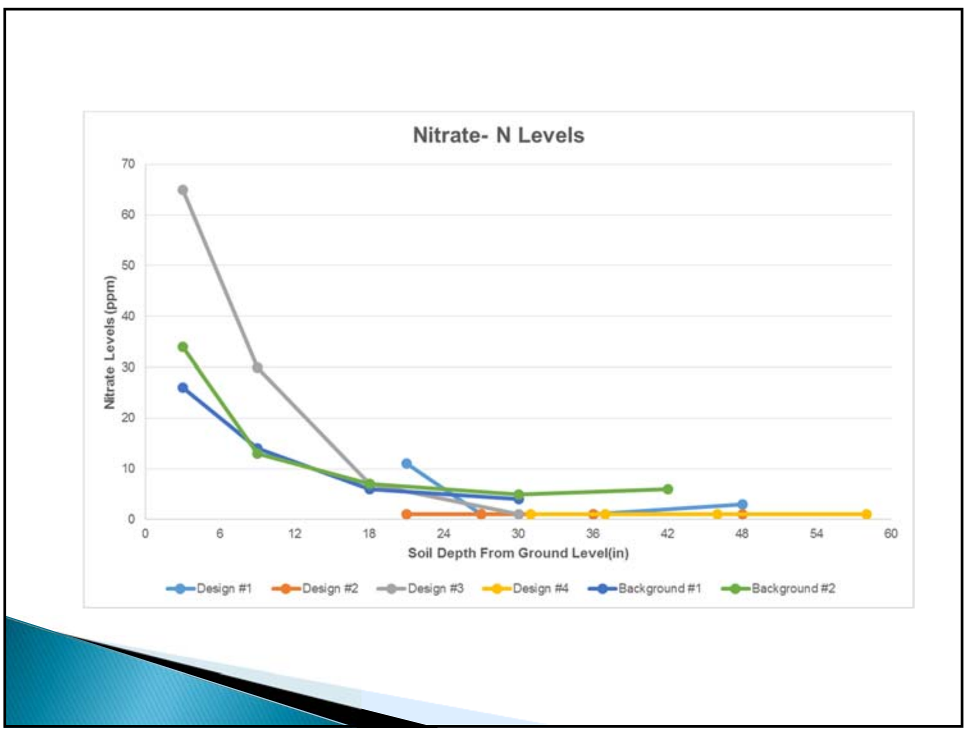
- Soil samples were collected beneath each design and in 2 background samples
  - Assessed nutrient levels
- Assessed carcass decomposition
  - 95% in design 1, 2, and 3
  - 60% in design 4

Nutrient Assessment

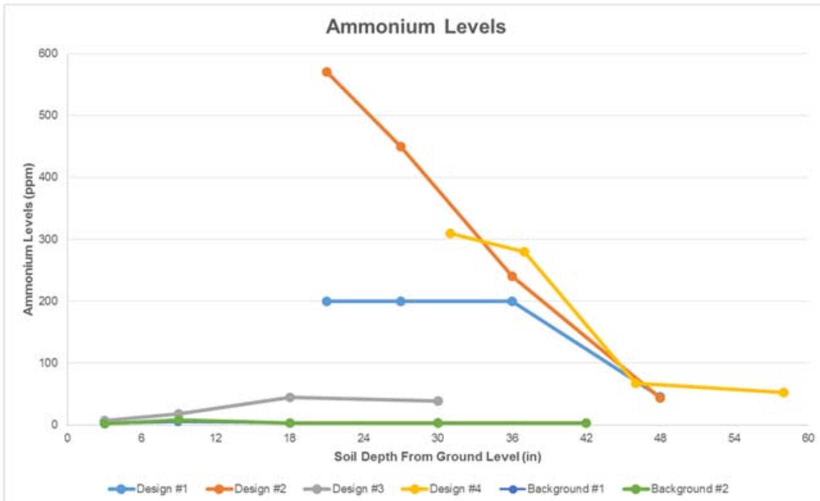
- Most soil nutrients comparable to background samples throughout the soil profile
  - pH, phosphorus, organic matter, estimated nitrogen release, potassium, calcium, magnesium
- Other nutrient levels are elevated within the first 24 inches from the start of the trench
  - Nitrogen i.e. nitrate-N and ammonium-N



Phosphorus Levels
Phosphorus Levels (ppm)
700
600
500
400
300
200
100
0
0
6
12
18
24
30
36
42
48
54
60
Soil Depth From Ground Level (in)
Design #1
Design #2
Design #3
Design #4
Background #1
Background #2



Nitrate- N Levels
Nitrate Levels (ppm)
70
60
50
40
30
20
10
0
0
6
12
18
24
30
36
42
48
54
60
Soil Depth From Ground Level(in)
Design #1
Design #2
Design #3
Design #4
Background #1
Background #2



Conclusions and Design Recommendations

- Soil characteristics and depth to groundwater are critical siting criteria
- Design Recommendation
  - 20-24 inch trench depth
  - 8 inch carbon base
  - Cap of excavated soil
  - Vegetated with regionally appropriate species

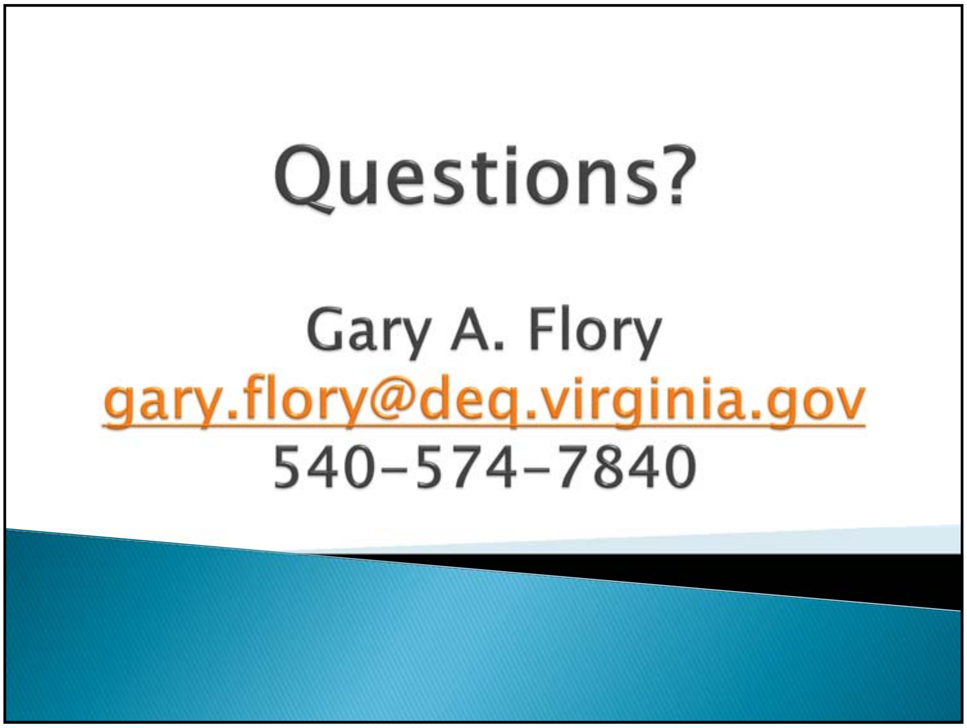
Next Steps

- Future projects to further evaluate nutrient migration
- Continue to work with partners at NRCS and APHIS
- Controlled implementation
- Prepare Standard Operating Procedures

Take Home Points

- Practical alternative to traditional burial pits for small to medium sized operations
- Faster decomposition than traditional burial – more aerobic activity
- Decreased risk of groundwater contamination

Special thanks to cooperating producer Mr. Kenneth Knicely who graciously shared his property, equipment and, most importantly, his extensive knowledge of animal mortality management.


Questions?
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Viral Bio-Threat Agent Persistence in US Landfill Leachate

Megan W. Howard, Nola Bliss, Teara Nil, David Guistino, Jazmine Quinn, Andrew Bullard; Battelle Memorial Institute
Paul Lemieux, Eric Rhodes, Worth Calfee, Susan Thorneloe; US EPA, Office of Research and Development
Mario Ierardi; US EPA, Office of Resource Conservation and Recovery
Douglas Hamilton; Oak Ridge Institute of Science and Education
Mark Sobsey; University of North Carolina at Chapel Hill

EPA Decontamination International Conference Research and Development Conference
RTP, North Carolina, Nov 1-3, 2016

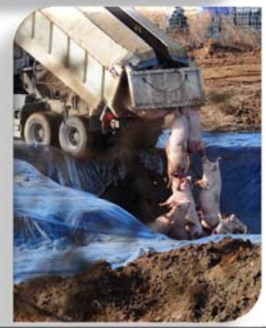
Disclaimer

- The U.S. Environmental Protection Agency (EPA), through its Office of Research and Development's National Homeland Security Research Center, funded and managed this technology evaluation through Task Order 0002 of Contract No. EP-C-15-002 with Battelle. Mention of trade names or commercial products does not constitute endorsement or recommendation for use of a specific product.

Human and animal waste containing viruses enter into our landfills daily.

Municipal Solid Waste (MSW landfills) dominate US solid waste disposal.

Aerosol-generation, manual sorting and other practices potentially expose workers.



Viruses, including HPAI, persist on glass and galvanized metal surfaces for >13 days depending on environment.[1]

Viral persistence can lead to a risk to human health and the environment.

We still have limited understanding of viral persistence in landfill leachate.

1: Wood et al. ES&T 44(19):7515-7520 (2010)

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Study Scope

Current disposal practices for building materials, animal carcasses, non-patient waste, diapers, etc. can result in infectious viral agents placed into US Landfills. Residual agents in materials from natural outbreaks, terrorist or unintentional events, etc. may persist long enough to potentially expose workers. Viral persistence in landfills can lead to a risk to the environment and the public.

Do viruses pose a threat to environmental and human health once introduced into a landfill?

Can viruses in landfills persist in leachate long enough that they are a risk to the environment and the public?

How does the persistence of viruses in leachate vary between landfills?

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Study Landfills

Characteristic	Landfill A	Landfill B	Landfill C
Waste Acceptance Rate	In 2014, accepted approximately 3,200 tons per day	3,500 to 5,000 tons per day, Approximately 1,000,000 tons of waste received in 2014	Average 1,400 tons/day
Footprint	100 acres state permitted	283 acres state permitted	168 acres state permitted
Year Opened	1997	1995	1995
Expected Closure Date	2023 or 2024 (could extend by 25 years via expansion)	2030 to 2045	Information not provided
Gas collection system	Yes	Yes (~190 gas collection wells/points)	No

Leachate Accumulation Sites at each landfill

Landfill A

Landfill B

Landfill C

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Leachate Characterization

Analyte	Leachate A	Leachate B	Leachate C
Metals (mg/L)			
Calcium	11.6	200	312
Iron	6.36	17.4	31.5
Magnesium	130	84.3	297
Manganese	0.0468	0.152	2.26
Potassium	468	260	937
Sodium	1,880	1,500	2,360
Zinc	0.140	0.0199	0.0711
Biological Oxygen Demand (mg/L)			
BOD	187	2,020	2,350
Anions (mg/L)			
Chloride	2,070	1,980	2,810
Nitrate-N	4.00	3.08	<1.00
Sulfate	3.19	10.1	33.0
Total Alkalinity as $CaCO_3$ (mg/L)			
Total Alkalinity	6,100	2,600	8,040
Ammonia as Nitrogen (mg/L)			
Ammonia	1,050	386	1,370
Chemical Oxygen Demand (mg/L)			
COD	1,500	2,470	9,060
pH (Standard Units)			
pH	7.76	7.06	7.55
pH (field)	7.88	7.14	7.36
Oxidation Reduction Potential (millivolts)			
ORP (field)	47.4	-60.7	-96.8
Temperature (ºC)			
Temperature (field)	21.8	25.0	20.0
Total Dissolved Solids (mg/L)			
TDS	6,680	5,980	13,500
Total Organic Carbon (mg/L)			
TOC	448	796	2,960
Total Suspended Solids (mg/L)			
TSS	12.3	82.0	72.0
Visual Observations			
Color	yellow	brown	dark brown
Particulates	not significant	significant	significant

Microbial Abundance in Landfill Leachate

Test	Start Date	Leachate	pH	CFU/mL	
				Bacteria	Fungi
Initial Test	2/15/16	A	8.02	$3x10^6$ (3-5 colony types)	$3x10^2$ (3 colony types)
		B	7.37	$9x10^5$ (3-4 colony types)	$8x10^4$ (10-20 colony types)
		C	7.73	$8x10^5$ (8-10 colony types)	$9x10^3$ (10-20 colony types)
Secondary Test	4/27/16	A	ND	$>3x10^7$ [a] (~5 colony types)	$6x10^5$ (3 colony types)
		B	ND	$1x10^6$ (4 colony types)	$6x10^5$ (5-10 colony types)
		C	ND	$5x10^6$ (~5 colony types)	$3x10^3$ (~10 colony types)

ND= not determined (note: pH of the leachates was measured in July, 2016 and did not shown discernible changes, having pH readings of 8.09, 7.36, and 7.55 for Leachates A, B, and C, respectively.)

[a]: Colonies on all plates of all dilutions returned were too numerous to count. As the maximum number of countable colonies per plate is 300, the CFU/mL of the sample is greater than this quantity.

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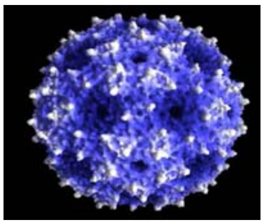
Approach

Survival of three surrogate viral agents in leachate were determined under controlled conditions to assess persistence risk.

MS2

non-enveloped ssRNA Bacteriophage

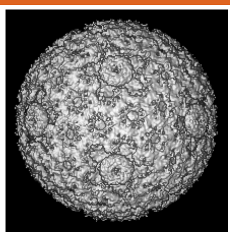
Surrogate for: Polio, Rotavirus, FMD



Phi6

Enveloped dsRNA Bacteriophage

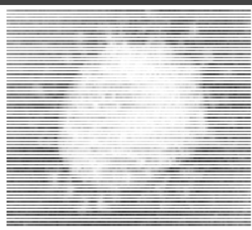
Surrogate for: Rotavirus, Influenza, SARS, Ebola



TGEV

Enveloped ssRNA virus, *alphacoronavirus*

Surrogate for: SARS, MERS, Influenza, Ebola



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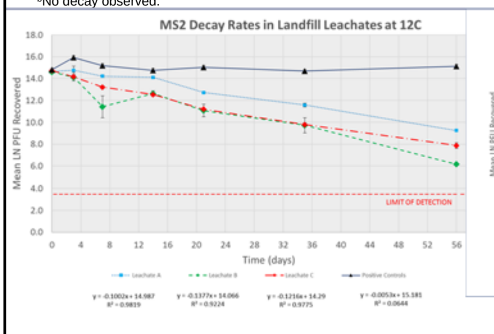
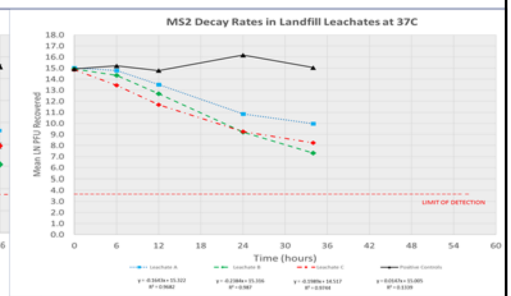
Viral Persistence (MS2, non-enveloped)

	12°C			37°C		
	Slope	D-Value (days)	Persistence[a] (days)	Slope	D-Value (days)	Persistence[a] (days)
Leachate A	-0.1002	10.0	113	-0.1643	0.3	3
Leachate B	-0.1377	7.3	75	-0.2384	0.2	2
Leachate C	-0.1216	8.2	87	-0.1989	0.2	2
PBS	-0.0053	188.7	ND[b]	0.0147	ND[b]	ND[b]

[a]Calculated time in days at which measured linear decay rate intersects with assay limit of detection.
[b]No decay observed.





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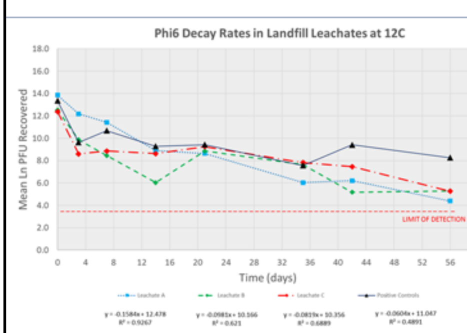
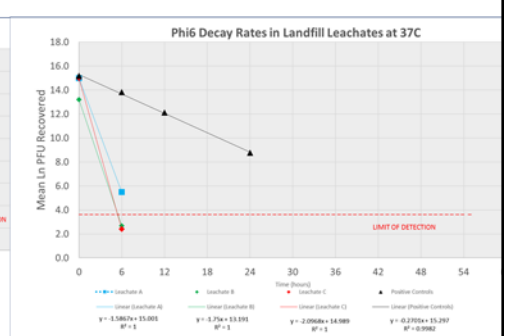
Viral Persistence (Phi6, enveloped)

Matrix	12°C			37°C		
	Slope	Measured D-Value (days)	Persistence[a] (days)	Slope	Measured D-Value (days)	Persistence[a] (days)
Leachate A	-0.1584	6.3	55	-1.5867	0.03	0.3
Leachate B	-0.0981	10.2	66	-1.7500	0.02	0.2
Leachate C	-0.0819	12.2	81	-2.0968	0.02	0.2
PBS	-0.0604	16.6	122	-0.2701	0.15	1.8

[a]Calculated time in days at which measured linear decay rate intersects with assay limit of detection





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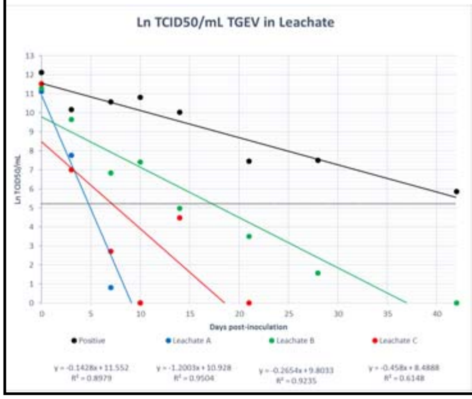
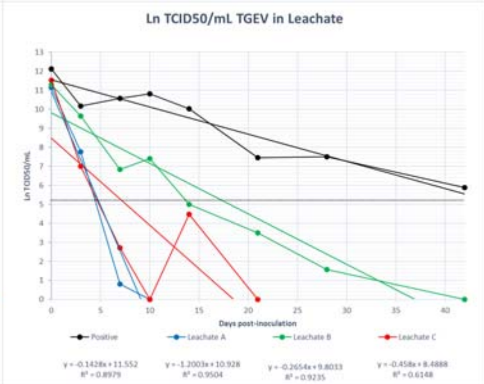
Viral Persistence (TGEV, enveloped)

12°C			
Matrix	Slope	Measured D-Value (days)	Persistence [a] (days)
Leachate A	-1.2003	0.8	4.6
Leachate B	-0.2654	3.8	16.6
Leachate C	-0.4580	2.2	6.7
Incomplete EMEM Medium (Control)	-0.1428	7.0	43.1

[a] Calculated time in days at which measured linear decay rate intersects with assay limit of detection





Summary Findings

Virus	Temperature Test Condition	Calculated Days Until No Longer Detected[a]			
		Leachate A	Leachate B	Leachate C	Control Matrix[b]
Transmissible Gastroenteritis Virus (enveloped RNA virus)	12°C	5	17	7	43
MS2 Bacteriophage (non-enveloped phage)	12°C	113	75	87	NR[c]
	37°C	3	2	2	NR[c]
Phi6 Bacteriophage (enveloped phage)	12°C	55	66	81	122
	37°C	0.3	0.2	0.2	2

Virus	Temperature Test Condition	Measured D-value in Days			
		Leachate A	Leachate B	Leachate C	Control Matrix[b]
Transmissible Gastroenteritis Virus (enveloped RNA virus)	12°C	1	4	2	7
MS2 Bacteriophage (non-enveloped phage)	12°C	10	7	8	189
	37°C	0.3	0.2	0.2	NR[c]
Phi6 Bacteriophage (enveloped phage)	12°C	6	10	12	17
	37°C	< 0.1	< 0.1	<0.1	0.15

[a] Calculated time (days) when measured linear decay rate intersects with assay limit of detection.
[b] TGEV in sterile incomplete Eagle's Minimum Essential Medium (EMEM) medium; bacteriophage in sterile phosphate buffered saline.
[c] No decay, or minimal, observed within incubation period tested

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Conclusions and Implications

- Persistence time decreases rapidly with increasing temperature for enveloped and non-enveloped viruses.
- Persistence in leachate is variable. Choice of test agents is critical for accurate risk estimate and prediction.
- Viral Persistence at 12ºC is on the order of days to months, suggesting that viral Biological Warfare Agents may persist in landfill matrices for extended times.

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Objectives of Field Test

Side-by-side comparison of HPAI decontamination methods

- Seven-day heat treatment at 100-120° F
  - ✓ Three consecutive days ≥ 100° F (**USDA**)
- Chlorine dioxide (ClO_2) fumigation, 1-day
  - ✓ CT 25,000 ppm_v-hr, 75° F, 80% RH (***SABRE*** **bioWALL**)

Employ advanced BIs to compare treatment efficacies

- Discretely quantifiable, spatially distributed, biocidal efficacy
  - ✓ Surrogate-based approach using custom-manufactured coupons
- Various porous & non-porous building materials
  - ✓ Account for differential virucidal/sporicidal efficacy on diverse surfaces
  - ✓ Whole-coupon extraction for enhanced recovery of viable organisms

Analyze time & cost considerations from stakeholder perspective

- Impact of environmental conditions (fall / winter seasons)

(1)

2015 HPAI Response | Efficacy Criteria | Operational Challenges | Economics | Lessons Learned

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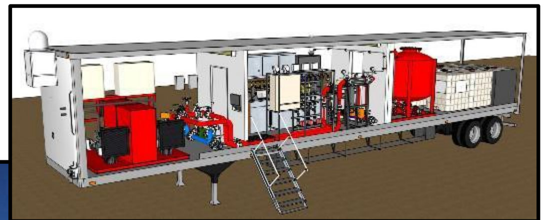
Prior ClO_2 Agricultural Response Efforts

Summer 2015: highly pathogenic avian influenza outbreak
- Fumigated 11 layer barns; 250+ environmental PCR samples
- Known limitations of environmental swabs

Advanced clearance methods should be required for repopulation.



2015 HPAI Response
Efficacy Criteria
Operational Challenges
Economics
Lessons Learned

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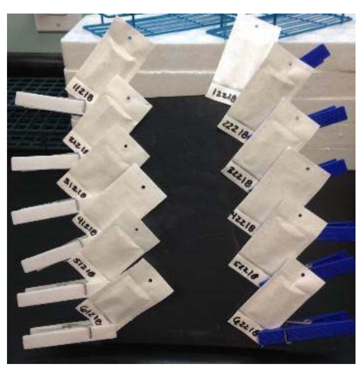
Custom BIs – "Sentinel Surrogate" Coupons

Quantify log-reductions in viral and bacterial spore populations
- *B. subtilis* spores (ATCC 6633): 5 × 10^7 CFU per carrier
- MS2 bacteriophage (ATCC 15597-B1): 5 × 10^8 PFU per carrier

Direct comparison to commercially available spore strips (Mesa Labs)



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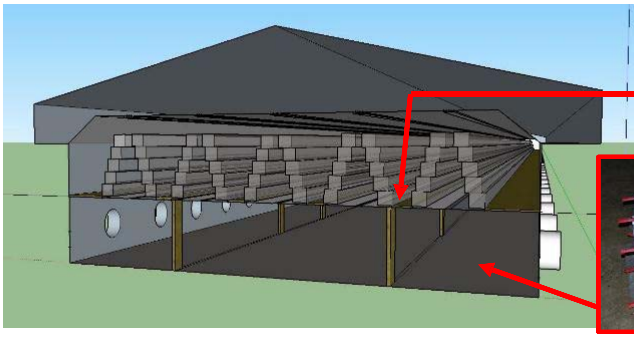
Monitoring Locations in Test Barns

Egg Layer Barn – Eagle Grove, Iowa

- **50 ft × 600 ft**; Ground Level, Cage Level, and Attic
- 10 monitoring locations in each barn
  - ✓ Temperature, Relative Humidity, ClO_2 Conc.
  - ✓ Custom Coupons and/or Spore Strips



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2015 HPAI Response | Efficacy Criteria | Operational Challenges | Economics | Lessons Learned

Equipment Considerations: Heat Treatment

5

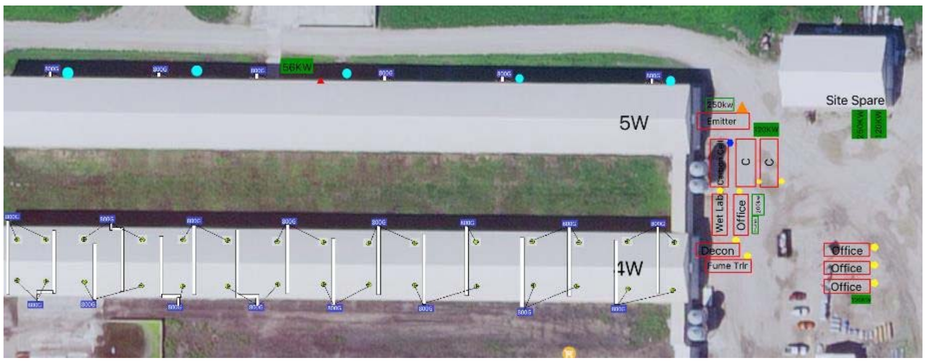
2015 HPAI Response | Efficacy Criteria | Operational Challenges | Economics | Lessons Learned

Equipment Considerations: Heat Treatment

24 Heaters used for a single barn (1 million cubic feet)

- 800,000 BTU
- 20,000 CFM

Positive pressure maintained on heated barn for 7 days



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Equipment & Staffing: Heat Treatment

- **24 × Indirect Fire Single Pass Diesel Heaters**
- **48 × 18-inch by 60-foot Distribution Ducts**
- **50 × 36-inch, 22,000 CFM Mixing Fans**
- **1 × Skid Steer and Portable 500 gal Fuel Tank**
- **Six person set up, 48-hrs**
- **24-hr Staffing** – 7 days, 2 Shifts, 2 Personnel, Tech Supervisor
- **18,000 gal Diesel**

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2015 HPAI Response | Efficacy Criteria | Operational Challenges | Economics | Lessons Learned

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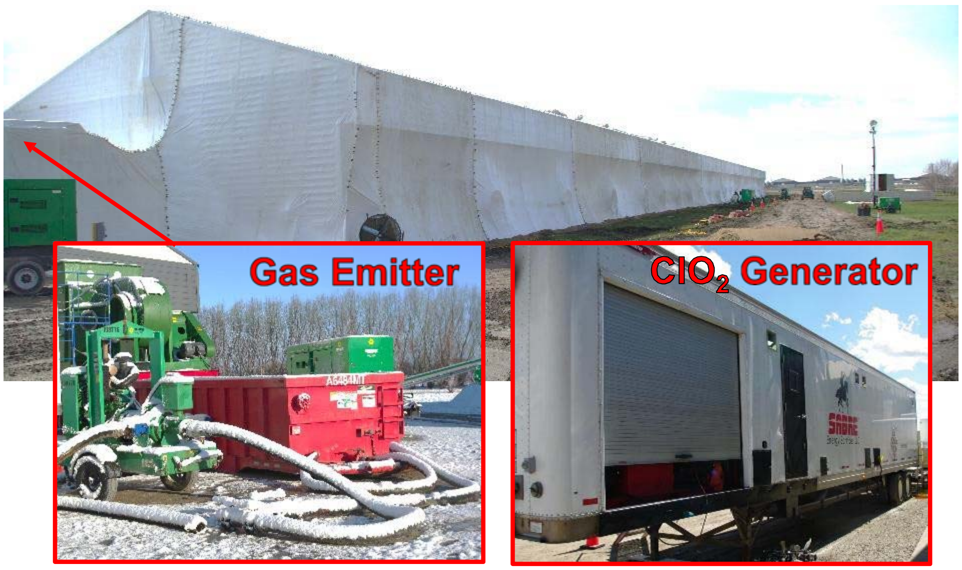
Equipment Considerations: Chlorine Dioxide



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Efficacy Criteria

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Equipment & Staffing: Chlorine Dioxide

- **1 × Sabre GEN8 Redundant Chlorine Dioxide Generator**
  - 12,000 pound per day, Command and Control Unit
- **1 × Sabre EMSYS 20,000 CFM Chlorine Dioxide Infusion System**
- **10 × 30,000 CFM Mixing Fans**
- **1 × Humidifier (1,000 lb/min steam)**
- **1 × CONSYS 20K Redundant Negative Air System**
- **8 × person set up, 12-hr, Tarps & Clips for Encapsulation**
- **18-hour operation -** Supervisor, Diklor Tech, 2 Operations Techs
- **750 (~300 for heat) gallons of Diesel, 4 Heaters (only 2 used)**
- **4 × Totes Each of Chlorine Dioxide Precursors**

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Efficacy Criteria

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Lessons Learned

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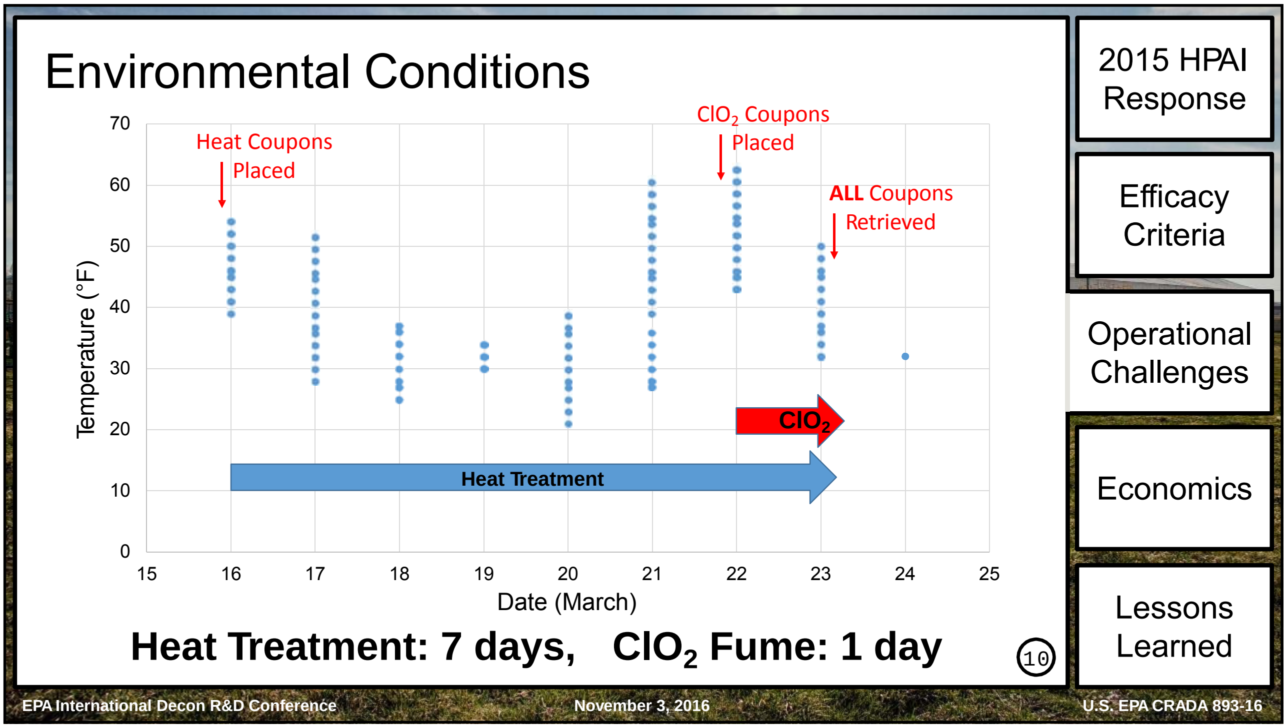
Environmental Conditions
Heat Coupons Placed
ClO2 Coupons Placed
ALL Coupons Retrieved
ClO2
Heat Treatment
Temperature (°F)
Date (March)
70
60
50
40
30
20
10
0
15
16
17
18
19
20
21
22
23
24
25
Heat Treatment: 7 days, ClO2 Fume: 1 day
10
2015 HPAI Response
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Economics
Lessons Learned
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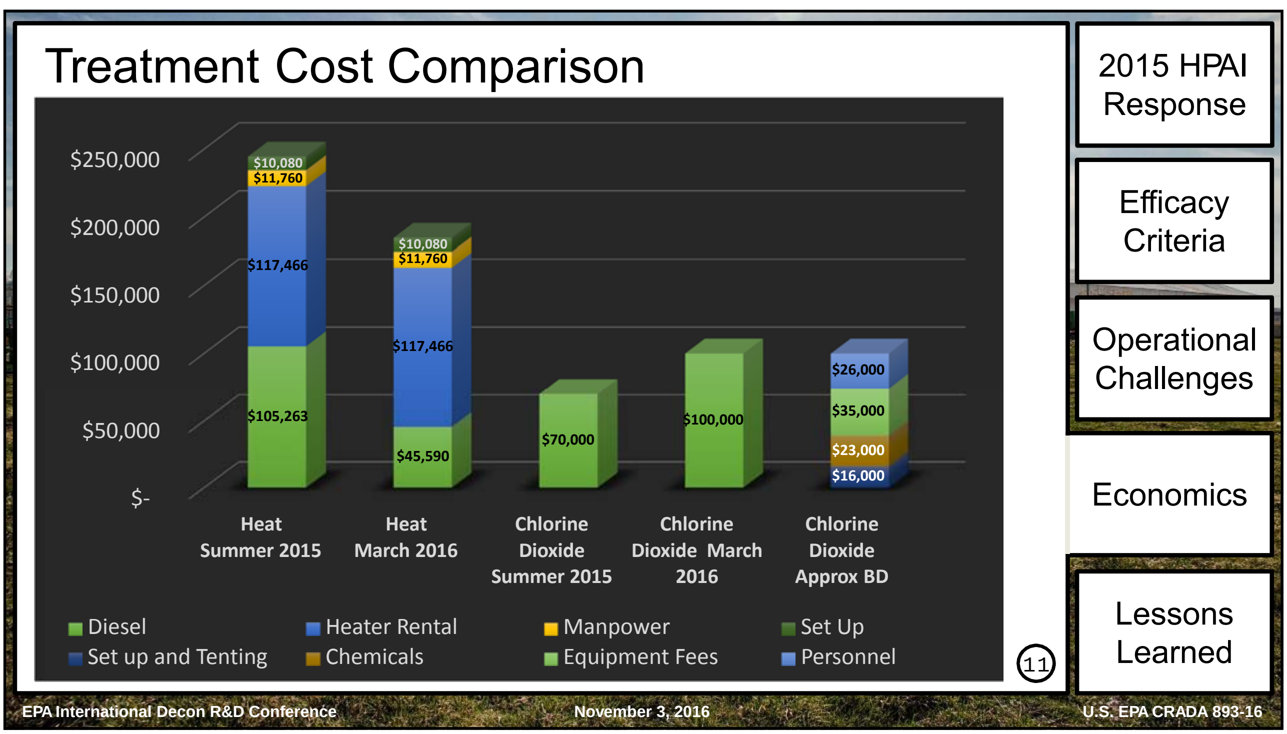
Treatment Cost Comparison
$250,000
$200,000
$150,000
$100,000
$50,000
$-
$10,080
$11,760
$117,466
$105,263
$10,080
$11,760
$117,466
$45,590
$70,000
$100,000
$26,000
$35,000
$23,000
$16,000
Heat Summer 2015
Heat March 2016
Chlorine Dioxide Summer 2015
Chlorine Dioxide March 2016
Chlorine Dioxide Approx BD
Diesel
Heater Rental
Manpower
Set Up
Set up and Tenting
Chemicals
Equipment Fees
Personnel
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ClO_2 Treatment Cost Evolution

	Original Cost	ft^2	Cost / ft^2	2017 Equivalent
Daschel Suite & HVAC	$ 2,300,000	**16,000**	$ 144	**$ 80,000**
Brentwood	$186,000,000	**700,000**	$ 266	**$ 3,500,000**
AMI Building	$ 7,000,000	**70,000**	$ 100	**$ 350,000**
Hospital (CHW)	$ 28,000,000	**500,000**	$ 56	**$ 2,500,000**
Danbury	$ 280,000	**2,800**	$ 100	**$ 280,000**
2015 HPAI Response	$ 70,000	**100,000**	$ 0.70	**$ 70,000**
2016 Commercial Operations	$ 200,000	**40,000**	$ 5	

2015 HPAI Response
Efficacy Criteria
Operational Challenges
Economics
Lessons Learned

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Lessons Learned

- ✓ **Should have consistent biosecurity practices for facility decon**
  e.g., a requirement for negative pressure and containment
- ✓ **Surrogate coupons are the best challenge we have ever seen**
  Should consider *"microbiological sentinels"* as the standard metric for decontamination.
- ✓ **See Julian Rosenberg's poster on microbial surrogate efficacy**
  We don't want to spoil the surprise! (Poster #27)
- ✓ **Eliminating 21-day fallow period required after heat treatment**
- ✓ **"Wide Area" perimeter and carcass issues must be addressed**

2015 HPAI Response
Efficacy Criteria
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Material Effects: Organic Debris, Heat Barn

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2015 HPAI Response

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Lessons Learned

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Material Effects: Chlorine Dioxide Fumigation

Untreated

After Fume

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Material Effects: Chlorine Dioxide Fumigation

Untreated

After Fume

- 2015 HPAI Response
- Efficacy Criteria
- Operational Challenges
- Economics
- Lessons Learned

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The U.S. Environmental Protection Agency, through its Office of Research and Development, collaborated in the research described here under a CRADA with SABRE Corp. 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.

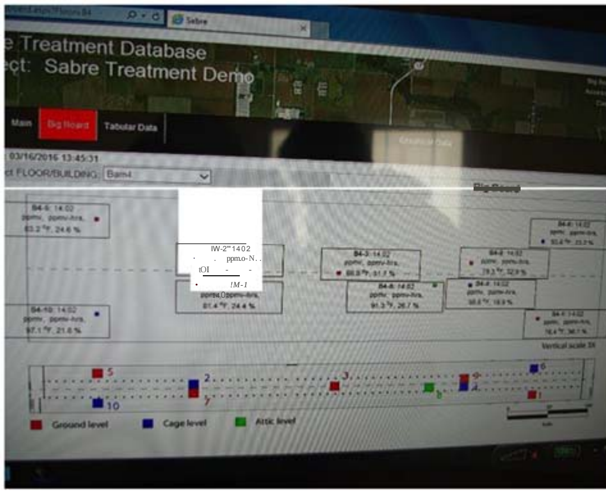
Thank you.

Questions

See Poster #27

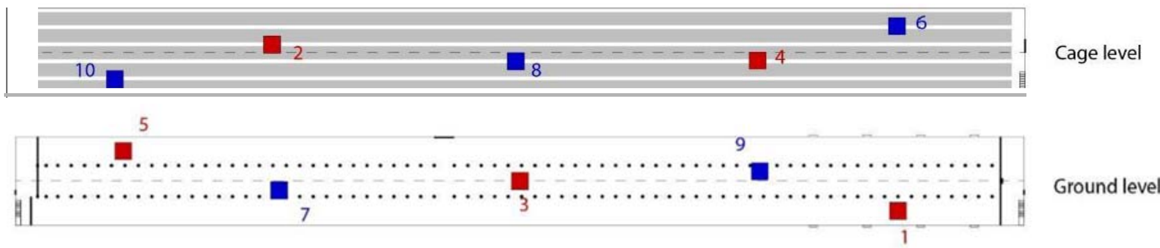
Rosenberg *et al.* Employing microbiological surrogates to compare chlorine dioxde fumigation and heat treatment of commercial poultry barns under field conditions

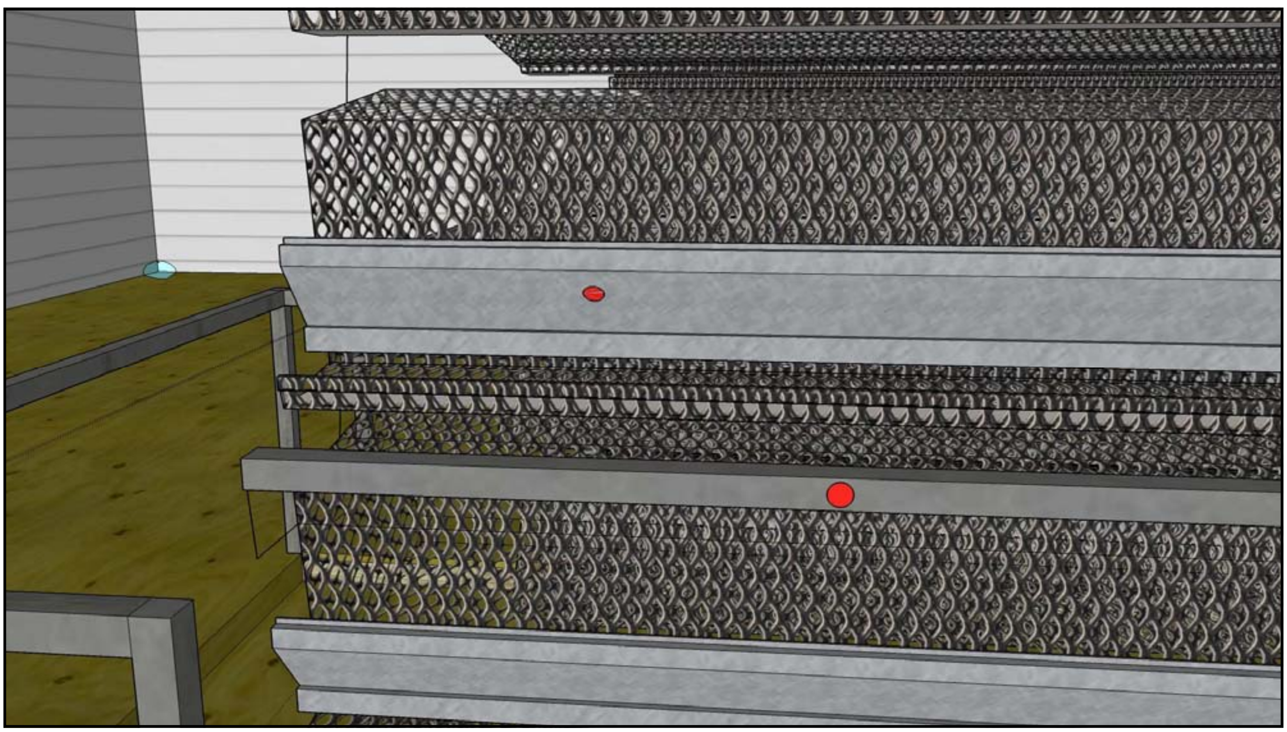
Direct & Remote Temperature Observations



Real-Time Chlorine Dioxide Gas Monitoring

Ten Monitoring Locations in Each Barn





EnviroSafe field study - June 2016

- C. Ramsey
USDA-APHIS-PPQ
CPHST Lab – Fort Collins, CO

Study goal

- Evaluate mobile autoclave under field conditions
- Measure thermo parameters while steam treating three test materials
- Made by EnviroSafe Treatment Solutions
- Location – Covington, IN
- Dates – June 13-16, 2016

2

Mobile autoclave background

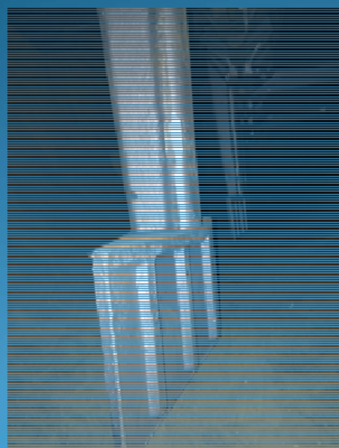
- Maximum weight capacity – 6,000 to 8,000 lb/batch load
- Operating volume capacity – 3 - 5 cu. yds.
- Continuously churn waste material with 26 paddles at 42 RPM
- Fully adjustable heat and pressure settings to match treatment standards or target pest efficacy needs
- Ability to sterilize any animal and plant waste, as well as soil and bio-contaminated water

3

Study photos

4

Study photos



5

Study objectives

- Measure autoclave pressure and temperature for six test runs using five wireless sensor/data loggers
- Determine Scotch broom seed efficacy for six test runs
- Determine the three test material percent moisture content before and after steam treatments for each run

6

Study methods

- Fabricate steel canisters to protect wireless sensors
- Place five wireless temperature and pressure sensors in 10 steel canisters made of 14 gauge steel and filled with steel wool scrubbing pads to cushion sensors
- Place two Scotch broom sachets inside of two pressure sensor canisters
  - 30 seeds/sachet for total of 60 seeds per test run
- Conduct autoclave run for approximately 30 – 45 minutes

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Study photos – wireless temperature and pressure sensors

8

Study photos

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Study methods

- Unload test material from autoclave after steam treatment
- Retrieve wireless sensor canisters from autoclave
- Download and compile temperature and pressure data from 5 temperature and pressure data loggers
- Graph temperature and pressure data over time for each sensor, each run, and for each test material
- Develop table for steam exposure times above 100 and 115 C for all three test materials

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Study photos

11

Study photos

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Study methods – seed germination

- Scotch broom seeds retrieved from canisters
- Return seeds to Fort Collins CPHST greenhouse for seed germination test
- Plant seeds in seed trays, labeled for each of six test runs, as well as untreated seeds
- Count seed germination rate at 60 - 70 days after planting
- Compare treated to control seed germination rates

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Maximum temperature and pressure for wireless sensors for six runs

Sensor	Wood chip #1 (C) – (F)	Wood chip #2 (C) – (F)	Loam soil #1 (C) – (F)	Loam soil #2 (C) – (F)	Clay soil #1 (C) – (F)	Clay soil #2 (C) – (F)
MadgeTech sensors	122 - 252	129 - 264	130 - 266	124 - 255	123 - 253	124 - 255

Sensor type	Wood chip #1 (PSI)	Wood chip #2 (PSI)	Loam soil #1 (PSI)	Loam soil #2 (PSI)	Clay soil #1 (PSI)	Clay soil #2 (PSI)
MadgeTech sensors	28.8	24.5	24.5	28.8	21.6	-

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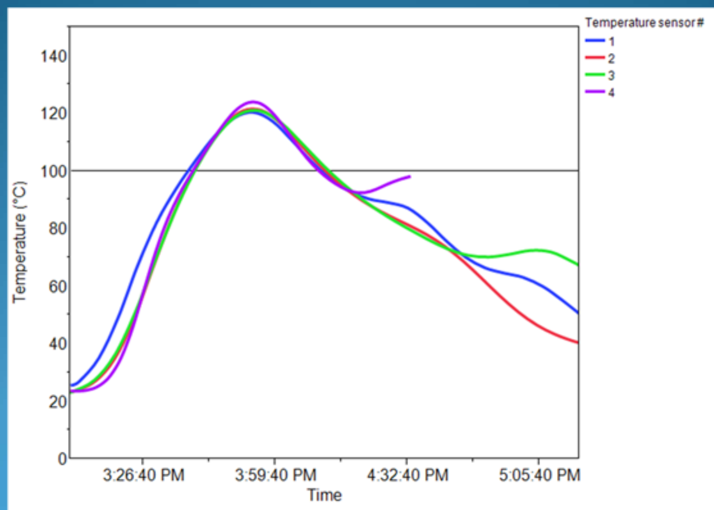
Wood chip – temperature for 2nd run for four wireless sensors



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Percent moisture content for 3 test materials – before and after steam treatment

	W1 (%)	W2 (%)	W3 (%)	L1 (%)	L2 (%)	L3 (%)	C1 (%)	C2 (%)	C3 (%)
Before trt	60	59	60	16	16	16	9	8	9
After trt	39	39	.	4	4	.	2	2	.

*W=wood chips, L-loam soil, C= clay soil

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Test material volume reduction estimates

Test material	Estimated volume reduction (%)
Animal carcasses	50 – 70%
Wood chips	30 – 40%
Soil	1-5%

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Scotch Broom seed germination results

- Seed germination counts on Sep. 1, 2016 at 71 days after planting
- Percent germination for control seeds was 48%
- Percent germination for steam treated seeds was 0%, or 100% inactivation

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Study results for wireless sensor data

- Target steam time of 30 minutes was met at 100 C (212 F) while operating at full capacity for all three test materials
- Target pressure of 15 PSI was met while operating at full capacity for all three test materials
- Mobile autoclave can sterilize woody and soil materials while operating at full capacity when steam time meets regulated pest heat treatment efficacy standards

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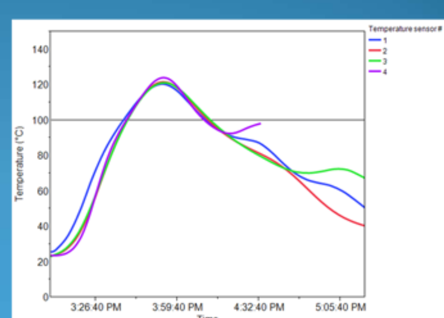
Study results

- All three test materials show a very sharp rise in material temperatures
- Soil temperature increased by 73 C (164 F) 35 min. for 3-4 yd^3 after opening steam valve
- Rapid heat transfer results in shorter steam exposure times which results in lower operating costs



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Coconut Rhinoceros Beetle (CRB) beetle and grub

CRB - Palm tree disposal

Questions

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United States
Environmental Protection
Agency

2016 U.S. EPA International Decontamination Research and Development Conference

Thursday, November 3, 2016

Concurrent Sessions 6

Biological [Ricin] Agent Research

RESEARCH

Developing an EPA Registered Anthrax Decontamination Product

Brian France, Ph.D.

2016 EPA International Decontamination Research and Development Conference

November 3, 2016

TDA Research Inc. • Wheat Ridge, CO 80033 • www.tda.com

Outline

- **Regulatory Requirements**
- **Data Requirements**
- **Products with Anthrax Claims**
- **From the Kitchen to the Battlefield**
  - Spin off technologies
- **EPA Regulatory Success**
- **Future Registered Products and Approaches**

EPA Registration

- **The EPA registers pesticide products**
  - Cleaning products with claims to mitigate an organism must be registered
  - "prevent, destroy, repel or mitigate any pest"
- **Cleaning products are not pesticides**
  - Do not require EPA registration, even if intended to remove hazardous materials
- **Decontaminants**
  - Chemical Agent Efficacy
    - No EPA registration
  - Biological Agent Efficacy
    - Human Health Pathogens
    - Public Safety
    - EPA REGISTRATION REQUIRED!

EPA Registration Evaluation

- **What is being claimed – The Label**
- **Formulation**
  - Confidential Statement of Formula
  - Analytical enforcement methods
- **Human Health Risks**
  - Toxicity of ingredients
  - Operator exposure
- **Environmental Risks**
  - Residue
  - Fate
- **Efficacy against target organism**
- **EPA will require additional studies if the supporting data are incomplete**

Products with Anthrax Claims

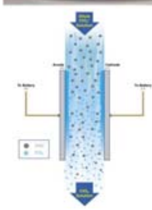
- **Registration Notice 2008-2**
  - The EPA restricts sales of anthrax mitigation products to the military, Federal On-Scene Coordinators (FOSCs) and their trained contractors
- **Business implications:**
  - Decontamination product won't be at Home Depot
  - Registration is expensive
    - PRIA Fees ($12,156 - $627,568)
    - EPA consultant labor
    - R&D subject matter expert labor
  - EPA registration review takes time: 12 to 24 months
  - Registration is not a sure thing
- **Despite these challenges, the U.S. Government requires an EPA-registered decontaminant to remediate anthrax events**

From the Kitchen to the Battlefield

- After the 2001 Anthrax attacks new technologies were sought
- Researchers at Procter and Gamble offered a technology they had been developing for consumer use
  - It showed better biological efficacy than hypochlorite (bleach)
  - Effective concentrations were lower than bleach
- P&G was developing a aqueous chlorine dioxide disinfectant product that utilized a miniaturized electrochemical cell in a sprayer

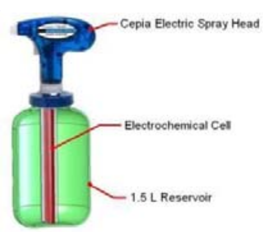
Electrochemical Production of ClO_2

- Electrochemical cell was scalable
- ClO_2 is generated on-demand as needed
- No chemicals required for generation
- ClO_2 is an Oxidizing agent
- ClO_2 is made from sodium chlorite ($NaClO_2$) solution
  - Long storage life, even at elevated temperature
  - Easily and safely transported



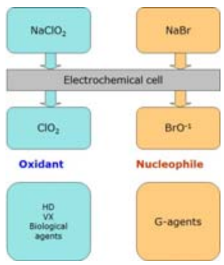
National Security Product

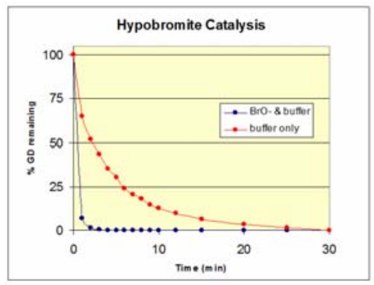
- P&G does not serve the national security market, TDA was brought in to work with P&G and the DOD to mature this decontamination technology
- Developing a National Security Decon Product
  - Chemical Agent Reactivity
  - Biological Agent Efficacy
  - EPA Registration
  - Form, Fit and Function



Chemical Reactivity

- Chlorine dioxide is an oxidant and will react with VX and HD but not G-nerve agents
- We identified additives to react with G-agents





- Improved surfactants for agent solubility
  - **Resulted in a separate decon technology**

$eClO_2$ Spin off Technology - Detergent Decon

- **A non-reactive detergent blend that is specifically formulated to spontaneously lift agents from surfaces**
  - Decontamination data has shown no scrubbing is needed
- **Any reactive decontaminant works better with a pre-wash**
  - Removing >90% of the agent, dirt and grime prior to decon

Advanced Surfactant Decontaminant, SSDX-12™

P&G

- A surfactant blend specifically designed to emulsify and lift agents from surfaces
- Non-reactive, non-corrosive, pH neutral, no-VOC, biodegradable
- High concentration (reduced shipping and storage)
- Dual use
- Commercially Available
- Non-hazardous, no DOT restrictions

Vehicle Decontaminant

- Compatible with mobile vehicle decontamination platforms

HaMMER ATD

- Based on large panel testing
- No scrubbing with SSDX-12™ prewash
- Removes 99.95% VX contact hazard
- Use prior to a reactive decon, allows VX decon to below 0.75 mg/m^2 requirements
- HD contact hazard can be lowered from 10g/m^2 to below 15 mg/m^2 <u>without reactive decontaminants</u>
  - Target Objective: <100mg/m^2
- SSDX emulsifies HD and prevents re-deposition onto non-contaminated areas better than water wash

France (2016) "Aircraft Decontamination, The Unique Challenges of Decontaminating Sensitive Equipment" HDIAC Journal, 3(3)

eClO$_2$ Biological Efficacy

- TDA had pre-application meetings with the EPA
- Efficacy standards in accordance with AOAC Method 2008.05 "Three Step Method" for sporicidal testing against *Bacillus anthracis* ΔSterne under GLP conditions
- Scientists at Naval Surface Warfare Center – Dahlgren completed the GLP testing on *Bacillus anthracis* ΔSterne and virulent *Bacillus Anthracis* Ames
- <u>Results</u>:
  - 6 different production batches were each evaluated three times on different days at 1, 5 and 15 min exposures periods
  - All tests resulted in <7 log reduction within **one** minute contact time.

T.L. Buhr, et. al. (2011) Decontamination of a hard surface contaminated with Bacillus anthracis delta Sterne and B. anthracis Ames spores using electrochemically generated liquid-phase chlorine dioxide (eClO2). J. App. Microbiol., 111, 1057 - 1064

EPA Registration of $eClO_2$

- TDA worked with an EPA consultant to assemble a complete registration package
- Fortunately, the active ingredient for this application is sodium chlorite
- Sodium chlorite is an established EPA pesticide chemical, thus its toxicity and environmental impact is established
- TDA received EPA registration of the eClO2 product on July 23, 2015, **U.S. EPA Reg. No. 85797-1**
- TDA is currently working on improved applicators

TDA

How It Works

- Materials
  - New or fully charged batteries in applicator
  - Packet A – Salts (including sodium chlorite)
  - Packet B – Surfactants
- Packet A and B are dissolved in available water
  - Salt quickly dissolve, ~1 min
  - Solution is stable for months
- Solution can be prepared in applicator reservoir
  - Smaller reservoir, easy replacement, light weight applicator
- Applicator is primed, solution turns yellow when activated
- Solution is sprayed onto the contaminated surface
  - Allow it to dwell for one minute or more

France (2016) "Decontaminants: Protecting the Warfighter Against Chemical and Biological Warfare" HDIAC Journal, 3(2)

TDA

Lessons Learned

- The final $eClO_2$ formulation is stronger than the initial consumer product
- In its current form, with anthrax claims, this is not a consumer product (could be dialed back)
- Few "decontamination" products go through this rigorous EPA registration process
- TDA looking to partner with companies interested in offering the technology for biodecon
  - Subject to US export control regulations

TDA

Future Products for Anthrax Spore Decon

- P&G approached TDA with technology for the photo-
- chemical generation of ClO_2 from aqueous chlorite solution
  - Again, TDA is developing the technology for markets that P&G does not serve
- Chlorine dioxide kills microbes and is reduced back to
- chlorite
  - Can be catalytically cycled
  - Works using visible light
- Biodegradable surfactants (SSDX-12™) help wet surfaces,
- improve contact with the oxidizing solution

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ntly providing support in an SBIR Phase II

TDA

Photo-ClO_2 Compared to eClO_2

- Photo-ClO_2 is effective for biodecon, but not as effective for chemical decon
- Photo-ClO_2 produces much lower concentration of ClO_2, and so requires a longer time
- Photo-ClO_2 requires a light source

BUT

- Photo-ClO_2 uses lower concentration of salts, for greatly improved materials compatibility
- Photo-ClO_2 does not require a special applicator
  - No electrochemical cell or batteries
- **<u>Potential consumer applications</u>**

Fundamentals

- New method sustains a low but effective level of oxidant over extended periods

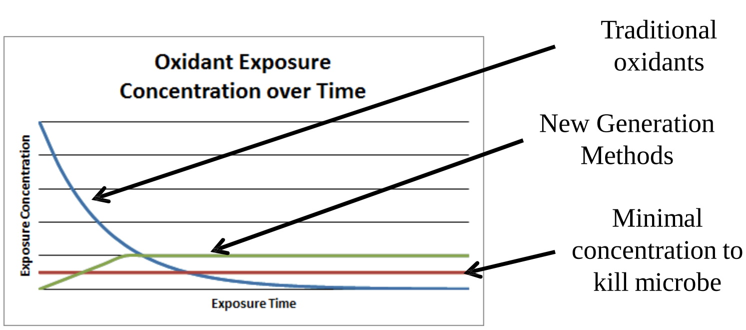
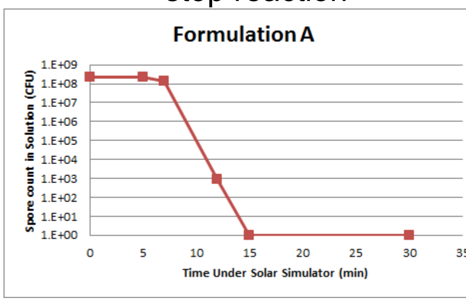
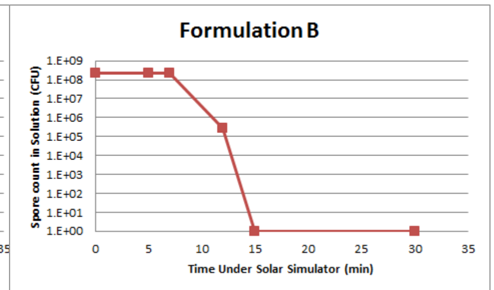


Photo-ClO_2 Sporicidal Efficacy

- **Multiple formulations showed 8 log kill within ~15 min**
  - *B. subtilis* – commercially available spore prep
    - a surrogate for Anthrax
  - In solution
  - Solution is quenched at specified times to stop reaction





Surface Decontamination Efficacy

- Surface decontamination is slower, because
- Oxidant generation has to dig through spores
- Decontamination is light dependent, lower light levels require longer exposure times

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

EPA Registration of National Security (Anthrax) Product

- Since our original EPA registration the EPA has published its Product Performance Test Guidelines OCSPP 810.2100 Sterilants – Efficacy Data Recommendations
- TDA had a pre-application meeting with the EPA
- Efficacy testing will require GLP testing under AOAC Method 966.04 – Sporicidal Activity of Disinfectant Test
- Organism: *Bacillus anthracis* ΔSterne
- 15 min kill with $1x10^7$ spore challenge
- Spores dried on hard surface

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National Security Product Formulation

- To meet the EPA's time performance have investigated formulation optimizations that will speed up decontamination
- These enhancements would not be required for consumer products
- The final National Security formulation would be increments of an available consumer product
- <u>Results</u>:
  - 7.34 log reductions, dried on glass slides, 15 minutes exposure
  - 7.34 log reductions, dried on Arizona Test Dust, 15 minute exposure

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Additional Photo-ClO_2 Products

- The following slides describe products TDA is developing based on the Photo-ClO_2 technology
- Potential consumer/commercial applications
- All will require EPA registration

TDA

Surface Sanitizer

- **EPA Surface Sanitizer Requirements**
  - Non-food contact, hard surface sanitizer
  - ASTM E 1153-03
  - 5-minute contact period
  - Glass substrates
  - 3-log reduction in test organisms
- **Independent lab results**
  - *Klebsiella pneumoniae*
    - 5 minute contact period
    - 5 replicates
    - 99.9992% reduction
  - *Staphylococcus aureus*
    - 5 minute contact period
    - 5 replicates
    - 99.9802% reduction

- **Passes test with > 3-log reduction**

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Outdoor Mold and Mildew Remediation

- Laboratory Efficacy
  - Third party testing
- EPA Registration
  - Submitted; decision expected January 2017

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Plant and Crop Protection

- Plants, including food crops, are susceptible to microbial pathogens too. Bacterial Leaf Spot (BLS) is a significant problem.
- Very few anti-bacterial products are available

BLS on Pepper and Tomato | Non-infected pepper | BLS on Geranium | Geranium treated with Photo-ClO_2 and then inoculated with BLS

- Photo-ClO_2 is effective against BLS on plants
- TDA is developing the technology with support from USDA

UNIVERSITY OF FLORIDA
IFAS

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Summary

- EPA registration of a biological decon national security product is:
  - Required
  - Not simple
  - Can be accomplished
- Anthrax products are not consumer products
- eClO_2 has been successfully registered
- Development and registration of other, dual-use products is in progress

TDA

Acknowledgments

- **Army Research Office**
  - STTR Phase II, Contract: W911NF-13-C-0096
- **US Air Force**
  - SBIR Phase II, Contract: FA8222-14-C-0001
- **Department of Homeland Security**
  - SBIR Phase II, Contract: HSHQDC-14-R-00035
- **U.S. Department of Agriculture**
  - SBIR Phase I, Contract: 2016-33610-25483

TDA

United States
Environmental Protection
Agency

2016 U.S. EPA International Decontamination Research and Development Conference

Thursday, November 3, 2016

Concurrent Sessions 6

Waste Management Practices

EPA United States Environmental Protection Agency

Attenuation of Ricin Toxin at Ambient and Elevated Temperatures - Lab Study

Joseph Wood (US EPA)
Will Richter, Andrew Lastivka (Battelle)

Presented at US EPA – Decontamination Conference, Research Triangle Park, NC, November 1-3, 2016

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Acknowledgements and Disclaimer

- EPA project team members:
  - –Larry Kaelin, CMAD
  - –Rich Rupert OSC R 3

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.

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Outline of Presentation

- Background, toxicity
- Incidents
- Rationale for study
- Methods
- Results
- Summary

Ricinus communis

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Background, toxicity

- Ricin toxin is a highly toxic protein produced within the beans of the *Ricinus communis* (castor bean) plant.
- The median lethal dose (LD_{50}) in mice is 5 micrograms per kilogram (µg/kg) via intravenous (IV) injection.
- From extrapolations, human LD_{50} is 1-5 milligrams per kg IV.
- Ricin aerosol LD_{50} for nonhuman primates is estimated to be 10-15 µg/kg.

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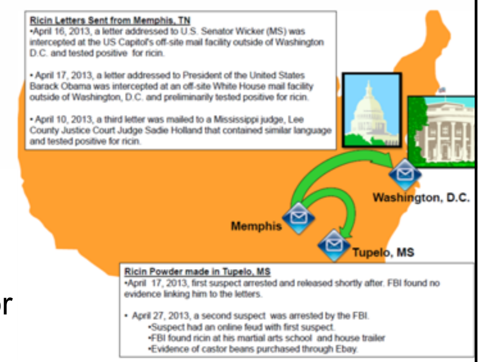
Ricin Incidents

- Capitol Hill, 2004
- Tupelo MS; Memphis TN, 2013
  - –Several letters that contained ricin toxin were sent from Memphis to various locations, including the White House and the office of the NYC mayor
  - –Ricin powder made in Tupelo



Map from Ben Franco

More Ricin Incidents with EPA involvement

- Oklahoma City, OK 2015
- Oshkosh, WI 2014
- National Capital Region, 2013
- Everett, WA 2009
- Seattle, WA 2005
- Kirkland, WA 2004
- Most sites, if found positive for ricin and decontaminated, were done so with diluted bleach or pH adjusted bleach

Sample collection Oshkosh

Tupelo decon lay down table

Photos from OSC webpage

Rationale for Study

- Minimal data available for attenuation of ricin on solid surfaces at air temperatures that could be used in a building
  - –One previous NHSRC study
- US Army reports ricin stable for one hr at pH 7.8, 50 C.
  - –No data provided; pH indicates test in liquid
- Other research on ricin stability in food or drinks (baby formula, juice), based on boiling or autoclaving

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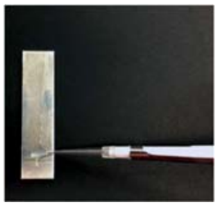
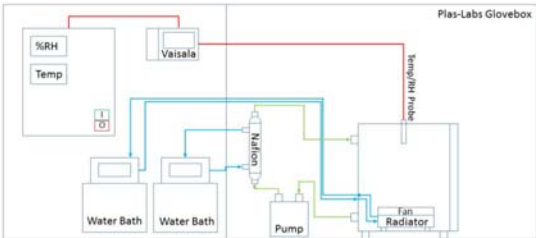
Methods

- Test variables/matrix included the following:
  - –Prep of ricin: crude and pure
  - –Ambient temperatures: 20, 25 and 30 C
  - –Heated temperatures: 40 and 50 C
  - –Relative humidity 40 or 75%
  - –Contact time: < 1 day to weeks





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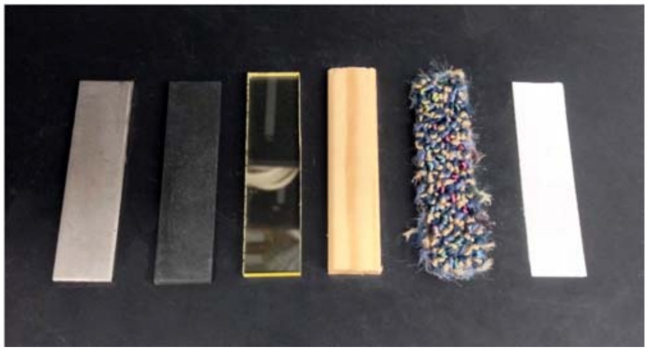
Methods



Coupon Materials from Left to Right: Mild Steel, Neoprene Rubber, Optical Plastic, Pine Wood, Industrial Carpet, Paper

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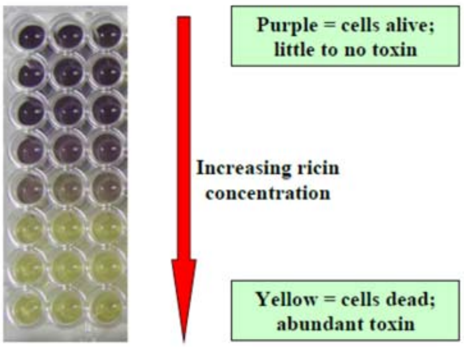
Methods

- 3-(4,5-dimethylthiazol-2-yl)-2, 5-diphenyltetrazolium bromide (MTT) assay used to measure toxicity



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Methods

Attenuation presented in terms of percent reduction

$$\frac{\text{Avg. mass ricin from positive controls} - \text{Avg. mass ricin from test coupons}}{\text{Avg. mass ricin from positive controls}} \times 100$$

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Results – actual test conditions

Test	Target Temperature °C	Actual Temperature °C	Target %RH	Actual %RH	Contact Time (Days)
1	30	30.09±0.30	75	73.60±2.49	7
2	25	25.01±0.09	45	47.03±0.30	7
3	25	24.99±0.22	45	46.39±1.06	14
4	25	25.95±1.35	75	72.43±7.20	7
5	25	25.58±1.07	75	73.93±5.50	14
6	30	29.70±0.16	45	48.09±1.73	7
7	30	30.03±0.42	45	45.61±3.52	14
8	30	30.31±0.21	75	72.96±1.16	14
9	20	20.41±0.23	45	45.22±1.47	7
10	20	20.59±0.29	45	45.26±1.40	14
11	20	20.80±0.55	75	75.28±1.05	7
12	20	20.84±0.80	75	72.43±5.14	14
13	20	19.80±0.53	45	44.81±4.03	21
14	20	19.82±0.47	45	45.06±4.18	28
15	50	50.26±0.24	uncontrolled	21.05±2.67	0.25, 1, 1.25, 2, 3, 4
16	40	39.95±0.43	uncontrolled	26.62±3.31	2, 3, 4, 5, 6, 7
17	50	50.41±0.72	uncontrolled	19.79±2.20	2, 3, 4, 5, 6, 7
18	40	40.37±0.49	uncontrolled	21.56±2.48	3, 4, 5, 6, 7, 10, 11, 12, 13, 14

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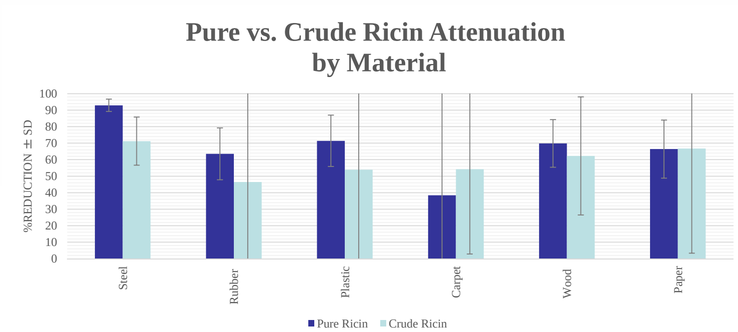
Results



Overall averages for 20-30 degrees C tests, Tests 1-14.

Crude results more variable and less attenuated most likely due to extraneous material from castor beans, not found in lab grade pure form

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Results – Average Percent Attenuation for each environmental conditions tested

Temp ° C/%RH	Test duration (days)	Average % Attenuation for Pure Ricin*	Average % Attenuation for Crude Ricin*
20/45	14	63%	7%
20/75	14	58%	56%
25/45	14	88%	73%
25/75	14	88%	51%
30/45	14	75%	81%
30/75	14	63%	39%
20/45	28	80%	77%

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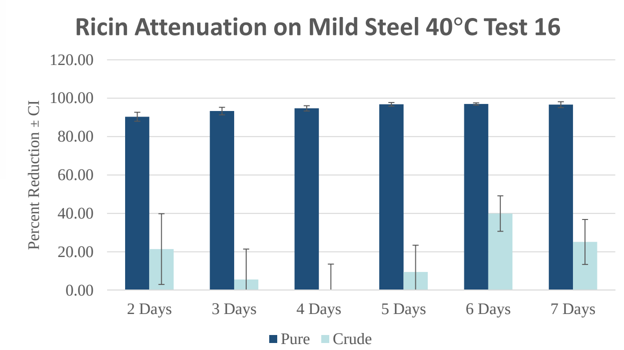
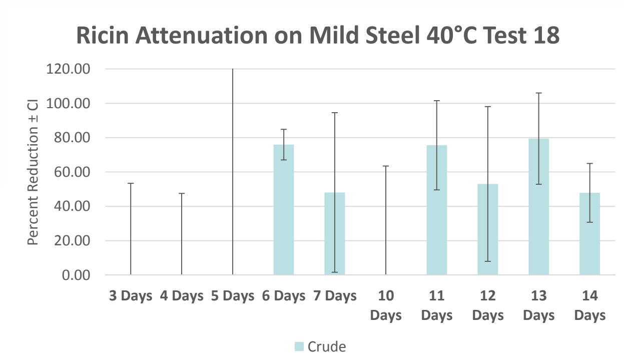
Results – Heat Treatment



At 40 degrees C, minimal attenuation of crude ricin at 7 days

Results – Heat Treatment



Even out to 14 days, still inadequate attenuation of crude ricin at 40 C

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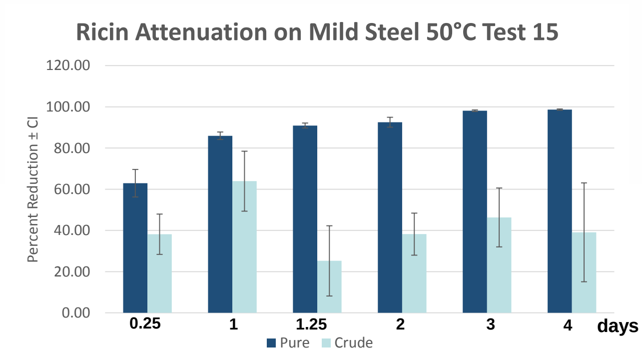
Results – Heat Treatment



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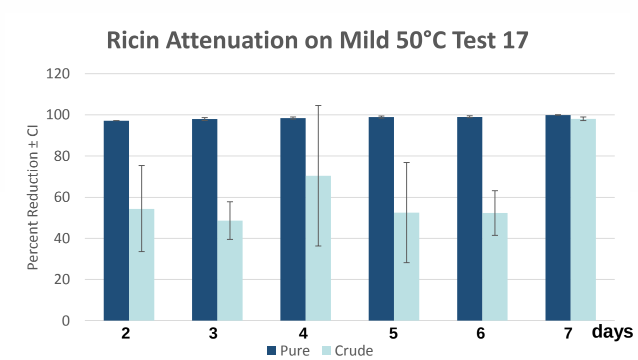
Results – Heat Treatment



98% attenuation of crude at 7 days

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Results

Test parameter combinations demonstrating over 99% attenuation*

Ricin Form	Temperature C	RH %	Contact time (d)	Material
Pure	25	75	7	Mild steel
Crude	25	75	7	Paper
Pure	25	75	14	Mild steel
Pure	30	45	7	Wood, paper
Pure	50	20	6	Mild steel

***out of over 200 test parameter combinations**

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Summary/Highlights

- Crude ricin less attenuated, more variable results than pure form
- Essentially zero attenuation of crude ricin after 14 days at room conditions, except on mild steel
- RH did not affect attenuation
- Increasing temp. generally increased attenuation, but not always
- Most attenuation seen on mild steel, but in general material effects were minor
- 7 day heat treatment at 50 C required to achieve 98% attenuation of crude

For report, Google or Bing search: EPA ricin attenuation

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THE FUTURE OF THE WASTE ESTIMATION SUPPORT TOOL

2016 EPA International Decontamination Research and Development Conference
RTP, NC
November 1-3, 2016

Timothy Boe, Paul Lemieux, Sang Don Lee
US EPA, Office of Research and Development

Colin Hayes
Eastern Research Group
Morrisville, NC

Office of Research and Development
National Homeland Security Research Center

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Outline

- WEST Description
- Methodology
- Systems Approach
- Future Enhancements
- International Scenario Demo
- Timeline

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WEST Description

- **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 starting points for policy discussions

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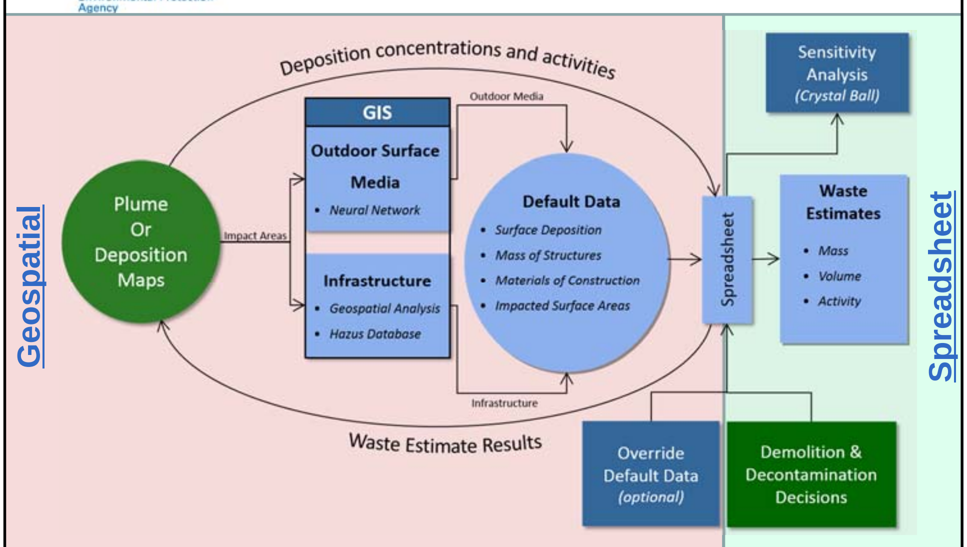
WEST Methodology



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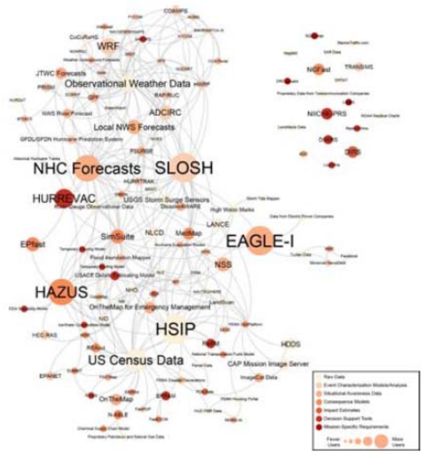
Systems Approach

- A system is a dynamic and complex whole, interacting as a structured cohesive unit
- Decisions made within these units can affect the output of the system
- Systems can get too noisy – this adds to the confusion
- Disaster response works in a similar way



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Transition to Future Development

- Recent updates focused on compatibility with Hazus
- This took time away from developing future enhancements
- Moving away from Hazus to self-sustained infrastructure dataset
- Allows for custom datasets and international scenarios
- Number of challenges remain (e.g., memory, up-to-date data, remaining operational)
- Recent interagency development effort with DHS National Urban Security Technology Laboratory (NUSTL)

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Database

- A large number of tools and data sources currently exist
- They individually consume separate sources of data that are susceptible to becoming obsolete and are costly to update
- Central repository (i.e., database) made of data from literature reviews, studies, and tools.
- Data made available by a web based platform and via API
- **Local**
  - Default HAZUS derived infrastructure files
- **Online**
  - HAZUS derived infrastructure + custom datasets
- **Custom**
  - Custom datasets can be stored locally or share via database

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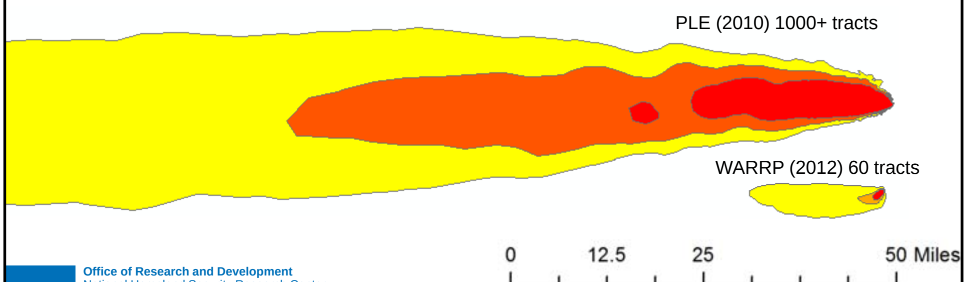
Platform Update

- **Current WEST platform is built on a VBA based Excel spreadsheet**
- **Inherent limitations of Excel limit size of scenario**
  - Scenarios limited to 250-300 census tracts
- **Efforts are underway to replace parts of WEST using Python**
- **This transition will slowly take place over next few years**
- **Goal is to resolve primary memory issues by FY18**



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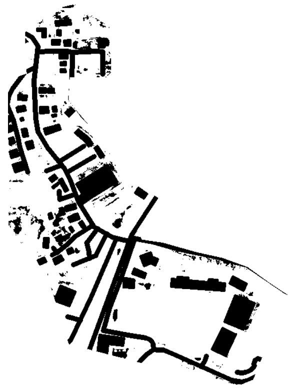
Surface Classification [old method]

Satellite Image



Concrete

Soil Vegetation

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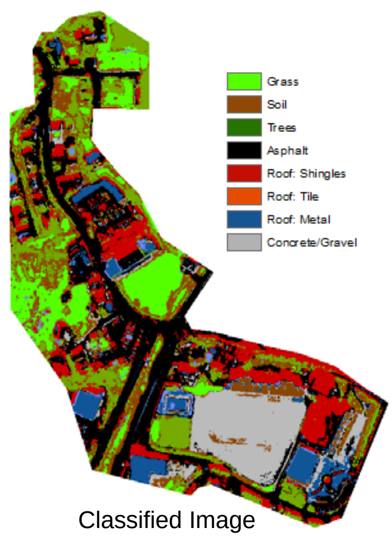
EPA United States Environmental Protection Agency

Surface Classification [new method]

Satellite Image



Classified Image

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National Homeland Security Research Center

Additional Waste Parameters

- Additional waste factors such as vegetation and vehicles are likely significant contributors to waste stream
- Inventory extracted using pre-existing models or by GIS via point cloud data

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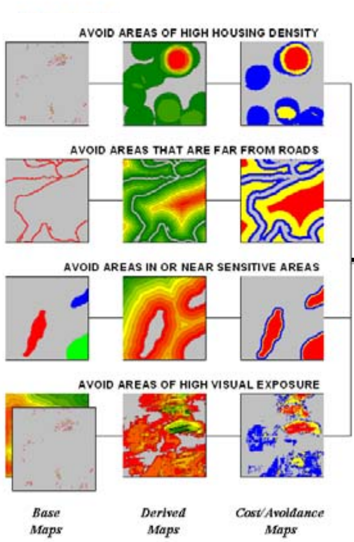
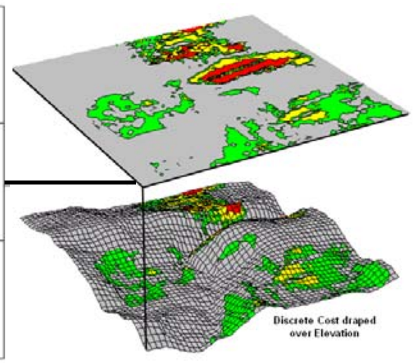
National Homeland Security Research Center

Logistics/Site Analysis





Use GIS to:

- Identify most optimal routes
- Recommendations on where to locate, expand, or consolidate waste staging and temporary storage locations

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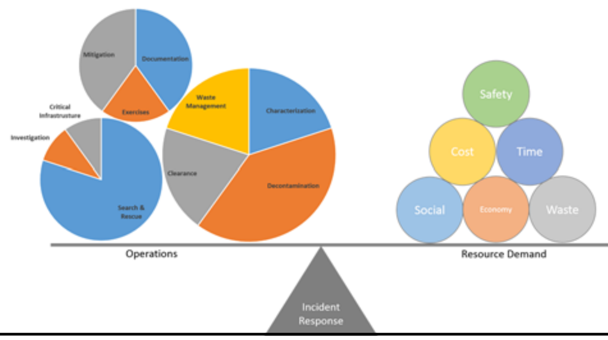
EPA United States Environmental Protection Agency

Resource Demand

- Other factors besides waste should be considered
- Cost and time factors directly impact resiliency
- Decon approach and/or waste management plan may be viable, but too costly or untimely
- All of these options must be weighed during planning and response



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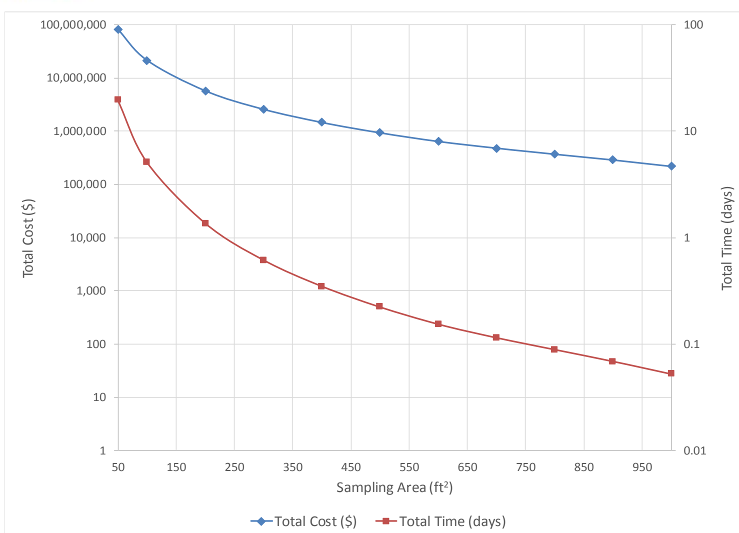
Resource Demand Cont.



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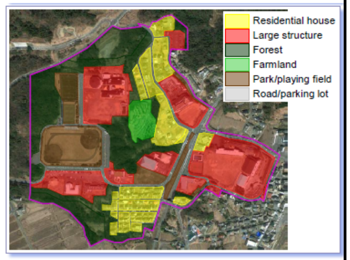
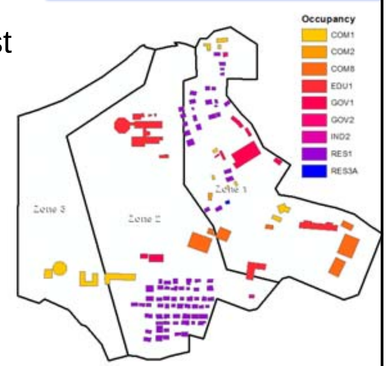
Support for OCONUS Study Areas

- Need for international support
- Fukushima serves as an opportunity to ground test results and add new decon tech
- Japan conducted "Decontamination Model Project"
- A series of towns were selected to test decon technologies
- NHSRC selected Hirono town as testbed
- Infrastructure and surface media information were collected using EPA tools





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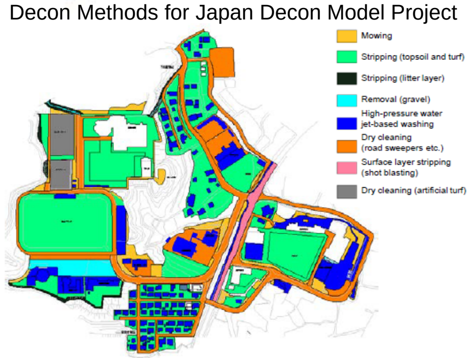
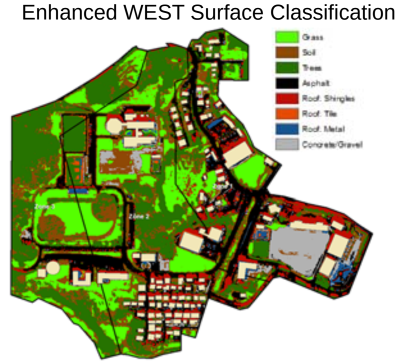
International Support Cont.

Decon Methods for Japan Decon Model Project



Enhanced WEST Surface Classification



Decon Methods for Japan Decon Model Project

Decontamination Method	Solid Waste Volume per Unit Area	Solid Waste Mass per Unit Area	Liquid Waste Volume per Unit Area	Liquid Waste Mass per Unit Area	Decon Method Distribution	Relative Surface Type
Mowing	12	1.4	None	None	17%	Grass
Stripping (turf)	50	70	None	None	17%	Soil
Stripping (litter)	50	7	None	None	27%	Trees
Removal (gravel)	30	48	None	None	6%	Concrete/gravel
Pressure Wash	None	None	20	20	15%	Roof
Shot Blasting	3	7.22	None	None	0%	NA
Dry Cleaning	1.5	2.6	None	None	18%	Asphalt
Artificial Turf	20	NA	None	None	0%	NA

Converted to WEST Method

Current classification method	Decon method	Decon Method Distribution
Soil	Stripping (turf)	62%
Concrete	Removal (gravel)	6%
Asphalt	Dry Cleaning	33%
Roof	Pressure Wash	100%

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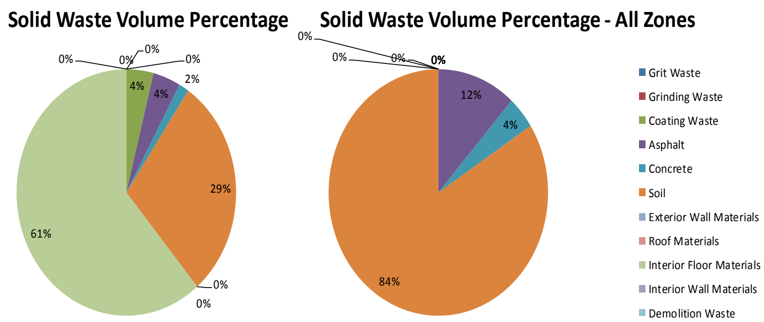
International Support Cont.



Decontamination of outdoor surfaces and interior walls

Decontamination of outdoor surfaces only

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Other Enhancements

- **Decon technology**
  - Update decon options using Japan data
- **Biological & IND support**
  - Application of decon and waste generation similar to rad
- **Scenario analysis**
  - Future versions help identify limitations and bottlenecks
- **Sharing**
  - Users can share scenarios, infrastructure, and decon technologies
- **Community outreach**

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Timeline

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Disclaimer

The U.S. Environmental Protection Agency (EPA) through its Office of Research and Development (ORD) funded and managed the research described here under Contract EP-D-11-006 to Eastern Research Group (ERG). It has been subjected to the Agency's review and has been approved for publication and distribution. 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.

The Waste Estimation Support Tool (WEST) Version 3.0 was created by the EPA, through ORD's National Homeland Security Research Center (NHSRC). This presentation and the first-order estimate of the waste and debris generated from the event described herein were generated using WEST Version 3.0. As of the release date of WEST Version 3.0, the EPA has not validated WEST against any real-world radiological contamination scenarios.

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Thank You

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2016 EPA International Decontamination Research and Development Conference

1

Evaluation of Porous Materials for Testing Antimicrobial Products Using the OECD Quantitative Method

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MICROBIOLOGY LABORATORY BRANCH
FORT MEADE, MD

Topics for Discussion

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- Background
  - Summary of Antimicrobial Product Registration
  - EPA's Interagency Agreement with DHS
- Study Attributes
  - Goals
  - Methodology
  - Results from recovery and efficacy studies
  - Conclusions
  - Ongoing studies and next steps

Disclaimer

3

This information is distributed solely for the purpose of pre-dissemination peer review under applicable information quality guidelines. It does not represent and should not be construed to represent any agency determination or policy.

Background
Antimicrobial Product Registration

4

- Under Federal Insecticide, Fungicide, and Rodenticide Act (FIFRA), EPA is responsible for the registration of pesticidal products.
- Antimicrobial pesticides are substances used to destroy or suppress the growth of harmful microorganisms on inanimate <u>environmental</u> surfaces.
- Label claims for control of microorganisms on inanimate environmental surfaces which are infectious to man are considered directly related to human health – these are known as <u>public health</u> antimicrobials.

Background
Antimicrobial Product Registration

5

- Under FIFRA, the registrant of an antimicrobial product with a public health claim is required to submit efficacy data in support of the product's registration.
- Antimicrobial products are used to treat agricultural/animal facility surfaces contaminated with high consequence animal pathogens such as highly pathogenic avian influenza.
- For products labeled for public health and/or non-public health uses, submission of efficacy data to EPA on certain animal disease pathogens and zoonotic microorganisms may be appropriate prior to approval of the label claim.

Background
Interagency Agreement (IA)

6

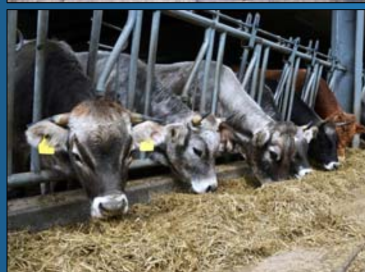
- IA established between the Department of Homeland Security's Science and Technology Directorate and EPA's Office of Pesticide Programs to:
  - support elements of a comprehensive response strategy – the decontamination component;
  - evaluate porous environmental surfaces using relevant carrier materials for efficacy tests;
  - assess the feasibility of testing viral and bacterial surrogates (e.g., Feline calicivirus, *Mycobacterium terrae*);
  - and develop suitable standardized test procedures appropriate for antimicrobial product registration.

Background

Diverse surfaces in agricultural settings

7






Study Goals

8

- Draft a standard operating procedure (SOP) for efficacy testing
  - OECD Quantitative Method
- Select and test porous test carriers
- Conduct feasibility and demonstration studies
  - Virus recovery (control carrier counts)
    - Seek control carrier counts suitable for assessing a proposed 4 log reduction
  - Efficacy tests with sodium hypochlorite
- Finalize the SOP and present for consideration as a regulatory method

Methodology
OECD Quantitative Method

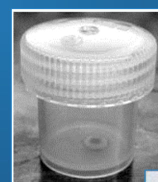
9

- Fully quantitative
- Accommodates a wide range of microbes
- Uses 1 cm diameter coupons inoculated with 10 µL of microbial suspension
- After drying, each treatment carrier is exposed to 50 to 75 µL (depending on material) of antimicrobial agent and following the contact time, 10 mL of neutralizer is applied, contents vortexed, serially diluted, and the viable test microbe is enumerated.
- The difference between control and treated counts is used to calculate a mean log reduction (LR) value.

1 cm brushed stainless steel disk (replaced by porous carrier)

10 µL dried inoculum

50 µL disinfectant



Vial with inoculated carrier/disinfectant

Enumeration

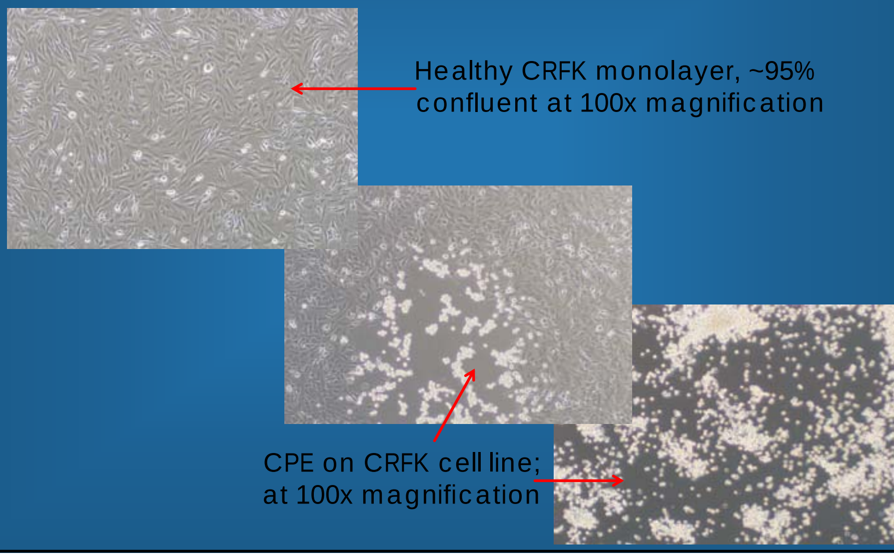
Methodology
Virus test system

10

- Feline calicivirus (FCV)
  - Non-enveloped virus belonging to the Caliciviridae
  - FCV (ATCC # VR-782) grown and assayed on Crandell Rees Feline Kidney cell line [(CRFK) (ATCC # CCL-94)]
  - FCV is accepted by the EPA for supporting human norovirus claims for hard surface disinfectants.
  - The presence of cytopathic effect (CPE) was used to determine presence of viable virus from the control and treated test carriers.

Methodology
FCV CPE

11



Methodology
Porous materials

12

1. Rubber (butyl rubber sheet)
2. Fabric (Duck canvas, 100% cotton heavyweight woven utility fabric)
   - BioSurface Technologies Inc., FC 110 – heavy cotton canvas 10 mm (3/8") x 0.63 mm thickness diameter disc coupons, untreated cotton
3. Pine Wood (untreated pine)
   - BioSurface Technologies Inc., FC 110-Pine 10 mm (3/8") x 2 mm thickness diameter disc coupons, untreated pine
4. Concrete
   - BioSurface Technologies Inc., Part # RD128-CC, polycarbonate cup filled with concrete

Methodology

Test conditions

13

- Three part soil load
- Pre-treatment of concrete carriers with fetal bovine serum prior to inoculation
- Increased the volume of the control and test substance from 50 µL to 75 µL for wood and concrete
- 5 minute contact time
- Neutralizer – Complete Growth Media (CGM) with 2% Fetal Bovine Serum (FBS)

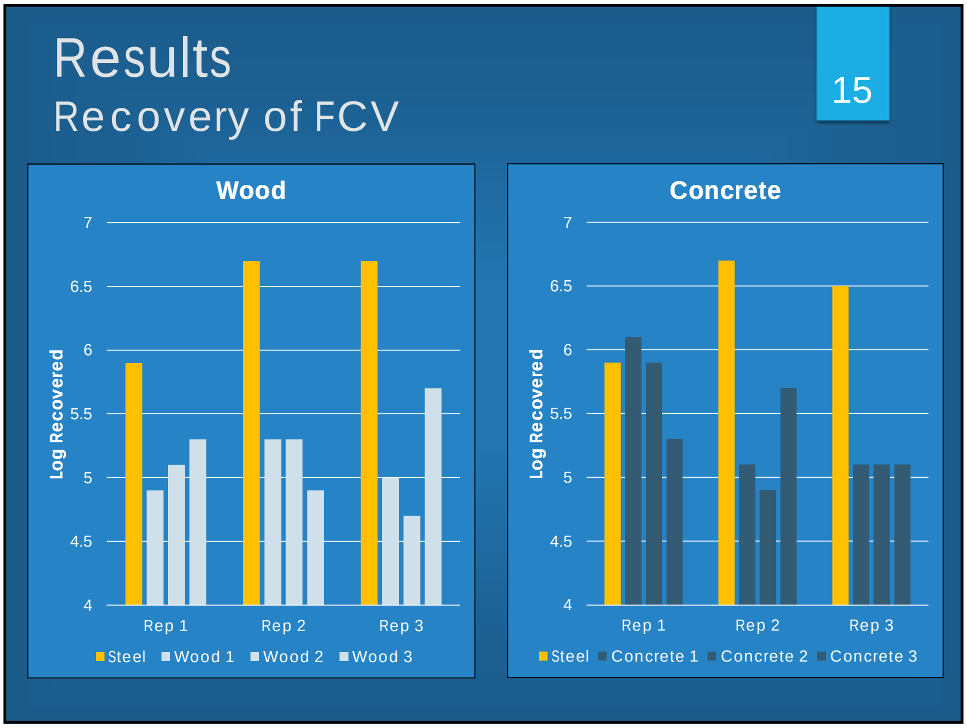
Methodology

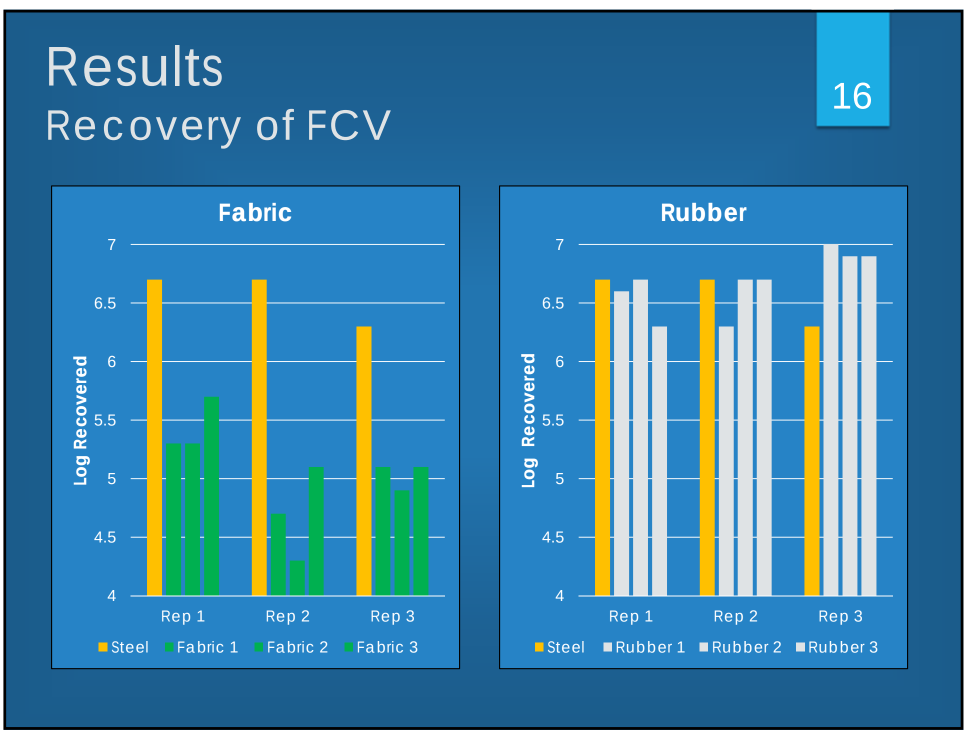
Carrier inoculation and drying

Inoculated Carriers

Drying Process

Dried Inoculated Carriers


Results
Recovery of FCV
15
Wood
Log Recovered
7
6.5
6
5.5
5
4.5
4
Rep 1
Rep 2
Rep 3
Steel
Wood 1
Wood 2
Wood 3
Concrete
Log Recovered
Steel
Concrete 1
Concrete 2
Concrete 3


Results
Recovery of FCV
16
Fabric
Log Recovered
7
6.5
6
5.5
5
4.5
4
Rep 1
Rep 2
Rep 3
Steel
Fabric 1
Fabric 2
Fabric 3
Rubber
Log Recovered
Steel
Rubber 1
Rubber 2
Rubber 3

Results

17

Control carrier counts - summary

- The data support the goal of achieving adequate control carrier counts for the porous carrier types; see efficacy studies for additional results.
- For wood, concrete, and fabric carriers, approximately 1-1.5 logs of FCV were not recovered compared to the stainless steel control.
- The control carrier counts for butyl rubber (9 total) were similar to the stainless steel.

Note: The starting virus stock titer was approximately 9.5 logs/mL and was diluted 1:5 for inoculation (recovery studies).

Methodology

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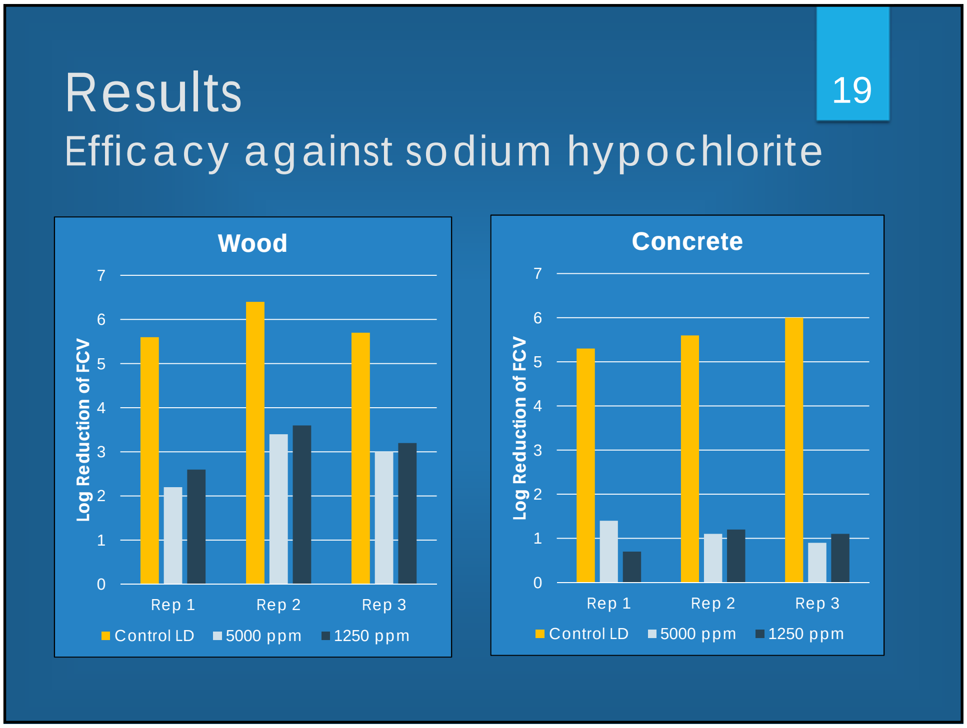
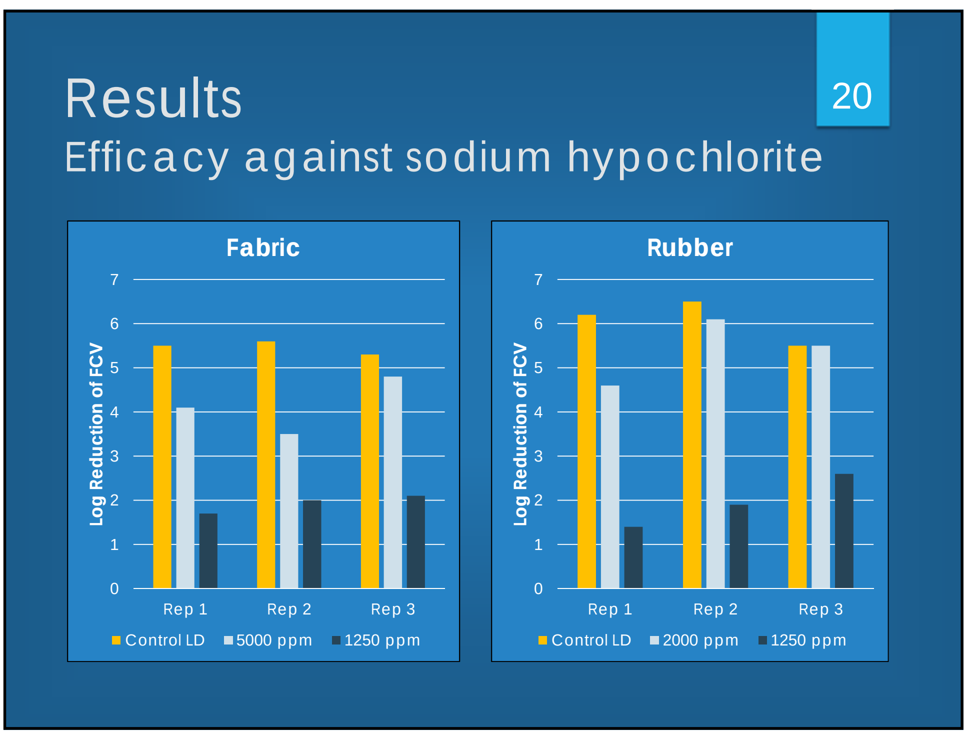
Demonstration of efficacy

- Test substance: reagent grade sodium hypochlorite (NaOCl)
- Three control and three treated carriers per rep
- The concentrations of NaOCl were selected to provide a range of inactivation of virus (i.e., high and low log reductions).
- The concentration of the NaOCl high efficacy treatment was increased from 2000 ppm to 5000 ppm following the first replication for wood, concrete, and fabric due to very low LR levels associated with the 2000 ppm solution.
- A concentration of 1250 ppm was used throughout the study as the lower efficacy treatment for all carrier types.

Note: Neutralization confirmation and cytotoxicity assays involving the treatment of porous carriers with NaOCl were conducted previously by MLB.


Results
19
Efficacy against sodium hypochlorite
Wood
Log Reduction of FCV
Rep 1
Rep 2
Rep 3
Control LD
5000 ppm
1250 ppm
Concrete
Log Reduction of FCV
Rep 1
Rep 2
Rep 3
Control LD
5000 ppm
1250 ppm


Results
20
Efficacy against sodium hypochlorite
Fabric
Log Reduction of FCV
Rep 1
Rep 2
Rep 3
Control LD
5000 ppm
1250 ppm
Rubber
Log Reduction of FCV
Rep 1
Rep 2
Rep 3
Control LD
2000 ppm
1250 ppm

Conclusions

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Efficacy tests – summary

- The OECD Quantitative Method (modified for porous materials) is deemed suitable for testing viruses on porous materials.
- Log density values of the control and treated carriers were consistent between carriers for each of the three replications.
- For wood and concrete, similar LR values were noted between the two sodium hypochlorite treatments.
- For fabric and rubber, method responsiveness was clearly demonstrated.

Conclusions

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Efficacy tests – summary

- NaOCl was shown to be an ineffective treatment against FCV on wood and concrete, thus a different active ingredient or use of pH adjusted NaOCl will be necessary to achieve higher LRs for use as reference standard.

Ongoing Studies/Next Steps

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- Recovery of FCV may be increased through additional means of extraction.
- The evaluation of additional active ingredients is underway.
- The evaluation of additional microbes such as human influenza virus and *Mycobacterium terrae* is underway.
- Identifying a commercial source of porous coupons is desirable for standard test methods.
  - Additional testing may be necessary to verify recovery from porous carriers made from other sources of materials (or different specifications).
- An inter-laboratory evaluation of the OECD Quantitative Method SOP for testing viruses on porous materials would be useful in assessing the clarity of the draft SOP and verifying the control carrier counts.

Acknowledgements

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- Department of Homeland Security/USDA – IA technical support and funding
- Jason Duncan, Microbiologist, EPA, MLB – lead scientist, data collection and SOP preparation
- Dr. Vipin Rastogi, Edgewood Chemical Biological Center – assistance with porous material selection and procurement

Treatment of CBRN Decontamination Effluent – A Research Project Exploring Feasibility

Victor F. Medina, Ph.D., P.E.

Technical Team Leader
Research Environmental Engineer
Environmental Laboratory

U.S. ARMY
US Army Corps of Engineers
ERDC Engineer Research and Development Center

Problem

- The Army has no capability to treat and/or recycle the effluent from its aqueous based chemical, biological, radiological and nuclear (CBRN) decontamination operations. This effluent is still very hazardous and a major handling, logistical, and potentially a political burden.

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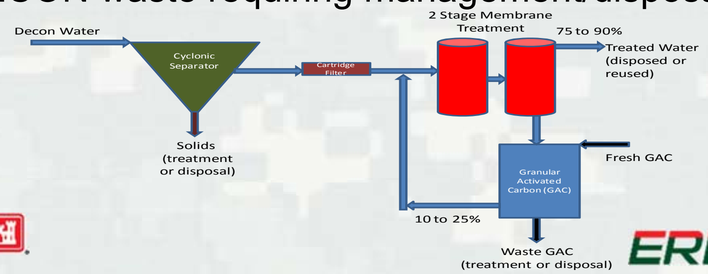
Solution

- A DECON effluent treatment system that can treat virtually anything , minimize DECON water requirements, be rapidly deployed and easy to maintain, and be able to minimize the volume of DECON waste requiring management/disposal.



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Task 1: Characterization of DECON Effluent

ERDC Information Paper that Estimates the Composition of Effluent from CBRN Decontamination

- We did not find documents on effluent composition
- Estimation of environmental constituents
- Estimation of treatment chemicals (bleach and surfactants)
- Simulant selection

https://www.researchgate.net/publication/306307888_Composition_of_CBRN_Decontamination_Effluent_and_Development_of_Surrogate_Mixtures_for_Testing_Effluent_Treatment_Technologies

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How much water?

- Adapted from Planning Factors of Operational DECON (Army G3/5/7 Decontamination Planning Factors)

Mission	Coverage	Water required (gal)	STB* required (lbs)	Time (min)
Detailed troop DECON	40 man unit	318	600	40
Supported Operational DECON	Wheeled Platoon (10 vehicles)	1500	0	30
Detailed Equipment DECON (Heavy decontamination)	Wheeled Platoon (10 vehicles)	4700	600	75
Terrain Decontamination	500 m x 30 m area	1500	300	40

*STB is Supertropical bleach

Troop DECON assumes troops were adequately protected (as opposed to mass casualty)

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Estimated Flow Rate for Experimental Reactor

Assumptions

- Large Event involving people and vehicles to give volume
- Assume treatment time per day of 12 hours

200 people

200	people	15	gal	1	day	1	hr	=	4.17	gpm
1	day	1	person	12	hr	60	min			

10 large military vehicles

10	Vehicles	4700	gal	1	day	1	hr	=	6.53	gpm
1	day	10	Vehicles	12	hr	60	min			

Total rate = 10.69 gpm. We chose 10 gpm.

This is a substantial rate, 600 gallons per hour or 14,400 gallon per day.

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CBRN Agents

- Chemical Warfare Agents (CWAs)
  - ► Organophospate compounds
  - ► Mustard agents
  - ► Strong, gaseous oxidants
  - ► Acids
  - ► Metals
- Biological Agents
  - ► Botullism, Ebola, Small Pox, Anthrax
  - ► Biotoxins – ricin, strychnine, botulism toxins

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CBRN Agents

- Radiological Agents

Alpha particle emitters	Beta particle emitters	Gamma ray emitters
Americium-241 (^{241}Am)	Phosphorus-32 (^{32}P)	Cobalt-60 (^{60}Co)
Plutonium-239/238 (^{239}Pu and ^{238}Pu)	Strontium-90 (^{90}Sr)	Iodine-131 (^{131}I)
Uranium (U-235)		Cesium-137 (^{137}Cs)
Thorium (Th-232)		Iridium-192 (^{192}Ir)

Adapted from Zimmerman and Loeb (2004)

- Improvised
  - ► Toxic Industrial Chemicals/Materials
  - ► Hazardous Materials/Waste

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Common residue

- Dirt and sediment
  - Common from vehicle washing
- Oils and grease
  - Vehicle washing
- Other organic matter
- Residuals from water sources
  - Natural organic matter
  - Salts and metals
  - Residual chlorine

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Car wash study

Contaminant	Concentration in mg/L	
	Average	Range
Oil & grease	22.8	6.7-60
Total nitrogen (TN)	4.17	0.2-5.6
Total phosphorus (TP)	4.61	0.3-12.1
Chromium (Cr)	0.045	0.006-0.072
Copper (Cu)	0.163	0.095-0.235
Lead (Pb)	0.051	0.016-0.070
Nickel (Ni)	0.028	0.020-0.037
Zinc (Zn)	0.49	0.22-0.98
Sodium (Na)	218.6	43-602
Chloride (Cl)	245.5	34-851
Total Suspended Solids (TSS)	42.14	6-117

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Decontamination Agents

- Bleach
  - ▸ Hypochlorite – a powerful oxidant
  - ▸ Sodium hypochlorite – common, household bleach
  - ▸ Chlorine dioxide – a gas that forms hypochlorite when dissolved in water & used in industrial application as well as disinfection after the 2001 anthrax mail attacks.
  - ▸ Supertropical Bleach (STB) – a mixture of calcium chloride, calcium hydroxide and calcium hypochlorite designed to maintain long shelf-life in warm, humid climates
  - ▸ High-Test Hypochlorite (HTH) – concentrated calcium hypochlorite with 70% available chlorine. Very powerful, but can be corrosive.

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Decontamination Agents

- Surfactants (Soap)
  - ▸ Surfactants decrease surface tensions with agents and water, allowing from increased removal.
  - ▸ Concentrated surfactants can cause cells to lyse, thereby having a disinfection process
  - ▸ Triton-X 100 – 1% v/v
  - ▸ Tergitol 15S-9 (Dow Chemical) – 1%
  - ▸ Synthetic nonionic detergent, military specification MIL-D-16791. - ~0,1 to 1%
  - ▸ Triethanolamine (commonly found in laundry detergent) – 3 to 5%
  - ▸ Sodium lauryl sulfate/sodium dodecyl sulfate (commonly found in dishwashing detergent) – 1 to 30%.
    - Probably most common. Very effective degreaser and mild to skin.
    - But can foam excessively.

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Formulations

- From the Massachusetts National Guard

Threat Agent	Decontamination formulations
G series nerve agents	1. Caustic soda solution (Sodium Hydroxide) 2. Washing soda solution (sodium carbonate) 3. STB slurry 4. Hot soapy water
Blister/mustard agents	1. HTH-HTB calcium hypochlorite 2. DS2 3. STB Slurry 4. Household bleach solution
VX nerve agent	1. HTB-HTH 2. DS2 3. STB 4. Household Bleach
Choking agents (phosgene, chlorine)	1. DS2 2. Caustic soda solution
Radioisotopes/Nuclear Residuals	Soap with warm water

DS2 = Decontamination Solution 2
STB = Super Tropical bleach
HTH = High-Test Hypochlorite
HTB = High Test Bleach

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Simulants

- CWAs
  - Malathion
  - Triethylphosphate
  - Dyes
- Radioisotopes
  - Non-radioactive isotopes
  - Cs 133
- Biologicals (studies deferred)
  - Non-infectious genera
  - *Bacillus globigii*
- Surfactants
  - Sodium laurel sulfate
- Bleach
  - STB, HTH
- TSS
  - Suspended clays
  - Collected water-Browns Lake
- TDS
  - Dissolved salts

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Example Composition

Component	Concentration	Comments
Malathion (simulant for VX)	100 mg/L	Upper solubility
STB	~5%	
Used motor oil	25 mg/L	
TSS	40 to 120 mg/L	Could be higher for a green mission with heavy off-road component
TDS	200 to 1000 mg/L	Bleach may greatly increase TDS

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Pilot Reactor

This design is based on commercially available products These have assembled in the laboratory for testing. In December/January, the components will be assembled on a trailer to complete a transportable system.

16

Treatment Strategy

- Sediment – Settling & sand filter
- Surfactant – Skimmer and GAC
- Bleach – Chemical and GAC
- Oils/Greases/Misc. Organic Compounds – Incidental removal, GAC, UF/RO
- Chemicals – Incidental removal, GAC, UF/RO
- Radioisotopes – Incidental removal, Sand, UF/RO (especially Cs)

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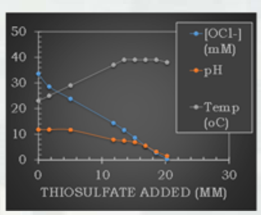
Bleach Removal Testing

Chemical Neutralization of Bleach

$4NaOCl\,(aq) + Na_2S_2O_3(aq) + 2NaOH(aq) \rightarrow 2Na_2SO_4(aq) + 4NaCl(aq) + H_2O(l)$ + heat

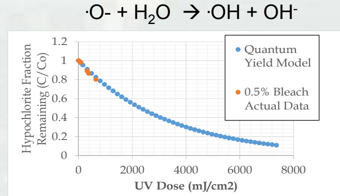


Key Experimental Results:
- Bleach was reduced effectively.
- Temperature spiked 15ºC under slow titration conditions.
- pH decreased to dangerous levels if fully neutralized (pH < 3, chlorine gas formation).

Photochemical Destruction of Bleach

$OCl^- + hv\,(UV) \rightarrow \cdot O^- + \cdot Cl$

$\cdot O^- + H_2O \rightarrow \cdot OH + OH^-$



Key Experimental Results:
- Bleach can be destroyed by UV light (slowly).
- Bleach is highly UV absorbent, making light penetration difficult.
- Byproduct radicals may aid CB agent destruction.
- Photocatalyst may be needed.

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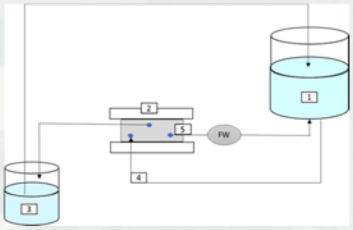
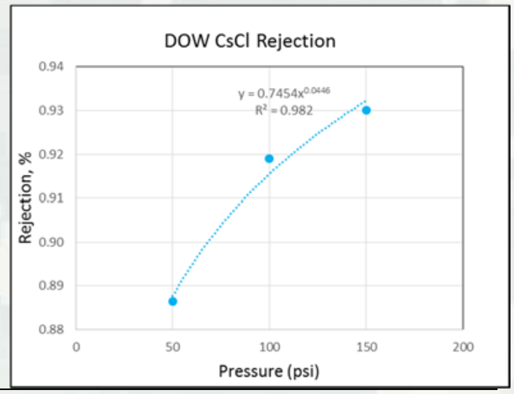
Benchtop RO Testing



Flat sheet RO Test Cell and Membrane SEM



Key Experimental Results:

- Effective removal of CsCl.
- Operating pressures are reasonably low
- CsCl removal often more challenging that NaCl
- Our pilot scale system is estimated to achieve 83% treated water recovery.

Product Name	Size (mm)	Material	Type
DOW BW30LE	190x140	Polyamide	Fouling Resistant
GE Osmonics TF RO SG	190x140	Thin Film	Chlorine Resistant
TriSep x210	190x140	Polyamide-urea	Fouling Resistant

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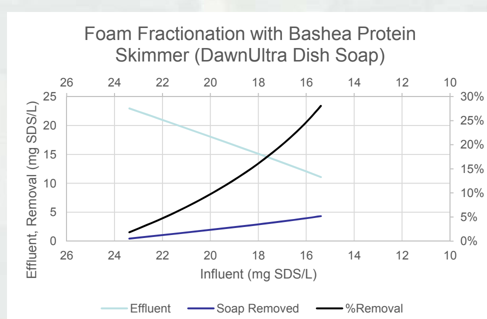
Surfactant Treatment – Protein Skimming



- Video - https://youtu.be/dHvA-usTieE

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Control Systems

- Development of System Controls
  - Real-time monitoring of treatment system.
  - Allows monitoring of multiple water quality parameters.
    - pH, Temperature, Turbidity, Conductivity, Oxidation-Reduction Potential (ORP), and Dissolved Oxygen (DO)
  - Records desired data parameters automatically
  - Alarms via SMS or email which allows monitoring and/or management from a single command and control center

WaspMote for Real-time Water Quality monitoring will be mounted in a flow cell And integrated into the system

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Next Steps (FY17-18)

- Sedimentation tank
- Testing of Sand and GAC filtration systems
  - Column testing
- UF/RO testing
  - Cs, malathion, dyes
- Multiple demonstrations planned
- Biological

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