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Report on the 2011 U.S. Environmental Protection Agency (EPA) Decontamination Research and Development Conference

Office of Research and Development
National Homeland Security Research Center

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2011 U.S. Environmental Protection Agency (EPA) Decontamination Research and Development Conference

National Homeland Security Research Center
Office of Research and Development
U.S. Environmental Protection Agency
Research Triangle Park, NC 27711

Office of Research and Development
National Homeland Security Research Center, Decontamination and Consequence Management Division

Disclaimer

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Foreword

Following the events of September 11, 2001, the mission of the United States Environmental Protection Agency (EPA) was expanded to address critical needs related to homeland security. Presidential Directives identify EPA as the primary federal agency responsible for the country's water supplies and for decontamination following a chemical, biological, and/or radiological (CBR) attack.

As part of this expanded mission, the National Homeland Security Research Center (NHSRC) was established to conduct research and deliver products that improve the capability of the Agency to carry out its homeland security responsibilities. As this research was being conducted and others in the homeland security research community were also conducting research in this area, there became a need for a forum to discuss the outcomes of this research and encourage collaboration among the community. The EPA Decontamination Conference was established in 2005. Since then, six EPA Decontamination Conferences have been held and a report has been generated summarizing each of these conferences. This year's report features an executive summary, a summary of the plenary session, the technical speakers' abstracts, their corresponding question and answer session, and their presentations.

NHSRC has made this publication available to facilitate collaboration among the homeland security research center and help the response community prepare for and recover from disasters involving CBR contamination. This research is intended to move EPA one step closer to achieving its homeland security goals and its overall mission of protecting human health and the environment while providing sustainable solutions to our environmental problems.

Jonathan Herrmann,
Director, National Homeland Security Research Center

Acknowledgments

The Environmental Protection Agency's National Homeland Security Research Center (NHSRC) would like to acknowledge the keynote speaker, Colonel Randall J. Larsen, at the 2011 Decontamination Conference. In addition, NHSRC would like to acknowledge the technical program speakers for providing the abstracts as well as the presentations published in this report. NHSRC would also like to acknowledge Eastern Research Group, Inc. for drafting the remaining portions of the report. Lastly, NHSRC would like to acknowledge Lukas Oudejans from its Decontamination and Consequence Management Division for review of the Executive Summary.

Executive Summary

The U.S. Environmental Protection Agency (EPA) held the "2011 EPA Decontamination Research and Development Conference" to enable participants from throughout the world to discuss decontamination related advances through science and engineering. In addition to an opening plenary session, the meeting had eight sessions that addressed the following topics:

- Responses, exercises, and program overviews
- Decontamination of water and wastewater infrastructure
- Decontamination of toxic industrial chemicals and chemical warfare agents
- Biological agent decontamination fate and transport
- Bio-Response operational testing and evaluation
- Radiological/nuclear agent decontamination and waste management
- Agricultural decontamination
- Biological agent sampling and decontamination.

Plenary Session

Dr. Emily Snyder (EPA), Mr. Jonathan Hermann (EPA), and Dr. Shawn Ryan (EPA) provided opening remarks at the conference and welcomed all participants, Dr. Peter Jutro (EPA) introduced the keynote speaker, Colonel Randall J. Larsen, Chief Executive Officer of the WMD Center, a not-for-profit research organization dedicated to homeland security issues. Colonel Larsen's keynote presentation addressed the 21st century threats of bioterrorism. The presentation identified misconceptions and realities associated with the current threats and consequences of bioterrorism. More simply, the presentation considered: Is bioterrorism a reality, or not? Colonel Larsen then reviewed a chronology of biological warfare programs and previous releases of biological agents to demonstrate that biological agents have already been tested and used in numerous countries for decades. He emphasized that one cannot fully appreciate the 21st century threats without understanding what has happened in the recent past. Colonel Larsen also discussed recent technological advances in developing, weaponizing, and disseminating biological agents that have greatly increased the threats of occurrence of bioterrorism attacks. Finally, Colonel Larsen discussed a report recently issued by the WMD Center—*Bio-Response Report Card*—that assesses the United States' current abilities to respond to bioterrorism events. Section 2 of this report provides additional detail on the keynote presentation and other points raised during the plenary session.

Responses, Exercises, and Program Overviews (Session 1)

The first session included six presentations from representatives of federal agencies of the United States, Canada, and the United Kingdom. Four of these presentations provided updates and perspectives from U.S. agencies, including EPA, the Nuclear Regulatory Commission, the Department of Homeland Security, and the Department of Defense. In addition to providing general overviews of these agencies' ongoing decontamination research activities, the talks focused on recent developments of interest and specific exercises, such as lessons learned from the Fukushima Dai-ichi nuclear crisis in Japan and an overview of the recent Liberty RadEx project—EPA's first National Level Exercise designed to test responders' ability to assess and clean up following a radiological dispersion device terror attack in an urban environment.

The fifth presentation provided updates from Canada's CBRNE Research and Technology Initiative, including a program overview and summaries of recent exercises, research and development activities, technology demonstrations, and national response capability. The final presentation provided similar updates from the United Kingdom's Government Decontamination Service. In addition to providing an overview of the

agency's ongoing activities, this presentation gave a detailed account of the recent "Silver Streak" exercise, which was designed to test response to a radiological device deployed in an underground subway tunnel.

A common theme of these presentations was continued demonstrated progress in the science and technology of decontamination for a wide range of attack scenarios. Section 3 of this report provides additional detail on the six presentations given during this session.

Decontamination of Water and Wastewater Infrastructure (Session 2)

This session opened with a presentation describing how contamination incidents impact drinking water and wastewater systems, the knowledge gaps related to mitigating these impacts, and how research is addressing those gaps. This presentation provided a general overview of recent research activities conducted by EPA's Water Security Division and National Homeland Security Research Center. These research activities included laboratory and field research projects and development of decision-making frameworks for specific attack scenarios.

The five other presentations described specific research projects. One speaker reviewed bench- and pilot- scale investigations evaluating the effectiveness of germinants for the decontamination of *Bacillus anthracis* spores adhered to iron and cement-mortar drinking water infrastructure. Effectiveness of decontamination varied with environmental conditions and coincident use of various disinfectants, and the research ultimately reported that germination followed by flushing and chlorination is an effective way to decontaminate spores from iron and cement mortar lined pipes. Another speaker reported findings from a project that used EPA's Persistence and Decontamination Experimental Design Protocol to evaluate the absorption, persistence, and possible decontamination approaches for *Bacillus globigii* on concrete-lined and polyvinyl chloride pipe, with the principal finding being that decontamination of these pipe materials may have less to do with rate of flow than the duration of the flow past the contaminated sections. The next speaker summarized bench scale investigations for decontaminating *Bacillus globigii* in wastewater—research that found effectiveness of decontamination varied with the amount of household bleach and vinegar used in the disinfectant recipes. The next speaker discussed ongoing research designed to use water-based solutions to remove cesium from surfaces common to urban settings (e.g., concrete, asphalt, brick, limestone, granite). Clays and other natural sequestering agents were used to sequester and immobilize the cesium. Removal efficiencies varied across surface types and composition of the decontamination solution. The final presentation summarized multiple research projects supported by EPA's Water Infrastructure Protection Division. These projects addressed many topics, from assessing the persistence and removal of chemical agents adhered to drinking water pipes to investigating the effectiveness of advanced oxidation processes in treating water contaminated with toxic chemicals prior to disposal into public sewers.

Section 4 of this report provides additional detail on the six presentations given during this session.

Decontamination of Toxic Industrial Chemicals and Chemical Warfare Agents (Session 3)

This session began with a presentation on Quick Reference Guides, which are brief two-page summaries of information that would be critical to federal On-Scene Coordinators in the first 24 to 48 hours of a response. These guides present information on worker protection measures, means for mitigating the spread of contamination, sampling and air monitoring methodologies, and health effects information. Though presented in the session on toxic industrial chemicals and chemical warfare agents, Quick Reference Guides are also available for numerous biological agents. Another presentation documented EPA's recent experience with decontaminating residences in

Ohio where malathion had been illegally applied indoors in attempt to rid homes of bedbugs. Data were presented on the observed contamination levels before and after cleanup and how these levels varied with the decontamination solution.

The remainder of the session consisted of five presentations documenting findings from recent laboratory evaluations of decontamination strategies for toxic industrial chemicals and chemical warfare agents. One presentation addressed research findings regarding the efficacy of liquid and foam decontamination techniques (e.g., undiluted bleach, chlorine dioxide, foams) for chemical warfare agents on indoor surfaces. The findings suggested that a combination of decontamination approaches will likely be necessary in many scenarios, because no individual decontamination technology proved to be highly effective across all surfaces considered, with porous surfaces being most challenging. Another presentation documented a research project that investigated how effectively two enzymatic solutions could decontaminate chemical warfare agents applied to five representative indoor building materials. This research noted discrepancies between vendor product evaluations (which are often based on decontamination of solutions) and the research results (which were based on decontamination of surfaces). The next presentation summarized research on the use of widely available household chemicals (e.g., ammonia floor cleaner, hydrogen peroxide, baking soda, rubbing alcohol) to decontaminate chemical warfare agents. Most testing measured effectiveness of decontamination in solutions, with limited results presented for surfaces. The next presentation evaluated fumigation methods for decontaminating chemical warfare agents on industrial carpets, galvanized metal, and vinyl surfaces. Data were presented on how effectiveness of decontamination varied with fumigation time and the material being decontaminated. The final speaker presented findings from ongoing research on the use of non-aqueous catalytic processes to decontaminate sensitive equipment (e.g., computers) contaminated with organophosphorus compounds. Findings were presented for two metallic catalysts in methanol solution that were applied to sensitive equipment either by immersion or spray.
Section 5 of this report provides additional detail on the seven presentations given during this session.

Biological Agent Decontamination Fate and Transport (Session 4)

The five presentations in this session addressed recent experience with biological agent decontamination. The presentations included studies of fate and transport of particles from contaminated surfaces, a proposed study to evaluate reaerosolization, and decontamination methodologies for biological agents and their surrogates.

The first speaker presented findings on use of common disinfectants against vegetative cells, pathogenic strains, and surrogates of *Francisella tularensis*, *Yersinia pestis*, and *Brucella melitensis*. The results demonstrated the utility of proposed surrogates and presented the first ever quantitative data on the effectiveness of EPA-registered disinfectants against selected highly infectious agents. The second presentation gave an overview of the "Scientific Program on Reaerosolization and Exposure"—a multi-agency program to be executed from 2011 through 2014. The program is being designed to develop a quantitative understanding of the public health risk from anthrax spore reaerosolization in an urban environment following an outdoor agent release. The presentation provided a general overview of the research program and anticipated outputs. The third speaker described the protocols recently applied in the United Kingdom when decontaminating residences and a village hall after detection of *Bacillus anthracis* spores associated with African drums made from contaminated animal hides. Chlorine dioxide fumigation was used, and the speaker discussed several challenges ranging from how to handle potentially contaminated pets to public perception of risk to discoloration of wall hangings from use of the fumigant. The next presentation described a recent study examining transfer of *Bacillus thuringiensis* spore powder from contaminated surfaces in a simulated

laboratory or office setting. Researchers directly measured transfer of the surrogate spores to uncontaminated surfaces and to operators entering the contaminated areas. Numerous findings were presented, collectively indicating that people accessing a site that has been exposed to a realistic biological aerosol cloud will: be exposed to the contaminant; collect the material on clothing, hands, and shoes; and transfer the contaminant to clean areas. The final speaker described ongoing research to assess application of fixatives to biologically contaminated surfaces as a means of preventing transfer of biological agents to clean areas. Testing will eventually be performed on candidate fixatives comprising different formulations to examine the potential for spore release from treated surfaces through physical contact (e.g., surface wipe sampling).

Section 6 of this report provides additional detail on the five presentations given during this session.

Bio-Response Operational Testing and Evaluation (Session 5)

This session included five presentations pertaining to the Bio-Response Operational Testing and Evaluation (BOTE) project—a multi-agency effort designed to operationally test and evaluate biological incident response from health and law enforcement response through environmental remediation. The first presentation gave an overview of the exercise, acknowledging the various agencies that participated. BOTE included two phases: a field-level decontamination assessment and a functional operational evaluation. Three decontamination methods were evaluated, using *Bacillus atropheus* as a surrogate for *Bacillus anthracis*.

The remaining presentations focused on specific aspects of BOTE. The second presentation, for instance, addressed sampling activities. Topics included preparation of sampling media (i.e., wipe-sponge sticks, swabs, and vacuum socks) and sampling kits prior to deployment, training the sampling personnel, sample collection protocols, and sampler proficiency testing. The third presentation reported preliminary results from a study of spore migration that occurred during BOTE. The study attempted to characterize the extent to which spores migrated from inside the test buildings to outside locations. Preliminary data analysis indicated that spores can be transported from inside a facility to outdoor areas, suggesting that future decontamination efforts need to consider not only indoor but also immediate outdoor environments when performing cleanup activities. The next presentation described a new research method used during BOTE for rapidly detecting and identifying—or ruling out the presence of—live *Bacillus anthracis* spores. This Rapid Viability Polymerase Chain Reaction (RV-PCR) method provided rapid results that were 95 percent consistent with results derived from conventional culture methods. The final presentation provided a preliminary cost analysis of the overall response. Costs were estimated for many activities, including sampling and analysis, application of decontamination technologies to the building, labor working on the project, equipment rental and consumables, waste management, and incident command. Preliminary cost analysis data were shared for various metrics, including the cost of applying a given decontamination technology per square foot or cubic foot of space and the cost of applying a given technology per unit of spore reduction.

Section 7 of this report provides additional detail on the five presentations given during this session.

Radiological/Nuclear Agent Decontamination and Waste Management (Session 6)

This session included nine presentations, most of which presented experimental findings pertaining to radiological or nuclear agent decontamination methodologies. The first presentation summarized laboratory experiments designed to assess the fate and transport of deposited cesium and cobalt following simulated rain events. This research found that the amount of cesium and cobalt rinsed off surfaces depended on many factors, including the building materials considered (e.g., asphalt, brick, concrete, granite). Another presentation described a study that used both laboratory experiments and modeling results to characterize surface interactions between cesium and common building materials in the presence of water. The experimental and modeling results provided insights into surface interactions and were expected to help inform selection of optimal decontamination strategies. Similarly, another presentation addressed theoretical and experimental results examining the mobility and bioavailability of radioactive cesium and strontium found near Chernobyl. Those research results might inform decisions about developing soil amendments to reduce bioavailability of the deposited radionuclides.

Additional experimental results were communicated in a presentation that evaluated decontamination of radionuclides from porous surfaces using a novel system of affinity-shifting agents, super-absorbing polymers, and non-ionic polymeric gels using conventional spray applicators. The decontamination system was shown to perform well in laboratory tests for certain materials, but improvements in decontamination efficiency were still desired for various combinations of substrates and radionuclides. Another presentation documented a decontamination efficacy testing methodology recently developed at EPA. This methodology was used to test the effectiveness of multiple decontamination technologies, including strippable coatings, mechanical methods, and chemical methods. The speaker discussed a broad range of research findings that varied by surface type, radionuclide, the applied decontamination technology, and many other factors. The fifth presentation presented experimental findings pertaining to the fate of radiological contamination from laundering activities—what fraction of radiological material originally found on fabric ends up in the wastewater, adhered to laundry machines, and retained on clothes. The study reported that washing effectively removes cesium contamination from fabric, with most of the cesium being transferred to the wastewater. The last presentation that included experimental results addressed simulated pressure washing for removal of gross contamination from critical infrastructure following detonation of an improvised nuclear device. This research found that use of ambient water in rotating water jet washers could remove more than 97 percent of fallout particles from concrete surfaces. The presentation also addressed operational considerations associated with using these washers under field conditions.

The session included two additional presentations that did not present new experimental results but included subject matter relevant to radiological or nuclear agent decontamination and waste management. First, a presentation addressed various activities being conducted at Defence Research and Development Canada. The focus of the presentation was on a recent shift from using short half life radioactive isotopes (e.g., sodium-24, lanthanum-140) to using longer lived isotopes (particularly strontium-85) in the agency's research and development activities. The speaker reviewed several examples of decontamination experiments that have been conducted using strontium-85. Finally, a speaker presented information on EPA's radiological dispersal device waste estimation support tool and explained how this tool can be used to evaluate tradeoffs between waste management and remediation strategies. The speaker reviewed functionalities currently coded into the software tool and discussed enhancements planned for future development, including modules for assessing the costs and time needed for transporting wastes and the costs and time

needed for application of certain decontamination methodologies.

Section 8 of this report provides additional detail on the nine presentations given during this session.

Agricultural Decontamination (Session 7)

This session included three presentations delivered by representatives of EPA and the U.S. Department of Agriculture (USDA). The first presentation gave an overview of the approaches USDA uses to clean and disinfect premises after they have been quarantined due to an animal disease outbreak. The presentation summarized relevant laws and regulations and described guidance, standard operating procedures, and training modules available on the agency's Animal and Plant Health Inspection Service website. In addition, the speaker presented a case study to illustrate logistical and environmental challenges faced during cleaning and disinfection projects. The second speaker presented a laboratory scale assessment of methods for decontaminating agricultural facility surfaces. Many variables were considered in the experimental setup, including two different surface materials (treated plywood or concrete), decontamination agents (Spor-Klenz and pH-adjusted bleach), application methodologies (backpack sprayer and gas-powered sprayer), and contact times (15 minutes and 30 minutes). *Bacillus globigii* was used as a surrogate for anthrax in the experiment. Results demonstrated how effectiveness of decontamination varied with contaminated materials, decontamination agents, and other experimental variables. The final presentation summarized findings from a two-stage decontamination study in which a mobile pressure washer followed by disinfectant foam application was used to decontaminate a farm cultivator. The field experiment used *Bacillus subtilis* as a surrogate for anthrax, but the full study results have not yet been published.

Section 9 of this report provides additional detail on the three presentations given during this session.

Biological Agent Sampling and Decontamination (Session 8)

The final session included seven presentations addressing sampling and decontamination of biological agents. One presentation focused on sampling and described parameters affecting recovery of bacterial spores and vegetative cells when conducting surface sampling. This research considered both spores (*Bacillus anthracis*) and vegetative cells (*Escherichia coli*, *Burkholderia thailandensis*, and *Bacillus cereus*) under different experimental conditions. For a given organism, dramatic differences in recovery across processing methods and extraction solutions were not observed. Lower recoveries observed in some cases may have resulted from adhesion of vegetative cells to the test tube walls.

Five of the remaining six presentations focused on research findings about decontamination strategies for biological agents. The first of these presentations characterized effectiveness of decontamination of peracetic acid dry fog for inactivating *Bacillus atrophaeus* and *Geobacillusstearothermophilus* spores on building materials. The study identified operational constraints associated with the fogging apparatus, which requires use of clean, dry, oil-free air and sufficient flow and pressure. Overall, fogging with hydrogen peroxide and peracetic acid showed promise but did not appear to be effective on concrete. The second presentation in this segment assessed gaseous decontamination technologies for use on spacecraft and their components. After testing and researching many candidate technologies and considering other factors (e.g., compatibility with materials and equipment), the researchers identified vapor hydrogen peroxide as the most appropriate decontamination technology for use by the European Space Agency and the National Aeronautics and Space Administration. Next, a presentation described experimental work designed to assess the potential for germination-lysis strategies for responding to anthrax spore attacks, particularly those occurring over wide areas. The germinants were low-cost, readily available materials, such as dilute chicken broth. The research showed that simple germinants

could induce rapid germination; the observed germination was complete at low spore levels but incomplete at higher concentrations. Improved spore removal might be observed with approaches using combined germinant and lytic enzyme formulations or addition of multiple germinants. The presentation that followed presented research findings for use of three liquid formulations to remove or inactivate biological agents on five material surfaces. The research evaluated decontamination of *Bacillus anthracis* spores and Flexal South American hemorrhagic fever virus (FLEV). Two of the three decontamination solutions achieved total inactivation of FLEV from the tested materials and effectiveness of decontamination was not compromised in experiments where dust was intentionally added to the surfaces to simulate common environmental interferences. The final presentation with experimental results discussed novel disinfection applications using a portable chlorine dioxide gas generation system, which was tested on both athletic gear contaminated with *Staphylococcus aureus* and animal skins inoculated with *Bacillus atrophaeus*. In both cases, the authors reported experimental conditions in which the chlorine dioxide fumigation eliminated the biological agents.

The last scheduled presentation at the conference evaluated multiple decontamination agents for their use in future bioterrorism attacks involving anthrax spores. Liquid solutions and fumigation methods were both considered and evaluated based on criteria that assess the advantages and disadvantages of the individual approaches. These criteria included effectiveness of decontamination, toxicity, and cost. The paper exercise documented in the presentation was expected to help EPA and other agencies develop consensus criteria for selecting liquid decontamination agents and fumigants for use in future cleanup scenarios.

Section 10 of this report provides additional detail on the seven presentations given during this session.

Note: The conference included an additional session on EPA's Quality Assurance Program as an optional training course designed to help conference participants develop a better understanding of quality assurance protocols for conducting homeland security research.

Table of Contents

List of Acronyms and Abbreviations

%P	percent persistence
AOP	advanced oxidation process
APHIS	Animal and Plant Health Inspection Service
AR	annular reactor
ATCC	American Type Culture Collection
ATD	Advanced Technology Demonstration
ATSDR	Agency for Toxic Substances and Disease Registry
Bg	*Bacillus globigii*
BOTE	Bio-Response Operational Testing and Evaluation
BSL	biosafety level
Bt	*Bacillus thuringiensis*
BW	biological warfare
C&D	construction and demolition
CARC-S	solvent-borne Chemical Agent-Resistant Coating
CARC-W	water-dispersible Chemical Agent-Resistant Coating
CBR	chemical, biological, radiological
CBRN	chemical, biological, radiological, nuclear
CDC	Centers for Disease Control and Prevention
CFIA	Canadian Food Inspection Agency
CFU	colony forming units
ClO_2	chlorine dioxide
Co	cobalt
CRTI	Chemical, Biological, Radiological-Nuclear, and Explosives Research and Technology Initiative
Cs	cesium
CWA	chemical warfare agent
DF-200	Sandia Decontamination Foam
DHMR	dry heat microbial reduction
DHS	Department of Homeland Security
DNA	deoxyribonucleic acid
DOD	U.S. Department of Defense
DOE	U.S. Department of Energy
DRDC	Defense Research and Development Canada
DTRA	Defense Threat Reduction Agency
EPA	U.S. Environmental Protection Agency
ESA	European Space Agency
ESF	Emergency Support Function
ESTS	Environment Canada, Emergencies Science and Technology Section
FBI	Federal Bureau of Investigation
FE	flushing evaluation
FEMA	Federal Emergency Management Agency
FLEV	Flexal South American hemorrhagic fever virus
GB	G-Series nerve agent (sarin), 2-(fluoro-methylphosphoryl)oxypropane
GC/MS	gas chromatography/mass spectrometry
GD	G-Series nerve agent (soman), pinacolyl methyl phosphonofluoridate
H2O2	hydrogen perocide
HaMMER	Hazard Mitigation, Material, and Equipment Restoration
HD	distilled mustard, bis(2-chloroethyl) sulfide

HE	hyperchlorination evaluation
HEPA	high-efficiency particulate air
HI-PS	high-impact polystyrene
HOC	U.S. Nuclear Regulatory Commission, Headquarters Operations Center
HP	hydrogen peroxide
HPV	hydrogen peroxide vapor
HVAC	heating, ventilation, and air conditioning
IBRD	Interagency Biological Restoration Demonstration
IND	improvised nuclear device
JSTO	Joint Science and Technology Office
LLNL	Lawrence Livermore National Laboratory
LLRW	low level radioactive waste
LRE	Liberty RadEx
LRN	Laboratory Response Network
LVS	Live Vaccine Strain
mg/cm^2	milligrams per square centimeter
mg/L	milligrams per liter
mL	milliliter
MLB	U.S. Environmental Protection Agency, Office of Pesticide Programs, Microbiology Laboratory Branch
MMAD	mass median aerodynamic diameter
MRSA	methicillin-resistant *Staphylococcus aureus*
MS	mass spectrometry
MSW	municipal solid waste
NASA	National Aeronautics and Space Administration
NDT	National Decontamination Team
NH_4Cl	ammonium chloride
NHSRC	National Homeland Security Research Center
NIOSH	National Institute for Occupational Safety and Health
NIST	National Institute of Standards and Technology
NMR	nuclear magnetic resonance
NRC	Nuclear Regulatory Commission
NRT	U.S. National Response Team
NSIR	U.S. Nuclear Regulatory Commission, Office of Nuclear Security and Incident Response
OP	organophosphorus
ORD	U.S. Environmental Protection Agency, Office of Research and Development
OSC	On-Scene Coordinator
OSWER	Office of Solid Waste and Emergency Response
PBS	phosphate buffered saline
PCR	polymerase chain reaction
PDED	pipe decontamination experimental design
PDEDP	Persistence and Decontamination Experimental Design Protocol
PE	persistence evaluation
PHAC	Public Health Agency of Canada
ppm	parts per million
PVC	polyvinyl chloride
qPCR	quantitative polymerase chain reaction
QRG	Quick Reference Guide
R/N	radiological/nuclear
RDD	radiological dispersal device
RDS	Radiological Decontamination Solution

RIHTOP	Research Institute of Hygiene, Toxicology, and Occupational Pathology
RV-PCR	Rapid Viability Polymerase Chain Reaction
RWJ	rotating water jet
SD	Secure Digital (memory card format)
SDF	Surface Decontamination Formulation
SPMPT	sewage plant microorganism performance testing
SPORE	Scientific Program on Reaerosolization and Exposure
Sr	strontium
TGD	nerve agent GD, thickened with 5% poly(methylmethacrylate)
TSA	trypticase soy agar
USAF	U.S. Air Force
USDA	U.S. Department of Agriculture
USPHS	U.S. Public Health Service
VHP	vaporous hydrogen peroxide
VX	V-series nerve agent, O-ethyl-S-(2-diisopropylaminoethyl)methyl phosphonothiolate
WARRP	Wide Area Recovery and Resiliency Program
WEST	Waste Estimation Support Tool
WISER	Wireless Information System for Emergency Responders
WMD	weapon(s) of mass destruction
WSD	U.S. Environmental Protection Agency, Water Security Division

1 Introduction

This report summarizes presentations and discussions from the "2011 U.S Environmental Protection Agency (EPA) Decontamination Research and Development Conference," which was held November 1–3 in Durham, North Carolina. The technical content of this report is based entirely on information and discussions from the workshop.

The workshop consisted of 50 speaker presentations organized in eight sessions, followed by brief Question and Answer Sessions. Mr. Jonathan Herrmann, Director of National Homeland Security Research Center (NHSRC), opened the Plenary Session and Colonel Randall J. Larsen, USAF (retired), Chief Executive Officer of the Weapons of Mass Destruction Center, served as the keynote speaker. Approximately 150 workshop participants represented federal, state, and local government agencies and laboratories; international organizations (five countries other than the United States); academia; and the private sector.

This report provides an overview of the Plenary Session and summarizes each presentation within the nine sessions. Each presentation summary consists of the abstract provided by the speaker and a review of the brief Question and Answer Session. The speakers' presentation slides, which include additional detailed information, are found in Appendix C of this report.

This report is organized by topic session and supporting information as follows:

- Section 2 summarizes the Plenary Session.
- Sections 3–11 contain the abstracts and Question-and-Answer summaries for nearly 50 presentations given over the course of the three-day conference. The presentations are organized according to the nine sessions included in the meeting agenda.
- Appendix A provides the meeting agenda, which lists the presentations and speakers in chronological order, as the presentations occurred during the workshop.
- Appendix B lists the workshop participants.
- Appendix C includes presentation slides for speakers who approved them for distribution.

2 Plenary Session

2.1 Opening Comments from EPA

Mr. Jonathan Hermann, Director of National Homeland Security Research Center (NHSRC), welcomed the conference participants and presenters to the 6th annual Decontamination Conference. Mr. Hermann noted that participation in the conference has grown over the years—from about 70 attendees at the initial conference to approximately 110 attendees at the 2011 conference. Mr. Hermann stated three goals for the 2011 conference:

- To bring together scientists who do CBR recovery research, persons conducting remediation activities (e.g. On-Scene Coordinators) and those who set policy related to CBR decontamination in U.S. and international governments, academia, and industry.
- To allow the exchange of information on scientific endeavors (e.g., basic and applied research, field demonstrations, guidance and tool development and field application) related to CBR recovery issues.
- To show the connection between basic or fundamental decontamination research and applied research as well as applied research and field application.

Mr. Hermann emphasized that the conference provides a forum for exchanging ideas and research, which promotes further collaboration and allows agencies involved in recovery after a homeland security incident to be cognizant of any new research and development findings. He added that the Decontamination Conference is important because it facilitates the transmission of recovery-related research outcomes to the customers who use the research results (e.g., Office of Emergency Management, On-Scene Coordinators).

Mr. Hermann then reviewed the conference agenda, which includes topics covering all phases of remediation from site characterization sampling and analysis all the way to waste disposal. He noted that this year's conference will include presentations on recent exercises, including the Bio-Response Operational Testing and Evaluation (BOTE) program and Liberty RadEx. Other presentations will address actual responses (e.g., the Nuclear Regulatory Commission's response to the Fukushima Dai-ichi Nuclear Crisis) and recent research focused on all-hazards decontamination. Mr. Hermann acknowledged that the conference is bringing participants together from across the federal government (e.g., the Department of Defense, the U.S. Department of Agriculture, the Department of Homeland Security, the Nuclear Regulatory Commission, the Federal Bureau of Investigation, and the National Institute of Standards and Technology). Participants also attended from academia, industry, and multiple international agencies and laboratories (e.g., the United Kingdom Ministry of Defense, Government Decontamination Services, and Health Protection Agency; Environment Canada and Defense Research and Development Canada; and Russia's RPA "Typhoon").

Dr. Shawn Ryan, Division Director of NHSRC's Decontamination and Consequence Management Division, also provided welcoming remarks. He first acknowledged the contributions of Dr. Emily Snyder, who served as Chairperson of the conference and organized the agenda and presentations. Dr. Ryan also acknowledged the contributions from the attendees, both presenters and participants. He added that the Decontamination Conference continues to remain dynamic, with presentations focused on current research, most often with novel and generally ground-breaking efforts being presented for the first time. Dr. Ryan noted that this dynamic format was first established when Dr. Nancy Adams and Mr. Blair Martin (retired EPA personnel) organized and pioneered the first Decontamination Conference. He said the

conference continues to be one of the premier forums in which a broad array of experts openly discusses homeland security issues specific to CBR decontamination.

Finally, Dr. Peter Jutro, Deputy Director for Science and Policy for NHSRC, introduced the conference's keynote speaker. This year's keynote speaker was Air Force Colonel (retired) Randall Larsen, Chief Executive Officer of the WMD Center, a not-for-profit research organization founded by former Senators Bob Graham (D-FL) and Jim Talent (R-MO). The keynote speaker previously served as Executive Director of the Congressional Commission on the Prevention of Weapons of Mass Destruction Proliferation and Terrorism. Larsen will discuss "The 21st Century Threat of Bioterrorism." Dr. Jutro noted that Colonel Larsen served in the military for more than 30 years and created and taught the first homeland security course at the U.S. Army War College. Dr. Jutro reviewed many other highlights from Colonel Larsen's resume, such as being one of the first witnesses to testify before the 9/11 Commission, testifying regularly before Congress on bioterrorism and related homeland security issues, and making numerous television appearances to comment on homeland security. Further, the organization that Colonel Larsen currently runs recently issued a report titled *Bio-Response Report Card*, a document that assessed the United States' current abilities for responding to bioterrorism events. The report gave relatively high marks to the nation's perceived ability for environmental cleanup following a small-scale, non-contagious bioterrorism attack but also assigned failing grades for large-scale attacks. The report and these specific findings were revisited and discussed numerous times during the 2011 Decontamination Conference.

2.2 The 21st Century Threat of Bioterrorism

Colonel Randall J. Larsen, USAF (retired), Chief Executive Officer of the WMD Center

Colonel Larsen's presentation addressed the 21st century threats of bioterrorism. A key to preparedness for bioterrorism events is ensuring that elected officials and policymakers fully appreciate the nature of 21st century threats and the current state-of-the-science in microbiology and other related fields, which can be a challenge given the limited science literacy in much of the United States population. Much of the presentation focused on misconceptions and realities associated with the threats and consequences of bioterrorism. More simply, the presentation addressed the question: Is bioterrorism a reality, or not? Colonel Larsen posed three questions that are frequently used to assess threat levels: (1) Do any non-state actors intend to use biological weapons? (2) Do these groups have the capability of accessing these weapons? (3) Is the United States vulnerable to such an attack? The remainder of the presentation primarily addressed the second and third questions and how best to understand 21st century bioterrorism threats.

Colonel Larsen first noted that many officials and national security leaders have mistakenly assumed that strategies for preventing use of other types of weapons of mass destruction (WMD) will also prevent bioterrorism attacks. For example, some officials have previously suggested that the United States could effectively address bioterrorism simply by adopting the model for minimizing risks of terrorist groups obtaining and detonating nuclear devices—locating loose nuclear material (e.g., highly enriched uranium), "locking down" facilities that contain this material, and eliminating this material. Such an approach will not work for bioterrorism, however, because individuals with limited background in microbiology can already develop biological weapons using readily available materials and equipment. As an example, in the early 2000s, microbiologists from Stony Brook University were able to synthesize viruses in laboratories, including the polio virus, using genetic material and equipment accessible through commercial laboratory supply networks. This example and others noted during the presentation emphasized that simply locating and shutting down facilities will not prevent motivated individuals with some experience in microbiology from developing biological weapons.

Another mentality that can compromise preparedness is the perception that biological weapons are extremely difficult to obtain or develop. Colonel Larsen reviewed a chronology of biological warfare programs and previous releases of biological agents to demonstrate that biological agents have already been tested and used in numerous countries for decades. He emphasized that one cannot fully appreciate the 21st century threats without understanding what has happened in the recent past. Colonel Larsen also discussed recent technological advances in developing, weaponizing, and disseminating biological agents that have greatly increased the threats of bioterrorism attacks occurring. A brief review of the chronology provided during the presentation follows:

- Colonel Larsen provided several examples of other countries testing or using biological agents during the World War II era. For example, the British tested release of anthrax spores at Gruinard Island—a location that has required several decades to decontaminate. In addition, the Japanese had a biological warfare program that used vectors (e.g., plague-infested fleas) to spread disease among enemy populations. Those weapons were used in China and were reportedly being planned for use in the United States.

- During and after World War II, the United States had an offensive biological warfare program. Examples of activities were presented, including controlled testing of certain biological agents on human volunteers at Fort Detrick as part of "Operation Whitecoat," dispersal of Q fever from aircraft at Dugway Proving Ground, and testing the dispersal of dry powder anthrax spores in remote areas of the Pacific and in Alaska. Several other examples were presented, all showing advances in technology over the years for disseminating the biological agents. These activities ceased in 1969, when President Nixon signed the Biological Weapons Convention and terminated the nation's offensive biological weapons program.

- Even after many nations signed this convention, large-scale research into offensive biological weapons continued in the Soviet Union and likely in other countries. The Soviet program included thousands of personnel working at dozens of facilities. Biological agents that were investigated as part of that program included smallpox, plague, and anthrax.

- In recent decades, advances in the field of synthetic biology have greatly expanded capabilities for developing biological agents. While terrorist organizations may not have the ability to develop or access sufficient quantities of biological agents for wide area attacks, such groups are likely to be capable of acquiring weaponized biological agents in smaller quantities. Crude methods for disseminating this material (e.g., leaf blowers, backpack sprayers, remote-controlled airplanes) are widely available.

Colonel Larsen used this chronology to demonstrate not only that development, testing, and use of biological agents occurred in recent decades but also that scientific and technological advances have increased the likelihood that acts of bioterrorism will occur in the future. To illustrate his concern, he noted that any country with a pharmaceutical industry could likely develop a biological warfare program and that many experienced microbiologists can manufacture smaller quantities of biological agents using naturally occurring material and equipment readily available from laboratory supply companies. Even these small quantities can have significant consequences: just two pounds of powdered anthrax, effectively disseminated in a densely populated urban center, could result in many thousands of casualties. Despite these concerns and consequences, many people in the United States are completely unaware of what has occurred previously and the current capabilities for

developing biological weapons. Colonel Larsen again emphasized that the United States cannot eliminate this threat simply by "locking down laboratories."

Colonel Larsen concluded his presentation by discussing a report recently issued by the WMD Center, an organization that he manages. The report—*Bio-Response Report Card*—assesses the United States' current abilities for responding to bioterrorism events. Colonel Larsen noted that the report gave the United States relatively high marks for the nation's ability for environmental cleanup following a small-scale, non-contagious bioterrorism attack, but the report assigned the country failing grades for response to large-scale, wide-area attacks. Colonel Larsen said the higher grade for the small-scale attacks is encouraging news and a significant improvement over previous assessments. He added that the failing grade for wide-area attacks will hopefully provide an incentive for the government to dedicate more resources to improving preparedness in this area. These additional resources could prove to be a worthwhile investment, given the significant economic consequences associated with wide-area bioterrorism attacks.

Question and Answer Session

Question 1: For bioterrorism incidents, do you anticipate a policy shift that will place greater emphasis on environmental cleanup as opposed to medical countermeasures?

Summary of response: Across the federal government, resources allocated to decontamination and environmental cleanup are currently minimal compared to those for medical countermeasures. However, allocating additional resources to decontamination and environmental cleanup would likely offer a better return on investment: very significant improvements can result from relatively small increments in resources for environmental cleanup when compared to the much greater resources needed to see major breakthroughs and advances in medical countermeasures. Part of the challenge in increasing resources for environmental cleanup is overcoming the mind set among policymakers that bioterrorism attacks can and will be prevented. If policymakers believed that a bioterrorism attack eventually will happen, they would be likely to allocate more resources to preparedness activities (e.g., decontamination and environmental cleanup).

3 Responses, Exercises, and Program Overviews

3.1 NRC's Response to the Fukushima Dai-ichi Nuclear Crisis

Scott A. Morris, Nuclear Regulatory Commission

Since May 2010, Mr. Scott Morris has served as the Deputy Director for Incident Response in the U.S. Nuclear Regulatory Commission's (NRC's) Office of Nuclear Security and Incident Response (NSIR). In this capacity, he is responsible for all aspects of the NRC's Incident Response Program, including the maintenance and staffing of the agency's 24/7 Headquarters Operations Center (HOC). The organization develops policies, programmatic guidance, plans, and procedures to ensure that NRC provides timely and effective response to national incidents and events involving NRC-licensed materials. Other key organizational responsibilities include the coordination and liaison with other federal, state, and international emergency response authorities.

A significant response effort in this past year was the NRC's response to the earthquake and tsunami that inflicted catastrophic damage to the coastline of Japan. NRC emergency responders staffed the HOC for more than three months and closely monitored the status of the Fukushima Dai-ichi reactors and spent fuel pools. Such an extreme set of circumstances led to a fast-paced response effort with a large degree of uncertainty about plant conditions. In responding to this unique challenge, the NRC dispatched more than 50 technical staff members to Japan in order to better coordinate its actions with the U.S. State Department, the Government of Japan, Tokyo Electric Power Company, and other federal agencies as part of the U.S. government's response to the event. Consistent with the agency's domestic response mission, the NRC did everything that could be done to ensure that the U.S. citizens living in that region of Japan were safe. Following the accident in Japan, the NRC directed its staff to conduct a systematic and methodical review of its response to the events and NRC processes and regulations to determine whether the agency should make additional improvements to its regulatory system. As a result of these reviews, the NRC has identified a number of good practices and lessons learned that will be used to improve its response to future events and its regulatory system.

Question and Answer Session

Question 1: To what extent has contamination been observed in the adjacent marine environment near the Fukushima facility?

Summary of response: The speaker was unaware of the extent of sampling that has occurred in the marine environment. Most efforts initially have focused on containing contamination, which eventually eliminated ongoing direct releases to the marine environment. However, migration of contaminated groundwater may contribute to contamination in the marine environment. Many other types of environmental monitoring are ongoing.

Question 2: Is there an international organization with oversight responsibility for environmental monitoring at nuclear power plants worldwide?

Summary of response: The International Atomic Energy Agency has that oversight role. A current focus is to improve the reporting of data from individual facilities and countries to a centralized location, which would eventually enable researchers to access those data. Since the Fukushima incident, various nuclear energy agencies worldwide have voiced concern about many aspects of operating and monitoring nuclear power plants.

Question 3: Would NRC consider including waste management issues as part of its emergency preparedness exercises?

Summary of response: NRC conducts many emergency preparedness exercises, with involvement from the Federal Emergency Management Agency (FEMA). These preparedness exercises typically focus on accident sequence and immediate response activities, but NRC has been involved with some exercises that considered longer-term response issues and will likely do more of these exercises in the future.

Question 4: How are authorities managing contaminated debris from the Fukushima facility?

Summary of response: This is an ongoing issue, as most initial response efforts have focused on containment and regaining control at the facility. Authorities are now conducting site characterizations and sectioning off different areas based on observed contamination levels. Various options are being considered for near-term and long-term waste management, such as building temporary concrete structures to store debris. However, the full range of final waste management decisions has not yet been made.

3.2 Recent R&D by Environment Canada on CBRN Decontamination

Carl E. Brown, Environment Canada

Aim of Work Presented

Over the last nine years, Environment Canada and Defence Research and Development Canada (DRDC) have led a number of successful collaborative projects (funded by the CBRNE Research and Technology Initiative, or CRTI) in decontamination-related research. Brief details of these projects will be presented.

Methods and Results

Environment Canada has been the lead Government of Canada department on several CRTI-funded projects over the first nine years of CRTI and has participated in a supporting role in projects led by other departments. Examples of these research and development, technology demonstration, technology acceleration and technology acquisition projects will be described in this presentation. The Emergencies Science and Technology Section (ESTS) of Environment Canada is currently leading two large decontamination projects and is a partner on a third project led by DRDC-Ottawa.

Technology acquisition projects have provided a significant level of funding for scientific capital equipment purchases, person-portable instrumentation for emergency response, mobile sampling, and personnel decontamination units for the ESTS Scientific Support Team, which provides support to Environment Canada during major environmental emergencies. Many of these projects have enhanced Environment Canada's scientific and operational capabilities and contributed to decontamination research efforts.

Conclusions

Through these decontamination research and development projects, a number of Canadian and international partner organizations have contributed to the advancement of knowledge in this field.

Significance and Impact of Work

As a result of these CRTI-funded decontamination research and development activities, the international community is better equipped to make decisions related to the decontamination and restoration of facilities following a CBRN event.

Question and Answer Session

Question 1: Does your agency support a program on testing foreign agriculture disease agents?

Summary of response: This is an active area of research at the Canadian Food Inspection Agency (CFIA) with funding support from CRTI and collaboration with the Public Health Agency of Canada (PHAC).

3.3 Wide Area Recovery and Resiliency Program—Targeted S&T Solutions to Enhance Interagency Capabilities

Chris Russell, DHS, Science and Technology Directorate

An abstract for this presentation was not available for publication.

Question and Answer Session

Question 1: What technologies are you considering for waste screening and segregation of radiological waste?

Summary of response: The speaker requested that a colleague respond to this question. That individual noted that EPA has a pending project to identify the best technologies for screening and segregating radiological waste and debris. EPA's work will consider what existing technologies for managing contaminated soil are adaptable to managing other types of waste streams.

Question 2: The "Bio-Response Report Card" recently gave the U.S. an "F" for the nation's ability to conduct environmental cleanup following a large-scale bioterrorism attack. What is DHS doing to improve this grade?

Summary of response: DHS is continuing efforts to improve abilities for environmental cleanup following large-scale bioterrorism attacks, largely through interagency collaboration with EPA and others. The speaker did not think the failing grade was warranted, given the various exercises and research that has been conducted to date. However, the failing grade may help stimulate additional funding and research that will continue to advance preparedness in this area.

Question 3: How has DHS helped state and local agencies look beyond initial emergency response and consider longer term issues, such as the roles and responsibilities of federal, state, and local agencies during waste cleanup and recovery?

Summary of response: All parties involved in emergency preparedness need to consider the importance of longer-term recovery. Having the right mix of people involved in exercises and preparedness planning is an important step. First responders are obviously essential in planning efforts, but they tend to focus largely on initial response activities. Planning efforts must also consider people who specialize in waste cleanup and longer-term recovery. In addition, there is a need to develop processes for recovery. FEMA has already implemented a conceptual recovery process in the *National Disaster Recovery Framework*. State and local agencies must also appreciate that recovery occurs in parallel with response, and decisions made early in the response process can have significant bearing on prospects for longer-term recovery.

Question 4: A participant clarified that the "Bio-Response Report Card" gave the U.S. a failing grade for response to large-scale bioterrorism attacks, but the U.S. received a "B" for the nation's ability to conduct environmental cleanup following a small-scale bioterrorism attack. Significant advances have been made in small-scale responses, and credit should be taken for the cleanup responses for the 2001 anthrax attacks.

Summary of response: The speaker agreed. The U.S. now has significant experience with cleaning indoor environments following small-scale bioterrorism attacks and is taking steps to increase its capabilities when responding to large-scale attacks. For example, the Wide Area Response and Resiliency Program (WARRP) represents a major effort to prepare for large-scale attacks. In addition, many of the presentations scheduled for the workshop document research that will help inform these large scale cleanup response efforts.

3.4 Overview of the DTRA/JSTO Decontamination Portfolio

L. Revell Phillips, Defense Threat Reduction Agency, Joint Science and Technology Office

Aim of Work Presented

The goal of the Defense Threat Reduction Agency/Joint Science and Technology Office (DTRA/JSTO) decontamination area is to develop science and technology that protects the warfighter from the full range of chemical and biological agents by supporting acquisition programs of record and providing the material developer with innovative and revolutionary alternatives that meet the user's needs.

Conclusions

This presentation will provide an overview of our ongoing and future decontamination research and development efforts, with the goal of discovering opportunities for synergy with the U.S. Environmental Protection Agency's research and development efforts.

Significance and Impact of Work

We are specifically looking to increase the effectiveness against both current and emerging threats, improve materials compatibility, and decrease logistical requirements.

Historically, there has been an emphasis on having a single decontaminant for use against all agents and on all surfaces; ongoing work seeks to provide a system of decontaminants allowing the warfighter to tailor the response to the specific situation. Enzymes for degrading nerve agents and biologically inspired options for wide area anthrax spore decontamination are two potential options for inclusion in this system.

Question and Answer Session

Question 1: Have you considered partnering with companies that perform large-scale manufacturing of enzymes through fungal or bacterial methods? Certain companies can make tons of enzymes and stabilize them.

Summary of response: Yes. Such interactions are important, and the agency is pursuing collaborative efforts.

3.5 Update on Government Decontamination Service

Rosina Kerswell, United Kingdom's Government Decontamination Service

An abstract for this presentation was not available for publication.

Question and Answer Session

Question 1: The U.S. received a failing grade on its ability to conduct environmental cleanup following a large-scale bioterrorism attack. What is the United Kingdom's ability for conducting large-scale cleanups?

Summary of response: Large-scale cleanup is obviously a difficult issue, and various agencies are trying to advance their preparedness. One example of relevant research is the United Kingdom's investigation of using area gamma monitoring to facilitate response to large-scale radiological attacks.

Question 2: The "Silver Streak" exercise mentioned during the presentation used a substance to simulate alpha-emitting particles. Please describe whether the substance effectively simulated alpha particles, especially considering interferences from where the study was conducted (a subway train).

Summary of response: The substance did not perfectly simulate alpha-emitters; for instance, it could not be shielded to prevent detection. However, the substance did simulate a property of alpha-emitters that was of particular interest: it could be detected only over a small range or distance. The primary purpose of using the substance was to demonstrate to local agencies the technical and logistical difficulties associated with detecting alpha-emitters following radiological events—and, in that sense, the "simulant" was effective.

3.6 Overview of Liberty RadEx and Lessons Learned

Bill Steuteville, EPA, Region 3

Liberty RadEx was EPA's first National Level Exercise and was designed to test responders' ability to assess and clean up following a radiological dispersion device terror attack in an urban environment. Radiological contamination from an event such as the LRE scenario poses many decontamination and technological problems including: safety of cleanup personnel, waste management and disposal, cleanup prioritization, technology selection and application, and cost. The exercise required coordinated effort from multiple agencies, scientists, response managers and responders, the general public and other stakeholders. LRE attempted to test such cleanup- and decontamination-related actions over three days by focusing on discrete areas or challenges. LRE's Operations Section deployed field teams to apply technologies selected by the National Homeland Security Research Center. The Waste Team attempted to develop a comprehensive waste management plan. The Technology Mitigation and Assessment Team attempted to select technologies and develop cleanup plans for two Philadelphia neighborhoods. The Community Advisory Forum challenged the public to prioritize the cleanup of Philadelphia and select temporary waste storage areas within the community. The Community Advisory Forum was made up of real community members from the notionally impacted communities with no prior radiation or exercise experience. All the groups worked long hours over three days and successfully met each goal.

Question and Answer Session

Question 1: Public perception of risk for radiation exposures is expected to be very challenging. To what extent was the public able to understand Geiger counter measurements, exposure dose estimates, and other technical communications in this exercise?

Summary of response: Public involvement occurred through a limited number of meetings, and those meetings generally focused on cleanup priorities (e.g., which neighborhoods should be cleaned first). Public participation in this exercise did not include testing a wide range of risk communication messages and strategies.

Question 2: What was your proposed approach for addressing radiological contamination on sidewalks and concrete? Were these going to be replaced? Or scoured and resurfaced?

Summary of response: This specific issue was not addressed during the exercise. In future events, whether sidewalks are replaced will depend upon funding decisions made by FEMA in the context of both Emergency Support Function (ESF) 10 (Hazardous Materials Response) and ESF 14 (Long-Term Community Recovery). Coordination between the ESFs will be necessary when making these decisions. The *National Disaster Recovery Framework* does not provide this level of detail or specificity in terms of environmental cleanup.

Question 3: Is there a report on Liberty RadEx that is publicly available?

Summary of response: Yes. The document should be available through the Lessons Learned Information Sharing service managed by DHS.

Question 4: Will the researchers reevaluate their Liberty RadEx findings in light of lessons learned following releases from the Fukushima facility in Japan?

Summary of response: The speaker suspected that EPA will evaluate information coming from Japan, but did not know for sure. Another participant at the workshop stated that representatives from various U.S. agencies have met with Japanese embassy officials to offer assistance in Japan's ongoing emergency response efforts.

Question 5: How were contaminated trees handled in the exercise?

Summary of response: In an actual event, a decision would have to be made about the fate of trees based on estimated risks. Most likely, the affected community would work with a health

agency to make this decision. There has been precedent for widespread removal of trees as part of environmental cleanup efforts, but widespread tree removal can raise quality of life concerns among residents.

Question 6: The presentation referred to estimating contamination levels on the rooftop of a convention center based on outputs from an air dispersion model. Were those estimates based on ground-level concentrations? Or was the model run to estimate how concentrations varied with height?

Summary of response: Some figures in the presentation depicted ground-level contamination. However, the evaluation of rooftop contamination was based on model estimates for deposition at the rooftop's actual height above ground surface. People interested in learning more about the issue were encouraged to read the details of the specific model used in the exercise.

4 Decontamination of Water and Wastewater Infrastructure

4.1 Water Decontamination Activities within EPA Water Security Division and National Homeland Security Research Center

Marissa Lynch, EPA, Office of Water

The consequences of intentional or unintentional contamination of water include 1) adverse public health impact, including hundreds to thousands of fatalities (such as a 1993 cryptosporidium contamination incident in Milwaukee that killed hundreds and sickened hundreds of thousands); 2) loss of water for public safety uses, such as fire fighting, hygiene, and decontamination; (3) economic damage resulting from remediation of hundreds of miles of pipes, lost productivity, fire losses, and so on; and 4) loss of consumer confidence. A contamination attack is likely to achieve multiple terror objectives, does not have to produce casualties to be successful, and will be perceived as an especially serious threat by the public, as confirmed by a recent crisis communication study.

The U.S. Environmental Protection Agency (EPA) is designated by Homeland Security Presidential Directive 7 as the federal agency responsible for the water security of the water sector. EPA's Water Security Division (WSD) is located within EPA's Office of Water and provides national leadership in developing and promoting security programs that enhance the sector's ability to prevent, detect, respond to, and recover from all hazards. WSD provides resources for water utilities, state and local governments, public health officials, emergency responders and planners, assistance and training providers, environmental professionals, researchers and engineers, law enforcement, and others. EPA's National Homeland Security Research Center (NHRSC) provides tools needed to improve water security and to recover from an attack or contamination incident involving chemical, biological, or radiological agents or weapons.

This presentation will discuss how contamination incidents impact drinking and wastewater systems, the knowledge gaps related to mitigating these impacts, and how research is addressing those gaps. The purpose of this presentation is to provide an overview of recent activities of EPA's WSD and NHRSC. This presentation will provide an introduction and context for the investigations detailed in this session of EPA's 2011 Decontamination Research and Development Conference.

Question and Answer Session

Due to time constraints, a question-and-answer session did not occur after this presentation.

4.2 Germinant Enhanced Decontamination of *Bacillus* Spores Adhered to Iron and Cement-Mortar Drinking Water Infrastructure

Jeff Szabo, EPA, Water Infrastructure Protection Division

Aim of Work Presented

Bacterial spores are persistent on drinking water infrastructure. Common decontamination methods such as flushing and chlorination have had limited decontamination success. Germination was evaluated as an enhancement to the disinfection of *Bacillus* spores from drinking water infrastructure with free chlorine and flushing.

Methods and Results

A pilot scale pipe loop was outfitted with iron (corroded) and cement-mortar coupons, which were conditioned in tap water for one month. *Bacillus globigii* spores were injected into the loop and allowed to adhere for two hours. Germinant was added after the adhesion phase, and allowed to contact the spores for an additional two hours. Germinant was flushed out of the loop, and chlorination, followed by

flushing, was performed. Experiments using only chlorination and flushing were also performed to determine the effectiveness of the germinant.

Decontamination with free chlorine at 5 milligrams per liter (mg/L) was ineffective (~0.2 log removal) on iron and achieved a 1.8-log reduction on cement-mortar. Increasing free chlorine concentration to 25 mg/L resulted in 1.2- and 2.2-log reductions of spores on iron and cement-mortar, respectively. Flushing after disinfection provided additional reduction, but spores persisted in each case except cement-mortar decontaminated with 25 mg/L, where they dropped to undetectable levels. Adding a germinant (trypic soy broth) alone decreased the number of spores adhered to cement-mortar and iron by 1.1 and 1.4 log, respectively. Chlorination after germination at 5 mg/L further reduced spores attached to cement-mortar to undetectable levels. Spores were reduced to undetectable levels on iron coupons by chlorinating at 5 mg/L and then flushing (increasing shear) after germination.

Conclusions

This study shows that germinating spores before application of disinfectant or flushing is an effective way to decontaminate drinking water infrastructure.

Significance and Impact of Work

Bacillus spores are persistent on drinking water infrastructure and few in situ decontamination options have been proposed. The data from this work show that germination followed by flushing and chlorination is an effective way to decontaminate spores from iron and cement-mortar. These data help prepare the drinking water sector for infrastructure remediation in the event of a contamination incident with spore forming bacteria.

Question and Answer Session

Question 1: The data plotted in the figures are based on "attached spore density"—a metric for the amount of spores that adhered to piping and surfaces. Did this study assess the fate of spores in the water?

Summary of response: The study did monitor the number of spores in the water, in addition to what adhered to surfaces. Spores were obviously detected in the bulk water after the initial injection of spores. Spores were also detected in the bulk water after addition of the germinant. However, shortly after the disinfectant was added, spores were not seen in the bulk phase because the disinfectant kills off the spores suspended in water faster than those attached to the coupons.

Question 2: Did this study consider mixed community bio-films?

Summary of response: Yes. The study evaluated bio-film density (e.g., how many heterotrophs per square centimeter), but did not extensively characterize the bio-films. Once fresh coupons were added to the experimental apparatus, water from the municipal supply was allowed to circulate around the coupons for 30 days. The study considered whatever microbes formed on the coupons during that time.

4.3 Biological Contaminant Persistence and Decontamination in Drinking Water Pipes Using the EPA Persistence and Decontamination Experimental Design Protocol

Ryan James, Battelle

Aim of Work Presented

The objective of this work was to evaluate the absorption, persistence, and possible decontamination approaches for *Bacillus globigii* (*Bg*) on concrete-lined and/or polyvinyl chloride (PVC) pipe using the U.S. Environmental Protection Agency (EPA) Persistence and Decontamination Experimental Design Protocol (PDEDP).

Methods and Results

The PDEDP uses annular reactors (ARs) to simulate conditions within operational drinking water pipes. The work included five components. Surface contamination and surface extraction method validations were first performed to confirm that pipe coupons could be contaminated with *Bg* from a bulk solution and that *Bg* could be extracted from the coupon surfaces. Additionally, persistence evaluation (PE) and flushing evaluation (FE) steps were performed by applying shear to *Bg*-contaminated concrete-lined and PVC coupon surfaces by setting the AR inner cylinder rotation to 100 revolutions per minute (rpm) (shear similar to flow in a 6 inch pipe) for the PE and as high as 250 rpm for the FE. Lastly, the hyperchlorination evaluation (HE) was performed by exposing *Bg*-contaminated coupons to 25 milligrams per liter (mg/L) and 50 mg/L free chlorine. Prior to contamination of pipe coupons, a bio-film was grown on all of the coupons.

Method Validation Results. The surface extraction method validation confirmed that *Bg* could be extracted from both concrete and PVC surfaces after direct contamination of *Bg*. The recovery of *Bg* from the concrete coupons was 74 percent ± 12 percent and from the PVC coupons was 80 percent ± 12 percent. The surface contamination method validation confirmed that concrete and/or PVC coupons could be contaminated reproducibly with *Bg* by exposing the coupons to a solution of contaminated water. For concrete, 4×10^5 CFU were contaminated onto four coupons with a relative standard deviation of 17 percent and for PVC, 3×10^5 CFU were contaminated onto four coupons with a relative standard deviation of 23 percent.

PE, FE, and HE Results. Persistence and flushing evaluations for the concrete and PVC coupons exhibited very similar results. For concrete, the percent persistence (%P) after four hours for the PE was 16 percent ± 11 percent, while the %P after four hours during the FE was 11 percent ± 2 percent. After 24 hours, both the PE and FE produced %Ps of approximately 0 percent. For PVC, %P after four hours for the PE was 40 percent ± 17 percent, and the %P after four hours during the flushing evaluation was 48 percent ± 14 percent. After 24 hours, both the PE and FE produced %Ps of approximately 0 percent. Therefore, *Bg* essentially did not persist on either type of coupon surface after 24 hours. For concrete, results indicated a statistically significant decrease in *Bg* on the coupon surfaces throughout the HE, while for PVC, the large uncertainties in the residual amounts of *Bg* did not allow distinguishing between experimental conditions.

Conclusions

PE and FE results suggest the decontamination of *Bg* from concrete and PVC pipe coupons has less to do with rate of flow than the duration of the flow past the contaminated pipe.

Measurement precision is important in determining differences in decontamination efficacy between experimental conditions (e.g., large uncertainties made it difficult to ascertain HE results).

Significance and Impact of Work

This work has laid the framework for future work to study additional contaminants, pipe materials, and decontamination approaches.

Question and Answer Session

Due to time constraints, a question-and-answer session did not occur after this presentation.

4.4 Decontamination of *Bacillus anthracis* in Wastewater

Capt. Colleen Petullo, USPHS, EPA OSWER, Environmental Response Team

Aim of Work Presented

This presentation will provide information on how to treat wastewater generated from decontamination activities following a *Bacillus*

anthracis contamination event with the goal of releasing the treated wastewater to a publicly owned treatment works.

Methods and Results

Information will be provided on how to prepare disinfectant solutions using amended bleach to achieve adequate levels of spore inactivation in wastewater. In addition, new data will be presented to indicate the efficacy of non-pH amended bleach for use in this setting.

Significance and Impact of Work

In the event of an anthrax attack, wastewater from either personal protective equipment wash water or water used in low technological decontamination procedures would be generated. Procedures for treating this water to make it acceptable for release to a publicly owned wastewater treatment facility are a major consideration. Information on appropriate disinfection methodologies for achieving this goal will be presented.

Question and Answer Session

Comment 1: Disinfectants will not be as effective when wastewater contains higher concentrations of organics. Some research has been published to quantify this.

Summary of response: This is precisely why one of the recommendations for future work is to assess the effectiveness of decontamination for "more challenging" wastewaters. The wastewater from typical environmental cleanup scenarios will likely have far higher concentrations of suspended solids and organic material than the waters considered in the experiments.

Question 2: The study was conducted using *Bacillus globigii* as a surrogate for *Bacillus anthracis*. Are there plans to conduct this research using live agents?

Summary of response: Hopefully such followup research will be conducted. Field personnel tasked with wastewater decontamination will have far greater confidence in their work knowing that effectiveness of decontamination has been demonstrated with live agents, rather than just with surrogates.

Question 3: One of the test trials mentioned during the presentation was based on bleach alone (5 percent by volume) with no other additives to adjust pH. Did this solution achieve 6-log reductions in just 5 minutes?

Summary of response: Yes. That is what was observed for the test conditions considered.

Comment 4: The research documented in this presentation used "suspension tests" to assess effectiveness of decontamination. However, suspension tests have been found to be much easier to pass than "coupon tests." Therefore, decontamination solutions found to be highly effective with suspension tests may be far less effective for coupon tests, especially for wastewater containing high concentrations of organic material and solids (e.g., solids scraped off surfaces that end up in wastewater). Further testing with more difficult challenges is encouraged to better understand how effectively the bleach-only solution decontaminates anthrax spores. However, until such testing is done, the current recommended method should continue to be used for decontamination purposes.

Summary of response: The speaker agreed with these points, and emphasized that the bleach-only solution is currently not an approved method for decontaminating wastewater. The purpose of the research was to indicate that wastewater decontamination options may eventually be available that use smaller quantities of inactivation solutions and shorter contact times.

Question 5: Other studies are investigating wastewater with different types and amounts of organics to assess how effectiveness of decontamination varies with organic demand in wastewater.

Summary of response: As noted previously, one of the recommendations for future work is to assess the effectiveness of decontamination

for "more challenging" wastewaters, including those having concentrations of suspended solids and organic material more comparable to what would be expected during field scenarios.

Question 6: Is the purpose of the research to identify inactivation solutions that would allow treated wastewater to be discharged directly to treatment facilities? Some treatment facilities may ask the government to certify that the wastewaters have been effectively decontaminated.

Summary of response: Coordination with water treatment facilities will be necessary to determine specific criteria for acceptability of decontamination wastewaters. Additional peer-reviewed research demonstrating the effectiveness of inactivation solutions may help address concerns about receiving these wastewaters.

Comment 7: Following previous anthrax attacks, some publicly owned treatment works refused to accept decontamination wastewater even after the water had been thoroughly decontaminated and pH-adjusted. Thus, risk perception challenges can be difficult to overcome, even when extensive data are available to demonstrate effectiveness of decontamination.

Summary of response: The speaker agreed with this comment.

4.5 Progress in the Development of a Rapid, Water-Based Technology for Removing Contamination Following an Urban Dispersal of Radioactivity

Carol Mertz, Argonne National Laboratory

Aim of Work Presented

We are developing an inexpensive water-based means of decontaminating an urban setting for the purpose of restoring critical infrastructure and operational activities after a radiological release. Our approach focuses on the removal of radioactive cesium from urban substrates such as concrete, asphalt, brick, limestone, and granite, and on the sequestration and immobilization of the removed cesium. Final recovery of cesium using common separation techniques will be developed. This technology provides a rapid, full-scale, cost-effective decontamination effort for large-scale operations.

Methods and Results

We have evaluated various natural cesium sequestering agents by batch partitioning measurements for sorption efficiency in the presence of wash solution additives. Grace vermiculite performed better than other clays for effectively sequestering the cesium at high wash additive concentrations, especially when combined with high clay loadings. In addition, static and flow decontamination tests were performed on urban substrate coupons of asphalt, brick, concrete, granite, and limestone using wash additives and clay slurries. We achieved up to 60 percent cesium removal from concrete in five-minute flow tests with 0.5 molar of ammonium chloride (NH_4Cl). A wetting agent was necessary to improve the decontamination of asphalt. Cesium recovery of 40 percent was obtained with 1 millimolar sodium dodecyl sulfate added to 0.5 molar of NH_4Cl for a one-minute asphalt flow test.

Conclusions

Large-scale implementation of urban substrate decontamination requires a balance between finding an effective decontamination formulation for the urban substrates and maximizing sorption based upon the sequestering properties of the clay in the presence of the wash solution additives. Our decontamination technology is based on inexpensive and readily-available materials in large-scale quantities. Water-soluble additives (NH_4^+) preferentially remove cesium from urban substrates followed by sequestration in the clay. Current application of our technology provides up to 60 percent cesium removal from concrete in five minutes with additional optimization possible based upon flow and clay slurry formulation. Dilution of the wash additive

solution after urban substrate decontamination would improve cesium sorption properties of the clay but would increase total solution volume requiring significant processing. We envision employing existing emergency equipment and sewer and waste reclamation infrastructures in deploying this technology.

Significance and Impact of Work

After a malicious release of radioactivity, large urban areas may be contaminated, thereby compromising efforts by first responders and law enforcement officials. Additional public services may be disrupted. In such an event, it is important that we deploy mitigation efforts in certain areas to restore response activities and public services. These mitigation efforts may not be as effective as a full-scale decontamination effort, but the speed with which mitigation efforts can be deployed and completed may be of critical importance immediately after a release event.

Question and Answer Session

Question 1: The presentation addressed spray application of wash solutions to decontaminate surfaces following a radiological release. How is the wash solution collected after it has been sprayed?

Summary of response: There are several options for containing and collecting residual wash solution. One is to install a flexible barrier to contain the wash solution until it can be collected and transported to a wastewater treatment facility. Another option is to divert the wash solution into retention ponds where treatment can take place. The most appropriate approach will depend on local conditions (e.g., proximity to existing retention ponds).

Question 2: The presentation mentioned some coordination with emergency responders in a large metropolitan area. To what extent do these first responders understand technical issues associated with responding to radiological releases?

Summary of response: In Chicago, most fire trucks and police squad cars are equipped with radiation monitoring devices, and firefighters and police officers have been trained on how to use the devices. However, when responding to fires, explosions, and other major incidents, the first responders said their initial priority is going to be saving lives, extinguishing fires, and addressing other immediate needs. In other words, checking readings on radiation monitoring devices is likely not going to be their first priority in many circumstances.

Question 3: The presentation mentioned use of clays as sequestering agents for cesium. How much clay would be needed to decontaminate a given area?

Summary of response: The speaker requested that a colleague respond to this question. The colleague noted that the exact amount of clay needed will depend on many factors. One such factor is the ammonium ion concentration in the water, because the presence of ammonium ion has been found to suppress the clay's ability to sequester cesium. However, decontamination of a large city block would likely require tens of tons of clay.

Question 4: Following cleanup activities, what would be done with the clay?

Summary of response: The spent clay, which will contain sequestered cesium, will likely have to be collected and disposed of, according to applicable waste management regulations.

4.6 Selected Homeland Security Water Decontamination Research Projects

Matthew Magnuson, EPA, Water Infrastructure Protection Division

The purpose of this presentation is to provide a brief discussion of U.S. Environmental Protection Agency (EPA) homeland security water decontamination research projects not previously detailed in this session of EPA's 2011 Decontamination Research and Development Conference.

Specific projects include:

1. Investigation of advanced oxidation processes (AOP) for the treatment and disposal of drinking water contaminated with toxic chemicals into public sewer (collection) systems.

This project involves studying the reaction between chemical contaminants of interest and AOPs, such as ozone with hydrogen peroxide. This research looks at the effectiveness of using ozone with hydrogen peroxide, as well as other AOPs, to break down the contaminant to something relatively nontoxic and suitable for public sewer discharge.

Suitability for public sewage discharge will be assessed through testing of the water destined for sewer discharge. The water will be tested for how it may impact the ability of the microorganism within the sewage treatment plant to continue to perform its intended function of breaking down "normal" plant influents. These studies will be performed on the laboratory scale and investigate at least two AOP processes. Aqueous solutions of chemicals of interest will be subjected to the AOP process, then those AOP-treated solutions will be used in the sewage plant microorganism performance testing (SPMPT). While SPMPT is sometimes referred to as "toxicity testing," SPMPT is used to avoid confusion with "human toxicity." Potential contaminants to be studied include potassium cyanide, chlordane, dichlorvos, aldicarb, and other contaminants of water security interest that will be selected in part through a literature review of existing data.

A key issue lies in the SPMPT testing, for which a workshop was held to discuss SPMPT issues and concerns with 15 to 20 technical experts, plant operators, state pre-treatment staff, and other stakeholders. The purpose of the workshop was to develop an understanding of the kinds of SPMPT testing to use for AOP or other oxidants, such as chlorinem and to inform EPA and this project of a suitable approach.

2. Persistence and removal of chemical contaminants from drinking water pipes studied with EPA's pipe decontamination experimental design

The Research Institute of Hygiene, Toxicology, and Occupational Pathology (RIHTOP) in Volgograd, Russia, is conducting experiments on the removal of chemical contaminants from a variety of drinking water pipe materials. The contaminants include arsenic, dichlorvos, disulfoton, and gasoline. The pipe materials include copper, polyvinyl chloride, cast iron, and mortar-lined ductile iron. Decontamination methods investigated include flushing and hyperchlorination.

This work simulates the problem of drinking water pipes adsorbing toxic chemicals that are introduced either accidentally or by some purposeful means. RIHTOP is using pipe coupon materials in small reactors that simulate the flow of water in a real water distribution pipe. The experiments are performed using a protocol developed by EPA known as pipe decontamination experimental design (PDED). PDED is designed to be implemented in a reproducible fashion across laboratories and is used to gain additional experimental information about the adsorption of contaminants to various drinking water pipe materials and test various methods to destroy, reduce, or remove adsorbed contaminants. Briefly, in the PDED, the conditions within operational drinking water pipes are simulated in commercial annular reactors (ARs). The ARs consist of a glass outer cylinder and a rotating polycarbonate inner cylinder with flush-mounted rectangular coupons that are made of materials that simulate drinking water pipe materials. Prior to contamination of any coupon as part of a PDED study, a bio-film is grown on the coupons. The PDED includes five steps, with appropriate controls. The first two steps validate surface contamination and surface extraction methods for each combination of contaminant and pipe material. Next, the AR is operated to simulate the contaminant's persistence under normal hydraulic shear and also on flushing induced shear. Finally, the effect of decontaminants, such as hyperchlorination, is assessed within the AR.

This work will enable making science-informed decisions about how to decontaminate domestic water pipes. As the PDED was used, decision makers will be able to compare the results of these studies with those performed elsewhere.

3. Impact of chemically, biologically, and radiologically contaminated sediments on flushing and decontamination of drinking water storage facilities

Among the concerns associated with such attacks is the adsorption of chemical, biological, or radiological (CBR) contaminants to sediments in drinking water storage tanks and reservoirs. Sediments can serve as sinks for contaminants. Therefore, adhesion to sediment particles following the introduction of CBR agents must be taken into account when developing treatment and decontamination strategies. Research is needed to better understand the adherence and persistence of selected contaminants on storage facility sediments and methods for flushing and decontamination.

Water storage facilities are used to store water from wells or water treatment facilities at times when demands for water are low for use during periods of high demand. Storage facilities may consist of large reservoirs behind dams (impoundments) or service storage reservoirs located at water treatment plants or at various places in distribution systems. Operational service storage tanks in distribution systems may include clear wells, pressure tanks, elevated tanks, ground level tanks or reservoirs, or underground facilities.

The scope of this project includes obtaining sediments from actual water tanks (from various locations) and then investigating the adsorption of selected contaminants (with a range of adsorptive properties) onto the sediments. These experiments will examine the adsorption potential of target contaminants to various sediment samples with different organic matter content and various particle sizes. Additional knowledge in this area will be useful to water utilities and other decision-makers in assessing impacts of an event and selecting effective methods for handling contaminated sediments and decontaminating the storage facilities. Potential contaminants to be studied will include metals, bacteria, and an organic pesticide.

Question and Answer Session

Due to time constraints, a question-and-answer session did not occur after this presentation.

5 Decontamination of Toxic Industrial Chemicals and Chemical Warfare Agents

5.1 Application of the Quick Reference Guides (QRGs) to CWA Decontamination

Larry Kaelin, EPA, OSWER, National Decontamination Team

The U.S. National Response Team (NRT) is an organization of 15 federal departments and agencies responsible for coordinating emergency preparedness and response to oil and hazardous substance pollution incidents. The U.S. Environment Protection Agency and the U.S. Coast Guard serve as NRT's chair and vice chair, respectively. The National Oil and Hazardous Substances Pollution Contingency Plan and the Code of Federal Regulations (40 CFR Part 300) outline the role of the NRT and regional response teams. The response teams are also cited in various federal statutes, including the Superfund Amendments and Reauthorization Act, Title III and the Hazardous Materials Transportation Act.

According to its website (www.nrt.org), the NRT is tasked with "providing technical assistance, resources and coordination on preparedness, planning, response and recovery activities for emergencies involving hazardous substances, pollutants and contaminants, hazmat, oil, and weapons of mass destruction in natural and technological disasters and other environmental incidents of national significance." Pursuant to these tasks, the NRT has developed more than 30 quick reference guides (QRGs) for a number of chemical and biological hazards, including chemical and biological warfare agents and biotoxins. The QRGs are brief, two-page summaries of information that would be critical to federal On-Scene Coordinators (OSCs) in the first 24 to 48 hours of a response. The goal of the QRGs is to provide information OSCs can use to initiate appropriate response efforts to protect worker health and safety, mitigate the spread of contamination, direct sampling and air monitoring, and start preliminary cleanup of contaminated areas and waste management, all without deleteriously impacting future site activities. QRGs also direct OSCs to appropriate reach-back assets for the later consequence management phase of the event. The QRGs are not prescriptive or site-specific, nor do they provide an exhaustive literature review of the hazards. QRGs do not cover long-term remediation actions, ongoing site monitoring, or site-specific clearance goals. The QRGs should not be used to select personal protection equipment and do not replace any existing regional response plans. The NRT currently has QRGs for seven chemical warfare agents, ethanol, 18 viruses and bacteria, and botulinum toxin. Most of these QRGs are being updated to reflect recent scientific studies. New QRGs are being prepared for chlorine, methyl isocyanate, ricin, *Coxiella burnetii* (the bacterium that causes Q fever), and additional viruses. All reference citations used to generate the QRGs are publicly available, with most citations posted on the NRT website.

This presentation will cover the general content of the QRGs, with a specific focus on the QRG decontamination section. The presentation will also discuss lessons learned during the drafting of these QRGs that are useful for their application.

Question and Answer Session

Question 1: The information covered in the presentation sounds similar to information available from the SmartPhone free application named "WISER" (Wireless Information System for Emergency Responders). Does this communicate the same type of information?

Summary of response: WISER is an excellent resource. In fact, some technical information included in the QRGs is taken from information available through WISER.

Comment 2: The QRGs are publicly available by selecting "Biological Hazards: QRGs and other links" or "Chemical Hazards: QRGs and other links" from the National Response Team's website (www.nrt.org). There are plans to eventually move these to www.nrt.org/qrg, but that has not yet happened.

Summary of response: Point noted.

5.2 Efficacy Evaluation of Liquid and Foam Decontamination Techniques for Chemical Warfare Agents on Indoor Surfaces

Deon Anex, Lawrence Livermore National Laboratory

Aim of Work Presented

While decontamination strategies have been developed and evaluated for military settings, significantly less is known about decontamination of civilian infrastructure. To improve the nation's preparedness for indoor facility restoration after a chemical warfare agent (CWA) release, liquid and foam decontamination technologies were tested against CWAs applied to typical indoor surface materials. The chosen materials had a range of porosity and permeability that challenges the efficacy of decontamination.

Methods and Results

The decontamination agents Allen Vanguard Surface Decontamination Foam (SDF™), Sandia Decontamination Foam (DF-200), Decon Green™ and 0.5 percent bleach with trisodium phosphate were each tested on a large number of CWA-surface combinations. The CWAs (including GB, GD, HD and VX) were applied to samples of surfaces (including stainless steel, glass, concrete, vinyl tile, urethane handrails, terrazzo tile, and wallboard) that are representative of indoor environments. For each CWA-surface combination, a number of coupons were contaminated with measured droplets of neat CWA. After waiting a period of time, coupons were removed for analysis to determine the recoverable contamination levels immediately before the beginning of the decontamination process. The remaining coupons were then treated with a selected decontamination agent. Coupons were subsequently removed for analysis over a span of 24 hours. A parallel series of contaminated coupons was not treated with decontamination agent but was analyzed over the same time course to measure the natural attenuation of the agent. After removal for analysis, remaining CWA and decomposition products were extracted from the coupons using organic solvent and the extract was analyzed and quantified by gas chromatography/mass spectrometry (GC/MS). Decontamination tests were performed in triplicate on both horizontal and vertical orientations of the sample coupons.

All decontamination technologies tested, except for the bleach solution, performed well on nonporous and nonpermeable glass and stainless steel surfaces. However, residual chemical agent contamination typically remained on porous and permeable surfaces, especially for the more persistent agents, HD and VX. Solvent-based Decon Green performed better than aqueous-based bleach or foams on polymeric surfaces, possibly because the solvent is able to penetrate the polymer matrix. Bleach and foams out-performed Decon Green for penetrating the highly polar concrete surface. For the less persistent CWAs on certain nonporous and nonpermeable surfaces (GB on glass and stainless steel and GD on stainless steel), the efficacy of the decontamination agents was not evaluated because of the fast natural attenuation of these combinations. Degradation products were also analyzed to assure that residual components did not represent a health risk.

Conclusions

Efficacy of decontamination for a particular approach depends on the CWA and the nature of the contaminated surface. Effective strategies for decontamination range from natural attenuation (e.g., GB on glass or stainless steel) to generally applicable decontamination methods (e.g., Decon Green, SDF or DF-200 for CWAs on nonporous and nonpermeable surfaces) to specific methods (e.g., Decon Green for

polymeric surfaces and bleach or foams for concrete). No single formulation for decontamination was effective at the clearance levels needed for all the CWA-surface combinations tested.

Significance and Impact of Work

These results suggest that the wide range of characteristics needed for universal decontamination may not be compatible with a single formulation. Since even trace amounts of residual chemical CWA may prove unacceptable in civilian settings, it is anticipated that an efficient remediation and recovery of contaminated complex facilities will require a range of technologies.

Question and Answer Session

Question 1: For vertical surfaces, did this research consider a "moving wall" of foam and the efficiency of penetrating porous surfaces?

Summary of response: No. The research to date has only considered single, static applications of foam.

Question 2: The presentation included data on effectiveness of contamination for certain chemical warfare agents. Were these data based on a single application of foam or multiple applications?

Summary of response: All data presented were for a single application of foam, with effectiveness of decontamination evaluated over a 24-hour period.

Question 3: Was the foam still present after the 24-hour period?

Summary of response: Some of the foam originally applied was still present on the vertical surfaces, but some had run off. Effectiveness of decontamination was estimated by testing for chemical agents in the foam that still adhered to the surface and foam that had run off.

Question 4: Following the 2001 anthrax attacks, foam technologies were used for decontaminating surfaces in indoor environments. In this study, were non-foam materials applied on vertical surfaces or only on horizontal surfaces? Past experience has suggested that reapplication is sometimes necessary when using non-foam materials on vertical surfaces.

Summary of response: In this study, every decontamination reagent was evaluated on both horizontal and vertical surfaces, considering only single applications. The research found that horizontal and vertical surfaces were decontaminated equally well by most reagents.

Question 5: Did the study evaluate whether the decontamination process resulted in the formation of toxic by-products?

Summary of response: Yes. All liquid and foam material was extracted into organic solvent and analyzed for chemical warfare agents and known by-products using gas chromatography and mass spectrometry. No toxic by-products or chemical warfare agents were detected in the liquid and foam material collected after each test.

Question 6: Did you also analyze these samples using liquid chromatography and mass spectrometry?

Summary of response: The speaker did not know if that analytical method was used.

5.3 Field Evaluation of Indoor Cleanup of Malathion

Jeanelle Martinez, EPA, OSWER, National Decontamination Team

Aim of Work Presented

On June 2, 2010, an unlicensed applicator sprayed a pesticide to exterminate the bedbugs at a residential duplex in Cincinnati, Ohio. The commercially available product, Spectracide, contained 50 percent malathion and had a label with the words "for outdoor use only." Severe toxicity symptoms reported by the tenants of this duplex prompted the involvement of Cincinnati

Health Department, the Ohio Department of Agriculture, Cincinnati Fire Department and the U.S Environmental Protection Agency (EPA). The property owner completed a partial decontamination plan utilizing a diluted bleach solution, while post-decontamination samples revealed the presence of residual malathion as well as the formed toxic degradation products isomalathion and malathion oxygen analog. Thus, it was questionable that the residence had undergone successful decontamination.

Significance and Impact of Work

In July 2011, an EPA Region 5 On-Scene Coordinator requested assistance from the National Decontamination Team (NDT) to conduct a decontamination study at this residence contaminated with malathion and partially decontaminated with diluted bleach solution. Preliminary assessment of this site indicated that 20 percent of surface wipe samples contained levels of malathion that were approximately five times that of the Agency for Toxic Substances and Disease Registry (ATSDR)-recommended cleanup values. The goals of this investigation include 1) determining if the residence is contaminated with malathion and/or the degradation products one year after a partial decontamination was initiated, 2) developing and implementing a cost-effective and commercially available decontamination approach that achieves ATSDR-recommended cleanup values, 3) reviewing the surface cleanup values, and 4) clearing the duplex apartment for re-occupation. The objectives of this decontamination study are to evaluate the fate and behavior of malathion on indoor surfaces that have previously been decontaminated with diluted bleach solution and to evaluate the effectiveness of a commercially available decontaminating agent previously demonstrated to be highly effective on CWAs. The results of this study will shed valuable information needed for effective remediation of indoor facilities contaminated with organophosphates. The study will determine if technologies developed for CWAs can be applied to other decontamination situations.

Question and Answer Session

Question 1: The presentation suggests that the unlicensed applicator sprayed malathion inside just a single residence. Did EPA or other parties follow up with the unlicensed applicator to identify other affected properties?

Summary of response: EPA was very concerned about this issue, but all accounts indicate that the unlicensed applicator used malathion inside this single residence.

Question 2: Did this application eliminate the bed bug problem?

Summary of response: The problem has apparently been eliminated but only through illegal indoor application of a toxic pesticide that is labeled for "outdoor use only."

Question 3: What were the approximate costs for the entire response, including sampling, decontamination, and disposal?

Summary of response: A complete tabulation of costs is not yet available, in part because the operation is ongoing. The cost to purchase the decontamination agent was relatively inexpensive (approximately $200). There was no cost associated with analyzing the air and wipe samples because the Ohio Department of Agriculture agreed to analyze the samples for free. The labor costs have not been quantified but can eventually be estimated from the number of hours that different people spent working on the site.

5.4 Enzymatic Decontamination of CWAs from Building Materials

Lukas Oudejans, EPA, Decontamination and Consequence Management Division

The research field that studies the use of enzymes to counter CWAs covers a broad range of applications, including medical pretreatments, therapeutics, and physical decontamination. Most of the research efforts involve improving stability (shelf life and pot life) of the various

enzyme systems and optimization of their activity. Only recently have commercially available enzymatic decontamination products for chemical contamination become available. Enzyme technology would appear to be an ideal decontamination method, as it safe and environmentally benign. Furthermore, enzyme technology may generally become a more appropriate alternative for existing decontamination technologies against chemical (and possibly biological) agents, especially when applied on materials that are otherwise adversely impacted by traditional decontamination methods such as hydrogen peroxide vapor or bleach.

In this work, the efficacies of two commercially available enzymatic decontamination products, DEFENZ VX-G and DEFENZ B-HD, were evaluated against chemical warfare agents VX, thickened soman (GD), and sulfur mustard (HD), as applied to five representative indoor building materials. Material-dependent efficacies up to 40 percent were obtained using the vendor's recommended application conditions. Enzymatic decontamination of VX did not result in formation of toxic byproduct EA 2192. Moderate improvements in efficacy were observed for longer enzyme contact times and higher enzyme solution concentrations. Additional data will be presented that show the impact of environmental parameters such as relative humidity and temperature on the enzyme efficacy using a CWA surrogate. The discrepancy between vendor provided efficacy data and data from this study will be discussed.

Question and Answer Session

Due to time constraints, a question-and-answer session did not occur after this presentation.

5.5 Decontamination of Chemical Warfare Agents Using Household Chemicals

George Wagner, U.S. Army, Edgewood Chemical Biological Center

Environmentally friendly hydrogen peroxide (H_2O_2) has been used to generate effective decontaminants for chemical warfare agents VX, GD, and HD. Decontaminants developed for military use, Decon Green and DF-200, utilize 35 percent and 8 percent H_2O_2, respectively. Yet decontaminants that employ such high H_2O_2 concentrations would generally be restricted to use by first responders and hazmat teams. Thus, for the general public, following a chemical attack, household bleach, although potentially corrosive, is the only apparent decontaminant currently available, but there are other, far less corrosive household chemicals that can be utilized. For example, household ammonia cleaners are specified in military field manuals as nonstandard decontaminants for G-type nerve agents such as GD. Unfortunately, ammonia cleaners are not suitable, in and by themselves, for decontaminating VX (a V-type nerve agent) and HD (a blister agent)—the formation of toxic EA-2192 results for the former and minimal detoxification occurs for the latter. Recent studies, however, have shown that VX and HD, as well as GD, can be decontaminated using low-concentration, topical 3 percent H_2O_2 combined with various common household chemicals, including ammonia-based cleaners. Therefore, simple, easy-to-mix decontaminants may be fashioned from 3 percent topical hydrogen peroxide, ammonia cleaners, baking soda, washing soda, and rubbing alcohol, providing safe, minimally-corrosive, and cost-effective decontamination capability that is accessible to the general public.

Question and Answer Session

Question 1: The presentation included data indicating how effectively various combinations of household chemicals decontaminated chemical agents. Were these data based entirely on solution tests? Were any data based on surface decontamination challenges?

Summary of response: Two different approaches were used. First, solution tests were used to identify the decontamination effectiveness of various combinations of household chemicals. (These data were shared during the presentation in slides 10 to 15). In these tests, chemical agents and household chemicals were injected into nuclear magnetic resonance (NMR) imaging tubes and stirred once. The tubes were then inserted in the NMR spectrometer, which then followed the progress of the chemical reactions. Second, the data shown on slide 7 represent the effectiveness of ammonia-based cleaners used to decontaminate GD on surfaces. Note that these surface decontamination data were generated for only one chemical agent.

5.6 Investigation of Hydrogen Peroxide/Ammonia Fumigation against VX, TGD, and HD

Harry Stone, Battelle

Aim of Work Presented

The U.S. Army Edgewood Chemical Biological Center has reported efficacy in the use of fumigation (hydrogen peroxide [HP; ~250 parts per million (ppm)] combined with ammonia [N; ~20 ppm]) to decontaminate VX, GD (soman), and HD (sulfur mustard) on military type materials. The U.S. Environmental Protection Agency's (EPA's) investigation focused on evaluating the efficacy of hydrogen peroxide/ammonia fumigation of VX, thickened GD, and HD from common building materials, including a nonporous material and an adsorptive material.

Methods and Results

Two µL droplets of neat chemical agent were applied to galvanized metal ductwork and industrial grade carpet positive control and test coupons (1.5 x 3.5 centimeters). The test coupons were placed into a custom test chamber. The fumigant was added and target concentrations of HP (~250 ppm) and N (~20 ppm) were maintained for specified contact times. The temperature was elevated sufficiently to prevent condensation. Positive control coupons were simultaneously placed into a control chamber (no fumigant present) in which the temperature profile approximated the test chamber temperature profile. At the end of each of the contact times, the test chamber and control chamber were opened. The coupons were removed and placed into individual vials containing a volume of hexane sufficient to cover the coupon. The amount of chemical agent extracted from the coupon by the hexane was then determined using gas chromatography/mass spectrometry. Efficacy was determined as the relative difference between the amount of chemical agent recovered from test coupons after fumigation and the amount of chemical agent recovered from positive control coupons that were removed from the control chamber at times parallel to the test coupon contact times. Various contact times (from two to eight hours) were evaluated. In addition, the test chamber atmosphere was sampled for gas phase chemical agent.

In all cases, the amount of chemical agent recovered from test and control coupons declined with time. Generally, the amount of chemical agent recovered from the control coupons was similar to the amount of chemical agent recovered from test coupons. Efficacy may be demonstrated for certain agent/material combinations.

Significance and Impact of Work

Data showing the efficacy of HP/N fumigation for decontaminating surfaces may be used to inform decontamination decisions in the event of a deliberate release of chemical agent by terrorists.

Question and Answer Session

Question 1: Did the fumigation chamber used in the experiment have air flow? Or was this a static chamber?

Summary of response: The fumigation chamber was not static: it included a fan (see slide 7) to promote air mixing. The two fumigants used—ammonia and hydrogen

peroxide—were pumped into the test chamber from separate lines, so that the desired ratios of each of the fumigants could be maintained.

Question 2: In some cases, the experiments showed high natural attenuation of chemical agents from the positive control coupons. Was the extent of natural attenuation surprising, particularly for HD?

Summary of response: Two factors might explain the extent of natural attenuation. First, the chambers had circulating air, which could have increased attenuation from the surfaces. Second, the experiments were run at temperatures of 40 to 50 ^{o}C. This temperature range was necessary to avoid condensation of the hydrogen peroxide fumigant, but the relatively high temperatures may also have contributed to losses of chemical agents from the positive control coupons.

Question 3: Are any followup experiments planned to examine how the effectiveness of decontamination varies with the size of droplets originally spiked on the coupons? This may be important for thickened agents to ensure that fumigants adequately penetrate larger droplets.

Summary of response: EPA currently does not have plans to conduct these experiments.

Question 4: Did the experiments attempt to identify any toxic by-products from the fumigation?

Summary of response: The experiments did not include measurements of by-products. A qualitative assessment of by-product formation was conducted for fumigation of HD agents, but not for fumigation of VX agents.

5.7 Non-Aqueous Catalytic Process for the Decontamination of Sensitive Equipment from Organophosphorus Compounds

Konstantin Volchek, Environment Canada

Aim of Work Presented

A recently developed metal-catalyzed methanolysis process reportedly demonstrated an effective destruction of organophosphorus (OP) compounds. Non-aqueous formulations do not contain highly corrosive components and can potentially be used for a rapid and non-destructive decontamination of sensitive equipment. The aim of the present work was to evaluate the applicability and efficiency of the catalytic methanolysis process for the decontamination of sensitive equipment materials.

Methods and Results

Decontamination of sensitive equipment materials from OP compounds, paraoxon (O,O-diethyl O-*p*-nitrophenyl phosphate) and parathion (O,O-diethyl O-[4-nitrophenyl] phosphorothioate) has been investigated. Five types of materials selected from sensitive equipment spiked with paraoxon and parathion were decontaminated with methanol-based catalytic systems, including a lanthanum-based catalyst (for paraoxon) and a palladium-based formulation (for parathion). Two modes of catalytic process were taken, including an immersion of sample materials into a catalyst system and spraying the catalytic system directly on sensitive equipment surfaces. Among tested materials, high-impact polystyrene (HI-PS) was found to be the most difficult for the decontamination. More than 99 percent of paraoxon on HI-PS was destroyed after contact with the catalyst system over 10 minutes. Decontamination of parathion was less efficient (93 percent) under the same conditions. Increasing the initial spiking level of paraoxon on HI-PS plastic from 1 milligram per square centimeter (mg/cm^2) to 5 mg/cm^2 reduced the decontamination efficiency from 99 percent to 87 percent. The complete destruction of both paraoxon and parathion in a runoff liquid was achieved after two minutes of contact. Application of a catalytic system by spraying provided about 50 percent decontamination of paraoxon on HI-PS plastic surface. Multiple applications of the liquid catalytic system on HI-PS plastic increased the decontamination efficiency to 90 percent. Evaporation of

methanol was a limiting factor for the application by spraying.

Conclusions

Non-aqueous catalytic process can be applied for the decontamination of sensitive equipment from OP compounds either by immersion or spraying. Paraoxon and parathion, representatives of OP compounds, can effectively be destroyed (90 to 99 percent) on some plastic surfaces within less than 15 minutes. Increasing the initial loading decreases the efficiency of decontamination. The run-off liquid doesn't contain paraoxon or parathion after two minutes of contact with catalysts. A single application of catalyst by spraying was not effective (less than 50 percent decontamination) due to a rapid evaporation of methanol. Multiple applications increased the decontamination efficiency to 90 percent.

Significance and Impact of Work

This investigation helped assess the applicability effectiveness of a nonaqueous catalytic method for the decontamination of sensitive equipment. The method can enhance CBRN response and recovery capabilities.

Question and Answer Session

Question 1: The research used a palladium catalyst for decontaminating parathion and a lanthanum catalyst for decontaminating paraoxon. Why were different metals used?

Summary of response: Due to catalyst selectivity, the most efficient catalyst will vary from one organophosphate agent to the next. The specific catalysts were previously developed by researchers from Queens University in Canada, and the current research project did not attempt to modify these.

Question 2: For spray application, how does effectiveness of decontamination vary with the number of repeated applications?

Summary of response: The research team has investigated the effects of repeat applications for spray application of the catalyst mixture but not for immersion in catalyst mixture. These investigations found that repeated spray applications improved effectiveness of decontamination (as shown on slide 18).

Question 3: Given the selectivity of the catalysts, to what extent will catalytic decontamination be viable for other chemical agents?

Summary of response: Some catalysts may be used on several organophosphate agents, but usually they are selective towards specific agents. One option is to use mixtures of catalysts, which can improve decontamination across a broader range of agents. However, further research in this area is necessary before applying this decontamination technique on a larger scale.

Question 4: How much do the catalysts cost?

Summary of response: While palladium is indeed expensive, the quantities needed for decontamination are relatively low. Moreover, the catalyst is not consumed in the decontamination process and can be reused, which is an important consideration if one needs to decontaminate large amounts of sensitive equipment. The researchers from Queens University (see slide 21) would likely be able to provide more detailed cost information for the palladium and lanthanum catalysts.

Question 5: Were circuit boards still functional after being immersed in the decontamination solution?

Summary of response: The operability assessment was limited to testing memory cards ("SD cards"). These cards were spiked with the organophosphate agent, immersed in the catalyst solution, and dried before the operability assessment. In every test, the memory cards continued to function after immersion. Operability assessments were not conducted on the other components, however.

6 Biological Agent Decontamination Fate and Transport

6.1 Efficacy of Disinfectant against Vegetative BW Agents and Their Surrogates

Vipin Rastogi, U.S. Army, Edgewood Chemical Biological Center

Aim of Work Presented

The efficacy of common disinfectants was evaluated against vegetative cells, pathogenic strains, and surrogates of *Francisella tularensis* (Schu S4 and Live Vaccine Strain, LVS), *Yersinia pestis* (Colorado 92 and A1122) and *Brucella melitensis* (16M and *Agrobacterium tumifaciens*). Quantitative test method AOAC2008-05 was modified to work with vegetative cells of pathogenic Gram-negative biological warfare (BW) agents. Appropriate media and culture conditions were optimized to obtain high-titer broth cultures of these strains.

Methods and Results

Freeze-dried cells of *F. tularensis* (Schu S4 and LVS), *Y. pestis* (Colorado 92 and A1122), and *B. melitensis* were obtained from Unified Culture Collection, Dr. Scott Bearden of the Centers for Disease Control and Prevention and Prevention of Vector-borne Infectious Diseases Bacterial Zoonoses Diagnostic and Reference Laboratory in Fort Collins, Colorado. Cultures of *Agrobacterium tumifaciens* were procured from ATCC. *F. tularensis* cells were grown on Chocolate agar (Culture Media Supplies) or supplemented Mueller-Hinton media at 36±1 ºC. Cells of *Y. pestis* were grown on brain-heart infusion media or tryptic soy agar at 29±1 ºC. Cells of *B. melitensis* and *A. tumifaciens* were grown on nutrient agar or nutrient broth at 36±1 ºC. Modifications to the AOAC2008-05 include 1) drying of cell aliquots for 60+15 minutes before use; 2) use of 5-milliliter eppendorf tubes for fraction A; 3) ratio of 1:10 between disinfectant:neutralizer; 4) use of Dey-Engley broth as a neutralizer; 5) no repeated washes of fraction A pellet; and 6) 15 minute incubation for recovering fraction C. Control carrier counts were determined to ensure overall recovery of >5-logs viable cells before initiating disinfectant efficacy testing. The disinfectant included [8.0 percent alkyl (50 percent Carbon-14, 40 percent Carbon-12, and 10 percent Carbon-16) dimethyl benzyl ammonium chloride, 6.15 percent sodium hypochlorite, 0.28 percent diisobutylphenoxyethoxyethyl dimethyl benzyl ammonium chloride with 17.2 percent isopropanol, and 1.1856 percent *n*-alkyl (50 percent C_{14}, 40 percent C_{12}, and 10 percent C_{16}) dimethyl benzyl ammonium chlorides. The results show recovery of over 5-logs viable cells from control carriers for each pair of surrogate and pathogenic counterpart. Comparable log reduction values for each pair were observed.

Conclusions

The results clearly demonstrate the suitability of the modified AOAC2008-05 method for disinfectant efficacy with vegetative cells, including Gram-negative select agents. Based on the log reduction values, the LVS, A1122, and *A. tumifaciens,* respectively, appear to be suitable surrogates for *F. tularensis*, *Y. pestis*, and *B. melitensis*.

Significance and Impact of Work

The quantitative data summarized in this study comprise the first ever demonstration of the effectiveness of U.S. Environmental Protection Agency registered disinfectants against highly infectious select agents. The modified AOAC 2008-05 method offers an attractive quantitative alternative to the current standard AOAC use-dilution method (964.02)

Question and Answer Session

Question 1: Some ongoing research is examining germination-kill strategies for *Bacillus* species. Have you done any testing on *Bacillus* species?

Summary of response: Some of the speaker's colleagues are currently researching persistence

of vegetative *Bacillus* species in water. The research is suggesting that vegetative cells can survive in water for several weeks, depending on experimental conditions. Further, some vegetative cells in dirty water were found to sporulate. Therefore, cleanup strategies that force germination—without killing the newly formed vegetative cells—may result in vegetative cells sporulating in water. The extent of *Bacillus* sporulation in water depends on various conditions, including temperature, availability of nitrogen, and other factors.

Question 2: Do these organisms or their surrogates produce bio-films over time?

Summary of response: Formation of bio-films was not part of this research project. However, bacteria (including *Yersinia pestis*) known to secrete exo-polysaccharides would be expected to form bio-films.

Question 3: At what temperature did you conduct the efficacy studies?

Summary of response: Experiments were typically conducted at temperatures of 21 ^{o}C (±2 ^{o}C). The experiments were conducted in incubators to maintain these temperatures.

Question 4: The presentation referred to "high treatment" and "low treatment" for killing vegetative cells. How were these treatment levels selected?

Summary of response: This approach followed methodologies employed in earlier EPA research on disinfection of other microorganisms (e.g., *Staphylococcus*). In that earlier work, "high treatment" levels were always based on recommendations made by manufacturers of the disinfectants, and "low treatment" levels were determined by reducing the concentration of the disinfectant and reducing the contact time. When selecting "low treatment" levels, it was important to select parameters that would lead to differences in decontamination effectiveness that could be reliably discerned by the analytical methods.
This same approach was adopted in the current research.

6.2 From Reaerosolization to Exposure, Connecting the Dots

Capt. Marshall Gray, EPA, Decontamination and Consequence Management Division

The "Scientific Program on Reaerosolization and Exposure" (SPORE) is a multi-agency program to be executed from 2011 through 2014. The purpose of the program is to develop a quantitative understanding of the public health risk from anthrax spore reaerosolization in an urban environment following an outdoor agent release. The presentation will provide a general program overview and anticipated outputs.

Question and Answer Session

Question 1: The methodology used to prepare *Bacillus thuringiensis* spores can have a significant bearing on reaerosolization properties. How is the spore preparation methodology being determined for this study?

Summary of response: The experimental design for the project is still being developed, and some of the speaker's collaborators are working on the issue raised in the question.

Question 2: When assessing exposures, will this project use models for assessing deposition of inhaled particles in the respiratory tract, possibly the model being developed by Dr. Jacky Rosati (EPA-NHSRC) and her colleagues?

Summary of response: The project team is very familiar with these models, but decisions have not yet been made regarding which specific models will be used. Once the study is conducted, the data collected could be used to evaluate the performance of these models.

Comment 3: When registering agricultural products containing *Bacillus thuringiensis*, manufacturers are required to submit extensive product data to EPA's Office of Pesticide Programs. However, those data are typically considered confidential. The research team might consider accessing any publicly available data from that source.

Summary of response: Point noted.

Question 4: Many disinfection studies have previously considered using *Bacillus thuringiensis* as a surrogate for *Bacillus anthracis*, but chose not to do so because *Bacillus thuringiensis* has certain properties that differ considerably from *Bacillus anthracis*. For instance, *Bacillus thuringiensis* is much more hydrophobic. Has this been considered in this research project?

Summary of response: The suitability of the proposed surrogate will be considered carefully before the study begins.

Comment 5: Many different factors likely affect the selection of the surrogate. Extensive research has previously been conducted using *Bacillus globigii* as a surrogate for outdoor studies. However, the rationale for selecting the surrogate may also be based on perceived risks for exposure. In that sense, *Bacillus thuringiensis* may be more desirable because it is a registered pesticide and has been used in previous outdoor studies.

Summary of response: It might be more difficult to obtain approval for an atmospheric release of *Bacillus globigii.* The speaker also requested that a colleague respond to this comment. That individual stated that the most appropriate surrogate for disinfection studies may not be the most appropriate surrogate for outdoor fate and transport studies. In addition, literature is available indicating that *Bacillus thuringiensis* is a suitable surrogate for evaluating reaerosolization. Justification for surrogate selection will be part of this research project.

Question 6: The presentation indicated that exposure will be evaluated using models. Will the project also include ambient air monitoring?

Summary of response: Predictive exposure modeling will be conducted initially to estimate fate and transport of the surrogate. During the field study, ambient air monitoring will be conducted to measure actual concentrations. The monitoring data will be used to improve the predictive ability of the models.

Question 7: Will the study include human subjects who will be evaluated for evidence of exposure?

Summary of response: The study will not consider human subjects. The modeling and monitoring data will be used to characterize breathing zone concentrations for hypothetical receptors, and those exposure concentrations can then be used to develop various risk estimates (e.g., the percentage of the population with deep lung deposition). A major goal of this effort is to develop defensible methodologies for estimating risk based on the presence of biological agents.

Question 8: The workshop's keynote speaker described an experiment from the 1950s involving aerial spraying of a surrogate that was thought to be benign, but resulted in infections among some susceptible individuals. How will such concerns be addressed in a study involving a release of a surrogate in a large urban area?

Summary of response: The proposed surrogate—*Bacillus thuringiensis*—is a registered pesticide product and has a long history of being used in populated areas. The speaker asked a colleague to provide further information. That individual agreed, emphasizing that *Bacillus thuringiensis* is routinely sprayed over major metropolitan areas, which gives confidence that the proposed study would not have the unintended consequences similar to those observed after the 1950s experiment.

6.3 An Investigation into the Sources of Two Inhalation Anthrax Fatalities Associated with African Drums

Jimmy Walker, United Kingdom Health Protection Agency, Biosafety Unit

Aim of Work Presented

Following the discovery that the deaths of a 50-year-old craftsman from Scotland and a 35-year-old Spanish folk musician from London were caused by inhalational anthrax, an investigation was carried out to identify the source of the disease.

Methods and Results

The Health Protection Agency Bioresponse Team, in conjunction with the local health authorities, took surface and air samples from a number of premises (the victims' homes, as well as workshops and addresses linked to the playing and manufacture of African drums) and removed potentially contaminated articles from these premises for subsequent sampling. Prior to commencement of the work, detailed risk assessments were developed and exacting safe working procedures were put in place and agreed by all interested parties of a multidisciplinary team, including the regulatory authorities, local health authorities and emergency services. These procedures covered personal protection, decontamination, sampling, sample handling, sample analysis, site entry and exit procedures. The samples were analyzed using both culture-based and polymerase chain reaction methods and contamination on a number of drums and within the properties of the spores of *Bacillus anthracis* was detected. Decontamination of the personnel, equipment used, and buildings will also be discussed.

Conclusions

Anthrax contamination was detected on a number of drums and surfaces within the domestic dwellings, indicating that the cause of inhalation anthrax was probably related to the making or playing of the African drums.

Significance and Impact of Work

The anthrax investigation provided an excellent opportunity to demonstrate the interaction that is required by multidisciplinary teams in a real exercise and to test the robustness of emergency procedures and methods that had previously been developed.

Question and Answer Session

Question 1: The photographs in the presentation show different practices for using personal protective equipment during cleanup activities. Some personnel donned "Level A" protection, while others used "Level C." What was the reason for this?

Summary of response: Different parties were responsible for deciding the appropriate personal protective equipment for their workers. Use of "Level A" offered the best protection, but was also cumbersome for workers and not as comfortable to wear. "Level C" protection was deemed adequate for certain personnel.

Question 2: Did the project include any research into the prevalence of *Bacillus anthracis* in the different regions of Africa where the animal hides originated?

Summary of response: That was not part of this research, but such insights are available from other publications.

Question 3: The presentation referred to the use of chlorine dioxide fumigation to decontaminate a village hall. Did this fumigation have any collateral effects?

Summary of response: The only effect observed was that some historic wall hangings were slightly discolored after the chlorine dioxide fumigation was finished.

6.4 Transfer of BW Surrogate Particles from Contaminated Surfaces

Richard Byers, Battelle

Aim of Work Presented

Fielded biological aerosol detectors are designed to collect biological threat agents in the air, providing a warning to government and public health officials of potential bioterrorism events. If a biological threat agent was collected, the collector and surrounding area could be contaminated due to bioaerosol deposition. This contamination could pose a hazard to the

sampler operator and may be a source of cross-contamination in clean areas. The operator could also pose a hazard to co-workers if the contamination were re-transferred to a laboratory or office.

Methods and Results

To assess this exposure source, a study was performed using a *Bacillus thuringiensis* (*Bt*) spore powder preparation to investigate material transfer from a contaminated site to an individual and from a contaminated individual to his or her surroundings. Air samples from an intentionally *Bt*-contaminated site showed reaerosolization of the spores, and analysis of swatches taken from the operator's clothes showed substantial transfer of spores to the operator. After leaving the contaminated site, the operator entered a laboratory/office complex and performed common tasks. Air and surface samples were taken to measure reaerosolization and secondary transfer of bioaerosol particles.

Contaminant transfer to the sampler operator was considerable. The average swatch collected from the operator contained 2.5×10^6 colony forming units (CFU) after performing routine maintenance on the collector over three and half minutes. In addition, the operator was exposed to a secondary aerosol of 24 CFU per liter of air during this time. Transfer of material from the contaminated operator to clean surfaces was also measured. On average, the test results showed that the field operator re-transferred an estimated 7 percent of the total contamination that collected on his clothing and shoes to previously clean areas. Indoor surface sampling results showed the highest levels of secondary contamination were found on the carpet, accounting for 75 percent of the particle transfer. Reaerosolization from the contaminated operator was also detected, as all rooms sampled were positive for aerosolized spores.

Conclusions

A field operator accessing a site that has been exposed to a realistic biological aerosol cloud will be exposed to the contaminant, collect the material on clothing, hands, and shoes, and transfer the contaminant to clean areas.

Significance and Impact of Work

Results from this study may provide insight into possible exposure hazards for fielded bioaerosol collector operators, how transfer of contaminants to secondary sites occurs, and the potential for subsequent building contamination.

Question and Answer Session

Question 1: The source of the *Bacillus thuringiensis* in this project was DiPel® powder. However, this powder typically contains only 5 to 10 percent spores, with various additives accounting for the rest of the mass. Is this considered representative of actual scenarios expected to be encountered?

Summary of response: The powder was considered suitable for an assessment of reaerosolization. The original powder had a mass median aerodynamic diameter (MMAD) of approximately 50 microns, and the original powder was then milled to generate finer particles that when aerosolized had a MMAD of approximately 12 microns.

Question 2: How was the aerosol particle size distribution characterized?

Summary of response: Both a Battelle Cascade Impactor and an Andersen Cascade Impactor were used to characterize the particle size distribution of bioaerosols.

Question 3: One study result indicated that carpeted rooms had the highest amount of reaerosolization. Were any "controls" run to assess aerosolization from carpet prior to injecting the tunnel with the DiPel® powder?

Summary of response: No. The study focused on reaerosolization of *Bacillus thuringiensis*, and there was no reason to expect this surrogate to be present prior to the testing. The carpet was not installed in the Ambient Breeze Tunnel itself, but rather in the secondary test trailer.

Question 4: The study was conducted in an "Ambient Breeze Tunnel." What was the air flow through the tunnel when workers entered and performed their routine standardized tasks?

Summary of response: There was no generated air flow during that time of the experiment. Thus, any airborne bioaerosols measured during that time would be expected to result primarily from the workers' activities in the tunnel.

Question 5: What was the condition of the carpet that was used in the project? New carpet has hydrophobic coatings, so the carpet's condition can be an important consideration, especially when examining how reaerosolization varies with relative humidity.

Summary of response: The carpet was not new. It was ripped out of an apartment, and the extent of previous use was not known. It was vacuumed thoroughly before being installed in the tunnel.

Comment 6: One of the findings reported in the study is that the surrogate was found on the shoes of workers who accessed the contaminated areas. NHSRC researchers have completed studies examining the extent to which human activity causes resuspension of particulate matter from carpet (see: "Resuspension of and Tracking of Particulate Matter from Carpet Due to Human Activity," document number EPA/600/R-07/131). Those findings should be considered as part of this ongoing work.

Summary of response: Point noted.

6.5 Fixatives Application for Risk Mitigation Following Contamination with a Biological Agent

Chris Campbell, Lawrence Livermore National Laboratory

Aim of Work Presented

Spore reaerosolization and transport following a release of *Bacillus anthracis* spores has the potential to increase human health risks and impede characterization and decontamination activities. Moreover, as rapid return to service is essential for recovery, methods are needed to reduce the potential for resuspension of spores in the respirable particle size range, prevent contaminant transport, and establish transportation corridors for access to critical infrastructure.

Lawrence Livermore National Laboratory (LLNL) in support of the Department of Homeland Security (DHS) Interagency Biological Restoration Demonstration (IBRD) briefly evaluated the theoretical application of fixatives in response to a biological agent release. The approach, however, requires efficacy testing. We propose to review other uses of fixatives for outdoor areas, including the use of horticultural oils and soil stabilizers for agriculture. In addition, the use of fixatives to prevent reaerosolization and subsequent migration of radioactive particles is a widely accepted approach. Fixatives were used following the Chernobyl accident to create transportation corridors and were recently used in Japan following the events at the Fukushima nuclear power plant to minimize reaerosolization of contaminated land. In fact, fixatives are commonly used in the nuclear industry to immobilize contamination and reduce reaerosolization and transport risks. Many of these materials were originally developed for dust and asbestos mitigation, but could be applied to the majority of hazardous particulate matter contributing to an inhalation risk. We will review the valuable information and experience provided by these related fixative applications and develop formulations that are optimized for bioagent (spore) treatment on relevant surfaces.

Methods and Results

LLNL is currently investigating fixative technologies in support of the DHS Wide Area Recovery and Resiliency Program (WARRP). These initial studies will focus on identifying existing fixatives with the potential to be effective in a wide-area biological contamination event. Testing will be performed on candidate fixatives comprising different formulations to examine the potential for spore release from

treated surfaces through physical contact (surface wipe sampling).

Conclusions

Our research progress to date will be summarized, along with a review of the fixatives concept for risk mitigation.

Significance and Impact of Work

The application of fixatives to biologically contaminated surfaces is another potential tool for rapid return to service following a biothreat agent release. The preliminary work discussed is building toward larger scale testing of fixative applications to reduce the risk of resuspended spores in the inhalation particle size ranges.

This work performed under the auspices of the U.S. Department of Energy by Lawrence Livermore National Laboratory under Contract DE-AC52-07NA27344.

Question and Answer Session

Question 1: Application of fixatives is an intriguing prospect for responding to bioterrorism attacks. However, is it possible that this activity itself would contribute to reaerosolization? For instance, use of backpack sprayers to apply fixatives may actually contribute to furthering the spread of spores.

Summary of response: This is a good point, and further research is needed to determine which application procedures would be expected to minimize reaerosolization. Ultimately, researchers would like to quantify how specific parameters (e.g., application velocities, droplet sizes) affect reaerosolization.

Question 2: Will future work use monitoring to assess whether fixative application contributes to reaerosolization?

Summary of response: Low-volume air monitoring systems can be deployed in future experiments to assess the extent of reaerosolization as a function of application parameters and surface types.

Question 3: Are you aware of the EPA research on use of strippable coatings for removal of radiological contamination from surfaces (see: "Radiological Decontamination Strippable Coating: Technology Evaluation Report," document number EPA/600/R-08/100)? That research has considered effectiveness of decontamination for multiple surface types.

Summary of response: The speaker's research collaborators are familiar with this research.

Question 4: Has this research considered adding peroxides to the fixatives? Such a mixture could result in both containment and decontamination. Another possibility is to add germinating agents to the fixatives.

Summary of response: These are excellent ideas. An initial challenge is demonstrating the potential utility of fixatives for decontamination purposes. Incorporating disinfectants and germinating agents (with lysis to follow) are important considerations for future work.

Question 5: The presentation included information on costs of fixatives and the associated application equipment, but it did not include cost information for labor, disposal, and other deployment costs. Will the full range of costs be considered when comparing different decontamination strategies?

Summary of response: The full range of costs should be considered when comparing different strategies.

Comment 6: Different environmental regulations may apply depending on the types of fixatives used. For example, physical containment of spores using fixatives would be covered by certain regulations. However, when disinfecting agents are included in those same fixatives, a different set of environmental regulations may apply. The applicable regulations would determine what registrations and exemptions are needed for a particular mixture.

Summary of response: Point noted.

7 Bio-Response Operational Testing and Evaluation

7.1 Overview of Bio-Response Operational Testing and Evaluation (BOTE)

Shannon Serre, EPA, Decontamination and Consequence Management Division

The Bio-response Operational Testing and Evaluation (BOTE) project was a multi-agency effort designed to operationally test and evaluate biological incident (anthrax release) response from health/law enforcement response through environmental remediation. The effort included the coordinated project planning, support, and/or involvement from the following:

- U.S. Environmental Protection Agency (EPA)
- Department of Homeland Security (DHS)
- Centers for Disease Control and Prevention (CDC)
- CDC/National Institute for Occupational Safety and Health (NIOSH)
- Laboratory Response Network (LRN)
- Department of Energy (DOE) National Laboratories
- Department of Defense (DOD) Defense Threat Reduction Agency (DTRA)
- Federal Bureau of Investigation (FBI)

The effort was established through initial interactions between EPA's National Homeland Security Research Center and the DHS Science and Technology Directorate in partnership to further develop research products to support EPA's response to incidents of biological terrorism. This project will help improve EPA's preparedness and capability to respond to a biological incident, specifically related to readiness for mitigating the effects of the release of a bio-agent over a wide area.

The BOTE project was divided into two phases: 1) a field-level decontamination assessment and 2) a functional operational evaluation. In Phase 1, three decontamination methods showing effectiveness against *Bacillus anthracis* spores in laboratory and/or field use were tested under field relevant conditions using *Bacillus atropheus*. Parameters included the decontamination method, level of contamination, and contaminated environment (e.g., office setting, residential area, and heating, ventilation, and air conditioning) and the assessment will include a cost-benefit analysis of application of each method. The intent of Phase 1 was to develop an improved understanding of response strategies for use in wide area remediation. In Phase 2, an interagency response to a covert *B. anthracis* spore release in a facility was conducted, including law enforcement response, public health response, decontamination, and facility clearance.

This presentation will serve as an overview of the BOTE project. Specific areas of the project will be presented by various speakers in this session.

Question and Answer Session

Question 1: The project involved multiple rounds of tests in the same building. How was the heating, ventilation, and air conditioning (HVAC) system decontaminated? What was done to ensure that HVAC ductwork—both on the supply side and the return side—had no residual contamination that carried over from one test to the next?

Summary of response: In two of the three test rounds, the HVAC system was actually used to disseminate the decontamination fumigant throughout the building; in this case, there was little concern about extensive residual contamination being observed in the subsequent experiment. In the other test round, the HVAC system was entirely capped off, which could raise some concern about residual contamination on the HVAC system components. However, the

likely amounts of residual decontamination were expected to be minimal when compared to the large quantities of *Bacillus* surrogates that were disseminated in each test round (i.e., approximately 1,000,000 spores per square foot).

Question 2: Was any sampling done inside the HVAC ductwork?

Summary of response: Yes. The next presentation will cover details of the sampling plan.

7.2 Overview of Sampling Activities at BOTE

Dino Mattorano, EPA, OSWER, National Decontamination Team

An abstract for this presentation was not available for publication.

Question and Answer Session

Question 1: How much time was needed to purchase bulk quantities of the materials required for the sampling packages?

Summary of response: The speaker requested that a colleague respond to this question. That individual noted that most of the equipment was purchased through a government contract, and it took more than a month just to obtain approval for certain purchases, particularly the more expensive items bought in bulk.

Question 2: The training and proficiency testing for sampling personnel is an interesting component of this study. During the proficiency testing, sampling personnel were apparently in "street clothes." Did you conduct any proficiency testing when sampling personnel were wearing respirators and other personal protective equipment?

Summary of response: The performance of the samplers was not expected to be significantly impaired by their use of personal protective equipment. Several observations were provided to support this statement. First, most of the personnel involved in the project were not only experienced samplers, but also had extensive experience collecting environmental samples while wearing personal protective equipment. Second, schedules for individual samplers were adjusted based on environmental conditions (e.g., to ensure that personnel were not forced to work long shifts on the warmest days). Third, all sampling rooms were equipped with surveillance cameras that enabled project managers to oversee sample collection procedures while samplers were wearing personal protective equipment. Finally, EPA observers accompanied every sampling team inside the buildings to observe sampling activities directly and ensure that samples were collected correctly; these observers also documented the amount of time it took samplers to perform certain tasks, and those data can be evaluated to assess sampler efficiency and performance. Taken together, these observations suggest that use of personal protective equipment did not impair the sampling activities conducted, even though this was not directly evaluated during the proficiency testing.

Question 3: The project considered vacuum sampling, swab sampling, and wipe sampling. How did efficiency of recovery vary across these three different sample types?

Summary of response: All three sample types have limited recoveries—in the range of 40 to 50 percent depending on the type of surface considered. Across all sample types, recovery from nonporous surfaces and materials tends to be better than recovery from porous ones. The sponge sticks, gauze wipe, and swab sampling methods seem to offer better recoveries than vacuum sampling, even when considering sampling from carpets.

7.3 Preliminary Results from a Study of Spore Migration Outside a Contaminated Building Using Soil Container Samples Collected during the BOTE Project

Erin Silvestri, EPA, Threat and Consequence Assessment Division

Aim of Work Presented

The Bio-Response Operational Testing and Evaluation (BOTE) project was conducted to evaluate the efficacy of three decontamination technologies on *Bacillus atrophaeus* subspecies *globigii* (*Bg*) spores disseminated in a building. During BOTE, a preliminary study investigating the potential for spores to migrate from the contaminated building and deposit in soils adjacent to the building, creating a secondary exposure pathway, was conducted. This presentation will show initial results from the study.

Methods and Results

Fifty grams of heat-sterilized reference sand was placed in 150-millimeter polystyrene Petri dishes. The dishes were positioned in multiple locations around the building near entrances, exits, and high traffic areas to assess spore deposition from each of three dissemination and decontamination activities. Sample dishes were also placed within the building to acquire field positive samples and to assess possible polymerase chain reaction (PCR) inhibition due to the decontamination agents. Collected samples were processed using two methods: the U.S. Geological Survey method, which allowed higher throughput using a smaller sample size, and the draft U.S. Environmental Protection Agency (EPA) method developed for this study that included an additional washing step and required a larger sample size. Both methods utilized PowerSoil™ DNA Isolation Kits to extract DNA before quantitative-PCR (qPCR) detection of *Bg* spores.

Conclusions

EPA data showed positive results outside the building pre- and post-decontamination during the amended bleach and chlorine dioxide rounds. U.S. Geological Survey data were non-detect for a majority of the samples, indicating sample processing had an impact on the results. Lessons learned from the sample placement and sampling methodologies will be presented along with the analytical results.

Significance and Impact of Work

The preliminary data analysis showed that spores can be transported from inside a facility to outdoor areas. Future decontamination efforts need to consider not only indoor but also immediate outdoor environments when performing cleanup activities. Results from this study provide information on sample collection and analysis of soils from a field site. The data also identified a possible route of exposure that should be considered when decontaminating sites in support of remediation efforts.

Question and Answer Session

Question 1: Results were shown for duplicate, collocated samples ("between-sample variability") but not for replicate analyses of individual samples ("within-sample variability"). Was within-sample variability characterized?

Summary of response: Yes. Though not covered in the presentation, replicate laboratory analyses of selected samples were conducted to characterize method precision and measurement variability.

Question 2: During the laboratory analyses of samples, how did the researchers determine the conversion factor used for computing spore counts from genomic equivalents?

Summary of response: This question is better answered by the microbiologist who was responsible for analyzing the samples.

Question 3: Did the spore migration study consider negative controls? This could have included sand that was never exposed to *Bacillus globigii* but placed alongside sand that was exposed.

Summary of response: Yes. The study included "trip blanks," which were heat sterilized sand samples sent to the field but never exposed to the surrogate. These were used as negative controls. These tested negative for the surrogate in two of the three test rounds, but positive detections in the negative controls occurred in the test involving vaporous hydrogen peroxide decontamination.

Question 4: The presentation mentioned that clearance sampling after decontamination included laboratory analyses using rapid polymerase chain reaction (PCR) assays. Were any culturing methods used in the analyses to determine the viability of detected spores?

Summary of response: Analyses of clearance samples were conducted using only PCR methods. In retrospect, culturing methods should have been included for some samples.

Question 5: How did the study consider background effects, especially considering the detections of *Bacillus globigii* in the negative controls?

Summary of response: The data analyses shown during the presentation are preliminary, and this issue will be considered in ongoing work.

7.4 Surface Sample Testing using Rapid Viability Polymerase Chain Reaction (RV-PCR) Method during the BOTE

Sanjiv Shah, EPA, Threat and Consequence Assessment Division

Aim of Work Presented

The Rapid Viability Polymerase Chain Reaction (RV-PCR) is a research method developed by the National Homeland Security Research Center within the Office of Research and Development of the U.S. Environmental Protection Agency (EPA) to rapidly detect and identify, or rule out, live *Bacillus anthracis* spores, during a bioterrorism event. The method has been developed in direct support of the Environmental Response Laboratory Network established by the EPA's Office of Emergency Management. Briefly, the RV-PCR is a combination of a reliable broth culture method and real-time PCR. The method was not previously challenged with the analysis of a large number of environmental samples with potential background interference and post-decontamination field samples. Phase I of the Bio-Response Operational Testing and Evaluation (BOTE) provided a unique opportunity to evaluate the performance of this method.

Methods and Results

Three decontamination technologies, namely, fumigation with vaporized hydrogen peroxide, fumigation with chlorine dioxide, and surface treatment with pH-adjusted bleach, were assessed in-between re-setting and re-staging of the facility during the BOTE. The study was performed using intentional release (aerosolization) of spores of *Bacillus atrophaeus* subspecies *globigii*, a surrogate for *Bacillus anthracis*. Using the *Bg*-specific culture conditions and PCR reagents, the performance of the RV-PCR method was tested with the surface wipe samples collected during pre- and post-decontamination events. After the spore recovery from each wipe sample, the spore suspension was split into two equal parts. Upon concentrating to generate equivalent spore numbers, one part was analyzed by the RV-PCR method and the other by the traditional culture method.

Conclusions

Out of a total of 262 samples, the Lawrence Livermore National Laboratory (LLNL) and the Microbiology Laboratory Branch (MLB) of the EPA's Office of Pesticide Programs analyzed 212 and 50 samples, respectively.

Significance and Impact of Work

Overall, the RV-PCR method provided rapid results that were 95 percent (250/262 samples) consistent with results of the culture method.

Detailed results from both the LLNL and MLB will be presented.

Question and Answer Session

Question 1: In the quest to find rapid methods for detecting viable cells, some researchers previously considered use of mass spectrometry (MS) methods, possibly looking for trace metals in spore coats. Might MS methods in conjunction with other methods (e.g., RV-PCR) hold promise for this application?

Summary of response: MS may hold some promise, but the method likely would not achieve the desired sensitivity and specificity for detecting biological agents. The lack of specificity would be most important for samples that contain many other substances. Another concern is that use of MS methods would require development of a large database of results to support the analyses.

7.5 BOTE Preliminary Results: Cost Analysis

Paul Lemieux, EPA, Decontamination Consequence and Management Division

In April through May, 2011, and September, 2011, a multi-agency field demonstration and operational exercise called the Bioresponse Operational Testing and Evaluation (BOTE) took place at the Idaho National Laboratory facilities near Idaho Falls, Idaho. The BOTE project consisted of two phases. Phase 1 was a field-level building decontamination assessment managed by the U.S. Environmental Protection Agency (EPA) and Department of Homeland Security (DHS), with the Department of Defense (DOD)/Defense Threat Reduction Agency (DTRA) coordinating among interagency participants. Phase 1 included an assessment of three decontamination methods (fumigation with hydrogen peroxide, fumigation with chlorine dioxide, and a wash down process using pH-adjusted bleach); associated sampling and analytical activities; and a cost analysis of test and processing subsequent sampling results. Phase 2 addressed facets of an interagency response to a biological attack on a facility and involved coordination among several federal agencies, including EPA, DHS, CDC, DOD, and the Department of Energy (DOE). The project utilized a nonpathogenic spore simulant, *Bacillus atrophaeus* subspecies *globigii* (*Bg*), a common surrogate for *Bacillus anthracis*.

This presentation will describe the cost analysis effort. Data were collected from decontamination and sampling activities, with a goal of estimating the residual number of spores in the air and on the surfaces resulting from the application of various decontamination technologies as a function of cost, materials, and time. The cost analysis approach made the assumption that, although certain pieces of information derived from the BOTE project are incident- and site-specific, the information can still be extrapolated to other events. Applicable variables include: 1) costs related to sampling and analytical activities; 2) costs related to the application of decontamination technologies to the building; 3) costs related to personnel entering and leaving the building; and 4) costs related to equipment rentals and consumables. It is also assumed that some costs critical to a cost analysis cannot be assessed purely based on the BOTE testing, either due to artificialities present in a field test situation or the fact that BOTE used a biological agent surrogate and not real *Bacillus anthracis*. These costs would include: 1) waste management costs, 2) some travel costs, and 3) and some incident command costs. The analysis of these costs was handled using a combination of data from the BOTE testing and various notional considerations (such as adjusting disposal fees by using multiplicative factors or estimating travel costs assuming that various teams were present on-site only as long as necessary). Costs that could not be assessed using data from the BOTE study, directly or indirectly, or from best engineering judgment, were not included in the cost analysis. Costs were assessed in several ways, including:

- Cost of each decontamination technology
- Cost of applying a given decontamination technology per square foot or cubic foot of space.

- Cost of applying a given decontamination technology per unit of spore reduction from initial level of contamination in the air or on surfaces.
- Cost of applying a given decontamination technology to achieve a final level of contamination in the air or on surfaces.

Question and Answer Session

Question 1: Has the decision logic for selecting bioterrorism decontamination strategies (e.g., when to use fumigation versus application of liquid decontaminants) changed since 2001?

Summary of response: The speaker deferred to the National Decontamination Team for official guidelines on decontamination decision logic. However, findings from the BOTE project and other research projects are expected to help inform future decisions regarding decontamination. For example, the cost evaluation from BOTE provides estimates on cleanup costs associated with different decontamination strategies and their associated effectiveness of decontamination. These findings and various other factors will likely help inform cleanup decisions for future events.

Question 2: The BOTE experiment used a biosafety level 2 (BSL-2) laboratory, because the experiment involved surrogates for *Bacillus anthracis*. In an event involving *Bacillus anthracis*, samples would likely have to be analyzed in BSL-3 laboratories. To account for this in cost projections, an adjustment factor was used to estimate BSL-3 costs based on actual BSL-2 costs from the BOTE experiment. Do you recall what the adjustment factor was?

Summary of response: The adjustment factor was based on an assessment of labor hours for analyzing samples in BSL-3 laboratories compared to that for BSL-2 laboratories. The factor used in the preliminary analysis was somewhere in the range of 2 to 2.5. The researchers will consult with representatives from the Laboratory Response Network to determine if this factor is reasonable.

Comment 3: A workshop participant shared three comments that pertain to cost and ability to respond quickly to incidents. First, hiring decontamination contractors through the federal procurement process can be complicated, and doing so in an expedited manner will be extremely difficult. Second, labor accounted for a very significant portion of overall costs for decontaminating the Brentwood mail facility following the 2001 anthrax attacks. Third, the BOTE study considered a relatively small building (approximately 4,000 square feet), and findings regarding effectiveness of decontamination may not apply to buildings that are hundreds of times larger.

Summary of response: Points noted.

Question 4: Data were presented on sampling and analysis costs. What type of sampling was included? Did this include the initial scoping sampling, confirmation sampling, and all blanks?

Summary of response: The average sampling and analysis cost listed ($681 per sample) was based on the total costs for sampling and analysis divided by the number of samples collected. Some finer details should also be considered. For instance, labor costs associated with sampling during different decontamination phases are expected to vary, depending on the level of personal protective equipment that must be used. Further, the labor hours needed per sample tended to decrease with sampling round, which suggested that sampling time decreased as the samplers gained experience.

8 Radiological/Nuclear Agent Decontamination and Waste Management

8.1 Fate and Transport of Radiological Dispersal Device (RDD) Material (Cs and Co) on Urban Building Surfaces: Effects of Rain

Sang Don Lee, EPA, Decontamination and Consequence Management Division

Cesium (Cs) and cobalt (Co) contaminated urban surfaces were exposed to a simulated rain event and the fate of Cs and Co on surfaces was characterized. Five different building materials, including asphalt, brick, concrete, granite, and limestone, were used. Known amounts of Cs and Co liquid solution were atomized and deposited onto the coupon surfaces. The initial state of Cs and Co particles on coupon surfaces was controlled by using two different solvents, methanol and water. Cs and Co particles using the methanol solution stayed more locally concentrated and closer to the surfaces than the particles in water because of methanol's faster evaporation rate. The rain rinsate from each coupon was collected in a container and analyzed for Cs or Co concentration. Cross sectioned coupon surfaces were analyzed for the subsurface concentration profile of Cs and Co. The results showed that the amount of Cs/Co rinsed off varied depending on the material and deposition type.

Question and Answer Session

Question 1: The research presented information on penetration of cobalt and cesium into various materials (e.g., asphalt, brick, concrete, granite). The depth profiles were obtained by cutting the sampling coupons. How difficult was it to obtain these depth profiles? Are the observed depth profiles known with confidence?

Summary of response: A diamond saw was used to cut the sampling coupons in order to assess depth profiles. This *cutting was necessary to have flat surfaces for purposes of analysis, but it may also have contributed to cross-contamination of samples. The extent of this cross-contamination has been examined but not yet quantified. The cross-contamination concern complicates efforts to quantify the cesium and cobalt penetration depths with a high degree of confidence.*

8.2 Mobility and Bioavailability of Long-Lived Chernobyl Radionuclides in the Environment and Their Consideration at Rehabilitation of Contaminated Sites

Alexey Konoplev, RPA "Typhoon"

Aim of Work Presented

The paper describes the results of theoretical and experimental studies on the behavior of the Chernobyl-origin radiocesium and radiostrontium in the "soil-water" system to develop the methodology for assessing their mobility and bioavailability.

Methods and Results

Study methods included laboratory and field experiments in combination with process-level physical-chemical modeling of radionuclide behavior in the environment. Fuel particles released as a result of the Chernobyl accident were shown to be responsible for two distinct features in the behavior of the Chernobyl-origin radionuclides: 1) the initial mobility and availability of the radionuclides in the near zone was lower than those observed in similar conditions as a result of the global fall-out and 2) the deposition of fuel particles on the underlying surface, primarily in the near zone, led to the non-uniform contamination with refractive radionuclides and a significant dependence of the initial mobility and bioavailability on the distance to the damaged reactor as compared to the more volatile radiocesium. Kinetic characteristics of the

radionuclides leaching from the fuel particles in natural conditions for different soils of the near zone were obtained. A conceptual model is proposed for the key processes of transformation of radiostrontium and radiocesium species in soil and water bodies. The model accounts for the radionuclides leaching from fuel particles, sorption-desorption by the ionic exchange mechanism, fixation, and remobilization.

The data obtained were used to identify the best ways to remediate the Chernobyl cooling pond. The remediation options include a controlled reduction in the surface water level of the cooling pond and stabilization of the exposed sediments. After the planned cessation of water pumping from the Pripyat Rver to the pond, part of the sediments will be drained and exposed to the air. This action will significantly enhance the dissolution rate of the fuel particles and, correspondingly, mobility and bioavailability of radionuclides will increase with time. In exposed sediments, fuel particles will be almost completely dissolved in 15 to 25 years, while in flooded parts of the pond it will take about a century.

The knowledge gained about the radiostrontium and radiocesium behavior provided a basis for developing amendments on base of industrial waste (hydrolysis lignin, clay-salt slimes, and phosphogypsum) and sapropel with a view to reduce the bioavailability of these radionuclides in soil.

Significance and Impact of Work

Nuclear accidents such as Fukushima-1, Chernobyl, and Three Mile Island could be considered prototypes of radiological/nuclear terrorist attack. Knowledge gained about radionuclide behavior in the environment after such accidents and efficiency of rehabilitation of accidentally contaminated territories should be used to develop decontamination techniques and strategies in case of radiological incidents.

Question and Answer Session

Due to time constraints, a question-and-answer session did not occur after this presentation.

8.3 Adsorption of Cesium from Solutions on Construction Materials

Konstantin Volchek, Environment Canada

Aim of Work Presented

The aim of the work was to study the interactions between cesium and common building materials in the presence of water.

Methods and Results

The adsorption of cesium on cement mortar from aqueous solutions was studied in series of bench-scale tests. The effects of cesium concentration, temperature, and contact time on process kinetics and equilibrium were evaluated. Experiments were carried out in a range of initial cesium concentrations from 0.0103 to 10.88 milligrams L-1 and temperatures from 278 to 313 K using coupons of cement mortar immersed in the solutions. Non-radioactive cesium chloride was used as a surrogate of the radioactive ^{137}Cs. Solution samples were taken after set periods of time and analyzed by inductively coupled plasma mass spectroscopy.

Adsorption equilibrium models (Freundlich and Langmuir) and kinetic models (first order, pseudo-second order, and intra-particle diffusion) were employed to interpret the test results. Adsorption activation energy was calculated to determine the "nature" of adsorption (physical versus chemical).

Conclusions

Experimental data generated in this study, as well as modeling results, helped better explain the nature of interactions in systems "cesium–construction materials" and to satisfactorily quantify the interactions. Furthermore, the models employed in the study enabled the prediction of the extent of adsorption and thus the suggestion of appropriate decontamination approaches. Study results will be instrumental in developing decision-making tools to select an optimum decontamination strategy.

Significance and Impact of Work

Study results will enhance the knowledge of interactions of cesium with construction materials. Prediction models will help better plan response operation.

Question and Answer Session

Question 1: Following RDD events, cesium contamination levels over large areas will be considerably lower than what was considered in this research. In such areas, might the low cesium concentrations and the presence of other abundant metals (e.g., sodium) affect the potential for cesium to reach adsorption equilibrium?

Summary of response: The research considered relatively high concentrations of cesium, but this was necessary given the use of chemical methods to detect the non-radioactive cesium isotopes. The use of radiological analytical methods and radioactive cesium isotopes would have indeed achieved lower detection limits and permitted lower concentrations. Nonetheless, the question raises an important point, and further testing would be needed to assess the validity of the partitioning model and coefficients at lower cesium concentrations. With respect to the influence of other abundant metals during field conditions, it is true that many other metals will be found at much higher concentrations than cesium. However, what must be considered is that cesium has a much greater affinity for binding to minerals in construction materials than other metals. It would therefore be preferentially adsorbed, as compared to competing metal ions.

8.4 Design and Performance of a Superabsorbing Hydrogel for Decontaminating Porous Materials

Michael Kaminski, Argonne National Laboratory

Aim of Work Presented

No radioactive decontamination technology can properly treat porous surfaces, as evidenced by the disasters in Chernobyl and Fukushima, where evacuation was mandated and cleanup options were abandoned or limited. The purpose of this work was to develop a novel chemical decontamination process for removing radioactivity from such porous surfaces as granite, marble, asphalt, and concrete following a recent deposition. We proposed a novel system of affinity-shifting agents, super-absorbing polymers, and non-ionic polymeric gels using conventional spray applicators. Key features of this approach are 1) i*n situ* dissolution of bound contaminants without dissolving or corroding structural components; 2) controlled extraction of water and dissolved radionuclides from the surface and pore/microcrack structures into a stabilize super-absorbing polymer; 3) rapid immobilization of the solubilized radionuclides within high-affinity and high-specificity sequestering agents suspended in the hydrogel; 4) low toxicity of reagents and very low volume of radioactive waste; and 5) decontamination of building surfaces to levels that minimize worker exposure.

Methods and Results

The SuperGel technology consists of a superabsorbing hydrogel containing water-based chemicals and solid sequestering agents designed to strongly sorb the target radionuclides. We developed formulas for decontaminating some high priority radionuclides. Our methods are centered on three sub-system evaluations. The first evaluation included the properties of the hydrogel. We evaluated a number of superabsorbing polymers and additives to produce a hydrogel that would be robust against dissolved ions, adhere to vertical substrates, and be removable by wet vacuum. Secondly, we evaluated solid sequestering agents for sorption of radionuclides from high ionic strength solutions. Finally, we tested combinations of ionic solutions and chelators or surfactants for desorption of radionuclides from components of the building materials. Decontamination was quantified by depositing dissolved radionuclide salts into crushed building material and then applying the wash solution. Hydrogel and wash

solutions combinations were then tested for decontamination from coupon samples.

Desorption of radionuclides from minerals common to building materials was highly variable. Ammonium salts performed as well as or better than more complex mixtures. Cement was easily decontaminated. The SuperGel successfully decontaminated concrete to 70 to 80 percent of initial levels in a single application. Additional applications improved decontamination. Materials with lower porosity than concretes could be decontaminated to more than 90 percent and more than 99 percent in a single application, while those with higher porosity were poorly decontaminated.

Conclusions

This hydrogel is sprayed onto the surface using conventional viscous sprayers. The gel retains its consistency in relatively high temperatures and humidity for many hours. The hydrogel is removed by wet-vacuum technology and the resultant material can be dehydrated to reduce the waste volume requiring disposal significantly. Although the SuperGel performed well in laboratory tests, improvements in decontamination efficiency are needed for a variety of substrates and radionuclides. A more mechanistic understanding is required.

Significance and Impact of Work

The Argonne SuperGel fills a technology gap for decontamination in an urban setting. Independent testing at Idaho National Laboratory established its competitiveness compared to other technologies recently introduced to the market.

Question and Answer Session

Question 1: The presentation noted that effectiveness of decontamination varied across two different types of concrete. Could these differences be explained by any specific material properties or compositions?

Summary of response: The testing considered in this study was based on two types of concrete: (1) concrete frequently used in the Midwest, which is typically made from crushed river rock aggregate (using sand as the fine aggregate); and (2) concrete typically used in tropical environments like Florida, which includes crushed seashells in the aggregate and is therefore rich in calcium oxide and calcium carbonate. The researchers originally expected the cesium to adhere more strongly to the crushed river rock than to the seashell-based material, based on the adsorption coefficients measured for the selected river rock. However, effectiveness of decontamination was similar across the two concrete materials. Further research would be needed to understand the mechanisms explaining this counterintuitive result.

8.5 Radiological Decontamination Technologies for RDD Recovery

John Drake, EPA, Decontamination and Consequence Management Division

Aim of Work Presented

The U.S. Environmental Protection Agency (EPA) is responsible for protecting human health and the environment from the effects of accidental and intentional releases of radiological materials, including such terrorist incidents as a radiological dispersal device (RDD) or "dirty bomb." The primary EPA responsibility of cleanup and restoration of urban areas would be affected if such an incident were to occur. In order to prepare for such an event, in 2007, the EPA's National Homeland Security Research Center (NHSRC) began conducting performance evaluations of commercial, off-the-shelf radiological decontamination technologies, such as those originally developed for the nuclear power industry and the U.S. Department of Energy complex.

Methods and Results

Desirable decontamination technologies must be effective in removing threat contaminants from typical building materials, while minimizing any

damage to building surfaces. Due to the fact that large areas are likely to be affected by such an event, the time required to perform effective decontamination and the cost of deployment are significant issues as well. NHSRC has developed efficacy test methods and facilities, tested a variety of chemical and mechanical decontamination technologies, and documented the results. These test methods, along with a summary of the results to date, will be presented.

Significance and Impact of Work

The process and results of this testing, along with an assessment of deployment issues associated with each technology, are being made available to the larger homeland security community for use in developing cleanup guidance. The process and results are also being made available to support decisions concerning the selection and use of decontamination technologies for large outdoor environments contaminated with specific radiological threat agents.

Question and Answer Session

Due to time constraints, a question-and-answer session did not occur after this presentation.

8.6 Assessment of RDD Contamination Removal from Laundering

Karen Riggs, Battelle

Aim of Work Presented

The U.S. Environmental Protection Agency is responsible for environmental cleanup after the detonation of a radiological dispersal device (RDD), which includes making recommendations on how the general public outside the evacuation zone can reduce their exposure to this contamination. The current recommendation for handling clothing radioactively contaminated by an RDD is to remove the clothing and bag it. It is unknown how effective it is to wash clothing items with water in order to remove RDD contamination and, perhaps more importantly, the impacts of the general public knowingly or unknowingly washing contaminated clothing are not characterized. The National Homeland Security Research Center is investigating the efficacy of machine washing for removing RDD contamination—specifically cesium 137 (^{137}Cs) and determining the fate of ^{137}Cs contamination after washing.

Methods and Results

This assessment involved identifying and demonstrating methods for depositing ^{137}CsCl on soft porous surfaces (material swatches) and for measuring the activity on the swatches and on a washing machine. Using those methods demonstrated, polyester and cotton material were contaminated with a known amount of ^{137}Cs, then washed in a standard front load, low volume, home-use washing machine with a common liquid detergent. Various wash temperatures were investigated. The amount of ^{137}Cs on the material swatches before and after laundering was measured to determine removal efficiency. In addition, the amount of ^{137}Cs that exited the washing machine in the wastewater and remained on the washing machine was measured. Additional parameters will be assessed.

Conclusions

Preliminary results suggest that washing is effective for removing RDD contamination, with most of the contamination displaced from the material to the wastewater. Washing appears slightly more effective for polyester than for cotton.

Significance and Impact of Work

The results of this work can be useful for developing recommendations related to the laundering of clothing and other porous soft surfaces contaminated due to an RDD. In addition, data could also potentially inform self-help recommendations for the general public after a nuclear power plant accident.

Question and Answer Session

Question 1: The underlying premise of the research is that residents will launder clothing that contains radioactive contamination, even if they are told that this will not remove all contamination. How likely is this to happen? Would residents be more likely to discard their contaminated clothing?

Summary of response: The speaker requested that a colleague respond to this question. That individual presented insights from the Liberty RadEx exercise. In that exercise, the most highly contaminated parts of the city would likely have been evacuated until decontamination was finished. However, residents would continue to live in many other parts of the city that had lower—but detectable—levels of radiological contamination. Some of those areas would eventually be decontaminated, but not right away. When presented with this information, citizen advisory groups asked EPA what residents in those cases should do to minimize their exposures until decontamination occurs. One concern expressed was about laundering clothes, sheets, towels, and other items. Therefore, this issue is likely going to be an important issue to some residents, and the results of this research should help answer questions about risk reduction measures.

Question 2: Another exercise considered forced evacuations of more than 200,000 residents from the city of Charlotte, North Carolina. In that case, residents reportedly did not want to keep and wash their clothes that had radiological contamination. Why is there a difference?

Summary of response: The speaker requested that a colleague respond to this question. That individual noted that the response to the first question (above) pertained to residents *outside* of evacuation areas who will continue living in their homes, despite detectable levels of radiological contamination. Those residents will have to make decisions about laundering clothes and other risk reduction measures, and findings from this research will help inform those decisions. Individuals *within* evacuation areas may be instructed not to bring any clothing with them.

Question 3: Were the fabrics colored? Were advanced fabrics considered, such as those containing silver nanoparticles for deodorant purposes? These questions may be important because dyes, nanoparticles, and other substances in the clothing could affect contamination removal.

Summary of response: The experiments evaluated polyester and cotton fabrics that were either blue or dark gray (see slide 7 for actual colors). The research did not consider the specific effects of dyes or evaluate so-called advanced fabrics, but those would be interesting to evaluate in future work for the reasons noted.

Question 4: In every test run, fabric was spiked with approximately 2 microcuries of cesium-137 before laundering. What was the basis for selecting this spiking amount?

Summary of response: This decision was based both on consultation with EPA and on measurement considerations—ensuring enough material was spiked to enable reliable measurements of cesium on the laundered cloth, on the washing machine surfaces, and in the wastewater.

Question 5: What are the implications of this research for water treatment facilities, especially those that might be receiving wastewater from washing machines throughout a community?

Summary of response: This research project was designed to assess the fate of radiological contaminants from laundering, which can be used to help address such bigger picture issues. A collaborator of the speaker further commented on the issue, noting that communities with widespread radiological contamination will have many sources of contaminated wastewater (e.g., runoff from precipitation). Further evaluation would be needed to determine the relative contributions from these and other sources, but this could be an important issue given that cesium would likely adhere to various components at wastewater treatment plants.

Another workshop participant emphasized that contaminated wastewater streams will be discharged to water treatment facilities following RDD events with widespread contamination, due to residents washing clothes and cars, runoff from precipitation, and other sources. Therefore, preparedness efforts should focus on how to address the contamination that will inevitably occur, instead of assuming that this contamination will somehow be prevented.

8.7 Simulated Pressure Washing for Removal of IND Fallout Particles

Emily Snyder, EPA, Decontamination and Consequence Management Division

Aim of Work Presented

Detonation of an improvised nuclear device (IND) would create large areas of destruction and contamination. In the early phase of a response to an IND, response efforts would be focused on life saving activities. These activities would require both mobile assets, such as response vehicles, and fixed assets (critical infrastructure) such as hospitals, power plants, water treatment plants, and roads for access into and out of contaminated areas. To continue to use these response assets and infrastructure, decontamination may be required. Decontamination methods must be easy to use, widely available, and have a fast application rate, in order to be employed in this early phase.

To learn the effectiveness of pressure washing—one of these gross decontamination methods—the U.S. Environmental Protection Agency's National Homeland Security Research Center evaluated rotating water jet (RWJ) technology for the removal of simulated fallout.

Methods and Results

As a part of this evaluation, a method for generating fallout representative of fallout seen following a detonation of an IND in an urban environment in the United States was developed. To evaluate pressure washing as a gross decontamination technology for removal of IND fallout, a RWJ attachment from River Jet Technologies LLC (Forest, Virginia) was coupled with a standard pressure washer (3,500 pounds per square inch, gas powered, and capable of generating water at 180 degrees Fahrenheit (ºF)). This attachment included a shroud that contained and collected the rinsate from the pressure washer mitigating the health and safety concerns linked to reaerosolization of the fallout particles during pressure washing. The RWJ technology was evaluated in two capacities: 1) with an ambient temperature (68 ºF) water source, and 2) using the hot water system included with the pressure washer (which generated water that was 180 ºF).

Fallout particles were applied to concrete coupons (15 centimeters [cm] × 15 cm square and approximately 4 cm thick) for decontamination testing. Following deposition of the radioactive simulated fallout particles, the gamma radiation from the contaminated coupons was measured. The RWJ technology was then used to decontaminate each of the concrete coupons. Finally, the gamma radiation emitted from the "decontaminated" coupons was measured and decontamination efficacy was calculated. During this evaluation, the qualitative operational aspects of the evaluation were also determined, including 1) a full description of the method used to apply the RWJ technology; 2) an itemization of costs incurred during use of the RWJ technology; 3) deployment and operational data including rate of surface area decontamination and other parameters that could include applicability to irregular surfaces and extent of portability of the RWJ technology; 4) secondary waste management, including the estimated amount and characteristics of the secondary waste; and 5) any health, safety, or legal concerns.

Conclusions

When ambient water was used as the water source, the percent removal was 97.5 percent and a very similar percent removal (97.3 percent) was observed for the technology when hot water (180 ºF) was supplied to the nozzle. These percent removals were comparable to those seen in the Civil Defense Era experiments

(Lanthanum-140 tagged sand particles were the simulated fallout particles) where percent removals of 98 percent were observed for a street flusher and greater than 99 percent were observed for a motorized vacuum street sweeper.

Significance and Impact of Work

These results indicate that standard pressure washing may remove a great deal of fallout contamination from the surfaces of response assets and critical infrastructure. The use of this technology and other gross decontamination technologies will assist continuity of response operations, thereby improving the response ability of federal, state, and local responders.

Question and Answer Session

Question 1: The simulated pressure washing device used in the project removed paint from certain surfaces. Why was it necessary to remove paint?

Summary of response: To remove fallout particles, it probably is not necessary to use pressures that would also scour paint. However, due to safety concerns for the laboratory personnel, the experimental setup had to use a pressure washing device that was completely enclosed, and that is the primary reason why the rotating water jet system was used for this research. Other types of pressure washers may very well be suitable for field purposes.

Question 2: Was this research intended to represent conditions following an air burst of a nuclear device or a ground burst of a nuclear device?

Summary of response: A surface burst.

Comment 3: As noted during the presentation, previous research assessed fallout particle removal efficiency for street flushers and street sweepers (see slide 17). However, most cities and towns currently use street sweepers that exhaust air with limited or no filtering—and this exhaust could essentially spread contamination. Other mobile sweeping models are available that come equipped with high-efficiency particulate air (HEPA) filters to reduce emissions, but these models are far more expensive than conventional street sweepers.

Summary of response: The research team also noted these concerns about using conventional street sweepers for removing fallout particles. That is why the research considered other approaches (e.g., power washing, vacuuming with HEPA filters). Another benefit of the power washing is that it pushes contamination away from the operators, in contrast to street sweepers that would concentrate fallout particles in the vicinity of the drivers.

Question 4: Power washing of surfaces to remove fallout particles will generate wastewater with radioactive contamination. Will this be a problem for operators of water treatment facilities? How will workers at these facilities be protected?

Summary of response: This project focused on gross decontamination strategies during initial response efforts. For instance, an important first step will be to decontaminate essential response assets and critical infrastructure (e.g., major roads) in order to allow first responders to more safely engage in lifesaving activities. The pressure washing was not envisioned for extensive cleanup throughout an urban area. Nonetheless, the issues raised in the question are important and will need to be addressed.

Comment 5: Should contamination result from improvised nuclear devices, nearby water treatment plants are inevitably going to be contaminated due to storm water and other sources. Use of limited quantities of spray water to decontaminate critical infrastructure in the interest of lifesaving activity will likely be viewed as an acceptable tradeoff, even if it results in contaminated runoff.

Summary of response: Agreed.

Question 5: What surface decontamination technologies are being used near the Fukushima facility in Japan?

Summary of response: The speaker did not know the full range of decontamination technologies being used at Fukushima, but was aware that decontamination gels are being used in some areas. However, those gels are not a gross decontamination technology.

Question 6: Do residents who remain in the Fukushima area launder their clothes in washing machines?

Summary of response: Most likely, but this issue was not part of the research project.

Comment 7: Several questions posed during this session voiced concern about discharging contaminated wastewater to treatment facilities. One option for addressing this issue is by containing wastewater generated in the field and treating it on site with conventional filtration and membrane separation. A presentation at the 2010 EPA decontamination workshop showed how this on site collection and treatment strategy can dramatically reduce quantities of wastewater that are discharged to treatment facilities.

Summary of response: Point noted.

8.8 R/N Decontamination Capability Development at DRDC Ottawa: The move to ^{85}Sr Decontamination Testing

Marc Desrosiers, Defense Research and Development Canada

An abstract for this presentation was not available for publication.

Question and Answer Session

Question 1: The presentation referred to two decontamination solutions: "Surface Decontamination Formulation" (SDF) and "Radiological Decontamination Solution" (RDS). What are the primary ingredients in these solutions?

Summary of response: The speaker noted that his background pertains more to the laboratory methods used to test for effectiveness of decontamination and asked that a colleague provide information on the composition of the decontamination solutions. That individual noted that SDF is a commercial product from Canada that was originally designed to decontaminate chemical and biological agents, and therefore includes various oxidizers. SDF was subsequently modified with additives known to sequester radiological isotopes. Individuals interested in the composition of RDS were referred to the manufacturer (Kärcher Futuretech) for further details.

8.9 RDD Waste Estimation Support Tool to Identify Tradeoffs between Waste Management and Remediation Strategies

Timothy Boe, EPA, Decontamination and Consequence Management Division

Management of waste and debris from the detonation of a radiological dispersal device (RDD) will likely comprise a significant portion of the overall remediation effort and possibly contribute to a significant portion of the overall remediation costs. As part of the national level exercise Liberty RadExthat occurred in Philadelphia in April, 2010, EPA developed the RDD Waste Estimation Support Tool (WEST) to generate a first-order estimate of a waste inventory for the hypothetical RDD from the exercise scenario. Determination of waste characteristics and whether the generated waste is construction and demolition (C&D) debris, municipal solid waste (MSW), hazardous waste, mixed waste, or low level radioactive waste (LLRW), and characterization of the wastewater that is generated from the incident or subsequent cleanup activities, will all influence the cleanup costs and timelines. Decontamination techniques, whether they involve chemical treatment, abrasive removal, or aqueous washing, will also influence the waste generated and associated cleanup costs and timelines. Current work is focused on increasing the number of identifiable radionuclides, revamping the tool's interface, enabling variable cleanup levels, and decreasing the time needed to generate results. The tool has spawned numerous versatile tools, including a surface type identification system and a HAZUS-MH database extraction application used to quickly aggregate preliminary data for the RDD WEST. This presentation describes the ongoing efforts to enhance the RDD WEST to further support RDD planning and response activities.

Question and Answer Session

Question 1: The title of this presentation suggests that this decision support tool is specific to RDD release scenarios. Could the software be expanded to include decontamination following chemical and biological attacks?

Summary of response: The decision support tool can be used for chemical and biological events. In those cases, the software would follow the same algorithms for processing satellite images and characterizing local building stock, and it would make similar calculations when estimating the quantities of different types of wastes (e.g., soils, asphalt, concrete). Some parameters would have to be updated in the software to evaluate chemical and biological agents, but the software can readily accommodate those scenarios. Note also that the software can be used to evaluate events occurring outside the United States, such as releases from the Fukushima plant in Japan.

9 Agricultural Decontamination

9.1 Agricultural Decontamination

Lori Miller, U.S. Department of Agriculture (USDA), Animal and Plant Health Inspection Service (APHIS)

The purpose of this presentation is to inform stakeholders about Animal and Plant Health and Inspection Service (APHIS) resources for cleaning and disinfecting a location after it has been quarantined due to an animal disease outbreak. The presentation summarizes relevant laws and regulations, highlights guidance, standard operating procedures, and training modules available on the APHIS website, as well as briefly explains the overall response process and organization. In addition, a case study is discussed to illustrate some of the logistical and environmental challenges faced during cleaning and disinfection (C&D). A brief overview of the C&D procedure is provided and several issues are highlighted with information about how the issues may be addressed. Examples of APHIS guidance documents are shown and information on how stakeholders can get additional assistance is also covered. As a result, it is hoped that stakeholders will gain a clearer understanding of the C&D process, and learn how to access additional resources.

Question and Answer Session

Question 1: The previous presentation described a Waste Estimation Support Tool that can be used to estimate the quantities of different types of waste generated following chemical, biological, and radiological events. Would it be useful to have this software expanded to estimate wastes and costs for agricultural decontamination scenarios (e.g., following foreign animal disease outbreaks)?

Summary of response: It would be very helpful for the Waste Estimation Support Tool to be applied to agricultural decontamination scenarios, and this would be an excellent opportunity for further collaboration between EPA and USDA.

Question 2: Is there an upcoming conference on agricultural decontamination?

Summary of response: Yes. In May, 2012, the University of Michigan will be hosting the Fourth International Symposium on Managing Animal Mortalities, Products, By-Products, and Associated Health Risk. DHS is sponsoring the symposium.

Question 3: The cold temperature decontamination exercise involved a mixture of antifreeze and bleach, which can mix to form chlorinated organic compounds. Were wastewaters tested for these by-products? This issue raises concerns for worker exposure and wastewater treatment, but may be viewed as an acceptable tradeoff when trying to stop an infectious disease outbreak.

Summary of response: The speaker was not aware of any testing of wastewater runoff from the cold temperature decontamination exercise. Wastewater testing for chlorinated organic compounds should be considered in future exercises to determine if chemical contamination in runoff is an important issue with respect to worker exposure and wastewater treatment facilities.

Question 4: The presentation described the process of decontaminating buildings at a quail facility. Did the costs of decontamination exceed the value of the facility itself? Who paid for the decontamination?

Summary of response: The question raises an important point regarding agricultural decontamination approaches—when does it make sense to decontaminate a facility versus demolish the facility? In the case of the quail facility, APHIS hired a contractor to conduct the decontamination, and the project cost was approximately $250,000. In these cleanups, USDA typically pays for the decontamination

and then tries to recover the costs from facility owners.

Question 5: Does USDA have a legislatively-mandated framework or regulatory structure, similar to the EPA Superfund program, for recovering costs incurred during agricultural decontamination events?

Summary of response: The economics of decontamination events will depend on the situation. As one example, USDA may have reason to seize all livestock from a facility, perhaps to control an infectious disease outbreak. In such cases, the agency generally pays indemnity to the facility owner for their seized livestock. In that sense, the cost recovery framework for EPA's Superfund program is different from the current USDA model.

9.2 Laboratory-Scale Assessment of Agricultural Facility Decontamination

Worth Calfee, EPA, Decontamination and Consequence Management Division

Aim of Work

Two surface decontamination approaches were evaluated for their efficacy of contamination removal from two surface materials common to animal production facilities.

Methods and Results

Material coupons (treated plywood and concrete) were contaminated with ~1 x 10^7 spores of *Bacillus atrophaeus* by aerosol deposition. Decontaminants (pH-adjusted bleach or Spor-Klenz®, a peracetic acid-based solution) were applied to vertically-oriented 14 inch by 14 inch coupons by one of two methods: a backpack sprayer or gas-powered pressurized sprayer. Over 10 tests, contact time, reapplication frequency, rinse method, and decontaminant delivery method were varied. In addition to surface removal efficacy, relocation of biological agent to the rinsate and aerosol fractions was determined. Following the completion of the ten tests with 14 inch by 14 inch coupons, two tests were conducted with larger (40 inch by 40 inch) coupons of treated plywood and concrete. Decontamination approaches for the larger coupons were selected based upon test results from the 14 inch by 14 inch coupons. A summary of test design, execution, and results will be presented.

Conclusions

Decontamination efficacy was affected by material type, application procedure, and decontaminant. Incomplete surface decontamination can result in viable biological agent being relocated to rinsates and as an aerosol and can therefore be a potential source of contamination spread during remediation.

Significance and Impact of Work

These data help remediation officials and On-Scene Coordinators develop effective remediation plans following biological contamination events.

Question and Answer Session

Question 1: The "Spor-Klenz" decontamination solution contains peroxides and other compounds that react with monovalent and divalent cations. Was there any evidence of surface reactions following application of this decontamination solution on concrete?

Summary of response: Previous research has demonstrated that concrete is not compatible with peroxide-based decontaminants. Therefore, it was not surprising that this research found "Spor-Klenz" to be more effective on wood than it was on concrete. However, no evidence of chemical effects on concrete surfaces was observed following application of "Spor-Klenz."

Question 2: To what extent were results consistent with previous research involving these decontamination solutions?

Summary of response: First, for pH-adjusted bleach, the current research found the solution to achieve highly effective decontamination on

both wood and concrete, while previous research on smaller scales suggested that bleach may be somewhat ineffective on wood surfaces. Second, for "Spor-Klenz," decontamination was more effective on wood than on concrete, and this finding was consistent with expectations and with previous research results.

Question 3: How consistent were findings with regards to transfer of contaminants to rinsate?

Summary of response: The current research showed that transfer to rinsate varied with many factors, including the number and duration of applications, whether decontaminant was applied using backpack sprayers or pressurized sprayers, the decontamination solution used, and the type of surface (see slides 26 and 27). Some tests in the current research showed less transfer of contaminants to rinsate when compared to previous research involving a greater number of contaminant applications. However, the more consistent finding across studies is that poor efficacy of surface decontamination leads to greater transfer of agents to rinsate.

Question 4: One finding is that "Spor-Klenz" was more effective on wood than on concrete. Was this finding statistically significant?

Summary of response: Yes.

Question 5: Please provide additional detail on the aerosol sampling. What activities were taking place when samples were collected?

Summary of response: Aerosol sampling took place during all spraying conducted for a given set of experimental conditions. For a given test run, a "Via-Cell" bioaerosol collection cassette sampled throughout the decontamination spraying; and the same cassette then sampled throughout the rinsing process.

Question 6: Was any monitoring conducted on the backpack sprayer to determine the particle size distribution of the decontamination spray? What nozzle tips were used for this spraying?

Summary of response: The project did not involve measuring the particle size distribution of the aerosols generated by the backpack sprayer. However, sprayers were operated in a uniform fashion across experiments (e.g., the same nozzle setting, the same spray pressure). Flow checks were also performed before and after each experiment to ensure consistent application rates, which were approximately one liter per minute.

Question 6: Did the aerosol sampling include size differentiation to assess what fraction was respirable?

Summary of response: No. The aerosol sampling consisted of bulk measurements, without particle size selection.

Question 7: Based on the results of the experiments, what type of advice should be given to On-Scene Coordinators regarding strategies for minimizing reaerosolization when using these decontamination methods?

Summary of response: The aerosol data collected during the experiment were limited and sometimes inconsistent with expectations (e.g., aerosol levels were sometimes lower during pressurized spraying than during backpack spraying). The main inference to make from the aerosol data is simply that reaerosolization will be an important issue during decontamination. The best approach to advising On-Scene Coordinators might be to seek input from aerosol physicists about spray application practices that would be expected to minimize reaerosolization. However, decisions about modified spray practices must be balanced against other factors, such as the need to decontaminate large areas over short time frames.

Comment 8: The test results from this project found aerosols containing viable spores—a finding that has important implications for worker safety and minimizing the spread of contamination. This participant recommended that further consideration be given to practices and controls that can be implemented to reduce reaerosolization, without compromising effectiveness of decontamination.

Summary of response: Point noted.

9.3 Decontamination of a Farm Cultivator Using a Pressure Washer with a Water Containment Mat, Followed by a Chlorine Dioxide Disinfectant Foam Application

Craig Ramsey, USDA, APHIS

Aim of Work Presented

A two-stage decontamination study was conducted with farm equipment to determine the effectiveness of a mobile pressure washer, followed by a disinfectant foam application. The study was conducted from October 24 to October 27, 2011.

Methods and Results

The study consisted of three tests using a strip tilling implement that was spiked with endospores of *Bacillus subtilis*. The two stages included pressure washing with a water containment mat, followed by chlorine dioxide disinfectant foam treatments. There were five treatments for each of the three tests, which included positive and negative control samples, as well as treated samples. The two study factors were the number of decontamination stages (foaming versus pressure washing and foaming), and two chlorine dioxide formulations. The tiller was surface sampled on the cutting disks before and after the pressure washing and foam applications. Twenty samples were collected from the treated surfaces and twenty samples were divided among the positive and negative control treatments needed for each test. The samples were placed in sterile vials, frozen, and shipped to a private microbiology laboratory. The samples will be cultured to quantify the viable colony forming unit counts for each treatment. Results will be evaluated on whether oxidant based disinfectants could be used to decontaminate field equipment with high organic debris challenges.

Significance and Impact of Work

The broader goal of this study is to develop a mobile system that can decontaminate farm, military, and construction equipment without contaminating the soil or groundwater with a large, portable water containment and wastewater recycling system. The other goal of the study is to achieve a high degree of decontamination with a disinfectant that can be applied as a longlasting foam, with low human health risks to the applicator.

Question and Answer Session

Question 1: The presentation mentioned using spray foam to decontaminate a farm cultivator. How difficult was it to clean up the foam after it had been applied?

Summary of response: The cultivator was inside a barn when the foam was applied. After application, the cultivator was eventually moved outdoors and rinsed with a garden hose, at which point the foam dissipated relatively quickly—within 30 to 40 minutes.

10 Biological Agent Sampling and Decontamination—Research Results and Their Implications on Current Cleanup Recommendations

10.1 Parameters Affecting Bacterial Spores and Vegetative Cells Surface Sample Collection Recovery

Sandra da Silva, National Institute of Standards and Technology (NIST), Biochemical Science Division

Aim of Work Presented

Reliable and precise methods for detection and quantification of biological threats deposited on surfaces in buildings prior to and post decontamination are fundamental to public health and safety. A comprehensive review of surface sampling literature has demonstrated that surface sampling efficiency is impacted by numerous experimental parameters, including extraction method and deposition technique. In the current work, the effect of experimental conditions on the recovery of Gram negative and Gram positive bacterial cells was investigated to optimize and better understand sources of variability in biological surface sampling performance. In addition, concepts of surface thermodynamics were used to predict bacterial interactions with the surrounding environment and overall surface sample collection efficiency. The information obtained for vegetative cells was compared with *B. anthracis* spores obtained previously in similar conditions.

Methods and Results

Four types of bacteria, *B. anthracis* spores, *E. coli*, *B. thailandensis* and *B. cereus* vegetative cells under different experimental conditions such as sample processing time, physical dissociation methods, and solutions with different chemical contents were investigated. The study was conducted by inoculating a known concentration of bacteria directly onto a pre-moistened, polyester-rayon wipe followed by sample processing after one hour of drying time (no drying time for *B. anthracis*). Furthermore, sample controls were performed by inoculating the bacteria directly into solutions from which the maximum number of cells were recovered. Losses associated with the interaction of bacteria with the centrifuge tube wall and wipe as well as losses in bacterial viability were investigated by applying measurements of surface thermodynamics components and cell viability.

Conclusions

Our results have shown no dramatic difference in recovery across processing methods or extraction solutions for a given organism. In contrast to previous observations with *B. anthracis* Sterne spores, extraction solution components including Tween 80 or peptone had limited impact on recovery efficiency for vegetative cells. However, the effect of the extraction solution was dependent on the organism. Surface charge measurements of *E. coli* indicated possible adhesion to the tube walls and may explain the overall lower observed recovery values.

Significance and Impact of Work

Developing a better understanding of the critical parameters affecting biological surface sampling is essential to identifying the contributing factors to overall surface sample collection efficiencies. The identification of these contributing factors will allow for the prediction and development of more efficient and reliable sampling methodologies relevant to public health and biodefense.

Question and Answer Session

Question 1: The presentation addressed recovery efficiency for different wipe materials. Has similar work been done for assessing how

recovery efficiency varies with time? This may be an important consideration for holding time requirements, given the amount of time that typically elapses between sample collection and analysis.

Summary of response: In this study, wipes dried for one hour before laboratory analysis. The one-hour time frame was selected based on input from colleagues at the Centers for Disease Control and Prevention. The experiment considered how various factors affect recovery (e.g., wipe material, extraction solution, physical dissociation method) but generally did not consider recovery efficiency as a function of time. However, some earlier experiments demonstrated that vegetative cells typically died off within a few hours after samples were collected. This finding underscores the importance of rapid analysis and limited holding times when working with vegetative cells.

Question 2: Did this research use microscopic analyses or other techniques to assess whether spore aggregation and clumping contributed to low recovery efficiencies? Spore aggregation and clumping might help explain the lower recovery efficiencies for *Escherichia coli*, given the tendency for these bacteria to clump together.

Summary of response: Microscopic analyses were not performed, but this would be a good idea for future work. Based on the low surface charge for *Escherichia coli*, it is likely that the low recovery efficiency was caused by clumping or bacteria adhering to the centrifuge tube walls.

Question 3: Data shown during the presentation showed extremely poor recoveries for *Bacillus anthracis* spores when extracted in phosphate buffered saline (PBS) solution. Poor recovery was even observed for the reference case for the PBS solution. What might be causing these low recoveries?

Summary of response: The most likely explanation is that spores were clumping or adhering to the centrifuge tube walls, especially considering that adding surfactant to extraction solutions tended to improve recovery efficiencies. This observation is also consistent with the fact that the outer layers of *Bacillus anthracis* spores are more hydrophobic when compared to vegetative cells. In the case of vegetative cells, the impact of PBS was not so pronounced as with *Bacillus anthracis* spores.

Question 4: What was the "reference" mentioned during the presentation? Were recoveries calculated from the reference observations?

Summary of response: The experiments focused on recovery efficiencies for microorganisms inoculated onto different types of wipe materials. For the "reference" case, the microorganism was inoculated directly into the extraction solution, without any use of wipes. Percent recoveries were calculated by comparing the amount of microorganism recovered during laboratory analysis to the amount of microorganism present in the initial inoculation.

10.2 Dry Fogging of Peracetic Acid for Bacillus Spore Inactivation—Results of a Large Decontamination Chamber Study

Joe Wood, EPA, Decontamination and Consequence Management Division

Aim of Work Presented

The study was conducted to obtain data on the efficacy of a peracetic acid dry fog in the inactivation of *Bacillus atrophaeus* and *Geobacillus stearothermophilus* spores in a pilot-scale chamber.

Methods and Results

A commercially available fogging system was used to generate droplets (less than 10 microns in diameter) of peracetic acid within a pilot-scale chamber. Numerous tests were conducted to assess the effect of fogging process conditions such as sterilant quantity, relative humidity, and dwell time on how well *Bacillus anthracis* spore surrogates were inactivated. Assays included the use of biological indicators as well as spores

aerosolized into the stainless steel chamber via nebulization. In the latter tests, large coupon materials were also used to assess the effect of material on decontamination efficacy.

Conclusions

Results of the testing will be presented.

Significance and Impact of Work

Results will be interpreted and lessons learned will be presented.

Question and Answer Session

Question 1: Most of the data presented were for tests involving overnight dwell times. Given the emphasis placed on rapid response, why did the experiment not include shorter dwell times (e.g., 10 minutes, 1 hour)? Also, does this mean that the fogging occurred for 12 hours?

Summary of response: Fogging occurred only between 10 and 30 minutes. "Dwell time" is the amount of time that elapsed between the end of fogging and the beginning of aeration. Based on input from the manufacturer of the sporicidal liquid, a dwell time of a few hours was originally evaluated. However, when a few hours did not achieve the target log reductions, longer dwell times were implemented. While rapid decontamination is certainly desirable, effectiveness of decontamination is also extremely important when considering the viability of a decontamination strategy. Overnight dwell times do not seem unreasonably long, except for some instances (e.g., disinfection in hospitals) where immediate decontamination is essential.

Comment 2: One finding of the study was that biological indicators can vary from one manufacturer to the next. This finding is consistent with experiences from the 2001 cleanups of anthrax-contaminated buildings in Washington, DC. Specifically, spore strips provided by Raven Labs were used during the first buildings that were decontaminated, but these strips tended to show high amounts of positive detections—even after sterilization. Some individuals involved with the cleanups voiced concerns about quality control issues for these particular biological indicators (i.e., spore strips from Raven Labs). As a result, spore strips provided by other laboratories were used during subsequent cleanups of additional buildings, and those biological indicators did not exhibit the same quality control issues. The experience from these cleanups might be relevant to some of the research findings described in this presentation (see slide 14).

Summary of response: Point noted.

Question 3: Were airborne hydrogen peroxide concentrations in the experimental apparatus measured throughout the dwell time?

Summary of response: Yes.

Question 4: Were fans used to ensure adequate distribution of hydrogen peroxide?

Summary of response: Yes. The experimental apparatus was equipped with small fans that operated throughout the dwell time.

Question 5: The presentation noted that past research found the sporicide formulation to be effective in its liquid form. In addition to assessing effectiveness of decontamination for fogging, did the current study's researchers assess effectiveness of decontamination for the liquid sporicide from which the fog was generated? Such supplemental tests would help confirm that the starting sporicide solution is an effective formula, and enable researchers to rule out lot variability as a potential confounding factor.

Summary of response: No, this was not done. The sporicide solution was purchased off-the-shelf and assumed to contain the active ingredients and exact composition reported by the manufacturer.

10.3 Efficacy of Gaseous Decontamination Technologies for Use on Spacecraft Materials and Their Components

Jimmy Walker, United Kingdom Health Protection Agency, Biosafety Unit

Aim of Work Presented

The European Space Agency (ESA) and National Aeronautics and Space Administration (NASA) currently use dry heat microbial reduction (DHMR) at more than 110 °C for more than 30 hours to decontaminate whole spacecraft modules or components. However, as DHMR is a lengthy process that precludes the use of heat sensitive materials, the aim of this study was to assess a range of low temperature decontamination technologies.

Methods and Results

Following an extensive literature review and selection process, three gaseous decontamination technologies including vaporous hydrogen peroxide (VHP, STERIS, Inc.), hydrogen peroxide vapor (HPV, Bioquell Ltd.) and chlorine dioxide (ClorDiSys Solutions Inc.) were tested for biological efficacy, material compatibility, and residue formation at ambient pressure within a 20-square-meter environmental chamber. Following exposure at the highest concentrations both the VHP (STERIS Inc.) and HPV (Bioquell Ltd) technologies resulted in a 6 log reduction in commercially available biological indicators within 20 minutes. The ClorDiSys technology resulted in a >4 log microbial reduction after exposure for a one-hour period. Three naturally occurring microorganisms typically found in clean rooms used for spacecraft components were also tested as biological indicators. *Bacillus thuringiensis* exhibited survival rates similar to *Geobacillus stearothermophilus* after exposure to both VHP and HPV, but *B. thuringiensis* demonstrated greater resistance to chlorine dioxide. A range of 30 materials was exposed to the decontamination technologies. No change was witnessed with the hydrogen peroxide systems, while several materials showed signs of degradation after exposure to chlorine dioxide. Residue analysis carried out on exposed silicon wafers demonstrated that each decontamination system produced elemental and nitrogen-containing hydrocarbon contamination, while chlorine dioxide resulted in additional sulfate and hypochloride residues, as well as an oxide layer.

Conclusions

VHP was recommended as the most appropriate decontamination technology for ESA and NASA to use as an alternative to DHMR.

Significance and Impact of Work

This work demonstrated that while a number of decontamination technologies may be significantly effective at achieving the required microbial reduction, they may have different impacts on materials and equipment that are being decontaminated.

This work was funded by the European Space Agency (contract no.: 21243/07/NL/EK).

Question and Answer Session

Question 1: The decontamination system used was ClorDiSys—a system that automatically generates chlorine dioxide gas. What was the relative humidity during the experiments?

Summary of response: The relative humidity was between 60 and 75 percent.

Question 2: Was this relative humidity level maintained throughout the experiment?

Summary of response: Yes.

Question 3: The figures (see slides 18 to 20) showing linear D-values were interesting, and consistent with results EPA has observed both for chlorine dioxide-based and hydrogen peroxide-based fumigants.

Summary of response: It is encouraging to hear about the similar findings regarding linear D-

values, because peer reviewers have previously questioned these results.

10.4 Germination-Lysis for Wide-Area Decontamination of *Bacillus anthracis* Spores

Staci Kane, Lawrence Livermore National Laboratory

Aim of Work Presented

Methods to rapidly restore facilities and the environment after a wide-area anthrax attack are currently lacking. We are investigating a low-cost, environmentally benign, wide-area decontamination method that induces rapid spore germination followed by lysis with lower disinfectant levels, enzymes, or simply by desiccation or ultraviolet exposure. The approach involves use of low-cost, readily available germinants and disinfectants alone or in combination with enzyme-based methods for spore cortex degradation (during germination) and/or lysis of newly germinated cells. Combined approaches may be necessary to achieve the required log-kill levels. The germination-lysis approach is being evaluated under relevant environmental conditions including temperature, pH, ionic strength, available water, and matrix interferences (surface debris and indigenous microbial populations). Work is also focused on germinant and disinfectant formulations and dissemination methods, with the goal of scaling the approach to chamber testing with the U.S. Environmental Protection Agency National Homeland Security Research Center and, ultimately, field-testing. Surrogate strains are being compared with virulent strains (e.g., Ames) for different treatments enabling their use in chamber and field tests.

Methods and Results

Experiments were conducted with *B. anthracis* Sterne spores under saturated conditions with time points at 0, 30, and 60 minutes; spore counts were obtained by heating at 65 °C for 20 minutes while total counts (cells and spores) were obtained by plating directly. We demonstrated that inexpensive materials such as dilute chicken broth resulted in ~100 percent germination of 10^3 Sterne spores and 3 percent hydrogen peroxide resulted in ~100 percent death of 10^4-10^5 Sterne cells within 30 minutes. Testing of additional germinants (low concentrations of culture media components, amino acid/purine mixtures) and disinfectants (dilute bleach, ethanol) also showed promising results. Experiments starting with 10^6 spores showed about 3-log germination with chicken broth or alanine/inosine/ammonium chloride solution, and >4-log germination with a second addition of germinants at 30 minutes. Enzymatic approaches showed 1) enhanced germination with addition of cortex-lytic enzymes and 2) rapid lysis of Sterne cells upon exposure to low concentrations (100 nanomolar) of lytic *B. cereus* proteins.

Conclusions

Results showed that simple germinants could induce rapid germination; although low spore levels (10^3 spores/mL) showed complete germination, incomplete (4- to 4.5-log) germination was observed when starting with 10^6 spores/mL. Combined approaches using germinant/lytic enzyme formulations and/or multiple additions of germinants may further improve the extent of spore removal. Germination-lysis approaches followed by monitored natural attenuation may be useful for areas that are difficult to treat with traditional sporicides.

Significance and Impact of Work

Low-cost, effective approaches are needed to rapidly restore large urban areas to safe conditions in the event of a wide-area release of *B. anthracis* spores. The range of conditions for the use of these approaches must also be clearly defined. Forced spore germination followed by rapid lysis of newly germinated cells may provide another tool for rapid decontamination under certain conditions and reduce timelines for restoration of a contaminated site.

This work was performed under the auspices of the U.S. Department of Energy by Lawrence

Livermore National Laboratory under Contract DE-AC52-07NA27344. Funding was provided by the Department of Homeland Security through the Wide Area Recovery and Resiliency Program.

Question and Answer Session

Question 1: Research using atomic force microscopy has shown that spores change with age (e.g., thickening of spore coats, deeper furrowing in external areas) in a manner that makes the spores more resistant to decontamination. Would thickening of spore coats with age also make spores more resistant to germination?

Summary of response: The experiments in this research project did not include microscopic imaging. However, the project team is aware of publications by Alexander Malkin and other researchers who used atomic force microscopy to characterize the structure of spore coats for different *Bacillus* species. Some of that work found that spore coats have pitted layers, which has important implications for germination. This structural feature may be the pathway by which small molecules penetrate into the inner membrane of spores to initiate germination. In addition, factors other than aging may trigger changes to spore coat structure, such as changes in environmental conditions (e.g., moisture content).

Comment 2: A common agricultural industry practice involves adding hydrated lime to pits when burying animal carcasses, particularly for animals that died from anthrax. This hydrated lime use can reportedly enhance sporulation.

Summary of response: This research did not consider how hydrated lime interacts with *Bacillus* spores, but this is an interesting comment.

10.5 Decontamination of Flexal Hemorrhagic Fever Virus and *Bacillus anthracis* Vollum Spores Dried onto Material Surfaces

Young Choi, Battelle

Aim of Work Presented

This study is part of the Department of Defense (DOD) Hazard Mitigation, Material, and Equipment Restoration (HaMMER) Advanced Technology Demonstration (ATD). The study determined the ability of liquid decontaminant formulations to remove or inactivate biological agents from five material surfaces. This study also evaluated the potential interference of a common environmental material on decontamination efficacy.

Methods and Results

Purified *Bacillus anthracis* Vollum (V1B, ~ 1 x 10^8 total colony forming units) spore suspension and concentrated Flexal South American Hemorrhagic Fever Virus (FLEV, ~ 2 x 10^6 total plaque forming units) were inoculated onto solvent-borne Chemical Agent-Resistant Coating (CARC-S), water-dispersible Chemical Agent-Resistant Coating (CARC-W), Lexan™, styrene butadiene rubber, and enhanced CARC-S (with a strippable polyurethane coating) "pristine" material coupons to evaluate the efficacy of each decontaminant formulation. In a separate evaluation, the material surfaces were uniformly coated with 10 milligrams of Arizona test dust prior to agent inoculation and then exposed to the decontaminants. All materials were rinsed with sterile water to remove residual decontaminant from all surfaces prior to agent extraction.

Testing showed total inactivation (≥ 4.71-log reduction) of FLEV within the detectable limit for two of three formulations on all materials. Surface application of Arizona test dust did not negatively impact decontaminant efficacy of FLEV from these materials.

Efficacy results with V1B spores for one formulation achieved total inactivation (≥ 6.45-log reduction) on all pristine materials; two of

three formulations that did not achieve total inactivation attained high efficacy (average of 6.63-log reduction). Similar to FLEV testing, no negative impact on V1B efficacy was seen when Arizona test dust was applied to the surfaces.

Conclusions

This study is the first to demonstrate the persistence and decontamination of an emerging bioterrorism threat agent (FLEV), leading to quantitative results consistent with the results for other bacterial organisms tested in the same program, including V1B spores. Moreover, the presence of a common environmental interferent applied to the surfaces of the materials did not decrease decontamination efficacy.

Significance and Impact of Work

Most arenaviruses that cause hemorrhagic fever and debilitating sickness are considered biosafety level (BSL)-4 agents. FLEV is a pathogenic New World arenavirus, classified as a BSL-3 select agent. Since pathogenesis of FLEV is not widely understood, the virus is transmissible in humans and there are no vaccines or therapeutics for the virus. In addition, FLEV is considered a potential biological warfare agent. Three optimal decontaminant formulations were identified in this study to remove and/or neutralize these types of agents, including V1B spores. A novel method to uniformly deposit and control the amount of an environmental interferent onto a test surface was also developed and successfully used for decontaminant efficacy testing.

Question and Answer Session

Question 1: Multiple presentation slides refer to a desired 6-log reduction in contamination for Flexal hemorrhagic fever virus. What was the basis for wanting a 6-log reduction? Note that EPA criteria for registering disinfectants typically require 4-log reductions for viruses.

Summary of response: A colleague of the speaker clarified that the 6-log reduction target is based on a Department of Defense requirement for decontamination over a unit area.

10.6 Novel Disinfection Applications Using a Portable Chlorine Dioxide Gas Generation System

Anthony Newsome and Jeannie Stubblefield, Middle Tennessee State University, Department of Biology

Aim of Work Presented

Chlorine dioxide (ClO_2) gas is approved as a decontaminant for anthrax and has a history of use in water treatment and food preparation. More widespread ClO_2 use has been hampered because the gas is too unstable for shipment and must be prepared at the application site. It is now feasible to easily produce the gas for local use with a minimum of material needs and personnel training. One system (ICA TriNova) consists of an impregnate within a sachet that is gas permeable that can produce ClO_2 gas or be submerged in water creating a ClO_2 solution. The aim of the work was to demonstrate the use of this system in novel disinfection applications such as elimination of bacteria on sports equipment (football pads) and respiratory firefighter masks. ClO_2 also proved effective in elimination of bacterial cells (including spores) on deceased animal (swine) skin.

Methods and Results

Bacteria were readily recovered from used football helmets and shoulder pads by rubbing the pad surface (50 square centimeters) with a sterile cotton swab and plating onto trypticase soy agar (TSA) plates. Pads were placed in a 113 liter (30 gallon) plastic garbage bag. A sachet generating 500 milligrams of ClO_2 was placed in the bag overnight. Following treatment, an adjacent area was sampled and plated onto TSA. Chlorine dioxide gas significantly eliminated bacteria on pad surfaces ($p < 0.001$). Gas treatment also eliminated laboratory applied *Staphylococcus aureus* on pad surfaces and in the underlying foam pad layers. SCBA respiratory masks were inoculated

with methicillin-resistant *Staphylococcus aureus* (MRSA). It is suspected that MRSA can be transmitted from protective gear among firefighters. Studies showed the bacteria can survive on masks.

Prior to ClO_2 gas treatment, the mask surface was sampled using cotton swabs and plated onto agar. After treatment, samples were taken from adjacent sites. Low dose (less than 200 parts per million [ppm]) and contact time (less than three hours) reduced (3 log or greater) MRSA recovery. Masks were subject to 20 treatments and are undergoing function tests. The ability of ClO_2 gas to eliminate bacteria on animal surfaces to decrease potential risks associated with disposal of animal carcasses was examined. Untreated swine skin (from a food processing facility) was inoculated with suspensions (up to 10^7) of *Bacillus atrophaeus*. Cotton swabs and agar contact plates were used to recover bacteria from ClO_2 treated and untreated controls. ClO_2 gas eliminated naturally-occurring bacteria associated with swine surface tissue (two hours at 1,000 ppm $Cl0_2$). If treatment time was increased to six hours, spores inoculated onto the skin surface were eliminated.

Significance and Impact of Work

This work adds to the disinfection methodology that could be employed in both current and unforeseen future decontamination needs.

Conclusions

There is potential for more broad-scale use of ClO_2 to eliminate infectious agents that occur in proximity to human activity. These applications are relevant in normal mitigation activities, disinfection activities following a natural disaster, or the mitigation needs following deliberate release of microbes with potential harm to humans.

Question and Answer Session

Question 1: The presentation discussed a study using chlorine dioxide as a potential decontaminant to reduce infectious risks that might be associated with an animal disease outbreak event. In that study, swine skins were inoculated with *Bacillus atrophaeus* as a surrogate for *Bacillus anthracis*. Were swabs used to sample the skins after decontamination?

Summary of response: In preliminary studies, the researchers tried using RODAC™ contact plates for sampling, but found the levels of pre-treatment contamination were too high to quantify with that method. The results presented here were all obtained using samples collected with swabs.

Question 2: Physical changes in pig skin were observed following inoculation. To what extent might those changes have affected sample recovery and potentially biased the results?

Summary of response: Quantitative sample recovery estimates were not generated.

Question 3: One way for qualitatively assessing sample recovery would be to culture entire skin samples at the end of test runs to confirm sterility. Was this done?

Summary of response: No. The purpose of the research was to assess decontamination of the skin surface. However, the samples used in the research included multiple layers of skin and even some fat that underlies the skin. Post-test cultures were not conducted because there was no way to perform them only on the surface material.

10.7 Evaluation of Liquid and Fumigant Decontamination Products for Use Following Future Anthrax Attacks

Dorothy Canter, Dorothy Canter Consulting LLC

Aim of Work Presented

The aim of this research was to compare and contrast liquid decontamination agents and fumigants that could be used to remediate specific contaminated areas following future anthrax attacks, as well as to develop proposed criteria for choosing among the products in each class of agents.

Methods and Results

The approach involved generating a list of liquid decontaminants by selecting the eight agents for which the U.S. Environmental Protection Agency (EPA) granted crisis exemptions following the 2011 anthrax attacks; permitting their use to treat facilities and items contaminated with *Bacillus anthracis* spores by adding the two liquid antimicrobial products subsequently registered by EPA as sporicidal decontaminants specifically to treat *Bacillus anthracis*-contaminated, pre-cleaned, hard, nonporous surfaces; and choosing three other antimicrobial agents demonstrated in recent research to be effective sporicides on several nonporous and/or porous materials. The 13 agents selected for evaluation included: Sabrechlor 25, DrewChlor 4107, Akta Klor 25, pH-amended bleach, Spor-Klenz RTU sterilant, Oxonia Active, Actril Cold Sterilant, Vortexx, Peridox, Steriplex Ultra™ CASCAD™ SDF, Decon Green, and Easy Decon 200.

Conclusions

This paper evaluates those products with respect to a number of key factors, including active ingredients, conditions of use, contact time, toxicity, and product container volumes. Further, the paper evaluates the three fumigants for which EPA issued crisis exemptions to remediate the interiors of buildings contaminated during the 2001 attacks, namely, chlorine dioxide, vaporized hydrogen peroxide and paraformaldehyde. The paper also evaluates methyl bromide, which demonstrated sporicidal efficacy in research sponsored by EPA. Key factors considered are generation of agent, maximum volume of space that can be fumigated at one time, fumigation process variables, demonstrated efficacy, penetration capability, mode of fumigant removal, toxicity, and materials compatibility.

Significance and Impact of Work

Based upon the factors evaluated, the paper proposes two sets of criteria, including one for selecting liquid decontamination agents and the other for choosing fumigants to remediate contaminated locations following future anthrax attacks, whether limited in scope or encompassing wide areas. The paper then utilizes the criteria to assess some of the agents, highlighting their respective advantages and disadvantages. It is anticipated that this work will contribute to the development of consensus criteria for selecting liquid decontamination agents and fumigants from available products that will be beneficial in recovering from future bioterrorist attacks.

Question and Answer Session

Comment 1: A participant shared three comments. (1) The presentation included information from "Alcatel-Lucent studies" regarding decontaminating computers. This information was from a much larger body of recent research managed by EPA and DHS, with collaboration from Alcatel-Lucent Bell Laboratories. Considering the entire range of those research findings is important when evaluating decontamination options. (2) One of the limitations mentioned for methyl bromide as a fumigant is its relatively long contact time (48 hours) documented in previous research. Recent research has demonstrated methyl bromide fumigation times as short as 9 hours for *Bacillus anthracis*, and the details of that research should be explored further when commenting on the viability of methyl bromide fumigation. (3) EPA publications on material compatibility for selected decontaminants (e.g., chlorine dioxide) have recently been posted on the NHSRC website, and publications for additional decontaminants will be posted in the near future.

Summary of response: Points noted.

Question 2: Please comment on the cost effectiveness of the different fumigants.

Summary of response: Every fumigant has advantages and disadvantages that affect overall cost. Therefore, the answer to this question depends on many factors. For example, if a large building with complex areas needs to be decontaminated quickly, chlorine dioxide may be the most cost effective choice.

Question 3: One of the proposed criteria for evaluating liquid decontamination products is demonstrated sporicidal efficacy (see slide 9). Should a criterion be included regarding the number of spores detected in confirmatory samples?

Summary of response: When evaluating chemical contamination, quantitative cleanup goals are based on robust exposure and risk assessment calculations. For biological agent contamination, quantitative risk assessment capabilities are limited due to incomplete information on dose-response (i.e., how many spores must be inhaled or contacted in order to cause disease) and exposure assessment. As long as major uncertainties remain, the criteria for re-occupancy of building interiors will likely be based on confirmation sampling (e.g., all tests negative for spore growth) rather than on risk assessment calculations (e.g., a minimum spore count).

11 Conducting Homeland Security Research

11.1 EPA's Quality Assurance Program

Eletha Brady-Roberts, EPA, National Homeland Security Research Center

Note: The final workshop session was not documented for purposes of this report.

Appendix A: Agenda

2011 U.S. EPA Decontamination Research and Development Conference

Hilton Raleigh Durham Airport
Durham, NC
November 1-3, 2011

Agenda

Meeting Objectives

- To provide information on scientific endeavors, including applied research, field demonstrations, guidance and tool development and field applications related to CBR remediation issues.
- To understand the connection between basic or fundamental decontamination research and applied research, as well as applied research and effective field application.
- To provide information on the gaps related to all phases of CBR cleanup (characterization, decontamination, disposal and clearance).

DAY 1: TUESDAY, November 1, 2011

7:30 am Continental Breakfast

8:00 am Check-in

OPENING SESSION

8:30 am **Purpose and Objectives of the Meeting and Introduction of Speaker** .....*Peter Jutro*
Deputy Director for Science and Policy, EPA's National Homeland Security Research Center

Speaker: **The 21st Century Threat of Bioterrorism** ..... *Colonel Randall J. Larsen*
USAF (Retired), Chief Executive Officer of the WMD Center

9:45 am BREAK

RESPONSES, EXERCISES AND PROGRAM OVERVIEWS
HOW CAN RESPONSES AND EXERCISES BE INFORMED BY RESEARCH
Presentations and Q&A Moderated by Juan Reyes and Shawn Ryan

10:10 am **NRC's response to the Fukushima Dai-ichi Nuclear Crisis** .....*Scott A. Morris*
Nuclear Regulatory Commission

10:35 am **Recent R&D by Environment Canada on CBRN Decontamination** ..... *Carl E. Brown*
Environmental Canada

DAY 1: TUESDAY, November 1, 2011 (Continued)

11:00 am **Wide Area Recovery and Resiliency Program – Targeted S&T Solutions to Enhance Interagency Capabilities**..... *Chris Russell*
DHS Science and Technology Directorate

11:25 am **Overview of the DTRA/JSTO Decontamination Portfolio** ..... *L. Revell Phillips*
Protection and Hazard Mitigation Defense Threat Reduction Agency
Joint Science and Technology Office

11:50 am **Update on Government Decontamination Service**..... *Rosina Kerswell*
UK's Government Decontamination Services

12:15 pm LUNCH (Optional Group Lunch)

1:15 pm **Overview of Liberty RadEx and Lessons Learned** ..... *Bill Steuteville*
EPA's Region 3

DECONTAMINATION OF WATER AND WASTE WATER INFRASTRUCTURE RESEARCH RESULTS AND HOW THEY CAN AFFECT CURRENT POLICY
Presentations and Q&A – Matthew Magnuson and Marissa Lynch

1:40pm **Water Decontamination Activities within EPA Water Security Division and National Homeland Security Research Center** ..... *Marissa Lynch*
EPA's Office of Water

2:00pm **Germinant Enhanced Decontamination of *Bacillus* Spores Adhered to Iron and Cement-Mortar Drinking Water Infrastructure**.....*Jeff Szabo*
EPA's Water Infrastructure Protection Division

2:25 pm **Biological Contaminant Persistence and Decontamination in Drinking Water Pipes Using the EPA Persistence and Decontamination Experimental Design Protocol**..... *Ryan James*
Battelle

2:50 pm **Decontamination of *Bacillus anthracis* in Wastewater**.....*CAPT. Colleen Petullo*
USPHS, EPA's OSWER, Environmental Response Team

3:15 pm BREAK

3:40 pm **Progress In the Development of a Rapid, Water-Based Technology for Removing Contamination Following an Urban Dispersal of Radioactivity** ..... *Carol Mertz*
Argonne National Laboratory

4:05 pm **Selected On-going Homeland Security Water Decontamination Research Projects**..... *Matthew Magnuson*
EPA's Water Infrastructure Protection Division

DECONTAMINATION OF TOXIC INDUSTRIAL CHEMICALS AND CHEMICAL WARFARE AGENTS RESEARCH RESULTS AND THEIR IMPLICATIONS ON CURRENT CLEANUP RECOMMENDATIONS
Presentations and Q&A – Moderated by Lawrence Kaelin and Joe Wood

4:20 pm **Application of the Quick Reference Guides (QRGs) to CWA Decontamination**.....*Larry Kaelin*
EPA's OSWER National Decontamination Team

4:45 pm **Efficacy Evaluation of Liquid and Foam Decontamination Techniques for Chemical Warfare Agents on Indoor Surfaces**.....*Deon S. Anex*
Lawrence Livermore National Laboratory

5:10 pm ADJOURN

DAY 2: WEDNESDAY, NOVEMBER 2, 2011

7:30 am Continental Breakfast

Concurrent Sessions

BIOLOGICAL AGENT DECONTAMINATION FATE AND TRANSPORT CURRENT PROGRAMS AND THEIR APPLICATION TO RESPONSE ACTIVITIES Presentations and Q&A – Moderated by Sang Don Lee and Dino Mattorano		**DECONTAMINATION OF TOXIC INDUSTRIAL CHEMICALS AND CHEMICAL WARFARE AGENTS (CONT.)**	
8:05 am	**Efficacy of Disinfectant against Vegetative BW Agents and Their Surrogates** *Vipin Rastogi, BioDefense Branch, R&T Directorate, US Army, Edgewood Biological and Chemical Center*	8:05 am	**Field Evaluation of Indoor Clean Up of Malathion** *Jeanelle Martinez, US EPA's OSWER National Decontamination Team*
8:30 am	**From Reaerosolization to Exposure, Connecting the Dots** *Capt. Marshall Gray, EPA's Decontamination and Consequence Management Division*	8:30am	**Enzymatic Decontamination of CWAs from Building Materials** *Lukas Oudejans, EPA's Decontamination and Consequence Management Division*
8:55 am	**An Investigation Into the Sources of Two Inhalation Anthrax Fatalities Associated with African Drums** *Jimmy Walker, Biosafety Unit, UK's Health Protection Agency*	8:55 am	**Decontamination of Chemical Warfare Agents Using Household Chemicals** *George Wagner, Army's Edgewood Chemical Biological Center*
9:20 am	**Transfer of BW Surrogate Particles from Contaminated Surfaces** *Richard Byers, Battelle*	9:20 am	**Investigation of Hydrogen Peroxide/ Ammonia Fumigation against VX, TGD, and HD** *Harry Stone, Battelle*
9:45 am	**Fixatives Application for Risk Mitigation Following Contamination with a Biological Agent** *Chris G. Campbell, Lawrence Livermore National Laboratories*	9:45 am	**Non-Aqueous Catalytic Process for the Decontamination of Sensitive Equipment from Organophosphorus Compounds** *Vladimir Blinov, Environment Canada*
10:10 am	BREAK	10:10 am	BREAK

BIO-RESPONSE OPERATIONAL TESTING AND EVALUATION
HOW TO INTEGRATE RESPONSE AND RESEARCH ACTIVITES
Presentations and Q&A – Moderated by Leroy Mickelsen and Hiba Ernst

10:35 am **Overview of Bio-Response Operational Testing and Evaluation (BOTE)**.....*Shannon Serre*
EPA's Decontamination and Consequence Management Division

10:55 am **Overview of Sampling Activities at BOTE**.....*Dino Mattorano*
EPA's OSWER National Decontamination Team

11:15 am **Preliminary Results from a Study of Spore Migration Outside a Contaminated Building using Soil Container Samples Collected during the BOTE Project**.....*Erin E. Silvestri*
EPA's Threat and Consequence Assessment Division

11:40am **Surface Sample Testing using Rapid Viability Polymerase Chain Reaction (RV-PCR) Method during the BOTE**.....*Sanjiv Shah*
EPA's Threat and Consequence Assessment Division

12:05 pm **BOTE Preliminary Results: Cost Analysis**.....*Paul Lemieux*
EPA's Decontamination Consequence and Management Division

12:30 pm LUNCH (Optional Group Lunch)

RADIOLOGICAL/NUCLEAR AGENT DECONTAMINATION AND WASTE MANAGEMENT
RESEARCH RESULTS AND THEIR IMPLICATIONS ON CURRENT CLEANUP RECOMMENDATIONS
Presentations and Q&A – Moderated by Paul Lemieux and James Michael

1:30 pm **Fate and Transport of Radiological Dispersal Device (RDD) Material (Cs and Co) on Urban Building Surfaces: Effects of Rain**.....*Sang Don Lee*
EPA's Decontamination and Consequence Management Division

1:55 pm **Mobility and Bioavailability of Long-Lived Chernobyl Radionuclides in the Environment and Their Consideration at Rehabilitation of Contaminated Sites**.....*Alexey Konoplev*
RPA "Typhoon"

2:20 pm **Adsorption of Cesium from Solutions on Construction Materials**.....*Konstantin Volchek*
Environment Canada

2:45 pm **Design and Performance of a Superabsorbing Hydrogel for Decontaminating Porous Materials**.....*Michael D. Kaminski*
Argonne National Laboratory

3:10 pm **Radiological Decontamination Technologies for RDD Recovery**.....*John Drake*
EPA's Decontamination and Consequence Management Division

3:35 pm BREAK

4:00 pm **Assessment of RDD Contamination Removal from Laundering** ..... *Karen Riggs*
Battelle

4:25 pm **Simulated Pressure Washing for Removal of IND Fallout Particles** ..... *Emily Snyder*
EPA's Decontamination and Consequence Management Division

4:50 pm ADJOURN

DAY 3: THURSDAY, November 3, 2011

8:00 am Continental Breakfast

RADIOLOGICAL/NUCLEAR AGENT DECONTAMINATION AND WASTE MANAGEMENT (CONT.)

8:30 am **R/N Decontamination Capability Development at DRDC Ottawa: The move to ^{85}Sr Decontamination Testing** ..... *Marc Desrosiers*
Defense Research and Development Canada

8:55 am **RDD Waste Estimation Support Tool to Identify Tradeoffs between Waste Management and Remediation Strategies** ..... *Timothy Boe*
EPA's Decontamination and Consequence Management Division – ORISE Post Doctoral Fellow

AGRICULTRUAL DECONTAMINATION
CURRENT PROGRAM ACTIVITIES AND RESEARCH RESULTS
Presentations and Q&A – Moderated by Jeanelle Martinez and Lukas Oudejans

9:20 am **Agricultural Decontamination**..... *Lori Miller*
Department of Agriculture's Animal and Plant Health Inspection Service

9:45 am **Lab-Scale Assessment of Agricultural Facility Decontamination** ..... *Worth Calfee*
EPA's Decontamination and Consequence Management Division

10:10 am BREAK

10:35 am **Decontamination of a farm cultivator using a pressure washer with a water containment mat, followed by a chlorine dioxide disinfectant foam application**..... *Craig Ramsey*
Department of Agriculture's Animal and Plant Health Inspection Service

BIOLOGICAL AGENT SAMPLING AND DECONTAMINATION RESEARCH RESULTS AND THEIR IMPLICATIONS ON CURRENT CLEANUP RECOMMENDATIONS

Presentations and Q&A – Moderated by Worth Calfee

11:00 am **Parameters Affecting Bacterial Spores and Vegetative Cells Surface Sample Collection Recovery** ..... *Sandra M. Da Silva*
National Institute of Standards and Technology, Biochemical Science Division

11:25 am **Dry Fogging of Peracetic Acid for *Bacillus* Spore Inactivation – Results of a Large Decontamination Chamber Study**..... *Joe Wood*
EPA's Decontamination and Consequence Management Division

11:50 am **Efficacy of Gaseous Decontamination Technologies for Use on Spacecraft Materials and Their Components**..... *Jimmy Walker*
Biosafety Unit, Health Protection Agency

12:15 pm LUNCH (Optional Group Lunch)

1:15 pm **Germination-Lysis for Wide-Area Decontamination of *Bacillus anthracis* spores**..... *Staci Kane*
Lawrence Livermore National Laboratory

1:40 pm **Decontamination of Flexal Hemorrhagic Fever Virus and *Bacillus anthracis* Vollum Spores Dried onto Material Surfaces**..... *Young W. Choi*
Battelle

2:05pm **Novel Disinfection Applications Using A Portable Chlorine Dioxide Gas Generation System**..... *Anthony L. Newsome and Jeannie M. Stubblefield*
Department of Biology, Middle Tennessee State University

2:30 pm **Evaluation of Liquid and Fumigant Decontamination Products for Use Following Future Anthrax Attacks** ..... *Dorothy Canter*
Dorothy Canter Consulting LLC

2:55 pm BREAK

CONDUCTING HOMELAND SECURITY RESEARCH DEVELOPING A BETTER UNDERSTANDING OF EPA'S QUALITY ASSURANCE SYSTEM

3:15 pm **EPA's Quality Assurance Program** ..... *Eletha Brady-Roberts*
Quality Assurance Manager EPA's National Homeland Security Research Center

4:45 pm ADJOURN

Appendix B: List of Participants

2011 U.S. EPA Decontamination Research and Development Conference

Hilton Raleigh Durham Airport
Durham, NC
November 1-3, 2011

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Appendix C: Presentation Slides

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UNITED STATES
ENVIRONMENTAL PROTECTION AGENCY


UNITED STATES

A few days after 9/11, a retired Air Force colonel named Randall Larsen entered the northwest gate of the White House, crossed a courtyard to the Eisenhower Executive Office Building, stepped through the front door and stopped dead in his tracks.

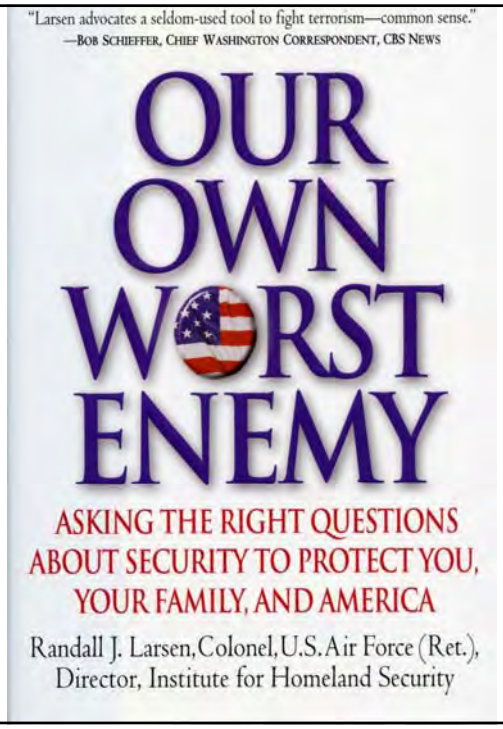
In place of the usual security checkpoint, there was an elaborate upgrade that included not only metal detectors but also machines to sniff out radiation and explosives, elaborate pat-downs and a mandatory search of all personal belongings. It was the search that worried Larsen most.

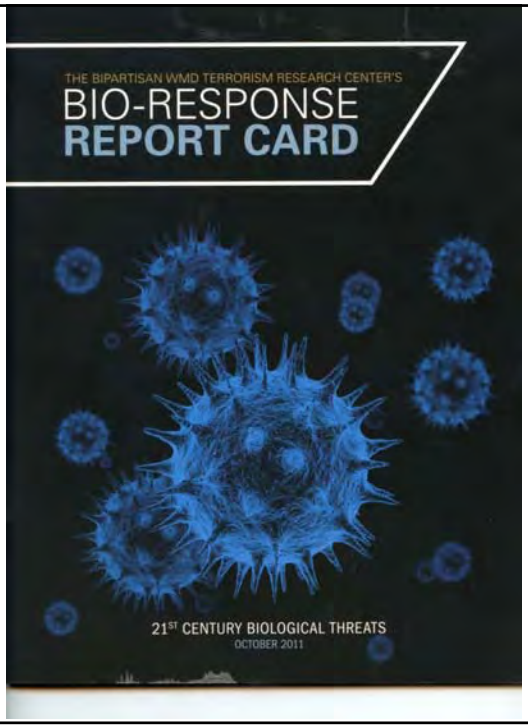
After passing through a body scan, he stood quietly while a guard thumbed through the contents of his briefcase. It was mostly books and papers, but after a few seconds, the agent pulled out a respirator mask and shot Larsen a quizzical look. "That's just for demonstration," Larsen said quickly. "You saw Mayor Giuliani wear one at ground zero, right?" The agent turned the mask over a few times, then stuffed it back in the briefcase. Seconds later, Larsen was through.

Inside the building, he followed a long corridor to a room where Vice President Dick Cheney and members of the national-security staff awaited him. Also in the room were Tara O'Toole, who is now the Obama administration's top official for biodefense research at the Department of Homeland Security, and Thomas Inglesby, who runs the Center for Biosecurity. Three months earlier, Larsen, O'Toole and Inglesby had collaborated on a national-security exercise to simulate the effects of


THE NEXT BIOTERROR WEAPON:
THE APOCALYPTIC VIRUS


CONGRESSIONAL CMSN: BIO-TERROR A BIGGER WORRY THAN NUKES
studio B


"Larsen advocates a seldom-used tool to fight terrorism—common sense."
—Bob Schieffer, Chief Washington Correspondent, CBS News
OUR OWN WORST ENEMY
ASKING THE RIGHT QUESTIONS ABOUT SECURITY TO PROTECT YOU, YOUR FAMILY, AND AMERICA
Randall J. Larsen, Colonel, U.S. Air Force (Ret.), Director, Institute for Homeland Security


THE BIPARTISAN WMD TERRORISM RESEARCH CENTER'S
BIO-RESPONSE
REPORT CARD
21ST CENTURY BIOLOGICAL THREATS
OCTOBER 2011

Protecting People and the Environment

EPA Decontamination Conference

Briefing on the NRC and its Incident Response Efforts Associated with the Fukushima Dai-ichi Nuclear Power Plant

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Protecting People and the Environment

The U.S. NRC

NRC Organization:

- The Energy Reorganization Act of 1974 established the independent U.S. Nuclear Regulatory Commission to regulate commercial use of nuclear materials
- NRC is headed by four Commissioners and a Chairman, all appointed by the President and confirmed by the Senate for staggered five-year terms
- NRC employs about 3,700 people at its Maryland headquarters and has four regional offices (Pennsylvania, Georgia, Illinois, and Texas)
- NRC has assigned resident inspectors to 65 operating reactor sites and three fuel facilities

2

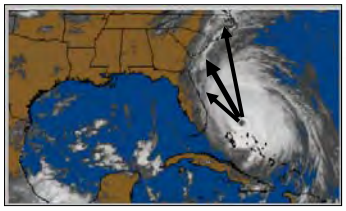
Primary NRC Functions

Functions:

- Establish rules and regulations
- Provide oversight through inspection, enforcement, and evaluation of operational experience
- Conduct research to provide support for regulatory decisions
- Issue licenses
- Respond to emergencies

3

NSIR Focus Areas



Emergency Preparedness

Incident Response

Security Policy

Security Operations

4

U.S.NRC
Protecting People and the Environment

Incident Response

NRC Response Organization:

← HQ Operations Officers

Executive Team →

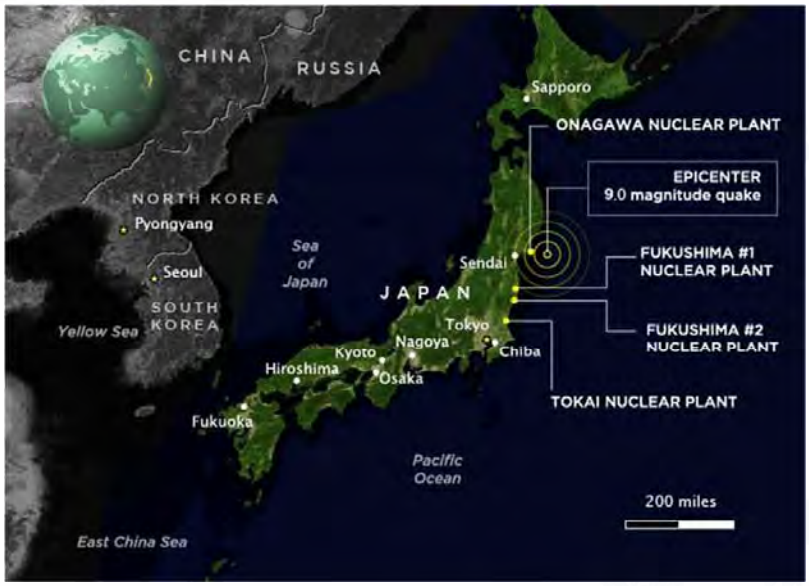
← HQ and Regional Assessment Teams

Site Team →

U.S.NRC
Protecting People and the Environment

Fukushima Dai-ichi

Japan's Earthquake



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Fukushima Response

NRC Actions:

- **Activated the NRC Headquarters Operations Center**
- **Dispatched NRC Experts to Japan**
- **Focused on Safety**
- **Extensive Outreach to Stakeholders**
- **Continued Support for U.S. Response**

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Continued NRC Activities

Near-Term Activities:

- Inspection Activities
- Generic Communications
- Near-Term Task Force Recommendations

Long-Term Activities:

- Lessons Learned and Recommendations
- Regulatory Actions (21 & 45-Day Papers)
  - Research Projects
  - Generic Issues
  - Regulatory Enhancements

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Japanese Activities

Current Path Forward:

- Japanese Response and Recovery Efforts
- Status of Fukushima Dai-ichi and Local Industry
- Decontamination Efforts
- Outreach to Stakeholders

TEPCO

10

U.S.NRC
Protecting People and the Environment

Questions?

U.S.NRC

NUCLEAR SECURITY • INCIDENT RESPONSE
NRC

Environment Canada Environnement Canada

Canada

Recent R&D by Environment Canada on CBRN Decontamination

C.E. Brown and K. Volchek
Emergencies Science and Technology Section, Environment Canada

Overview

- CRTI Program
- Chemical Science Cluster
- Exercises
- R&D
- Technology Demonstration
- Technology Acceleration
- Technology Acquisition
- Science Town
- National Response Capability to CBRNE
- The Future

CRTI Program

The CBRNE Research and Technology Initiative (CRTI) is a Canadian Government program that is mandated to fund projects in science and technology (S&T) that will strengthen Canada's preparedness for, prevention of, and response to potential CBRNE threats to public safety and security. Through this collaborative, coordinated initiative, the federal S&T community and its partners are working to enhance Canada's capability and capacity to respond to CBRNE threats to public security.

Environment Canada and CRTI

This presentation will describe the involvement of Environment Canada in the CRTI program through discussions of research and development (R&D) projects, leadership of the CRTI Chemical Science Cluster and the planning, preparation and undertaking of a large number of training exercises with colleagues from other federal departments.

CRTI Program Mandate

To strengthen Canada's preparedness for, prevention of, and response to potential CBRNE attacks by fostering new investments in research and technology, CRTI generates knowledge and technology, and supports their application, by;

- creating science clusters of federal laboratories that build science and technology (S&T) capacity to address the highest risk terrorist attack scenarios;
- funding research and technology to build capability in critical areas, particularly those identified with chemical, biological, and radiological attacks;
- providing funds to areas where national S&T capacity is deficient because of obsolete equipment, dated facilities, or inadequate scientific teams; and
- developing and sharing CBRNE S&T expertise and knowledge through symposia, exercises, workshops, and studies.

CRTI Chemical Cluster

- Initially the Chemical Laboratory Cluster
- Laboratories of federal and provincial government departments and agencies
- Identify chemical related priorities
  - Toxic industrial chemicals (TICs)
  - Chemical warfare agents (CWAs)
- Evaluate chemical-related risks through consolidated risk assessment
  - Intelligence
  - Security
  - Science
- Gradual transition to Chemical Science Cluster
  - "Community of Practise"

CRTI Chemical Cluster

- Identify departmental/agency laboratory capabilities to analyze priority chemical agents
  - TICs and CWAs
- Sample matrices
  - Air, water, soil, food, bodily fluids, etc
- Fit with organizational mandate
- Unknown samples
- Standard operating procedure for acceptance of samples into laboratories
  - Sample triage, personnel safety
- Development and regular update of Cluster work plan

Chemical Cluster Exercises

- Training exercises are an important part of Cluster work plan
- Means to gauge the growth of the CRTI program as a whole and more specifically, the functionality of the individual clusters
- Clusters cut across the broad spectrum of the science-based federal government departments
- Prior to the formation of the clusters these departments had minimal linkages

Chemical Cluster Exercises

- March 2003 3-day training chemical analysis exercise at DRDC-S
- May 2003 CRTI First Responder Workshop at Canadian Police College, Ottawa
- May 2003 TTX
  - Engage cluster labs, SOPs, roles, surge capacity, identify gaps
  - Chemical Cluster CBRN Emergency Technical Advisory Plan
- November 2004, Biological and Chemical clusters DRDC-S
  - Objective - resolution of CBRN terrorist incident through the framework of the National Counter Terrorism Plan
  - Link and integrate the expert resources of the cluster organizations with the functions of traditional first responders in an operational context
- April 2005, cluster members observed first responders in Government of Canada CBRN First Responder Training Program
  - Sample gathering, scientific support to first responders

Chemical Cluster Exercises

- November 2005, mock scenario G20 event, activation of cluster labs, interaction with first responders, sample analysis
- May 2006, DRDC-S C/B/F exercise CBRN terrorist incident as part of the national response through the framework of the National Counter Terrorism Plan
- October 2007, laboratory analysis training DRDC-S
- February 2008, Exit08 and Sea Barrier exercises in Vancouver and Victoria, B.C.

Chemical Cluster Exercises

- November 2008 Exercise Bronze, Richmond, BC
- October 2008 le Sommet Francophonie and Exercise Initial Response (ExIR-08) – live exercise, **birth of Science Town**
- November 2008 Capability Exercise (CAPEX-08), Sydney, Australia
  - Technical Response Group (TRG) of the Chemical, Biological, Radiological (CBR) Quadripartite
- February 2009 Exercise Silver, Richmond, BC
- October 2009, Chemical Restoration Operational Technology Demonstration Project (with US DHS)
- November 2009 Exercise Gold, Richmond, BC
- October 2010 Exercise Firedrake, DRDC-S, AB
  - Advanced chemical support – live exercise
- March 2011 Capability Exercise (CAPEX-11), London, UK

ESTS Participation and Delivery

Environment Canada's Emergencies Science and Technology Section (ESTS) is an active participant in the delivery of the CRTI program. ESTS undertakes hazardous material spills related research and development (R&D) activities and operational scientific support under the Environmental Emergencies Program (EEP). The EEP has an active interest in the S&T activities and outcomes resulting from CRTI participation as this involvement directly relates to their mandated activities under the 1973 Cabinet Directive on Environmental Emergencies Activities.

EC Research and Development - 1

- CRTI 02-0041RD Real-Time Determination of Area of Influence of Chemical, Biological, Radiological, and Nuclear Releases (Meteorological Service of Canada (MSC) lead)
- CRTI-02-0067RD Restoration of Facilities and Areas after a CBRN Attack
- CRTI 02-0093RD Advanced Emergency Response System for Chemical, Biological, Radiological, and Nuclear Hazard Prediction and Assessment for the Urban Environment (MSC lead)
- CRTI-04-0018RD Development of Standards for Chemical and Biological Decontamination of Buildings and Structures Affected by Terrorism

EC Research and Development - 2

- CRTI 06-0156RD Radiological Dispersal Device Contamination Interactions with Urban Surfaces (DRDC-O lead)
- CRTI-06-0170RD Organophosphorous Agent Decontamination
- CRTI 06-0252RD Protocols for Modeling Explosive Threats in Urban Environments (Public Safety Canada lead)

CRTI-06-0170RD Organophosphorous Agent Decontamination

- Environment Canada (lead), Royal Military College of Canada, Queen's University, SAIC Canada, Research Institute of Hygiene, Occupational Pathology and Human Ecology (RIHOPHE); State Research Institute of Organic Chemistry and Technology (GosNIIOKhT).
- The primary objective of this study is to develop an effective and rapid catalytic decontamination method to remove and destroy organophosphorus (OP) compounds, such as chemical warfare agents and pesticides, from building materials, sensitive equipment, and soils.
- The newly developed methods for decontamination of sensitive equipment, building materials, and soils will have a significant impact on Canada's ability to prepare for and recover from a chemical terrorism event. The rapid and complete destruction of OP agents will prevent the risk of contamination of the environment by the breakdown products. The reuse of the solvents and catalysts will make the methods both environmentally friendly and cost competitive.

Technology Acceleration & Demonstration

- TA
  - CRTI-06-0169TA Universal Surface Decontamination Formulation
- TD
  - CRTI-04-0019TD Field Demonstration of Advanced CBRN Decontamination Technologies
  - CRTI-06-0196TD Towards an Operational Urban Modeling System for CBRN Emergency Response and Preparedness (MSC lead)
  - CRTI-08-0192TD ERIN – Emergency Resource Inventory Network (Public Safety Canada lead)

CRTI-06-0169TA Universal Surface Decontamination Formulation

- Environment Canada (lead), DRDC Ottawa, SAIC Canada, US Environmental Protection Agency, Allen-Vanguard Corporation, Research and Development Institute of Construction Technology (NIKIMT).
- The aim of this project was to modify CASCAD™ (Canadian Aqueous System for Chemical-Biological Agent Decontamination) to make it much more effective for radiological decontamination.
- This study will result in the development of a formulation that can be used in response to chemical, biological, and radiological incidents, whenever the decontamination is required. The formulation will have a higher efficiency, simplified waste treatment, reduced operation time, and lower costs.
- It will help enhance the preparedness and response capabilities of first responders and technology users in a CBRN event.

CBRN Response Workshops

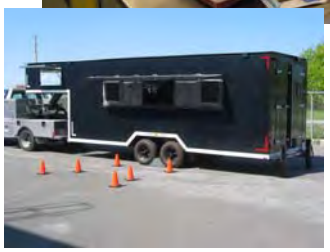
Environment Canada, in collaboration with CRTI and DFAIT have organized a series of CBRN response workshops that were attended by leading Canadian and International experts.

- May 2003 – Ottawa, Canada
- April 2004 – Ottawa, Canada
- April 2005 – Ottawa, Canada
- June 2005 - Volgograd, Russia
- February 2006 – Ottawa, Canada
- October 2006 – Moscow, Russia
- October 2007 – St. Petersburg, Russia
- April 2009 – Ottawa, Canada
- October 2010 – Niagara Falls, Canada

Technology Acquisition

- EC, HC, CFIA, CBSA, RCMP, DRDC, RMC, NRC

- Analytical laboratory equipment
- Person portable field equipment
- Portable meteorological stations
- Sampling equipment
- Mobile sample handling facility (triage trailer)



Pan Cluster Technology Acquisition

- CRTI Pan Cluster Technology Acquisition Project to procure mobile biological, chemical (warfare agent) and forensic lab system
  - To support first responders, investigators and federal government departments in the event of a CBRNE incident.
  - A joint agency effort between PHAC, DND (DRDC-S) and the RCMP
- Mobile capability that can be pre-deployed to provide first responders with rapid identification of the CB hazards at major events (e.g. V2010, G8/G20)
- Four Mobile Nuclear Laboratories (MNLs) were deployed in British Columbia, Manitoba, Ontario, and Nova Scotia through CRTI acquisition

EC Mobile Chemical Laboratory

- Funded through EC Capital Investment Plan
- Designed for response to environmental emergencies
  - Spills of toxic industrial chemicals
  - EC mandated activities
  - Scientific support to security related incidents
- Rapid response
- Self-sufficient (generator)
- Self deployable (G-class license)
- Ability to travel on secondary highways

Science Town

- CBRNE Subject Matter Experts (SMEs)
  - Rapid provision of scientific advice to RCMP CBRNE National Team
- Sample triage capabilities - Forensics
- Mobile laboratory capabilities C,B,R/N
- Genesis at ExIR-08 (Quebec City)
- Operational at V2010 in Vancouver and Whistler
  - Predeployment
- Operational at G8/G20
  - Leaner and meaner
- Support and coordination by MECSS (Major Events Coordinated Security Solutions)

National Response Capability to CBRNE

- Domestic response to incidents in Canada
  - Intelligence, Security and Scientific communities
  - Federal, Provincial/Territorial, Municipal departments and agencies
  - First responders
- International response
  - Partnerships with US Department of Homeland Security
  - CBRN Technical Working Group
  - Partnership with UK
  - Additional bilateral arrangements (future)

Conclusions

- Environment Canada's participation in the CRTI program and leadership of the Chemical Science Cluster has been beneficial for both the department and the CRTI program as a whole.
- The R&D programs of decontamination and CBRN material modeling led by Environment Canada are world-class.
- The results of these research efforts are directly applicable to the Emergencies Science and Technology Section's mandated role in providing scientific support in response to spills of chemical hazardous materials.

Conclusions

- The Chemical Science Cluster has transformed into a community of practice that has developed a capacity to provide chemical scientific support to the National CBRNE Response Team for domestic incidents.
- Collaborations have been forged with the intelligence, security and scientific communities, federal/provincial/municipal departments and agencies and first responders.
- Internationally, the Cluster has contributed to the development of research partnerships with the United States and the United Kingdom.
- Through these decontamination R&D projects, a number of Canadian and International partner organizations have contributed to the advancement of knowledge in this field.

Significance and Impact of Work

- As a result of these CRTI funded decontamination R&D activities, the international community is better equipped to make decisions related to the decontamination and restoration of facilities following a CBRN event.

Acknowledgements

- Funding provided by the CRTI Program, Centre for Security Science, Defence R&D Canada.
- Norman Yanofsky, Chemical Science Cluster Portfolio Manager.

Partners

- Public Health Agency of Canada, Defence R&D Canada (Ottawa, Valcartier, Suffield), US Environmental Protection Agency, SAIC Canada, Allen Vanguard, VNL Technologies, Hytech Hydrocarbon Reclamation Inc., HC, Atomic Energy of Canada, Russian Institute of Hygiene, Toxicology, and Occupational Pathology (RIHTOP), Lawrence Livermore Laboratories, Canadian Nuclear Safety Commission, Wehrwissenschaftliches Institut fur Schutztechnologien – ABC-Schutz, Research Institute of Hygiene, Occupational Pathology and Human Ecology (RIHOPHE), State Research Institute of Organic Chemistry and Technology (GosNIIOKhT), Research and Development Institute of Construction Technology (NIKIMT), Amita Corporation, Canadian Association of Fire Chiefs, Emergencies Medical Services Chiefs of Canada, New Brunswick Department of Public Safety, McGill University, York University, University of Ottawa, University of Leeds (UK), University of New Brunswick, University of Ontario Institute of Technology, Royal Military College of Canada, Queen's University, Carleton University.

Thank You!

- Questions?

Government Decontamination Service GDS

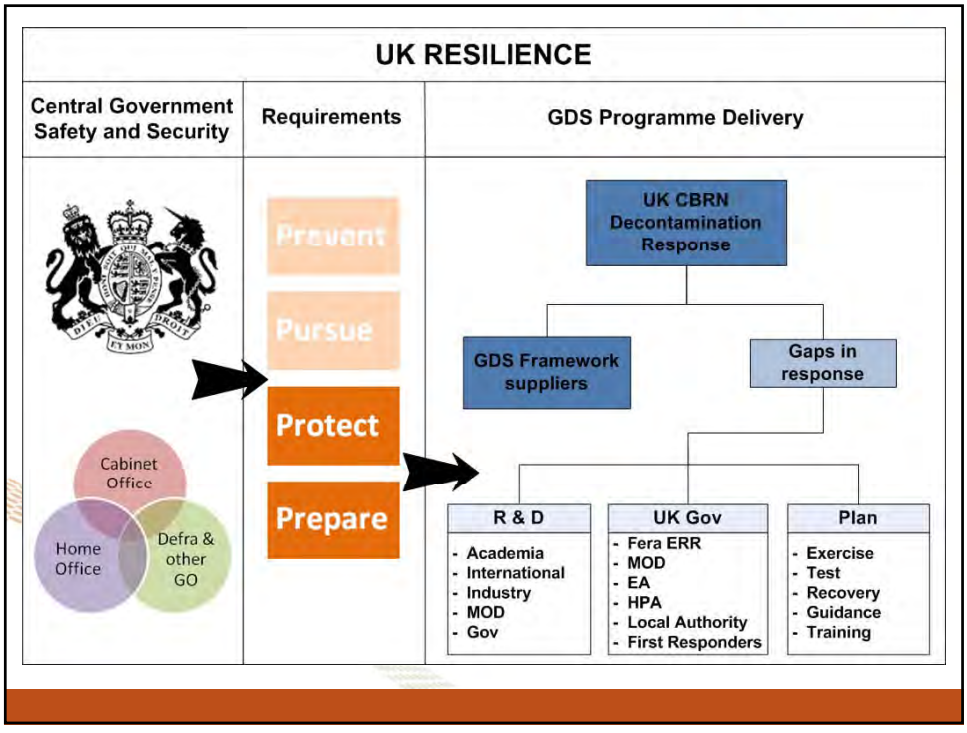
Rosina Kerswell

Contents

- Who are GDS
- UK Government
- GDS Specialist Suppliers
- GDS Projects

GDS Remit

- Providing advice, guidance and support to those responsible for dealing with the consequences of an accidental or deliberate release of CBRN and hazardous materials;
- Facilitating quick access to an assured Framework of specialist suppliers able to offer 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.



GDS Framework Suppliers

UK Government Decontamination Service

Normal Environment	Counter Terrorism Environment
Nuclear power station maintenance, decommissioning and legacy remediation	Radiological Dispersal Devices and improvised Nuclear Devices (IND)
Clinical sterilisation and oil extraction	Anthrax remediation (dispersion of bacillus anthracis)
Industrial chemical spills and asbestos removal	Deliberate releases of chemical warfare agents

GDS Framework Renewal

UK Government Decontamination Service

Chemical Lot 1	Biological Lot 2	Radiological Lot 3 / Lot 4
Sampling, Monitoring and Analysis A	Sampling, Monitoring and Analysis A	Sampling, Monitoring and Analysis
Decontamination B	Decontamination B	Decontamination
Waste Management and Disposal C	Waste Management and Disposal C	Waste Management and Disposal
		National Arrangements for Incidents Involving Radioactivity (NAIR)

GDS Supplier Roles

- Sampling and monitoring to determine the extent of the contamination;
- Prioritising the appropriate resources and equipment for decontamination;
- Decontamination of the built and open environment, transport assets and other items;
- Sampling and monitoring to assess the effectiveness of decontamination for reoccupation or reuse;
- Managing contaminated waste (throughout).

Case Studies

Radiological

- Street Wise
- RDD
- Busy Urban environment
- Decontamination
- Case Study (paper based)

Biological

- May First
- Wool Sorter
- Generic baseline office decontamination
- Case Study (paper based)

Chemical

- May Second
- Sheep Dip
- Generic baseline office decontamination
- Case Study (paper based)

Street Wise

- RDD
- Busy urban environment

- Site handover
- Waste, movement, storage, disposal
- Time and cost
- Joint response
- Share of information
- Contamination of hire equipment

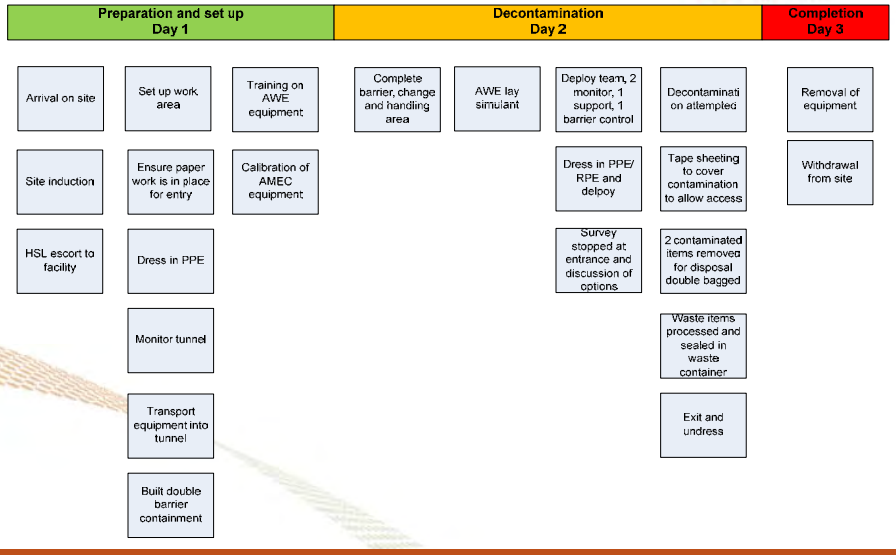
Exercises

- Based on case studies
- Deployment and practical assessment of capability
- Typically test lessons identified from case studies
- Identification of the limitations in supplier deployment capability

Silver Streak

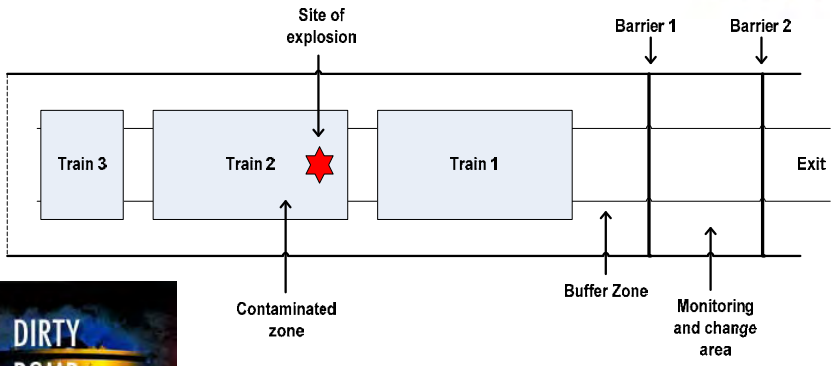
- Underground attack
- Policy drivers
- Location
- Facility
- Radiological Deployment Exercise

Silver Streak Radiological



Silver Streak Radiological

UK Government Decontamination Service



Findings

- Supplier deployment to site
- Practicality of PPE
- Barrier construction
- Use of simulant
- Interface with first responders
- Sharing of data

RIMNET

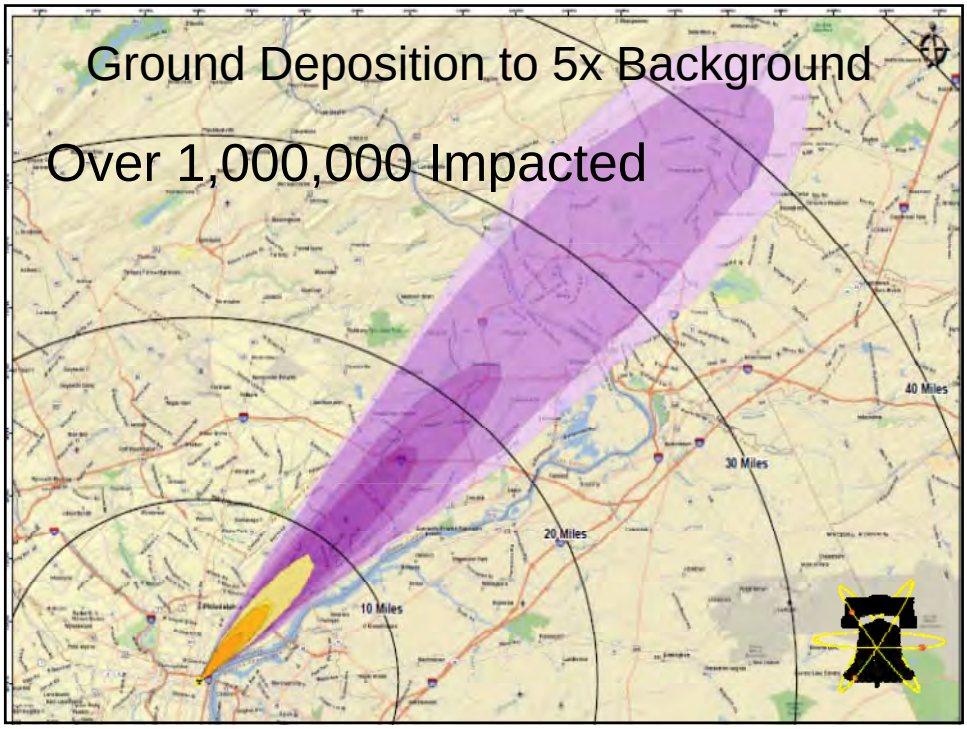
- The National Radiation Monitoring Network and Emergency Response System (RIMNET)
- What is RIMNET
- Capabilities
- How are GDS going to use RIMNET
- www.metoffice.gov.uk

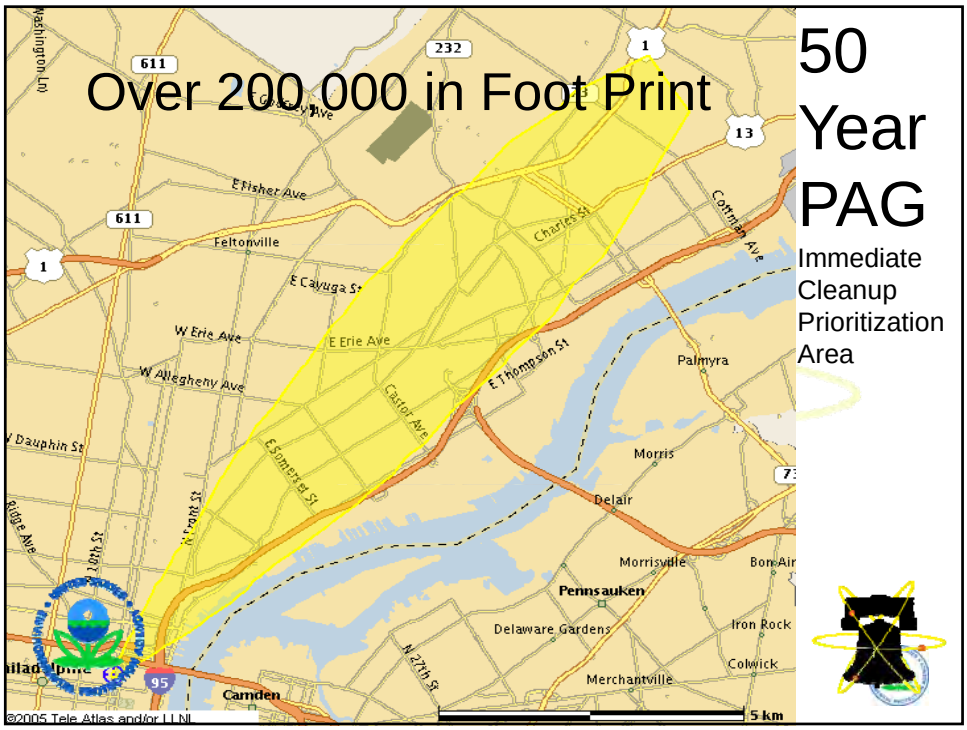
Incidents

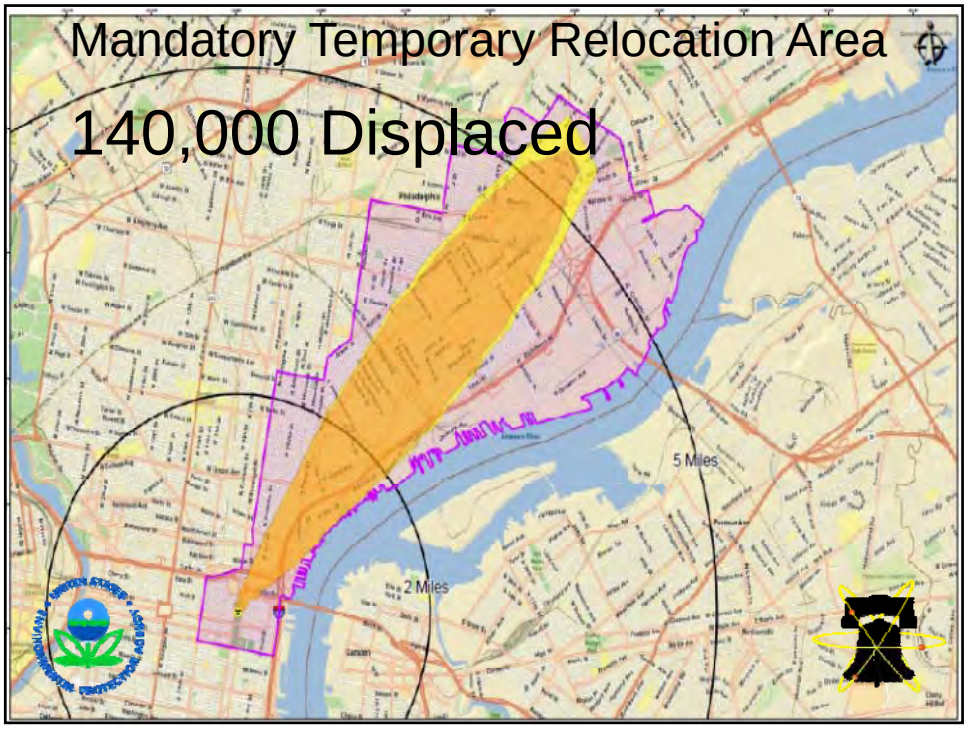
International Exchange

- Collaborative work
  - Share of exercise and testing information
  - Technical scientific expertise
  - Exchange of lessons learnt
  - Wide area
  - Critical national infrastructure
  - Contamination containment
  - Incident recovery timeline
  - Testing of suppliers using international facilities
  - Determine future road map


UK Government
Decontamination
Service
Questions


Ground Deposition to 5x Background
Over 1,000,000 Impacted
10 Miles
20 Miles
30 Miles
40 Miles


Over 200,000 in Foot Print
50 Year PAG
Immediate Cleanup Prioritization Area
611
232
1
13
Feltonville
Palmyra
Morris
Delair
Morrisville
Pennsauken
Delaware Gardens
Merchantville
Colwick
Iron Rock
Camden
95
5 km
©2005 Tele Atlas and/or LLNL



Decon Technology Deploymnent

Test EPA's ability to deploy multiple teams using three different mitigation technologies on multiple real-world surfaces.

Mitigation Activity

Summary of Mitigation Team Actions

- Employ three types of remediation techniques:
  - ❑ Mechanical: Wire Brush
  - ❑ Strippable Coating: StripCoat TLC™
  - ❑ Chemical Removal EAI Rad-Release I©
- Test of people and application.
- Not a test of technological ***efficacy***

Franklin Square (PATCO station)

200 N 6th St

Abandoned station located at Franklin Square in Philadelphia

Vendor / Product

Industrial Contractors Supplies, Inc. (ICS)

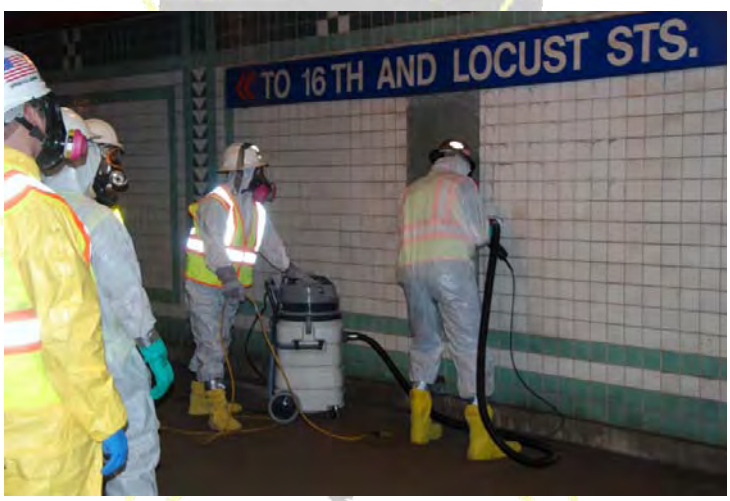
Dust Director

Vendor / Product

Bartlett Services, Inc.

StripCoat TLC

Mechanical Removal



Strippable Coating

Strippable Coating

- Real World Safety Issue
  - A high concentration of ammonia was released after the strippable coating was applied (nuisance level only)
  - NH^3 not listed on the product MSDS
  - Inadequate ventilation in subway station

Response to ammonia issue

- Both onsite “play safety representatives” and “real world safety representatives” monitored the situation closely and determined it to be a non-issue.
- The situation did demonstrate the ability of the safety representatives to quickly respond to an unexpected issue.

Chemical Removal

- Spray on Chemical treatment
- 60 minute dwell time
- Wet-vac removal
- EAI Rad-Release I©

All Three Technologies: Limited Use

- Small areas
- Low concentrations
- High value items
- Low future exposure potential
- Won't replace traditional methods over large areas or outdoor settings

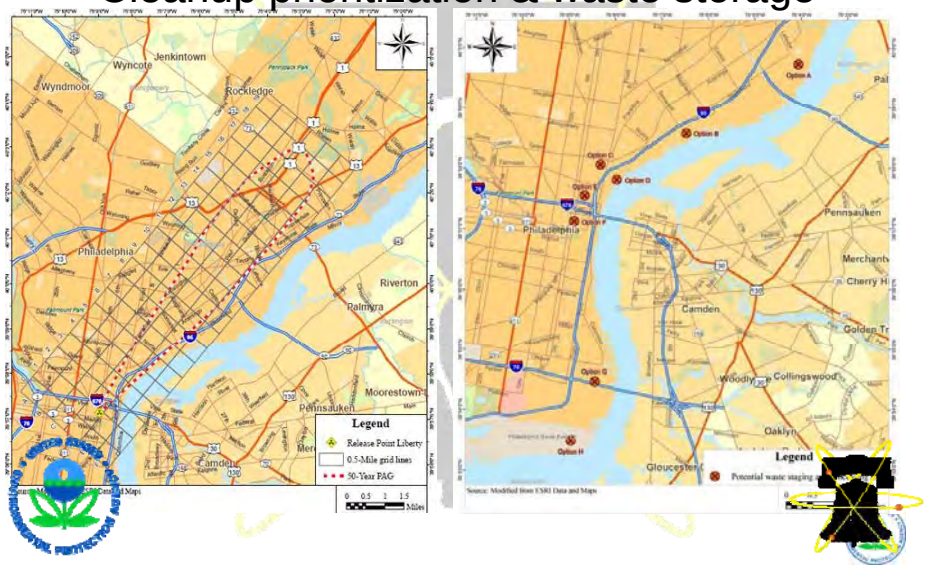
Other PATCO Safety Issue

- Real World Safety Issue
  - High levels of dust detected
  - PATCO construction activity in subway tunnel nearby
  - Inadequate ventilation in subway station
  - PATCO shut down construction during exercise hours

Community Advisory Forum

- Cleanup Prioritization
- Temporary waste storage locations

Stakeholder Panel Challenges: Cleanup prioritization & waste storage



Cleanup Prioritization Plan – Three Options

- Option 1 – Cleanup of Areas in and around the 50 year Protective Action Guide (PAG)
  - 1a: Cleanup Prioritization Based on Population Only
  - 1b: Cleanup Prioritization Based on Contamination Level
  - 1c: Cleanup Prioritization Based on a Combination of Population Data, Contamination Level and Economic Impact
- Option 2 – Cleanup of Areas addressing only the populated areas of the 50 Year PAG
  - 2a: Cleanup Prioritization Based on Population Only
  - 2b: Cleanup Prioritization Based on Contamination Level
  - 2c: Cleanup Prioritization Based on a Combination of Population Data, Contamination Level and Economic Impact
- **Option 3** – Cleanup is Based Solely on Geography, beginning at the blast zone

Temporary Waste Staging and Processing Options

Option A: A large tract along the Delaware River riverfront bounded by Orthodox Street, Richmond Street, and Jenks Street with other bordering streets.

Option B: A section of the Delaware River riverfront east of I95 and Richmond Avenue between Delaware Avenue and Allegheny Avenue which include the Winzinger Recycling facility located at 2879 East Allegheny Avenue.

Option C: Four irregular blocks in an area of high contamination bounded by 2nd Street, Girard Avenue, North Hancock Street, West Wildey Street and Germantown Avenue.

Option D: A section of Delaware River riverfront east of Delaware Avenue between the foot of Frankford Avenue and the foot of Shackamaxon Street.

Temporary Waste Staging and Processing Options (cont.)

Option E: Several blocks immediately north of I-95 and west of I-95 in the area of highest contamination including the blocks between Callowhill and Spring Garden Streets and between 2nd and 4th Street and the adjoining blocks between Spring Garden and Brown Streets and between 2nd and 3rd Streets.

Option F: Part of Independence National Historic Park bordered by 6th Street to the west, Race Street to the north, 5th Street to the east, and Market Street to the south.

Option G: Two large tracts immediately north of the Walt Whitman Bridge on either side of Columbus Boulevard.

Option H: Part of the former Philadelphia Naval Yard along Kitty Hawk Avenue.

LRE Waste Team
Waste Management Plan

- **Estimated Volumes & Quantities of Wastes by Zone**
  - **Zone1**: 1,000 micro Ci/sq meter (based upon the highest concentration deposition zone)
  - **Zone 2**: 2.0 rem (based on Federal 1 year relocation protective action guide (PAG))
  - **Zone 3**: 0.5 rem (based on state 2nd year relocation PAG)

Waste Classification

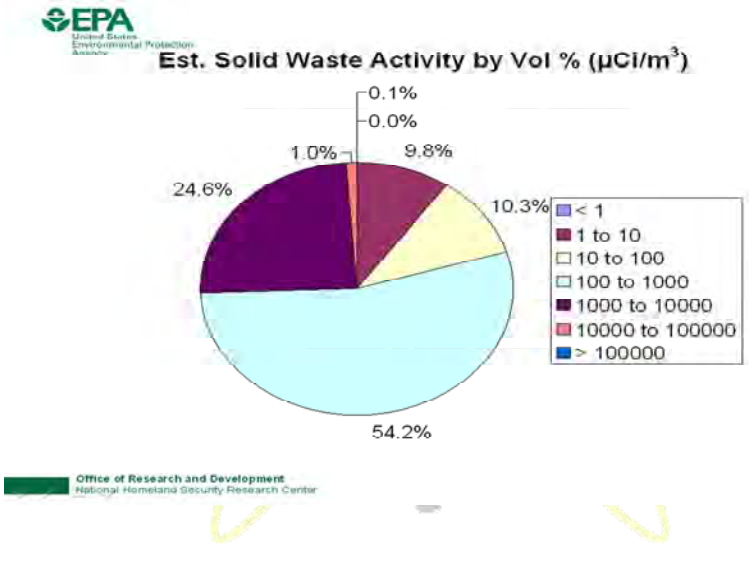
NRC Classification of LLRW as it relates to Cs-137:

- **Class A: 0-1 Ci/cubic meter**
- **Class B: 1 – 44 Ci/cubic meter**
- **Class C: 44 – 4600 Ci/cubic meter**

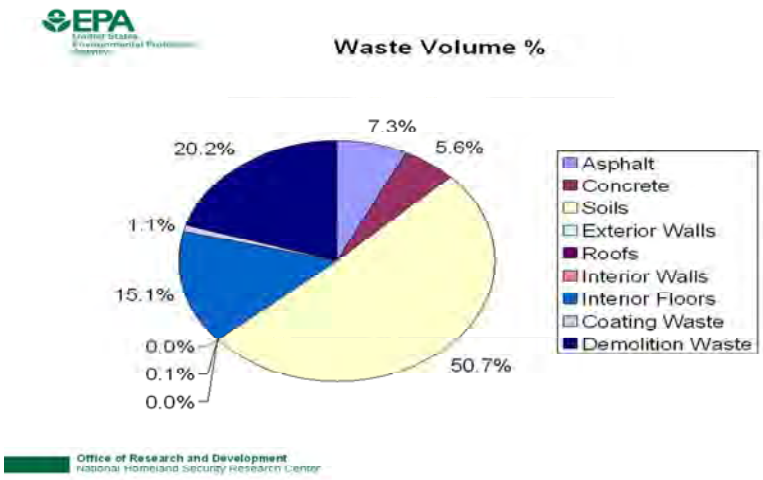
Waste Classification

1. Class A Low Level Radioactive Waste (LLRW). **NOTE:** This is over 99% of the waste material.
2. Class B LLRW (higher activity levels from blast zone or onsite concentration efforts)
3. LLRW with Asbestos (i.e., old steam pipes from demo buildings)
4. LLRW with PCB's (i.e., PCB transformer oils coating demolished building exteriors)
5. Low Level Mixed Waste (LLMW) (RCRA hazardous waste and low-level radioactive waste)
6. Personal Protective Equipment (PPE) waste
7. Sludge from onsite decontamination efforts
8. Sludge from WWTPs
9. Laboratory samples
10. Contaminated clothing from off-site health facilities
11. Non-radiological solid or hazardous waste for disposal in RCRA C or D landfills

LRE Waste Volume by Activity



LRE Waste Volumes by Type



Disposal Options and Costs

Waste Cat	Concentration	Amount/ cubic meters	% of total	Disposal Options	Cost
Low-activity waste--"less than 1 mrem/yr to a resident farmer at a landfill	40-100 pCi/gram limit Approximately	35,000 est.	10%	RCRA D landfills	Low—estimated to be $100 - $300 per cubic meter. **Total cost estimated to be $7M**
Class A LLW	100 pCi-gram – 800,000 pCi/gram	Nearly 700,000	90%	EnergySolutions Clive facility in Utah DOE facilities—NV, possibly other (Oak Ridge?)	As low as $450/per cubic meter, per EnergySolutions. This does not include transportation costs. **Total cost = $450M**
				Build and license a special facility in PA	Cost to develop a disposal facility on the order of $100 million? Operating costs assumed to double cost of disposal Janti/Martin/Allard to weigh in on this. This works out to $280 per cubic meter **Total cost = $196M**

Disposal Options and Costs (Continued)

Waste Cat	Concentration	Amount/ cubic meters	% of total	Disposal Options	Cost
"Low activity waste"– defined as < Class A limit, but > than RCRA D. Suitable for RCRA C facilities	200 pCi/gram? Actual limit TBD based on site specific analysis. USEcology Idaho facility has accepted Cs at this concentration.	300,000 ?	40% est.	RCRA Subtitle C—could be US Ecology Idaho, or another hazardous waste site in the east. Will identify possibilities	Typically about half of EnergySolutions disposal cost, so $250/cubic meters. **Total cost = $70M** for 40% of the waste.
Class B LLW	Greater than 1 Ci/cubic meter	14	<1%	None for waste in PA, Barnwell SC for NJ waste. Texas site is a possibility in future. Might also be able to persuade WA or SC to take all of it. DOE site also a possibility	Very high per unit volume, but quantities very small. Estimated cost is $100,000 per cubic meter at commercial site, probably much lower at DOE site. **Total cost = $1.4M**

Disposal Options and Costs (continued)

Waste Cat	Concentration	Amount/ cubic meters	% of total	Disposal Options	Cost
Mixed waste (conventional)	Assume it includes all of the Class A range	25,000	3%?	Clive Utah DOE site, PA new site Some could go to existing RCRA C sites in east or USEcology Idaho	$5000 per cubic meter **Total cost = $125M**
MW with PCB's	Assume that it includes all of Class A range	824	<1%	Clive ? DOE? Some RCRA C sites?	High **$4.12M** minimum
MW with asbestos	Same as above	7336	1%	Same as above	High **$36.7M** minimum

LRE – Technology and Mitigation Assessment Team

TMAT – Cleanup Plan

Cleanup Tactics and Technologies

Overall Clean-up Goal :

- Reduce the dose rate to or below 15 mrem / year for occupants of the Residential neighborhood

Most Effective Strategies:

a) Roof Replacement
b) Soil Removal
c) Street and Sidewalk Surface Removal.

TMAT Cleanup Plan:
Area Estimates for Residential Cleanup

Residential Neighborhood

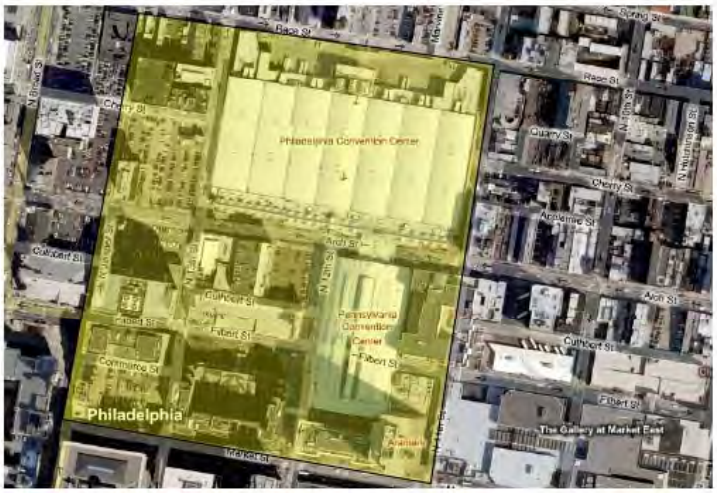
- North Philadelphia
- Breakdown of Area Estimates

Proposed Cleanup Area	Area (Sq. ft.)	Percentage
	264,700 (6.08 acres)	
Open Area	117,370	44.3%
Roof Area	82,050	31.0%
Roadway Area	32,080	12.1%
Sidewalk Area	33,200	12.5%

TMAT Cleanup Plan:
Estimated Costs: Residential Neighborhood

Cleanup Priority	Area/ Vol. est.	Total Cost	Cost/ Acre	Cost/ Structure
Roof Removal/ Replacement	81,000 S.F	$682k	$111.8k	$4,550
Yards/Dirt Lots	2150 C.Y.	$326k	$53k	--
Sidewalks/Concrete	33,200 S.F	$103k	$16.9k	--
Street Resurface and Milling	3,000 S.F	$290k	$46.9k	--
Total		**$1.4MM**	**$229k**	**$8,325/lot**

TMAT Study Area 2:
Business District – Downtown Philadelphia



TMAT Cleanup Plan:
Estimated Costs: Residential Neighborhood

Cleanup Priority	Area/ Vol. est.	Total Cost
Metal Roof Decontamination	645k S.F	$17MM
Street Resurface and Milling	2 miles	$2MM
Sidewalks/Concrete	153k S.F	$458k
Parking Areas	120k S.F	$1.2MM
Total		**$21.4MM**

Water Decontamination Activities within EPA Water Security Division and National Homeland Security Research Center

Marissa Lynch[1] , Matthew Magnuson[2] & Scott Minamyer[2]
[1]U.S. EPA, Office of Ground Water and Drinking Water, Water Security Division
[2]U.S. EPA, Office of Research and Development, National Homeland Security Research Center

November 1, 2011

EPA Roles in Homeland Security

- Protecting water and water infrastructure
- Indoor and outdoor clean-up following attack or natural disaster
- Reducing vulnerability of the chemical & hazardous materials sector
- Research to protect water infrastructure & buildings
- Hazardous materials emergency response

2

Protecting Water and Water Infrastructure

- EPA's Office of Water, Water Security Division provides national leadership in developing and promoting security programs that enhance the sector's ability to prevent, detect, respond to, and recover from all-hazards.
- EPA's water security research focuses on developing tools and applications that can provide contamination warnings to water utilities in the event of terrorist attacks with chemical, biological, or radiological weapons.

3

Water System Threats: Problem Statement

- Through studies, analyses and simulations, experts have concluded that:
  - Water systems are vulnerable to contamination
  - Contamination can be "all hazards"
  - Wide range of contaminants pose a viable threat to water
  - Under some scenarios, could produce significant consequences
  - Consequences can escalate rapidly

4

http://www.bbcnewsupdate.com/militant-%E2%80%98plotted-to-poison-water-spanish-judge.html

5

Consequences

- Adverse public health impact: 100-1000's of fatalities (a 1993 incident in Milwaukee killed 100's and sickened 100,000's)
- Loss of water for public safety uses (fire fighting, hygiene, etc.)
- Economic damage: remediation of 100's of miles of pipes, lost productivity, fire losses, etc.
- Loss of consumer confidence

6

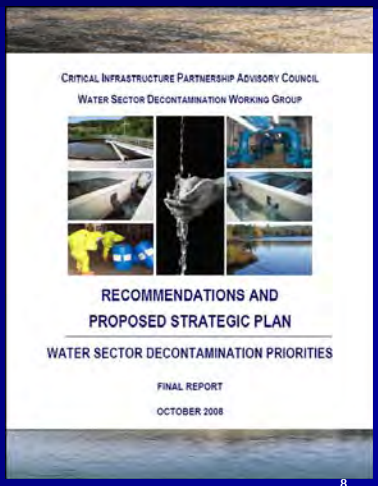
Intentional Contamination

- Is likely to achieve multiple terror objectives
- Does not have to produce casualties to be successful
- Will be perceived as an especially serious threat by the public, as confirmed by recent Crisis Communication study

7

CIPAC Water Sector Decontamination Working Group

- Who: WSD, SCC, & GCC
- Strategic Plan – October 2008
  - Priority Issues (16)
  - Recommendations (35)

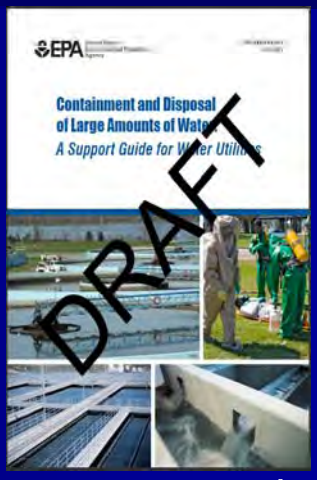


8

Disposal Guidance for the Water Sector

CIPAC Recommendation:
Revise existing guidance or develop new guidance for containment and disposal of decontamination waste, including large amounts of water and associated solid waste (**Issue 1, Recommendation 2)**

Activity: Developing a disposal guide for the water sector



9

Containment and Disposal of Large Amounts of Water: A Support Guide for Water Utilities

Organization of the Guide

1. Introduction
2. Containment and Disposal as Part of Remediation and Recovery
3. Containment and Treatment of water
4. Disposal of Water
5. Storage and Transportation of Water
6. Appendices
   - A. Risk Communication
   - B. Potential Treatment Methods
   - C. Sample Disposal Checklist
   - D. Resources
   - E. Summary of Applicable Laws and Regulations
7. References

10

Guide Overview Contaminants Included

Chemical	Biological	Biotoxin	Radiological
Hydrophobic Compounds Pesticides Heavy Metals Chemical Warfare Agents	Bacteria Viruses Protozoa	Algal Toxins Fungal Toxins Bacterial Toxins Plant Toxins	Alpha Beta Gamma

11

Decision- Making Frameworks/ Roles and Responsibilities

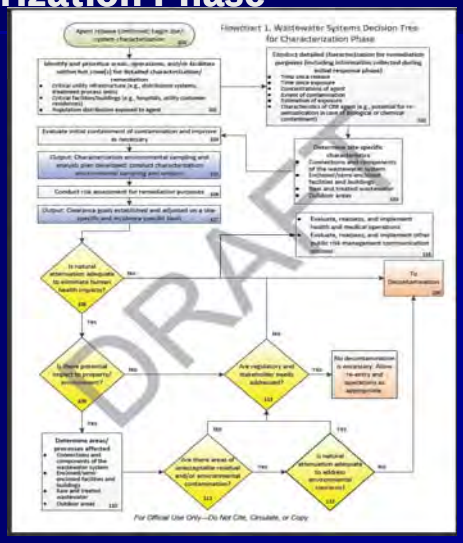
CIPAC Recommendation: Develop a decision-making Framework for the decontamination of CBR agents in water systems specifically to be used by utilities, responders, and other decision makers

CIPAC Recommendation: Identify the progression of role and decision making authority to be used by the utilities and responding/coordinating agencies during decontamination, treatment and recovery

Activity: Development of decision-making frameworks that could be used in emergency response planning and during or after decontamination activities that also identify the progress of roles and responsibilities for utilities and responding/coordinating agencies during decontamination.

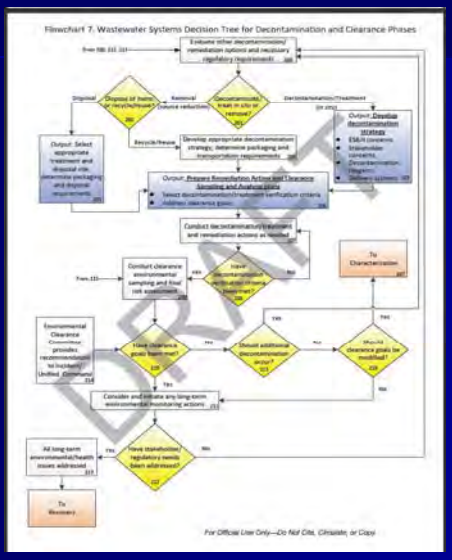
12

Example Flowchart: Wastewater Systems Decision Tree for Characterization Phase



13

Example Flowchart: Wastewater Systems Decision Tree for Decontamination and Clearance Phases

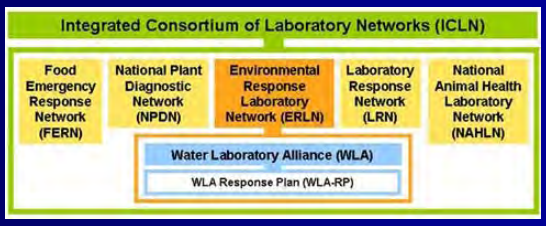


14

Laboratories Capabilities & Capacities - Decontamination

CIPAC recommendation: Leverage existing efforts to identify laboratory capabilities and laboratory capacities specific to CBR agent decontamination needs (**Issue** 14, **Recommendation 2)**

Activity: Developing a fact sheet

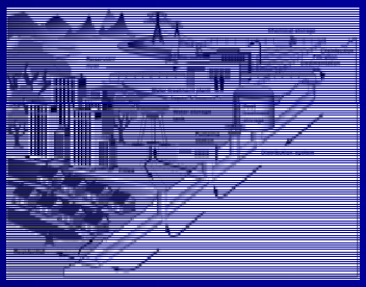


15

Development of Decontamination Training for the Water Sector

CIPAC Recommendation: Develop and provide two types, one each for drinking water and wastewater, of facility-based, decontamination training programs from "ground up" for Water Sector stakeholders and national response teams.

Activity: Plan to develop decontamination training for drinking water and wastewater utilities



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Next Steps

- Disposal Guide
  - Prepare for Publication- Date TBD ✔
- Decision-Making Framework/Roles and Responsibilities
  - Complete of internal review
  - Review by external stakeholders
  - Determination of appropriate release
  - Projection of completion in Spring 2012
- Laboratories Capabilities and Capacities
  - Completion of internal review

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Water Infrastructure Protection Division

- Conducts applied research to help secure the nation's drinking water and waste water systems from threats and attacks
  - Prevention, detection, containment, treatment, and decontamination
  - Produces tools, procedures, methodologies, technology evaluations, models, and decontamination techniques
- Works with EPA's primary water security stakeholders — both internal and external

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Treatment and Decontamination Research

- "Treatment" refers to contaminated water and wastewater
- "Decontamination" refers to contaminated infrastructure
- Research based on:
  - Critical science and technology needs identified by NHSRC and key stakeholders, including the Water Critical Infrastructure Partnership Advisory Council (CIPAC)
  - Contaminant-specific literature reviews
  - Previous and ongoing research efforts

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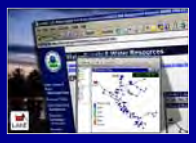
Treatment and Decontamination Research, cont.

- Identify which priority chemical, biological, or radiological (CBR) contaminants will attach to wetted surfaces and how they can best be remediated
- Determine inactivation and removal capabilities of typical water treatment and disinfection technologies for biological contaminants
- Determine the efficacy of typical water infrastructure decontamination technologies to destroy or remove chemical and radiological contaminants

20

Treatment and Decontamination Research, cont.

- Expand treatability information on contaminants most likely to be used to contaminate drinking water supplies and systems
- Develop models for developing/evaluating distribution system decontamination strategies



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Some completed projects

- Inactivation of bacterial bioterrorism agents
- Detection and treatment of biotoxins in drinking water
- Pilot-scale adhesion and decontamination of chemical and biological contaminants
- Adhesion and decontamination of radioisotopes

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Thank You

If you have any questions, please contact:
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23

Germinant enhanced decontamination of *Bacillus* spores adhered to iron and cement-mortar drinking water infrastructure

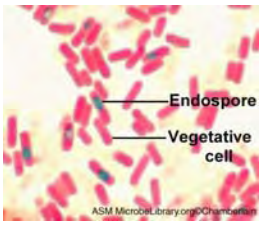
Jeff Szabo, Nur Muhammad, Lee Heckman, Gene Rice and John Hall
EPA/NHSRC/WIPD
November 1, 2011

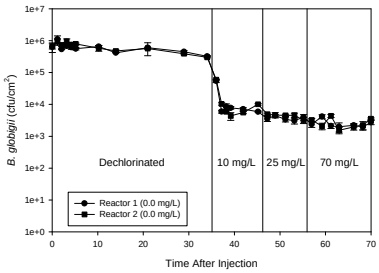
Overview

- *Bacillus* spore association with water infrastructure
- Bench scale experimental design
- Pilot scale decontamination results
- Future work
- Closing thoughts

Why focus on *Bacillus* spores?

- Some biological agents are persistent on drinking water infrastructure with and without biofilm
- *Bacillus* spp. is particularly persistent since it forms spores
- Causative agent of anthrax
- It is difficult to decontaminate from water infrastructure





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3

Germination as a decontamination tool

- Germination: spore -> vegetative
- Sporulation: vegetative -> spore
- Instead of chlorination and/or flushing, why not germinate first?
- What do you germinate with?
  - Culture media (tryptic soy broth, nutrient media)
  - L-alanine and inosine
- Germinants do not necessarily affect all *Bacillus* species in the same way

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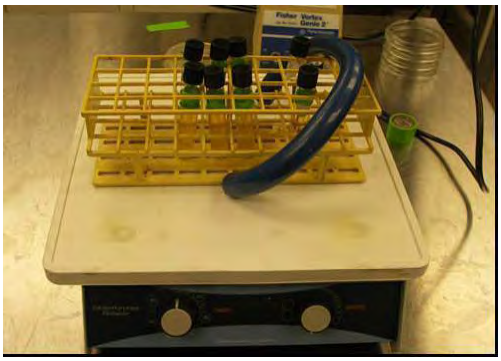
4

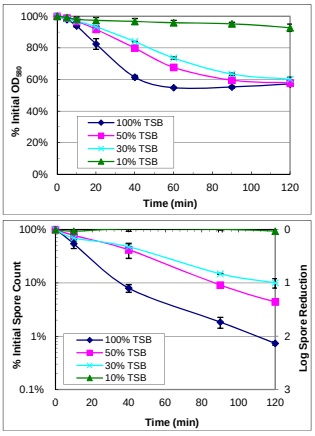
Bench Scale Experiments: Optimal Germination

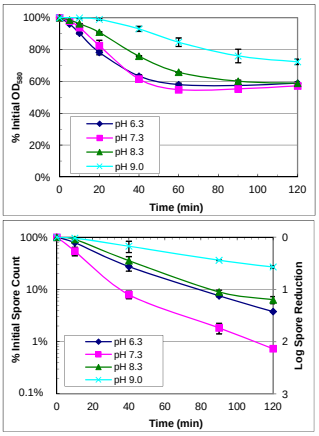
- *Bacillus globigii* spore dilutions in 20 ml vials
- TSB dilutions: 10, 30, 50 and 100% of the standard recipe
- pH: 6.3, 7.3, 8.3 and 9.0
- Temperature: 5°, 15°, 20° and 25° C
- Germination monitored for 2 hours by culture and optical density (OD_{580})



Bench Scale Germination Results

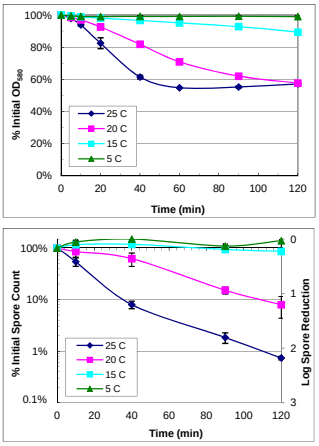
- Higher germinant (broth) concentration was better, but we chose a 50% solution
- Neutral pH was optimal, but lower pH worked



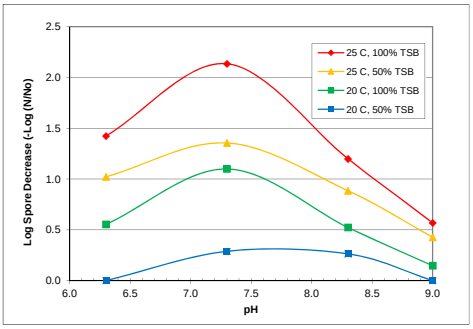


Bench Scale Germination Results

- Germination was limited under 20°C



- We chose 25°C, pH 7.3 and 50% TSB



Decontamination Pipe Loop

- Clear PVC
- Coupons (1 in^2) made of iron (corroded) and concrete
  - 30 slots for coupons
- 6-inch diameter pipe, total system volume of 220 gal
- Flow rates up to 100 gpm
- 10-12 psi operating pressure
- Fire hydrant meant to simulate a connection to a water main running under a street or sidewalk
- Contaminants can be directly introduced into the pipe or through the fire hydrant

Coupons/Infrastructure Materials

- Coupons are meant to represent common drinking water infrastructure materials
- Coupons condition in tap water before contamination (>30 days)
  - Iron starts out uncorroded

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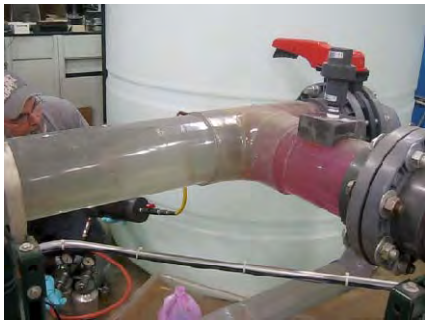
Contamination/decontamination

Contamination: Contaminant is added directly into the pipe or through the hydrant and allowed to contact coupons. Coupons are harvested to assess persistence.

Decontamination: Decon undertaken if contaminants persist. Flushing, disinfection, pH adjustment, oxidation, surfactants, etc. Decontaminating agents added in the same way as contaminants.

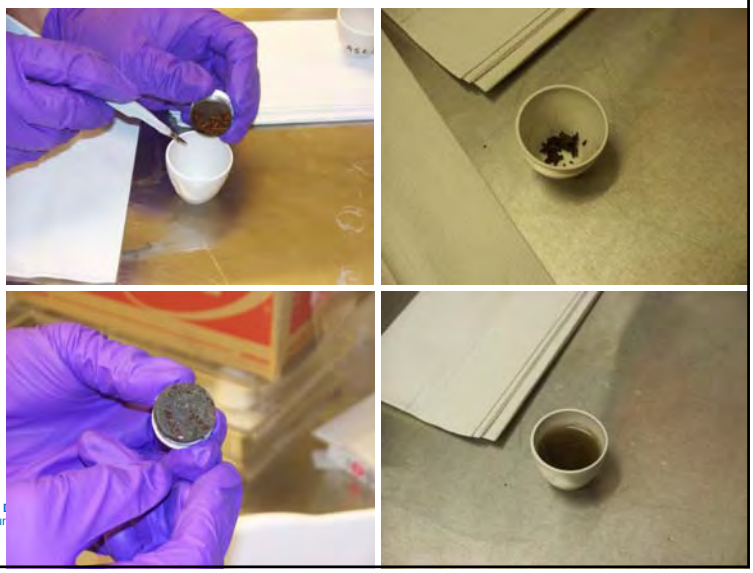


- Contaminant contacts coupons
- Coupons are harvested

Sampling/Analysis

Coupons scraped in the lab

Scraped coupons rinsed. Ready for analysis or further sample prep.



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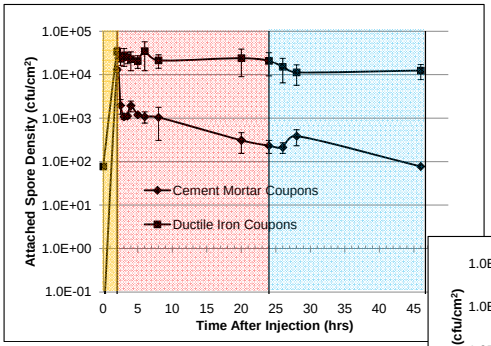
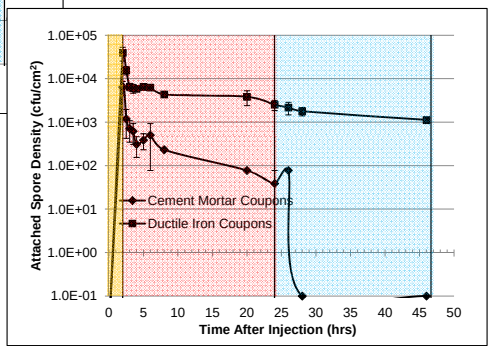
Decontamination with free chlorine



5 mg/L free chlorine

- 5 mg/L Ct: 5,800-7,200 mg/L-min
- 25 mg/L Ct: 32,900-26,600 mg/L-min

Orange = spore injection
Red = disinfection (5 or 25 mg/L free chlorine, no flow)
Blue = flushing (88 gpm, 1 ft/sec)



25 mg/L free chlorine

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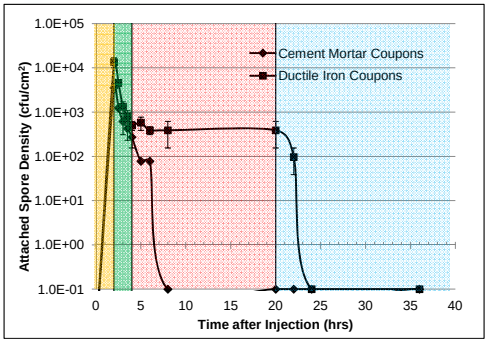
Decontamination with free chlorine and germinant

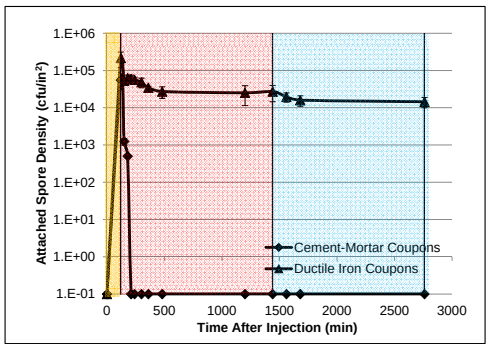


- 5 mg/L with germinant: Ct 1,300-1,700 mg/L-min
- Ductile iron: Germinant assisted flushing
- Cement-mortar: Germinant assisted chlorination

Orange = spore injection
Green = germination (50% TSB, 25 C, pH 7.3)
Red = disinfection (5 mg/L free chlorine, no flow)
Blue = flushing (88 pgm, 1 ft/sec)

Decontamination with Chlorine Dioxide

- Preliminary work performed with chlorine dioxide (5 mg/L)
- Effective against spores adhered to cement-mortar
- Better than free chlorine on ductile iron



Conclusions and Future Work

- Adding germinant helps free chlorine and/or flushing decontaminate corroded iron and cement-mortar drinking water infrastructure
  - Won't work in cold weather, less effective at high pH
- What is the best germinant for pathogenic *Bacillus anthracis* and what is the lowest effective concentration?
- The impact of other disinfectants with or without germinant
  - Chlorine dioxide (5 and 25 mg/L)
  - Ozone
  - Monochloramine (maybe)
  - Acidified nitrite (green)
  - Peroxide (green)
  - Mixed oxidants and other commercial products

Questions

Testing the Pipe Decontamination Experimental Design for the Study of Biological Contaminant Persistence and Decontamination in Drinking Water Pipes

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

Water System Decontamination

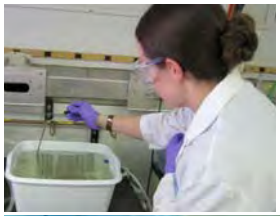
- ✓ Possibility of attacks on water systems is coupled by reality of decontamination
  - ➢ Treatment plants
  - ➢ Distribution systems
- ✓ What decontamination approaches would be used?
- ✓ How effective are they?
- ✓ What levels need to be achieved?

Objective

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

Technical Approach

- ✓ Pipe Selection
  - ➢ Cement-lined and PVC annular reactor coupons
- ✓ Contaminant Selection
  - ➢ *Bacillus globigii (Bg)*
- ✓ Contamination Method
  - ➢ Biofilm growth in dark
  - ➢ Direct inoculation
  - ➢ Equilibration with contaminated solution
- ✓ Contaminant Detection Methodology
  - ➢ Selective plate enumeration



Experimental Design

- ✓ Step 1: Contaminant Extraction
  - ➢ Five drops (15 µL *Bg*) added directly to biofilm covering coupon surface at concentration of 2 x 10^7 CFU/mL
  - ➢ Extraction of contaminant from surface using vortex mixing of concrete only
- ✓ Step 2: Surface Contamination
  - ➢ Equilibrate coupons in 1 L of contaminated deionized water for 2 hours
    - 1 x 10^5 CFU/mL *Bg*
    - Annular reactor rotating at 100 rpm

Step 1 - Surface Contamination Extraction Results

Bg on Concrete

Coupon #	Amount spiked (cfu)	Avg. amount recovered from concrete (cfu)	Avg. amount recovered from backing (cfu)	Avg. total recovered (cfu)	Total % Recovery
1	1.50E+06	6.93E+05	2.43E+05	9.37E+05	62%
2		1.03E+06	3.06E+05	1.34E+06	89%
3		8.00E+05	2.09E+05	1.01E+06	67%
4		8.00E+05	3.41E+05	1.14E+06	76%
Average		8.32E+05	2.75E+05	1.11E+06	74%
SD		1.42E+05	5.97E+04	1.77E+05	12%
%RSD		17%	22%	16%	16%

- ✓ Direct spike onto concrete resulted in 75% of Bg recovered from concrete and 25% from backing
- ✓ Average overall recovery of 75%±12% of total spores

Step 1 - Surface Contamination Extraction Results

Bg on PVC

Coupon #	Amount spiked (CFU)	Avg. CFU recovered	Total % Recovery
1	1.50E+06	1.39E+06	93%
2		1.36E+06	91%
3		1.38E+06	92%
4		1.08E+06	72%
5		7.60E+05	51%
Average		1.27E+06	80%
SD		1.68E+05	18%
%RSD		13%	23%

✓ Average overall recovery of 80% ± 18% of total spores

Step 2 - Surface Contamination Results

Bg on Concrete

Contaminated Coupon	Amount Recovered from Concrete (CFU)	Amount Recovered from Backing (CFU)
#1	4.48E+05	[a]
#2	4.26E+05	5.07E+04
#3	3.81E+05	6.73E+04
#4	3.19E+05	4.93E+04
#5	[a]	4.47E+04
Avg.	3.94E+05	5.30E+04
St. Dev.	5.07E+04	9.9E+03
%RSD	14%	19%

[a] removed as outlier

✓ 88% of *Bg* on concrete, 12% on backing

✓ RSD of 14%

Bg on PVC

Contaminated Coupon	CFU Recovered from PVC
#1	4.17E+05
#2	2.81E+05
#3	2.73E+05
#4	3.77E+05
#5	2.51E+05
Avg.	3.20E+05
St. Dev.	7.27E+04
%RSD	23%

✓ RSD of 23%

Surface Contamination Results Summary

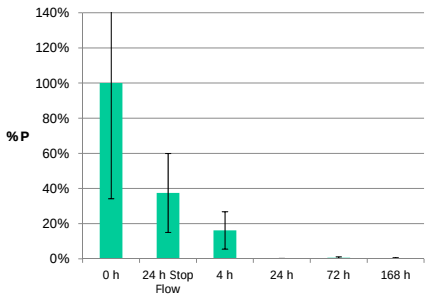
- ✓ Step 1 - Surface contamination extraction
  - Bg was recovered on average 74% across both backing and concrete surface
  - Bg was recovered on average 80% from PVC surface
  - Reproducibility of the extraction procedure was very good
  - Determined that *Bg* could be extracted and measured
- ✓ Step 2 – Surface Contamination
  - Following bulk contamination, 88% of *Bg* was recovered from the concrete and 12% from the backing
  - No %R calculated because exact level of contamination not known
  - Reproducibility of extraction and measurement reasonable (RSD <25%) given the variables

Persistence Evaluation Experimental Design

- ✓ Equilibrated coupons in 1 L of contaminated deionized water for 2 hours
  - 1 x 10^5 cfu/mL *Bg*
  - Annular reactor rotating at 100 rpm with no flow
- ✓ Removed three coupons as control coupons
- ✓ Filled AR with tap water and had no flow or rotation for 24 hours (removed three coupons)
- ✓ Flow water set at 0.2 L/min and rotating AR at 100 RPM and removed three coupons after 4 hr, 1 day, 3 days, and 7 days.

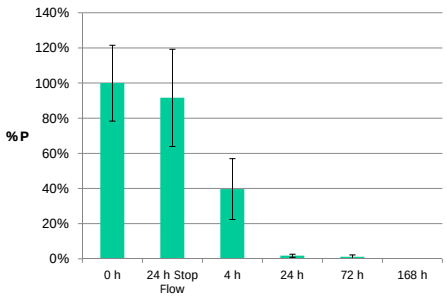
Persistence Evaluation

%P *Bg* - Concrete



0 h: 5 x 10^5 spores

%P *Bg* - PVC

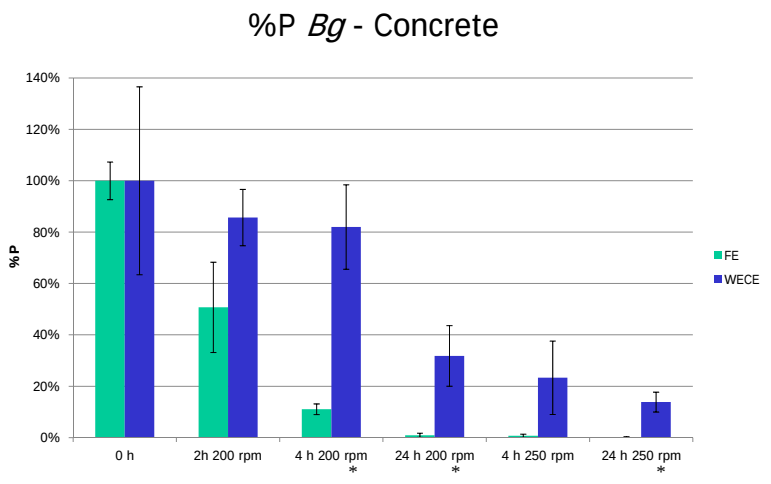


0 h: 4 x 10^5 spores

Flushing Evaluation Experimental Design

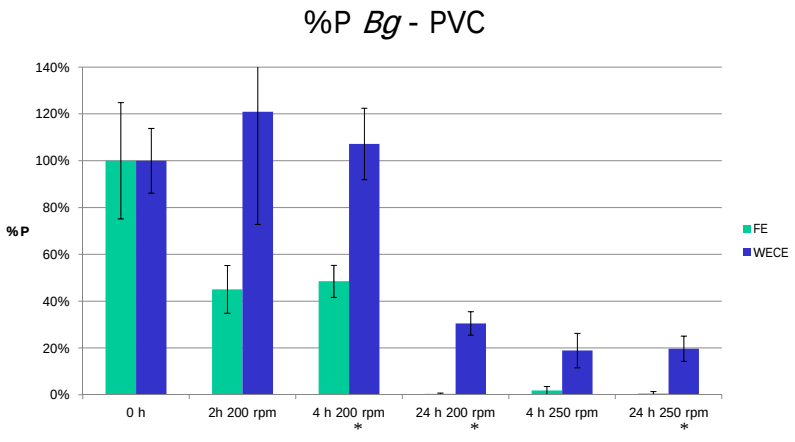
- ✓ Same as persistence evaluation except
  - ➢ No 24 hr stopped flow
  - ➢ Flow water set at 0.2 L/min and rotating AR at 200 RPM and removed three coupons after 2 hr, 4 hr, and 1 day
  - ➢ Increased AR to 250 RPM and removed three coupons after 4 hr and 1 day
- ✓ Results compared directly to Water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

Flushing and WECE on Concrete



0 h: 1 x 10^5 spores

Flushing and WECE on PVC



0 h: 3 x 10^5 spores

Persistence and Flushing Results Summary

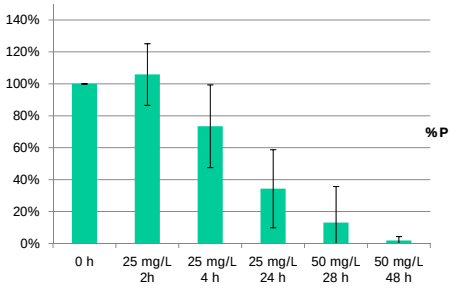
- ✓ Persistence Evaluation
  - %P goes to 0% after 24 hours on both concrete and PVC
- ✓ Flushing Evaluation
  - Results for *Bg* were similar to persistence evaluation despite increase in AR rotation from 100 rpm to 200 - 250 rpm
  - Precision of results was adequate to determine significant differences for several time periods of persistence evaluation
  - Comparison with WECE revealed that flushing is significantly more effective that just allowing coupon to be exposed to fresh tap water

Experimental Design

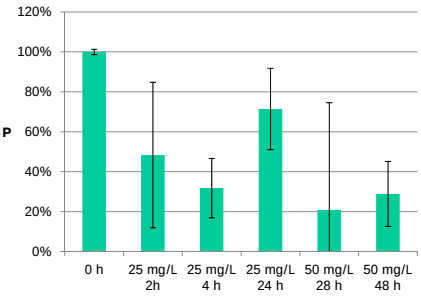
- ✓ Description of Hyperchlorination Evaluation
  - Contaminate coupons (covered with biofilm) with bulk solution of deionized water containing *Bg*
  - Remove three coupons as control coupons
  - Fill AR with tap water and adjust chlorine concentration to 25 mg/L (remove three coupons)
  - Flow stopped and AR not rotating. Remove three coupons after 2 hr, 4 hr, and 1 day
  - Increase chlorine concentration to 50 mg/L and remove three coupons after 4 hr and 1 day

Hyperchlorination Evaluation Results

%P on Concrete



%P on PVC



- Hyperchlorination on concrete shows steady decline over time and increasing chlorine concentration
- 30% of Bg persists on PVC after treatment with 25 and 50 mg/L chlorine
- PVC HE %P similar to WECE %P indicating lack of efficacy of chlorine on Bg

Summary of Results

- ✓ Persistence and flushing evaluation suggest effective decontamination with flowing water for *Bg*
- ✓ Water exposure control evaluation with no flow demonstrated higher persistence of *Bg* than flushing evaluation
- ✓ Hyperchlorination effective on concrete, but uncertainties too high to make determination on PVC

Possible Next Steps

- ✓ Study of the importance of biofilm in decontamination
- ✓ Use of pipe harvested from underground use
- ✓ Additional biological organisms
- ✓ Additional chemicals on concrete and PVC
  - ➢ Organophosphates as available toxic pesticides and simulated chemical agents
  - ➢ Metals to simulate RAD
- ✓ Additional pipe materials
- ✓ Additional pipe cleaning chemicals
- ✓ Comparison with experimental design without flow

- ✓ Work performed by Battelle for U.S. EPA National Homeland Security Research Center
- ✓ Contract No. EP-C-10-001 Work Assignment 1-16

- ✓ Any opinions expressed in this report are those of the authors and do not, necessarily, reflect the official positions and policies of the U.S. EPA. Any mention of products or trade names does not constitute recommendation for use by the U.S. EPA.

Bacillus anthracis Decon Wastewater Inactivation Protocols

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USPHS & USEPA-Environmental Response Team
Vicente Gallardo
National Homeland Security Research Center, USEPA

Acknowledgements

- The Shaw Group, contractor for USEPA
  - Nur Muhammad
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  - Radha Krishnan
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  - Gene Rice, EPA
  - Matthew Magnuson, EPA
  - Dino Mattorano, EPA
  - Frank Schaefer, EPA
  - Blake Velde, USDA
  - Tyler Willis, Endyna (Contractor to USEPA)

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Presentation Outline

- Historical issues with cleanup wastewater from buildings contaminated with *B. anthracis*
- Current recommended method for treating contaminated wastewater
- Results from one study that tested the current recommended method
- Results from one modified method trial
- Future Work

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U.S. Capitol Building Cleanup (2001-2002)

- *B. anthracis* spores in 7 of 26 buildings
- Types of contaminated wastes:
  - **14,235 gallons of BA wastewater**
  - 300,000 lbs Material & Equipment
    - classified material, PPE, medical waste
  - 700 Metal drums
  - 3,200 Bags of critical items
  - 4,000 Mail packages

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14K Gallons of Wastewater

- Wastewater Sources:
  - Personnel decon
  - Equipment/vehicle decon
- Guilt by association
  - i.e., May contain *B. anthracis* spores, maybe not
- Inactivation protocol used
  - Steam sterilization at Fort Detrick, MD and then disposal at on-site treatment plant

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Issues associated with the Inactivation Protocol Used

- 14,000K gallons were steam sterilized
  - Slowwwww process
  - HazMat Handling & Transportation issues!
    - Wastewater transferred from source (e.g., kiddy pool, mop bucket, etc.) and
    - Then transferred to 55 gallon drums and
    - Then transferred to tanker trucks and
    - Then transported to Ft. Detrick, 50+ miles away.

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Current Recommended Method (CRM) for Inactivating B. anthracis in Wastewater

- For a given volume of wastewater
  - Add 10% household bleach & 10% white vinegar by volume
    - Yields a 0.5% Sodium Hypochlorite (NaOCl) solution
    - e.g., 100 gal. wastewater, 10 gal. household bleach & 10 gal. white vinegar = 120 gal. of 0.5% NaOCl solution
    - Household bleach contains 6% NaOCl by volume
  - Allows for on-site treatment
  - Vinegar added to lower pH to ~7
- 1 hour contact time

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"Recipe" Using CRM

- 55 gallon drum: <85% filled, no overflow
- Wastewater amount: 0.7 x 55 = 38.5 gallons
- Bleach amount: 0.07 x 55 = 3.85 gallons
- Vinegar amount: 0.07 x 55 = 3.85 gallons
- Total volume = 46 gallons (83.6% filled)

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Potential Issues with CRM

- Method developed for surfaces, NOT water.
- Method NOT tested for wastewater matrix, which led to the following questions....
  - Is method effective in wastewater?
  - Does particulate or organic matter interfere or diminish chlorine's ability for inactivation?

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What Happened Next?

- Research was conducted to test CRM
  - *B. globigii* selected as a surrogate for *B. anthracis*
  - *B. globigii* spores have been reported to be more resistant to chlorine than *B. anthracis* spores.
  - Analyzed viable spores via culturing

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Outline of Bench Scale Test of CRM

- Wastewater characteristics:
  - Turbidity = 220 NTU (Drinking H_2O ≈ 1 NTU)
  - Chemical Oxygen Demand (COD) = 5,450 mg/L
  - Total Suspended Solids (TSS) = 120 mg/L
  - pH = 9.5
- Wastewater generated by washing floors and cabinets with water and water/detergent mix
  - Water rung out from mops/sponges & collected
  - 1.5 liters of wastewater used per inactivation test

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Results of Bench Scale Test of CRM

- Highly Effective Inactivation
- >99.99% Kill (4 log reduction) in 1 minute

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Conclusions of Bench Scale Test of CRM

- Recommended amount of household bleach (10%) is excessive for 6 log removal (i.e., 99.9999% Kill).
- Recommended method developed for hard and porous surfaces.
  - Spores in water have >> contact with solution. May be the cause of greater/faster inactivation.

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What Happened Next?

- Three modified "recipe" bench scale trials
  - Household bleach @ 1, 3, 5%
  - Eliminated vinegar in all 3 trials
  - Contact time = 30 minutes in all three trials

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Results for 5% Modified "Recipe" Bench Scale Trial

- Inactivation Solution: Added 5% by volume Household Bleach, No White Vinegar and Contact Time = 30 minute
  - 6 log kill in 5 minutes!
  - > 7 log kill in 10 minutes!

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Conclusions from 5% Modified "Recipe" Bench Scale Trial:

- Success with shorter "contact time" would allow for greater volumes of wastewater processed/unit time
- Safer field operations
  - Overdose of vinegar in a bleach solution could yield chlorine gas
  - ↓ HazMat "Handling" issues since procedure can be performed on-site

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Future Work:

- Additional (more challenging) wastewaters
- Additional species of *Bacillus* spores
- Different environmental conditions (e.g., temperatures)

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EPA United States Environmental Protection Agency

Selected Homeland Security Water Treatment and Decontamination Research Projects

Matthew Magnuson, Scott Minamyer, Steve Clark, John Hall, Jeff Szabo
US EPA/NHSRC Water Infrastructure Protection Division

Elena P. Vekhter, Igor E. Pildus, Elena A. Demenkova
Research Institute of Hygiene, Toxicology, and Occupational Pathology, Volgograd, Russia

Ryan James, Elizabeth Hanft, Battelle-Columbus

Office of Research and Development
National Homeland Security Research Center, Cincinnati, Ohio

EPA United States Environmental Protection Agency

Current study

Impact Of Chemical, Biological, and Radiological Contaminated Sediments on Flushing and Decontamination of Drinking Water Storage Facilities

Scott Minamyer, John Hall, Matthew Magnuson, Jeff Szabo
USEPA National Homeland Security Research Center
Water Infrastructure Protection Division

Ryan James, Elizabeth Hanft
Battelle, Columbus

Office of Research and Development/National Homeland Security Research Center

Contaminated Storage Tank Sediment Study

Investigating adherence of contaminants (with a range of adsorptive properties) onto storage tank sediments

- Obtain sediments from water storage facilities at various locations
- Categorize samples by organic, inorganic, and physical characteristics
- Perform bench-scale study to estimate the adsorptive behavior of target contaminants for each sediment group

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Contaminated Storage Tank Sediment Study, Cont.

Provide data on interaction and retention of selected contaminants within storage tank sediments.

- Determine susceptibility to adverse effects of contamination by various types of contaminants
- Plan for impacts on overall treatment and decontamination activities following an event
- Take preventive measures to reduce potential impacts where heightened vulnerabilities exist (such as cleaning tanks more often)

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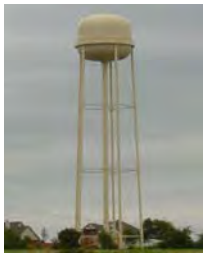
Technical Approach – Sediment Selection

- Water utilities will anonymously provide a total of 10-15 sediment samples



- **Sediment sample analysis:**
  total organic carbon, organic matter, sand, silt, and clay content (grain size), pH, phosphorus, potassium, calcium, magnesium, boron, sulfur, copper, iron, zinc, manganese, cation and anion exchange capacity, etc

- **Likely contaminant selections**: Radiological (non-radioactive cesium), organic (lindane), and biological *(E. coli, Bacillus globigii)*

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Current Study

Investigation of advanced oxidation processes (AOP) for the treatment and disposal of drinking water contaminated with toxic chemicals into public sewer (collection) systems

Stephen Clark, Matthew Magnuson, Scott Minamyer
USEPA National Homeland Security Research Center
Water Infrastructure Protection Division

Ryan James
Battelle, Columbus

Office of Research and Development/National Homeland Security Research Center

Question:
How to deal with large volumes of decon washwater and contaminated water & wastewater?

Answers?
Incinerate Water? Haul thousands/millions/billions of gallons long distances to specialty facility? Drain disposal to local wastewater plant?

Challenge:
Drain disposal requires appropriate pre-treatment and assurance that pre-treated water will not impact wastewater operations and will result in dischargable effluent.

Goal: Procedure that will enable drain disposal for all contaminants

Approach:
- Workshop to discuss and develop adequate assurance for chlorine, ozone, and AOP; i.e., how to test the pre-treated water to make sure the waste water plant can accept it
- Perform AOP experiments and conduct testing of treated water

Advance Oxidation Process (AOP)

- Processes that generate free radicals in large quantities. Radicals can be powerful oxidants, but can be difficult to control and generate.
- Focus on AOP because it is a stronger oxidant than chlorine and ozone, and may more completely break down contaminants, without chlorinated by-products. AOP by-products can be good food for sewer plant microbes.
- Several ways of generating radicals suitable for field application will be investigated: Ozone/UV, ozone/peroxide, UV/persulfate, electrochemical generation, etc.

hydroxyl radical

Miss Moneypenny: Have you got a mission, James?

James Bond: Yes. I am to eliminate all free radicals.

Miss Moneypenny: Ooh. Be careful.

Current study

Persistence and Removal of Chemical Contaminants from Drinking Water Pipes: Application of USEPA's Pipe Decontamination Experimental Design

Elena P. Vekhter, Igor E. Pildus, Elena A. Demenkova
Research Institute of Hygiene, Toxicology, and Occupational Pathology, Volgograd, Russia

Stephen Clark, Matthew Magnuson
USEPA National Homeland Security Research Center
Water Infrastructure Protection Division

Volgograd

USEPA's Pipe Decontamination Experimental Design (PDED)

- **Goal**: Experimental design for realistic studies of persistence and decontamination that can be implemented in reproducible fashion across laboratories and for various contaminants and pipe materials

- **Approach:**
  - Conditions within operational drinking water pipes are simulated in Biosurface Technologies annular reactors (ARs)
  - ARs contain coupons of pipe materials

annular reactor

coupons

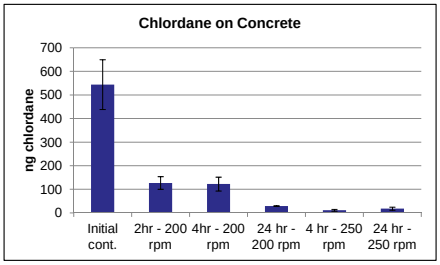
USEPA's Pipe Decontamination Experimental Design (PDED)

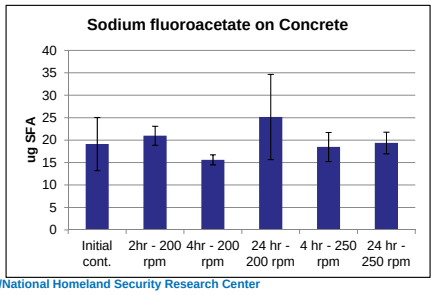
Experimental:

- For realism, biofilm grown on coupons
- Five steps in PDED for each combo of material and contaminant:
  - Validate surface contamination procedure
  - Validate surface extraction methods
  - Examine persistence under normal sheer
  - Examine persistence under flushing sheer
  - Determine efficacy of decontaminant under various sheers

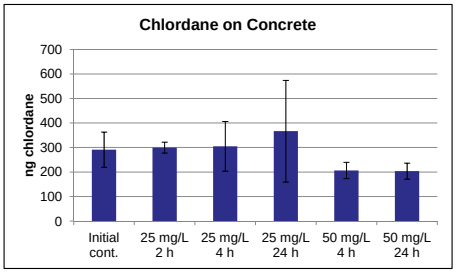
Harversting coupons

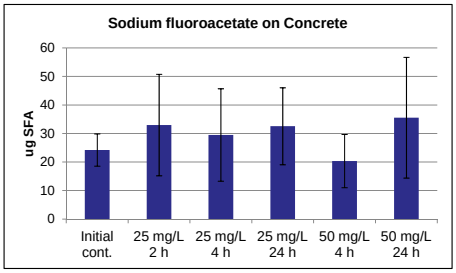
Example Flushing Evaluation Results (reported at 2010 Water Security Congress)





Example Hyperchlorination Results (reported at 2010 Water Security Congress)





RIHTOP USEPA PDED studies (on-going)

- Initial studies by EPA (shown previously) used pipe materials and contaminants with very different adsorption mechanisms (e.g. hydrophobic and ionic).
- RIHTOP studies
  - –Contaminants: arsenic, dichlorvos, disulfoton, and gasoline.
  - –Pipe materials: copper, PVC, cast-iron, and mortar lined ductile iron.
  - –Decontamination methods: flushing and hyperchlorination.
- Status: Method validation, initial AR studies
- Completion: Late 2012

Thank you!

epa.gov/NHSRC

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Office of Research and Development/National Homeland Security Research Center

Application of National Response Team (NRT) Quick Reference Guides (QRGs) to Decontamination

Developed By: ***NRT, Weapons of Mass Destruction (WMD) Subcommittee***
Capt. Colleen Petullo, USPHS, Chair, WMD Subcommitte

Presented By: ***Lawrence Kaelin, Chair, Chemical Workgroup***

Prepared By: ***Matthew Magnuson, Emily Snyder, Lukas Oudejans***

Outline

- What are QRGs?
- What are QRGs not?
- Scope of Decon in QRGs
- Lessons learned from development of QRGs

What are QRG's?

- Developer: U.S. National Response Team via consensus workgroup from Team agencies
- Audience: Federal On Scene Coordinators (DoD, USDA, EPA, etc.)
- Format: Single page – double sided
- Data Sources: Open literature
- Purpose: To provide information needed in the first 24- 48 hours of a response and to prevent activities in first 24-48 hours from harming OSCs and the public or complicating the rest of the site activities

What are QRG's not?

- Not: solely an EPA document
- Not for: general responder community, but may be useful if applied with caution.
- Not to: provide detailed guidance about long-term decontamination planning.
- Not: exhaustive literature review
- Not: replacement for safety plan
- Not: prescriptive and site specific
- Not: a source for site clearance goals.

Contaminants Covered in QRGs

- **Currently posted:**
  - **CWA: lewisite, tabun, sarin, soman, cyclosarin, VX, HD**
  - **Ethanol**
  - **Botulinum toxin**
  - **14 viruses**
  - **Bacteria causing: Anthrax, Plague, Brucella, Glanders, Meliodosis, Q Fever, Tularemia**
- **In review or preparation:**
  - **Updates to current QRG agents except ethanol**
  - **Chlorine**
  - **Methylisocyanate**
  - **Ricin**
  - **Viruses: expanded to include related types**
  - **Bacteria causing Q Fever**

Contents of Quick Reference Guides

- Agent Characteristics
- Release Scenarios
- Health Effects
- Effect Levels
- Personnel Safety
- Field Detection
- Sampling & Analysis
- Decontamination
- Waste Disposal

Example QRG: Sarin (GB)

Agent Characteristics

Release Scenarios

Health effects

Effect Levels

Personnel Safety

Field Detection

Sampling

Analysis

Decontamination Cleanup

Waste Disposal

Key References in separate document

Emphasis on the Decontamination/Cleanup Section

- Previous sections of the QRG are more descriptive in nature
- Decontamination requires the OSC to make site decisions which may effect future site activities and efforts
- Decon/Cleanup section of the QRGs will direct the OSCs' initial efforts

Scope of QRG Decon Section

- Contents of Decon Section
- Difference with traditional clean-up
- Impact of Release Scenario on Decon
- Data Sources
- Gaps in decon data

Contents of Decon/Cleanup Section

- General considerations
- Disposal option
- Monitored natural attenuation
- Fix in place option (when applicable)
- Decon strategy *
  - Surface Hot Spot
  - Large Volumetric Spaces
  - Sensitive Equipment
- Cautions

* For Chem Agents

Scope of QRG Decon Section vs Traditional Cleanup Activities

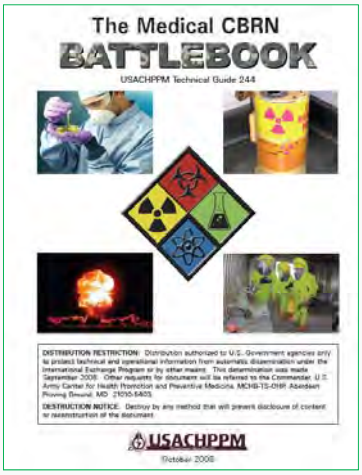
- Decontamination technologies selected in QRG must be widely available (proprietary products mentioned where applicable but not the emphasis)
- Focused on decon for response activities
- Not focused on selecting technologies to get to final cleanup goals
- Designed to prevent activities in first 24-48 hours from complicating the rest of the site activities

Release Scenarios Considered and Impacts on Decon

- Release scenarios included air/aerosolization, soils, surfaces, and water. Decon impacted by
  - Reaesolization, including firefighting
  - Ambient weather relative to agent physical properties
  - Ability of contaminant to accumulate in lower areas of building
  - Persistence of contaminant on surfaces and in water
  - Decon and environmental byproducts, some of which are themselves highly toxic.

Data Sources -- All Public

- Military manuals
- Government reports
- Journal publications (both applied studies and solution based chemistry)
- Difficult to verify some information in all types of sources



Data Gaps for CWAs

- Most Weapons of Mass Destruction decon information not developed for civilian environmental clean-up. Most for military and chem weapons destruction purposes.
  - Tolerance levels for decon efficacy assurances not the same for civilian and military
  - Not all the decon parameters reported or applicable
  - Choice of surfaces different. Most widely available decon methods are damaging to environmental surfaces

Lessons Learned from QRGs

- Each situation is extremely site specific. Use reachback, which was reorganized as result of this QRG development effort.
- Initial activities affect public and worker safety and can seriously influenced later activities.
- Difficult to achieve consensus on application of decon data developed for other purposes to environmental clean-up.
- Clean-up levels do not drive initial decon activities as much as they drive long term remediation activities.
- Role of decon and environmental byproducts in sampling plans not clearly defined.

Website Address for QRGs

http://www.nrt.org

WMD Subcommittee Agency Members

- EPA – NHSRC, NDT, ERT, Region 8
- U.S. Army/DoD
- USDA
- CDC
- FBI
- NOAA
- DHS
- Contractors – Endyna

WMD Subcommittee Workgroup Members

- Colleen Petullo, Deborah McKean, Dino Mattorano, Emily Snyder, Frank Schaefer, Gene Rice, Lawrence Kaelin, Lukas Oudejans, Matthew Magnuson, Philip Campagna, Tyler Willis, Blake Velde, Joselito Ignacio, Kenneth Mioduski, Veronique Hauschild, and James Holler

Lawrence Livermore National Laboratory

Efficacy Evaluation of Liquid and Foam Decontamination Techniques for Chemical Warfare Agents on Indoor Surfaces

Deon Anex, Ellen Raber, Christopher Bailey, M. Leslie Hanna and Adam Love

This work performed under the auspices of the U.S. Department of Energy by Lawrence Livermore National Laboratory under Contract DE-AC52-07NA27344.

Understanding physical and chemical properties of CWA is critical for effective response and recovery

Programmatic Goals:

- Optimize detection capabilities to protect human health
- Mitigate spread of contamination
- Determine most appropriate decontamination methods
- Understand medical countermeasure options
- Allow for attribution and forensics

Scientific Goals:

- Measure critical CWA properties
  - Agent stability
  - Degradation pathways
  - Adsorption, affinity, and surface penetration
- Improve understanding of CWA fate and reactivity
  - Relevant surfaces
  - Solvents
  - Decontamination methods
- Provide data for confirmation of and input to models

Lawrence Livermore National Laboratory

CHEM OTD: An understanding of CWA fate and reactivity guides response and recovery

Agents: HD, GB, GF, VX, GD, others
Indoor surfaces studied:
- Glass
- Silanized glass
- Stainless steel
- Vinyl floor tile
- Latex painted wallboard
- Concrete
- Rubber handrail
- Thermoplastic urethane handrail
- Polyester flexible duct
- Galvanized steel HVAC duct
- Bakelite paneling
- Siliconized acrylic caulk
- Terrazzo tile
- DIA roof material

This work is part of the DHS sponsored "Remediation Guidance for Major Airports after a Chemical Attack"

Develop agent and material specific data to deepen understanding of contamination after a release

Lawrence Livermore National Laboratory

We have evaluated the efficacy of different liquid and foam decontamination techniques on surfaces

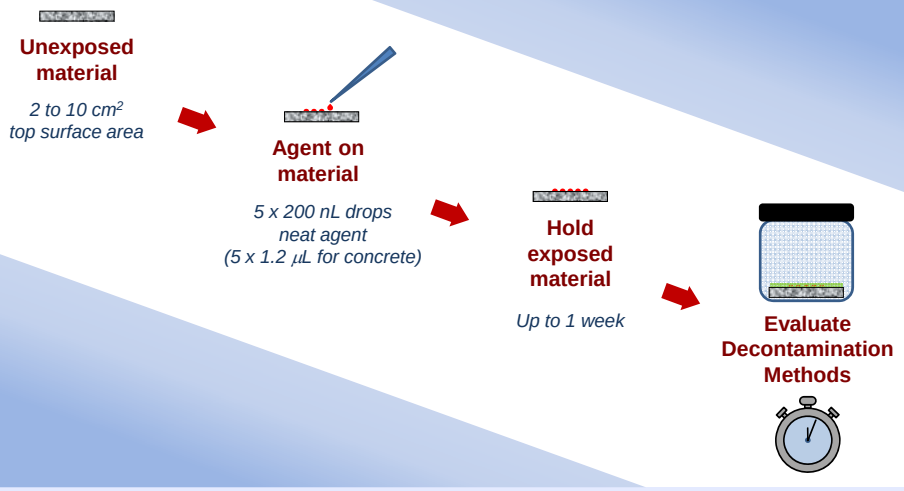
Decontamination agents:
- Diluted bleach (0.5%) plus TSP (0.0625%)
  - Aqueous
  - Sodium hypochlorite
- CASCAD/SDF™ foam
  - Aqueous anionic foam
  - Chlorinating agent
- EasyDECON™ DF200 foam
  - Aqueous foam
  - Hydrogen peroxide
- Decon Green™
  - Solvent based
  - Hydrogen peroxide
  - Non-ionic surfactants

Applied on vertical and horizontal surfaces
Evaluated up to 24 hours after treatment

Suggested clearance goal: 0.3 μg/cm^2

Lawrence Livermore National Laboratory

Experimental: Coupons exposed to droplets of CWA and held before decontamination evaluation



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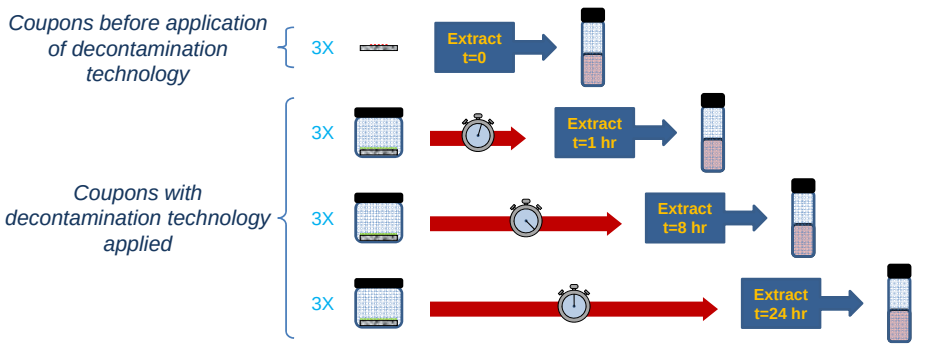
Experimental: Coupons are extracted after variable exposure times to decontamination technology



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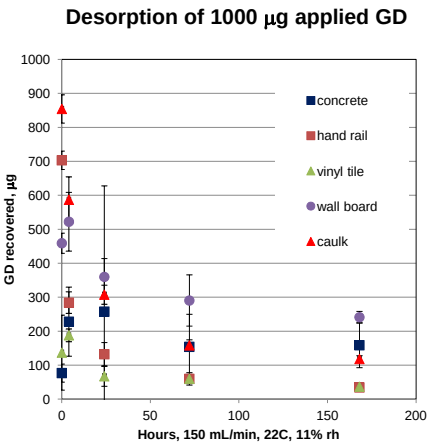
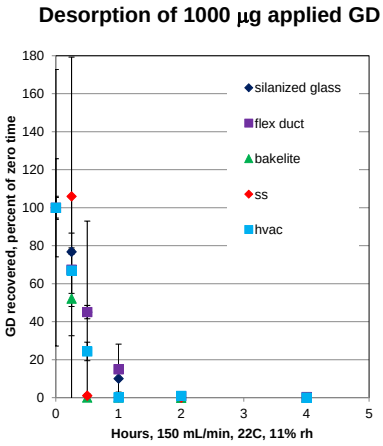
CWA desorption (no decontamination): Liquid agents persist most on organic, porous material





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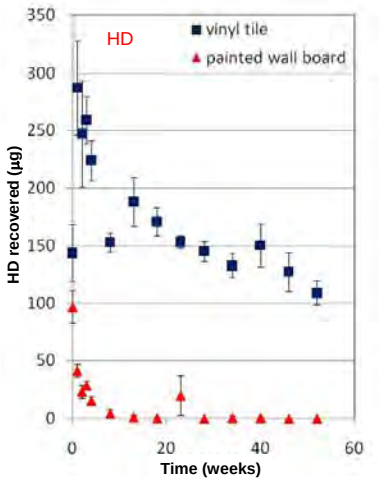
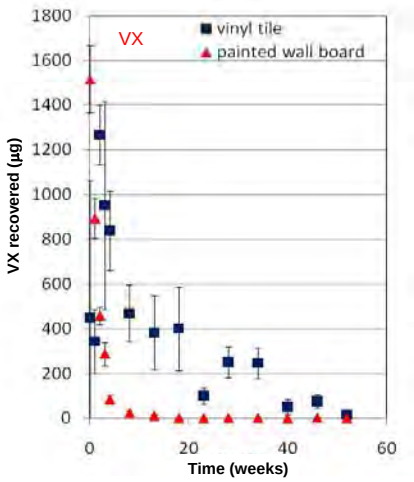
CWA desorption (no decontamination): Agent can persist for over a year on some surfaces





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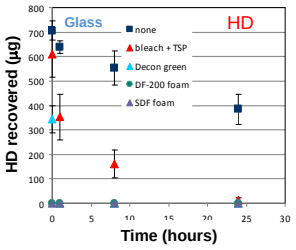
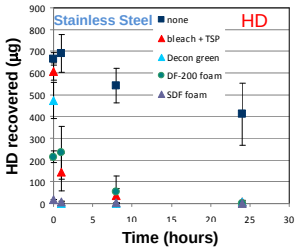
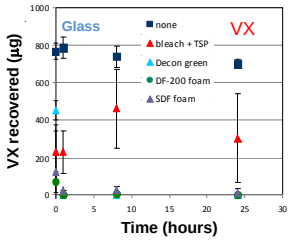
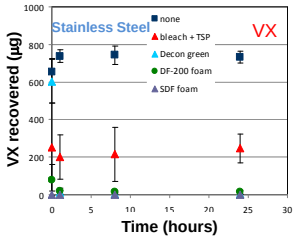
Non-porous materials are readily decontaminated by most methods









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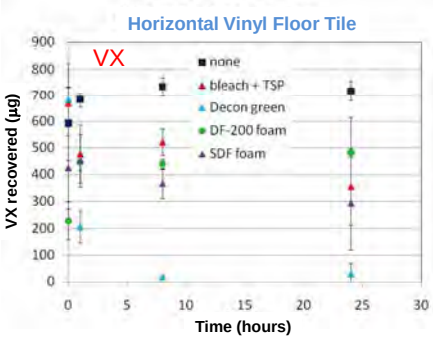
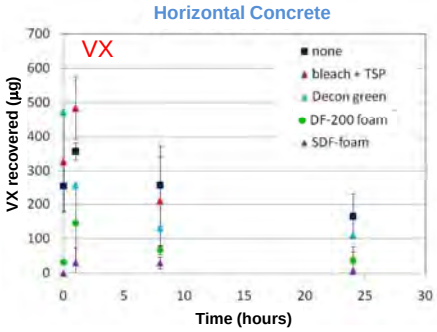
Decontamination efficacy varies on different surfaces





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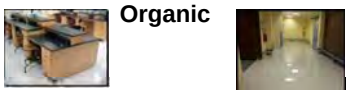
This knowledge of agent/surface interaction drives source reduction and recovery strategies

Non-porous, Non-permeable Inorganic

Least potential for contamination

Non-porous, Non-permeable Organic

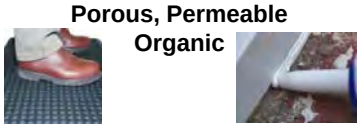


Surface contamination potential

Porous, Permeable Inorganic

Contamination within matrix potential

Porous, Permeable Organic



Bulk contamination potential

See: Efficacy of liquid and foam decontamination technologies for chemical warfare agents on indoor surfaces. J. Hazard. Mater. (2011), doi:10.1016/j.jhazmat.2011.09.005 (in press).

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Follow-on studies include additional materials and decontamination strategies

Extended studies to site specific materials
- Terrazzo tile
- DIA roof material

Expanded list of decontamination technologies:
- Undiluted bleach (5%)
  - Aqueous
  - Sodium hypochlorite
- Oxone
  - Aqueous
  - Potassium peroxysulfate
- Chlorine dioxide
  - Aqueous
  - Sodium Chlorite + acetic acid
- Decon Green
- DF200 foam
- SDF foam

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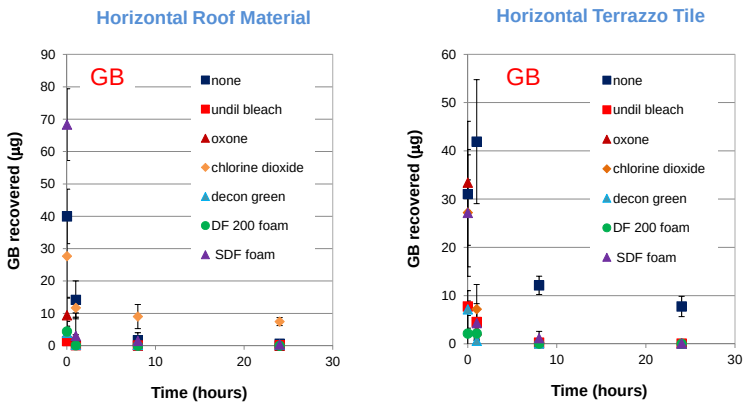
GB decontaminated by all candidate technologies except chlorine dioxide



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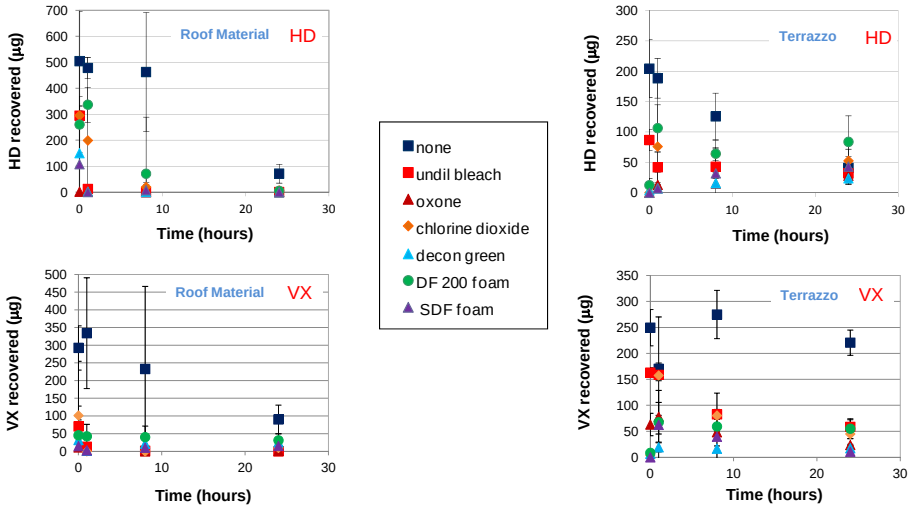
Persistent agents continue to pose a decontamination challenge on porous or permeable surfaces



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Experimental test results guide potential decontamination strategies

- All but diluted bleach work well on non-porous and non-permeable glass and stainless steel
- Residual contamination on porous and permeable surfaces, especially for persistent agents (*e.g.* VX and HD)
- Solvent-based Decon Green performed better than aqueous systems on polymers
- Bleach and foam better for concrete
- Horizontal and vertical surfaces were decontaminated equally well by most reagents



No perfect decontamination technology exists for all materials; a combined approach is likely necessary

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Decontamination efficacy varies relative to clearance goals

- Suggested clearance goal is 0.3 μg/cm^2
  - Developed for persistent agents (VX, HD)
  - 24 hour exposure for a child passenger
- Porous/permeable materials like vinyl floor tile cannot be decontaminated to levels below suggested clearance goals
- Major structural materials can be decontaminated relative to suggested clearance goals
  - Non-porous/non-permeable materials such as stainless steel and glass
  - Concrete with selected decontamination technology



Efficacy relative to clearance goals determines whether material should be decontaminated or removed.

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These studies have enabled better decisions to be made in response to CWA release

- An improved understanding of CWA fate is intended to provide better guidance, not fully predict, contamination dynamics
- First responders phase:
  - Mitigate any subsequent spread of contamination
- Characterization phase:
  - More quickly determine the extent of contamination
- Decontamination phase:
  - Identifying materials that are easily decontaminated and those that should be removed
  - Determine the most appropriate decontamination approach for the contamination scenario and agent/material combination
  - Recommended specific treatment for compounds

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Efficacy of Disinfectants against Vegetative BW Agents and Surrogates

TECHNOLOGY DRIVEN. WARFIGHTER FOCUSED.

Vipin Rastogi[1], Lalena Wallace[1], Lisa Smith[1], Mary Wade[1], Steve Tomasino[2]

1. BioDefense Branch, R&T Directorate, US Army-ECBC, APG, MD
2. US EPA, OPP, Microbiology Lab Branch, Fort Meade, MD

Presentation on November 2, 2011 at 2011 US EPA DRD Conference in RTP, NC

Programatics

Comparative Sensitivity of Pathogenic *Francisella tularensis*, *Brucella melitensis*, and *Yersinia pestis* and their non-pathogenic surrogates to common antimicrobial chemicals using modified AOAC 2008-05

- **IAG**: Dr. Steve Tomasino, EPA, OPP
- **Principal Investigator**: Dr. Vipin Rastogi
- **Sponsoring Agency**: EPA, OPP
- **Performing Agency**: ECBC

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Program Objectives

1. **Provide technical assistance to EPA for surrogate selection for *Yersinia pestis*, *Francisella tularensis*, and *Brucella melitensis* – justify the basis of their selection**
2. **Provide information on proper ID of pathogens and their surrogates**
3. **Provide information on culture, growth, and maintenance of pathogens and surrogates**
4. **Procure the organisms from authentic sources**
5. **Develop procedures for initiating, maintaining, and storage of the pathogens and surrogates**
6. **Conduct and optimize, if necessary, carrier counts with each organism based on a research study provided by EPA, using the modified AOAC 2008-05 Quantitative Test Method**
7. **Perform comparative efficacy testing of common disinfectants against select vegetative BW agents and their surrogates**

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Test Method and Modifications

- **Modified AOAC 2008-05**
  - Use of Dey-Engley neutralization broth for neutralization,
  - Drying time shortened to 60 minutes (visibly dry)
  - Use of 5-mL eppendorf tubes, and the ratio of chemical:neutralizer = 1:10 (0.4 mL decon + 3.6 mL D-E);
  - Fraction A samples, no repeated washing and resuspension; direct plating of 0.4mL
  - Fraction C – incubation time reduced to from 30 to15 min
  - In more recent work, fraction B and C combined in one tube, instead of two tubes

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Vegetative BW Agents/Surrogates

1. *Brucella melitensis* (16M)

- Aerobic, non-motile, gram-negative, non-spore-forming, facultative, intracellular coccobacilli
- Cause of brucellosis, typically leading to abortions in infected animals
- No BSL-2 strains available, therefore *Agrobacterium tumefaciens* was selected as a surrogate

2. *Francisella tularensis* (SchuS4)

- A gram-negative, non-motile, coccobacillus capable of an intracellular pathogen *in vivo*
- Two key species, *F. philomiragia* and *F. tularensis*
- Live vaccine strain (LVS) is a BSL-2 derivative, and selected as a surrogate

3. *Yersinia pestis* (Colorado-92)

- Three out of 11 species of *Yersinia* are pathogenic
- Caused plague and can occur in bubonic, septicemic, and pneumonic form
- *Y. pestis* is gram-negative, coccobacillus (0.5-0.8-μm x 1-3-μm)
- A1122 is a BSL-2 derivative of *Y. pestis*, and was selected as a surrogate

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Agrobacterium for *Brucella*

- **Selected surrogate should be genetically related and physiologically similar to the select agent**
- ***Brucella* is the only genus of the family *Brucellaceae* and belongs to the alpha-2 sub-class of proteobacteria, which includes *Agrobacterium*, *Rickettsia*, *Rhodobacter* and *Rhizobium***
- **Phylogenetically, the closest relative to *Brucella* is *Ochrobactrum anthropi* and *Bartonella quintana* followed by *Agrobacterium tumefaciens* with *B. abortus* being 95.7 and 95.1% similar to *B. quintana* and *A. tumefaciens*, respectively, based on percent similarities between 16S rRNAs**
- ***Ochrobactrum* is an opportunistic human pathogen, and *Bartonella* is classified as BSL-2 and is known to cause disease in humans (cause of trench fever)**
- ***Bartonella* requires a humid, CO_2-rich atmosphere and direct plating onto blood agar and can take several days to weeks before colonies appear on blood agar plates**
- ***Agrobacterium* is a plant pathogen, classified as BSL-1 and does NOT cause disease in humans, and is easy to grow (at 28ºC on TYE agar / broth or nutrient agar / broth)**

•Therefore *Agrobacterium* is recommended to be the most appropriate surrogate!

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LVS for *Francisella*

- ***Francisella*** **is the only genus of the family Francisellaceae and belongs to the γ-subclass of proteobacteria**
- **Based on 16S rRNA gene sequence, there are no close relatives of the Francisellaceae family**
- **Taxonomic classification divides *Francisella* into only 2 species*, F. philomiragia* and *F. tularensis***
- ***F. philomiragia*** **is an opportunistic pathogen often associated with water and is virulent only in immunosuppressed individuals**
- **Four subspecies within *F. tularensis* are genetically and biochemically most related to the etiological agent of tularemia**
- **LVS strain, a non-pathogenic derivative of holarctica – one of the four subspecies - is genetically most related and therefore the most appropriate surrogate!**

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A1122 for *Yersinia*

- **Avirulent strain A1122 (lacking one of the three virulent plasmids, pCad1) is genetically most related to the etiological agent of plague,*Y. pestis***
- **Based on chromosomal DNA sequence, *Y. pseudotuberculosis is* also related to the *Y. pestis***
- **Even though *Y. pseudotuberculosis is related, it is a different species* and causes intestinal infections quite diverse from *Y. pestis***
- **A1122 is derived from *Y. pestis* and is avirulent, and therefore is recommended to be the most appropriate surrogate**

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Summary - Culture Conditions

Microbe	Media	Temp (°C)	Shaking (175 rpm)	Comments
B. melitensis	Brucella broth	35-37	Yes	Single colonies appear after 3-4 days. One 48 hour initial seed culture followed by a final subculture for 48 hours @1/50th dilution
A. tumifaciens	Nutrient broth	28-30	Yes	Single colonies appear after 2 days. One 24-48 hour initial seed culture followed by a final subculture for 24-48 hours @1/50th dilution
Y. pestis/ A1122	Brain-heart infusion broth/ TSA plates	28-30	Yes	Single colonies appear after 2 day growth on TSA plates. One 48 $\pm$ 2 hr initial seed culture followed by a final sub-culture for 48 $\pm$ 2 hr @ 1/50th dilution
F. tularensis/ LVS	Mueller-Hinton media fortified with glucose, isovital-X, ferric pyrophosphate/ Chocolate agar plates	35-37	*Yes*	Single colonies appear after 3-4 days of growth on Chocolate agar plates. One 48 $\pm$ 2 hr initial seed culture followed by a final sub-culture for 48 $\pm$ 2 hr @ 1/50th dilution

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Disinfectants & Treatment

	LOW		HIGH	
Brucella* vs. *Agrobacterium				
• TBQ	1:2560	10 min	1:128	10 min
• Bleach	1:2000	5 min	1:25	5 min
• Cavicide	1:10	3 min	RTU	3 min
***Y. pestis* vs. A1122**				
• Lysol	RTU*	1 min	RTU	10 min
• TBQ	1:2560	10 min	1:128	10 min
***F. tularensis* vs. LVS**				
• TBQ	1:2560	10 min	1:128	10 min
• Bleach	1:2000	5 min	1:25	5 min

* RTU = ready to use

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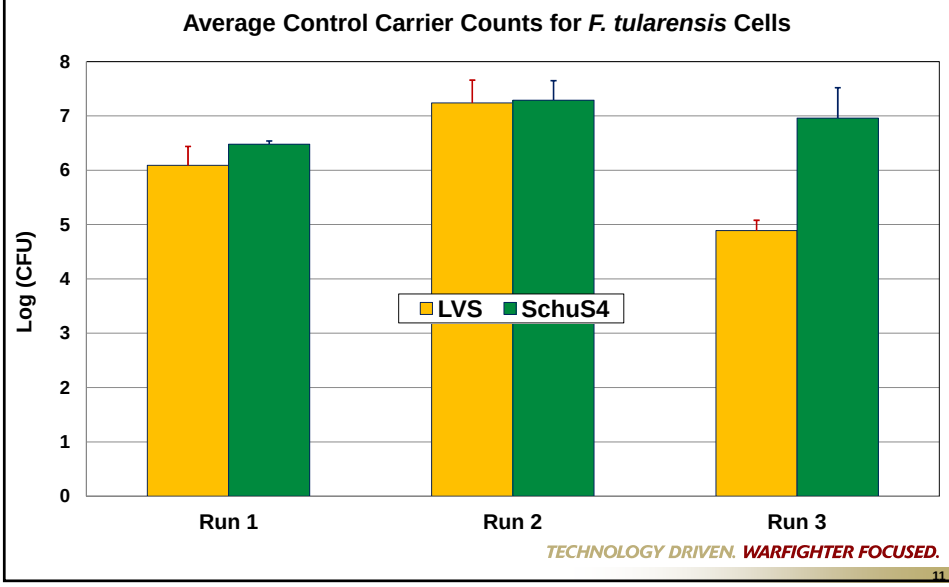
F.t. - Control Carrier Counts



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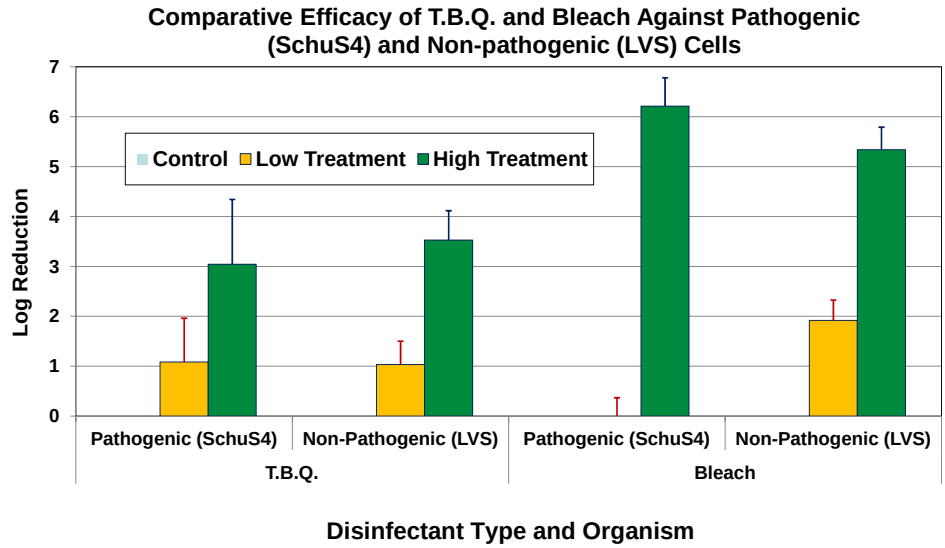
F.t. – Efficacy as LR



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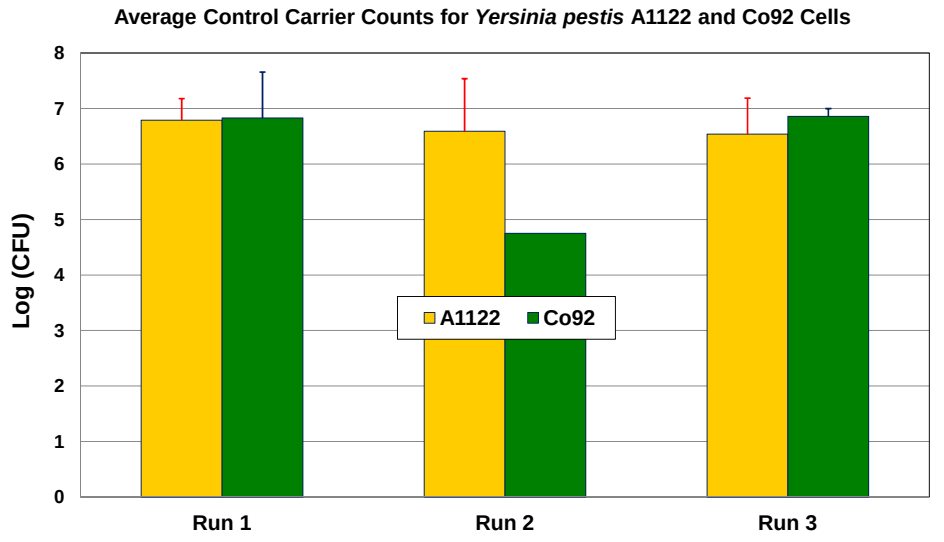
Y.p. - Control Carrier Counts



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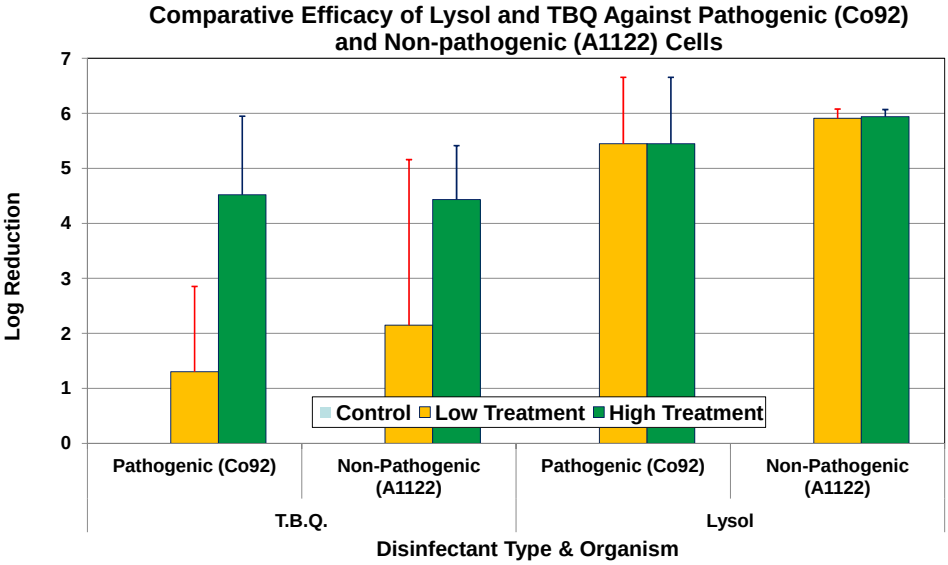
13

Y.p. – Efficacy as LR



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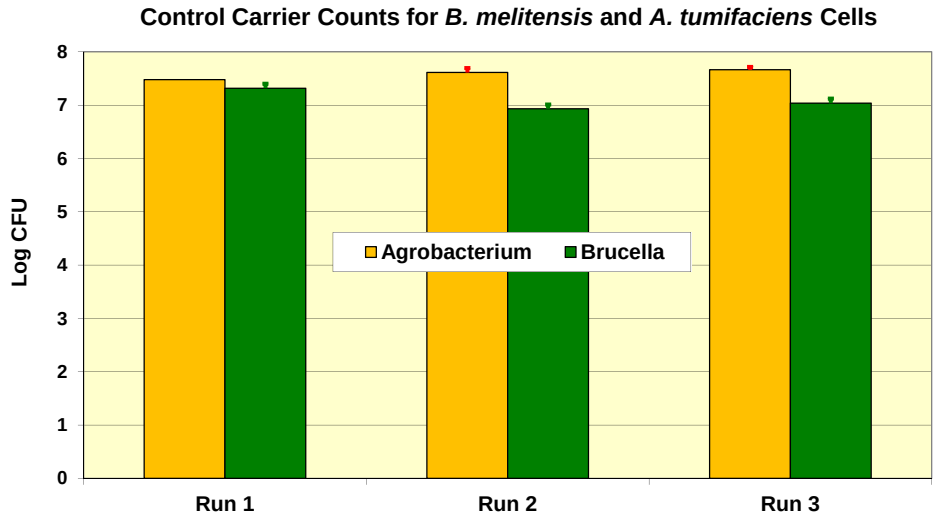
Brucella- Control Carrier Counts



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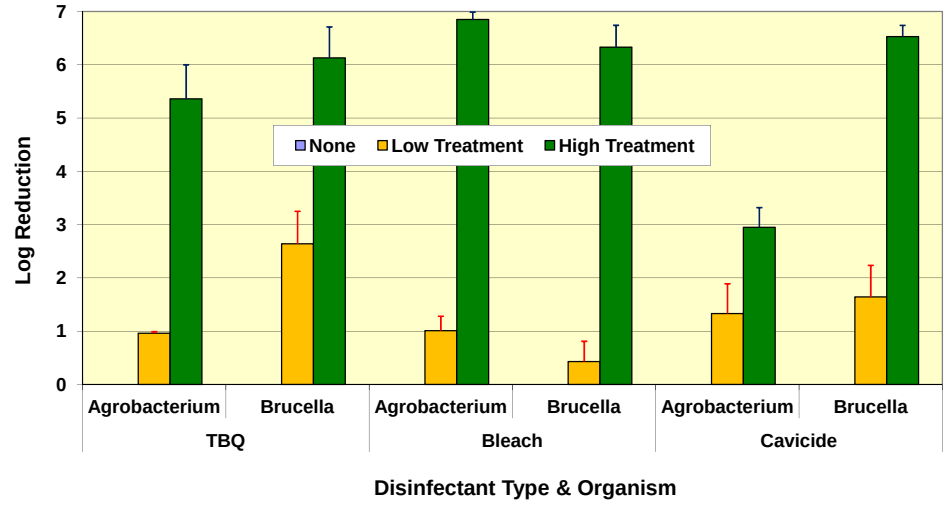
15

Brucella – Efficacy as LR



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Conclusions

1. The quantitative test method, AOAC 2008-05, was found to be suitable for efficacy studies with vegetative BW agents (with minor modifications)
2. Appropriate surrogates for all three BW agents, i.e. *F. tularensis*, *Y. pestis*, and *B. melitensis*, were identified on the basis of phylogenetic and genetic relationships
3. High titer broth cultures for all three agents and their surrogates were successfully grown, enabling testing with vegetative cells
4. Typical losses due to drying ranged between 90 – 99%
5. Control carrier counts for all runs ≥ 5-6 logs, with the exception of LVS in one run and Colarado-92 in one run
6. Ambient RH and temperature are conjectured to be the factors for variable degree of persistence

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Conclusions

7. Overall, with the exception of Lysol, the modified AOAC 2008-05 was able to discriminate between the two treatment levels
8. Based on efficacy results, LR values for all three disinfectants against, *Agrobacterium* appears to a suitable surrogate for *Brucella*
9. LR values for bleach and TBQ against LVS appears to be > than those for pathogen at low treatment level, however, at high treatment level, both strains appear to be equally sensitive, suggesting LVS is an appropriate surrogate for *F. tularensis*
10. LR values for Lysol are high at both treatment levels against both the strains, A1122 and Colorado-92, of *Y. pestis*. With TBQ, low and high treatment levels resulted in differential LR values. Both strains appear to comparable in their sensitivity, suggesting suitability of A1122 as a surrogate for *Y. pestis*
11. TBQ was tested against all six strains, and overall, *Agrobacterium tumefaciens* cells appear to be the most resistant strain to this disinfectant

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Future Work

1. Since surrogate strain used for each of the three BW agents displayed comparable sensitivities to their pathogenic counterparts, future studies can be conducted with the surrogate strains
2. Persistence of vegetative cells appears to be impacted by prevailing temperature/RH, future work is recommended to evaluate the effect of environmental conditions on cell persistence, preferably on both hard and porous surface
3. Further efficacy testing with 4-5 antimicrobial chemicals using two quantitative methods with just one or two surrogates is recommended for generating additional data
4. Genomic approach, i.e. gene expression in response to sub-lethal exposure of antimicrobial chemicals, should be explored for surrogate selection
5. Further investigation using *Agrobacterium* cells is also recommended, since this strain appeared to be most resistant to TBQ
6. Use of porous surface is recommended to generate additional data

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CREDITS

- Program Discussion - Steve Tomasino, EPA
- Helpful Suggestions - Rebecca Pines, EPA
- Technical Assistance - Michelle Ziemski, Joe Insalaco, ECBC

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An investigation into the sources of two inhalation anthrax fatalities associated with African drums

Jimmy Walker
Biosafety Unit
Health Protection Agency

EPA 2nd November 2011

Aims

To give an overview of the two incidents

Discuss decontamination of personnel involved

Describe decontamination of the buildings

How to decontaminate a cat?

Two Investigations

Scottish Borders (2006)

Hackney, London (2008)

Scottish case

50 year old male patient died in south Scotland, July 2006,

Cause of death diagnosed as inhalational anthrax

Man was a musician and wood-carver

Hackney case

34 year old male patient died on the 2nd November 2008

Post mortem was carried out following infection

Man was a musician and made and repaired

African style Djembe drums

Cause of death: sepsis and toxaemia due to inhalation anthrax

Possible source of infection

- Patients made and played animal hide drums
- The main supplier of animal skins reported importing hides from the West Africa including Gambia
- There were possibly other sources of skin but not known to the families

HPA risk assessment:

- The main risk: drum making
- Shaving hair from infected animal skin results in aerosolised anthrax spores that can be inhaled

Epidemiology of anthrax

1981 to 2006: 18 possible cases of cutaneous anthrax in E&W.

Bacteria isolated in only one case

Serological confirmation in another two

The last case of pulmonary anthrax in E&W in 1974:

Linked to bonemeal fertilizer

The previous case was in 1965

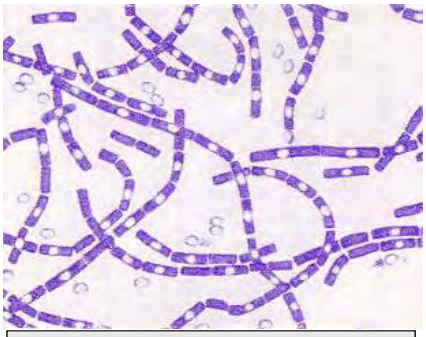
One case of naturally acquired inhalation anthrax in the US in 2006

In a drum maker who used animal skins imported from Ivory Coast

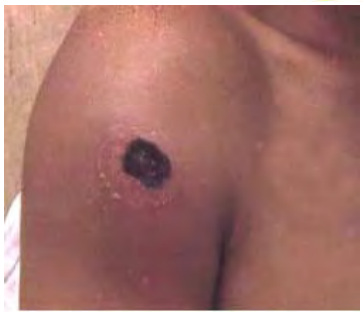
Anthrax – the disease

Bacillus anthracis

large, non-motile, non-haemolytic gram-positive bacillus, forming endospores



Gram-positive, spore-forming rod



Cutaneous anthrax

small papule or vesicle, ulcerates with central necrosis, painless, localized, non-pitting oedema surrounds ulcerated area, black eschar

Anthrax – the disease

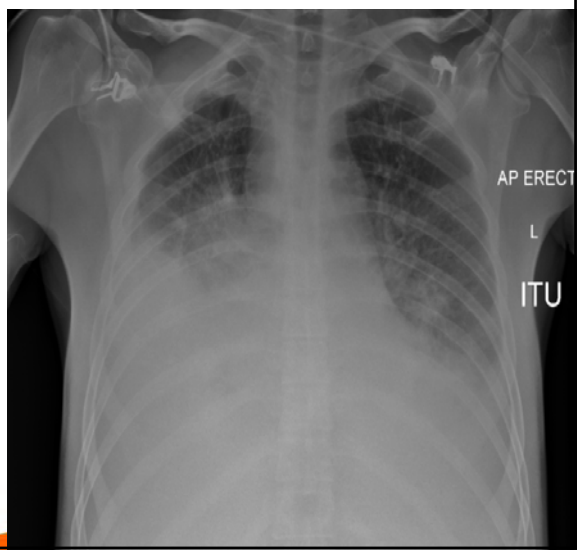
Inhalation anthrax

fever, chills, drenching sweats, cough, dyspnoea, respiratory distress;

CXR: mediastinal widening, pleural effusion

Intestinal anthrax

fever, abdominal tenderness, diarrhoea, ascites, ulceration, haemorrhage, intestinal obstruction, or perforation



Incident Control Team (ICT) Scotland

Health Protection Scotland

Health Protection Agency

- **Porton Down: NADP**
- **Centre for Infection**
- **HPA North East**

Local services

- Lothian and Borders Police
- Fire brigade

Other organisations involved

- Defra,
- Government Decontamination Service
- Health & Safety Executive
- CDC Atlanta
- Sabre, USA
- Steris, Inc

Working sub groups formed:

- Clinical Team
- Epidemiological and Contacts Investigations Team
- Environmental Investigations Team
- Communications and Media team

Incident Control Team (ICT) Hackney

Health Protection Agency

- **Porton Down: NADP**
- **Centre for Infection**

Local services

- **London Borough of Hackney**
- **City and Hackney PCT**
- **Homerton University Hospital**
- **Local Emergency Services**
  - **Fire brigade**
  - **Police**

Other organisations involved

- **Defra,**
- **Government Decontamination Service**
- **Health & Safety Executive**
- **Vet employed to remove Chica the cat!**

Working sub groups formed:

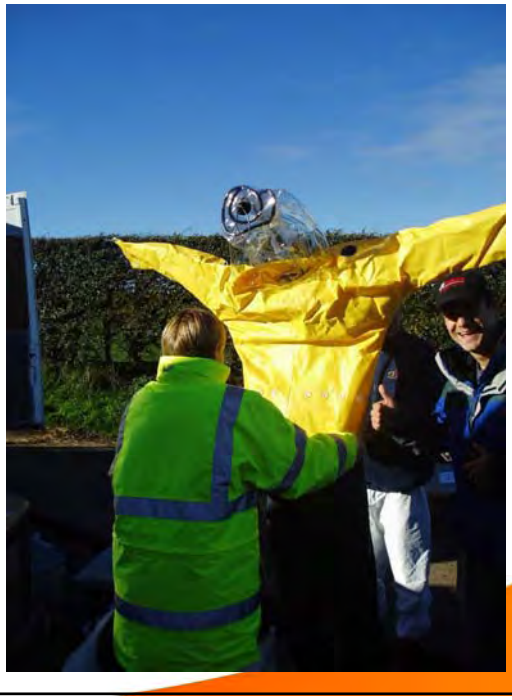
- Clinical Team
- Epidemiological and Contacts Investigations Team
- Environmental Investigations Team
- Communications and Media team

Environmental Site sampling

Environmental testing included visiting a number of properties to sample:

- **Samples from animal skins, drums, tools, surfaces and air at the studio flat**
- **Drums stored at the family home**
- **Animal skins and tools**

Scotland



No Pressure?

Detection of Areas of Contamination

Village homes sealed off in hunt for killer anthrax

The Builder


“Chain of custody” - Coroners Office

Hackney – view of studio flat and Dalston Lane activity

Environmental testing results Hackney

- *B. anthracis* isolated from one drum removed from the studio flat (not related to patient strain)
- Spores also isolated from some sections of 2 out of 5 animal hides found in the studio flat (identical to patients strain)
- All samples taken from family home were negative
- Samples taken from the workshop of the supplier of the animal skins were also negative

Environmental Testing in Scotland

- Strain isolated from patient identical to those isolated from drums
- Spores recovered from the hides not related to strain isolated from patient
- This drum was not made by patient; he bought it approximately 5 years earlier and played it regularly
- Number of samples were PCR positive but culture negative
- No air samples were found to be positive

Decontamination of personnel

On exit of the buildings

Sprayed with 1000 ppm $HClO_2$

Boot bucket 1000 ppm $HClO_2$


Health
Protection
Agency

Decontamination Tent

Decontamination personnel at work

Environmental Decontamination Procedure

A Chlorine Dioxide decontamination company from the US, Sabre, were chosen to carry out the decontamination of all contaminated Scottish sites

Sabre had previously decontaminated government buildings sorting offices and the AMI building in Boca Raton after the 2001 anthrax letters. They had also been active in decontamination of damp affected buildings in New Orleans post-Katrina

Smailholm Village Hall

Problems

Anthrax detected by culture and pcr at a few locations in the village hall (chairs, floor, brooms)

Old building

Leaky

No HVAC systems

Historic wall hanging sensitive to potential bleaching

Scotland in March

Village hall had been in operation for a few months after drumming class

Local opposition

Support Services

Protective Equipment

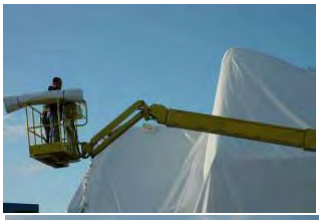
HSE Inspector

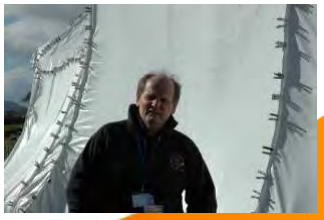
First Tarpaulin

Preparing the Second Layer

Heating required between the tarpaulins in order to control temperature

Securing The Second Layer





Folding, adhesives and heavy duty clips required to secure and seal the tarpaulins

Introducing the Chlorine Dioxide




Press Interest


VILLAGERS' FURY AT ANTHRAX CLEAN-UP

"It's outrageous. There's more poison in the pesticides I bring home in my weekly groceries than there is in that hall."

"Now we've got lots of fat little men in dark glasses who have descended upon this village, strutting about like they're the Mafia"

Outcome

Spore strips to assess effectiveness of process (flown to Utah for assay) - All spore strips negative

Anthrax sampling using swabs and air samplers (assayed at HPA CEPR) - No anthrax detected

Belford

Private residence rented by drum maker and partner

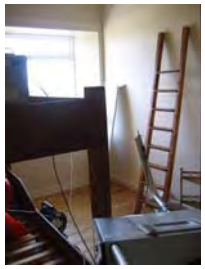
Owned by farmer and located on farm

Anthrax positive drums removed from site

Anthrax positive rug also removed

Belford

VHP®100-P



Indicators and Detectors

Result

Surface Cleaning carried out before gaseous disinfection

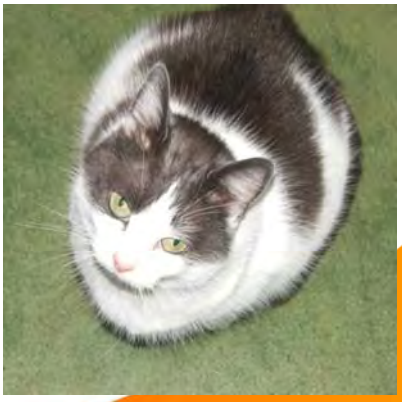
All biological indicators negative

No anthrax positive samples

Bagged material autoclaved

Decontamination of the cat - who did not have anthrax!

- Chica the only occupier of the flat in Hackney after patient's admission
- To carry out sampling and decontamination, Chica was removed
- A vet visited the flat in full PPE, washed and decontaminated Chica
- Transferred to Animal Reception Centre at Heathrow and received 60 days of CONVENIA injections (cefovecin, a third generation cephalosporin given every 14 days)
- She was later adopted by one of HPA staff!



Djembes and Dunduns

Discussion

- Infection most likely due to handling and manipulating the contaminated hides rather than playing contaminated drum
- The source of contaminated animal skins were not found during the investigations
- Despite ongoing import of (untreated and uncertified) animal skins and popularity of animal hide drums the disease incidence in the UK remains very low
- CDC, HPA & HPS linked to revise guidance
- Existing HPA advice to drummers and drum makers can be found on the HPA and Defra's website.

Many thanks to....

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NE&NC London HPU
HPA, Centre for Infection
HPA, London Region
HPA, NADP, Porton Down
City & Hackney PCT
London Borough of Waltham Forest
Defra, Animal Health
HP Scotland and many more
Fire Bridgade
Police
Government Decontamination Service
Health & Safety Executive
CDC Atlanta
Sabre, USA
Steris, Inc

Transfer of BW Surrogate Particles from Contaminated Surfaces

Richard Byers*, Michael Dickens, Kent Hofacre, Steven Medley, and Melanie Samsonow

2011 Decontamination Research and Development Conference
Raleigh Durham, NC
November 2, 2011

*Presenting Author

1

Overview

- Background
- Approach
- Test Results
- Conclusions
- Recommendations

2

Background

- Fielded biological aerosol samplers designed to collect biological threat agents in the air are part of a warning system for safety and public health officials of potential bioterror events
- If a biological threat agent was collected, the collector and surrounding area could be contaminated due to bioaerosol deposition
- Presence and reaerosolization of this contamination could respectively pose a cutaneous and respiratory hazard to the technician maintaining the aerosol sampler
- Contaminated technician may then serve as a source for cross-contamination to clean areas that are subsequently visited
  - In addition to cross-contamination, contaminated individual may pose a hazard to others in the area via resuspension of particles

3

Objectives

- The key objectives of this study were
  - To assess and characterize the transfer of deposited BW surrogate particles from contaminated surfaces
  - To asses and characterize reaerosolization of deposited BW surrogate particles due to human activity
  - To estimate secondary airborne inhalation hazard and potential cross-contamination associated with physical contact with contaminated surfaces

4

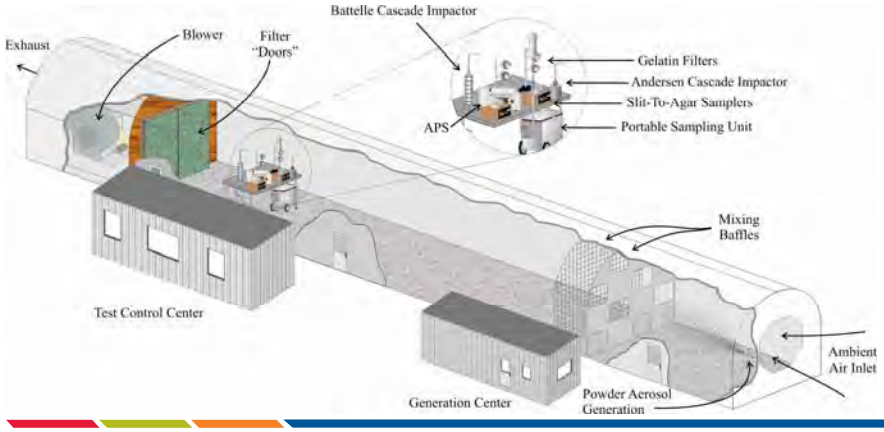
Approach - Overview

- Generate a bioaerosol to contaminate test site with *B. thuringiensis*
- Phase I
  - Characterize the transfer from a contaminated site to an individual through:
    - Contact
    - Reaerosolization
- Phase II
  - Characterize the transfer from a contaminated individual:
    - Via contact to previously clean areas
    - Via reaerosolization

5

Approach

- Generate a powder aerosol of DiPel® containing *B. thuringiensis* subsp. *kurstaki* in the Ambient Breeze Tunnel (ABT)
- Generate 10 grams of powder over one minute, collect samples of the bioaerosol, allow the particles to settle over 10 minutes, then enter the chamber and perform specific tasks



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Approach

- Aerosol generation performed with a venturi eductor
- Aerosol samplers included gelatin filters, Slit-To-Agar samplers, a Portable Sampling Unit, an Andersen Cascade Impactor, a Battelle Cascade Impactor, and an Aerodynamic Particle Sizer

Aerosol generation in the ABT

Aerosol sampling in the ABT

7

Approach – Phase I

- A test operator had 3in. x 3in. swatches of material affixed to 11 locations
  - Swatches were cotton, denim, latex and rubber
- Test operator entered the ABT and performed routine maintenance on the Portable Sampling Unit
- During the 3.5 minutes of activity, 9 of the 11 swatches made physical contact with contaminated surfaces
  - Ankle swatches did not contact any surface
- Aerosol samplers were activated to collect particles reaerosolized as a result of the activities
- Swatches and bioaerosol reference materials were analyzed to quantify initial transfer of contaminant to test operator through contact and via reaerosolization

8

Approach – Phase II

- After exiting the contaminated test area, the operator entered a clean area representing a laboratory and office complex
- The operator performed routine, standardized tasks, with both active and passive samplers used to sample the air and surfaces (floor tiles, desktops and carpet) for the biomaterial transferred

9

Approach – Phase II

- After ABT contamination, operator walked through the test trailer
  - Swipe sample locations and bioaerosol collectors were placed throughout the rooms to quantify surface and airborne hazards as the contaminated operator moved through the clean area
  - While air samplers were placed near the areas of greatest activity, surface sample locations were determined using Visual Sample Plan (VSP), a software tool used to select the number and location of samples to ensure high statistical confidence

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Approach – Phase II

- After operator finished walking through the test trailer
  - Swipe samples and bioaerosol collectors were analyzed to quantify surface and airborne hazards

Surface Sampling

STA Plate

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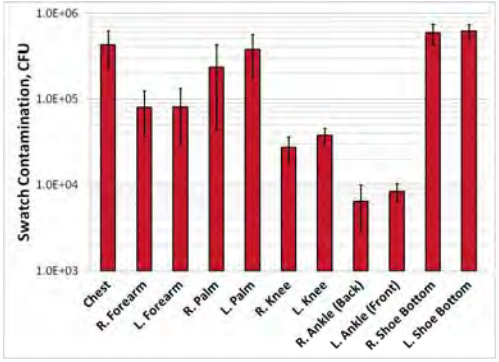
Phase I Test Results

- Average bioaerosol concentration was 2.7E+04 CFU/L_{AIR}
- Swatch Results
  - Average swatch contamination per test was 2.5E+06 CFU
  - Swatches that collected the highest number of spores were affixed to the shoe bottoms
  - Swatches attached to the operator's ankles collected the least
    - Swatches did not contact any contaminated surfaces
    - Implies that spores were reaerosolized by walking and collected on the ankles
  - Hand and chest swatches comparable loading to shoes



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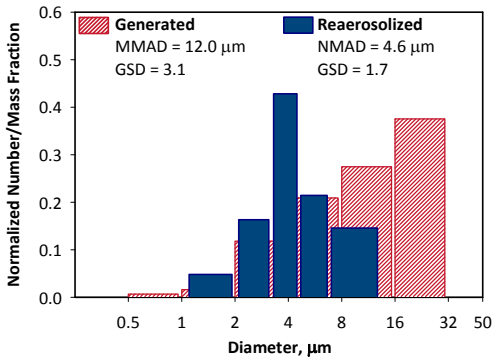
Phase I Test Results Cont'd

- Initial Bioaerosol and Reaerosolization Results
  - Initial powder had a MMAD of 12 μm with a fairly broad distribution, while the reaerosolized particles had a smaller diameter (NMAD = 4.6 μm) and tighter distribution
  - Initial bioaerosol concentration was 2.7E+04 CFU/L_{AIR}
  - Reaerosolized bioaerosol concentration was 3.5E+01 CFU/L_{AIR}



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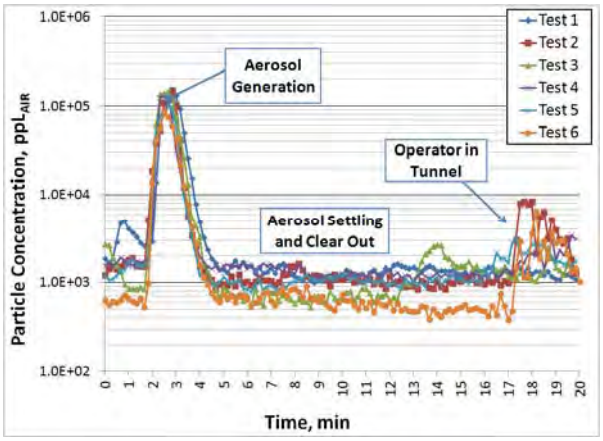
Phase II Test Results

- Initial Bioaerosol and Reaerosolization Results
  - Large initial bioaerosol spike present on APS
  - Reaerosolized particle spike evident



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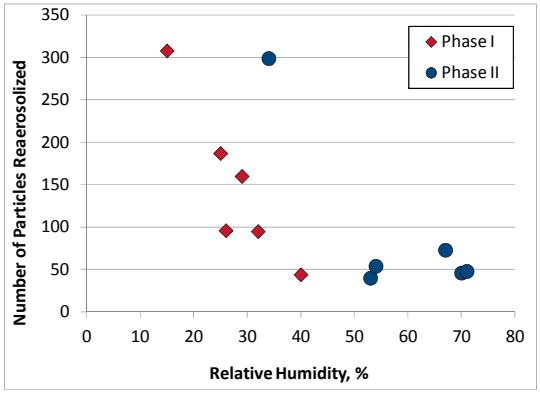
Phase II Test Results

- Reaerosolization Results
  - Differences in relative humidity may have led to different reaerosolization rates between the two test phases
  - Reaerosolization was significantly higher for all tests where the relative humidity was less than 40%
  - With more moisture present in the air, the particles may have more adhesion to surfaces and to each other



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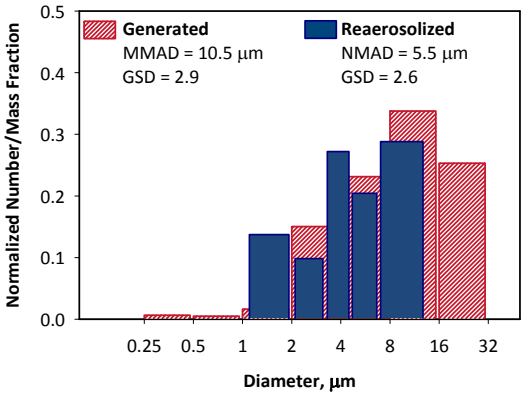
Phase II Test Results Cont'd

- Generated Bioaerosol and Reaerosolization Results
  - Generated bioaerosol had a MMAD of 10.5 µm with a fairly broad distribution, while the reaerosolized particles had a smaller diameter (NMAD = 5.5 µm) and similar distribution
  - Initial bioaerosol concentration was 4.1E+04 CFU/L_{AIR}
  - Reaerosolized bioaerosol concentration was 1.5E+01 CFU/L_{AIR}



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Phase II Test Results Cont'd

- Test results showed surface contamination in each of the rooms visited
  - 123 out of 125 surface samples were positive for Btk spores (both judgmental and random sample locations)
  - Meeting Area Room had the highest level of contamination; majority of the material was sampled from the carpet
  - Surface contamination decreased with each successive room (carpet samples excepted) the contaminated operator entered
- Particle resuspension was detected in each room
  - Carpeted room also had the highest rate of reaerosolization
  - Fewest number of reaerosolized spores in the final (Office) room visited

Secondary Contamination	Surface Contamination, CFU	Reaerosolized Concentration, CFU/L_{AIR}	NMAD, GSD
Room 1 (Lab)	4.8E+04	17	5.8 µm, 2.3
Room 2 (Meeting Area)	1.8E+05	29	4.0 µm, 1.9
Room 3 (Office)	7.8E+02	11	4.1 µm, 2.2

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Phase II Test Results Cont'd

- Two samples were taken from the carpet using a HEPA vacuum
- The first section of carpet contacted had higher Btk contamination, though both were the heavily contaminated
  - Implies many of the particles were removed upon first contact with the carpet
  - The carpet in the room was replaced after each test to eliminate buildup of contamination with each successive test

Room 2 (Meeting Area)		
Carpet Sample 1, CFU/ft^2	Carpet Sample 2, CFU/ft^2	Carpet Total, CFU/ft^2
1.3E+05	4.0E+04	1.7E+05

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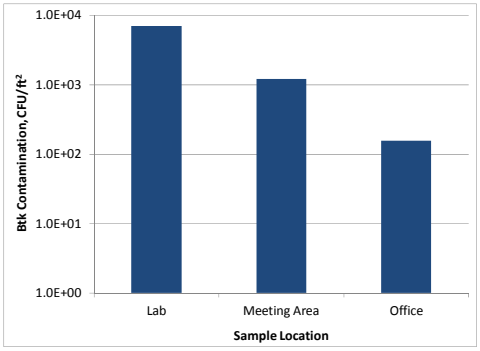
Phase II Test Results Cont'd

- The first room encountered by the operator, the lab, was the most contaminated
- Contamination decreased with each successive room (excluding the carpet contamination)



- Decontamination
  - Surface areas of the trailer were decontaminated using Bleach-Rite® 0.525% sodium hypochlorite spray
  - 20-minute contact time, washed with 70% isopropyl, then rinsed with deionized water
  - Spore removal verified by PCR analysis by the 52nd WMD-CST

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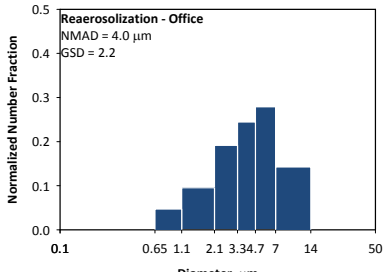
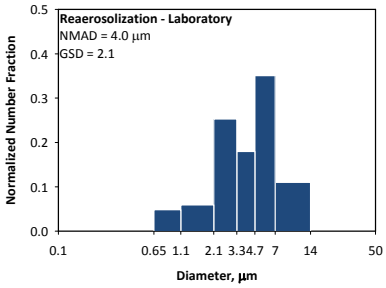
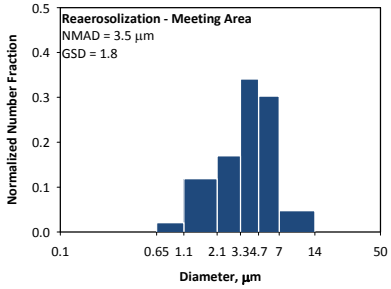
Phase II Test Results Cont'd

- Similar reaerosolized particle size distributions were measured
  - Majority of the particles collected were in the respirable range (taken to be < 10 μm)







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Conclusions

- Biological particles deposited onto surfaces from initial aerosol source can lead to secondary contamination in clean areas and are resuspended via human activity. The test results showed the following:
  - A field operator accessing a site that has been contaminated by a realistic biological aerosol cloud will be exposed to the contaminant; collect the material on clothing, hands, and shoes; and transfer the contaminant to clean areas
  - The relative humidity appeared to affect reaerosolization, with the reaerosolization concentration considerably higher when RH levels were below 40 percent
  - The biological contamination reaerosolized during field operations in both test phases at an average concentration of 24 CFU/L_{AIR} and had an NMAD of 5.5 μm and a GSD of 2.6
  - The biological contamination reaerosolized during laboratory and office operations at an average concentration of 18 CFU/L_{AIR} and had an NMAD of 4.6 μm and a GSD of 2.1
  - Reaerosolized spores were measured in each room the operator entered
  - The highest levels of secondary contamination were found on the carpet, with 75 percent of the particle transfer occurring in the carpet

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Recommendations

- Based upon the results of this study, recommendations are as follows:
  - Mitigation techniques should be researched to protect field operators and prevent transfer of contamination to clean areas
    - N95 masks and disposable shoe covers
  - The effect RH has upon reaerosolization should be studied in depth, as the influence may be significant
  - The transfer of biological particles to, and reaerosolization by, carpet should be further investigated, as this likely led to the highest transfer and reaerosolization
    - Carpet collected high concentration of particles and then was a source of reaerosolization
  - Reaerosolization rates need to be used in exposure models to estimate a threshold clearing level

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Acknowledgements

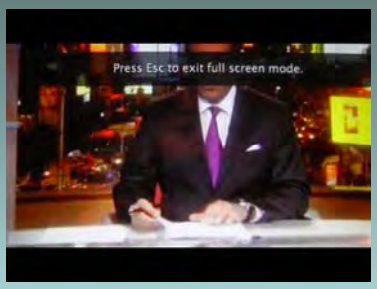
- This was an internally funded study
- The authors wish to acknowledge the Ohio and US EPA, the Ohio Department of Health, the Ohio 52nd WMD-CST, the Ohio Department of Health Laboratory, and the CDC–NIOSH for their generous assistance in conducting this study

23

Cincinnati Malathion Site
Cincinnati, Ohio
November, 2011

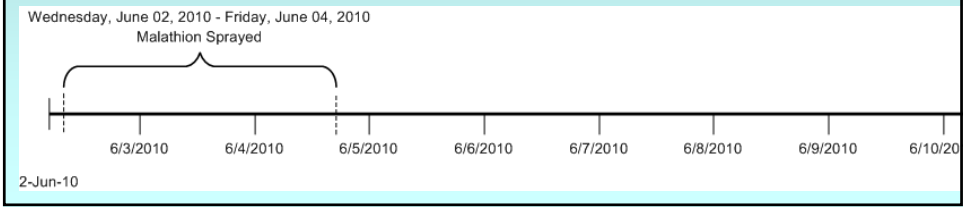
Background

- You Tube Video: 0-1:39
- http://www.youtube.com/watch?v=VYSVByuVTSs&feature=related
- Duplex Rental Property – Apartment in Cincinnati, Ohio
- **2352** and 2254 Warsaw Avenue
- Tenants had a bedbug problem



Background – June 2- 4, 2010

- On June 2, 2010, the Owner hired an unlicensed applicator [UA]) to spray a pesticide to exterminate the bedbug problem
- The UA purchased an insect spray from Home Depot, manufactured by Spectracide and was labeled Malathion (50%) "For Outdoor Use Only"
- June 2, 2010 – UA sprayed AM & PM
  - a few of the tenants began showing symptoms such as headaches, lightheadedness, nausea and severe diarrhea.



Cincinnati Health Department (CHD) & Ohio Department of Agriculture (ODA)

- On June 4, 2010, the tenants reported symptoms to CHD, and were taken to a local hospital where five of the Tenants received 2-PAM4 shots.
- The CHD called ODA who immediately mobilized to the property and collected wipe samples.
- The wipe samples showed Malathion concentrations as high as 7,800 ug on a table and was detected on mattresses in the 500 microgram range.

ATSDR

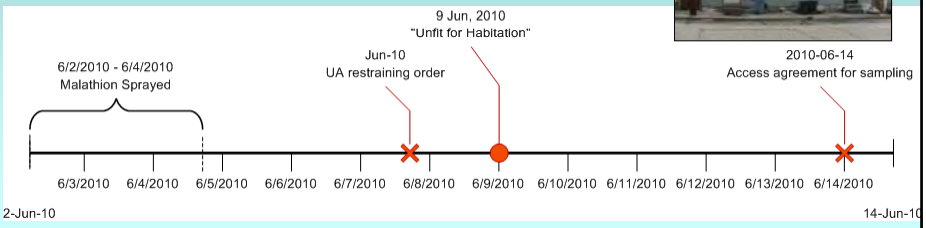
ACTION LEVELS

AIR SAMPLES
Malathion – 20 µg/m³

WIPE SAMPLES
Malathion – 15 µg/100cm²

Background – "Unfit for Human Habitation"

- Cincinnati Fire Department (CFD) submitted a restraining order against the UA
- U.S. EPA OSC, U.S. EPA Pesticide Division, ATSDR, ODA, CHD, City of Cincinnati and the property owner are involved.



Pre-Decontamination Air Sampling results prove 2352 Warsaw had air levels above ATSDR action level

- 8-hr PUF air sample, Isomalathion and the malathion oxygen analog were also analyzed as breakdown *p*roducts (no detections).
  - PUF air samples were analyzed by the ODA Laboratory,
- 8-hr SUMMA canister air sample to evaluate VOCs (no detections)
  - Method TO-15 analysis
- 2352 Warsaw: baby's room had a Malathion concentration of 24.58 µg/m^3 (highest)
- 2354 Warsaw: master bedroom had a Malathion concentration of 9.63 µg/m^3 (highest)

ATSDR Air Action Level: 20 µg/m^3

Pre-Decontamination #1 – Wipe Sampling Results Prove 2354 Warsaw had surface values above the ATSDR action level

- The wipe sampling media, media charging agent and the 100 cm^2 templates were supplied by ODA.
  - Wipe samples were collected (baseboards, walls and various heights, countertops, appliances and the hardwood or linoleum flooring).
  - All wipe samples were analyzed by the ODA Laboratory, Reynoldsburg, OH
  - Isomalathion and the malathion oxygen analog were also analyzed – no detections
- 2352 Warsaw: 10/23 wipe samples showed a Malathion detection 8.16 µg/cm^2 (highest).
- 2354 Warsaw: 10/17 wipe samples showed a Malathion detection of 56.3 µg/cm^2 (highest).
  - **ATSDR Wipe Action Level: 15 µg/cm^2**

Decontamination #1 – Property Owner

- July 28, 2010, local environmental company hired by owner and mobilized and conducted the following in both apartments:
  - Filled three 20-yd^3 rolloffs with porous items from both units (furniture, carpet, clothes, etc)
  - Sprayed and wiped down walls and floors and non-porous items with bleach solution

Post Decontamination #1 - Air Sampling Results Suggest Success

August 2010:

All 6 PUF air samples showed Malathion concentrations less than 2.9 µg/m^3, which is less than the 20 µg/m^3 action level.

Air samples also showed non-detect for isomalathion and the malathion oxygen analog

Post Decontamination #1 – Wipe Sampling Results Prove Surface Contamination Remains Elevated

EPA collected 3 samples from 2352 Warsaw (August 2010).

ODA wipe sample analytical results in µg/100cm^2

- Master Bedroom (floor): **262.5 / 1.35 / 24.85**
- Living Room (baseboard): **64.1 / non detect / 0.696**
- Master Bedroom (baseboard): **371 / 18.1 /11**

(Malathion / Isomalathion / Malathion Oxygen Analog)

ATSDR surface wipe action level = 15 µg/100cm²

Property owner has had No Further Action in this unit. Remains vacant & posted in 2011.

EPA OSC requested NDT assistance

Do these contamination levels detected in August, 2010 remain in August 2011?

The **goals** of this decontamination field test (implemented in October 2011) were to

1) Determine if malathion and/or the degradation products remained measurable one year following a bleach decontamination
2) To further evaluate under field conditions a surface wipe media
3) To implement a cost effective and commercially available decontamination approach that achieves clean up values
4) To review the surface clean up values
5) Clear the duplex apartment for reoccupation

NDT Project Objectives

The **objectives** of this decontamination case study are

1) To evaluate the fate and behavior of malathion on indoor surfaces that have previously been decontaminated with a dilute bleach solution.

2) To evaluate the efficiency of a commercially available decontaminating agent that had been shown to be effective on chemical warfare agents (CWAs).

Does Malathion contamination persist at 2252 Warsaw Ave?

The **goals** of this decontamination field test

1. Determine if malathion and/or the degradation products remained measurable one year following a partial decontamination``

August 18, 2011

- 10 wipe samples obtained by EPA and analyzed by ODA
- 20% of samples were five fold over ATSDR action level.
- Results as high as 78 ug/100 cm2

Conclusion: 2010 malathion contamination present in 2011

Goal #2
Surface Wipe Objective:

- Evaluate the surface wipe protocols used compared to those recommended by ORD.
- What is the best approach to sample, how many samples do we need to obtain a representative distribution.
- How can one go into a room and use some approach to obtain a snapshot of information
- State representatives, do targeted sampling. Can we make recommendations for a minimal of how to sample and where to sample.

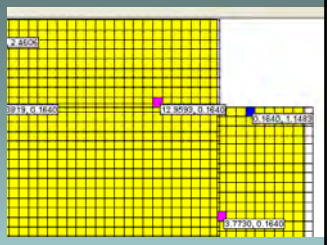
Sample Media – What (Goal #2)

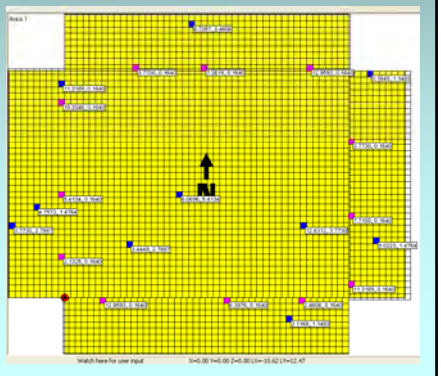
- Special sample media was obtained from ORD
  - Pre-cleaned media
- 2 ml of acetone used to charge media
- 3 step wipe pattern utilized

Sample Media – How? Using Visual Sample Plan

Sampling Design

- Combined Judgemental and Random (CJR)
  - Used to establish a high confidence that a large fraction of the decision area is acceptable-provided that none of the samples are found to be unacceptable
  - To achieve 95% confidence that 95.5% of area is acceptable, using 12 judgement samples, 10 additional grids are required (12X15 area room)





Pre-Decon #2 Sampling

- Pre-Decon Sampling was completed on October 26, 2011.
- 22 floor and baseboard samples collected
- Characterize Pre-Decon #2 extent of contamination (malathion and breakdown products)

Decon Plan (Goal #3)

- Goal was to identify appropriate decon agent that
  - Commercially available
  - Tested for efficacy against CWA
  - Practical
  - Affordable

Decon Agents Considered

Decontaminant	Contact time - efficacy CWA	Contact time - efficacy PESTICIDES	Commercil Availability/Costs
DF-200	8-12 min brush scrubbing >99% for TGD on CARC, composite, and steel (GD, GB, GA). 8-12 min brush scrubbing Poor (removed 60-70% on CARC and composite) (HD). 15 min in solution >99% (VX).		EasyDECON DF200 - 5 Gal Pail Kit $210 . This amount is capable of covering an area in compresses air foam approximately 350 ft² in size. Dispersal is through Macaw Backpack Compressed Air Foam System (~$4,000). Clean up is simple using a wet-dry vacuum and water to rinse away the residue.
CASCAD	30 min ->99% on CARC & alkyd paints		Foam AllanVanGurad 300 gallon: $8076 (~ $27/gal). Small scale decontamination unit is not priced at this time. Defoamer system $6,390.
Decon Green	15 min - >99.9 % on bare aluminum panels	Not tested	Not available
UltraKlean	24 hrs – 93% on polyurethane painted oak, 80% on acrylic painted steel	2	5 gallon ($15.50/gallon)
FlexD		Not tested	Four 5 gallon kits ($11,000)
Fast-Act	Tested by Batelle	Not tested	http://www.nanoscalecorp.com/content.php/chemdecon/fast_act/

Decon Agent Selected

- Sterilix Ultra Kleen was selected for the following reasons:
- Commercially available
- Liquid spray
- Decontamination efficacy has been evaluated for CWAs and organophosphate pesticides
- Used extensively in post hurricane home clean ups for mold
- Used at the 1995 EPA Methyl Parathion residential decontamination (235 residences)
- EPA not endorsing this product

Goal # 4 – Review the ATSDR Surface Clean Up Action Level

Fraction Transferred Model

Exposed skin surface area of 1944 cm2

Proposed Hybrid Model

Skin contact rate (cm2/hr)

Rate of skin contact with a contaminated surface

Surface-specific fraction transferred value (P/NP)

NonPorous = 70 ug/100cm2
Porous = 350 ug/100cm2

Decon

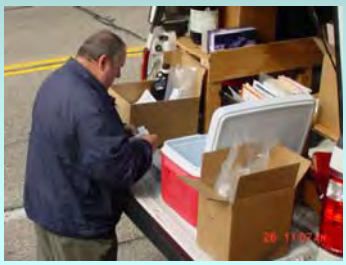
- Gross decon included removing carpet foam padding, dirt and debris removal
- Decontamination was completed on October 31, 2011
- Decon procedures included:
  - 12.8 oz Solution 1 + 12.8 oz Activator up to 1 gallon of tap water
  - Sterilix solution sprayed on walls/baseboards (pre-soak)
  - Scrub with brush
  - 10 minute retention
  - Rinse with water
  - Remove excess with Shop Vac

Post Decon Sampling

- Post Decon Sampling will occur on Nov 3, 2011
- Visual Sample Plan utilized
  - Minor adjustments were made in set up:
  - Judgements samples were relocated
  - A priori probability that a judgement sample would be acceptable increased to 90%

Conclusion..?

The **results** of this case study will be useful to local, state and federal responders (OSCs) and shed valuable information needed for effective remediation of indoor facilities contaminated with organophosphate insecticides.

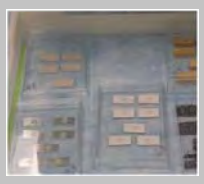


Thank You!

- Tim Anderson and Jim Belt, ODA
- Amy Myrsy, R5
- Dan Stout, ORD
- Emily Snyder, ORD
- Dino Mattorano, NDT
- Larry Kaelin, NDT
- John Wilson, PNNL
- Stephanie Hines, Batelle

Enzymatic Decontamination of CWAs from Building Materials

2011 US EPA Decontamination Research and Development Conference, Research Triangle Park, NC November 02, 2011



Lukas Oudejans

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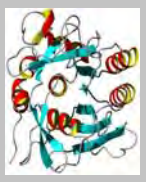
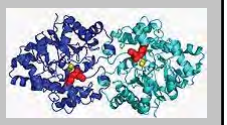
National Homeland Security Research Center
109 TW Alexander Dr
Research Triangle Park, NC 27711





ACKNOWLEDGEMENTS & DISCLAIMER

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Office of Research and Development
National Homeland Security Research Center, Decontamination and Consequence Management Division

Motivation:

➢ Many efficacious CWA decontamination solutions can be detrimental to the underlying material due to their extreme pH values (e.g. bleach at pH = 12.5)

⇔*A need exist for more benign decon methods*

++: Enzymes are efficacious in neutral pH environments.
-- : (Published) Enzyme efficacy data is from stirred reactor research only

Question: How effective are (commercially available) enzyme products when applied to surfaces contaminated with chemical agents?

Significance and Impact

• Assessment of currently available enzyme decon products

❖ How to implement enzymatic decontamination? Are there limitations in its ability to decontaminate (e.g. temperature)?
❖Are there concerns on the shelf life and potlife of these type of products?

This information is (to be) used by
- EPA Special Teams
- EPA On-Scene Coordinators
- DoD

General Experimental Approach

Two commercially available enzymes were evaluated: DEFENZ™ VX-G and DEFENZ™ B-HD

Manufacturer: Genencor, a division of Danisco

Two research efforts conducted in parallel:

1. Efficacy of enzyme product against CWA
   - 5 materials (metal, carpet,wood,laminate,vinyl)
   - Is there (toxic) by-product formation?

2. Engineering control studies using CWA surrogates
   - Effect of T and RH on efficacy (galvanized metal only)

DEFENZ™ VX-G Product:

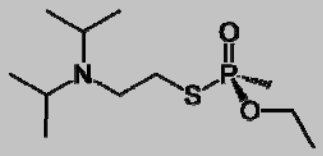
- **DEFENZ™ VX-G** is a blended, buffered (granulated) product that targets G-Agents (GA, GB, GD, GF) and VX.
  - Also includes organophosphate pesticides, paraoxon
- Buffer is Sodium bicarbonate ($NaHCO_3$)
- Composition:
  - DEFENZ™ 120 (OPAA, organophosphorous acid anhydrolase)
  - DEFENZ™ 130 (OPH, organophosphate hydrolase)
  - Sodium bicarbonate ($NaHCO_3$)
- Dissolution is in 10L (2.7 gal) water
  - Dissolution pH = 8.3 (+/- 0.2)

According to vendor….DEFENZ is “non toxic..***non corrosive..***non flammable..easy to use.. ***environmentally friendly***..***highly efficient***..compatible..easy scalable..little or no rinsing.. active in tap, hard, and salt water”

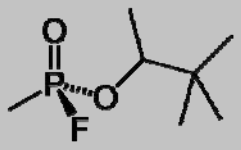
Chemical Agents

DEFENZ™ VX-G

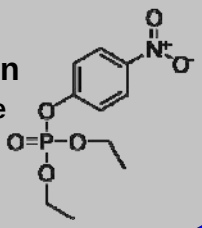
VX



GD

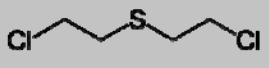


Paraoxon (surrogate G-agents)

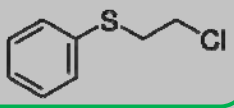


DEFENZ™ B-HD

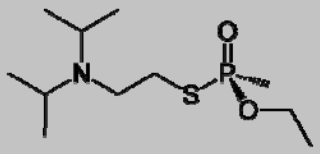
HD



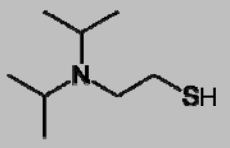
CEPS

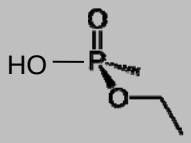


OPH Enzyme Decon of VX:



+ H_2O + DEFENZ™ VX-G →





Diisopropyl aminethyl thiol

EMPA
(Ethyl methylphosphonic acid)

Genencor information:
DEFENZ 130: 1.5 Grams of VX Hydrolyzed in 10 Min/Gram Enzyme

OPAA Hydrolysis of GD / paraoxon:

pinacolyl methylphosphonate

Thickener for GD in this study: 5% acrylic polymer

paraoxon

4-nitrophenol

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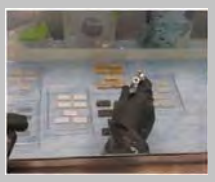
Experimental Method/Approach:

Decontamination of CWA:



1. Apply 1 μL agent on ~ 5 cm^2 surface (~2 g/m^2)
2. Five different materials
3. Positive Controls (5) and test coupons (5) in same environment (hood&covered / glove box)
4. Enzyme solution applied; representative of spray amount (50-100 μL); start of decon time
5. End of decontamination time through extraction of complete coupon in solvent (10 min sonication)
6. GCMS analysis of extract

Decon of surrogate CWA:

1-6 As above *plus*

- RH and T control (5,20,35C; 30/60-80% RH)
- one material (galvanized metal) only

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Experimental Design:

Default interaction time (15 min) and concentration; 5 materials

Choice of 2 materials that are connected to high and low efficacy

Low Efficacy: Improvement with longer time, higher conc?

High Efficacy: Shorter interaction time feasible?

Experimental Results:

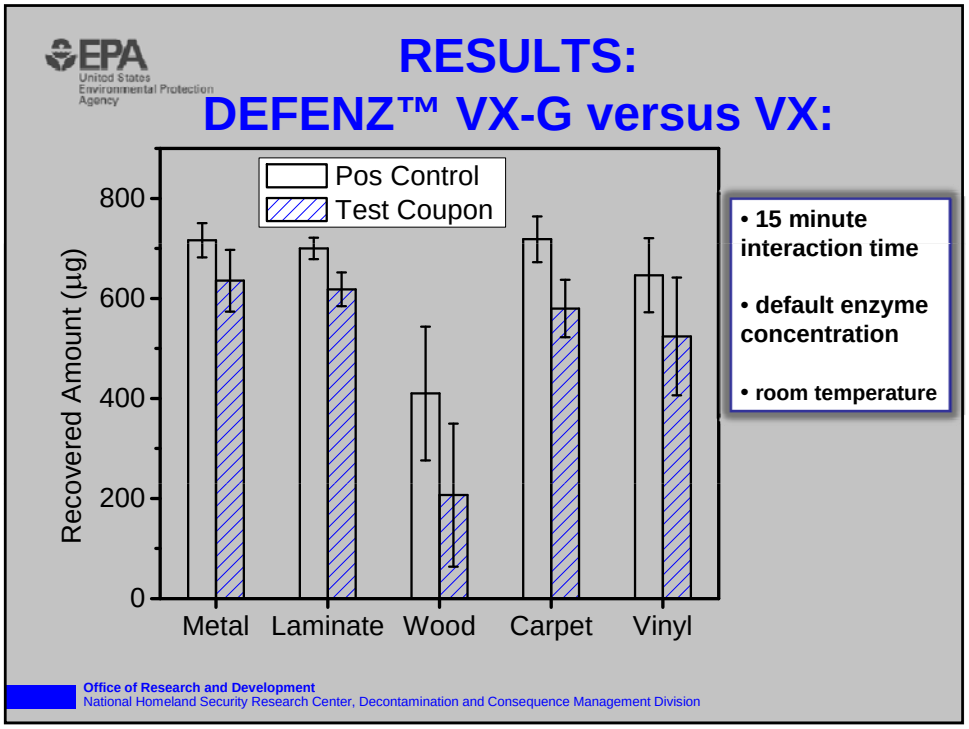
Method Development prior to testing:

- Better than 70% recoveries from all materials for all agents
- Demonstrated the ability to quench enzyme reaction through extraction with solvent (hexane or dichloromethane)

Additional controls:

• Buffer solution (predominantly sodium bicarbonate in water) *without* enzyme present does *not* result in decontamination of the material

• Laboratory blanks and procedural blanks were always negative (no agent present)


EPA
United States Environmental Protection Agency
RESULTS:
DEFENZ™ VX-G versus VX:
Pos Control
Test Coupon
Recovered Amount (µg)
800
600
400
200
0
Metal
Laminate
Wood
Carpet
Vinyl
• 15 minute interaction time
• default enzyme concentration
• room temperature
Office of Research and Development
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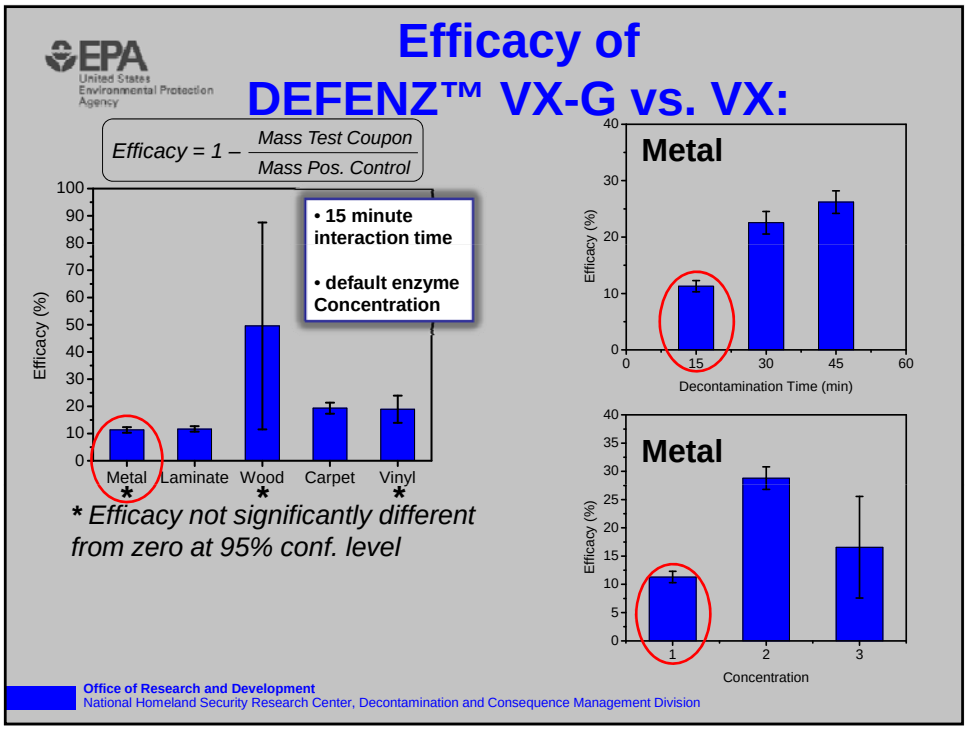
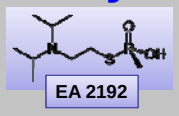

EPA
United States Environmental Protection Agency
Efficacy of
DEFENZ™ VX-G vs. VX:
Efficacy = 1 – Mass Test Coupon / Mass Pos. Control
Efficacy (%)
Metal
Laminate
Wood
Carpet
Vinyl
• 15 minute interaction time
• default enzyme Concentration
* Efficacy not significantly different from zero at 95% conf. level
Metal
Efficacy (%)
Decontamination Time (min)
Metal
Efficacy (%)
Concentration
Office of Research and Development
National Homeland Security Research Center, Decontamination and Consequence Management Division

VX byproduct EA 2192 analysis:

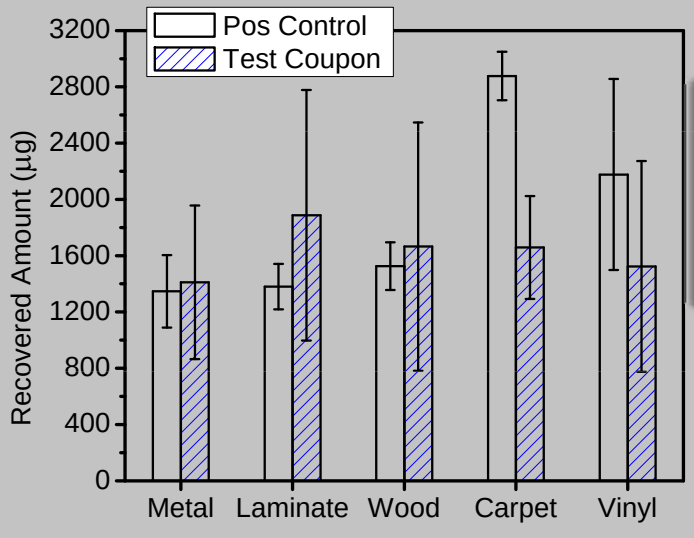


Semi quantitative analysis by LCMS.
(solution testing only; no material present)

- **EA 2192 was present in VX stock (observed in the positive controls).**
- **EA 2192 in positive controls *without* the enzyme present was significantly *more* (63%; Student's t-test p = 0.005)**

⇔No apparent formation of EA 2192 byproduct during enzymatic decontamination; in fact, DEFENZ VX-G appears to be able to decontaminate EA 2192 as well

DEFENZ™ VX-G versus TGD:



- **15 minute interaction time**
- **default enzyme concentration**
- **room temperature**

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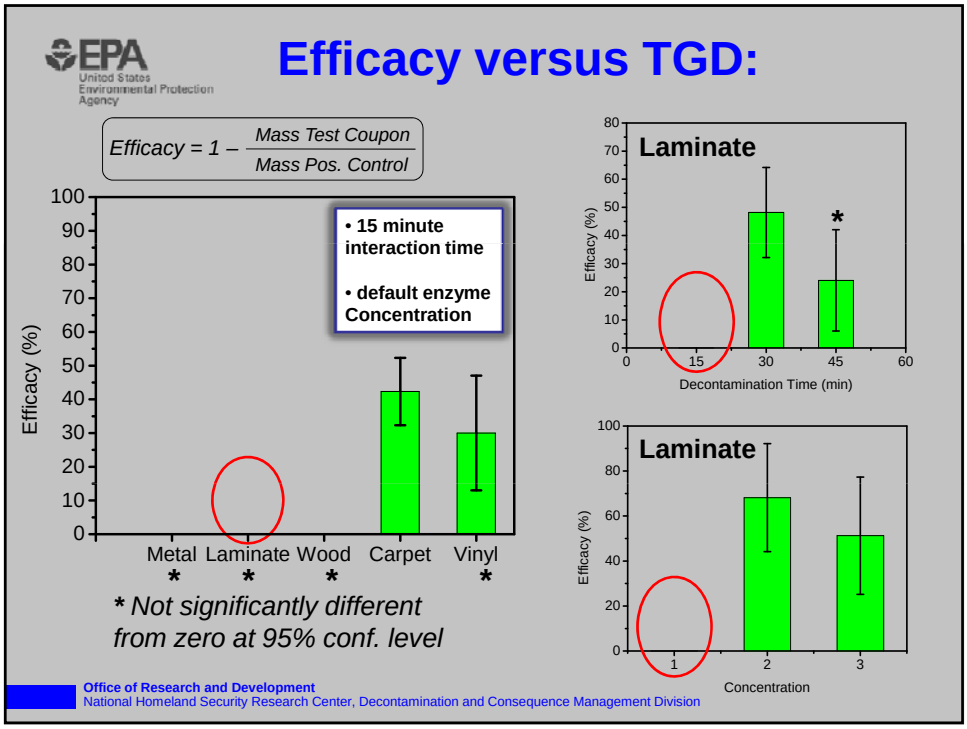
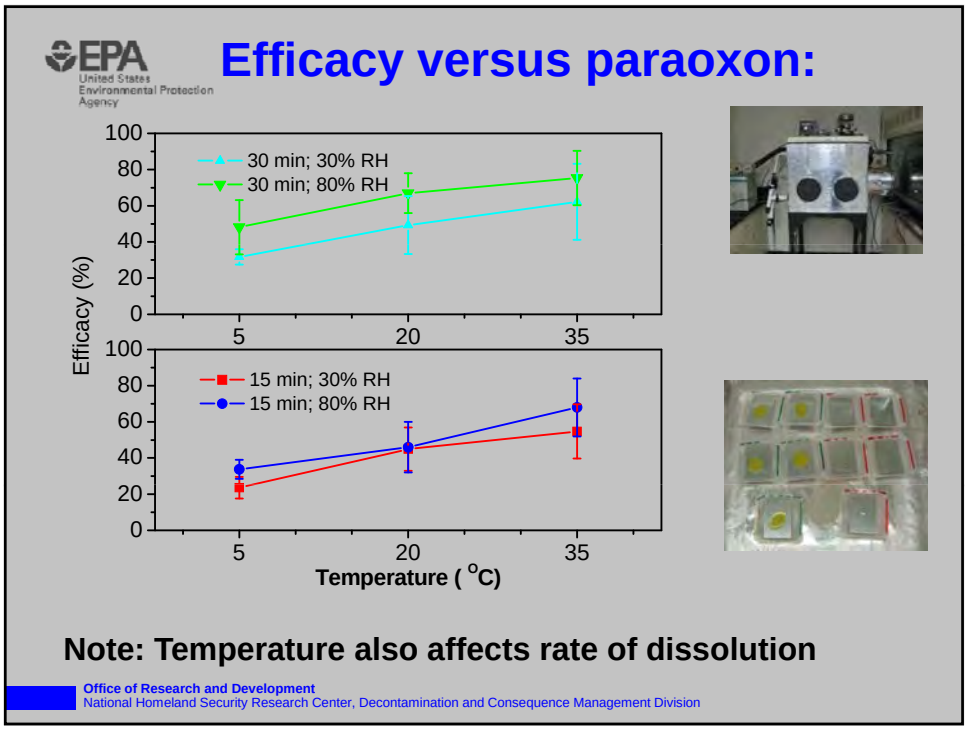
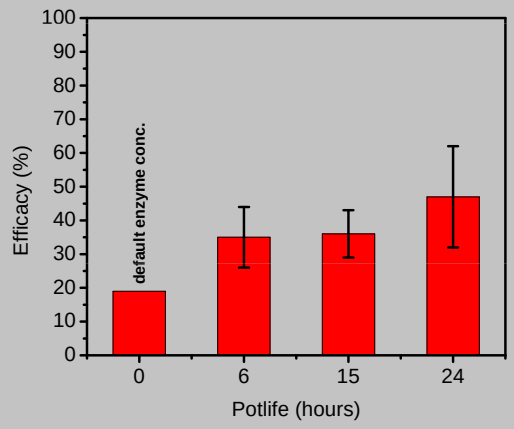

EPA
United States Environmental Protection Agency
Efficacy versus TGD:
Efficacy = 1 – Mass Test Coupon / Mass Pos. Control
• 15 minute interaction time
• default enzyme Concentration
Efficacy (%)
Metal Laminate Wood Carpet Vinyl
* Not significantly different from zero at 95% conf. level
Laminate
Efficacy (%)
Decontamination Time (min)
Laminate
Efficacy (%)
Concentration
Office of Research and Development
National Homeland Security Research Center, Decontamination and Consequence Management Division

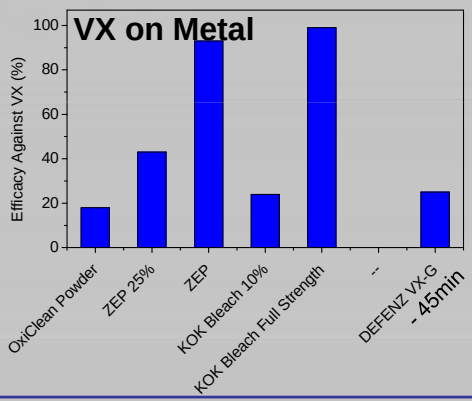

EPA
United States Environmental Protection Agency
Efficacy versus paraoxon:
30 min; 30% RH
30 min; 80% RH
15 min; 30% RH
15 min; 80% RH
Efficacy (%)
Temperature (°C)
Note: Temperature also affects rate of dissolution
Office of Research and Development
National Homeland Security Research Center, Decontamination and Consequence Management Division

Additional Results:

Potlife of DEFENZ VX-G versus VX
(3x default enzyme concentration, carpet):



Comparison with household cleaning solutions:



EPA/600/R-11/055, 2011
Emily Snyder, NHSRC

	pH:
OxiClean® Versatile Stain Remover (1% in water)	**10.5**
Zep® Industrial Purple Cleaner and Degreaser Concentrate	**12.5**
K-O-K® Household Bleach:	**12.5**

Summary

- ❑ DEFENZ™ VX-G shows marginal (for default 15 min interaction time) decontamination efficacy against VX and TGD; modest efficacy against paraoxon
- ❑ Higher efficacy up to ~ 30% observed for higher concentrated solution of DEFENZ VX-G or longer interaction times
- ❑ Results are comparable with (diluted) ZEP or bleach data with advantage of this enzyme product being pH neutral

Comparison with vendor data:

VX and DEFENZ™ 130: "1.5 Grams of VX hydrolyzed in 10 Min/Gram Enzyme"
EXPERIMENTAL WEIGHT RATIO ENZYME over VX: **1.5**

GD and DEFENZ™ 120: "8,525 Grams of GD hydrolyzed in 10 Min/Gram Enzyme"
EXPERIMENTAL WEIGHT RATIO ENZYME over TGD: **834**

Paraoxon&DEFENZ™130: "13,750 Grams of paraoxon hydrolyzed in 10 Min/Gram Enzyme"
EXPERIMENTAL WEIGHT RATIO ENZYME over paraoxon: ***10,793***

There is abundant enzyme available. This would not explain the observed modest efficacies

Summary / Conclusions

EPA United States Environmental Protection Agency

❑ Observed large discrepancy between available stirred reactor efficacy data and data presented here.

May be attributed to limited mass transfer of agent into water/enzyme containing solution
- ➢ A surfactant would help this process
- ➢ Care must be taken not to overwhelm the enzyme

❑ (Vendor) enzyme product evaluations should also include surface decontamination efficacy values rather than only stirred reactor results

Decontamination of Chemical Warfare Agents Using Benign Household Chemicals

TECHNOLOGY DRIVEN. WARFIGHTER FOCUSED.

2011 U.S. EPA Decontamination Research and Development Conference
George W. Wagner, Ph.D.
November 2, 2011

Support provided by DTRA projects BA06DEC016 and BA06DEC052

A Brief History of Hydrogen Peroxide-Based Decon

- **G-Agents:** Larsson, L. "A Kinetic Study of the Reaction of *iso*Propoxy-methyl-phosphoryl Fluoride (Sarin) with Hydrogen Peroxide" *Acta. Chem. Scand.* **1958**, *12*, 723-730.
- **VX:** Yang, Y.-C.; Szafraniec, L. L.; Beaudry, W. T. "Perhydrolysis of Nerve Agent VX" *J. Org. Chem.* **1993**, *58*, 6964-6965.
- **HD:** Drago, R. S.; Frank, K. M.; Wagner, G.; Yang, Y.-C. "Catalytic Activation of Hydrogen Peroxide – A Green Oxidant System" *Proc. 1997 ERDEC Sci. Conf. Chem. Biol. Def. Res.*, pp. 341-342.

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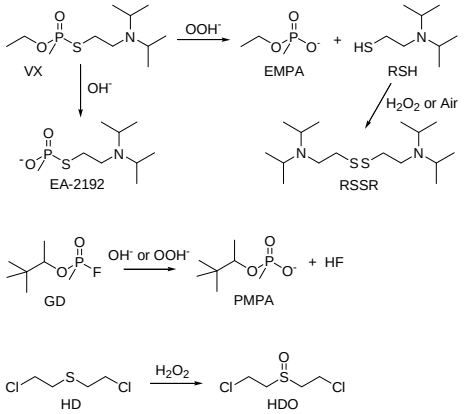
Hydrogen Peroxide Reactions for VX, GD, and HD



- Perhydrolysis (OOH^-) much faster for VX than simple basic hydrolysis (OH^-), avoids formation of toxic EA-2192
- Oxidation of cleaved thiol (RSH) to the disulfide (RSSR) precludes possible reformation of VX
- GD perhydrolysis slightly faster than simple base hydrolysis
- HD oxidized to non-vesicant sulfoxide

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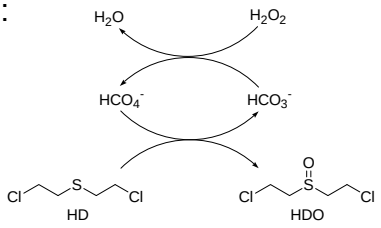
Activation of Hydrogen Peroxide for CWA Decon

- $NaHCO_3$ (baking soda) and Na_2CO_3 (washing soda) effective pH-adjusters to allow perhydrolysis
- $NaHCO_3$ further acts as an oxidation catalyst for HD (faster than H_2O_2 alone):

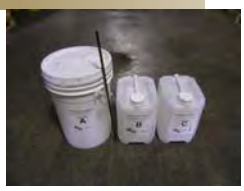


- Co-solvent/surfactant needed to dissolve oily HD

Wagner and Yang "Rapid Nucleophilic/ Oxidative Decontamination of Chemical Warfare Agents" *Ind. Eng. Chem. Res.* **2002**, *41*, 1925-1928.

TECHNOLOGY DRIVEN. WARFIGHTER FOCUSED.

Decon Green® Decontaminant





- Can be deployed at low temp, -32 °C (freezing point of 35 % H_2O_2 is -33 °C)
- Effective against Anthrax (EPA-registered sterilizer)
- Efficacy shown for radioisotope (^{60}Co) removal from difficult surfaces ("dirty bomb" decon)

Wagner, et al. "All-Weather Hydrogen Peroxide-Based Decontamination of Chemical Warfare Agents" *Ind. Eng. Chem. Res.* **2010**, *49*, 3099-3105.

TECHNOLOGY DRIVEN. WARFIGHTER FOCUSED.

Progression of Hydrogen Peroxide-Based Decontaminants

- Early development of Decon Green® used 50 % H_2O_2
- Switch made to 35 % H_2O_2 (50 % banned from air cargo)
- Easy Decon™ DF200 (developed by Sandia National Labs and deployed to Iraq) utilizes 8 % H_2O_2 (less restricted for transportation and air cargo)
- Topical 3 % H_2O_2?

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Foray into Household Chemical Decon

- Development of fumigant decontaminant mVHP® [1] showed the remarkable effectiveness of gaseous ammonia for GD decontamination
- Even ammonia-based cleaners (i.e. window cleaner "Windex") showed good efficacy for GD on surfaces
- Stronger ammonia floor cleaners were better still
- However, such cleaners were not effective for HD or VX (toxic EA-2192 formed, in the absence of hydrogen peroxide)

Time (min)	GD Decontamination			
	Window Cleaner		Floor Cleaner	
	1:50	1:500	1:50	1:500
2	86.6 %	63.0 %	20.5 %	ND
5	70.4 %	33.6 %	1.2 %	
15	57.9 %	17.4 %	ND	

1. Wagner, et al. "Decontamination of VX, GD, and HD on a Surface Using Modified Vaporized Hydrogen Peroxide" *Langmuir* **2007**, *23*, 1178-1186.

TECHNOLOGY DRIVEN. WARFIGHTER FOCUSED.

Need for Household Chemical Decontamination

www.ready.gov

FEMA Chemical Attack Guidance

- Shelter-in-place (duct tape, plastic sheeting, etc.)
- Caution against touching or handling items outside the home that may have been exposed
- Bleach recommended to decontaminate personal items such as eye glasses
- Less-corrosive alternative to bleach is desirable to decon personal property – doors, door knobs, railings, pets, walkways, car, etc.

TECHNOLOGY DRIVEN. WARFIGHTER FOCUSED.

Suitable Household Chemicals for Decon

- Efficacy of baking soda and washing soda activators already known from previous work
- Isopropyl alcohol (rubbing alcohol) known to dissolve HD
- Is topical 3 % hydrogen peroxide of sufficient strength to be efficacious?

TECHNOLOGY DRIVEN. WARFIGHTER FOCUSED.

Other Suitable Household Chemicals for Decon





Agent	Ammonia Floor Cleaner	Topical 3 % H_2O_2	Baking Soda $NaHCO_3$	Washing Soda Na_2CO_3	Rubbing Alcohol 70 % *i*-PrOH	Result
VX	50 vol %	50 vol %	–	–	–	ND 6 min
GD	50 vol %	50 vol %	–	–	–	ND 1 min
HD	–	50 vol %	–	–	50 vol %	$t_{1/2}$ 47 min
HD	–	50 vol %	2 wt %	–	50 vol %	$t_{1/2}$ 10 min
HD	–	50 vol %	5 wt %	–	50 vol %	$t_{1/2}$ 8 min
VX	–	50 vol %	5 wt %	–	50 vol %	49 %, 15 min
GD	–	50 vol %	5 wt %	–	50 vol %	3.5 %, 15 min
VX	–	50 vol %	–	1 wt %	–	ND 4 min
GD	–	50 vol %	–	1 wt %	–	ND 15 min
GD	–	50 vol %	5 wt %	–	–	ND 4 min
VX	–	50 vol %	5 wt %	–	–	31 %, 15 min

TECHNOLOGY DRIVEN. WARFIGHTER FOCUSED.

Other Suitable Household Chemicals for Decon

Agent	Ammonia Floor Cleaner	Topical 3 % H_2O_2	Baking Soda $NaHCO_3$	Washing Soda Na_2CO_3	Rubbing Alcohol 70 % *i*-PrOH	Result
VX	50 vol %	50 vol %	–	–	–	ND 6 min
GD	50 vol %	50 vol %	–	–	–	ND 1 min
HD	–	50 vol %	–	–	50 vol %	$t_{1/2}$ 47 min
HD	–	50 vol %	2 wt %	–	50 vol %	$t_{1/2}$ 10 min
HD	–	50 vol %	5 wt %	–	50 vol %	$t_{1/2}$ 8 min
VX	–	50 vol %	5 wt %	–	50 vol %	49 %, 15 min
GD	–	50 vol %	5 wt %	–	50 vol %	3.5 %, 15 min
VX	–	50 vol %	–	1 wt %	–	ND 4 min
GD	–	50 vol %	–	1 wt %	–	ND 15 min
GD	–	50 vol %	5 wt %	–	–	ND 4 min
VX	–	50 vol %	5 wt %	–	–	31 %, 15 min

TECHNOLOGY DRIVEN. WARFIGHTER FOCUSED.

Other Suitable Household Chemicals for Decon

Agent	Ammonia Floor Cleaner	Topical 3 % H_2O_2	Baking Soda $NaHCO_3$	Washing Soda Na_2CO_3	Rubbing Alcohol 70 % *i*-PrOH	Result
VX	50 vol %	50 vol %	–	–	–	ND 6 min
GD	50 vol %	50 vol %	–	–	–	ND 1 min
HD	–	50 vol %	–	–	50 vol %	$t_{1/2}$ 47 min
HD	–	50 vol %	2 wt %	–	50 vol %	$t_{1/2}$ 10 min
HD	–	50 vol %	5 wt %	–	50 vol %	$t_{1/2}$ 8 min
VX	–	50 vol %	5 wt %	–	50 vol %	49 %, 15 min
GD	–	50 vol %	5 wt %	–	50 vol %	3.5 %, 15 min
VX	–	50 vol %	–	1 wt %	–	ND 4 min
GD	–	50 vol %	–	1 wt %	–	ND 15 min
GD	–	50 vol %	5 wt %	–	–	ND 4 min
VX	–	50 vol %	5 wt %	–	–	31 %, 15 min

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VX	–	50 vol %	5 wt %	–	50 vol %	49 %, 15 min
GD	–	50 vol %	5 wt %	–	50 vol %	3.5 %, 15 min
VX	–	50 vol %	–	1 wt %	–	ND 4 min
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VX	–	50 vol %	5 wt %	–	50 vol %	49 %, 15 min
GD	–	50 vol %	5 wt %	–	50 vol %	3.5 %, 15 min
VX	–	50 vol %	–	1 wt %	–	ND 4 min
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TECHNOLOGY DRIVEN. WARFIGHTER FOCUSED.

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HD	–	50 vol %	–	–	50 vol %	$t_{1/2}$ 47 min
HD	–	50 vol %	2 wt %	–	50 vol %	$t_{1/2}$ 10 min
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GD	–	50 vol %	5 wt %	–	50 vol %	3.5 %, 15 min
VX	–	50 vol %	–	1 wt %	–	ND 4 min
GD	–	50 vol %	–	1 wt %	–	ND 15 min
GD	–	50 vol %	5 wt %	–	–	ND 4 min
VX	–	50 vol %	5 wt %	–	–	31 %, 15 min

TECHNOLOGY DRIVEN. WARFIGHTER FOCUSED.

Best Decontaminants Identified for VX, GD, and HD*

Agent	To Mix One Gallon of Decontamination Solution:
G GB (Sarin), GD (Soman)	Use straight ammonia window or floor cleaner (no mixing needed).
V VX	Stir two (2) level tablespoons washing soda into one (1) gallon topical hydrogen peroxide (3 %) until completely dissolved.
H HD (Mustard)	First stir ¾ level cup baking soda into ½ gallon topical hydrogen peroxide (3 %) until completely dissolved. Then add ½ gallon rubbing alcohol, with stirring.
Universal For G, V, H agents when identity unknown	Use H solution above.

•The views in this presentation are those the speaker and do not reflect the official policy or position of the Department of Army, Department of Defense, or the U.S. Government

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TECHNOLOGY DRIVEN. WARFIGHTER FOCUSED.

Investigation of Hydrogen Peroxide/ Ammonia Fumigation against VX, TGD, HD, and THD on Industrial Carpet, Galvanized Metal, and Vinyl

Harry Stone*, Emily Snyder†, Lukas Oudejans†, James Rogers*, and Autumn Smiley*

*Battelle

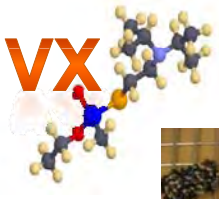
†U.S. EPA, National Homeland Security Research Center

1

Chemical Agents, Materials, and Decontamination Technologies

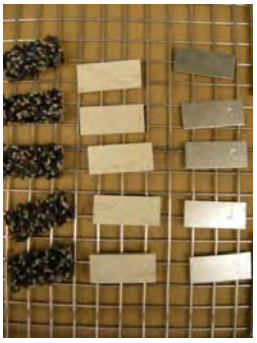
Chemical Agents (Neat with or without Thickener)

- VX
- Thickened soman (TGD)
- Sulfur mustard (HD)
- Thickened sulfur mustard (THD)



Materials

- Industrial grade nylon carpet
- Galvanized metal ductwork
- Vinyl flooring



Fumigant Decontamination Technology

- Hydrogen peroxide (H_2O_2, 250 ppm) / ammonia (NH_3, 16 ppm)

2

Procedure for Efficacy Testing

- Coupons: 1.5 x 3.5 cm
- Thickener: Paraloid K-125™ polymethyl methacrylate, 4.5% weight:volume
- Spike: 2 × 1 µL drops per coupon (thickened - 1 x 2 µL drop per coupon)
- Expose to fumigation
- Extraction:
  - 10 mL hexane
  - shake by hand 5 - 10 sec
  - sonicate (40 - 60 kHz) 10 min

- Quantify chemical agents in extract using GC/MS
- "Efficacy": agent recovered from test (fumigated) coupons is less than that recovered from positive control coupons after natural attenuation for comparable times and temperatures

3

H_2O_2 – NH_3 Fumigation, Mixing, and Control Chambers

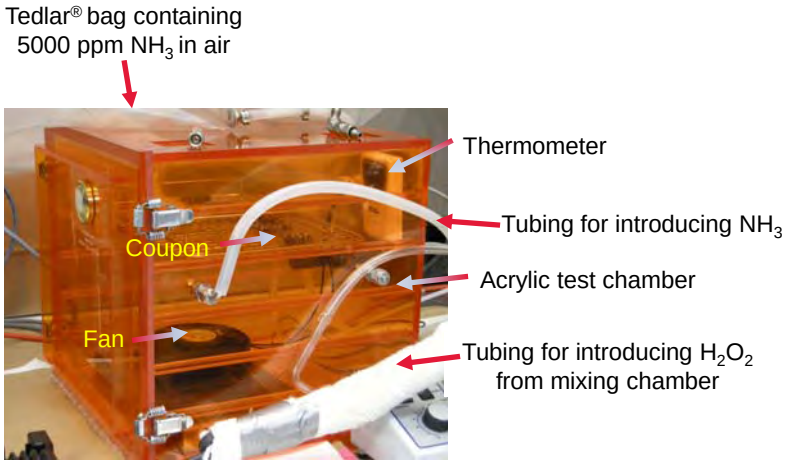
Control Chamber

Fumigation Chamber

Mixing Chamber

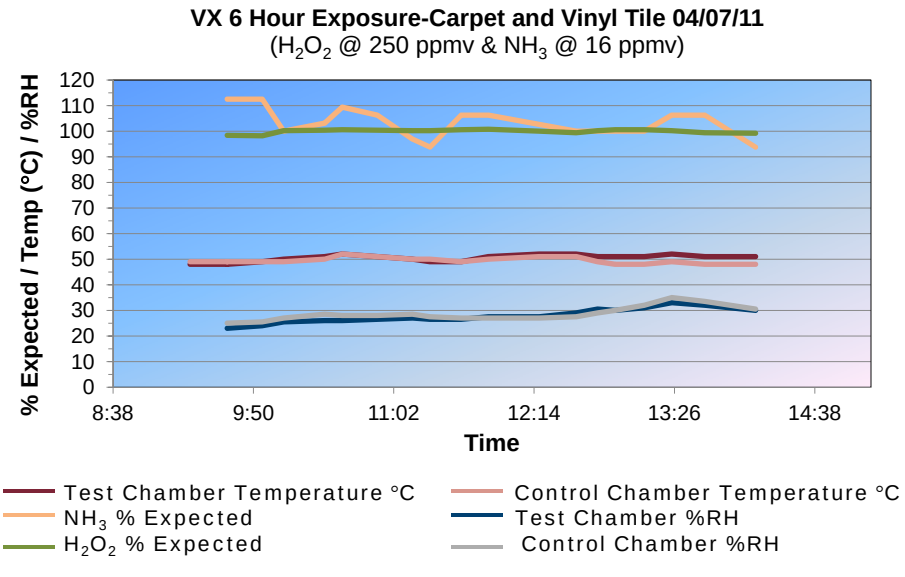
4

H_2O_2 – NH_3 Fumigation Chamber



5

Example of Parameters During Test



6

Fumigation Test Matrix

Agent	Fumigant Concentration	Coupons	Contact Time, hours
VX	H_2O_2: 250 ppmv; NH_3: 16 ppmv	Carpet, Vinyl	2, 7
		Carpet, Metal, Vinyl	4, 6
		Carpet, Metal	8
VX	H_2O_2: 350 ppmv; NH_3: 23 ppmv	Carpet, Metal	4
HD	H_2O_2: 250 ppmv; NH_3: 16 ppmv	Carpet, Vinyl	1, 2
THD	H_2O_2: 250 ppmv; NH_3: 16 ppmv	Carpet, Vinyl	1, 2
TGD	H_2O_2: 250 ppmv; NH_3: 16 ppmv	Carpet, Vinyl	0.5, 2

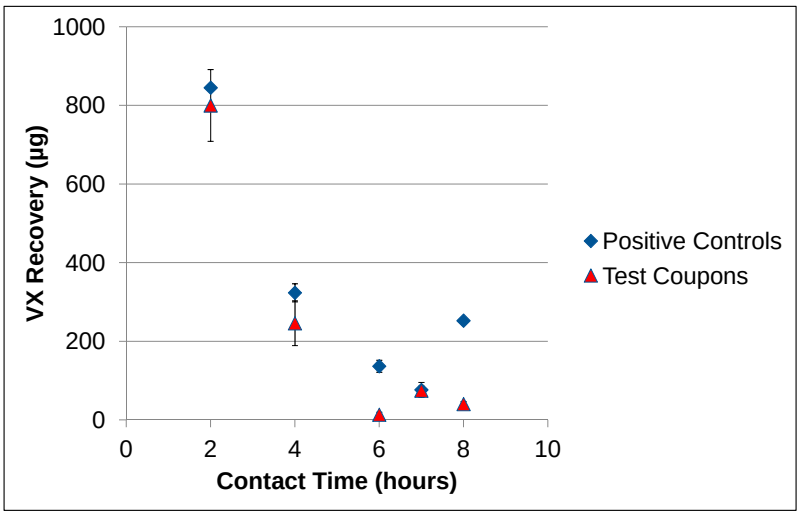
7

Coupon Functions Included in Fumigation Test Matrix

Sample Type	Number of Coupons of Each Material Type
Process Control Coupon	1 (for each fumigation event)
Laboratory Blanks	3 (for all testing with a given agent)
Procedural Blanks	2 (for each fumigation event)
Positive Control Coupons	3 (for each fumigation event)
Test Coupons	5 (for each fumigation event)

8

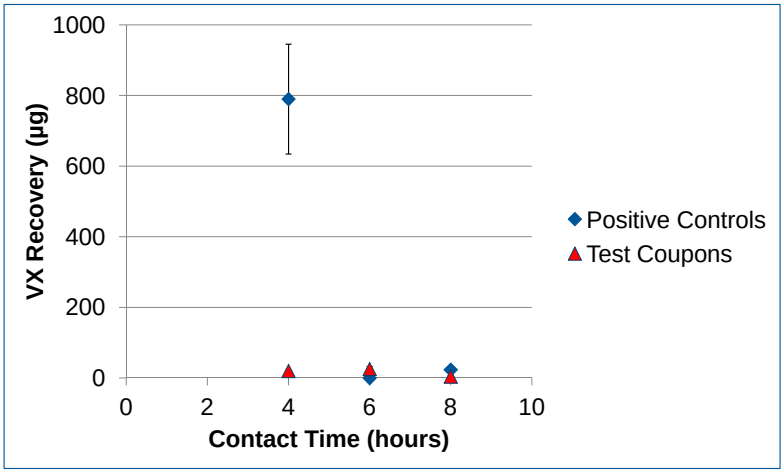
VX: Carpet Test (H_2O_2 250 ppmv / NH_3 16 ppmv) and Positive Control Coupons



SIGNIFICANT EFFICACY WAS OBSERVED AT 4, 6 AND 8 HOURS

9

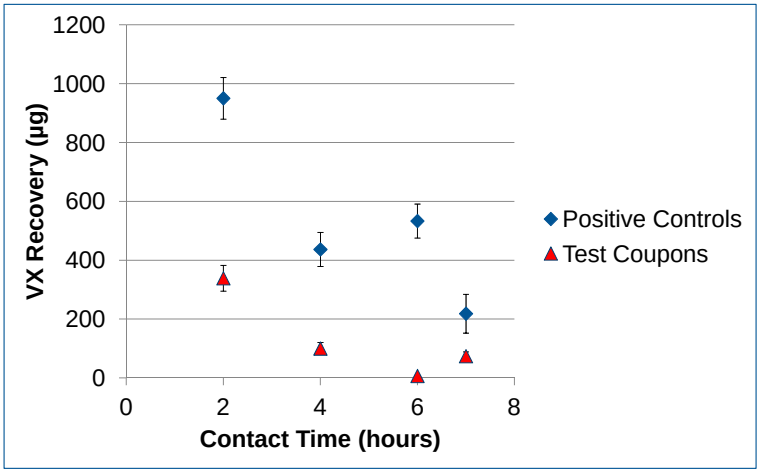
VX: Metal Test (H_2O_2 250 ppmv / NH_3 16 ppmv) and Positive Control Coupons



SIGNIFICANT EFFICACY WAS OBSERVED AT 4 HOURS

10

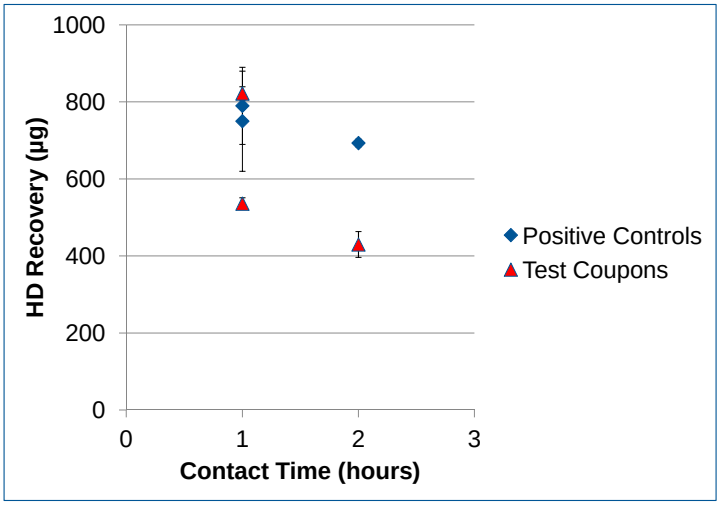
VX: Vinyl Test (H_2O_2 250 ppmv / NH_3 16 ppmv) and Positive Control Coupons



SIGNIFICANT EFFICACY WAS OBSERVED AT ALL TIME POINTS TESTED: 2, 4, 6 AND 7 HOURS

11

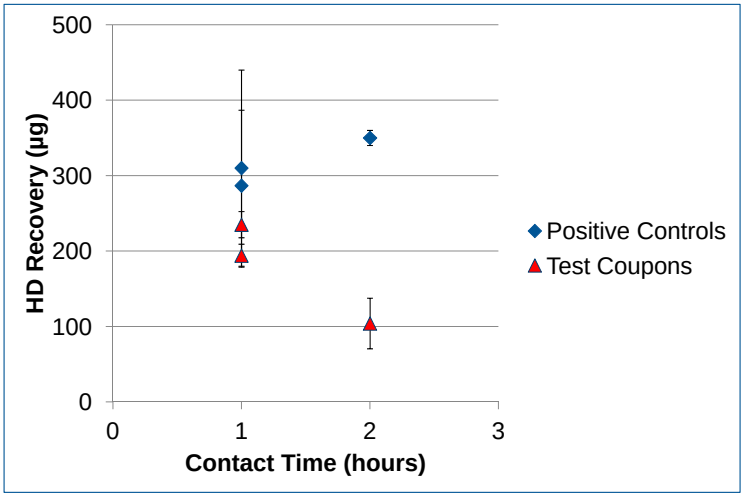
HD: Carpet Test (H_2O_2 250 ppmv / NH_3 16 ppmv) and Positive Control Coupons



SIGNIFICANT EFFICACY WAS OBSERVED AT 2 HOURS

12

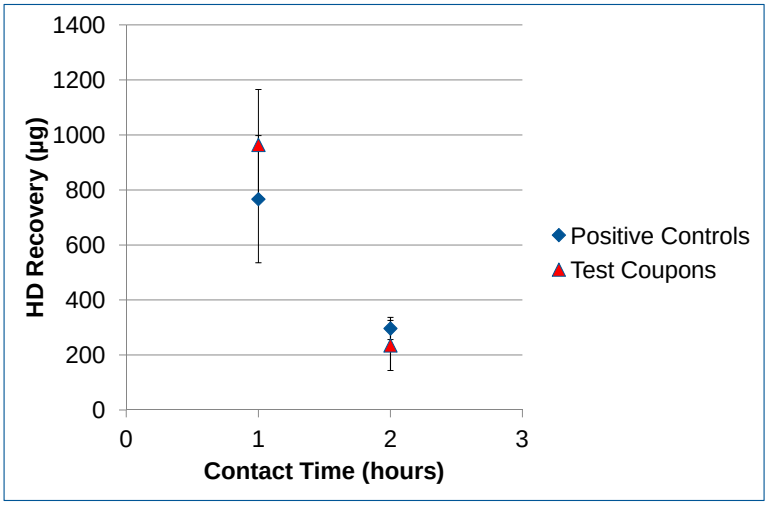
HD: Vinyl Test (H_2O_2 250 ppmv / NH_3 16 ppmv) and Positive Control Coupons



SIGNIFICANT EFFICACY WAS OBSERVED AT 2 HOURS

13

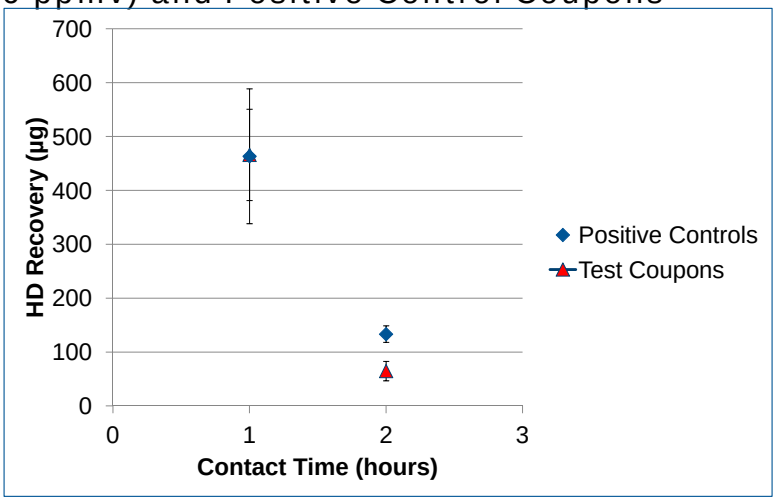
THD: Carpet Test (H_2O_2 250 ppmv / NH_3 16 ppmv) and Positive Control Coupons



NO SIGNIFICANT EFFICACY WAS OBSERVED AT 1- OR 2-HOUR FUMIGATION TIMES

14

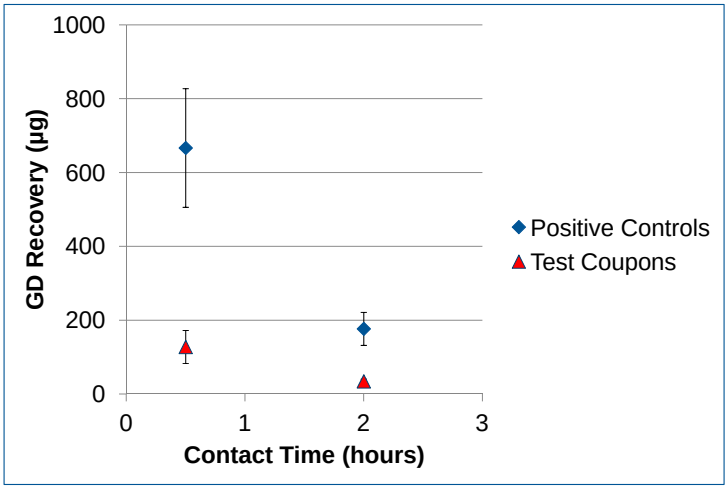
THD: Vinyl Test (H_2O_2 250 ppmv / NH_3 16 ppmv) and Positive Control Coupons



SIGNIFICANT EFFICACY WAS OBSERVED AT 2 HOURS

15

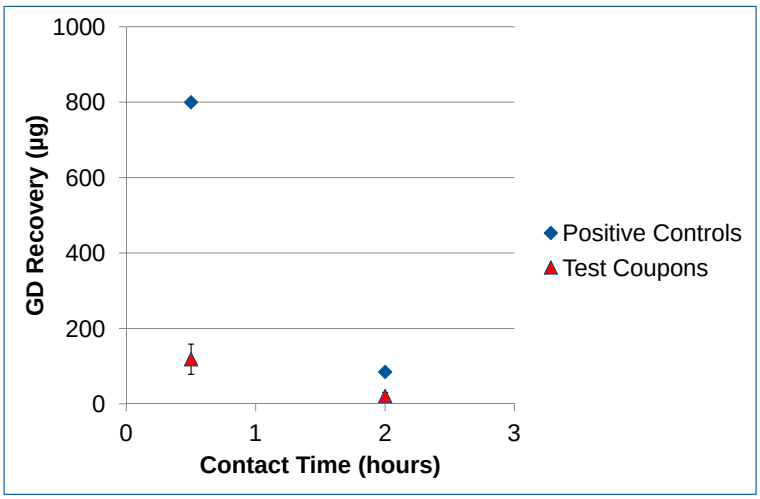
TGD: Carpet Test (H_2O_2 250 ppmv / NH_3 16 ppmv) and Positive Control Coupons



SIGNIFICANT EFFICACY WAS OBSERVED AT BOTH TIME POINTS TESTED: 0.5 AND 2 HOURS

16

TGD: Vinyl Test (H_2O_2 250 ppmv / NH_3 16 ppmv) and Positive Control Coupons



SIGNIFICANT EFFICACY WAS OBSERVED AT BOTH TIME POINTS TESTED: 0.5 AND 2 HOURS

17

Measuring Chemical Agent in Test Chamber Atmosphere

- Vapor sample collected @ 200 mL/min for 5 min onto Carboxen sorbent (at the end of the exposure)
- Carboxen beads extracted in 1.0 mL chloroform
- Chloroform extract analyzed by GC/MS
- Reported recoveries based on raw peak area

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Results of Air Sampling in Test Chamber

Agent	Exposure Time, hours	Concentration (µg/L of air)
VX	2, 4, 6, 7, and 8	Not detected
HD	1	2.2
HD	1	3.5
HD	2	Not detected
THD	1	12
THD	2	3.1
TGD	0.5	0.72
TGD	2	0.68

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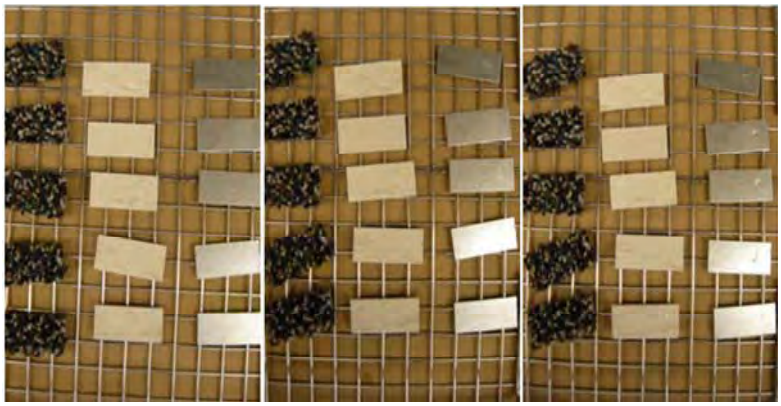
H_2O_2 / NH_3 Fumigation: No Visible Damage to Carpet, Vinyl, or Metal



Coupons before application of chemical agent (left), after application of chemical agent (center), and after fumigation (right)

20

Summary of H_2O_2 / NH_3 Fumigation

- May be effective for decontamination of VX, HD, THD, and TGD from nonporous and porous or absorptive materials
- Efficacy against THD on carpet (not demonstrated at 2-hour contact time) may require longer fumigation times (not tested)
- Fumigation time required depends on chemical agent, material being decontaminated, and acceptable levels of residual agent

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Summary of H_2O_2 / NH_3 Fumigation (continued)

- Chemical agent recovered from positive control coupons declined with time
- High natural attenuation from control coupons resulted in no significant fumigation efficacy being observed in some cases
- Chemical agent (HD and GD) was detected in the test chamber atmosphere and transfer to procedural blanks was detected in some cases
- Fumigation caused no visible damage of the coupon materials

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Acknowledgment and Disclaimer

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- Questions concerning this presentation or its application should be addressed to Emily Snyder, National Homeland Security Research Center, Office of Research and Development, U.S. Environmental Protection Agency, 109 TW Alexander Dr., Research Triangle Park, NC 27711, 919-541-1006.

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EPA United States Environmental Protection Agency

Bio-response Operational Testing and Evaluation (BOTE) Project

2011 US EPA Decontamination Research and Development Conference
Nov. 1-3, 2011

Office of Research and Development
National Homeland Security Research Center

EPA United States Environmental Protection Agency

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1

Overview

- Purpose: to conduct and evaluate field-level facility biological remediation
- Interagency involvement
  - Environmental Protection Agency (EPA)
  - Department of Homeland Security (DHS)
  - Defense Threat Reduction Agency (DTRA)
  - Centers for Disease Control (CDC)
  - Federal Bureau of Investigation (FBI)
  - Department of Energy (DOE/INL)

2

Objectives

- Phase 1– Remediation Study (April – May 2011)
  - Conduct and evaluate field-level facility remediation studies of three decontamination technologies
  - Assess potential risk of exposure to spores
  - Evaluate effectiveness of waste/washwater collection, treatment, and disposal procedures
  - Determine total cost of applying selected decontamination technology or remediation method/strategy (i.e., including waste management)
  - Identify any damage to building or contents
- Phase 2 – Interagency Exercise (September 2011)
  - Operationally test and evaluate biological incident response from health/law enforcement response through environmental response (remediation).

3

Background

- EPA research products and technical expertise have been used in field responses, exercises, and program office policy development
  - Sampling/analysis
    - Water pathogen concentrator
    - Selected analytical methods (SAM)
  - Risk/exposure assessment (situation specific)
    - Provisional Advisory Levels (PALs)
    - Resuspension and exposure studies
  - Decontamination (situation appropriate)
    - Efficacy, engineering, and application
  - Waste management
    - Waste management research and tools
    - Wastewater treatment research

4

Facility

PBF-632 at Idaho National Laboratory

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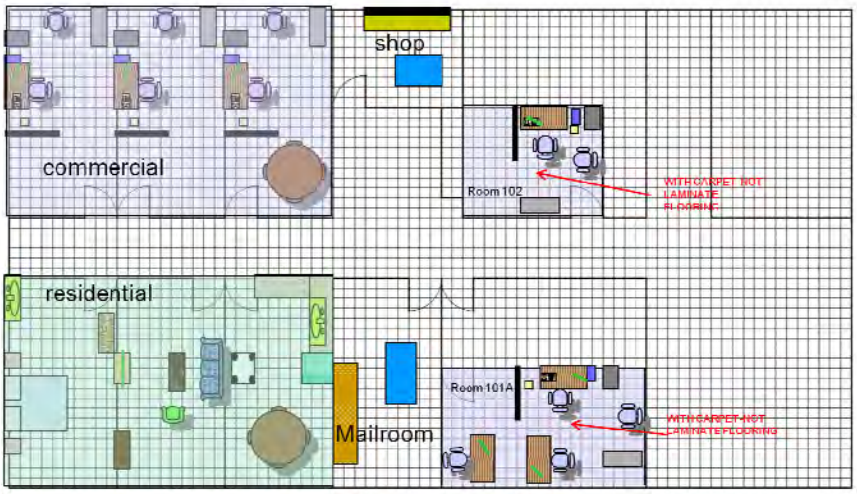
First Floor Schematic



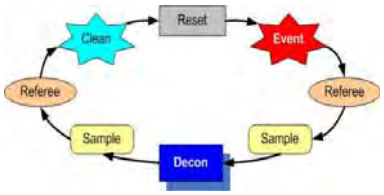
6

Example Rooms




Phase I: Remediation Study

- Three Separate Rounds - Conducted in April/May 2011
- A Round is defined as:
  - Dissemination of *Bacillus atropheus* (subspecies *globigii*) spores in facility
    - First Floor – high contamination (~10^6 spores/ft^2)
    - Second Floor – low contamination (~10^2 spores/ft^2)
  - Pre-decontamination sampling
  - Application of specified decontamination procedure(s)
  - Post-decontamination sampling
  - Post-test analysis (assessment of effectiveness)
  - Reset facility for next round of testing



8

Phase I: Dissemination

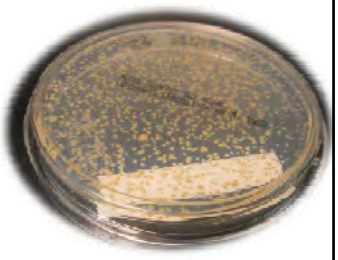
- Dissemination of BG into HVAC using nebulizer
- IBACS – 10/floor

9

Sampling

Phase 1: Decontamination Methods

- Round 1: Fumigation with STERIS Vaporized Hydrogen Peroxide (VHP®)



- Round 2: Treatment Process incorporating pH-adjusted bleach
- Round 3: Fumigation with Sabre chlorine dioxide (ClO_2)

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STERIS VHP®

- Full-facility fumigation with vaporized hydrogen peroxide
  - Two generators
  - Separate injection points on top and bottom floors
- Target conditions:
  - 250 ppmv for minimum 90 min
  - Temp>70 °F
- No tenting/sealing of facility
- No removal of materials
- Biological indictors (*G. stearothermophilus*) and chemical indicators placed throughout facility
- 3 days (setup, fumigation, aeration)

12

STERIS VHP®

13

pH-adjusted Bleach Process

- Procedure:
  - Negative air machines to clean air ([re]aerosolized spores)
  - Removal of all porous materials in facility (PPE Level C)
    - Bagging and spraying with pH-adjusted bleach
  - Spraying of all remaining surfaces in the facility with pH-adjusted bleach solution (PPE Level B)
    - Target minimum 10 min wetted
  - Vacuum standing water
  - Decontamination of HVAC return with pH-adjusted bleach
  - HVAC supply lines were capped and not decontaminated
- 3 days for removal of porous material and decontamination of facility
- 3 days for drying of facility

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pH-adjusted Bleach Process




pH-adjusted Bleach Process

Sabre ClO_2 Fumigation

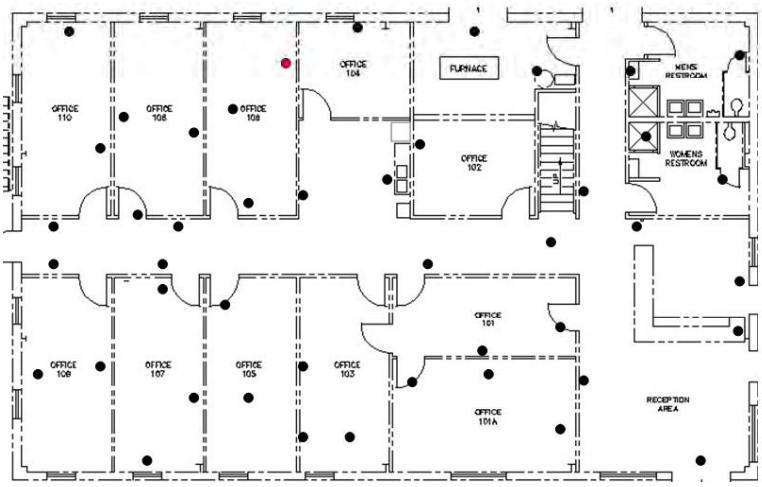
- Fumigation of entire facility w/ ClO_2
- Sealing of facility via tenting (under outer containment and draw through NAM)
- Removal of some porous materials due to potential off-gassing (longer aeration times)
- Target conditions:
  - 3000 ppmv for min 3 hrs (9000 ppmv-hrs)
  - >65% RH, >65 °F
- 6 Log Biological indictors (*B. atropheus*) on stainless steel placed on each floor
- ClO_2 sampling with impinger/titration & EPA with prototype remote sensor
- 3 days (setup, fumigation, aeration) [plus 2 pre-staging days] 17

Sabre ClO_2 Fumigation

18

Biological Indicators for ClO_2

6 Log *Bacillus atropheus* on stainless steel – First Floor



Average T=76 °F Average RH=80%

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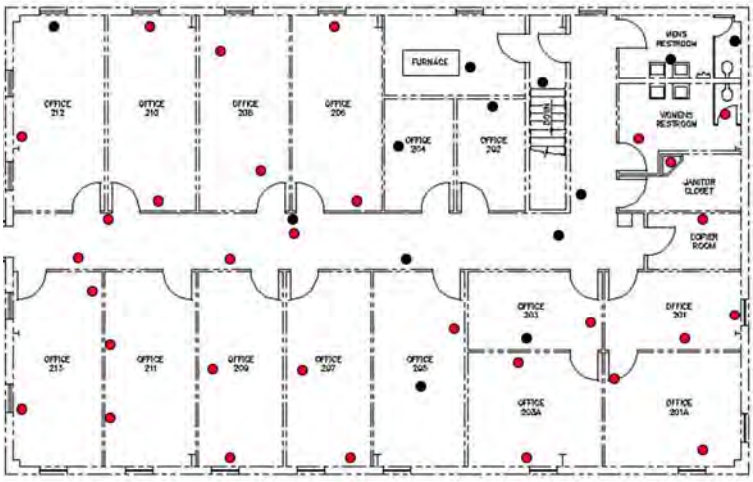
Biological Indicators for ClO_2

6 Log *Bacillus atropheus* on stainless steel – Second Floor



Average T=81 °F Average RH=64%

20

Preliminary Results (Positive Samples)

Description	Floor 1	Floor 2
Pre-Decon VHP	151/153	125/133
Post VHP	44/153	7/134
Pre-Decon AB	146/147	109/124
Post AB	1/134	7/111
Pre-Decon ClO_2	138/142	114/129
Post ClO_2	1/138	0/127

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Summary (Phase I)

- BOTE project provided:
  - Information on efficacy of several decontamination methods
  - Information on time requirements, labor requirements, waste generation, and adverse impacts on facility
  - Exposure assessment planning tool to assess potential risk of exposure to spores
  - Information that can be used to estimate costs associated with a decontamination approach
  - Data that can be used to help guide decision making for future events
  - Opportunity for federal agencies to work together

22

Following Me

- Sampling Aspects – CMDR Mattorano
- Spore Migration – Ms. Silvestri
- RV-PCR – Dr. Shah
- Cost Analysis – Dr. Lemieux

23

Phase 2: Interagency Exercise

- Planned using Homeland Security Exercise and Evaluation Program (HSEEP) guidance
  - To operationally test and evaluate biological incident response from health/law enforcement response through environmental response (remediation).
- Conducted in September 2011
- Blind release in facility using envelope
- Coordinated interagency response
- Decontamination with methyl bromide
- After Action Report (AAR) coming soon

24

Questions

- Shannon Serre
  - serre.shannon@epa.gov, 919-541-3817
- Shawn Ryan
  - ryan.shawn@epa.gov, 919-541-0699
- Chris Russell
  - christopher.e.russell@dhs.gov, 202-254-5876

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Sampling Activities – BOTE

NOVEMBER 2, 2011

Dino Mattorano, MS, CIH
CDR, USPHS

Today's Agenda

1. Sampling: what was done
2. Preparation before study
3. Sampling training
4. On-site preparation
5. What if a large event happens?

2

Sample Types

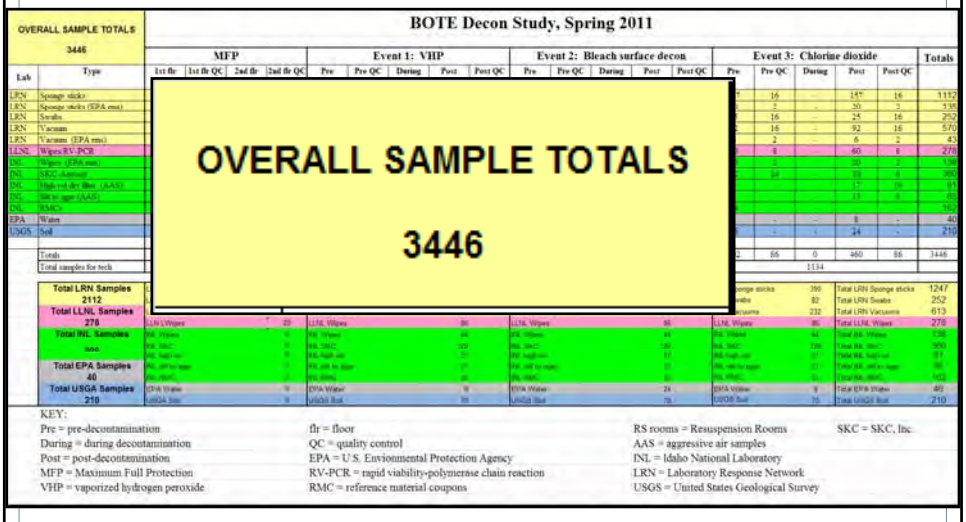
1. Wipe – sponge stick
2. Swab
3. Vacuum sock

Purpose:

- Evaluate 3 decon technologies
- Side by side sampling

3

Samples by the Numbers



4

Sample Preparation

- **Order materials**
- **Assemble individual sampling kits**

Sponge-stick = 2500

Vacuum = 800

Swab = 400

5

Sample Preparation

- **Order materials – Products list**

MACROFOAM SWAB SAMPLING				
PRODUCT	PRODUCT NUMBER	PRODUCT MANUFACTURER	NUMBER OF UNIT IN A PACKAGE	Web Site
1-Sterile Foam Tipped Applicator	25-1607	Puritan Medical Products	1 Package = 50 Swabs	www.puritanmedproducts.com
1-10 ml Neutrilizer Buffer Solution* -- 2ml flip top vial with 1ml NB Microstein	K105	Hardy Diagnostics	1 Package = 20 Vials	www.hardydiagnostics.com
1-15ml High Clarity Polypropylene Conical Centrifuge Tube	352097	Becton Dickinson Supplies	1 Package = 50 Tubes	www.bd.com
2-Sample Labels	Unknown			label vial and quart size bag
1-Re-sealable plastic bag; 1 Quart or smaller	Unknown	Various	Unknown-1 per sample for overpack	will contain swab, wetting solution, and conical tube if we do not pre moisten.
1-Re-sealable plastic bag; 1 Gallon or larger	Unknown	Various	Unknown-1 per sample team per day	
Nitrile Gloves-multiple sets	Unknown	Various	Unknown-1 pair for each person	
2 X 2 in Sampling Template (4 Square Inches)	225-2415	SKC	1 Pack = 250 Disposable Templates	www.skcinc.com

6

Sample Preparation

Assemble individual sampling kits

Swab Kits:

Pre Assembly:

- Autoclave 2.0 ml microcentrifuge tubes
- Aliquot 1.0 ml Neutralizing Buffer into tube, one for each sample kit

In 6" x 10" 4 mil bag place:

- One 2.0ml tube containing 1.0 ml Neutralizing Buffer
- One individually wrapped, sterile swab
- One small 4"x 6" 4 mil bag
  - inside 4"x 6" bag, place one 15ml Falcon conical tube

Bar Code Labels:

- Affix one replicate label to 15ml conical tube (making sure bar code lines are parallel with tube graduates)
- Affix one replicate label to 4"x 6" bag
- Affix one replicate label to 6" x 10" kit Bag

7

Sample Preparation

8

Sample Preparation

- Assemble individual sampling kits

9

Sample Preparation

10

Sample Preparation

11

Sample Preparation

Sponge stick	Swab	Vacuum
• 200 kits • 2.5 hours	• 2oo kits • 5 hours	• 200 kits • 6.5 hours

NOTE: Sample media not prewetted,

TRIPLE assembly time!

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Training Samplers

- 3-4 hours of training (15-25 individuals)
- Lecture
- Hands-on demo (BBFB)
- Site walk-through

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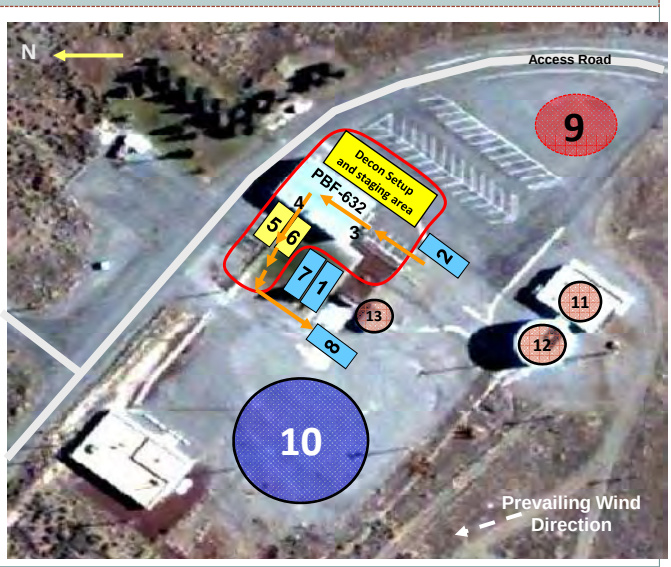
Site Map

1. Command-Control Trailer
2. Sampling Prep Trailer
3. Building Ingress
4. Building Egress
5. RSU Decon Support
6. RSU Decon Support
7. Sampling/Decon Support Trailer
8. Crew Recovery Trailer
9. General Emergency Rally Area
10. General Parking
11. PBF-638
12. Water Tower
13. Pump House

Exclusion Zone:

Orange Line:
- Personnel facility operational flow



14

Training Samplers

- **Lecture**
  - Background and purpose
  - Expectations
  - Sampling methods
  - BROOM sample tracking system
- **Hands-on demo**
  - Sampling methods
  - BROOM
  - Demonstrate proficiency
  - Helps determine what you have

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Training: Site Walk-through

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Training: lecture

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Sponge-stick Collection Protocol

Assistant	Sampler
1. Remove 10”x 10” template and kit from bin 2. Open packaging and position sponge-stick for sampler to acquire 3. Scan barcode and fill in fields 4. Position inner bag to receive sponge 5. Seal inner and outer bags	1. Remove sponge-stick from packaging without touching sides 2. Gently place template to minimize disturbing settled aerosol 3. Horizontal, vertical and diagonal S-strokes and perimeter wipe, turn sponge over each time 4. Place sponge in bag and break off stick 5. Discard template and stick in waste

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Sponge-stick Collection Protocol

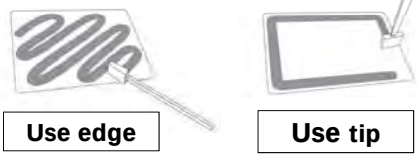
Sampler

1. Remove sponge-stick from bag without touching sides
2. Gently place template at location to minimize disturbing settled aerosol
3. Horizontal, vertical and diagonal S-strokes and perimeter wipe, turn sponge over each time
4. Place sponge in bag
5. Discard template and stick in waste

1. Horizontal 2. Vertical

Turn sponge over

3. Diagonal 4. Perimeter



Use edge Use tip

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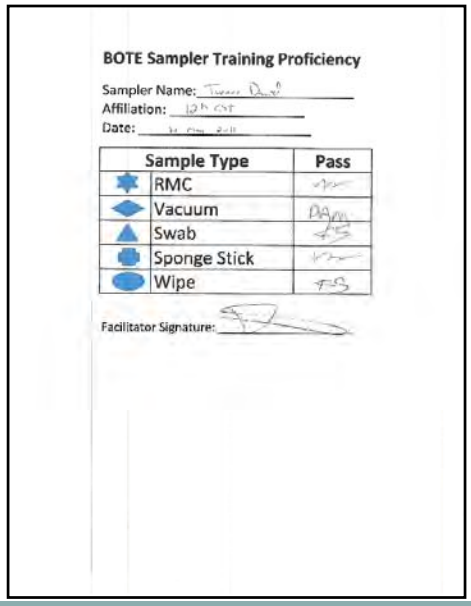
Proficiency Testing



BOTE Sampler Training Proficiency

Sampler Name: _____

Affiliation: _____

Date: _____

Sample Type	Pass
RMC	
Vacuum	
Swab	
Sponge Stick	
Wipe	

Facilitator Signature: _____

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Proficiency Testing / Hands on Demo

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Samplers

Agency	Numbers	Location
DOD WMD CST	60	1, 8, 12, 24, 33, 41, 42, 43, 45, 46 48, 54, 73, 81, 83, 84, 102, 103
DOD USMC CBIRF	3	
USCG PST	3	Pacific Strike Team
USEPA OSCs	28	1, 2, 3, 4, 7, 8
USEPA	10	NHSRC, OEM
Total	**104**	**All over country**

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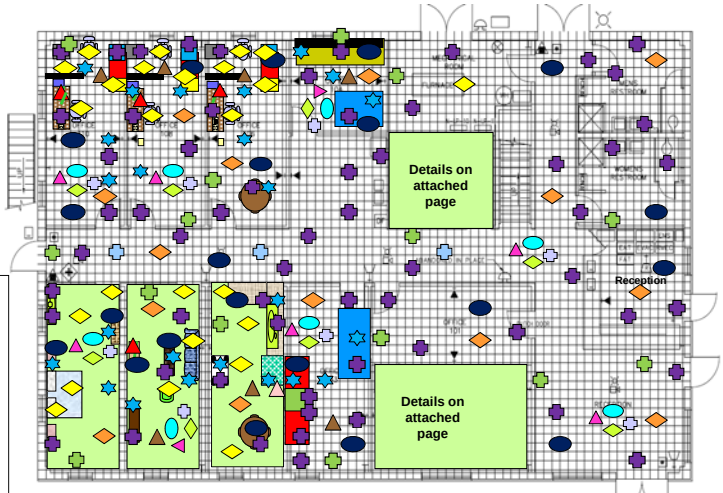
On-site Preparation

- **On-site preparation**
  - Develop sampling maps
  - Pack sampling kits
  - Build sampling carts

23

Interior Layout Of PBF-632 : First Floor 1 square = 1 ft^2

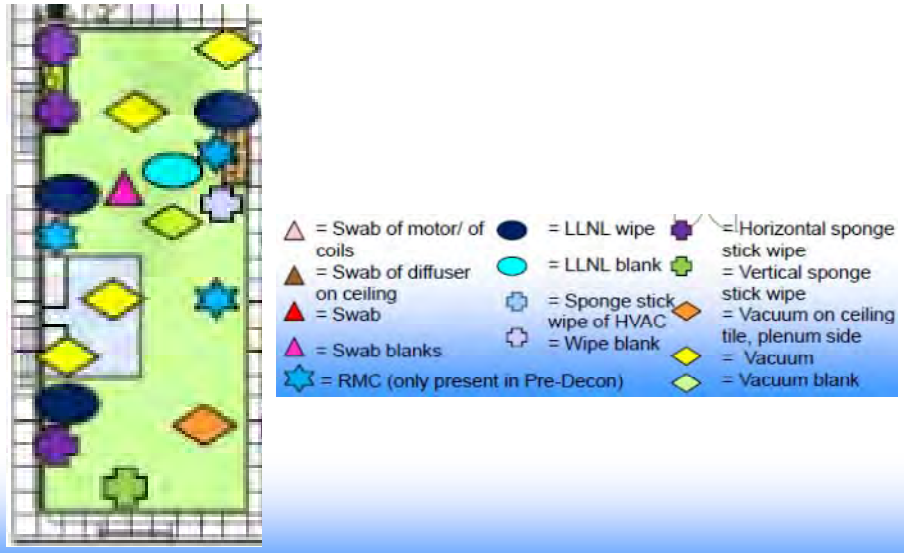


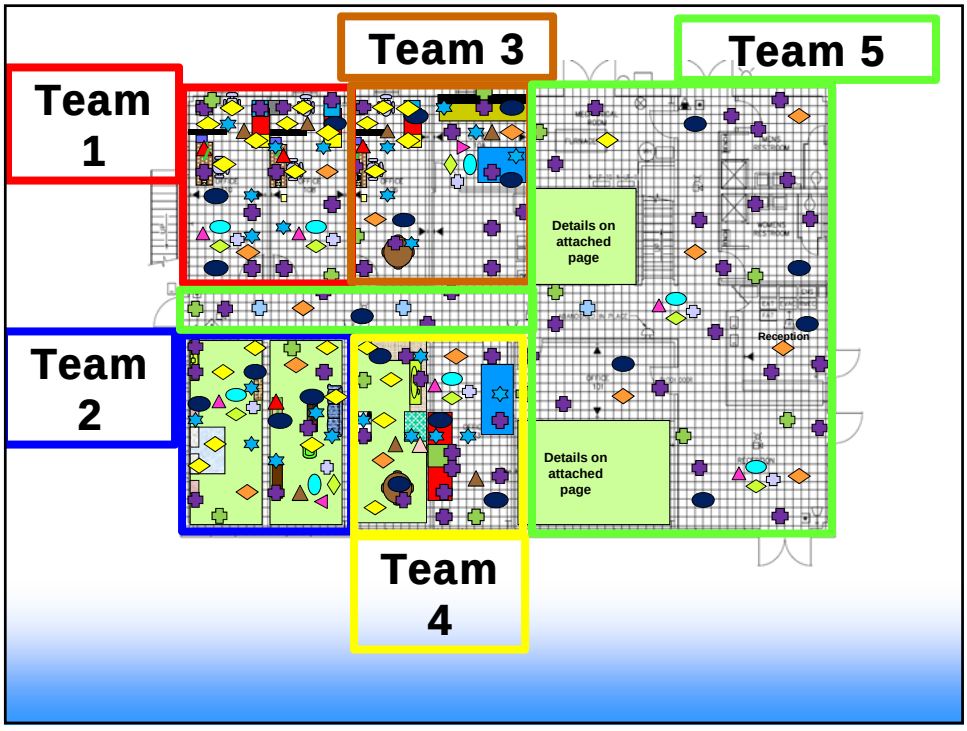
Note 1: Each Post-Decon Sample will be a predefined area adjacent to the pre-decon sample.

Note2: RMC and Settle Plate samples are co-located and represent one sample of each.

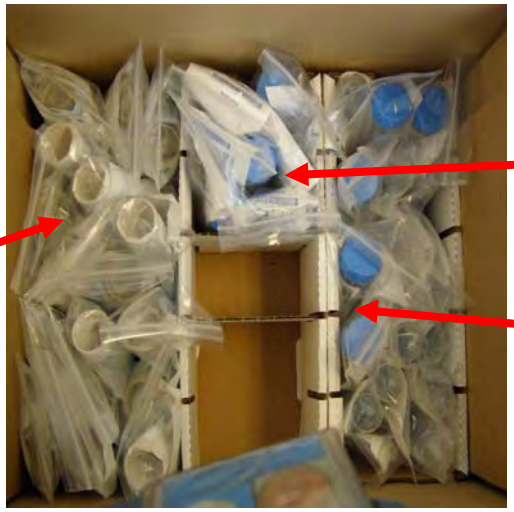
= Book Shelves
= Mail slots
= Swab of motor/coils
= Swab of diffuser
= Swab
= Swab blanks
= RMC (only pre-decon)
= LLNL wipe
= LLNL blank
= Sponge wipe of HVAC
= Wipe blank
= Horizontal sponge wipe
= Vertical sponge wipe
= Vacuum on ceiling tile, plenum side
= Vacuum
= Vacuum blank

Interior Layout Of PBF-632 : First Floor 1 square = 1 ft²





Sampling Kits



27

Build Sampling Kits

28

Build Carts

29

Build Carts

Samplers Prep for Entry

Pre-entry

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Summary

Sampling takes lots of work!!

- **Pre study prep**
  - Develop product list for ordering supplies
  - Assemble sampling kits remotely
- **Train samplers (on-site)**
  - Lecture
  - Hands on demo (proficiency testing) !!!!!!
- **Build sampling maps and kits**
- **Build carts**

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Summary

- **What if something big happens tomorrow?**
  - Platform for high volume sampling
  - Just in time training (lecture and hands on)

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Summary

- Questions?

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Training Samplers












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EPA United States Environmental Protection Agency

BOTE Preliminary Results: Cost Analysis

Office of Research and Development
National Homeland Security Research Center

EPA United States Environmental Protection Agency

BOTE Overview

- Purpose: to conduct and evaluate field-level facility biological remediation
- Interagency involvement
  - Environmental Protection Agency (EPA)
  - Department of Homeland Security (DHS)
  - Defense Threat Reduction Agency (DTRA)
  - Centers for Disease Control (CDC)
  - Federal Bureau of Investigation (FBI)
  - Department of Energy (DOE/INL)

CDC

INL Idaho National Laboratory

1

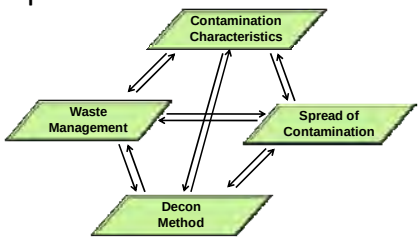
Objectives

- Two Phase Approach
  - Phase 1 (April – May 2011) – Remediation Study
  - Phase 2 (September 2011) – Operational Evaluation
- Phase 1 (remediation study):
  - Conduct and evaluate field-level facility remediation studies of various decontamination technologies
  - Assess potential risk of exposure to spores
  - Evaluate effectiveness of waste/washwater collection, treatment, and disposal procedures
  - Determine total cost of applying selected decontamination technology or remediation method/strategy (i.e., including waste management)
  - Identify any damage to building or contents

2

Motivation

- What are the most appropriate remediation strategies?
  - Site-specific clean-up goal(s)
  - Sampling/analysis capability/capacity
  - Decontamination capability/capacity
  - Waste management options
- Systems approach to research and response



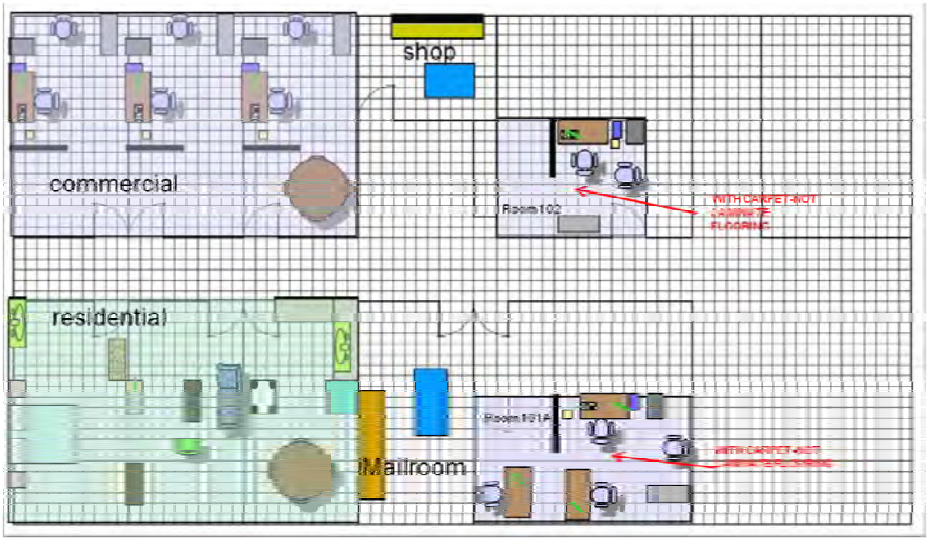
3

Facility

PBF-632 at Idaho National Labs

4

Facility Layout – 1st/2nd Floor



5

Example Rooms

Mail Room

Shop

6

Sampling

- Surface sampling using current techniques (some validated)
  - Swab, wipe, sponge stick, vacuum
- Collected pre- and post-decontamination samples side-by-side on most surfaces in study rooms
- Samplers
  - EPA OSCs from 7 Regions and ORD Researchers
  - NGB WMD CSTs
- Training
  - 4 hr lecture and hands-on demo
  - Included sampling techniques and BROOM tool used for tracking and mapping samples

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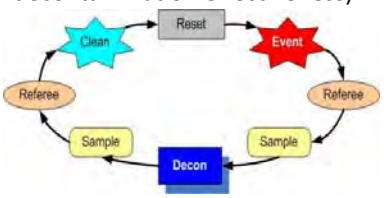
Phase 1: Remediation Study

- Three Separate Rounds - Conducted in April/May 2011
- A Round is defined as:
  - Dissemination of "prepared" *Bacillus atrophaeus* subspecies *globigii* spores in facility
    - First Floor – high contamination (~10^6 spores/ft^2)
    - Second Floor – low contamination (~10^2 spores/ft^2)
  - Pre-decontamination sampling
  - Application of specified decontamination procedure(s)
  - Post-decontamination sampling
  - Post-test analysis (assessment of decontamination effectiveness)
  - Reset facility for next round of testing



8

Phase 1: Decontamination Methods

- Round 1: Fumigation with STERIS Vaporous Hydrogen Peroxide (VHP®)
- Round 2: Treatment Train incorporating pH-adjusted Bleach
- Round 3: Fumigation with Sabre chlorine dioxide (ClO_2)

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Waste Management

Description of Items/Waste	Waste Classification*	Waste Management Facilities
Liquid Waste		
Decontamination wastewater, contaminated	HW, IW	RCRA Subtitle C Hazardous Waste Facility (e.g., incinerator)
Decontamination wastewater, uncontaminated	NH/NI	Publically Owned Water Treatment Plant
Solid Waste		
PPE, contaminated	HW	RCRA Subtitle C Hazardous Waste Facility (e.g., incinerator)
PPE, contaminated	IW	Medical Waste Incinerator
PPE, uncontaminated	NH/NI	Solid Waste Management Landfill
Office Waste and General Trash (e.g., papers, PPE packing boxes)	NH/NI	Solid Waste Management Landfill
Building Materials (e.g., ceiling tiles, drywall, carpeting)	NH/NI	Solid Waste Management Landfill
Furniture	NH/NI	Solid Waste Management Landfill
Electronic Waste	NH/NI	Solid Waste Management Landfill

Waste Classification (As defined by Federal, State or Local Requirements as applicable):

NH/NI: Non-Hazardous & Non-Infectious through sampling or process knowledge
HW: Hazardous Waste as tested or through process knowledge
IW: Infectious Waste as tested or through process knowledge

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Cost Elements

Sampling Cost

+ Decon Cost

+ Restoration Cost

Total Cost

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Sampling/Analytical Cost Elements

- ∑ over number of entries
  - Building Entry Costs
  - Team Preparation
  - Team Decontamination
  - Waste Management
- ∑ over number of samples
  - S&A Costs
  - Team Labor for Sampling
  - Materials for Sampling
  - Labor for Analysis
  - Materials for Analysis
  - Waste Management
- Other
  - Preparing Kits
  - Travel for Sampling Teams
  - HOBOs
  - BROOM Support
  - Analysis & QA of Data

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Decon Cost Elements

- ∑ over number of entries
  - Building Entry Costs
  - Team Preparation
  - Team Decontamination
  - Waste Management Due to Entering
- Labor
  - Decontamination
  - Removal
- Materials and Equipment
  - Decontamination
  - Removal
- Waste Management from Decontamination
- Other
  - Travel for Decon/Rem Teams
  - Fixed Contractor Costs
  - IC Support (e.g., safety)
  - HOBOs

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Building Restoration Cost Elements

- Post-Decon Removal
  - Labor to Remove
  - Waste Management
- Replacement
  - Labor to Replace
  - Cost of Items

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Approach to Tracking Costs

- Based on Entries
  - Sampling team labor
    - Estimate of time per sample to derive sampling labor
    - Sample kit prep time
  - Decon team labor
  - Removal team labor
  - Decon Line Ops labor
- Based on Waste Quantity
  - Waste transportation costs
    - Adjusted for anthrax waste
  - Waste handling costs
  - Waste disposal costs
    - Adjusted for anthrax waste
  - Waste characterization costs (assumed 1 sample per 100 lb of solid waste and 1 sample per 55 gal drum of liquid waste)
- Based on Days and Hours
  - Travel
  - Training
  - BROOM
  - Incident Command/Safety
  - Purchasing
  - Writing Documentation
    - Notional
  - Regulatory Coordination
    - Notional
  - Lab Analytical Labor Costs
    - Adjusted for BSL-3
- Other Costs
  - Purchases
    - Supplies
    - Equipment
  - Decon contracts

15

Approach to Labor Costs

Teams Used in Analysis

- Sampling Team
- Decontamination Team
- Removal Team
- Decon Line Ops Team
- Sample Packaging Team
- Waste Handling Team
- Lab Analyst Team
- BROOM Team
- Data Analysis Team
- Sample Kit Prep Team
- Aggressive Air Sampling Team
- Building Upfit Team
- Health and Safety Team
- Documentation/Plan Writing Team
- Command Team
- OSC
- Regulatory Coordination Team
- INL Equipment Purchase Team
- Room Sample Box Prep Team
- EPA Purchasing Team
- Waste Sampling Team
- Water Sampling Team

Approach Used

- Define team labor mix
- Generate loaded hourly rate for team
- Allocate hours for different activities by teams

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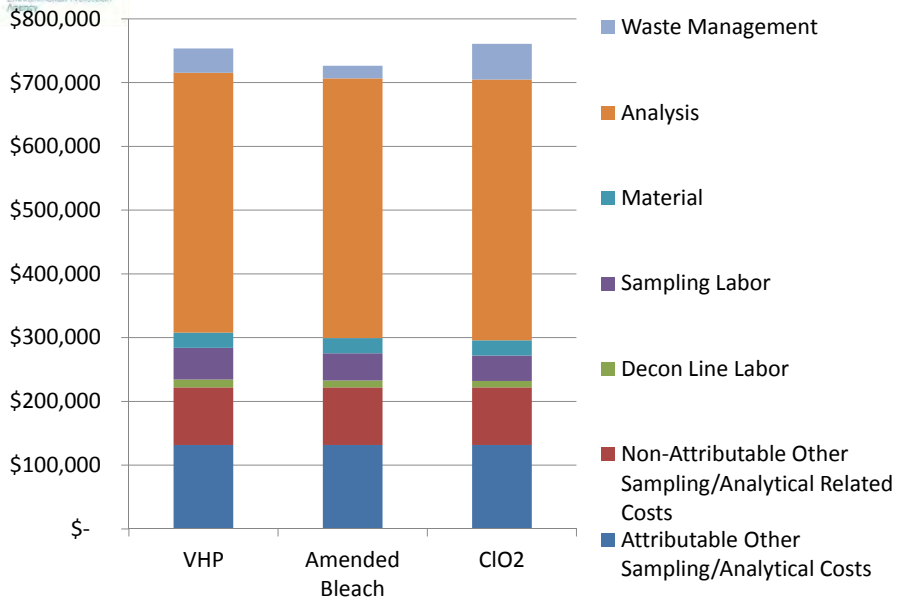
Sampling and Analytical Cost Breakdown



NOTE: S&A Total Costs are Very High Due to # of Samples
Sampling + Analytical Costs ≈ $681/sample

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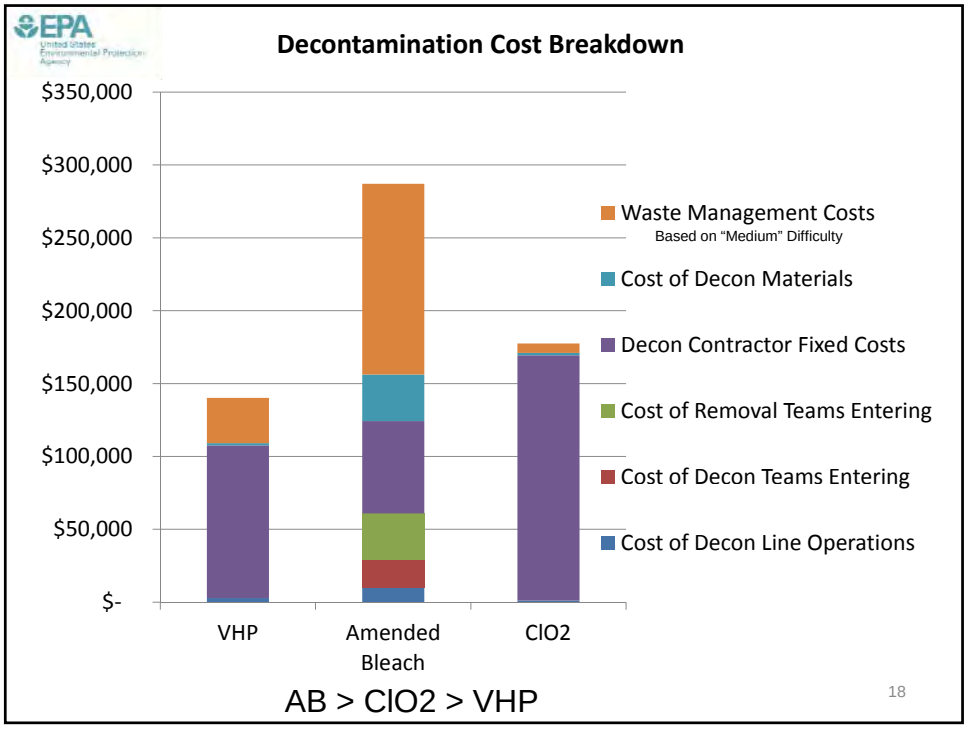
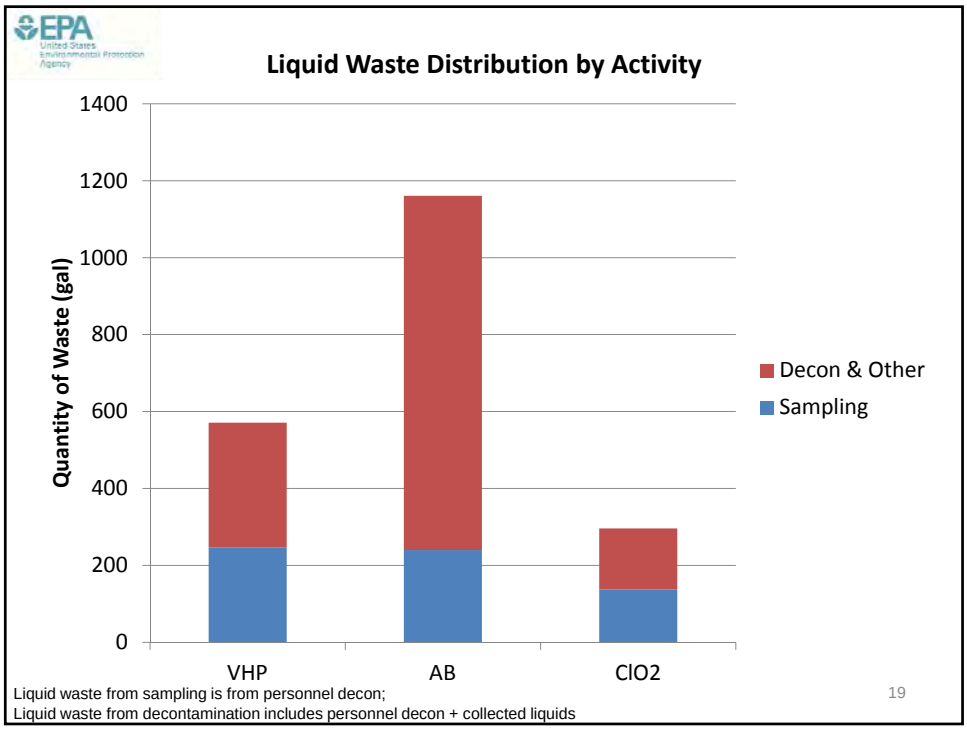
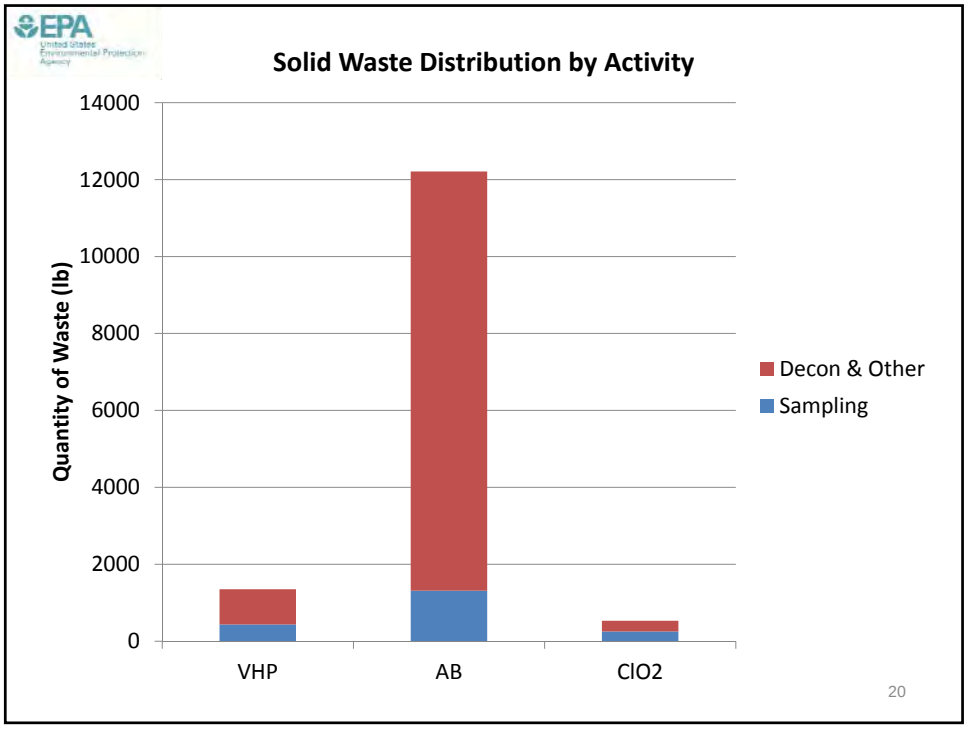
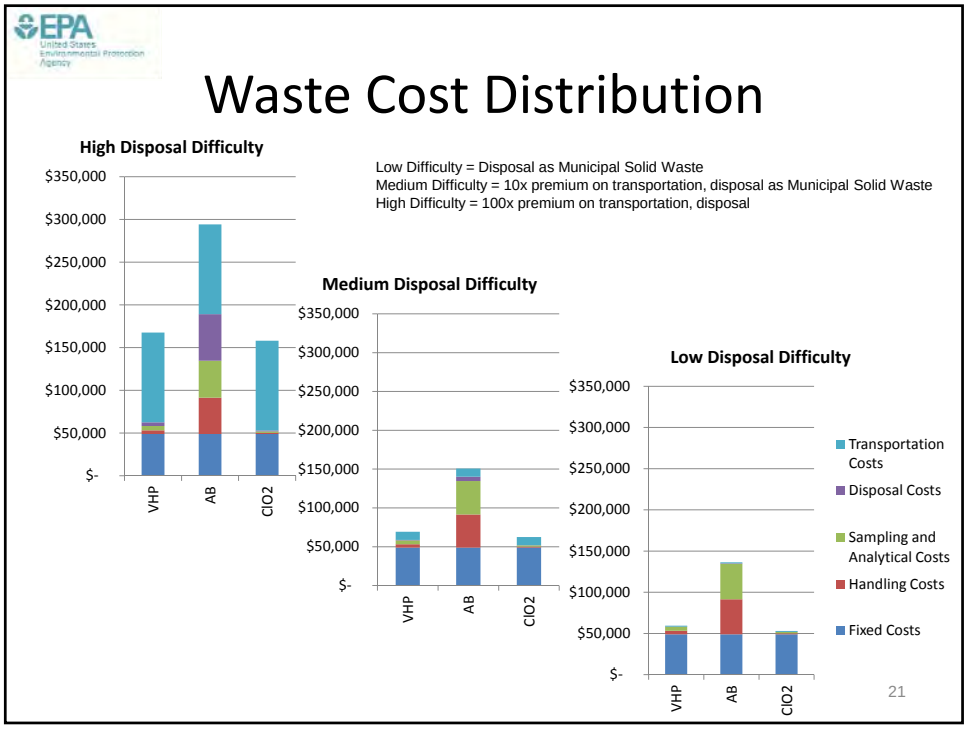
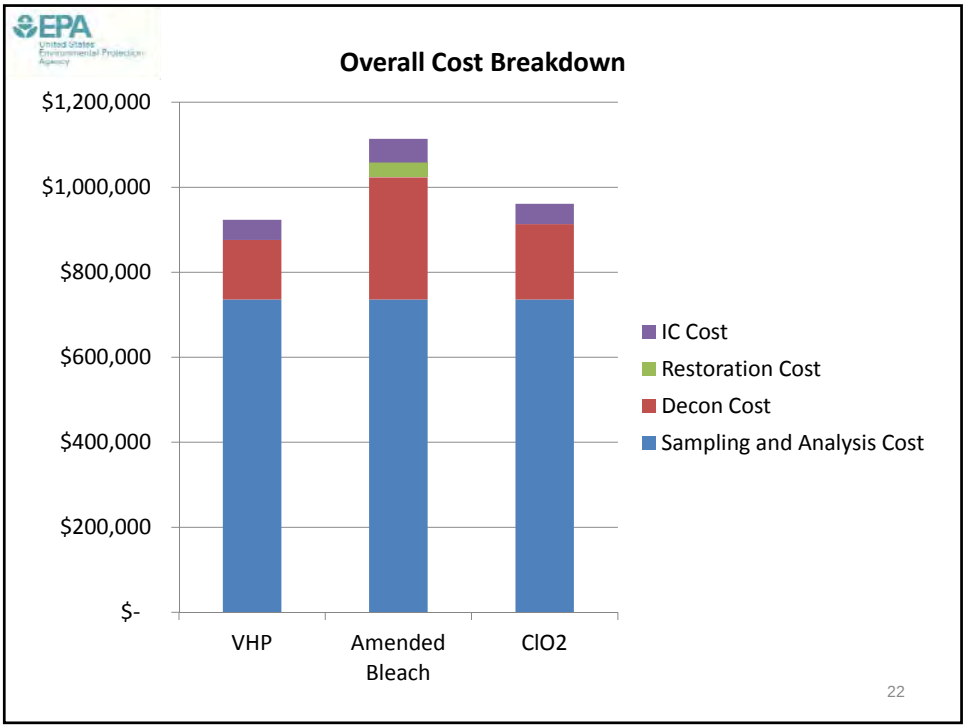

Decontamination Cost Breakdown
$350,000
$300,000
$250,000
$200,000
$150,000
$100,000
$50,000
$-
VHP
Amended Bleach
ClO2
Waste Management Costs
Based on "Medium" Difficulty
Cost of Decon Materials
Decon Contractor Fixed Costs
Cost of Removal Teams Entering
Cost of Decon Teams Entering
Cost of Decon Line Operations
AB > ClO2 > VHP
18


Liquid Waste Distribution by Activity
Quantity of Waste (gal)
1400
1200
1000
800
600
400
200
0
VHP
AB
ClO2
Decon & Other
Sampling
Liquid waste from sampling is from personnel decon;
Liquid waste from decontamination includes personnel decon + collected liquids
19


Solid Waste Distribution by Activity
Quantity of Waste (lb)
14000
12000
10000
8000
6000
4000
2000
0
VHP
AB
ClO2
Decon & Other
Sampling
20


Waste Cost Distribution
High Disposal Difficulty
Medium Disposal Difficulty
Low Disposal Difficulty
Low Difficulty = Disposal as Municipal Solid Waste
Medium Difficulty = 10x premium on transportation, disposal as Municipal Solid Waste
High Difficulty = 100x premium on transportation, disposal
$350,000
$300,000
$250,000
$200,000
$150,000
$100,000
$50,000
$-
VHP
AB
ClO2
Transportation Costs
Disposal Costs
Sampling and Analytical Costs
Handling Costs
Fixed Costs
21



BOTE Cost Analysis Preliminary Observations and Conclusions

- Sampling and Analytical Costs
  - Total sampling and analytical costs very high due to artificially large numbers of samples taken for study
  - Approximately $681/sample
  - S&A costs roughly distributed between sampling (1/3) and analysis (2/3)
- For this building, Decon Costs for AB > ClO2 > VHP
  - AB had increased labor costs for removing, decontaminating materials
  - AB had increased costs due to entry in Level B PPE
  - AB had increased costs due to replacement of damaged items
  - NOTE: EPA experts recommended that some materials be removed prior to VHP decon, and they weren't; VHP decon was cheaper, but not very effective

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BOTE Cost Analysis Preliminary Observations and Conclusions Cont.

- "Don't generate any waste" – M. Nalipinski
  - Waste Mgt Costs for AB >> ClO2, VHP
  - Significant fixed costs for waste management (plans, regulatory discussions)
  - Greater amount of removed materials for AB
  - Transportation is a significant cost
  - Significant cost savings that may be realized by disposal in RCRA Subtitle D facilities offset by waste characterization S&A charges
  - Waste characterization sampling and analysis may be a significant cost, and final disposal pathways should be worked out prior to initiating waste characterization sampling

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Mobility and bioavailability of long-lived Chernobyl radionuclides in "soil-water" environment and their consideration at rehabilitation of contaminated sites

Alexei Konoplev
Research and Production Association “Typhoon”
Federal Service for Hydrometeorology and Environmental Monitoring of Russian Federation
konoplev@obninsk.com

Outline

- Fuel particles, their decomposition and leaching of radionuclides;
- Radionuclide speciation, their transformation – kinetics and mechanisms;
- Bioavailability;
- Chernobyl Cooling Pond Decommissioning and Remediation;
- Waste-based amendments for remediation of contaminated soils;
- Fate and transport of radiocesium, radiostrontium and radiocobalt on urban surfaces – EPA-ISTC Partner project #4007

Speciation

- Mobility and bioavailability of radionuclides are determined by ratio of radionuclide chemical forms in fallout and site-specific environmental characteristics determining rates of leaching, fixation/remobilization as well as sorption-desorption of mobile fraction (its solid-liquid distribution).

De Cort M. et al. (2001). Atlas…

2011 US EPA Decon Conference 3

Fuel Particles in the Chernobyl fallout

- Dominant part of radionuclides deposited on the soil surface in the Chernobyl NPP vicinity was incorporated within fuel particles.
- Particles dissolution was the key process governing radionuclides mobility and bioavailability in soils during first years after the accident.
- Reliable prediction of radionuclide transfer in the Chernobyl area during these years was impossible without understanding and correct modelling of fuel particles behaviour in soils and sediments.

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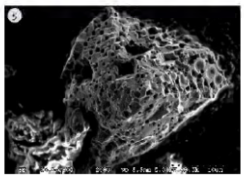
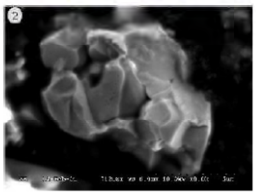
Release of fuel particles as a result of the Chernobyl accident accounts for two major features in behavior of the Chernobyl origin radionuclides:

- Initial mobility and availability of radionuclides in near zone was lower those observed in similar conditions in case of global fallout, Kyshtym accident and application of isotope solutions;
- Deposition of fuel particles on underlying surface, primarily into near zone, led to strong dependence of the radiocaesium initial mobility on the distance to damaged reactor.

UOx matrix fuel particle



U-Zr-O matrix fuel particle



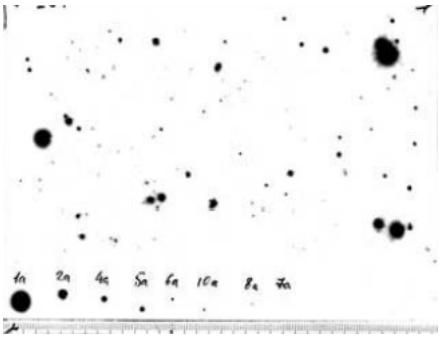
After B. Salbu

Estimation of fuel particle dissolution rate

It has been shown that fuel particle dissolution in soils is satisfactorily described by the first-order kinetics:

$$\frac{dF_t}{dt} = -k_l F_t$$

$$F_t = F_0 \exp(-k_l t)$$



Estimation of fuel particle dissolution rate

- To calculate fuel particle dissolution rate in natural conditions data on ^{90}Sr speciation in soil/sediments can be used (Konoplev et al., 1992; Kashparov et al., 1999);
- ^{90}Sr fraction in fuel particles is assumed to be equal to a fraction of its non-exchangeable form minus fraction of the fixed form;
- ^{90}Sr is convenient to use because its fixation by soil is weak

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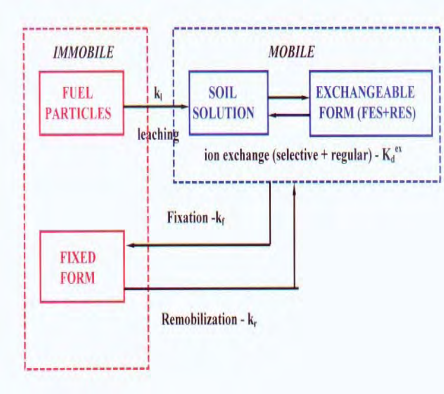
Conceptual model for transformation of radionuclide chemical forms in soil-water systems

- The model accounts for leaching of radionuclides from fuel particles, fixation/remobilization as well as sorption/ desorption by ion exchange mechanism



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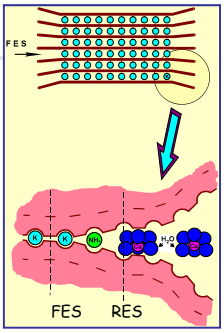
Selective sorption and fixation of radiocaesium

- High retention of radiocaesium in soils is caused by two main processes: selective reversible sorption on illitic clay minerals and fixation
- Methods have been proposed for determining the capacity of selective sorption sites (Frayed Edge Sites – FES) and radiocaesium interception potential (RIP);
- Quantitative data were obtained for a wide range of soils and bottom sediments with respect to FES capacities and RIP.



$$FES-M+{}^{137}Cs^{+} \xleftrightarrow{K_c^{FES}(Cs/M)} FES-{}^{137}Cs+M^{+}$$

$$RIP^{ex}(M)=K_d^{ex}(Cs)\times m_M=K_c^{FES}(Cs/M)\times[FES]$$

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Radionuclide distribution in soil-water system K_d

- The total distribution coefficient for radionuclides can vary in a wide range (4 orders of magnitude for radiostrontium and 5 – for radiocesium) as a function of fallout characteristics and environmental conditions;
- Radionuclide distribution coefficient is a dynamic characteristic and depends on transformation rates of chemical forms;
- For reducing uncertainty in estimates and predictions of radionuclide behavior K_d was parameterized through key environmental characteristics responsible for their sorption-desorption and fixation.

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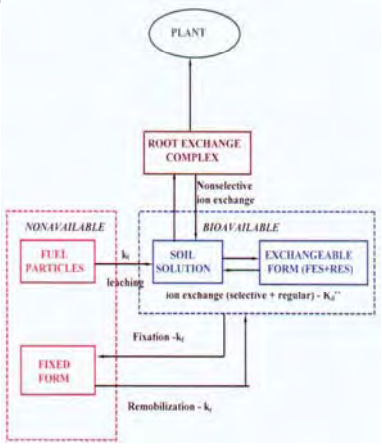
Parameterization of radiocesium and radiostrontium distribution coefficients K_d through soil characteristics

$$K_d^{ex}(^{137}Cs) = \frac{RIP^{ex}(K)}{([K^+]_W + K_c(N/K)[NH_4^+]_W)}$$

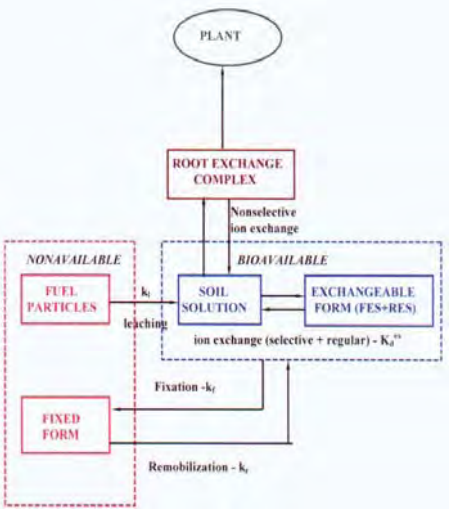
$$K_d(^{90}Sr) = \frac{CEC}{[Ca]_w + [Mg]_w}$$

Conceptual model of radionuclide soil-plant transfer

- A model accounts for transformation of chemical forms in soils, sorption/desorption in soil-solution system including selective sorption, ion exchange in solution - root exchangeable complex and reversible transport through root cell wall.



Parameterization of radionuclide soil-plant transfer



$$TF \sim A = \frac{\alpha_{ex}}{RIP(K)} \times \frac{m_K + K_c(NH_4/K) \times m_{NH_4}}{\sqrt{(m_{Ca} + m_{Mg})}}$$

- Radiocaesium Bioavailability ~ 1/RIP
- Radiostrontium bioavailability ~ 1/CEC

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Chernobyl Cooling Pond

After A.Antropov

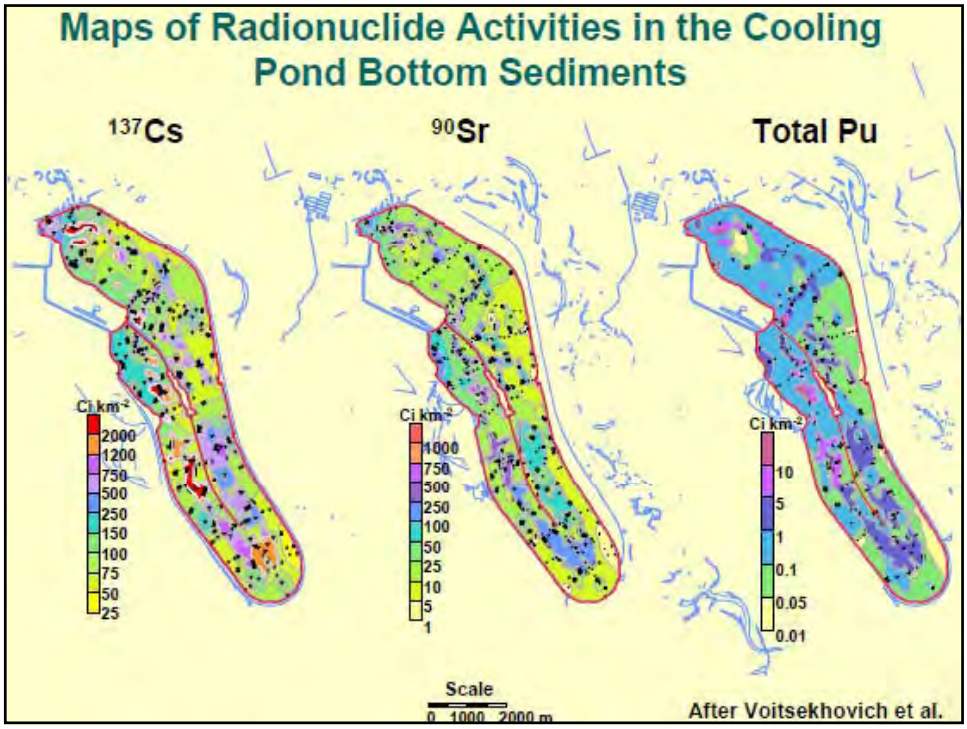
- Area ~ 22 km^2
- ~1.5 × 10^8 m^3 of water
- Water is pumped from the Pripyat River to the Cooling Pond

Sources of Contamination

- Dispersed fuel particles
- Heavily contaminated water from the reactor basement and soils.
- Total radioactivity— >200 TBq, including ^{137}Cs-80%, ^{90}Sr-10%, ^{239,240,241}Pu-10%

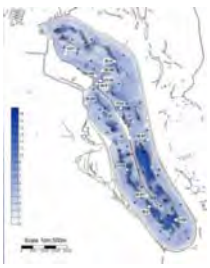
Decommissioning

- Separating the inflow and outfow channels from the pond
- Alternative source of cooling water--groundwater pumping wells



Fuel particles in Cooling Pond

- By now fuel particles have been almost completely disintegrated in terrestrial soils.
- Due to a low dissolved oxygen concentration and a high pH, dissolution of fuel particles in the Cooling Pond (CP) sediments is significantly slower than in soils.
- As a result, in the CP sediments the prevailing part of ^{90}Sr activity still occurs in the form of fuel particles.



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During the coming years, management and remediation strategy for the Cooling Pond is going to be implemented. Remediation options include a controlled reduction in water level of the cooling pond and stabilisation of exposed sediments.

- After designed cessation of water pumping from the Pripyat river to the pond a part of sediments will be drained and exposed to the air.
- *This will significantly enhance the dissolution rate and, correspondently, mobility and bioavailability of radionuclides will increase with time.*

Expected Areal Distribution of Exposed Sediments During the Pond Water-Level Drawdown

Normal scenario

Water levels in residual ponds
H=104.2 – 105.5 m a.s.l.,
Exposed area = 12.9 km²

Dry scenario

Water levels in residual ponds
H=101.2 – 103.3 m a.s.l.,
Exposed area = 18.5 km²

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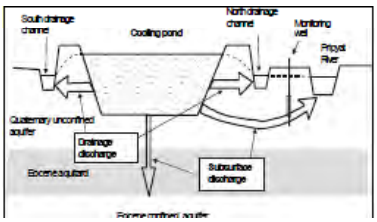
δ_0

Components of ^{90}Sr balance in the CCP

- Initial ^{90}Sr activity in the pond A_0~ (4÷7)*10^{13} Bq;
- Inflow with Pripyat river water A_{IN}~ 1.8*10^{12} Bq;
- Outflow with infiltration flux A_L~ 2*10^{13} Bq;
- Mean fraction in pore water and exchangeable form ~ 2.8 %
- Fraction of fixed form ≤ exchangeable fraction
- Fraction of ^{90}Sr associated with fuel particles in the Chernobyl fallout δ ~ 90 %



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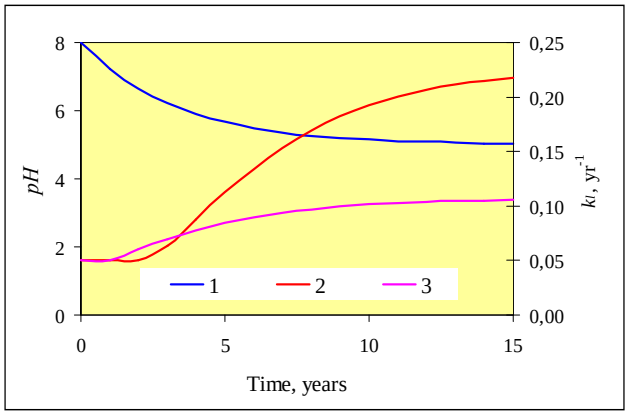
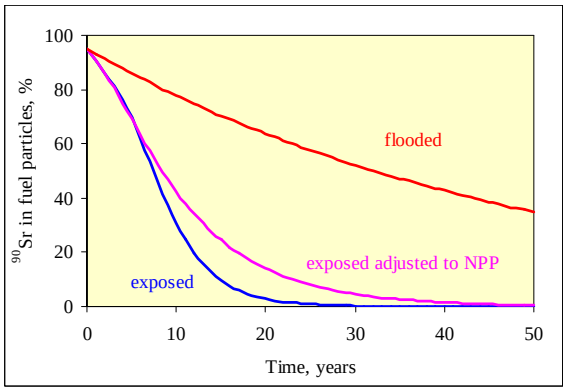
Predicted dynamics of pH and dissolution rate constants in newly exposed CP sediments (1 – **pH** ; 2 – rate constant for exposed sediments of the main part of CP ; 3 – rate constant in exposed sediments of CP part adjusted to the NPP)



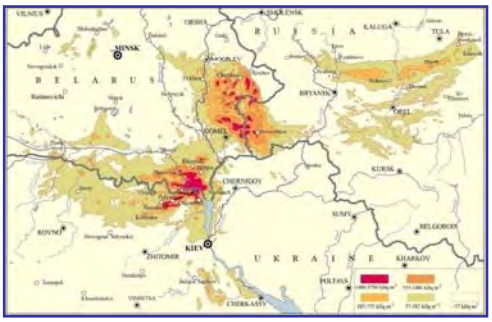
Prediction of fuel particle dissolution and dynamics of ^{90}Sr exchangeability in Cooling Pond sediments



Two major environmental problems to be solved

- Utilization of industrial wastes

Generation (million ton per year):
1. Clay-salt slimes = 2.0
2. Hydrolized lignin = 0.24
3. phosphogypsum = 0.42



- Rehabilitation of territories contaminated by ^{137}Cs and ^{90}Sr as a result of the Chernobyl Accident

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Objectives

- To develop efficient and ecologically safe amendments based on industrial waste and natural raw materials for remediation of soils contaminated by ^{137}Cs and ^{90}Sr;
- To develop methods and models for prediction of efficacy of such countermeasures as part of remediation.

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Objects of the investigation

Source materials

Clay-salt slimes – waste of potassium production containing clay minerals

Hydrolyzed lignins - waste of paper pulp production

Sapropels – organic rich bottom sediments of lakes

Organo-mineral Mixtures

Binary, Ternary, Quaternary

Soils

SPS-RF

HGS-RF

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Distribution coefficients K_d of radiocaesium and radiostrontium in soils

$$K_d(^{137}Cs) = \frac{RIP(K)}{([K^+]_W + K_c(N/K)[NH_4^+]_W)}$$

Clay-salt slimes increase RIP of soils

$$K_d(^{90}Sr) = \frac{CEC}{[Ca]_w + [Mg]_w}$$

Organic sapropels and hydrolized lignin increase CEC of soils

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Characteristics of source components and soils

Sample code	C_{org}, %	pH_{KCl}	CEC, $cmol_c\ kg^{-1}$	RIP(K), $mmol\ kg^{-1}$
CSS-1-RB	1,50±0,12	7,7	14.2±1.0	6343±1120
CSS-2-RB	1,96±0,29	7,3	162.±1.0	3041±334
PG-RB	0,05±0,01	4,9	-	17.6±1.6
HL AR-RB	34,6±1,7	3,0	100±3	7,2±0,8
HL NR-RB	47,8±2,4	6,3	64.3±0.8	23,3±1,8
HL DR-RB	39,8±1,9	2,8	72.4±2.0	32,2±1,2
SaprSilica R-RB	14,3±0,6	4,7	69.6±5.0	596,7±0,3
SPS-1- RB	0,30±0,05	4,2	8.7±1.6	35.1 ±1.2
SPS-RF	0,62±0,03	3,6	5.7±0.3	440 ±70
HGS-RF	8,6±0,6	3,2	33.9±0.4	1200 ±70

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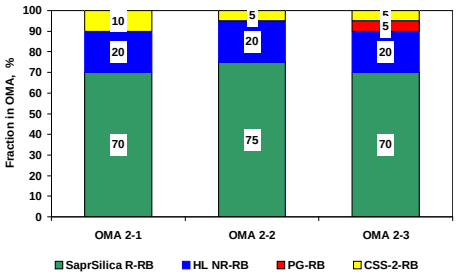
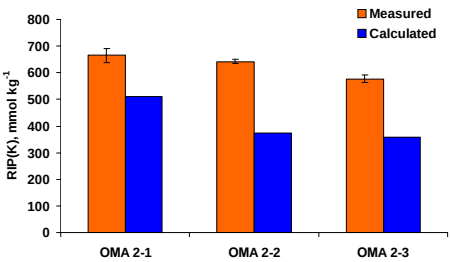
RIP in ternary and quaternary OMAs (CSS-2-RB)

Composition of OMAs 2



$$\frac{RIP(K)_{Exper}}{RIP(K)_{Calcul}} = 1.3 - 1.7$$

RIP(K)



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Fate and Transport of Cesium, Strontium and Cobalt Particles on Urban Surfaces

US EPA-ISTC Partner Project #4007
Contractor: Research and Production Association "Typhoon"



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Objectives

The objectives of the project are:

- **to investigate fate and transport of water soluble radiocesium, radiostrontium and radiocobalt deposited on common urban building materials (concrete, brick, asphalt, limestone, and granite) under various environmental conditions;**
- **to study radiocesium, radiostrontium and radiocobalt sorption/desorption on components of drinking water distribution systems (iron, plastic, copper and concrete pipes)**

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Materials and methods





Asphalt Brick Limestone Concrete Granite

Material	*Density, g/cm³*	*Porosity total, cm³/cm³*	*Hygroscopic moisture, %*	CEC, meq/kg	C_{org},%	pH	
						H_2O	KCl
Asphalt	*2.71*	*0.21*	*0.09*	*-*	*0.36±0.03*	*12.3*	*12.5*
Limestone	*2.72*	*0.17*	*0.03*	*-*	*0.092±0.004*	*9.5*	*9.6*
Concrete	*2.73*	*0.32*	*0.40*	*12.0±2.5*	*0.30±0.08*	*10.7*	*10.5*
Brick	*2.76*	*0.27*	*0.07*	*5.9±0.6*	*0.092±0.004*	*10.0*	*9.7*
Granite	*2.77*	*0.05*	*0.02*	*19.3±0.7*	*2.9±0.03*	*9.6*	*9.5*

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Building materials have been characterized in terms of ability to sorb radiocesium selectively

$$RIP(K) = \frac{(C_o - C_e) \cdot V \cdot C_K}{m_s \cdot C_e}$$


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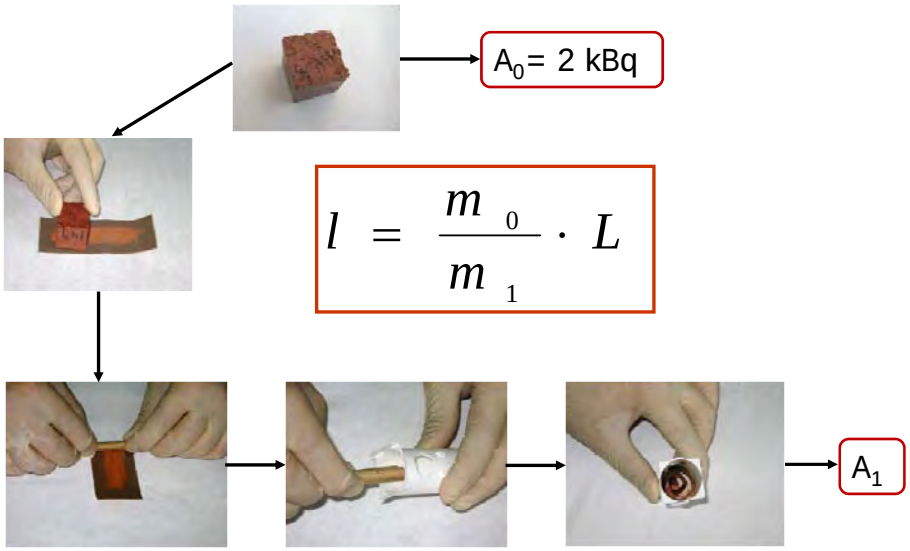
Methodology for determining radionuclides depth profile in building materials using layer-by-layer grinding has been developed



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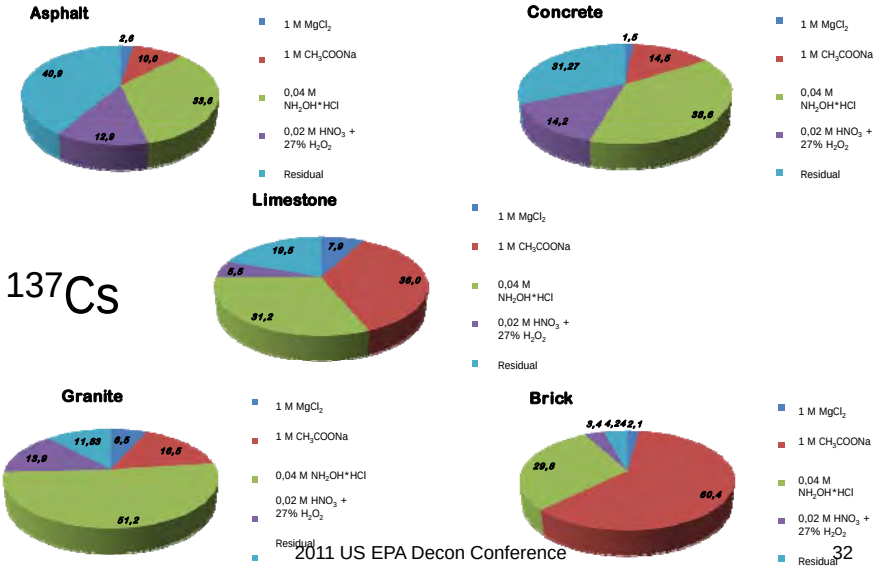
Sequential extractions have been used to investigate radionuclide speciation in building materials

^{137}Cs



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Project findings

✓ Ability to bind radiocesium selectively has been shown to increase in the order: limestone > brick > concrete > granite > asphalt.
✓ By the ability to bind ^{137}Cs with the residual fraction, the studied materials form the following sequence: asphalt > concrete > limestone > granite > brick.
✓ Effective method to study radionuclides distribution in depth of building materials using layer-by-layer grinding has been developed.
✓ About 70-75% of ^{60}Co are bound to carbonates in limestone and brick and about 50% in granite. The iron and manganese oxides bind 14% of ^{60}Co in limestone and 43% in asphalt. ^{60}Co does not practically bind (<1%) to organic compounds and silicate matrix.
✓ Major part of ^{85}Sr occurs in exchangeable form and bound to carbonates. Remaining fractions compose not more than 5 % for all materials under study.

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First results on radionuclide sorption by pipes

- **Surprisingly high sorption of ^{85}Sr on irons pipes;**
- **Relatively high sorption of ^{60}Co on iron and plastic pipes;**
- **Very low sorption of ^{60}Co on copper pipes**

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Main messages

- Nuclear accidents (Three Mile island – 1979; Chernobyl – 1986; Fukushima -2011) could be considered as a prototype of large scale radiological incidents in general;
- Only information on radionuclide deposition levels is not enough for accurate predictions and dose assessment. Data on speciation in fallout, rates of transformation processes and site-specific environmental characteristics determining these rates are needed;
- Information on radionuclide chemical forms, their transformation in other words mobility and bioavailability should be taken into account when rehabilitation and decontamination strategies are developed on local or regional scale.

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Thank you very much for your attention!

Questions?

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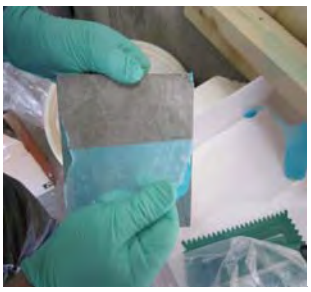
Radiological Decontamination Technologies for RDD Recovery

John Drake
National Homeland Security Research Center
Office of Research and Development
US Environmental Protection Agency

2011 U.S. EPA Decontamination Research and Development Conference
Durham, NC
November 1-3, 2011

Overview

- *What did we do and Why?*
  - Developed efficacy testing methodology
  - Tested a variety of technologies
  - Chemical, mechanical, coatings
  - EPA's WMD cleanup mission
- *How?*
  - Test program/protocols/facilities
- *Results*
  - Which ones worked best?
- *Future Work*



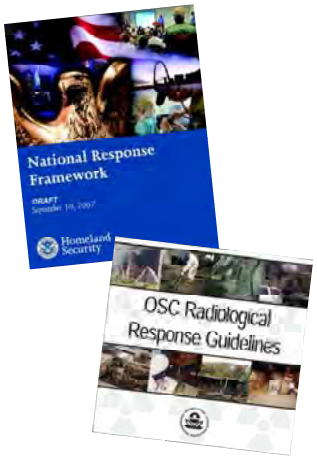
DISCLAIMER

This presentation does not represent EPA policy or product endorsement.

EPA's WMD Cleanup Mission

(short version)

- National Response Framework (NRF)
  - Multi-Agency document outlines scenarios planned for and responsibilities of each Fed agency
  - Scenario #11 is urban "Dirty Bomb"
  - EPA tasked to manage clean up during "Late Phase" of a response
- EPA response community (OEM, OSCs Special Teams) manages cleanup at the site
  - NHSRC is a resource for technology and scientific information to support the cleanup



Radiological Decontamination Technologies for RDD Recovery

What did we do?

- Developed radiological decon technology efficacy testing methodology based on DARPA research
- Tested variety of products
- Per vendor instructions
- "Dirty Bomb" contaminant
  - Cs-137 (to-date)
  - Am, Sr, Co (beginning FY2011)
- Urban materials
  - Exterior: concrete
  - Interior: residential surfaces

Dry run SDF foam at INL

Office of Research and Development
National Homeland Security Research Center, Decontamination and Consequent Management Division

How?

- EPA/NHSRC does technology evaluation for decontamination products for CBRN contaminants
- Technology Testing and Evaluation Program (TTEP)
- Emphasis on performance of commercially available cleanup technologies applicable to buildings, equipment, outdoor areas
- Radiological decontamination evaluations included strippable coatings, chemical methods, mechanical methods, commercial cleaning products

Radiological Decontamination Technologies for RDD Recovery

Purpose of the testing

- Measure decontamination efficacy
  - Percent Removed %R = $(1-A_f/A_o) \times 100\%$
    - A_o = radiological activity measured on each coupon before application of the decontamination technology
    - A_f = radiological activity of the coupon after application
  - Decontamination Factor DF = A_o/A_f
- Evaluate deployment characteristics
  - Decontamination rate
  - Applicability to irregular surfaces
  - Skilled labor requirements
  - Utilities required
  - Portability
  - Set-up time
  - Secondary waste management
  - Surface damage

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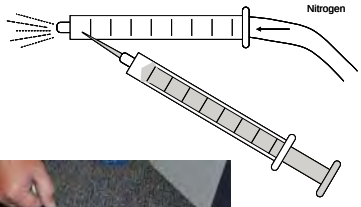
Test Protocols

- Coupon material (exterior surfaces)
  - Representative of common building material
  - Clean, smooth (not polished)
  - Type II Portland cement ASTM C150-7
  - Affinity for likely contaminant is Cs-137
  - 6x6x2-inch
  - Derived from early DARPA tests

Radiological Decontamination Technologies for RDD Recovery

Test Protocols

- Coupon preparation
  - Lightly brushed/rinsed with DI water
  - Deposit aqueous Cs-137 (CsCl) 1.0 µCi/coupon
  - Measure activity before/after decon: high purity germanium detector (Canberra LEGe Model GL 2825R/S)
  - Coupon “ages” for 7-10 days
  - Early experiments showed no significant difference for 7-30 day aging
  - Low RH due to environmental conditions at INL



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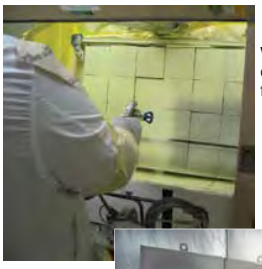
Test Protocols

- Facilities
  - Initial method development utilized fume hood
  - Horizontal and vertical orientation with crevices
  - Vertical geometry proved to be more challenging
  - 9x9-ft stainless steel "wall"
  - Pockets for 9 coupons



Wall of coupons in fume hood

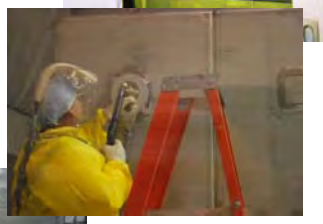
9x9 ft wall with inset coupons

Radiological enclosure at INL

Technologies tested to-date

- Strippable coatings (4 products)
- Mechanical methods (5 products)
- Chemical methods (8 products)
- Commercial cleaner on interior surfaces (1 product + water baseline)

Bartlett Stripcoat TLC



River Technologies Rotating Water-jet

Interior surfaces cleaned with Simple Green

ANL SuperGel

Radiological Decontamination Technologies for RDD Recovery

Strippable coatings

- Tested 4 technologies/ 3 vendors
  - CBI DeconGel 1101 & 1108
  - Isotron Orion
  - Bartlett Stripcoat TLC

CBI DeconGel

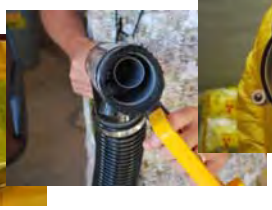
Isotron Orion

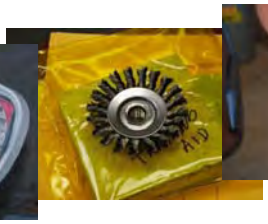
Bartlett Stripcoat TLC

Radiological Decontamination Technologies for RDD Recovery

Mechanical technologies

- Tested 5 technologies/vendors
  - CS Unitec (sander)
  - River Technologies (rotating water-jet)
  - Empire Blast (abrasive blast)
  - Dust Director (wire brush)
  - Dust Director (diamond flap wheel)
- All utilize effluent capture





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Radiological Decontamination Technologies for RDD Recovery

Chemical technologies

- Tested 9 technologies/5 vendors
  - EAI Rad-Release I & II
  - Rad Decon Solutions Liquid & Foam
  - INTEK ND-75 & ND-600
  - ANL SuperGel
  - Allen-Vanguard SDF

Radiological Decontamination Technologies for RDD Recovery

Strippable Coatings Decontamination Efficacy

Decontamination Technology	Pre-Decon Activity µCi / Coupon	Post-Decon Activity µCi / Coupon	%R	DF
Isotron Orion	53.3 ± 1.9	15.3 ± 3.8	71.5 ± 6.3	3.7 ± 0.8
Decon Gel 1108	1.07 ± 0.02	0.36 ± 0.09	67 ± 9	3.2 ± 0.9
Decon Gel 1101	1.10 ± 0.03	0.60 ± 0.09	49 ± 7	1.9 ± 0.2
Bartlett Stripcoat TLC	54.4 ± 2.6	36.0 ± 6.4	33.8 ± 10.7	1.5 ± 0.2

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Chemical Technologies Decontamination Efficacy

Decontamination Technology*	Pre-Decon Activity µCi / Coupon	Post-Decon Activity µCi / Coupon	%R	DF
EAI Rad-Release II	1.02 ± 0.08	0.15 ± 0.03	85 ± 2	7.0 ± 1.1
Argonne SuperGel	1.03 ± 0.01	0.28 ± 0.05	73 ± 5	3.8 ± 0.7
EAI Rad-Release I	1.11 ± 0.04	0.34 ± 0.14	71 ± 13	3.9 ± 1.5
QDS Liquid	1.10 ± 0.03	0.52 ± 0.09	53 ± 7	2.1 ± 0.3
INTEK ND-600	1.08 ± 0.03	0.52 ± 0.12	52 ± 12	2.1 ± 0.4
QDS Foam	1.02 ± 0.11	0.49 ± 0.07	51 ± 8	2.1 ± 0.4
INTEK ND-75	1.12 ± 0.05	0.60 ± 0.04	47 ± 6	1.9 ± 0.2

*Allen-Vanguard SDF testing completed Aug 2011. Data analysis/QA in progress.

Radiological Decontamination Technologies for RDD Recovery

Mechanical Technologies Decontamination Efficacy

Decontamination Technology	Pre-Decon Activity µCi / Coupon	Post-Decon Activity µCi / Coupon	%R	DF
DD Wire Brush	1.16 ± 0.05	0.72 ± 0.09	38 ± 7	1.6 ± 0.2
DD Diamond Flap Wheel	1.13 ± 0.07	0.12 ± 0.09	89 ± 8	14 ± 8.5
CSU Sander	1.15 ± 0.07	0.53 ± 0.12	54 ± 10	2.3 ± 0.7
RT Rotating Water-jet	1.13 ± 0.03	0.72 ± 0.05	36 ± 4	1.6 ± 0.09
EB Grit Blaster	1.17 ± 0.04	0.03 ± 0.03	96 ± 3	41 ± 21[a]

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Commercial Cleaner Decontamination Efficacy

Material	DF (Simple Green)	DF (water)	%R (Simple Green)	%R (water)
Formica	41.3	15.4	97.60%	93.40%
Vinyl Flooring	31.0	25.5	96.70%	96.00%
Granite	1.6	1.1	31.4%	7.7%
Poly coated wood	3.1	3.2	67.20%	68.10%
Painted wallboard	1.1	1.1	9.50%	7.30%
Stainless steel	39.3	19.3	97.50%	94.80%

Conclusions

- Efficacy varies greatly depending on material decontaminated
- Difference between Simple Green® and water not significant for some materials
- Both Simple Green® and water were ineffective on wallboard and minimally effective on polyurethane coated wood

Radiological Decontamination Technologies for RDD Recovery

Operational Factors

Some factors are ***quantitative*** and some are ***qualitative***

- Decontamination rate (hours/sq meter)
- Secondary waste management
- Cost of materials ($/sq meter)
- Utilities required
- Applicability to irregular surfaces
- Skilled labor requirements
- Extent of portability
- Set-up time
- Surface damage

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Decontamination rate

- Time required to decontaminate a surface (hours/sq meter)
- Affected by
  - Technology type (e.g. chemical spray, mechanical speed, etc)
  - Need for multiple steps, repeated applications, dwell time, cure time, etc.
  - Mobility/weight of equipment
  - Operator skill requirements
  - Surface material and topography
- Measured time required to complete treatment per manufacturers recommended process
- Training/set-up times not included

Note: Bench scale decon rates should NOT be extrapolated to larger areas by a direct multiplier. There are many scale-up factors which would need to be considered.

Radiological Decontamination Technologies for RDD Recovery

Secondary waste management

- Measured as waste volume/area cleaned (L/m^2 or m^3/m^2)
- Affected by
  - Technology type (chemical, mechanical)
  - Effluent collection method (e.g. vacuuming, manual coating removal, absorbent media, etc)
  - Need for multiple steps, repeated applications
  - Surface material and topography
- Training/set-up waste not included
- *Bench scale waste generation rates are considered indicative of waste generation expected for larger areas.*

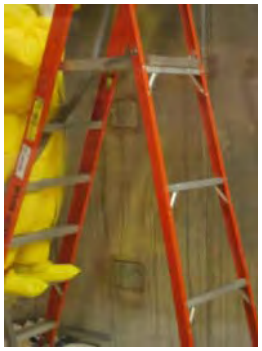

Figure 5-1. Water running onto other coupons.

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Operational Factors

Cost of Materials

- Materials cost was reported as $/sq meter cleaned
- Labor cost not evaluated
- Equipment cost and procurement method (rent vs. buy) not evaluated
- One technology tested is available only as a contracted service

Utilities required

- Varies by technology. Some require 110v for vacuum or sprayer. One required diesel powered high pressure water supply or air compressor.
- Scale up would require more complex equipment such as large capacity sprayers/vacuums.
- Scale up for some technologies tested would require equipment or methods not currently available (e.g. large scale wiping method).

Radiological Decontamination Technologies for RDD Recovery

Operational Factors

Applicability to irregular surfaces

- All technologies were judged to be applicable to irregular surfaces, but those requiring vacuum removal may prove to be more difficult depending on the surface and available vacuum attachments.

Skilled labor requirement

- For most technologies a brief training session is adequate. Scale up would require somewhat more complex equipment and/or contractor support with corresponding training requirements for equipment operation.
- All products used while in Level C PPE

Extent of portability

- Varies by technology. Some require shore power or ancillary support equipment (e.g. air compressor, high pressure water)
- All technologies tested were judged adequately portable.

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Operational Factors

Set-up time

- Varies extensively by technology.
- Less than 15 minutes for some chemical technologies up to several hours to a day for others.
- Scaled up application would require increased set-up time consistent with higher capacity equipment.

Surface damage

- Some technologies caused no visible surface damage, while others caused some polishing of the concrete surface.
- One mechanical technology resulted in significant surface damage (grit blast).

Coupons before/after grit blast

Radiological Decontamination Technologies for RDD Recovery

Future Work

- Additional radionuclides
  - Americium
  - Strontium
  - Cobalt
- Additional surface materials
  - Asphalt
  - Brick
  - Limestone
  - Ceramic tile/grout
  - Metals/glass
- Adaptation of conventional technologies for radiological application
- New/developmental technologies
  - Emphasis on Wide Area

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Radiological Decontamination Technologies for RDD Recovery

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To download products go to: http://www.epa.gov/nhsrc/pubs.html

Radiological Decontamination Technologies for RDD Recovery

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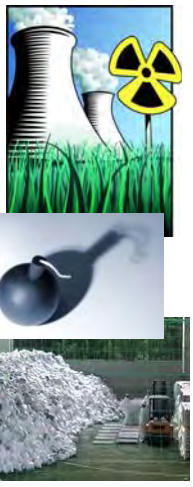
Assessment of RDD Contamination Removal From Laundering

2011 U.S. EPA Decontamination Research and Development Conference
Emily Snyder (U.S. Environmental Protection Agency)
Karen Riggs (Battelle)
Michael Lindberg (Battelle Pacific Northwest Division)

1

Background

- ✓Radiation contamination is possible public threat:
  - Release of radiological dispersal device (RDD)
  - Accident at nuclear reactor facilities
- ✓Current recommendation for handling radioactively contaminated clothing – take off clothing and bag
- ✓Washing clothing and other soft porous items may help people living outside of exclusion zone reduce their exposure to radiation



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BUSINESS SENSITIVE

2

Research Objectives

- ✓Determine efficacy of washing to remove radioactive contamination from soft porous materials
- ✓Examine fate of radioactive contamination after washing
  - In wastewater
  - Within the washing machine

Experimental Approach

- ✓Identify and demonstrate methods for:
  - Deposition of cesium chloride (Cs-137) on material swatches
  - Measuring activity of swatches before and after deposition
  - Measuring residual activity of washing machine used to launder contaminated material swatches
- ✓With demonstrated methods:
  - Evaluate efficacy of laundering for removing radioactive contamination from swatches
  - Evaluate eventual disposition of activity

Materials and Equipment

- ✓Material Swatches
  - 15 cm x 15 cm
  - Polyester and cotton
  - Pre-washed
- ✓Cs-137
  - Strong gamma emitter
  - Likely candidate for RDD
  - Isotope associated with nuclear accidents
  - Cesium chloride solution
- ✓Activity detectors
  - Broad energy germanium (BEGe)
  - High purity germanium (HPGe) system
  - Geiger-Mueller survey instrument

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Materials and Equipment (Cont'd)

- ✓Washing Machine
  - Front loading, low volume, used
  - Liquid Tide® HE detergent
  - Setup for wastewater collection
  - Installed inside radiological containment laboratory

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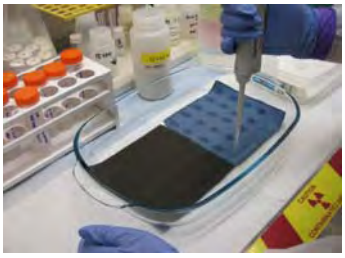
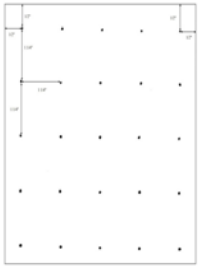
Experimental Procedures

- ✓Material Swatch Contamination
  - Activity measured before and spiking
  - Approximately <200 pCi before spiking (swatch background)
  - Each test and positive control swatch spiked with ~2 µCi of Cs-137 before laundering





Test Matrix

Material	Wash/Rinse Temperature	# of Test Swatches
Cotton	Hot/Cold	5
Cotton	Cold/Cold	5
Polyester	Cold/Cold	5

Quality Control Samples

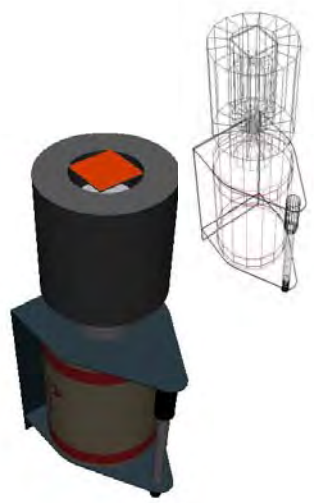
•Positive control – swatch spiked with Cs-137, and not washed

•Procedural blank - swatch not spiked with Cs-137, and washed with each test swatch

•Machine blanks – swatch not spiked with Cs-137, washed between loads with contaminated test swatches

Experimental Results – Method Demonstration

- ✓Cs-137 Application on Material Swatches
  - Consistent across replicate swatches (cotton and polyester) – 3% RSD
  - Consistent across two BEGe detectors – 2% RSD
- ✓BEGe Swatch Detection Limit
  - 0.000185 µCi (20 min counting time)



Experimental Results

- ✓Positive Controls
  - Contaminated and handled in same manner as Cs-137 spiked test swatches; processed through all procedures except washing (drying after contamination, measurement of radioactivity before and after run load)
  - No significant difference between pre- and post-activities - indicating activity is not lost due to experimental procedures

Sample	Pre Activity (µCi)	Post Activity (µCi)
Cotton 1	1.98 ± 0.09	1.96 ± 0.09
Cotton 2	2.03 ± 0.09	1.97 ± 0.09
Cotton 3	2.01 ± 0.09	1.98 ± 0.09
Polyester 1	1.90 ± 0.08	1.90 ± 0.08
Polyester 2	1.96 ± 0.09	1.91 ± 0.08
Polyester 3	1.96 ± 0.08	1.92 ± 0.08

Experimental Results

- ✓Procedural Blanks
  - Not spiked with Cs-137
  - Washed with each Cs-137 spiked test swatch

Procedural Blank	Activity (nCi)
Cotton 1	14 ± 1.1
Cotton 2	14 ± 1.0
Cotton 3	16 ± 1.4
Cotton 4	15 ± 1.0
Cotton 5	15 ± 1.3
Cotton 6	13 ± 1.2
Cotton 7	15 ± 1.2
Cotton 8	14 ± 0.95
Cotton 9	15 ± 1.3
Cotton 10	14 ± 1.4
Polyester 1	0.38 ± 0.056
Polyester 2	0.71 ± 0.077
Polyester 3	0.80 ± 0.091
Polyester 4	0.64 ± 0.074
Polyester 5	0.45 ± 0.075

Table 6. Results for Machine Blanks

Experimental Results

- ✓Machine blanks
  - Not spiked with Cs-137; washed in separate loads run between loads with Cs-137 spiked test swatches
  - Activity <0.00026 µCi
  - Suggest contamination may not transfer from load to load

Machine Blank	Washed Between Loads	Activity (nCi)
BLK1	Loads 1 and 3	<0.21
BLK2	Loads 3 and 5	<0.23
BLK3	Loads 5 and 7	<0.20
BLK4	Loads 8 and 10	<0.26
BLK5	Loads 10 and 12	<0.25
BLK6	Loads 15 and 17	<0.24

- ✓Residual Contamination in Washing Machine
  - 0.07 µCi

Experimental Results

Laundering of Contaminated Swatches

Material	Wash/Rinse Temperature	Average* Percent Removal	Average* Decontamination Factor
Cotton	Hot/Cold	94% ± 0.46%	18
Cotton	Cold/Cold	96% ± 0.97%	25
Polyester	Cold/Cold	97% ± 0.28%	30
*Cotton**	*Cold/Cold*	*92%*	*12*

- *Decontamination Factor (unit less) = Activity pre-Wash/Activity post-Wash*
- *Percent removal = [1 – (Activity post-Wash/Activity pre-Wash)] x 100%*

**Five replicates*
***Without detergent; preliminary results*

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Experimental Results

Activity of Washing Machine Wastewater

Material	Wash/Rinse Temperature	Average Activity for 5 Individual Washes (pCi/mL)	Average Total Activity/ Load (µCi) Based Upon 20 L collected
Cotton	Hot/Cold	86 ± 2.6	1.7
Cotton	Cold/Cold	83 ± 5.8	1.7
Polyester	Cold/Cold	89 ± 2.9	1.8
Machine Blank	--	--	<0.04

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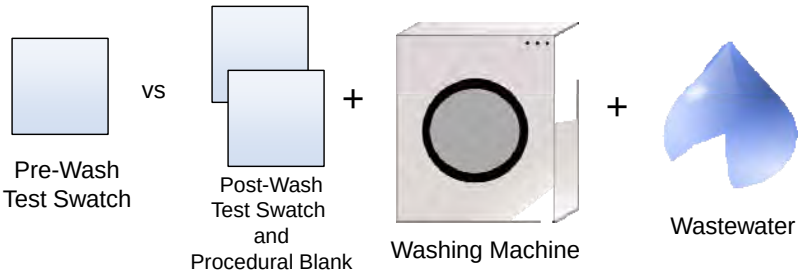
Experimental Results

Material Balance



Material	Wash/Rinse Temperature	Average Material Balance
Cotton	Hot/Cold	96%
Cotton	Cold/Cold	92%
Polyester	Cold/Cold	95%

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Conclusions

- ✓Preliminary results indicate laundering can significantly reduce radiation contamination from clothing
- ✓Majority of activity from contaminated clothing ends up in wastewater
- ✓Slight differences observed in effectiveness between materials (may be within experimental variability)
- ✓Additional studies ongoing to evaluate effect of multiple wash cycles, full load, and use of no detergent

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Simulated Pressure Washing for Removal of IND Fallout Particles

EPA's 2011 Decontamination Research and Development Conference

Emily Snyder[1], Rick Demmer[2], and Ryan James[3]

[1] EPA/ORD/NHSRC
[2] Idaho National Laboratory
[3] Battelle

Outline of Presentation

- Why is this work being done and what is being learned from this study?
- What is the goal and how do we accomplish this goal?
- Results related questions
  - How do we generate the fallout simulant for ground level detonation in an urban environment?
  - What is the efficacy of simulated pressure washing for removal of this fallout?
  - What are the operational parameters of this technology?
- Where do we go next?

1

Significance and Impact of this Research

- Assessment of how well gross decontamination technologies remove IND fallout particles from surfaces representative of critical infrastructure and response assets.
- How these technologies can best be implemented in the field during a response
- Who uses this information:
  - NIRT
  - EPA Special Teams
  - EPA On-Scene Coordinators
  - DOD

2

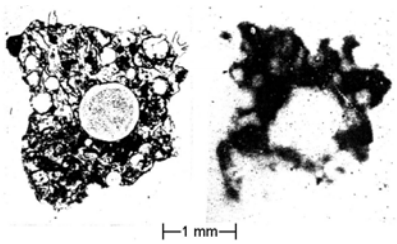
Gross Decontamination Technologies

Decon method	How easy to implement?
Fire hose rinsing	Easy
Fire hose w/ detergent	Easy
Fire hose w/ detergent and scrubbing	Moderate
Street vacuum sweeping	Easy
Street flushing	Easy
Pressure washing	Moderate
Steam cleaning	Moderate
Broom / hand sweeping	Easy
Indoor surface vacuuming/ washing	Moderate
Lawn mowing	Easy
Soil plowing/turning	Moderate
Earthmoving (removal of top soil)	Moderate
Sealing / painting	Moderate
Strippable coating	Difficult
Sand / media blasting	Difficult
Road heater/planer	Difficult

3

Existing Data on Decontamination of Fallout

- Civil Defense Era decon data used sand for evaluations of gross decontamination technologies
- Other decon data collected from Chernobyl – NPP fallout ≠ IND fallout in terms of chemical composition and particle size
- Based fallout composition for these current studies on recent outputs from Oak Ridge National Laboratory's modeling efforts using DELFIC and ORIGEN codes
- Fallout composition in urban environment somewhat different than sand



Fused-silicate sand fallout particle from the Nevada Sugar ground burst, 1951 taken from: http://glasstone.blogspot.com/2007/03/dr-carl-f-millers-fallout-and.html

4

Experimental Approach Generating Fallout Particles

- Particles must be generated that are similar in size and chemical composition
  - Attempted to simulate the particle size distribution from surface burst tests
    - A bimodal log normal particle size distribution ranging from submicron to 1000s of micron
    - Particle size dependent on the weapon, meteorological conditions and the surface where the weapon is detonated

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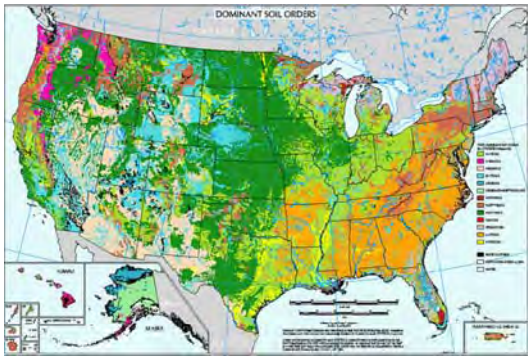
Experimental Approach
Generating Fallout Particles

- Chemical composition – According to ORNL model fallout particles for a ground level detonation in an urban environment will be made up of whatever the local soil composition is



- Vaporized material forms small metallic oxide particles which become radioactive through dissolution of fission products into the metal
- Particles of dirt that are swept into the fireball incorporate radionuclides through condensation of fission products on the surface of the particles or through agglomeration with the metal oxide particles

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Experimental Approach
Generating and Applying Fallout Particles

- Particles made up of 75% cesium specific aluminosilicate adsorbent (sized with a mortar and pestle so the particles will pass through a 710 µm sieve) and 25% kaolinite clay (300 µm sieve)
- Tagged with cesium (a fission product) because already completed method development for cesium on urban material coupons
- Deposition method included sprinkling particles from mesh-covered plastic bottles; relative standard deviation for amount applied less than 10%
- Fallout particle mass contamination level = 6.7-11.1 mg/cm^2. This is a low mass range according to the fallout decon literature, but lower contamination levels have been shown to be more difficult to decon

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- Surface activity for cesium = 26 nCi/cm^2

Surface Selection

- Concrete selected because of its prevalence as an urban building material (also found on many types of critical infrastructure) and porosity
- Have well characterized concrete samples left over from DTRA studies at INL (cement:water ratio, percent air entrainment, admixtures, the ratio of tricalcium silicate and dicalcium aluminate, etc. are known)
- These coupons are used in NHSRC's other technology evaluations

Particle Deposition

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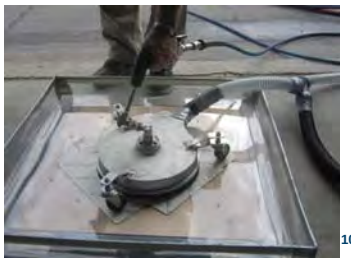
Simulated Pressure Washer

- River Technologies, LLC 3-Way Decontamination Rotating Water Jet (RWJ) System
- Chosen to simulate pressure washing
- The RWJ connects to a standard high pressure washer (cold or hot water) and an air-powered vacuum recovery system
- The RWJ consists of a pressure washer spray tool equipped with rotating spray nozzles enclosed by a vacuum shroud



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Video of RWJ Operation

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Testing Procedures

- All coupons placed into glove bag for deposition
- Five coupons had simulant deposited onto surface, procedural blank did not
- Coupons taken out of glove bag and bagged separately for pre-decon measurement
- After measurement, all six coupons placed into glove bag for decontamination
- Perform decon on a each of five test coupons and procedural blank
- Take coupons out for post decon measurement
- RH and Temperature were measured

ORTEC portable high purity germanium detector counting Cs-137 gamma radiation on a concrete coupon

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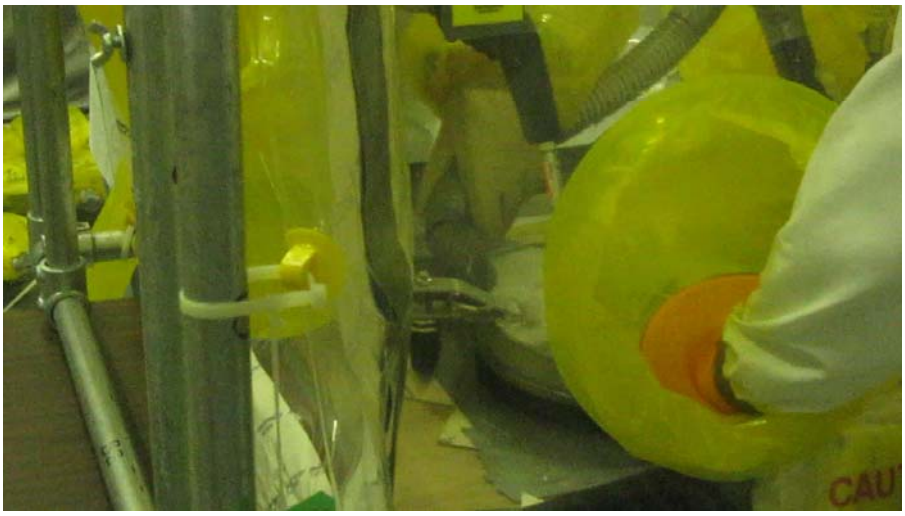
Video of Testing



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Percent Removal and Decon Factor Data

	Average %R	Standard Deviation in %R	Average DF	Standard Deviation in DF
Dry Vacuum Only	95.4	1.6	14.1	2.7
Ambient Water RWJ	97.5	0.7	15.8	3.8
Hot Water RWJ	97.3	0.7	17.9	5.0

No significant difference in percent removals for ambient and hot water RWJ

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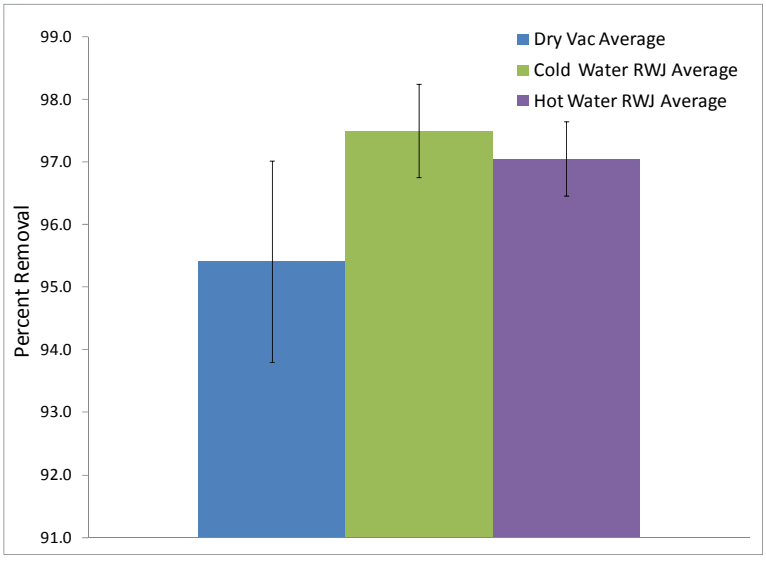
Summary of Percent Removal Data



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Specifications for Vacuum

- Nederman Inc., Westland, Michigan
  - Norclean Model NE52
  - Compressed air powered: Requires 106 cubic feet per minute (cfm) at 100 psi
  - Vacuum: -7.5 psi (typical Shop-Vac, ~-2 psi)
  - Air flow: 200 cfm

Diesel-powered air compressor

Vacuum unit and collection reservoir

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How do these results compare to other nuclear fallout decontamination testing?

Technology	Surface	Fallout Particle Mass Loading, mg/cm²	Average Percent Removal Over 44-700 µm Range	Percent Removal 177-300 µm	Percent Removal < 700 µm
RWJ Ambient	Concrete	6.7-11.1			97%
RWJ Hot	Concrete	6.7-11.1			97%
RWJ Vacuum Only	Concrete	6.7-11.1			95%
Street Flusher1	Concrete	21.5	98%		
Street Flusher[1]	Asphalt	21.5	97%		
Firehosing (5/8 inch nozzle)[2]	Asphalt	4.09-5.45	80%		
Motorized Street Sweeper (optimized conditions – single pass)[3]	Concrete	21.5		>99%	

[1] Clark and Cobbin, Removal of Simulated Fallout from Pavements by Conventionial Street Flushers, 1964
[2]Wiltshire, L. L.; Owen, W. L. Three Tests of Firehosing Technique Equipment for the Removal of Fallout from Asphalt Streets and Roofing Materials; U.S. Naval Radiological Defense Laboratory: San Francisco, California, 1966.
[3]Clark, D. E.; Cobbin, W. C. Removal Effectiveness of Simulated Dry Fallout from Paved Areas by Motorized and Vacuumized Street Sweepers; USNRDL-TR-746; U.S. Naval Radiological Defense Laboratory: San Francisco, California, 1963.

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EPA United States Environmental Protection Agency

Operational Considerations for RWJ

- Decontamination rate
  - 15 sec per 225 cm^2 coupon (~900 cm^2/min), rate typical for application of the RWJ (vendor determined)
- Applicability to irregular surfaces
  - Use on non-flat surfaces problematic because of possible interference with the rotating jets
  - Vertical or horizontal flat surfaces would be acceptable
- Skilled labor requirement
  - Brief training session would be required, but no specialized skills
- Utilities requirement
  - High pressure water and air

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EPA United States Environmental Protection Agency

Operational Considerations for RWJ:

- Extent of portability
  - Dependent on availability of utilities; gas/diesel fuel-powered compressors make portability very possible
- Secondary waste management
  - Secondary waste includes 2.5 gal water per minute (at ~ 2500 psi) of tool use (collected by vacuum). Corresponds to 15 sec per coupon so about 0.6 gal per coupon.
  - It was solidified with a desiccant and disposed as solid waste.
- Surface damage
  - No visible surface damage
- Cost
  - $900 for the tool that would need to be connected to a standard pressure washer (does not include labor or waste cost)

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Conclusions and Future Work:

- Conclusions:
  - RWJ is a slow decontamination method – use of this technology would not be feasible for response phase activities but would be feasible for small areas during final cleanup activities
  - Pressure washing is likely a good method for removing fallout from surfaces and could be used for response phase gross decontamination activities
  - Issues with reaersolization and runoff when using standard pressure washer – can add shroud to off the shelf pressure washers
- Future work:
  - Vehicle decontamination
  - Vacuum cleaning with standard HEPA vacuum

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Acknowledgements

- FEMA NIRT Program for funding
- MACWG (Vince Jodoin, ORNL) for input on the fallout particle composition

Disclaimer:
The views expressed in this presentation are those of the authors and do not necessarily reflect views or policies of the U.S. EPA. Mention of trade names or commercial products does not constitute endorsement or recommendation for use.

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RN Decontamination Capability Development at DRDC Ottawa: The Move to ^{85}Sr Decontamination Testing

2011 US EPA Decontamination Research and Development Conference

November 2011

Presented by: Marc Desrosiers

Defence Research and Development Canada | Recherche et développement pour la défense Canada

Canada

One Topic of Research at DRDC Ottawa Radiological/Nuclear Groups is Contaminated Environment which covers:

1. Hazard avoidance,
2. Personal protective equipment (PPE) with integrated RN specific protection,
3. Contaminated equipment hazard assessment tools (detectors, detection systems),
4. Decontamination procedures and protocols,
5. Integrated contaminated environments hazard assessment and decision tool,
6. Training.

2

Current and Past Decontamination Areas of Interest

- Testing decontamination methods for protocol development
  - CRTI-02-0067RD Restoration of Facilities and Areas after a Chemical, Biological, Radiological and Nuclear Event (EC Lead).
  - **CRTI-06-0169TA Universal Surface Decontamination Formulation.**
- Sensitive equipment
  - Canadian Forces Decontamination Of Sensitive Equipment (CFDOSE).
- Process Cost
  - CRTI-04-0019TD Field Demonstration of Advanced Chemical, Biological, Radiological and Nuclear (CBRN) Decontamination Technologies (Little House on the Prairie) (EC Lead).
- RDD contamination interaction
  - **CRTI-06-0156RD RDD Contamination Interactions with Urban Surfaces.**
- Decision Procedures and Tools
  - Decontamination Decision Tool (DDT).

3

Decontamination Protocol (Procedures) Development and Past Decontamination Experiment.








4

- Development of Protocols: Isotopes
  - Have used Na 24, Tc 99m and La 140 in various chemical and physical forms.
  - Short Half Life (less than 15 days) Isotopes are ideal for the development of procedures and allow us to build safety cases for the use of longer lived isotopes.
  - This has allowed us to use Sr 85, and Ac 225 recently.
  - We are also exploring the possibility of using Ir 192 and Ba/Cs 131 in the near future.

5

Example of Protocol development

- Contamination procedures developed from our short half lives isotope work:
  - Salt Shaker for powders
    - DRDCO-RAD-SOP-0003 Surface Contamination Using the Salt Shaker Method
  - Pipette for liquids.
    - DRDCO-RAD-SOP-0013 Surface Contamination using the Pipette Method
  - We have also used a “puff” method for contamination and airborne contamination for PPE testing
  - We are also working on the development of a micro spray technique to disseminate small volume, uniform surface contamination.
- Above techniques were all developed using short half life isotopes. This experience then allows us to migrate the techniques to longer lived isotopes.

6

- Other procedures have also been developed and adopted from our short half lives isotope work:
  - Decontamination Procedures
    - HEPA Vacuum
      - DRDCO-RAD-SOP-0004 Surface Decontamination Using the Vacuum Method.
    - Small Scale Foam
      - DRDCO-RAD-SOP-0001 Preparation, Application, and Removal of Decontamination Foam.
  - Measurement Procedures
    - Linearity over the range of activities.
    - Precision and Reproducibility.
    - HPGe total contamination.
    - SVG2 determination of surface contamination.

7

The move to Sr 85 for Decontamination Testing

- DRDC Ottawa definition of a medium half life radioisotope is between 15 to 75 days.
- This defines Sr 85 as a medium lived isotopes (64.7 days).
- A medium half life isotope allows the waste management to be done on site in a practical way. Waste storage is less than 2 years with no disposal issues.
- Sr 85 is a replacement for Sr 90 for decontamination experiments;
  - Unlike Sr 90, Sr 85 is a gamma emitter (514 keV).
  - It has a shorter half life than Sr 90 (28.5 years).
  - It is commercially available compared to other Sr isotopes (Sr 82 is available, but it often comes with Sr 85).
  - Medium half life isotopes are practical to keep in stock, on site, compared to short half life isotopes that need to be replenished for each experiment.

8

Recent Strontium 85 Decontamination Testing

- What we used for testing:
  - Initial Stock:
    - Chemical form $SrCl_2$ in solution of 1 N HCl.
    - 18.5 MBq (500 μCi).
    - 0.084 mL volume of Stock
  - Diluted depending on activity concentration required.
- Recent Experiments using Sr 85.
  - Two experiments as part of CRTI-06-0169TA Universal Surface Decontamination lead by Environment Canada.
  - One experiment as part of CRTI-06-0156RD RDD Contamination Interactions with Urban Surfaces. An agreement for this experimentation exists between the Government of Canada and the Ministry of Defence of the Federal Republic of Germany. This was done during an RN decontamination workshop.

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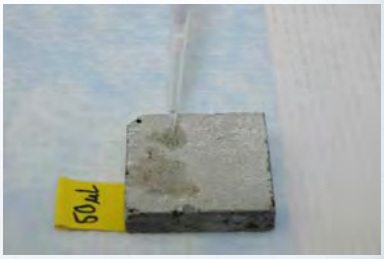
CRTI-06-0169TA Universal Surface Decontamination: First Experiment

- First time DRDC Ottawa used Sr 85 for decontamination experiments.
- Experimental setup:
  - Surface tested concrete.
  - 3 coupons per decontamination solution.
  - Size of surface 5 cm by 5 cm.
  - Contamination as DRDC O pipetting SOP.
    - 4 large (50 μl) dots for contamination.
    - 12.5 kBq/coupons (500 Bq/cm^2).
    - Contamination different than EC spiking.
    - Approximately 24 hours between contamination and decontamination



10

CRTI-06-0169TA Universal Surface Decontamination First Test

- The decontamination formulations tested were:
  - Deionised water.
  - Deionised water with salts.
  - Surface Decontamination Formulation (SDF).
  - Modified SDF.
- Application process defined by client

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Measurements

- Using ORTEC Trans-SPEC 100 (40% HPGe).
- Peak Analysis done using ORTEC Isotopic Supervisor.
  - Peak used 514 keV
  - ROI From 511.6 to 516.0 keV
- Linearity/precision per DRDC Ottawa procedures
- No Decay correction used (only 2 day experiment)

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Preliminary Results

- Precision: 2 percent

	Pre Decon		Post Decon			
Sample ID	Time	Net Cnts in ROI	Time	Net Cnts in ROI	% Removed	Average
SDF-1	935	7881	1401	7350	6.74	
SDF-2	937	7667	1405	7075	7.72	
SDF-3	940	7417	1408	6802	8.29	7.58
Water-1	954	8282	1412	7503	9.41	
Water-2	958	7625	1415	6755	11.41	
Water-3	1000	8076	1418	7398	8.40	9.74
MOD-1	943	7826	1422	6893	11.92	
MOD-2	947	7700	1426	5708	25.87	
MOD-3	951	7982	1429	7045	11.74	16.51
Water Salts-1	1004	8050	1437	7108	11.70	
Water Salts-2	1008	7425	1441	6191	16.62	
Water Salts-3	1012	7782	1444	6696	13.96	14.09
Bkg1	930	0				
Bkg2	1043	0				
Bkg3	1140	4				
Bkg4	1357	4				
Bkg5	1500	8				

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CRTI-06-0169TA Universal Surface Decontamination: Second Experiment

- Repeat of the first with the following changes:
  - Used 4 coupons for each case.
  - The decontamination formulation tested were:
    - Deionised water.
    - Surface Decontamination Formulation (SDF).
    - Modified SDF.
  - used 20 small (1 μl) dots.
  - Less dilution of initial stock (higher HCl concentration)
  - 7.1 kBq/coupons (280 Bq/cm^2)

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Preliminary Results

- Precision 3 percent.
- Background was 0 counts.

	Pre Decon	Post Decon		
Sample ID	Net Cnts in ROI	Net Cnts in ROI	% Removed	Average
SDF-1	897	873	2.68%	
SDF-2	836	874	-4.55%	
SDF-3	1014	837	17.46%	
SDF-4	747	700	6.29%	5.47%
MOD-1	855	820	4.09%	
MOD-2	817	735	10.04%	
MOD-3	1083	938	13.39%	
MOD-4	1048	889	15.17%	10.67%
Water-1	1020	866	15.10%	
Water-2	938	929	0.96%	
Water-3	995	945	5.03%	
Water-4	725	675	6.90%	6.99%

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CRTI-06-0156RD and German MOU

- Repeat of the first 169TA experiment with the following changes:
  - The decontamination formulation tested were:
    - deionised water.
    - Radiological Decontamination Solution (RDS 2000).
  - CARC painted steel used in the experiment in addition to concrete.

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Results

- Precision 3 percent
- Back ground 3 counts

	Sample ID	Initial Counts	1st Post decon	% Decon	Average
Concrete	RDS1-con	1643	1429	13%	
	RDS2-con	1503	1415	6%	
	RDS3-con	1595	1431	10%	10%
CARC	RDS4-met	1521	317	79%	
	RDS5-met	1473	338	77%	
	RDS6-met	1574	373	76%	78%
Concrete	water1-con	1504	1419	6%	
	water2-con	1476	1522	-3%	
	water3-con	1477	1447	2%	2%
CARC	water4-met	1469	288	80%	
	water5-met	1511	425	72%	
	water6-met	1419	300	79%	77%

	Sample ID	2nd Post Decon	Total % Decon	Average
Concrete	RDS1-con	1478	10.04%	
	RDS2-con	1435	4.52%	
	RDS3-con	1399	12.29%	9%
CARC	RDS4-met	147	90.34%	
	RDS5-met	193	86.90%	
	RDS6-met	189	87.99%	88%

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Future Development

- Possible third experiment for CRTI-06-0169TA. Neutralizing the strontium solution
- Development of micro spray contamination for replicate surface contamination and possible dry deposition (currently no dry method for Sr 85)
- Using other medium half life isotopes (Ir 192).

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Conclusion

- DRDC Ottawa has successfully and safely performed many contamination/decontamination experiments using short half life isotopes.
- Using the experience gained,
  - We are now moving to longer lived isotopes.
  - Developing new procedures for contamination
  - Expanding our research capability (PPE testing and evaluation)

19

DEFENCE R&D DÉFENSE

RDD WASTE ESTIMATION SUPPORT TOOL TO IDENTIFY TRADEOFFS BETWEEN WASTE MANAGEMENT AND REMEDIATION STRATEGIES

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US EPA, Office of Research and Development
D. Schultheisz, T. Peake
US EPA Office of Radiation and Indoor Air
M. Ierardi
US EPA Office of Resource Conservation and Recovery
C. Hayes and M. Rodgers
Eastern Research Group

EPA United States Environmental Protection Agency

Outline

- Why are we doing this?
- Project objectives
- Background
- Methodology
- Results
- Implications
- New enhancements

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Why We Are Doing This Work?

- RDD waste management issues linked with decontamination and restoration timeline
- Waste decisions need to be made early
  - Pre-selection of disposal options
  - Identification for triage/staging/storage areas
- Tool for Liberty RadEx (April 2010) to examine waste issues

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National Homeland Security Research Center

Project Objectives

- 1st order estimate of waste from radiological incident
- Tool that can be used for planning and response
- Use commercially available software/databases, NARAC plume models
- Adjust parameters based on decontamination, demolition options
- Ability to perform sensitivity analysis on results

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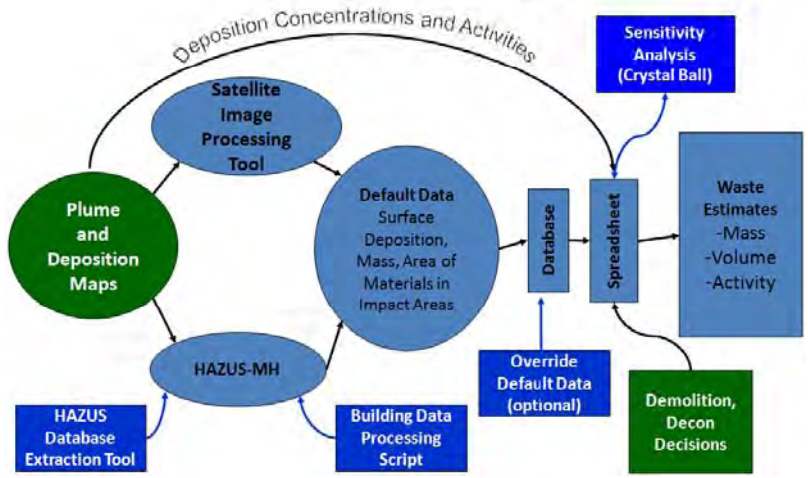
Methodology



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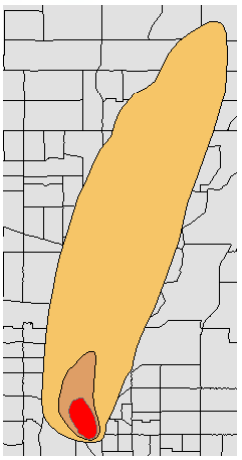
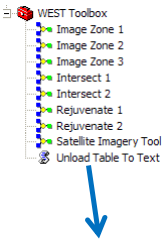
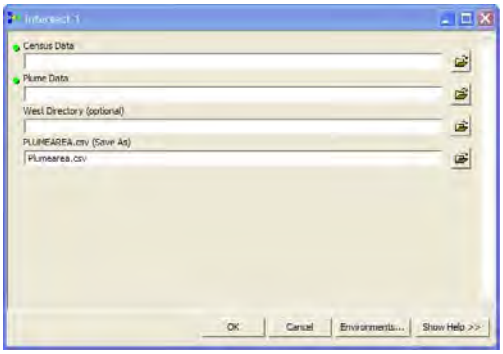
Latest Version: GIS Tools







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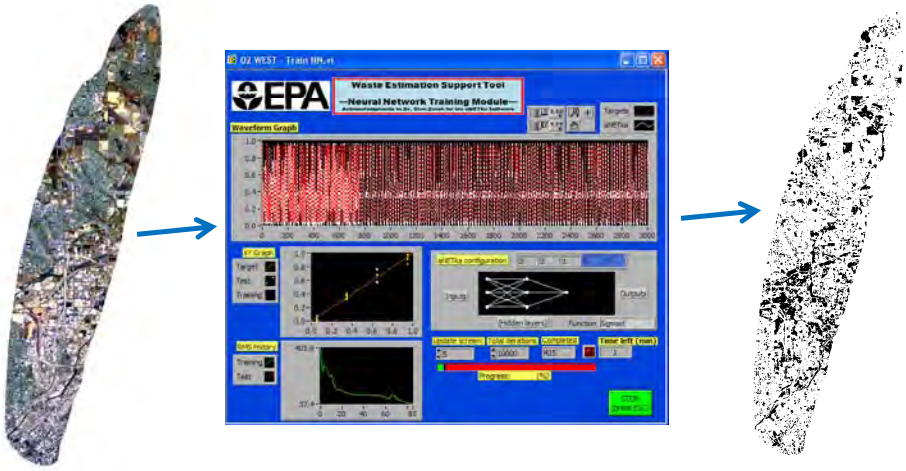
Latest Version: Surface Detection Application



Carved Satellite Imagery

Segmented Concrete

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HAZUS-MH Database Tool

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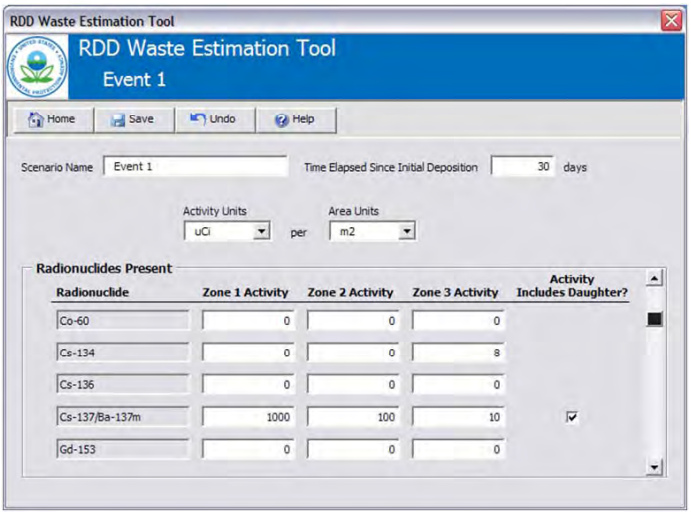
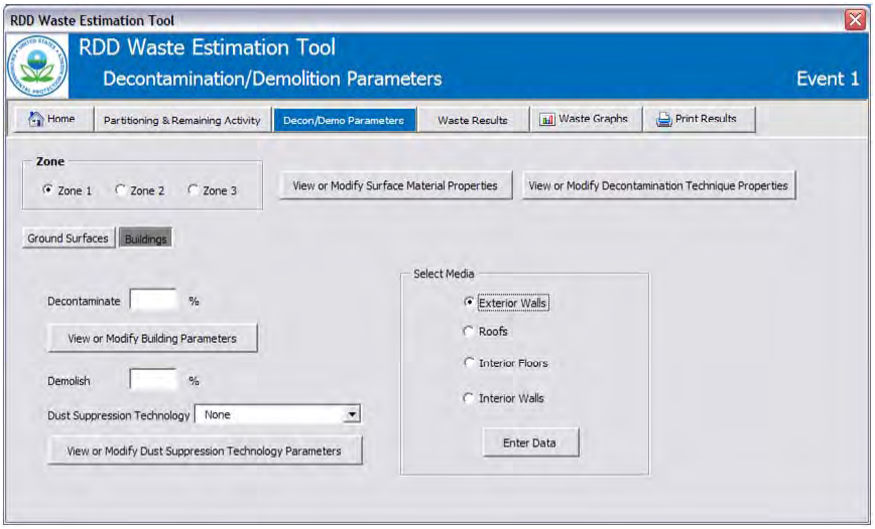
Radionuclide Selection



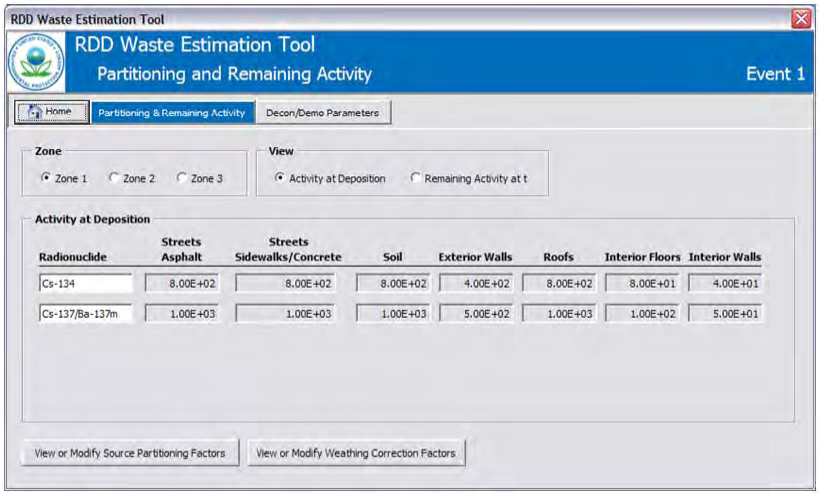
Adjustable Parameters

- Demolition/decontamination % for each zone
- % Distribution of decontamination technologies (includes solid/aqueous waste, removed material per unit area)
  - Washing
  - Abrasive removal
  - Strippable coatings
  - 2 optional “generic” decontamination technologies
  - “No decontamination” option
  - NOTE: Decontamination factors not included at this point

Decon/Demolition Parameters



Remaining Activity

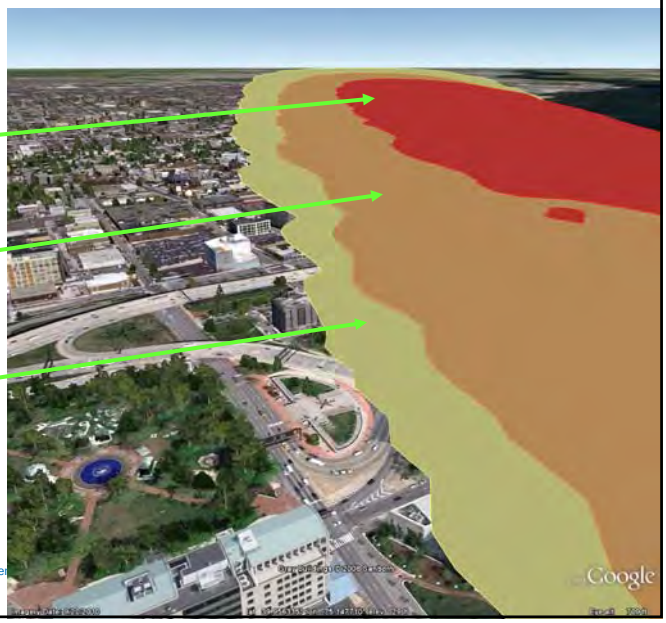


Liberty RadEx Plume Files

Zone 1 (Red)
1,000 µCi/m^2

Zone 2 (Orange)
2 Year PAG
240 µCi/m^2

Zone 3 (Yellow)
50 Year PAG
112 µCi/m^2



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LRE Default Demolition/Decon Assumptions Used

Media	Zone 1: 90% demolition, 10% decontamination	Zone 2: 10% demolition, 90% decontamination	Zone 3 10% demolition, 90% decontamination
Asphalt	1" removal	1" removal – 70% Wash – 30%	1" removal – 70% Wash – 30%
Concrete	1" removal	1" removal – 70% Wash – 30%	1" removal – 70% Wash – 30%
Soil	6" removal	6" removal	6" removal
Ext. Walls	1 mm removal	1 mm removal – 20% Wash – 80%	Wash
Roofs	1 mm removal	1 mm removal – 20% Wash – 80%	1 mm removal – 20% Wash – 80%
Int. Walls	1 mm removal	1 mm removal – 20% Wash – 30% Strip. Coat. – 50%	1 mm removal – 20% Wash – 30% Strip. Coat. – 50%
Floors	1" removal	1" removal	1" removal – 50% Wash – 50%

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Results: "View Summary"

Demolition and Decontamination Waste Summary

Philadelphia - Liberty RadEx

	Zone 1	Zone 2	Zone 3	Total	
Solid Waste					
Demolition	66,883	82,548	142,110	291,540	MT
Decontamination	22,060	311,441	615,162	948,664	MT
Total	88,943	393,989	757,272	1,240,204	MT
Liquid Waste *					
Demolition	52,948,845	65,350,416	112,503,382	230,802,641	L
Decontamination	-	14,480,199,150	27,591,713,972	42,071,913,122	L
Total	52,948,845	14,545,549,566	27,704,217,354	42,302,715,765	L

Mitigation Strategy:

Prefer Demolition over Decontamination in Zone 1

Prefer Decontamination over Demolition in Zone 2

Prefer Decontamination over Demolition in Zone 3

Note: The estimated results do not account for effects from the blast.

* This is an estimate for the amount of wastewater that may be generated. This may not accurately reflect the amount of water that would be available for demolition or decontamination activities.

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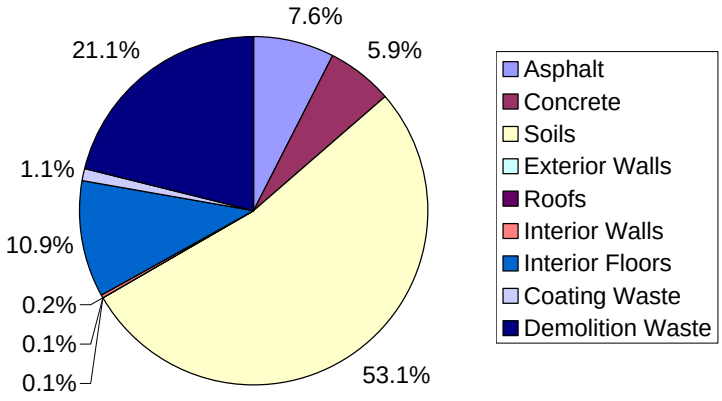
Waste Volume %



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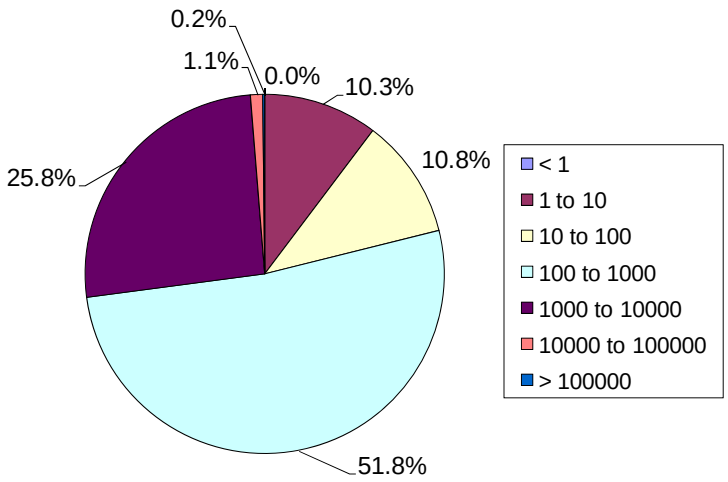
Est. Solid Waste Activity by Vol % (µCi/m³)



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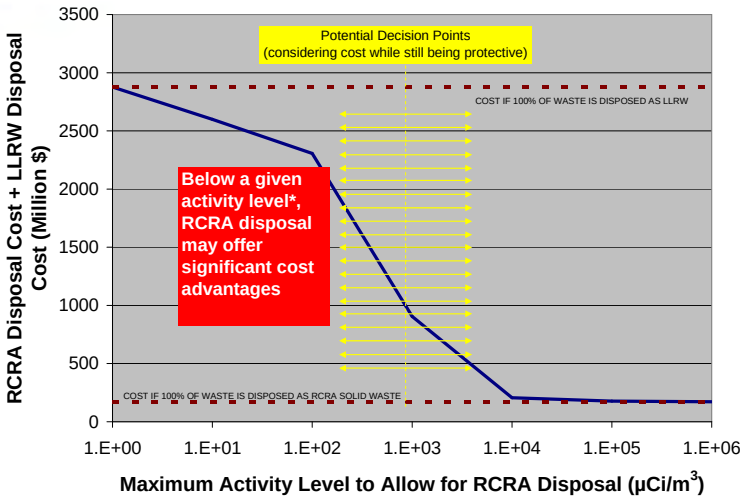
Results: Cost vs. Disposal Option



NOTE: Assumed $300/m³ for RCRA disposal and $5000/m³ for LLRW disposal
* Where RCRA disposal is protective of public health and safety

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Implications Identified by the Tool

- Need to consider waste when selecting decontamination options
- Advantages of on-site treatment to reduce waste
  - Soil is prime candidate for on-site treatment
  - Soil washing technology inadequacies suggest research need
- Identifies starting point for policy discussions
  - Use of RCRA-permitted disposal facilities for minimally-contaminated materials
  - Use of LLRW capacity for materials contaminated at higher levels

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Current Timeline for Development of Waste Estimate

- Import study regions into HAZUS-MH and export building stock data. (ArcGIS Script)
- Analyze study region satellite imagery to generate outdoor media estimate. (Image Segmentation Tool)
- Calculations on building parameter data to convert HAZUS-MH data into MS Access database needed for RDD Waste Estimation Spreadsheet. (HAZUS Database Tool)
- Load RDD Waste Estimation application and generate waste estimate (MS Excel)
- Current completion time: ~8 Hours
- Completion time for new version ≤1 Hour

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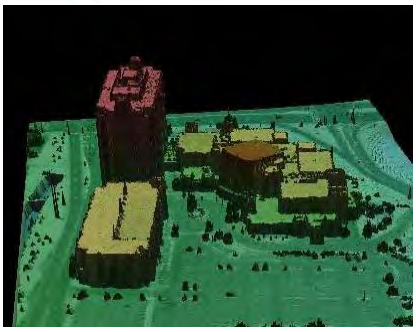
Other Features in New Version

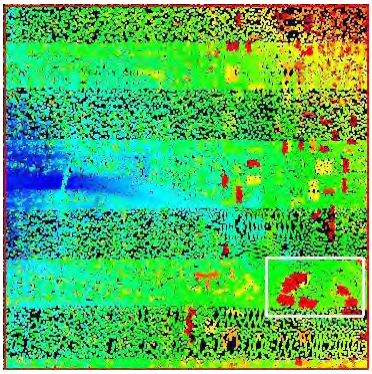
- Ability to save scenarios so that multiple estimates can be generated and saved without having to completely recreate the spreadsheet
- Multiple radionuclides and daughter products
- Ability to export the full spreadsheet to bypass GUI so that sensitivity analysis could be performed using software like Crystal Ball

Potential Future Enhancements



Structure Analysis

- Provides detailed estimation of building height and square footage
- Potential for discriminating biomass types



Detection of buildings and other entities contained within provided imagery to increase functionality

Other Future Plans

- Inclusion of decontamination effectiveness
- Inclusion of decontamination costs and time
- Inclusion of transportation cost, logistics, and time
- Ability to update pattern recognition algorithm
- Users can add custom surface types

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USDA Approach to Premises Cleaning and Disinfection

for

Animal Disease Outbreak Response

Lori P. Miller, PE
USDA APHIS
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Laws and Regulations

- Animal Health Protection Act – Delegates APHIS the authority to regulate animal health activities
- 9 Code of Federal Regulations – Animals and Animal Products; Subchapter B-Cooperative Control and Eradication of Livestock or Poultry Diseases
  - Cleaning and Disinfection of premises as approved by APHIS
  - Producer responsible for cost of cleaning and disinfecting premises
  - APHIS typically pays indemnity for animals ordered destroyed

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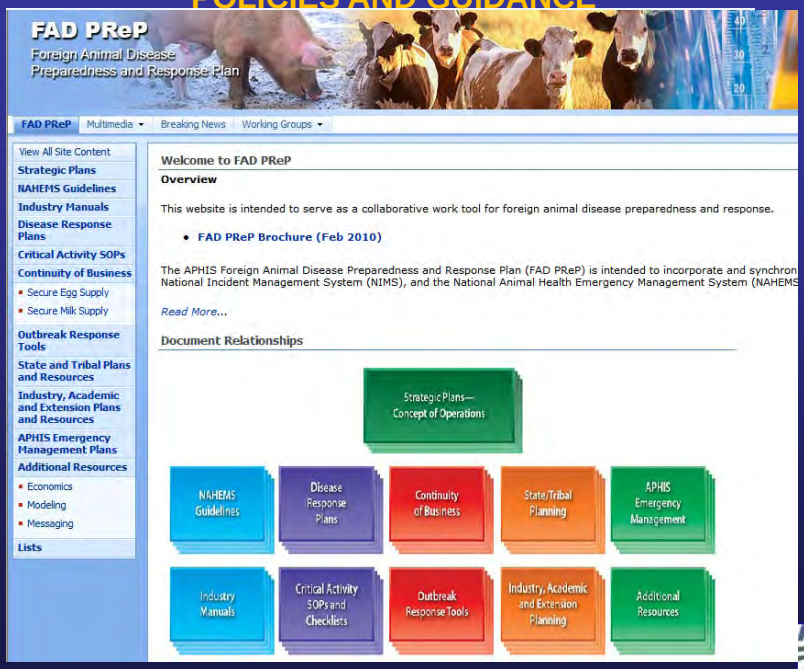
POLICIES AND GUIDANCE



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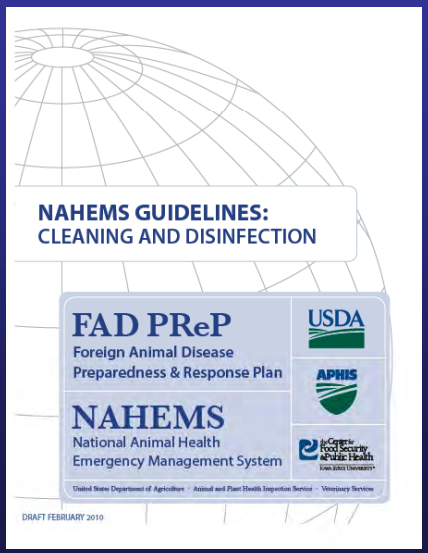
FAD PReP Guidance Documents



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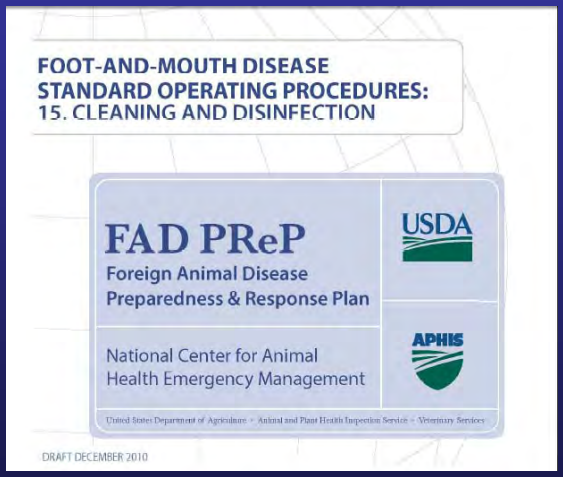
FAD PReP Generic SOPs



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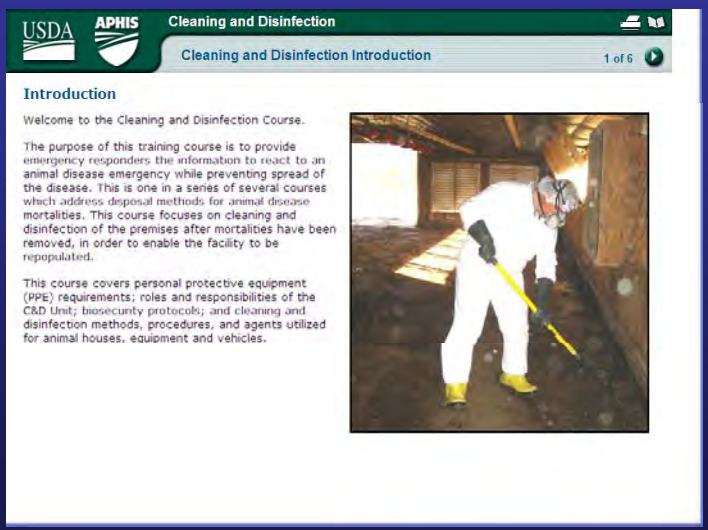
Online Training



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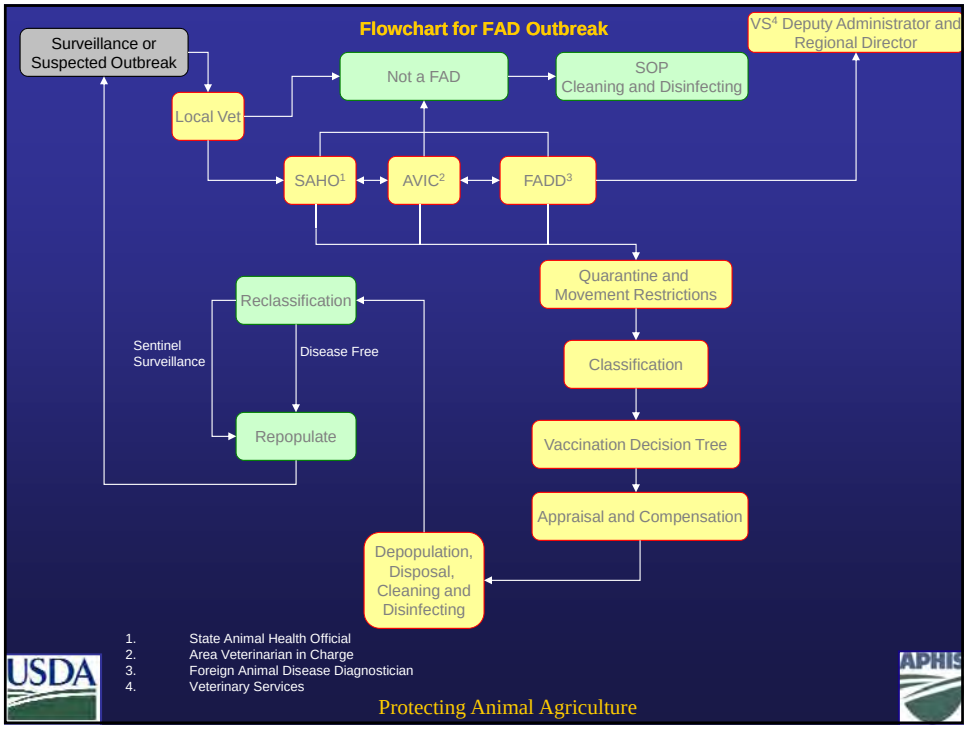
Flowchart for FAD Outbreak
Surveillance or Suspected Outbreak
Local Vet
Not a FAD
SOP Cleaning and Disinfecting
VS4 Deputy Administrator and Regional Director
SAHO1
AVIC2
FADD3
Quarantine and Movement Restrictions
Reclassification
Sentinel Surveillance
Disease Free
Repopulate
Classification
Vaccination Decision Tree
Appraisal and Compensation
Depopulation, Disposal, Cleaning and Disinfecting
1. State Animal Health Official
2. Area Veterinarian in Charge
3. Foreign Animal Disease Diagnostician
4. Veterinary Services
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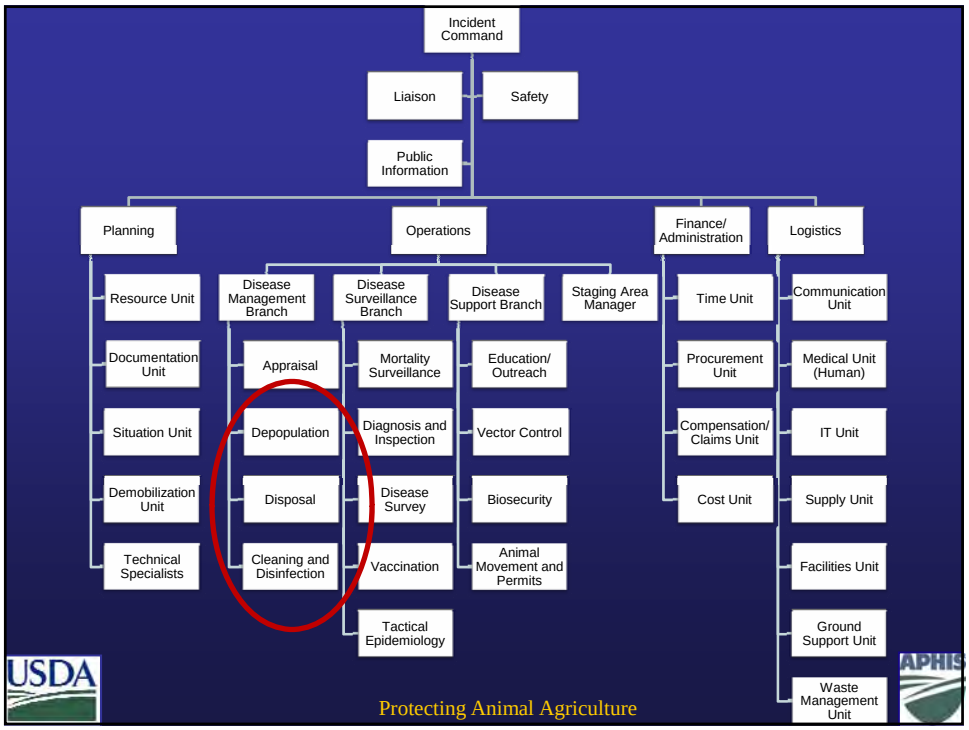
Incident Command
Liaison
Safety
Public Information
Planning
Operations
Finance/ Administration
Logistics
Resource Unit
Documentation Unit
Situation Unit
Demobilization Unit
Technical Specialists
Disease Management Branch
Appraisal
Depopulation
Disposal
Cleaning and Disinfection
Disease Surveillance Branch
Mortality Surveillance
Diagnosis and Inspection
Disease Survey
Vaccination
Tactical Epidemiology
Disease Support Branch
Education/ Outreach
Vector Control
Biosecurity
Animal Movement and Permits
Staging Area Manager
Time Unit
Procurement Unit
Compensation/ Claims Unit
Cost Unit
Communication Unit
Medical Unit (Human)
IT Unit
Supply Unit
Facilities Unit
Ground Support Unit
Waste Management Unit
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Cleaning and Disinfection Process

- Site Assessment
- Site-Specific Planning
- C&D Premises

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Site Assessment

Meeting with the premises owner to:

- Conduct a property assessment (i.e., location of electricity poles and lines, underground cables, phone lines, fuse box, meter, etc.)
- Determine areas and items requiring C&D
- Identify areas requiring specific decontamination action
- Identify any potential hazardous situations
- Identify the location of drainage and run off.

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Site-Specific C&D Plan Outline

I. Description/Map of the premises layout
II. Definition of the area to be cleaned and disinfected
III. Identification of staging areas for:
    - Vehicles and heavy equipment ; Personnel;
    - Small equipment
IV. Selection of cleaning agents and disinfectants
V. Outline of specific cleaning and disinfection steps
    - Dry Cleaning
    - Washing
    - Rinsing
    - Drying
    - Disinfecting
    - Contact time
    - Final rinse if needed
VI. Personnel requirements and assignments
VII. Materials, supplies, and equipment
VIII. Regulatory permits and approvals
IX. Disposal of wash water, disinfectants and materials
X. Quality Assurance/Quality Control (QA/QC)

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Clean and Disinfect

- Dry clean
- Wash
- Rinse
- Dry
- Disinfect
- Contact time
- Final rinse

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Excerpt from FAD-PreP C&D SOP

For general C&D, take the following steps to prepare:

1. Wear adequate PPE as identified in the site-specific health and safety plan during all steps of cleaning and disinfection. See the Biosecurity (2010), and Health and Safety/PPE *SOPs*.
2. Consult with the Vector Control Group concerning insect and vector control plans, and the proper disposal of dead rodents and other vermin.
   - Remove feed from all feeders and place in the area designated in the site-specific plan for biohazardous materials requiring appropriate disposal.
   - After all feed has been removed, place rodenticide along established runways.
   - Use insecticides on the inside and outside perimeters of the building.
   - Remove dead insects and rodents and dispose of according to the site-specific disposal plan. See the Disposal SOP (2010).
   - Apply insect and rodent control products as soon as the animals are removed.
   - Eliminate openings where wild animals and rodents can enter the building.
3. Disconnect utility supplies if indicated in the plan.

Issues and Considerations

- Is disinfectant effluent hazardous/ infectious for disposal purposes?
  - e.g., VirkonS is toxic to aquatic life
  - Recent USEPA study found viable pathogens in disinfectant effluent
- How should effluent be treated prior to discharge?
  - Collected, characterized, disposed accordingly?
  - Recycled?
- Qualitative versus quantitative verification?
  - Sentinel animals?
  - Wipe tests (protocols, analysis, standards)?

LPAI in Quail
New York, 2007

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Situation

Quail carcasses in bags

Poorly managed operation

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Situation – Years without maintenance



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Preparation




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Sorting and Piling

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Shoveling

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Containerizing

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Dust and Particulates

Dust Suppression Device: Edmonton, Alberta

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CAFS Disinfection Demos

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Dry Cleaning – Broom Clean

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Washing, Rinsing, Disinfecting

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Drying, Contact Time

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Ancillary Equipment Disinfection

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Collecting Effluent

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Demobilizing

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Transporting

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Transporting

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The Team

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Agricultural Decontamination

for

Animal Disease Outbreak Response

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Ag Challenges

- Remote settings
- Wide areas
- Weathered materials
- Limited funds
- Large susceptible population

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Decon = Clean and Disinfect

- Dry clean
- Wash
- Rinse
- Dry
- Disinfect
- Contact time
- Final rinse

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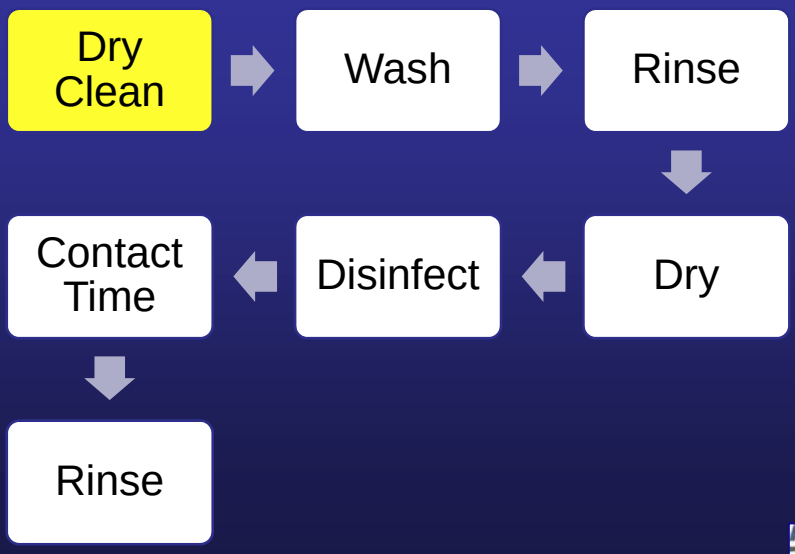
Ag Decon Process



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Dead infected poultry

Poultry waste

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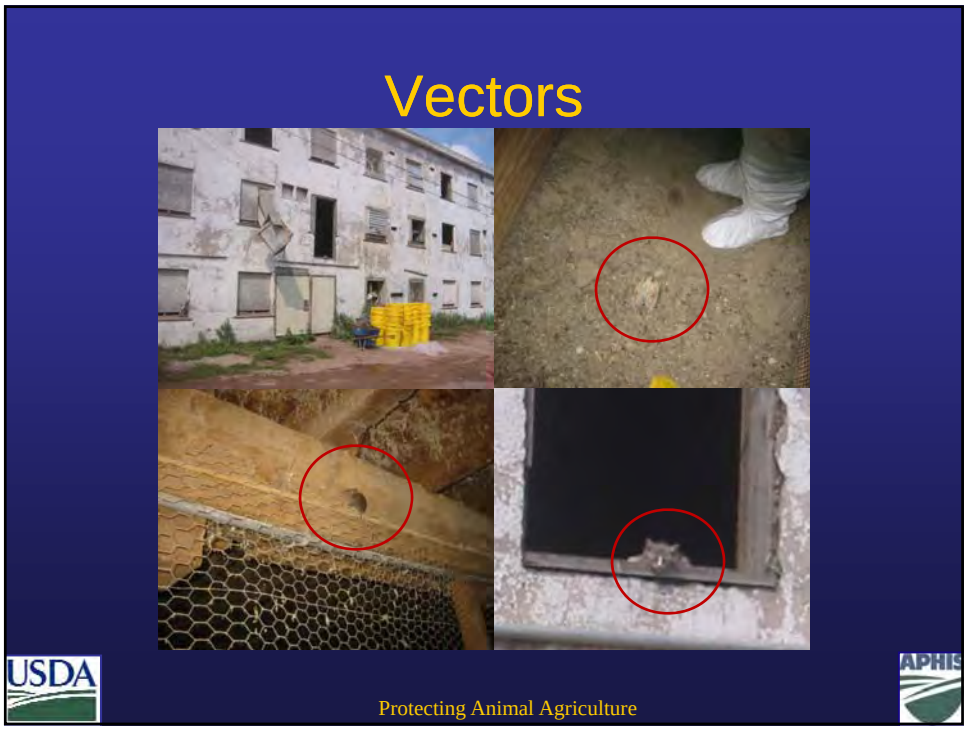
Vectors
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Sorting and Piling

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Shoveling

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Containerizing

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Dry Cleaning – Broom Clean

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Dust and Particulates

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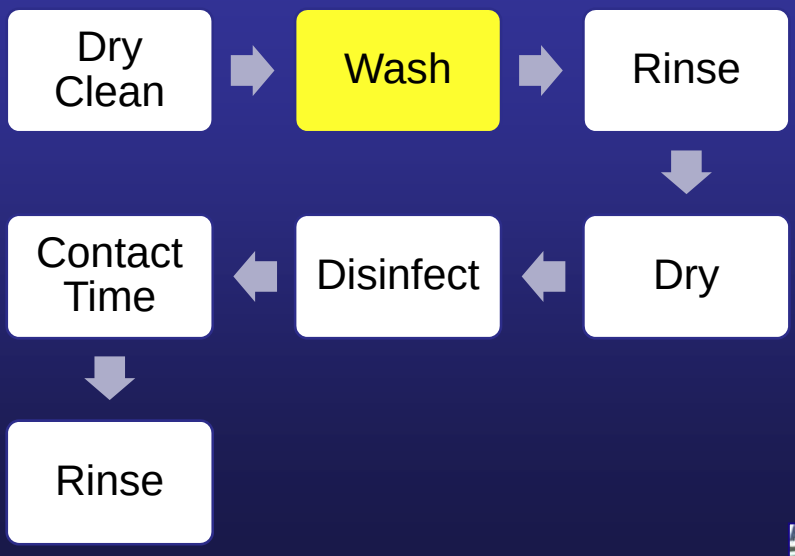
Ag Decon Process



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Washing

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Washing

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Washing

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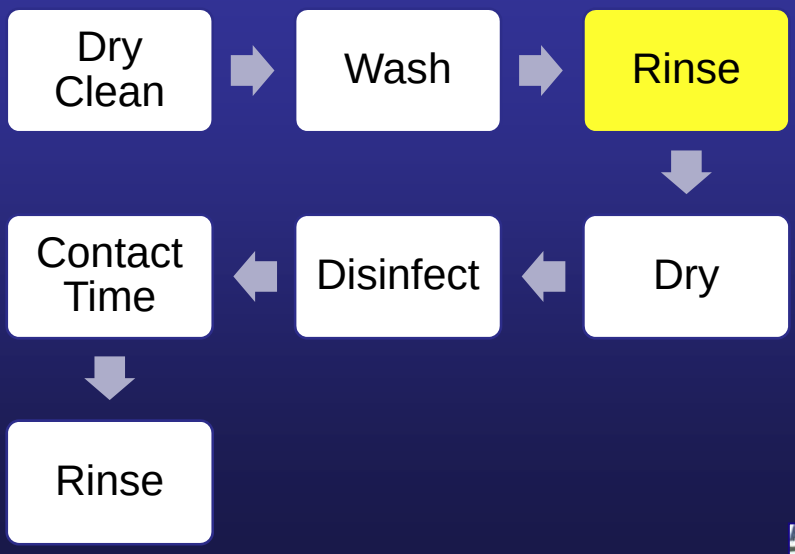
Ag Decon Process



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Rinse

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Containment

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Containment

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Temporary Manual Decon Station courtesy of Milkco, Asheville, NC

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Collection

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Collection

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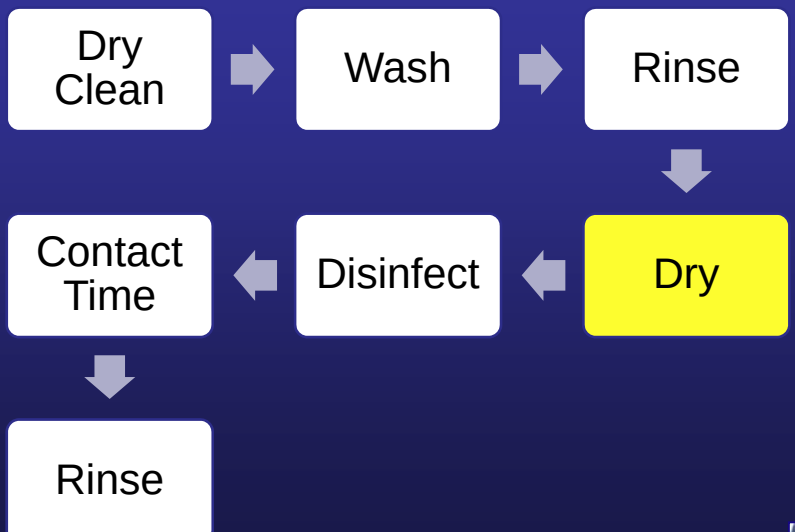
Ag Decon Process



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Drying, Contact Time

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Ag Decon Process

Dry Clean → Wash → Rinse → Dry → Disinfect → Contact Time → Rinse

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Disinfect

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Disinfect

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Ag Decon Process

Dry Clean → Wash → Rinse → Dry → Disinfect → Contact Time → Rinse

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Issues and Considerations

- Particulates – infectious?
- Rinsate – hazardous? Infectious?
- Contact time
- Qualitative versus quantitative verification?
  - Wipe tests (protocols, analysis, standards)?
  - Sentinel animals?
- Manual versus automatic?

Automate?

- Labor costs
- PPE
- Rest cycles
- Effectiveness
- Cost
- Ease of use

neptune
AUTOMATED WHEEL WASH & DISINFECTING SYSTEMS
IES
866.303.4IES

http://www.innovativeequipment.org/en/disinfecting-truck-wash

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http://www.tammermatic.com/Heavy-Duty-Wash/Applications/Tire-Wheel-Chassis/Biosecurity

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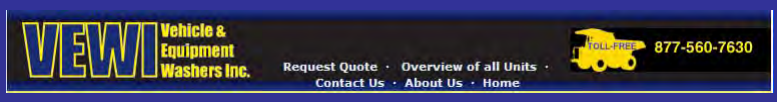

http://www.vewi.com/

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We Need to Find a Better Way…

- LRBAA – Long Range Broad Agency Announcements
- SBIR- Small Business Innovation Research Grants

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Lab-Scale Assessment of Agricultural Facility Decontamination

Worth Calfee
US EPA



November 3, 2011

Disclaimer of Endorsement:

This presentation has been peer and administratively reviewed and has been approved for publication. It does not represent EPA Policy. Mention of trade names or commercial products does not constitute endorsement or recommendation for use of a specific product.

Background and Relevance

- Foreign Animal Diseases (FADs) such as FMD, END, and BSE can result in tens of thousands of infected animals and contamination of their housing and processing facilities
- Outbreaks in South Korea and Japan have resulted in over $2B worth of damages in the last 2 years
- Homeland Security Presidential Directives (HSPD) – 5, 7, 8, 9, 10
  - Protection of US resources including food and livestock (HSPD 7 and 9)
  - Enhance response and recovery from agricultural attack (HSPD 9)
  - Collaboration among federal agencies (HSPD 5 and 7)

Questions:

How Effective are Surface Decontamination Methods at Reducing Contamination on Typical Animal Facility Surfaces?

What is the Fate of the Contaminants?

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Test Design



- 2 Decon Approaches
  - Backpack sprayer-applied decontaminant
  - Gas-powered sprayer-applied decontaminant
- 2 Decontaminants
  - pH-adjusted Bleach
  - Spor-Klenz RTU
- 2 Materials
  - Concrete (v)
  - Treated plywood (v)



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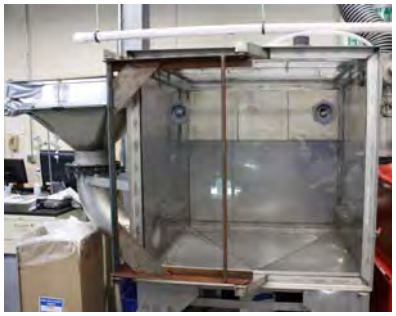
Test Methods

- 14” x 14” Coupons tested in a 4’ x 4’ x 4’ spray chamber



- 40” x 40” Coupons tested in a 9’ x 10’ x 8’ chamber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Test Methods

- Spores of *Bacillus globigii* used as FAD surrogate
  - Conservative surrogate for viruses (e.g., FMD)
  - Potentially accurate for Prion (e.g., BSE)
- Coupons contaminated by aerosol deposition
  - ~ 1 x 10^7 spores / coupon (14" x 14")
  - ~ 1 x 10^8 spores / coupon (40" x 40")
- Efficacy determined by "log reduction"
  - 6 replicate positive control coupons
  - 6 replicate test coupons

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Decon Methods

- **Method 1**
  - Apply decontaminant to coupons with backpack sprayer to fully wet surface (30 second spray per set of 3)
  - Wait 15 minutes
  - Reapply decontaminant
  - Wait 15 minutes
  - Rinse with H_2O (10 seconds per set of 3)

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Decon Methods

- **Method 2**
  - Apply decontaminant to coupons with gas-powered sprayer to fully wet surface (15 second spray per set of 3)
  - Wait 15 minutes
  - Reapply decontaminant
  - Wait 15 minutes
  - Rinse with H_2O (10 seconds per set of 3)

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Test Matrix

Test	Material	Size (in)	Reps (n)	Application	Decon	Total Exposure (min)
1	Concrete	14"x14"	6	Bkpk Sprayer	pH-AB	30
2	Wood	14"x14"	6	Bkpk Sprayer	pH-AB	30
3	Concrete	14"x14"	6	Chemical Sprayer	pH-AB	30
4	Wood	14"x14"	6	Chemical Sprayer	pH-AB	30
5	Concrete	14"x14"	6	Bkpk Sprayer	Spor-Klenz®	30
6	Wood	14"x14"	6	Bkpk Sprayer	Spor-klenz®	30
7	Concrete	14"x14"	6	Pressure Washer	Spor-Klenz®	30
8	Wood	14"x14"	6	Pressure Washer	Spor-Klenz®	30
9	Concrete	14"x14"	6	Bkpk Sprayer	pH-AB	15
10	Wood	14"x14"	6	Bkpk Sprayer	pH-AB	15
C1	Concrete	40"x40"	2	Bkpk Sprayer	pH-AB	30
C1	Wood	40"x40"	2	Bkpk Sprayer	pH-AB	30
C2	Concrete	40"x40"	2	Bkpk Sprayer	pH-AB	30
C2	Wood	40"x40"	2	Bkpk Sprayer	pH-AB	30

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Test	Application	Decon
1	Bkpk Sprayer	pH-AB
2	Bkpk Sprayer	pH-AB
3	Chemical Sprayer	pH-AB
4	Chemical Sprayer	pH-AB
5	Bkpk Sprayer	Spor-Klenz®
6	Bkpk Sprayer	Spor-klenz®
7	Pressure Washer	Spor-Klenz®
8	Pressure Washer	Spor-Klenz®
9	Bkpk Sprayer	pH-AB
10	Bkpk Sprayer	pH-AB
C1	Bkpk Sprayer	pH-AB
C1	Bkpk Sprayer	pH-AB
C2	Bkpk Sprayer	pH-AB
C2	Bkpk Sprayer	pH-AB

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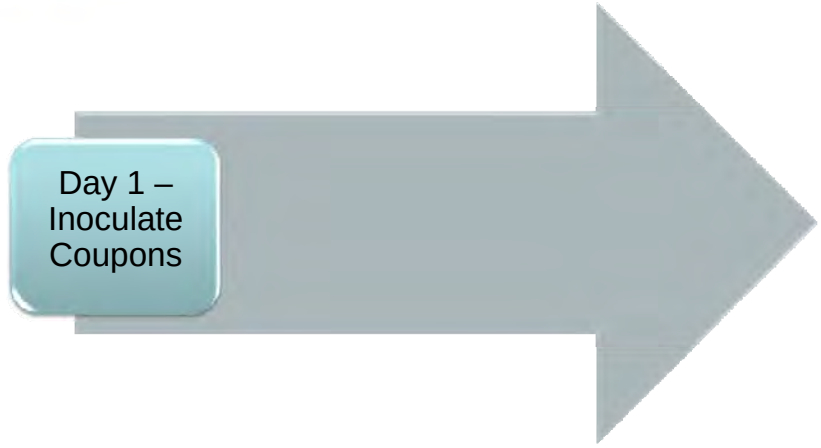

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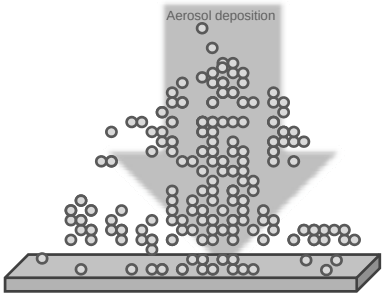
Inoculation



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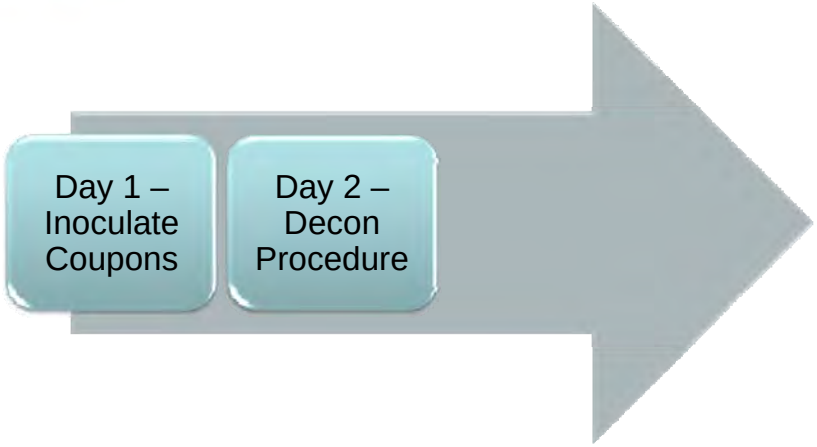

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Decontamination Procedure

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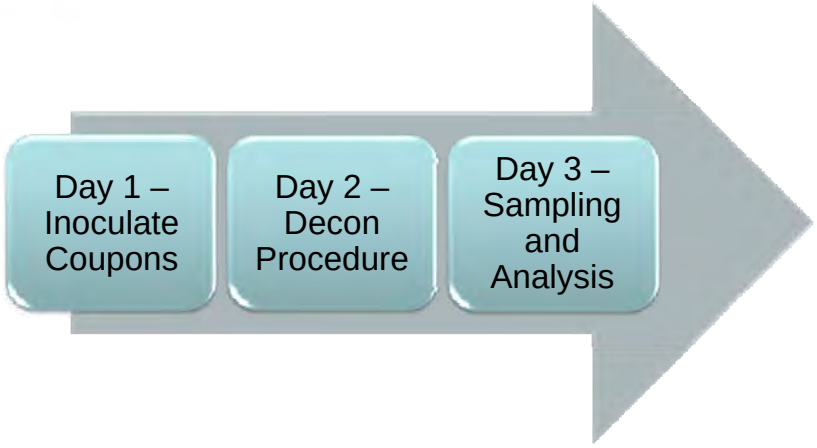

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Surface Sampling

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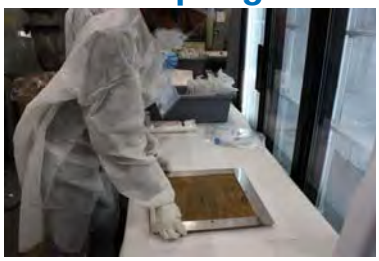
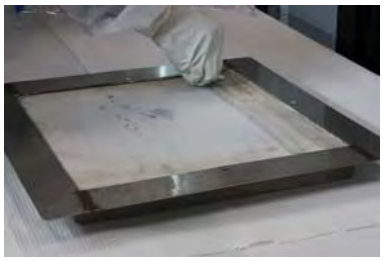
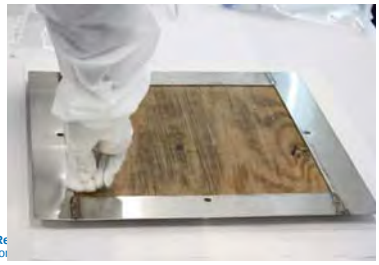
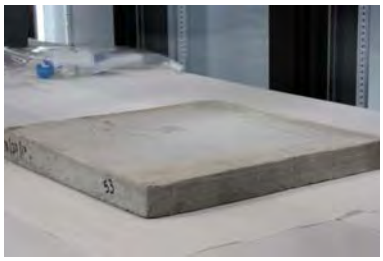
Surface Sampling









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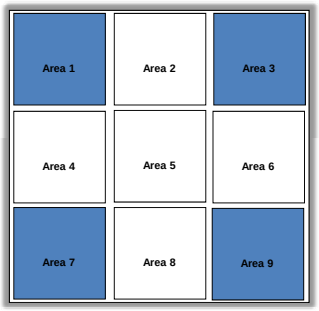
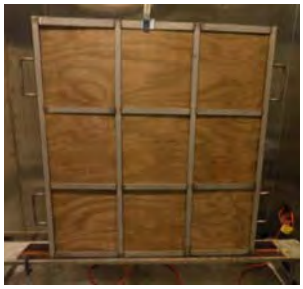
Sampling – Large Coupons

- 4 areas sampled before decon (positive controls)
- 5 areas sampled after decon





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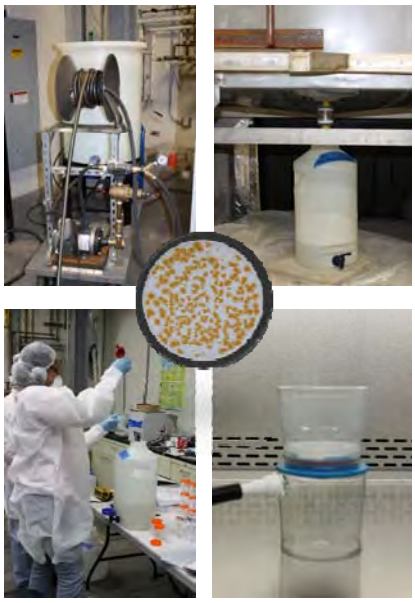
Rinsate Sampling

- All over-spray and coupon runoff collected in carboys
- Neutralized upon collection
- Analyzed replicate aliquots by filter-plate method



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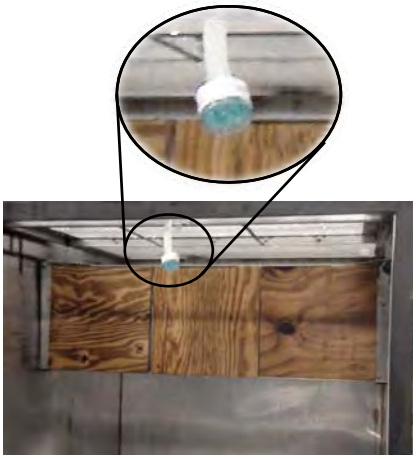
Aerosol Sampling

- "Via-Cell" Bioaerosol Collection Cassettes
- Collection from spray chamber during active spraying
- Non "Isokinetic"



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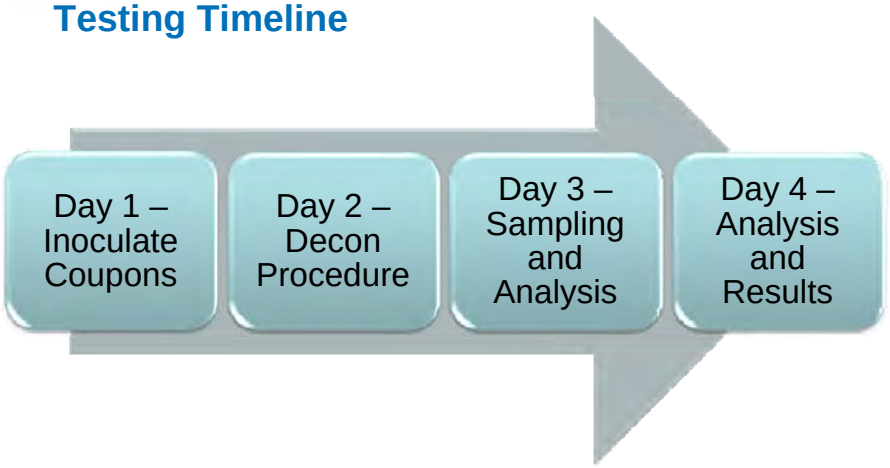
Testing Timeline



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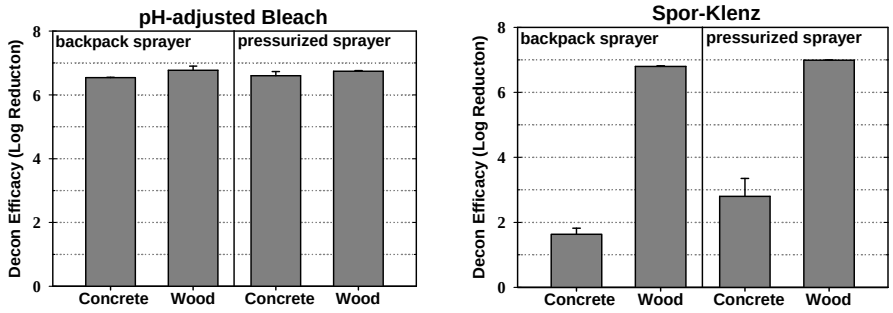
Results – Surface Reduction (14”x14”)

2 applications, 30 minute contact time



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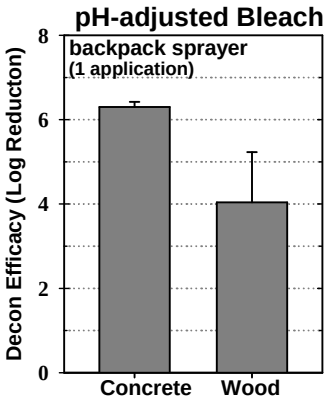
Results – Surface Reduction (14”x14”)

1 application, 15 minute contact time



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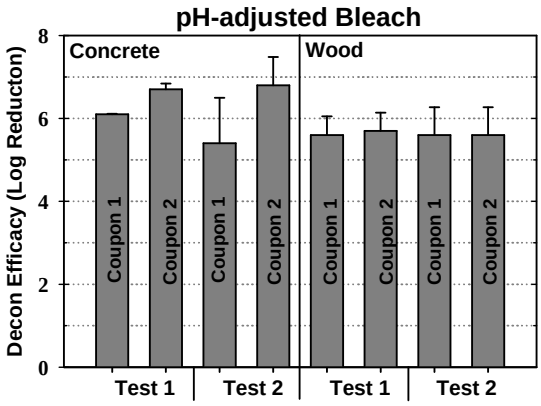
Results – Surface Reduction (40”x40”)



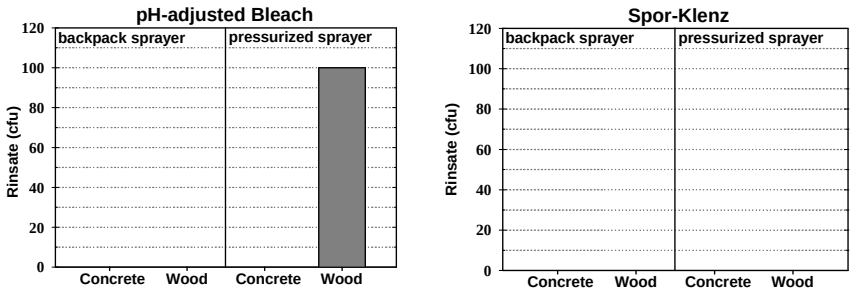
Test 1
Backpack sprayer
30 minute contact time
2 applications
Rinse 1

Test 2
Backpack sprayer
30 minute contact time
2 applications
No Rinse

Office of Research and Development
National Homeland Security Research Center

Results – Rinsate (14”x14”)

2 applications, 30 minute contact time



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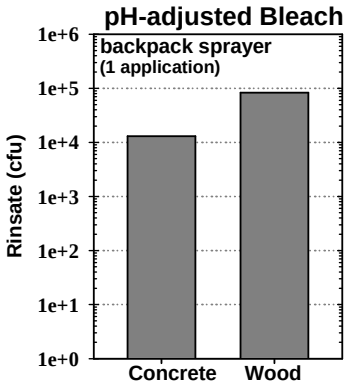
Results – Rinsate (14”x14”)

1 application, 15 minute contact time



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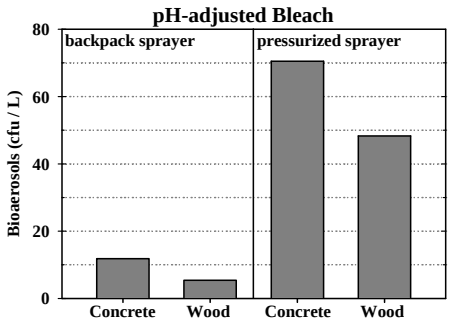
Results – Aerosol (14”x14”)

2 applications, 30 minute contact time



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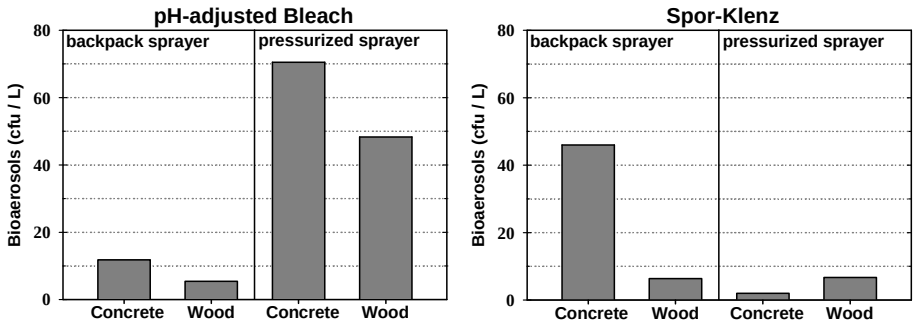
Results – Aerosol (14”x14”)

2 applications, 30 minute contact time



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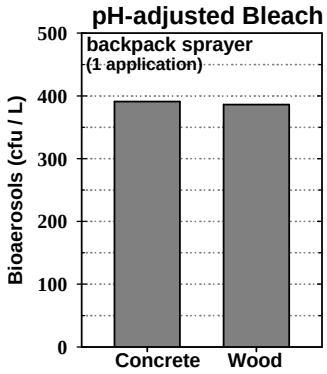
Results – Aerosol (14”x14”)

1 application, 15 minute contact time



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Summary

- pH-adjusted bleach (2 applications, 30 min contact time) was highly effective (approx 6 LR) on wood and concrete
- Spor-Klenz was more effective on wood than on concrete
- For concrete, pH-adjusted bleach was more effective than Spor-Klenz
- Abbreviated pH-adjusted bleach procedure (1 application, 15 min contact time) resulted in low surface decon efficacy and more spores in rinsate and aerosol
- Decon efficacy was similar between the two evaluated application devices
- Potential for contamination spread, esp. if low surface reduction
- Elimination of rinse step did not equate to low surface decon efficacy

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Acknowledgements

- Joe Wood – US EPA NHSRC
- Leroy Mickelsen – US EPA NDT
- Jeff Kempter – US EPA OPP
- Lori Miller – USDA
- Nathan Birnbaum – USDA
- Michelle Colby – DHS (funding)

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Decontamination of a farm cultivator using a pressure washer with a water containment mat, followed by a chlorine dioxide disinfectant foam application

Craig Ramsey, Rick Zink, Russ Bulluck, Mike Hennessey, Melinda Sullivan, and Lindsey Seastone
USDA-APHIS-PPQ-CPHST
Fort Collins, CO

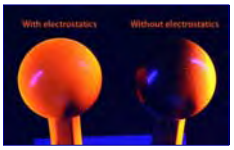
Overview

- Description of “customizable” chlorine dioxide biocide generation technology
  - Strategic Resource Optimization (SRO), Inc.
- Description of pressure washing system
  - S-K Environmental Co.
- Description of foam deployment backpack
  - Intelagard, Inc.
- Description of farm equipment decontamination study
- Videos of foam application

On-demand ClO_2 generation
Intelagard and Strategic Resource Optimization

- On demand chlorine dioxide generator
  - Formulation additives to match with pest conditions, or food health safety regulations, or material damage limitations
- System requirements:
  - water source, TDS (salts), power, additives
- Minimize transport and storage costs
- Minimize chemical half life, or shelf life issues

Application technologies



- Compressed Air Foam (CAF)
  - Extended foam contact time
  - Provides visual confirmation of treated areas
  - Expands resources for maximum coverage per volume
  - Equipment and transportation uses
- Air Aspirated Foam
  - High expansion foam

- Electrostatic Spray
  - Provides even coating of contaminated surfaces
  - Can be used around electronics and sensitive equipment
  - Facility and indoor uses

Chlorine dioxide (ClO_2) - Electro-BioCide™

- ClO_2 disinfects by oxidation
- Two oxygen atoms strip off five electrons in molecular reactions
- Low health risk – EPA Cat. IV
- Environmentally friendly- no THM formation
  - ClO_2 used in Germany, Italy, and USA as disinfectants for drinking water

Steel coupon corrosion test

Corrosion test on unprotected carbon steel coupons – 60 minute soak with air dry. Left to right: tap water at 6.9 pH; oxidant at 3.4 pH; oxidant at 7.0 pH; oxidant at 7.0 pH with anti-corrosion additive solution; oxidant at 10.2 pH with anti-corrosion additive solution.

Electro-BioCide™ Efficacy Testing

Microbe	EPA 10-Minute Kill	EPA GLP?	Testing Laboratory
Pseudomonas aeruginosa	>99.9999%	Yes	ATS Laboratories, Eagan, MN
Staphylococcus aureus	>99.9999%	Yes	ATS Laboratories, Eagan, MN
Methicillin-resistant *Staphylococcus aureus* (MRSA)	>99.9999%	Yes	ATS Laboratories, Eagan, MN
Vancomycin-resistant *Enterococci* (VRE)	>99.9999%	Yes	ATS Laboratories, Eagan, MN
Klebsiella pneumoniae	>99.9999%	Yes	ATS Laboratories, Eagan, MN
Acinetobacter baumannii	>99.9999%	Yes	ATS Laboratories, Eagan, MN
Influenza A (H1N1)	>99.9999%	Yes	ATS Laboratories, Eagan, MN
Rhinovirus Type 37	>99.9999%	Yes	ATS Laboratories, Eagan, MN
HIV-1	>99.9999%	Yes	ATS Laboratories, Eagan, MN
Hepatitis A	>99.9999%	Yes	ATS Laboratories, Eagan, MN
Salmonella enterica	>99.9999%	Yes	ATS Laboratories, Eagan, MN
Trichophyton mentagrophytes	>99.9999%	Yes	ATS Laboratories, Eagan, MN
Vancomycin-resistant *Staphylococcus aureus* (VRSA)	>99.9999%	Yes	ATS Laboratories, Eagan, MN
Clostridium difficile (C. diff spores)	99.9997%	No*	ATS Laboratories, Eagan, MN

* C. diff EPA GLP standards have been in flux and testing lab has, until very recently, recommended delaying further C. diff testing.

6

Recent USDA Test Results

Testing performed at Micro-Chem Laboratories, Euless, TX, per USDA guidelines, Nov – Dec, 2010.
Testing conducted with Electro-Biocide 2 formula at ~200 ppm and mixed oxidant (HOCl) formula.

Batch	Exposure Time	Orig. CFU/Carrier	Surv. CFU/Carrier	Log_{10} Reduction
12141003 (rep of 11221003) pH ~5.0	10 min	$3.17x10^6$	0	6.50
			0	6.50
			0	6.50
	20 min	$3.17x10^6$	0	6.50
			0	6.50
			0	6.50
	30 min	$3.17x10^6$	0	6.50
			0	6.50
			0	6.50

Testing against *Bacillus subtilis* spores prepared on glass slides

The average number of *B. subtilis* spores originally labeled onto a glass carrier and the average number of *B. subtilis* spores surviving after 10.0, 20.0, and 30.0 minutes of exposure to one batch of Electro-BioCide at ambient temperature. The culture was diluted ten-fold into sterile deionized water for use in this study.

Batch 12141003 killed 6.50 log 10 (total kill) of *B. subtilis* within 10 minutes of exposure at ambient temperature.

Electro-BioCide™ Toxicity Testing

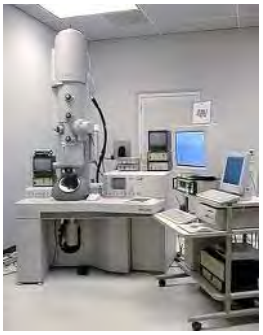
EPA Test	EPA Category	Interpretation	Testing Laboratory
Acute Eye Irritation	IV	"Practically Non-Toxic"	ToxMonitor Laboratories, Chicago, IL
Acute Dermal Toxicity	IV	"Practically Non-Toxic"	ToxMonitor Laboratories, Chicago, IL
Acute Inhalation	IV	"Practically Non-Toxic"	ToxMonitor Laboratories, Chicago, IL
Acute Oral Toxicity	IV	"Practically Non-Toxic"	ToxMonitor Laboratories, Chicago, IL
Acute Skin Irritation	IV	"Practically Non-Toxic"	ToxMonitor Laboratories, Chicago, IL
Acute Skin Sensitization	Non-Sensitizer	Non-Sensitizer	ToxMonitor Laboratories, Chicago, IL

* Category IV (per EPA Label Review Manual, Chapter 7) toxicity label requirements: "No statements are required." Category IV is the least toxic rating possible as assigned by the EPA.
** Does not require any warning labels (e.g., caution, danger, warning, etc.)

8

E. Coli images from a scanning electron microscope, at the University of Colorado at Boulder, Nanomaterials Characterization Facility

- Reveal the effects of Electro-BioCide's "electrically-triggered" kill mechanism
- This greatly minimizes any risk of mutation and the development of resistance.



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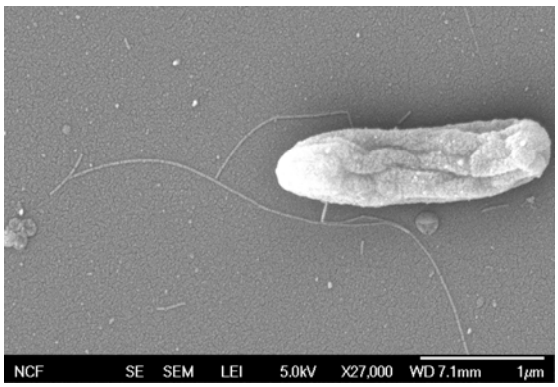
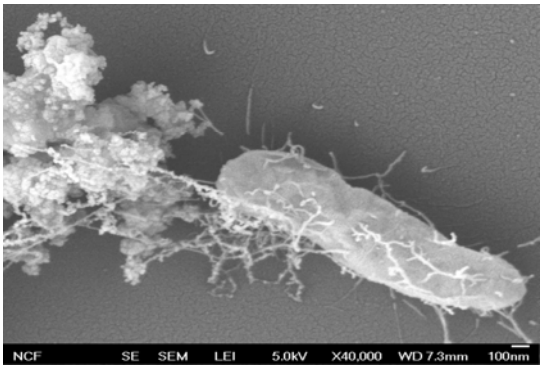
Typical *Escherichia coli* (E. coli) Bacterium



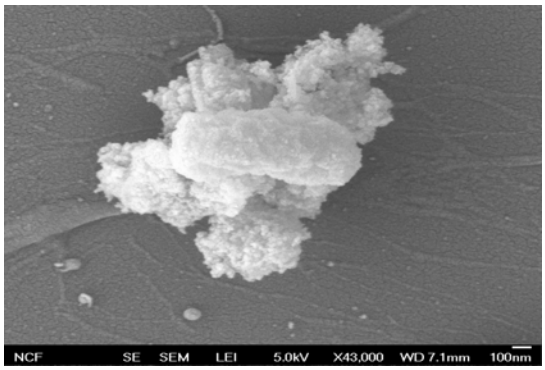
* Image captured by Scanning Electron Microscope, courtesy of University of Colorado at Boulder, Nanomaterials Characterization Facility
** A thin layer of suspended bacteria was applied to the surface of silicon wafer chips and allowed to air dry. Chips with adherent cells were covered in fixative (2% gluaraldehyde in 50 mM soldium cacodylate buffer, pH 7.3) for 2 hours at room temperature, rinsed in water, then dehydrated in increasing concentrations of ethanol. Samples were stored in 100% ethanol for 2 days and critical point dried with liquid carbon dioxide in a Tousimis PVT-3 CPD unit. Samples were then mounted onto SEM stubs, sputter-coated with gold-palladium (4 nm thick) and imaged in a JEOL 7401F FE-SEM at 5.0 KV.

E. Coli Bacterium Post-Spray with Electro-BioCide™



* Image captured by Scanning Electron Microscope, courtesy of University of Colorado at Boulder, Nanomaterials Characterization Facility
** A thin layer of suspended bacteria was applied to the surface of silicon wafer chips and allowed to air dry. Inoculated chips were sprayed with Electro-BioCide™. Chips with adherent cells were covered in fixative (2% gluaraldehyde in 50 mM soldium cacodylate buffer, pH 7.3) for 2 hours at room temperature, rinsed in water, then dehydrated in increasing concentrations of ethanol. Samples were stored in 100% ethanol for 2 days and critical point dried with liquid carbon dioxide in a Tousimis PVT-3 CPD unit. Samples were then mounted onto SEM stubs, sputter-coated with gold-palladium (4 nm thick) and imaged in a JEOL 7401F FE-SEM at 5.0 KV.

E. Coli Bacterium Post-Spray with Electro-BioCide™



* Image captured by Scanning Electron Microscope, courtesy of University of Colorado at Boulder, Nanomaterials Characterization Facility
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Pressure washing and disinfectant foaming system for biological containment

- Goal – Prevent animal/plant pathogens, insects, insects eggs, nematodes, or invasive plant seeds from entering the ground water or soil after equipment wash down
- Waste water containment mat collects all waste water
- Filters remove all recycled water debris down to 10 microns
- Waste water is recycled and disinfected with non-corrosive disinfectants

Portable pressure washing systems with waste water mats

S-K Environmental Co.

Equipment decontamination study

- Field study with farm equipment
- Location – Colorado State U. research farm
  - Fort Collins, CO
- Test dates
  - Oct 24 – 28, 2011

Study objectives

- Determine the effects of ClO_2 disinfectant foam on *Bacillus subtilis* efficacy
- Determine the effects of pressure washing and foam application on *B. subtilis* efficacy
  - First ClO_2 formulation – pressure wash + foam application
  - Second ClO_2 formulation – pressure wash + foam application

Study factors

- First ClO_2 formulation
  - ClO_2 conc. – 215 ppm
  - Two surfactants
  - ORP - + 835 mV
  - pH - 7.05
- Second ClO_2 formulation
  - ClO_2 conc. – 215 ppm
  - Three surfactants
  - ORP - + 844 mV
  - pH - 7.10

Study description

- Spike strip tillage implement with *B. subtilis*
  - Draw twelve 2.5” spots on steel surfaces
  - Apply *B. subtilis* with Q-tip swabs to spots

Study description

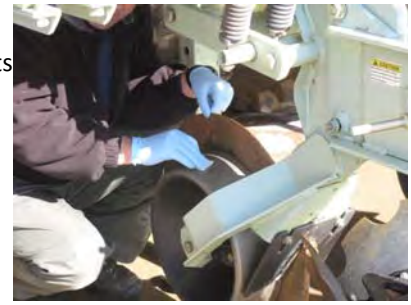
- Pressure wash to remove excess dirt, organic biofilms, or machinery oil
  - Water pressure - 2,000 PSI
  - 14' x 50' containment mat
  - Use hand wands to manually clean tiller
  - Waste water was collected mat with sump pump
    - Water filtered before re-entering tank
    - 350 gal tank
    - Three fabric filters
      - 200, 25, 10 micron

Study description

- Apply ClO_2 foam to tiller
  - Time for foam exposure – 30 min.
- Wash off residual foam with garden hose
- Collect *B. subtilis* samples from treated and untreated spots
- Average foam time on tiller
  - Approx. 1 to 5 min.

B. Subtilis sample collection

- Use autoclaved, wool swabs to collect samples
- Two or three wool swabs used per 2.5" spot
- Sample replicates
  - 20 samples for treated areas per test
  - 40 total samples for each of three tests
- Samples sent to MicroChem labs
  - Culture samples
  - Viable *B. subtilis* CFU counts



Pressure washing video

ClO_2 foaming video

Acknowledgements

- Sheilah Kennedy
  - S-K Environmental
  - Mobile pressure washer
- John Breedlove and Mike Peters
  - Strategic Resource Optimization (SRO)
  - Chlorine dioxide formulations
- David Shoffner
  - Intelagard
  - Pressurized McCaw backpack sprayer
- Chris Fryrear
  - Colorado State University farm coordinator
  - Use of farm facilities and farm equipment

Questions?

Dry Fogging of Hydrogen Peroxide/Peracetic Acid for *Bacillus* Spore Inactivation

EPA: Joseph Wood, Worth Calfee, Brian Attwood

Arcadis: A. Touati, M. Clayton, N. Griffin

Presented at US EPA Decontamination Research Conference Research Triangle Park, NC November 3, 2011

Acknowledgements

- Other Decontamination Research Laboratory Group participants:
  - Shannon Serre, Kim Egler
- Laboratory support engineers, scientists, technicians
  - Tim McArthur, Stella McDonald, Rob Delafield, Christina Slone

Disclaimer

- Reference herein to any specific commercial products, process, or service by trade name, trademark, manufacturer, or otherwise, does not necessarily constitute or imply its endorsement, recommendation, or favoring by the United States Government. The views and opinions of authors expressed herein do not necessarily state or reflect those of the United States Government, and shall not be used for advertising or product endorsement purposes.

Outline

- Why fog?
- Methods
- Test variables/matrix
- Results
- Lessons learned

Why fog?

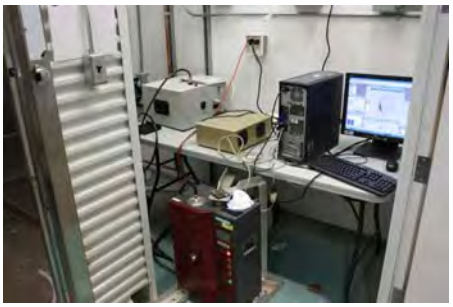
- In a wide area release of anthrax, every decontamination tool is needed
- Less costly, less expertise required
- Has been tested and reported in literature, but primarily as disinfection tool for health care settings

Methods

- COnsequence ManageMent ANd Decontamination Evaluation Room (COMMANDER) test chamber
- Fog equipment, liquid sporicide
- Microbiological assays and methods

COMMANDER Test Chamber

- State of the art decontamination chamber
- Measure and/or control temperature, relative humidity, hydrogen peroxide (H_2O_2) concentration, air flows, pressure



Fog and Related Equipment

- What is a fog? Dry fog?
- Fogging and related equipment

Fog and Related Equipment

- Relative humidity (RH) model

DATA	
Total Space Volume (m³) *	23
Relative Humidity in the Space (%) *	35%
Temperature (°C) *	22
Minncare Volume per m³ *	1.5
Specific Space Adjustment (Grams of Water/m³) *	1

* Need to be completed

CALCULATIONS	
Volume of Water to Introduce (ml)	408
Volume of Minncare to Introduce (ml)	35
Quantity of Diffused Water per m³ (ml)	17
Total Volume of Minncare Solution (ml)	443
Percentage of Minncare in Solution	7.9%
Estimated Diffusion Time (Minutes)	35.45

- Fog sporicidal liquid: Minncare Cold Sterilant (hydrogen peroxide/peracetic acid aka H_2O_2/PAA)

Test variables/matrix

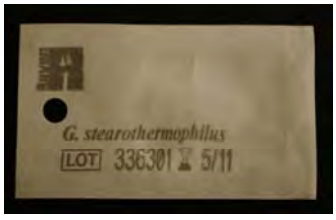
- Primary independent test variables
  - Amount of Minncare and water used
  - Contact time
- Tests with biological indicators (BI's)
- Log reduction (LR; i.e., inactivation) of spores nebulized into empty COMMANDER

Test variables/matrix

- LR of spores nebulized onto 4 ft x 4 ft coupons
- Coupon materials:
  - Deck wood (horizontal)
  - Carpet (h)
  - Concrete (vertical)
  - Wallboard (v)

Microbiological assays and methods

- Biological indicators (BI's)
  - 6 log *Geobacillus stearothermophilus* (*G.s.*), stainless steel disks in Tyvek; 2 manufacturers



- *G.s.* and *Bacillus atrophaeus* (*B.a.*) - surrogates for *Bacillus anthracis*

Microbiological assays and methods

- Approx.10^9 colony forming units (CFU) disseminated via nebulizer; *G.s.* and *B.a.*

- Sampling/analysis
  - –7 day growth/no growth for BI's
  - –Wipe sampling, extraction, dilution and filter plating

Results

- BI's
- LR of spores on walls and floor of empty COMMANDER
- LR of spores with 4 ft x 4 ft coupons
  - –Wood
  - –Concrete
  - –Drywall
  - –Carpet

EPA United States Environmental Protection Agency

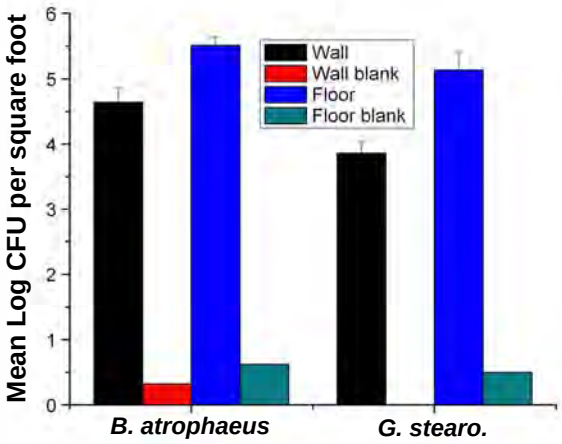
BI Results

H_2O_2/PAA used (mL)	Max RH	H_2O_2 ppm-hours	Apex *G.s.* # positive (n = 28)	Raven *G.s.* # positive (n = 28)
20	47	266	**4**	**28**
30	91	52*	**0**	**28**
60	97	303	**0**	**28**
60	75	170	**0**	**0**
80	82	497	**0**	**1**

* All overnight dwell except 2 hours for indicated test

EPA United States Environmental Protection Agency

COMMANDER Spore Deposition Results



***B. atrophaeus* yielded higher pre-fog values than *G.s.*, and pre-fog recoveries from floor were higher than the walls**

EPA United States Environmental Protection Agency

COMMANDER Decon Results

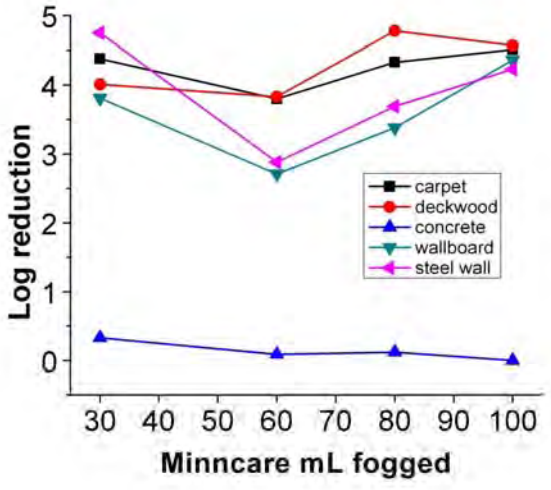
Bug	H_2O_2/ PAA (mL)	Max RH	H_2O_2 ppm-hours	Mean LR walls	Mean LR floor	
B. atro.	30	88	109*	4.03	4.14	No statistical difference
B. atro.	30	68	125	3.51	3.81	
B. atro.	60	79	411	3.56	3.93	No statistical difference
G. stearo.	60	82	282	3.91[a]	4.67	
G. stearo.	80	78	256	3.74	4.12	No statistical difference
G. stearo.	80	78	427**	3.80	4.25	

All overnight dwell except as follows: * Dwell 2.4 hrs ** Dwell time = 2 hours

[a] Only test which had a sample location (left rear wall, and right wall) completely decontaminated

EPA United States Environmental Protect Agency

Decontamination Results for Materials



Wallboard in 100 mL test only material completely decontaminated

Lessons Learned – Test Ops

- Nebulizer – spore deposition
- Concrete sampling issues
- RH measurement

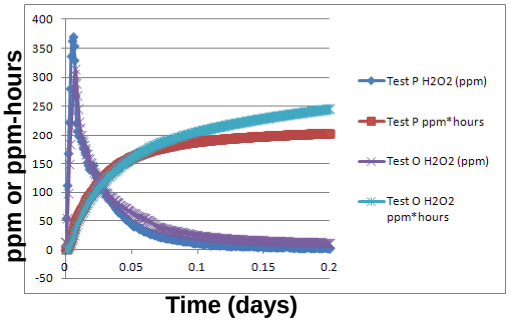
Lessons Learned – Fogging Ops

- Fogging only as effective as the fogger being used and liquid sporicide
- Fogger in this study requires some care in use:
  - Clean, dry, oil free air; sufficient flow & pressure
- Fogger vendor indicates max RH is important, but not always easy to control
  - Possible issues with using in very low or very high RH environments

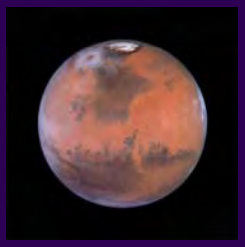
EPA United States Environmental Protection Agency

Lessons Learned - Results

- BI's easier to inactivate than spores on building materials
- Not all BI manufacturers the same
- Fogging with H_2O_2/PAA shows promise, but more tests are needed
- Not effective on concrete
- No clear connection between LR and max RH, H_2O_2 level, contact time



Efficacy of gaseous decontamination technologies for use on spacecraft and their components



Jimmy Walker

Health Protection Agency Microbiology Services, Porton

Thursday 3rd November: EPA Decontamination Conference

This activity is fully funded by the European Space Agency under the AURORA Core Exploration Programme and is performed under the Prime Contractorship of Systems Engineering & Assessment Ltd.
Contract nos: 21243/07/NL/EK
The view expressed herein does not reflect any official opinion of the European Space Agency.

Introduction

- Background
- Decontamination prior to going into space
- Technology selection
- Biological Testing
- Surface testing and residue analysis
- Recommendations

To boldly go.....

MIR/ISS Space station

Protecting equipment in space

From 1987 to 2000 there were at least 234 microbial species identified on the MIR Orbital Station Complex: 108 bacterial and 126 fungal with 10,000 spores/m^3

Background

• Planetary Protection guidelines are upheld by COSPAR and levels of contamination must be demonstrated and controlled before launch

• Current sterilisation process is Dry Heat Microbial Reduction (DHMR) to achieve 0.03 spores m^{-2}

	Temperature			
Surface	**110°C**	**115°C**	**120°C**	**125°C**
Free and Mated	32 hr	18 hr	11 hr	6 hr
Encapsulated	156 hr	90 hr	52 hr	30 hr

• Issues with DHMR and material compatibility have been raised on the EXOMARS project, leading to an investigation of alternative low temperature sterilisation technologies

Technology Selection

- Review existing gaseous decontamination technologies
- Trade off matrix to choose the most appropriate technologies

Scored over 9 weighted factors

Small components (50cm x 30cm x 30cm)

Rover vehicles (2m x 2m x 2m)

Technology Selection Trade Off Results

Technology	Small Enclosure	Large Enclosure
Steris (VHP)	71	71
Bioquell (HPV)	71	70
ClorDiSys (ClO_2)	65	64
Formaldehyde	61	51
Ethylene Oxide	54	51
Plasma	65	35
Ozone	57	29

Selected technology – Steris (VHP)

- Steris ARD-1000 generator uses Vapour Hydrogen Peroxide
- The technology is described as a 'dry' system, VHP continually injected below the dew point of the enclosure, therefore no condensation on the surfaces
- Technology previously used in a previous study by JPL – MD2000 vacuum chamber steriliser

Technology Selected – Bioquell (HPV)

- Bioquell RBDS generator uses Hydrogen Peroxide Vapour
- This technology uses 'microcondensation' to cover the surfaces within the enclosure
- The HPV is injected once and not replaced during the exposure period so concentration will decrease over time.
- Widely used especially in hospitals

Technology Selected – ClorDiSys (ClO_2)

- ClorDiSys Minidox M generator produces ClO_2 gas, by passing chlorine gas through sodium hypochlorite cartridges within the generator
- This system was the only 'true' gas decontamination technology tested
- The system was operated at 25°C rather than 35°C due to condensation build up on the photometer lens within the unit
- Widely used during anthrax letter clean up

Test Protocols

- Studies carried out in the Porton environmental chamber ($22m^3$)
- Temperature controlled at 35°C for H_2O_2 systems, 25°C for ClO_2
- Biological indicators (BI) kept in a sealed box until the correct concentration was achieved and the BIs were then exposed
- BIs removed for analysis (in triplicate)

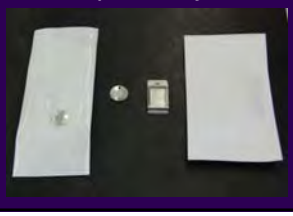
Biological Testing

Two commercially available indicators were chosen after initial assessment:
- *Geobacillus stearothermophilus* (GS, Steris) and *Bacillus atrophaeus* (BA, SGM Biotech)

Three Naturally Occurring Organisms (NOO) were chosen by ESA (all isolated from spacecraft assembly facilities):
Bacillus megaterium, *Bacillus safensis* and *Bacillus thuringiensis* (BM, BS & BT)

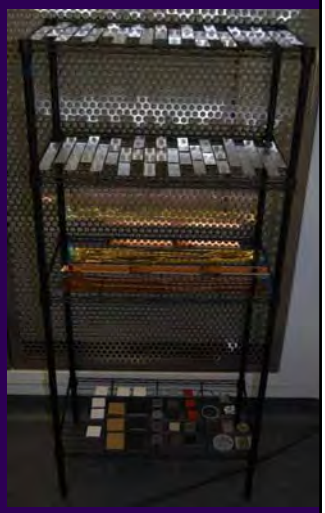
The commercially available indicators were exposed to triplicate cycles of 3 different sterilant concentrations

The NOOs were exposed to one cycle chosen by ESA



Spacecraft material Compatibility Testing

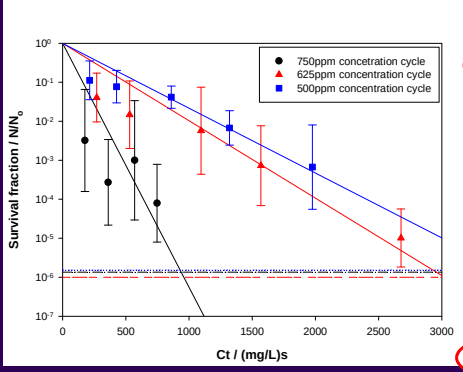
- 30 materials Supplied by ESA including
  - Adhesives
  - Films
  - Coating
  - Lubricants
  - Bulk materials
  - PCB
  - Windows
  - O rings
- Exposed to 3 cycles of chosen concentration
- Repackaged and sent to ESA for testing



Residue Analysis

- Carried out by Science and Facilities Technology Council, UK,
- Silicon wafers were SEMI standard single side polished and 100mm in diameter.
- These wafers were exposed to 3 cycles of the chosen sterilant concentration, vacuum packed and sent to RAL for analysis.
- The wafers were analysed using Raman spectroscopy and Time-of-Flight secondary ion mass spectrometry (TOF-SIMS) and the results reported to the HPA.

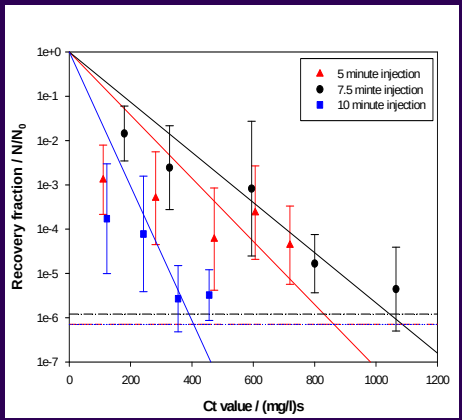
Biological Results - Steris



Organism	Conc.	D-value
GS	750ppm	159.8s
	625ppm	493.3s
	500ppm	585.4s
BA	750ppm	48.4s
	625ppm	76.9s
	500ppm	92.7s
BM	750ppm	45.8s
BS	750ppm	68.6s
BT	750ppm	175.4s

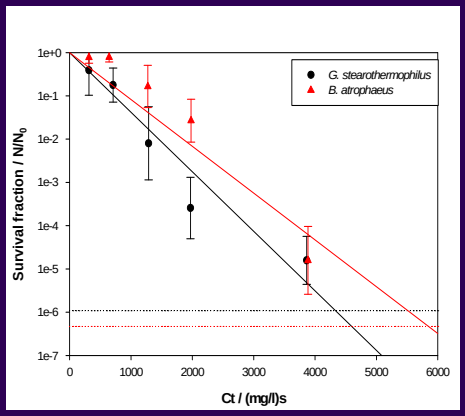
D-value is the amount of time it takes to achieve a one log reduction

Biological Results - Bioquell



Organism	Injection period	D-value
GS	10 min	66.0s
	7.5 min	176.5s
	5 min	140.3s
BA	10 min	90.7s
	7.5 min	152.0s
	5 min	97.3s
BM	10 min	60.7s
BS	10 min	37.5s
BT	10 min	132.5s

Biological Results - ClorDiSys



Organism	Conc	D-value
GS	1.1mg/l	726.7s
BA	1.1mg/l	924.4s
BM	1.1mg/l	757.8s
BS	1.1mg/l	627.8s
BT	1.1mg/l	6.6hrs

Material Surface Testing Analysis

- No significant changes in material properties identified for the hydrogen peroxide sterilisation processes
- Chlorine dioxide sterilisation resulted in observable degradation:
  - Germanium coating of Kapton/Ge film
  - Bulk adhesives CV 1152, CV 1142, Solithane 113
  - Bleaching of Alodine 1200 coating

Residue Analysis Results

Analysis Technique	Steris	Bioquell	ClorDiSys
Raman Spectroscopy	No change in peak shifts / new peaks indicating no new chemicals have been formed	No change in peak shifts/new peaks indicating no new chemicals have been formed	No change in peak shifts/new peaks indicating no new chemicals have been formed
TOF-SIMS	Least contaminated sample. Contamination mainly nitrogen hydrocarbons with sodium being the main elemental contamination	Contaminated with nitrogen hydrocarbons. Sodium, Calcium and magnesium were elemental contaminants	Most contaminated sample. High levels of hypochlorides, sulphates and nitrogen hydrocarbons. Chlorine and sodium were elemental contaminants
Ellipsometer measurements (silicon oxide thickness)	~10nm	~6nm	~6nm

Summary for selection of low temperature sterilisation

- The Bioquell HPV decontamination technology produced the fastest D-value for GS, then Steris VHP and ClorDiSys.
- Microcondensation appears to increase the decontamination speed but formed more residues - problems with control
- BT is shown to be as resistant, if not more (ClO_2), to the decontamination processes as GS
- H_2O_2 systems showed good material compatibility
- ClorDiSys produced most residues and had material compatibility issues
- Therefore Steris VHP was recommended for LTS of spaceraft materials

All Mars Images taken from
Preliminary Planning for an International Mars Sample Return Mission
Report of the International Mars Architecture for the Return of Samples (iMARS) Working Group June 1, 2008
http://mepag.jpl.nasa.gov/reports/iMARS_FinalReport.pdf

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Disclaimer

The views expressed in this manuscript are those of the authors not those of the HPA or any other funding source.

The use of trade names does not constitute an endorsement or recommendation for use.

Novel Disinfection Applications Using a Portable Chlorine Dioxide Gas Generation System

Anthony L. Newsome
Jeannie M. Stubblefield

November 3, 2011

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Introduction

- Long history as disinfectant
  - Effective against bacterial cells, bacteria spores, amoebae, yeasts, molds and viruses
- Limitations on chlorine dioxide gas use
  - Transportation restrictions (gas instability)
  - Generation challenges (cost, equipment, expertise)
- Research at MTSU has focused on applications of a portable, easily-used chlorine dioxide gas generation system

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Chlorine Dioxide Research at MTSU

Sports Equipment
Building Materials
Cooling Tower Water Treatment
Field Medical Kits
Disposable PPE
Food-borne Pathogens
First Responder Respirators
Animal Mass Casualty Response

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Chlorine Dioxide Gas Generation System

Two granulated components

Combined in gas-permeable sachet

Can be used to produce ClO_2 gas or solution

System provided by ICA TriNova (Newnan, GA)

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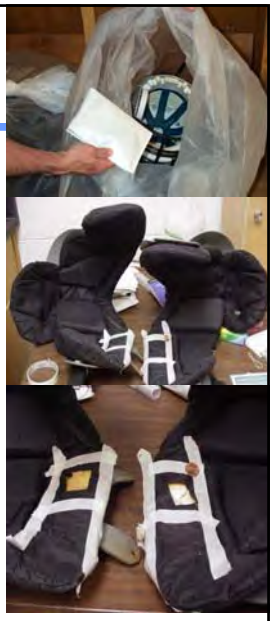
Sports Equipment

Treatment to reduce exposure to bacteria associated with shared sports equipment

Naturally-occurring bacteria and lab-applied *Staphylococcus aureus*



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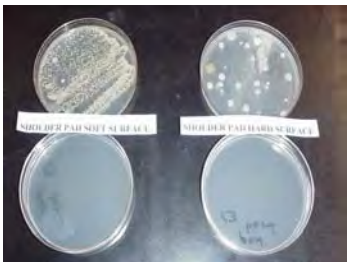
Sports Equipment Results

Recovery of bacteria colonies (numbers represent colony forming units) from used high school football pads before and after treatment with chlorine dioxide gas

	Shoulder Pad-Hard Surface		Shoulder Pad-Soft Surface		Helmet-Soft Surface Set	
	Before	After	Before	After	Before	After
1	50	0	TNTC*	0	30	0
2	300	0	400	0	50	0
3	200	2	TNTC	NA	100	0
4	200	1	TNTC	0	20	0
5	200	0	300	0	30	0
6	100	1	TNTC	50**	100	NA
7	100	0	TNTC	0	50	0
8	50	2	TNTC	50**	TNTC	1
9	50	0	TNTC	1	30	3
10	50	0	TNTC	0	150	1
11	75	1	200	10	50	1
12	TNTC	0	TNTC	0	50	1
13	200	0	TNTC	0	100	2
14	75	0	50	5	100	5



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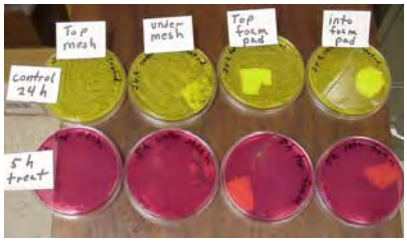
Sports Equipment Results

	Surface Mesh	Under Mesh	Top of Foam Pad	Inside Foam Pad (0.5cm)
Control (Untreated)	3,528	7,056	7,056	4,536
Treated (5 hour)	0	0	0	0



Application (1.3 X 10^8 CFU) of *Staphylococcus aureus* applied to football pads

Spores of *Bacillus atrophaeus* (10^3 spores on steel discs enclosed in Tyvak) were also treated. Treated strips (3 of 3) had no growth in TSB.

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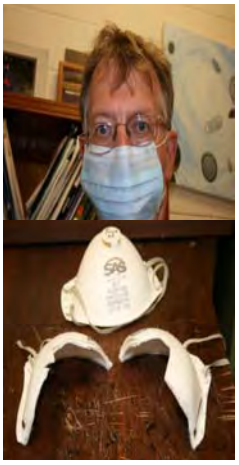
Personal Protective Equipment

- Potential to recycle health-care products that historically have been viewed as single-use items
- Decontaminate and sterilize protective apparel - disposable respirators, protective gowns
- Immediate benefit in third world countries where supplies and access to sterile apparel is often quite limited
- Potential use in this country when transportation/manufacturing disruption or a crisis situation could lead to shortages of protective apparel
  - 2008-09 concerns that demand for disposable respirators might exceed supply due to fears and perceived needs associated with the bird flu



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PPE Results

Recycling can provide an environmental and financial benefit

Potential in health care sector to explore ways to recycle items currently viewed as single use items

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First Responder Respirator Masks

Potential infectious risk from shared equipment

Evaluated levels of naturally-occurring bacteria on used mask

Sampling Area (1 in^2)	Viable CFUs Recovered
Filter – Outside mask	360
Filter – Inside mask	1,770
Shield – Inside mask	15,900
Face Contact Area – Forehead	3,930
Face Contact Area – Chin	3,000
Face Contact Area – Left Side	2,460
Face Contact Area – Right Side	1,980
Face Contact Area – Top Nose	4,380
Lower Nose Area (Non-contact area)	15,180
Inside drinking tube*	780
Cloth strap that attaches to mask	**187,200**
Mesh that fits on top of head	**124,000**

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First Responder Respirator Masks

Decontamination trials on masks using lab-applied bacteria

- Methicillin-resistant *staphylococcus aureus* (MRSA)

Dose and humidity measured in ClO_2Clave

				Cloth Straps			Rubber Mask		
Treatment Time (Hours)	Grams of Each Reactant	Max Chlorine Dioxide Achieved (ppm)	Max Relative Humidity Achieved	Average CFUs per 1 in^2 sample BEFORE Treatment	Average CFUs per $1in^2$ sample AFTER Treatment	Percent Killed	Average CFUs per 1 in^2 sample BEFORE Treatment	Average CFUs per $1in^2$ sample AFTER Treatment	Percent Killed
1	2	143	44	$1.9x10^4$	26	99.9%	$2.8x10^4$	201	99.3%
1	2	149	66*	$1.1x10^3$	0	99.9+%	$2.6 x10^4$	0	99.9+%
3	2	124	48	$2.8x10^4$	14	99.9+%	$6.1x10^4$	28	99.9+%
3	2	138	64*	$2.0x10^3$	6	99.7%	$3.3 x10^4$	0	99.9+%
1.5	5	192	47	$1.7x10^4$	0	99.9+%	$1.1x10^4$	60	99.5%
1.5	5	197	65*	$2.1x10^3$	1	99.9+%	$5.0 x10^4$	0	99.9+%

** Trials were conducted with humidity chips.*

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First Responder Respirator Masks

Conducted trials on new masks to simulate field-use for selected protocols

- Sanitation: Bi-monthly protocol
  - 6 treatments with 2:2 grams of media for 3 hour exposure, ~50% RH
- Decontamination: Potential bio-threat condition
  - 2 treatments, 1,000 ppm, 1 hour exposure at ~50% RH
  - Included spore strips (10^3) of *Bacillus atrophaeus*
- Treated masks are currently undergoing materials testing

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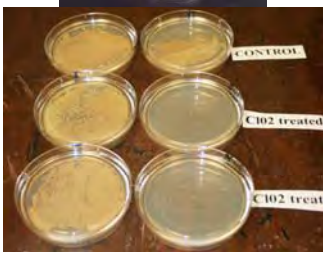
Animal Mass Casualty Response*

Evaluated chlorine dioxide as a decontaminant to reduce infectious risk in an animal mass casualty event

- Handling & Disposal
- Assumed an outbreak of natural or deliberate origins
- Pig skin was inoculated with spores of *Bacillus atrophaeus*
- Unique surface to decontaminate



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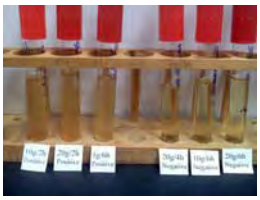
Animal Mass Casualty Response*

Growth from *Bacillus atrophaeus* Spore Strips Following Treatment**

Treatment Time	Mass of Each Reactant (grams)	ClO_2 Maximum (ppm)	10^4	10^6
2 Hours	10	1,109	Negative	Postive
2 Hours	20	2,760	Negative	Postive
4 Hours	20	3,035	Negative	Negative
6 Hours	5	558	Negative	Positive
6 Hours	10	1,451	Negative	Negative
6 Hours	20	3,067	Negative	Negative



***There was negative growth on all replicate of samples where a negative result is indicated. Strips were incubated in TSB at 37C for 24 hours.*

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Animal Mass Casualty Response*

Chlorine Dioxide Gas Treatment Results

Treatment Time	Mass of Each Reactant (grams)	ClO_2 Maximum (ppm)	Average CFUs per 1 in²(2.5 cm²) Untreated Control Samples	Treated Samples (1)	Change	Percent Reduction(2)
2 Hours	10	1,109	12,250,000	1,524	-12,248,476	99.9+%
2 Hours	20	2,760	6,825,000	24	-6,824,976	99.9+%
4 Hours	20	3,035	8,700,000	1	-8,700,000	99.9+%
6 Hours	5	558	10,950,000	64	-10,949,936	99.9+%
6 Hours	10	1,451	10,850,000	0	-10,850,000	100%
6 Hours	20	3,067	20,250,000	0	-20,250,000	100%

(1) There was no growth on any replicate of samples indicating zero CFUs. (2)Although replicates confirmed these results, sampling methods are not 100% effective in recovering all bacteria from a surface or transferring all recovered bacteria to a growth medium.

Gas Treatment

Control 6 hr/558ppm 6hr/1451 ppm

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Mass Casualty Response Comments*

Chlorine dioxide gas was effective in eliminating naturally-occurring skin bacteria as well as the spore-former *B. atrophaeus* that was inoculated onto pig skin.

Spray and dip treatments utilizing chlorine dioxide solutions were effective in eliminating a portion of naturally-occurring skin bacteria, but not effective in eliminating *B. atrophaeus* spores.

Skin is a unique surface to decontaminate and treatment protocols that were successful in eliminating spore-forming bacteria on spore strips were not equally effective on skin surfaces

There are clear applications for the use of chlorine dioxide in planning for local and broad scale responses to outbreaks to mitigate exposure risks in the handling and disposal of animal mass casualties.

Additional research is needed to optimize broad-scale application protocols for use in responding to a naturally-occurring outbreak or deliberate origin.

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Evaluation of Liquid and Fumigant Decontamination Products for Use Following Future Anthrax Attacks

US EPA Decontamination Conference
Research Triangle Park, NC
November 3, 2011

Dorothy A. Canter, Ph.D.
Carlton J. Kempter

1

Purpose

- Evaluate candidate liquid and fumigant decontamination products for possible use following future anthrax attacks
- Develop proposed product selection criteria
- Test the criteria using specific products
- Develop key conclusions/recommendations

2

Candidate Liquid Decontamination Products

- Products for which the US EPA granted crisis exemptions following the 2001 anthrax attacks (8)
  - Sabrechlor 25, DrewChlor 4107, Akta Klor 25, pH-amended bleach, Spor-Klenz RTU sterilant, Oxonia Active, Actril Cold Sterilant, Vortexx
- Antimicrobial products subsequently registered by EPA as sporicidal decontaminants specifically to treat *Bacillus anthracis (B.a.)*-contaminated, pre-cleaned, hard, nonporous surfaces (2)
  - Peridox + EDS, Steriplex Ultra™
- Products demonstrated in recent EPA research to be effective sporicides on several non-porous and porous materials (4)
  - CASCAD SDF, Decon Green, Easy Decon 200, Minncare Cold Sterilant

3

Active Ingredients of Liquid Decontamination Products

- Nine products contain hydrogen peroxide (H_2O_2) as the active ingredient or one of the active ingredients
- Three contain sodium chlorite as the active ingredient (chlorine dioxide aqueous solution generated in a closed system)
- One contains sodium hypochlorite as the active ingredient: pH-amended bleach
- One contains sodium dichloroisocyanurate as the active ingredient: CASCAD SDF

4

Liquid Decon Products Containing H_2O_2

Product	Active Ingredients	EPA Reg.†	Sporicidal Contact Time	Qualitative or Quantitative Sporicidal Testing	
				NP surfaces	P surfaces
Steriplex Ultra	Pt A: silver (0.03%); Pt B: H_2O_2 (22%), peroxyacetic acid (15%)	+SDC (*B.a.*)	≥30 min.[a]	180 porcelain penicylinders[a]	Not registered[a]
Peridox + EDS (electrostatic decon system)	H_2O_2 (24%)/peroxyacetic acid (1.2%) + EDS	+SDC (*B.a.*)	≥3 min.[a] or 30 min. (NP), 60 min. (P)[b]	20 glass & 20 aluminum[a], 5/5[b] (w/o EDS)	Not registered[a] 3/5[b] (w/o EDS)
SporKlenz RTU	H_2O_2 (1.0%), peroxyacetic acid (0.08%), acetic acid (≤10%)	+S	5 hrs[a] or 30 min.[b,c]	5/5[b] 2/3[c]	3/5[b] 2/3[c]
Oxonia Active	H_2O_2 (27.5%), peroxyacetic acid (5.8%)	+S	60 min.[d] or 30 min.[c]	3/3[d] 3/3[c]	3/4[d] 3/3[c]
Actril Cold Sterilant	H_2O_2 (0.8%), peroxyacetic acid (0.06%)	+S	10 min.[a]	180 porcelain penicylinders[a]	Not exempted[a]
Minncare Cold Sterilant	H_2O_2 (22%), peroxyacetic acid (4.5%)	+S	10 min.[d]	3/3[d]	1/1[d]
Vortexx	H_2O_2 (6.9%), peroxyacetic acid (4.4%), octanoic acid (3.3%)	+S	30 min.[a]	180 porcelain penicylinders[a]	Not exempted[a]
Easy Decon 200	Pt A: alkyl benzyl ammonium chlorides (3.2%); Pt B: H_2O_2 (7.95%)	+D	30 min. (NP)[b] 60 min. (P)[b]	5/5[b]	3/5[b]
Decon Green	H_2O_2 (35%)	NR	60 min.	5/5[b]	2/5[b]

5 †EPA Registration Status: S = sterilant; D = disinfectant; NP = hard, non-porous; P = porous; NR = Not registered

Data references: (FIFRA, 2002)[a], (EPA, 2010)[b] , (EPA, 2011)[c], (EPA, 2009) [d]

Liquid Decon Products Containing H_2O_2

Product	Conditions of use	Product Container Volume	Toxicity
Steriplex Ultra	Pour contents of Part B container into Part A container/mix by agitation for 15 sec.; use applicator	Part A: 1 qt. Part B: 1, 5, 55 gal.	Part A: eye/skin irritation Part B: corrosive to eyes/skin
Peridox + EDS	-Dilute 1 part product with 5 parts H2O -≤10 minutes later, treat with UV light using EDS wand at ≤2 ft from treated surface moving ≤1 ft/sec	1, 5 gal.	Corrosive to eyes/skin
SporKlenz RTU	Immerse items in undiluted product	1 qt/50 gal	Corrosive to eyes/skin
Oxonia Active	-Dilute 6.4 oz. of concentrate/gal H2O (5%v/v) -Circulate, coarse spray, or flood surface	Multiple volumes from 1–300 gal.	Corrosive to eyes/skin
Actril Cold Sterilant	-Immerse items in undiluted product -Rinse with H2O	1 gallon	Corrosive to eyes/skin
Minncare Cold Sterilant	-Immerse items in undiluted product -Rinse with H2O	1 gallon	Corrosive to eyes/skin
Vortexx	- Dilute 1 oz product/4 gallons H2O for 5% solution. - Circulate, coarse spray, or flood surface	1, 2.5, 4, 15, 30, 50, 300 gallons	Corrosive to eyes/skin
Easy Decon 200	-Mix equal portions of Parts A & B -Apply as spray		Corrosive to eyes/skin
Decon Green	Mix 3 part formulation and apply as liquid solution -		Unknown

Other Liquid Decontaminants

Product	Active ingredient(s)	EPA Reg.†	Sporicidal Contact time	Qualitative or Quantitative Sporicidal Testing	
				NP surfaces	P Surfaces
pH-amended bleach	Sodium hypochlorite (5-6%)	+ (S)	30-60 min.[a] 60 min.[b] 60 min.[d] 30 min.[c] 10 min.[c]	60 porcelain penicylinders[a] 5/5[b] -- 3/3[c] 3/3[c]	Ineffective on 60 silk suture loops[a] 3/5[b] 1/4[d] 3/3[c] 2/3[c]
Sabrechlor 25	Sodium chlorite (25%)	+ (D)	30 min.[a]	60 porcelain penicylinders[a]	Ineffective on 60 silk suture loops[a]
Drew Chlor 4107	Sodium chlorite (25%)	+ (D)	30 min.[a]	60 porcelain penicylinders[a]	Ineffective on 60 silk suture loops[a]
Akta Klor 25	Sodium chlorite (25%)	+ (D)	30 min.[a] .	60 porcelain penicylinders[a]	Ineffective on 60 silk suture loops[a]
CASCAD SDF	Sodium dichlorisocyanurate (48-85%)	NR	30 min. (NP)[b] 60 min. (P)[b] 30 min. [d]	5/5[b] 3/3[d]	5/5[b] 2/3[d]

†EPA Registration Status: S = sterilant; D = disinfectant; NP = hard, non-porous; P = porous; NR = Not registered

[7] **Data references: (FIFRA, 2002)[a], (EPA, 2010)[b] , (EPA, 2011)[c], (EPA, 2009) [d]**

Other Liquid Decontaminants

Product	Conditions of Use	Product Container Volume	Toxicity
pH-amended bleach	-Mix 1 part bleach, 8 parts H_2O, 1 part white vinegar -Circulate, coarse spray, or flood surface	Multiple sizes ≥1 quart	Corrosive to eyes/skin.
Sabrechlor 25	Use with chlorine dioxide generator to produce aqueous solution	Made on site to desired volume	Corrosive to eyes/skin; may be fatal if swallowed; irritating to nose and throat
Drew Chlor 4107	Use with chlorine dioxide generator to produce aqueous solution	Made on site to desired volume	Corrosive to eyes/skin; may be fatal if swallowed; irritating to nose and throat
Alta Klor 25	Use with chlorine dioxide generator to produce aqueous solution	Made on site to desired volume	Corrosive to eyes/skin; may be fatal if swallowed; irritating to nose and throat
CASCAD SDF	-3 reagents: decontaminant, buffer, surfactant -Make 2 separate solutions for decontaminant and buffer, mix & then add surfactant -Spray application from ≈ 1 foot	Up to 3,000 gallons	Corrosive; very destructive of mucous membranes; inhalation may be fatal

Proposed Criteria for Evaluating Liquid Decontamination Products

- Regulatory status: Have FIFRA registrations or exemptions been issued?
- Demonstrated sporicidal efficacy
  - Credible efficacy data for hard nonporous and/or porous surfaces
  - Contact time and other parameters needed for efficacy
- Safety concerns
  - Risks to humans and non-target organisms
  - Materials compatibility
- Practical considerations
  - Commercial availability of product or components
  - Ease of application/cleanup
  - Shelf life of product or components
  - Site-specific factors
  - Cost

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Applying Proposed Criteria to Selected Liquid Decontamination Products

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pH-Amended Bleach

- Regulatory status: Not registered, but crisis exemptions issued after 2001 anthrax attacks
- Demonstrated *B.a.* or surrogate sporicidal efficacy
  - On hard, non-porous and some porous surfaces (EPA, 2009, 2010, 2011)
  - 10-30 min. contact time (NP); 30-60 min. (P)
- Safety
  - Corrosive to eyes/skin
  - Corrosive effects on some materials (e.g., circuit/computer parts)
- Practical considerations
  - Extensive availability of container sizes ≥1 quart; long shelf life
  - Easy to formulate and apply; no visible residue
  - Large production volume
  - <$3 per gallon plus labor for applying product once every 15 min.

Candidate for all nonporous surfaces and some porous surfaces. Large-scale use possible due to widespread availability and low cost.

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Peridox + EDS

- Regulatory status: Registered as sporicidal decontaminant specifically for *B. a.* spores
- Demonstrated *B.a.* or surrogate sporicidal efficacy
  - Registered for hard, non-porous surfaces (i.e., tested on glass & aluminum coupons); ≥3 minute contact time followed by EDS (UV light wand) within 10 min.
  - Effective on 5 of 5 hard, non-porous materials and 3 of 5 porous materials (EPA, 2010) without the EDS for 30 min. and 60 min. contact time, respectively; these uses require an exemption
- Safety concerns
  - Corrosive to eyes/skin
  - May be fewer materials compatibility effects than pH-amended bleach
- Practical considerations
  - Only available in 1 and 5 gallon containers
  - Small application area
  - Must use specialized equipment (EDS UV light) 3-10 minutes after application using slow moving wand ≤1 ft/sec at ≤2 feet from treated surface
  - Limited production volume
  - Cost = $87.00 per gallon

Candidate for nonporous surfaces and some porous surfaces. Use may be limited by EDS, cost and production volume.

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CASCAD SDF

- Regulatory status: not registered by EPA under FIFRA; Canadian product
- Demonstrated *B.a.* or surrogate sporicidal efficacy
  - Effective on 5 of 5 non-porous surfaces and 5 of 5 porous surfaces (EPA, 2009, 2010)
  - Contact time: 30 minutes for non-porous surfaces; 60 minute for porous surfaces
- Safety concerns
  - Corrosive/lachrymator
  - Little data available on materials compatibility
- Practical considerations
  - Product pre-packaged in three components that are mixed with H_2O on site
  - Applied as foam using 2-compartment spray bottle; adheres to vertical surfaces
  - Question as to cleanup of foam following decontamination of large areas
  - Annual production volume not known
  - Cost = $10,095 for 300 gal. or $89,348 for 3,000 gal. (e.g., approx. $30 to $33/gal)

Candidate for nonporous and porous surfaces. Use may be limited by cost and production volume.

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Candidate Fumigants

- Fumigants for which EPA issued crisis exemptions to remediate building interiors following 2001 attacks
  - Gaseous chorine dioxide (ClO_2), hydrogen peroxide (H_2O_2) vapor, paraformaldehyde (pHCHO)
- Fumigant which demonstrated sporicidal efficacy in EPA-sponsored research
  - Methyl bromide (MeBr)

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Comparison of Candidate Fumigants

Fumigant	ClO_2 gas	H_2O_2 vapor	pHCHO	MeBr gas
Agent generation	On site reaction of liquid precursor chemicals to generate ClO_2 gas	On site vaporization of 35% H_2O_2 solution	On site heating of pHCHO to produce HCHO gas	On site heating of liquid MeBr to generate MeBr gas.
Process variables for efficacy	Temp ≥ 70°, 70% ≤ RH ≤ 95%, ClO_2 ≥ 750 ppm for 12 hours	Temp > 70°, RH ≤ 40%, H_2O_2 > 0.3 g/L for 4 hours	68° ≤ Temp ≤ 72°F , RH ≥ 50%, pHCHO ≥0.3 g/ft³ for 6-12 hours	Temp≥ 95°, 40% ≤ RH ≤ 75%, MeBr ≥300 mg/L for 48 hours
Mode of removal post-fumigation	Scrubbing with sodium compounds/carbon adsorption	Catalytic breakdown to H_2O and O_2	Reaction with NH_4HCO_3; white residue (methenamine)	Removal of MeBr by scrubber in prototypical research
Penetration capability	High	Low	High	High
Materials compatibility (computer parts)	Greatest extent of damage	Some damage	Not tested (no adverse effects - long history of use)	Some damage
Buildings fumigated	4 for anthrax attacks; multiple buildings for mold remediation in LA, TX and MS; registered for use in labs.	2 for anthrax attacks; registered for use in rooms, vehicles, etc.; registered for use in labs	1 (partial) for anthrax attacks; widely used but not registered for lab decon; exemptions for USAMRIID, DHS, USDA	Was once registered for fumigating homes & buildings for termites; some field studies done in trailer/home
Toxicity/Other	Highly acutely toxic	Highly acutely toxic	Human carcinogen, highly acutely toxic	Acutely toxic, neurotoxin; ozone depletor

Proposed Criteria for Evaluating Fumigants

- Regulatory status: Have FIFRA registrations or exemptions been issued?
- Proven efficacy
  - **Well established process variables**
  - **Penetration capability**
- Safety concerns
  - **Toxicity**
  - **Materials compatibility effects**
- Practical considerations
  - **Maximum volume of space that can be fumigated at one time**
  - **Demonstrated method(s) for removal of fumigant at end of process**
  - **Real-time monitoring of concentration throughout process**
  - **Commercial availability of fumigant, components and applicators**
  - **Cost**

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Applying Proposed Criteria to Selected Fumigants

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Chlorine Dioxide

- Regulatory status: FIFRA registered as disinfectant and sterilant; several crisis exemptions have been issued to treat *B.a.* spores
- Proven efficacy
  - vs. *B.a.* spores in 4 buildings after 2001 attacks; process parameters well established; efficacy in biosafety cabinets (BSCs) established by NSF-ANSI 49-2010.
  - Largest interior volume fumigated >12 million cu ft.
  - High penetration capability
- Safety concerns
  - Highly acutely toxic (IDLH: 5 ppm), not tested for carcinogenicity
  - Most damage to computer components of fumigants tested in DHS-EPA studies; damage to circuit breakers noted by USPS
- Practical considerations
  - Two methods used for removal of fumigant
  - Commercially available, but equipment and trained staff limited and product is not registered for *B.a.* spores
  - No real-time monitoring of fumigant concentration
  - Initially was very expensive, but costs have decreased markedly with tenting and other improvements

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Paraformaldehyde

- Regulatory status: FIFRA registrations voluntarily cancelled in 1991; 2 crisis exemptions issued in 2002
- Proven efficacy
  - Decades of use for decontamination of select agents by numerous federal, state, commercial and private labs; efficacy in BSCs established by NSF-ANSI 49-2010.
  - High penetration capability
- Safety concerns
  - Active ingredient formaldehyde acutely toxic (IDLH: 20 ppm), human carcinogen/genotoxin
  - Not tested in DHS-EPA materials compatibility studies of computer components
- Practical considerations
  - Demonstrated method for fumigant removal; white residue (methenamine) must be removed by washing
  - Volume of space to be fumigated might be limited
  - Commercially available , but not registered for *B.a.* spores
  - Inexpensive for small scale, but costs not known for large scale

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Methyl Bromide

- Regulatory status: FIFRA registered, but not as disinfectant or sterilant or for *B.a.* spores; exemptions granted only for research.
- Demonstrated efficacy
  - Research in lab/trailer/two-story home indicate efficacy vs. *B.a.* spores
  - High penetration capability
- Safety concerns
  - Not as acutely toxic as other fumigants (IDLH: 250 ppm), neurotoxin
  - Stratospheric ozone depletor – most uses prohibited under Clean Air Act (unless pre-2005 stockpile is used)
  - Some damage to computer components in DHS-EPA studies
- Practical considerations
  - 48 hour exposure required in above studies
  - Fumigant removal method available but not demonstrated at field level
  - Commercially available
  - Relatively inexpensive

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Conclusions/Recommendations – Liquid Decontamination Products

- Currently only 2 liquid decontaminants for *B.a.* spores can be bought and used without obtaining FIFRA crisis exemption (Steriplex Ultra; Peridox + EDS)
  - **But quarantine exemption issued by EPA in Oct. 2011 for 8 liquid decontaminants that previously received crisis exemptions**
  - **Crisis exemptions for other 4 products may be obtainable**
- Practical considerations (e.g., ease of use and cleanup, site characteristics, cost and availability) will be an important criterion in selecting liquid decontaminants from among those with comparable efficacy

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Conclusions/Recommendations – Fumigants

- Currently ClO_2 is the only fumigant that has been used for decontaminating interior spaces of ≥3 million cu. ft. at one time
  - **Sabre Technical Services is only vendor with equipment to generate ClO_2 to treat very large interiors at one time**
- MeBr might be useful fumigant for *B.a.* spores following wide area attack, **BUT** more research is needed to validate process variables and to develop/validate technology to remove fumigant at end of treatment
  - **A major hurdle is finding a way to obtain and use MeBr under the Clean Air Act since this use is not currently legal.**
- pHCHO proven fumigant for *B.a.* spores, **BUT** active ingredient formaldehyde is human carcinogen
  - **Would probably only be used under special circumstances following wide area attack (e.g., interior of building with minimal human usage)**
- H_2O_2 vapor would be useful to fumigate certain interiors of ≤250,000 cu. ft., **BUT** its low penetration capability would make the presence of porous materials be an issue

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Ultimate Conclusions

- No magic bullet exists for either surface decontamination or fumigation
- In a future *B.a.* attack, contaminated areas will need to be evaluated on a site-specific basis to determine which product(s) to use
- Value exists in having consensus criteria to perform such evaluations
- Criteria for evaluating decontaminants could also be applied to 'low tech' and physical methods of decontamination.
- Consensus criteria for evaluating these products will aid responders/Incident Commanders in making better informed and more timely selection decisions

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Note: This appendix includes copies of only those presentations that were authorized for use in this report. Some speakers requested that their presentations not be included in this document. Readers interested in learning more about those presentations are encouraged to contact the speakers.

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