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Report on the 2010 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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U.S. Environmental Protection Agency

Research Triangle Park, NC 27711

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, five 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 biological/chemical/radiological 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 plenary speakers, Dr. Paul Anastas and Congressman David Price, at the 2010 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 the Eastern Research Group for drafting the remaining portions of the report. Lastly NHSRC would like to acknowledge Dr. 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 "2010 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 the Plenary Session, the meeting addressed nine topic areas:

- Field Activities and Large-Scale Demonstrations,
- Cross-Cutting Recovery Activities,
- Tools and Guidance Development, Fate and Transport Research Activities Informing Recovery (Cross-Cutting),
- Activities to Support Wide-Area Biodecontamination,
- Persistence of Biological Agents and Other Bio-related Decontamination and Disposal Research, Radiological Recovery Research Activities, and
- Operational Considerations for Decontamination and Chemical Warfare Agent Recovery Research.

Plenary Session

Dr. Paul Anastas, the Assistant Administrator at EPA's Office of Research and Development, and the Honorable David Price, the Congressman from North Carolina's 4th District, opened the conference. Dr. Anastas emphasized the need for collaboration and innovation when developing solutions to decontamination issues. He stated that the conference provided an important forum for participants to share their overarching views of decontamination needs and concerns, as well as the details of their state-of-the-art techniques, technologies, and research needs. As the keynote speaker, Congressman Price provided perspective on the policy and budget issues that affected research programs at the Department of Homeland Security (DHS) and EPA. He noted that most government agencies and programs were facing budget cuts, including EPA programs supporting homeland security. Congressman Price cautioned that economic recovery and political decisions would ultimately influence future budgets, but he did not believe that long-term budget prospects were debilitating.

Field Activities and Large-Scale Demonstrations

The first three speakers in this session discussed activities and findings from decontamination events. First, a speaker described decontamination technologies (amended bleach and detergent) used during a response to a gastrointestinal anthrax case in Durham, New Hampshire. He noted that responders needed to evaluate the unique characteristics of each event when identifying appropriate decontamination methods. The second speaker presented a case study in which chlorine dioxide gas was used to decontaminate the ductwork of a Biosafety Level 2/3 laboratory prior to renovation. The third described source reduction activities at four facilities after the 2001 anthrax incidents and discussed lessons learned during these activities.

The last three speakers in this session described ongoing or planned demonstration projects. Two speakers provided information about projects aimed at addressing the restoration and recovery of transportation centers. One demonstration project sought to develop, identify, and/or select a set of plans, procedures, and technologies for the rapid recovery of major transportation facilities following a release of a chemical warfare agent or other highly toxic chemicals. The other demonstration project tested the ability to deploy a stabilizing coating on a train car and a contamination control barrier in a subway system tunnel. These technologies would be used in a radiological event to prevent the spread of contamination. The final demonstration project sought to evaluate the efficacy of numerous decontamination methods and

sampling methods, to conduct an economic analysis of a response, and to test the coordination of an interagency response to a biological agent release.

Cross-Cutting Recovery Activities

This session began with two presentations on decontamination concerns for water supply systems. The first of these presentations was an overview of several NHSRC studies focused on treating water and decontaminating water system infrastructure contaminated by biological and chemical agents. In the second presentation, a speaker described EPA efforts to develop a guide for water utilities responding to contamination events. This guide contained information about the containment, treatment, and disposal of large amounts of contaminated water.

During the remaining four presentations in this session, speakers provided information about various workgroup and agency activities. One speaker discussed the Threat Agent Disposal work group and two workshops focused on disposal issues related to recovery after a radiological dispersion device (RDD) event or a wide area anthrax event in an urban area. Other speakers provided information about current and ongoing work of the Validated Sampling Plan Work Group and the United Kingdom's Government Decontamination Service. The last speaker discussed the formation of the U.S.–Canada bilateral Technical Working Group and the role of this group in response and restoration efforts.

Tools and Guidance Development

The three presentations in this session described tools and guidance documents developed to assist in event response and recovery. The first speaker discussed the Analyzer for Wide-Area Restoration Effectiveness (AWARE) decision support tool and presented an analysis of different hypothetical anthrax release scenarios. The second described a Web-based, multiuser, interactive tool that allows implementation of the decision process flowchart provided in the draft document "Planning Guidance for Recovery Following Biological Incidents." The third speaker discussed the Department of Homeland Security's (DHS's) Protective Action Guides, developed for communities affected by nuclear and radiological incidents. These Protective Action Guides offer an approach for late-phase (long-term) recovery. The third speaker discussed optimization approaches, potential issues associated with late-phase recovery, and the need for more specific guidance on how to implement the optimization process.

Fate and Transport Research Activities Informing Recovery (Cross-Cutting)

Four speakers presented findings from research addressing the fate and transport of contaminants. Two speakers described projects that involved sampling for *Bacillus thuringiensis* var. *kurstaki* (Btk), a common pesticide with physical and biological properties similar to *Bacillus anthracis*. One of these projects involved sampling in and around buildings after an outdoor release of Btk. The results provided insight into spore infiltration into buildings as a function of building type and meteorological and land use variables. A separate but similar study was presented in which spore contamination characteristics were evaluated after the release of Btk in transit stations, including a limited comparison of the efficacy of different sample types in detecting levels of contamination. A third speaker described ongoing work related to outdoor dispersion, deposition, adhesion, and reaerosolization of particles as well as their subsequent infiltration into buildings. The last speaker described the Brooklyn Traffic Real-Time Ambient Pollutant Penetration and Environmental Dispersion (B-TRAPPED) study. The B-TRAPPED study sought to provide a better understanding of the transport of airborne particulate pollutants in a heavily populated urban neighborhood, from the sources on the streets, down the street canyon, and into and within the adjacent buildings.

Activities to Support Wide-Area Biodecontamination

Researchers from government agencies and private industry gave six presentations on the decontamination of biological threat agents. These presentations discussed findings from studies evaluating the efficacy of various physical, liquid, foam, and fumigation methods for decontaminating *Bacillus* spores from a variety of common indoor and outdoor surfaces. Data from these studies will inform the development of decontamination strategies for response and recovery events. In addition to *Bacillus* spores, one of these studies also evaluated the persistence and decontamination efficacy of five fumigant and four liquid technologies against *Brucella suis, Francisella tularensis,* vaccinia virus (a surrogate for the smallpox virus), and *Yersinia pestis* on various materials. All of the technologies in this study were effective against all of these bioagents. Another of these studies sought to evaluate the decontamination efficacy and the cost comparison for several methods of cleaning spores from the heating, ventilation, and air conditioning system. Results from this study are not yet available.

Persistence of Biological Agents and Other Bio-related Decontamination and Disposal Research

Eight presentations addressed additional concerns associated with the decontamination of biological agents. The first presentation discussed a method to deposit *Bacillus* spores onto various material surfaces using a metered dose inhaler. The deposition amount and repeatability were measured. Ultimately this deposition method will provide consistent deposition for benchtop decontamination and detection experiments. The second speaker discussed tests conducted to determine the effect of simulated sunlight on the persistence of *B. anthracis* on different materials. He also evaluated the persistence of *Brucella suis* (a Category B Centers for Disease Control and Prevention agent) and freeze-dried vaccinia virus (a surrogate for the variola virus, which causes smallpox) deposited on various materials under various environmental conditions. These tests confirmed that these agents can persist for extended periods of time depending on the environmental conditions and materials, and that decontamination of these materials may be necessary.

Three of the presenters described the development of new test methods. The first described a novel cell-based assay for detection of functional ricin. This assay could be used to determine the efficacy of disinfectants and to confirm findings in recently completed ricin decontamination studies. The other two presenters discussed the development of standardized methods for efficacy testing of liquid decontaminants against biotoxins and for testing disinfectants against foreign animal diseases on nonporous surfaces.

Three additional presentations discussed findings from biological agent decontamination studies. One speaker described results from a study that employed a three-step-method to test the sporicidal efficacy of six disinfectants on two different carrier surfaces contaminated with *B. atrophaeus*. Another speaker presented findings from a project to evaluate multiple disinfectant strategies for their effectiveness at inactivating Newcastle disease virus on mechanical equipment. Test data showed that current methods recommended for agricultural disease response were not sufficient and additional research was required to provide effective recommendations for the field. The third speaker described a bench-scale landfill flare system developed to study the destruction of *Geobacillus stearothermophilus* spores, a surrogate for *B. anthracis*. This presentation included information regarding the design of the flare system, problems encountered during setup of this system, sampling methods, spore losses throughout the system, and preliminary data on flare spore destruction.

Radiological Recovery Research Activities

The nine presentations in this session discussed issues associated with radiological contamination (and decontamination). Two speakers provided updates on programs regarding radiological contamination. One speaker provided an update on the EPA Agency Airborne Spectral Photometric Environmental Collection Technology (ASPECT) program, which assists first responders by providing an aerial tool to collect photographic, chemical, and physical (infrared and gamma radiation) information quickly and relay this information directly to decision-makers in the field. Another speaker discussed Defence Research and Development Canada, Ottawa's radiological research program, which was investigating problems associated with large-area contamination resulting from an RDD incident.

Three presentations addressed the fate and transport of radiological contamination. One presentation provided findings from a study of the interactions of cesium, resulting from a simulated RDD incident, with urban materials. This presentation also provided recent results on modeling and experimental studies for RDD radionuclide chelators. Another presentation discussed a bench-scale research project seeking to understand the association between drinking water pipe material and surrogate (nonradioactive) isotopes for cesium, strontium, and cobalt. This project also examined mechanisms of attachment and the efficiency of water decontamination/treatment methods. The third presentation described a series of experiments intended to investigate the interactions of cesium chloride with variety of urban surface materials.

Two speakers described research into the efficacy of decontamination technologies. One research project focused on the identification and evaluation of chelating agents that could improve the radiological decontamination efficiency of an existing commercial decontamination foam. Researchers in this study sought to modify this foam so that it would be effective for the removal of cesium, strontium, and cobalt from a variety of common urban surface materials. The second speaker discussed NHSRC's Technology Test and Evaluation Program (TTEP), in which a series of performance evaluations of commercial, off-the-shelf radiological decontamination technologies to gauge their effectiveness in the removal of cesium from concrete were recently completed.

Disposal of waste resulting from a radiological contamination event is an important consideration for restoration and recovery. A presenter described an EPA effort to provide a first-order estimate of waste resulting from an RDD event including decontamination activities. This estimate has been used in RDD response planning activities and exercises. The methodology used to generate this estimate allows further examinations of scenario-specific categorized waste amounts as a function of radiation acceptance levels and cleanup goals. Another presenter described a series of tests conducted to evaluate the removal of radionuclides and other hazardous components from liquid decontamination wastes.

Operational Considerations for Decontamination

The impact of decontamination technologies on treated materials, especially electronic equipment, was the topic of three presentations. The first presentation described a project that evaluated the effect of lowering the relatively humidity on the sporicidal effectiveness of chlorine dioxide gas and corrosive effects associated with the use of chlorine dioxide. Experiments found that as relative humidity decreased, the concentration × time (CT) needed to reach 100 percent sporicidal efficacy increased. Corrosion effects were found to be independent of CT but were dependent on the relative humidity. The other two presentations examined the impact of chlorine dioxide and hydrogen peroxide fumigation on electronic equipment. These two projects provided objective assessments of fumigation-induced damage of electrical components, materials, and subsystems.

Chemical Warfare Agent Recovery Research

During this session, one speaker provided an overview of basic research programs in decontamination funded through the U.S. Army Research Office. The remaining five speakers described issues associated with the decontamination of chemical warfare agents. One speaker discussed a chemical testing methodology that provided a new approach for evaluating decontaminant performance on porous or complex surfaces. Another speaker described a series of experiments assessing the fate and behavior of chemical agents on building surfaces and in the surrounding air as a function of temperature, surface concentration, and construction material. Two speakers provided results from experiments and projects to assess decontamination strategies for various chemical warfare agents, including vapor and/or liquid sarin, mustard agents, and VX, found on different building material surfaces. Another speaker described a demonstration of rapid, effective knockdown and neutralization of chemical warfare agent simulant aerosol releases using electrostatically charged decontaminant sprays. This demonstration project also sought to explore and optimize spray system parameters that will improve knockdown and neutralization. Findings from this project indicated that a release mitigation spray safety system could remove airborne contaminants from an accidental or intentional release and could protect personnel and limit the spread of contamination.

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List of Abbreviations

ASFV	African swine fever virus
ASPECT	Airborne Spectral Photometric Environmental Collection Technology
AWARE	Analyzer for Wide-Area Restoration Effectiveness
BDR	building decontamination residue
BOTE	Bio-response Operational Testing and Evaluation
Btk	*B. thuringiensis* var. *kurstaki*
BSL	Biosafety Level
B-TRAPPED	Brooklyn Traffic Real-Time Ambient Pollutant Penetration and Environmental Dispersion
°C	degrees Celsius
CBRN	chemical, biological, radiological, and nuclear
CDC	Centers for Disease Control and Prevention
CFU	colony-forming unit(s)
ClO_2	chlorine dioxide
cm^2	square centimeter
COT	commercial off-the-shelf
CSFV	classical swine fever virus
CT	concentration and time values
CWA	chemical warfare agent
DCMD	Decontamination and Consequence Management Division
DHS	U.S. Department of Homeland Security
DNDO	Domestic Nuclear Detection Office
DOD	U.S. Department of Defense
DOE	U.S. Department of Energy
DRDC	Defense Research and Development Canada
DTRA	Defense Threat Reduction Agency
ECBC	Edgewood Chemical Biological Center
EPA	U.S. Environmental Protection Agency
ERT	Environmental Response Team
°F	degrees Fahrenheit
FAD	foreign animal disease
FBI	Federal Bureau of Investigation
FEMA	Federal Emergency Management Agency
FMDV	foot and mouth disease virus
GB	sarin
GD	soman
GDS	U.K. Government Decontamination Service
GEM	Gamma Emergency Mapper
H_2O_2	hydrogen peroxide
HD	mustard agents
HEPA	high-efficiency particulate air
hr	hour
HVAC	heating, ventilation, and air conditioning
IND	Improvised Nuclear Device

IBRD	Interagency Biological Restoration Demonstration
LANL	Los Alamos National Laboratory
LC/MS	liquid chromatography/mass spectrometry
m	meter
m^2	square meter
MDI	metered dose inhaler
mg	milligram
mg/L	milligrams per liter
mL	milliliter
mVHP	modified vaporous hydrogen peroxide
NAS	National Academy of Sciences
NBIC	National Biosurveillance Integration Center
ng/mL	nanograms per milliliter
NHSRC	National Homeland Security Research Center
NRC	Nuclear Regulatory Commission
NYCT	New York City Transit
ORD	Office of Research and Development
OSHA	Occupational Safety and Health Administration
OTD	Operational Technology Demonstration
PM	particulate matter
PPE	personal protective equipment
PSU	Personal Sampling Unit
ppm	parts per million
ppmv	parts per million by volume
R&D	research and development
RCRA	Resource Conservation and Recovery Act
RDD	radiological dispersal device
RH	relative humidity
RTP	Research Triangle Park
SNL	Sandia National Laboratory
TOF-SIMS	time-of-flight secondary ionization mass spectrometry
TSM	three-step method
TSP	trisodium phosphate
TWG	Technical Working Group
U.K.	United Kingdom
U.S.	United States
UV	ultraviolet
VHP	vaporous hydrogen peroxide
WMD	weapon of mass destruction
XPS	x-ray photoelectron spectroscopy

1 Introduction

This report summarizes presentations and discussions from the "2010 U.S Environmental Protection Agency (EPA) Decontamination Research and Development Conference," which was held April 13–15 in Durham, North Carolina. The technical content of this report is based entirely on information and discussions from the workshop.

The workshop consisted of 53 speaker presentations organized in nine sessions, followed by brief question and answer periods. Dr. Paul Anastas, the Assistant Administrator for EPA's Office of Research and Development (ORD), opened the Plenary Session and the Honorable David Price, Congressman, 4th District, North Carolina, 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 9 sessions. Each presentation summary consists of the abstract provided by the speaker and a review of the brief question and answer period. 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 presentation abstracts and question and answer period summaries for each of the nine topic areas/sessions: Field Activities and Large-Scale Demonstrations, Cross-Cutting Recovery Activities, Tools and Guidance Development, Fate and Transport Research Activities Informing Recovery (Cross-Cutting), Activities to Support Wide-Area Biodecontamination, Persistence of Biological Agents and Other Bio-related Decontamination and Disposal Research, Radiological Recovery Research Activities, Operational Considerations for Decontamination, and Chemical Warfare Agent Recovery Research.
- 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 distribution.

2 Plenary Session

Ms. Cynthia Sonich-Mullin, chair of the Plenary Session, welcomed the conference participants and presenters. She noted that conference attendance has grown each year. This year, attendees represented a range of domestic and international agencies and organizations, including attendees from multiple EPA offices, the United Kingdom, Canada, and Singapore.

She also noted that presentations would include discussions of not only decontamination research and development, but also field activities and demonstrations, cross-cutting decontamination recovery activities, tool and guidance development, and operational considerations. Biological, chemical, and radiological agents and contaminants were to be the focus.

Ms. Sonich-Mullin also pointed out that, over the years, this conference has been extremely beneficial in building relationships, developing collaborations, and sharing information to further homeland security and decontamination research programs. At EPA, researchers have the daunting task of conducting research that will provide the scientific basis for operations and decision-making related to EPA's mission. These researchers strive to find innovative solutions and responses to contamination events which may result from terrorist attacks or natural disasters. EPA research alone, however, cannot address the many issues involved in preparing for, responding to, and recovering from contamination events, so, EPA welcomed this opportunity to collaborate and share information.

2.1 Protecting Human Health and the Environment through Innovation

Dr. Paul Anastas, Assistant Administrator, EPA, ORD

The National Homeland Security Research Center (NHSRC) began hosting the Decontamination Research and Development Conference in 2005. Dr. Paul Anastas reiterated the important role that the conference has played in bringing together researchers and decision-makers from both the public and private sectors and from around the world. He stated that the conference exemplifies the collaboration and innovation needed for this group to come together and meet their mission. Participants not only provide an overarching view of decontamination needs and concerns, but also discuss the details of the state-of-the-art techniques, technologies, and research needs.

The conference is geared toward facilitating scientific exchange, as illustrated by the participation of EPA, the Department of Defense (DOD), the Department of Energy (DOE), the Centers for Disease Control and Prevention (CDC), and the many other organizations represented. These organizations have a shared mission in decontamination research and practice. This conference allows individuals in these organizations to discuss their everyday activities and ensure that their work is broadly known among the larger community. Dr. Anastas noted that silence is the enemy of progress; therefore, this conference is essential for sharing knowledge and fostering progress.

Dr. Anastas reviewed EPA's missions in relationship to homeland security. EPA is the primary federal agency responsible for the decontamination and remediation of indoor and outdoor areas affected by chemical, biological, and radiological contaminants. EPA's responsibilities also include decontamination of water. EPA's ORD, specifically NHSRC, is responsible for ensuring that their research supporting decontamination and remediation efforts is relevant and timely. ORD and NHSRC focus on finding solutions to the many homeland security challenges faced by EPA and others.

In seeking solutions, researchers often measure, monitor, review, and characterize problems. At some point, however, the only reason to understand a problem is to inform a solution. Dr. Anastas said that a solution-oriented approach to

decontamination research is essential. This approach, Dr. Anastas felt, is a refreshing departure from the typical tendency to understand and quantify a problem at the expense of developing solutions. If research efforts to quantify and understand a problem exceed the research necessary to find a solution, then that research has not met EPA goals. Dr. Anastas noted that NHSRC research focuses on homeland security, but often has broader applications to EPA's mission to protect the environment.

Dr. Anastas emphasized the importance of applying a systems approach to decontamination problems. Researchers have decades of experience in approaching problems in a fragmented way, such as by environmental media (i.e., water, air, land) or by industrial sector. The more researchers fragment problems, he stated, the greater the risk of unintended consequences. For example, a solution for one medium may result in greater challenges for another medium. Not until researchers consider entire systems and examine how threats flow from one medium or sector to another can they understand the breadth of the problems. This approach also creates greater degrees of freedom for the solutions. Many of the presenters at this conference apply a systems approach.

According to Dr. Anastas, a systems approach and perspective allows for resiliency. Resiliency is often discussed, but not deeply understood. When asking, "What is the nature of a resilient system?" researchers can discuss characteristics and describe what a resilient system might be. Researchers, however, still try to understand the basic characteristics of resilient systems so they can design a resilient system.

Dr. Anastas noted as a strength the ability of NHSRC research to respond quickly to the EPA response community's needs. He provided the decontamination of anthrax in Danbury, Connecticut, as an example. For this decontamination, field personnel needed a method to determine if optimum decontamination conditions were being met. These conditions dictate the efficacy of the selected decontamination technology. NHSRC researchers provided a novel technique they had recently evaluated to meet this need. Subsequently, an incident of anthrax contamination occurred in New Hampshire. Due to communication and collaboration, responders in New Hampshire were aware of the new assessments of decontamination techniques used in the Connecticut remediation. Preliminary results from the NHSRC research in Connecticut informed the New Hampshire response. This example highlights the importance of not only testing, but also information sharing.

Many approaches exist to address the challenges faced in homeland security. Dr. Anastas felt, however, that a mindset of innovation is essential. He stated that innovation involves more than polishing existing approaches; innovation means finding new approaches to address problems. Dr. Anastas quoted EPA Administrator Lisa Jackson from her speech at the National Press Club about the essential role of innovation in EPA's mission: "I have no interest in leading an agency that only tells us what we can't do. I want to work together on the things that we can do." In assessing how researchers engaged an innovative spirit, Dr. Anastas emphasized his belief that innovation was essential for success.

In closing, Dr. Anastas emphasized the need to share and discuss research needs and knowledge. He also noted the need to discuss data gaps and uncertainties, which are the catalysts of innovation. An upcoming demonstration project at Idaho National Laboratory, which will involve multiple agencies working together to find innovative solutions, exemplifies the type of work needed to find solutions to decontamination issues.

2.2 Keynote Speaker

Honorable David Price, Congressman, 4th District, North Carolina

The Honorable David Price serves as the Congressman for the 4th District in North Carolina, which includes the Research Triangle Park (RTP) area and surrounding communities. He thanked NHSRC for inviting him to serve as

keynote speaker for the Decontamination Research and Development Conference. He noted that he did not have in-depth knowledge of the scientific issues faced by the participants; rather, he would provide perspective on the policy and budget issues that affect research programs.

Previously, Congressman Price was involved in the nine-year process to design and build EPA's RTP facility. The RTP facility is the largest facility ever designed and built by EPA. More recently, Congressman Price sat on the committee that funded EPA research budgets and supported EPA's mission to research climate change and ensure clean air and water. His committee regularly met with EPA representatives about budgetary needs. Congressman Price examined the programs and policies that addressed homeland security and prepared first responders for terrorist events and natural disasters.

The Department of Homeland Security (DHS) is the third-largest institution in the Executive Branch, but DHS does not encompass all aspects of homeland security. DHS receives a portion of the total budget allocation to homeland security. DOD and the Department of Health and Human Services also receive funding. As the lead agency in addressing exposure concerns, EPA also receives a portion of the homeland security budget. Other EPA funding not designated as homeland security funding has also funded research relevant to homeland security.

For fiscal year 2011, Congressman Price stated, EPA's portion of the homeland security budget will be reduced. Reductions will be seen in research, development, and technical support activities funded through EPA's homeland security research program. Research on materials decontamination and disposal, threat assessment, and sampling and analytical methods helps fill critical knowledge gaps and enhances abilities to respond and recover from homeland security events. Some of the homeland security funding reductions are the result of non-recurring investments and transfer of programs to other areas. However, budgets throughout EPA have been reduced, so all funding requests will require thoughtful and careful scrutiny.

Congressman Price acknowledged that conference participants were most concerned about how homeland security budget reductions affect chemical, biological, and radiological agent and contaminant decontamination research. Budget questions themselves are important, but Congressman Price noted that budget discussions also provide a broader view of the range of research activities and the decisions about priorities.

The DHS Science and Technology Directorate oversees a variety of research and development programs related to security threats. The overall DHS research portfolio is slated for reductions in 2011. The chemical and biological program remains the largest research and development program, followed by explosives, then radiological and nuclear research. Congressman Price mentioned ongoing projects of possible interest to participants, such as efforts to develop a handheld biological agent detector to classify unknown samples. Researchers are also developing a technology that would screen for multiple pathogens in environmental, food, water, animal, plant, and human clinical samples. The innovations group is moving forward with a demonstration project that will place miniaturized chemical agent detectors into personal monitoring devices. This demonstration project will examine the process of creating a ubiquitous network for chemical agent detection. The group responsible for test and evaluation standards is developing performance standards for chemical and biological detection equipment and is developing guidance for first responders to chemical and biological incidents. Congressman Price noted that these projects are of interest because they focus on advanced warning systems and support for first responders.

When the Science and Technology Directorate was established within DHS in 2003, Congress was concerned about setting research and development priorities, establishing mission-oriented research, and ensuring that research was complementary rather than redundant.

Congressman Price noted that the capstone integrated project teams are a key effort initiated by the Science and Technology Directorate. These teams include the end users of research findings. These end users helped identify existing capability gaps and establish research and development priorities. The first responder product team comprises end users from the fire fighting community. Fire fighters are concerned about chemical and biological agent detection. Congressman Price noted that research initiatives should directly impact the identified capability gaps.

DHS also oversees two programs related to biological threat surveillance: BioWatch and the National Biosurveillance Integration Center (NBIC). DHS is currently developing the third generation of BioWatch detector technology, intended to provide automated detection capabilities for high-priority biological threat agents. In response to technical questions and concerns about the underlying rationale for BioWatch, the National Academy of Sciences (NAS) assessed the program. NAS specifically considered the cost of airborne surveillance systems versus public health benefits. Congressman Price noted that this assessment was recently completed; NAS concluded that early warning and detection were complementary to public health assessments. In addition, NAS concluded that an early warning system in the absence of public health assessment would be ineffective. NAS also noted serious concerns raised by state and local partners. These partners lacked confidence in the BioWatch technology and worried about receiving insufficient support, as well as the lack of coordination between agencies. NAS also warned about the technological difficulties associated with developing BioWatch. Given these concerns, Congressman Price noted, funding for BioWatch needed careful consideration

NBIC was originally designed to act as a central resource for collecting and sharing information about biological threat agents. Under current budget proposals, NBIC would work to integrate state-level research on biosurveillance. Congressman Price felt that this shift in the NBIC focus highlighted efforts to enhance surveillance in the public health arena. Based on North Carolina's expertise in this area, the Office of Health Affairs is working with the state to develop an integrated health surveillance system that could be replicated in other states.

The Water Security Initiative is a relatively small program. Budget proposals, however, included an approximately 40 percent reduction in funding. Congressman Price felt that this proposed budget cut for this program, combined with a proposed increase in the BioWatch budget, highlighted inconsistencies in funding approaches toward water and air research. He noted that the budget committees needed to carefully review the proposed funding to ensure appropriate budget allocations for biological threat agent research.

DHS founded the Domestic Nuclear Detection Office (DNDO) in 2005 to improve capabilities to detect and report unauthorized attempts to import, process, store, develop, or transport radiological or nuclear materials. DNDO supports DHS's research and development for nuclear detection, but the 2011 budget proposed moving a portion of this research to the Directorate of Science and Technology. The program would receive a moderate funding increase for programs such as mobile stand-off detection systems, replacement technologies for existing helium-based technologies, and innovative tools for inspection environments. Congressman Price noted that the overall DNDO strategy has shifted from fixed-unit detection to more mobile and deployable systems, such as human-portable radiation detector systems for field deployment, long-range radiation detection capabilities, and operational testing and evaluation processes for other detection systems. Increased funding was also proposed for DNDO training and exercise programs for federal, state, and local law enforcement and first responders.

Congressman Price concluded with an overview of the budget process and budget concerns. In most cases, budgets will remain flat or be reduced. A modest increase, however, has been proposed for DHS. This increase would fund improved aviation security (e.g., enhanced

screening technologies in airports) and resolve outstanding costs from previous national disasters, such as Hurricane Katrina. The DHS budget also includes the BioWatch third generation procurement, consolidation of DHS headquarters, and personnel cost-of-living increases. These additional expenses exceed the increased funding. Congressman Price noted that most agencies are facing budget pressures. The Appropriations Committee is completing budget and oversight hearings and is beginning to discuss the details of the annual funding bills. Congressman Price anticipated that the difficult budget decisions and the political situation would lead to a more contentious appropriations process than normal. He emphasized the need for Congress to focus on legitimate questions and priorities in order to write the best allocation bill possible.

Question and Answer Period

- *Given the cuts in funding for 2011, were future cuts (e.g., 2012 and beyond) likely or would budgets remain flat?*
  The answer to this question, said Congressman Price, depends upon many contingencies. In general, the constrained budget environment will probably continue, and the economic and political environment will dictate how these constraints are manifested. The general state of the economy is the overriding challenge faced by Congress. Addressing the economy in the short and long term consists of three components: recovery, financial regulatory reform, and fiscal balance. Congressman Price noted that tension exists regarding the best approach to addressing the budget concerns. In the short term, Congress has increased funding in some areas and research budgets have benefited. Congress has also realized that ongoing homeland security functions are necessary. In the long term, however, the current spending rate cannot continue; the administration is slowly working toward building a balanced budget, which requires difficult decisions about future funding. Congressman Price cautioned that economic recovery and political decisions will ultimately influence future budgets. Overall, he believed, the long-term budget constraints are not debilitating.

- *The programs noted as important to homeland security primarily address surveillance, detection, and protection. This conference, however, focused on decontamination issues. Would future funding continue to focus on protection or was an increase in decontamination research possible?*
  Congressman Price has been struck by the disproportionate nature of some of the budget reductions. He and his staff will critically review the impact of funding reductions to ensure that the budgetary sub-committee fully understands the ramifications of these reductions. Congressman Price feels that the rationale for these cuts was inadequate. Efforts to address waterborne threats and to enhance decontamination capabilities are complementary to other aspects of homeland security, so Congressman Price will continue to carefully assess the proposed research funding allocations.

3 Field Activities and Large-Scale Demonstrations

3.1 Case Study: Decontamination of a Community Building Containing Low Concentrations of *Bacillus Anthracis* Spores, Durham, New Hampshire

Ted Bazenas, EPA, Region 1

There are no presumptive decontamination strategies for anthrax. Each case is unique and requires a careful evaluation of many factors to achieve protection of public health. This case study will include a presentation of the incident chronology of the Durham, New Hampshire, gastrointestinal anthrax infection case. At this incident, the Unified Command used data from environmental sampling, epidemiology, medical science, and unpublished research to inform the decision process, leading to the selection of decontamination methods and strategies for the interior of a ministry building adjacent to the University of New Hampshire Campus in Durham. Photographs and discussion of the implementation of the decontamination methods will be presented. The authors acknowledge the contributions of others at the EPA Region 1 Office and the New Hampshire Department of Environmental Services; the EPA National Decontamination Team; ORD, NHSRC; CDC and the National Institute for Occupational Safety and Health; the National Guard 12th Civil Support Team, Concord, New Hampshire; and the New Hampshire Department of Health and Human Services.

In this case study, the selected decontamination method for low concentrations of anthrax spores was spray application of an amended bleach solution (one part bleach, eight parts water, and one part white vinegar at pH 6.0 to 7.0) for a 10-minute contact time, followed by a detergent solution (bleach/trisodium phosphate/vinegar) scrub with a sponge or brush. All surfaces washed with these solutions received a final rinse with clean water. Residual water was collected with a wet/dry high-efficiency particulate air (HEPA) vacuum. This method was applied to vertical and horizontal surfaces, including floors, ceilings, and walls.

Carpeted surfaces were first vacuumed with a wet/dry HEPA vacuum, then sprayed with the amended bleach solution (10-minute contact time), followed by a final wet/dry HEPA vacuuming. Smaller durable items were submerged in a large container of amended bleach for 10 minutes, then rinsed with water. Porous items such as books, paper, clothing, and furniture were sprayed with amended bleach for a 10-minute contact time. At the discretion of the property owner, items damaged in the decontamination process were discarded and disposed of as solid waste per New Hampshire state regulations. Post-decontamination sample collection for anthrax spore culture is under consideration.

Unpublished research conducted by NHSRC explored various combinations of decontamination solutions and cleaning methods. Although this specific combination was not part of the research, use of these decontamination solutions and methods on porous and non-porous surfaces that were contaminated with high levels of *Bacillus atrophaeus* (approximately 7-log) spores should result in a 3- to 4-log reduction of spores. At the much lower levels of spores (20 to 400 colony-forming units (CFU)) identified in this case study, these methods would likely result in reduction of spores to levels below public health concern (e.g., nondetect).

The readily available, easily applied decontamination approach used here provides a viable method for *Bacillus anthracis* spore reduction from surfaces. The approach uses easily attainable equipment and materials, does not require specialized equipment, and can be accomplished with minimal training. Such an approach significantly enhances our ability to respond to a wide-area anthrax event to reduce spore loads and potentially successfully remediate areas of low contamination.

Question and Answer Period

Conference participants posed no questions at the conclusion of the presentation.

3.2 Decontamination of a Facility and HVAC System Ductwork using Chlorine Dioxide Gas

Mark Czarneski, ClorDiSys Solutions, Inc.

This case study presents the use of chlorine dioxide gas to decontaminate the ductwork of a pharmaceutical manufacturing facility prior to renovation. The ductwork was contaminated with penicillin and had to be decontaminated prior to use for other nonmanufacturing proposes. The facility was being renovated to build a new training facility. Many samples were taken in rooms and duct work and many positive penicillin samples were taken from the duct work. Removing the ductwork would have been costly due to the special procedures that the contractors would require for safety. Decontaminating the ductwork first meant that the demolition contractors would not need to have special personal protective equipment (PPE) or to follow safety precautions.

This presentation will start with a discussion of the facility's need to decontaminate the ductwork before renovation. Methods for connecting the chlorine dioxide gas generator to the ductwork will be described, as well as methods used to contain the gas during decontamination. Background information on the gas's efficacy will be presented to illustrate the target parameters that were established. Methods for testing the efficacy of the decontamination will also be discussed. Pictures, figures, and graphs will be used where appropriate.

Results of the decontamination cycle will be shared, showing the success of the decontamination. Benefits of using chlorine dioxide gas will be discussed, including its material compatibility, excellent distributive properties, and ability to withstand temperature gradients.

This case study is significant because ductwork is not easy to decontaminate thoroughly using most agents. Thorough decontamination by manual methods is extremely costly, time-consuming, potentially dangerous if harmful organisms are present, and not completely effective. Ductwork is also a haven for many organisms that are sucked into the exhausts or returns during normal functionality. In the context of homeland security, if a commercial property were to suffer a biological attack, both the building and its heating, ventilation, and air conditioning (HVAC) system and ductwork would require thorough decontamination.

Question and Answer Period

- *How did you sample for penicillin? ClorDiSys conducted the fumigation because of a concern about penicillin acting as an allergen. Allergen fragments are thought to be capable of causing an allergic reaction, so the fumigation must address penicillin as a whole and as fragments.*
  The building's owner conducted sampling for penicillin before and after fumigation. ClorDiSys Solutions, Inc., however, has previous experience with chemical fumigations and has found that a target chlorine dioxide concentration of 7,000 parts per million (ppm)–hours was sufficient to breakdown the beta-lactams. A conference participant noted that the chlorine dioxide would oxidize the penicillin into small fragments.

- *Was environmental sampling conducted subsequent to fumigation?*
  Sampling conducted after fumigation reported no positive results.

- *Seven positive detections were found in the HVAC system. How many samples were collected in total?*
  Czarneski was unsure about the total number of samples collected. Most of the positive detections were found in the HVAC systems because the rooms were cleaned prior to the fumigation, but the HVAC system could not be cleaned.

- *What was the target relative humidity (RH)?*
  Steam generators raised the RH to the target range of 65 to 70 percent.

- *Did steam generation occur during fumigation with chlorine dioxide or did steam generation cease once the target concentrations were reached?*
  The steam generators operated only until the RH reached the target level. Steam generation did not occur during the chlorine dioxide generation. Monitoring for RH also did not occur during the gas generation.

- *Was the facility equipment removed prior to fumigation*?
  Equipment remained in the facility during fumigation.

- *The presentation indicated that the equipment in the facility showed no visible signs of degradation after fumigation. Did the owner test or run this equipment to ensure that the equipment remained functional? If so, what were the results?*
  Czarneski indicated that he spoke with the owner one and six months after the fumigation and all equipment remained functional.

- *Indoor sampling detected no chlorine dioxide after the venting period. Did the fumigation system include scrubbers to remove chlorine dioxide from the air during venting?*
  During fumigation, the HVAC system was blocked to re-circulate the chlorine dioxide during treatment. When venting, the HVAC system was reopened and allowed to vent the chlorine dioxide without treatment. The building was located in a campus area with a limited number of neighbors who could be affected by the vented chlorine dioxide. Czarneski noted that monitoring for chlorine dioxide leaks occurred throughout the fumigation process to ensure public safety.

- *When was the fumigation conducted?*
  The fumigation occurred in 2009.

3.3 Source Reduction Following the 2001 Anthrax Attacks: Lessons Learned

Dorothy Canter, Dorothy Canter Consulting LLC

Following the 2001 biological terrorism attacks, source reduction consisted of removing essential items for offsite treatment (and returning them for reuse) and removing nonessential items for ultimate disposal, either as waste or through recycling. For highly-contaminated facilities, source reduction activities also included physical cleaning and/or chemical pre-treatments of the surfaces of materials that remained on site and of the interior structure. In the post-2001 cleanups, a number of different methods were used to treat essential and nonessential items. Two offsite methods were used for items designated as essential: gamma ray or ion beam irradiation and treatment in an ethylene oxide (EtO) sterilization chamber. Five methods were employed for nonessential items: EtO sterilization followed by recycling, on site surface decontamination followed by either recycling or disposal in a hazardous waste landfill, hazardous waste incineration, medical waste incineration, and steam sterilization. Pre-treatment of interior surfaces and items was also conducted at a number of sites at which fumigations were performed.

This paper will address source reduction activities at four facilities following the 2001 anthrax attacks—namely, the Capitol Hill Anthrax Site, the Department of State mail facility, the U.S. Postal Service Trenton Processing and Distribution Center, and the Department of Justice mail facility. Key lessons learned from these activities will be presented, including the need to limit the removal of nonessential items before the main decontamination process.

Question and Answer Period

Conference participants posed no questions at the conclusion of the presentation.

3.4 An Overview of the Chemical Restoration Operational Technology Demonstration (OTD) Project

Mark D. Tucker, Sandia National Laboratories

The Chemical Restoration OTD is a collaborative project between Sandia National Laboratories, Lawrence Livermore National Laboratory, Oak Ridge National Laboratory, and Pacific Northwest National Laboratory that is funded by DHS's Directorate of Science and Technology. The primary objective of this project is to develop, identify, and/or select a set of plans, procedures, and technologies for the rapid recovery of major transportation facilities following a release of a chemical warfare agent or other highly toxic chemicals. The primary focus is on the recovery of major airports; Los Angeles International Airport is being used as a representative facility. By conducting in-depth analyses at one facility, this project is examining in detail many factors that must be considered in a recovery operation.

Objectives of this project include:

- Application of an end-to end systems approach for recovery of critical transportation facilities following a chemical agent release, including elements such as:
  - Planning tools
  - Cleanup guidelines
  - Decontamination methods
  - Sampling and analysis methods
  - Decision support, analysis, and simulation tools
  - Waste management guidelines.
- Pre-planning of the recovery process at a representative critical transportation facility.
- Addressing data, technology, and capability gaps critical to conducting recovery operations.
- Executing the developed plans and procedures in a series of workshops, tabletop exercises, and a final demonstration.
- Transfer of the systems approach and pre-planning capabilities to other critical transportation facilities.

The effort in this project has been focused in three areas:

- A systems analysis to gain a comprehensive understanding of the complex recovery process and identification of technology, capability, and data gaps for this process.
- Development of both generic and site-specific plans for facility recovery, including a comprehensive remediation guidance document, an interactive decision framework for decision-makers to follow, and a simulation tool to estimate the time and costs of recovery using various resources and remediation strategies.
- A series of focused experimental and technology development efforts to fill data, information, and technology gaps critical for recovery operations.

Work in these three areas has provided a greater understanding of the recovery process (i.e., improved knowledge), the development of plans and procedures for recovery following a chemical agent release (i.e., improved planning), and development of better methods to conduct the recovery process (i.e., improved operations).

Efforts conducted by this project have (1) allowed a greater understanding of the end-to-end recovery process; (2) developed comprehensive generic and site-specific plans for recovery, including planning aids such as a comprehensive and interactive decision framework and a simulation tool to estimate time and cost for recovery; and (3) filled data and technology gaps critical for recovery operations. The project has also worked extensively with other agencies at the local,

state, and federal levels to address this difficult problem.

The plans and procedures developed by this project are expected to begin to fill the critical need for better methods for recovery of critical facilities following the release of a chemical warfare agent or other highly toxic chemicals.

Question and Answer Period

Conference participants posed no questions at the conclusion of the presentation.

3.5 Two Recent Proof of Principle Tests of Deployable Countermeasures to Support Recovery of Critical Mass Transit Facilities

Robert Fischer, Lawrence Livermore National Laboratory

The Subway Safety Initiative, currently underway in New York City, is charged with developing recovery plans for the rapid restoration of critical transportation infrastructure in the event of a terrorist attack involving the dispersal of radioactive materials. In conjunction with developing recovery plans, two critical countermeasure proof of principle demonstrations were conducted in 2009. The proof of principle demonstrations were designed to test the efficacy of (1) stabilizing a radioactively contaminated train car for transport and (2) deploying a contamination control barrier in a subway system tunnel.

The first proof of principle demonstration addressed stabilization of a typical Metro North rail car in preparation for transit to a recovery facility for full decontamination. The testing included application of two different sprayable stabilization agents (a temporary fixative and a strippable coating) and the physical covering of the car in plastic wrap. Qualitative assessment of contamination control was made using UV active contamination simulation powders. The testing demonstrated the feasibility of using plastic wrapping materials and fixatives in combination and individually. The results indicated that it is possible to contain and stabilize a single rail car and indentified areas where further improvements would need to be made before the methodology could be considered a deployable countermeasure.

The second proof of principle demonstration tested the efficacy of deploying contamination control barriers in subway tunnels. Recovery plans being developed for New York City Transit (NYCT) assume that sections of the subway system can effectively be isolated from one another as a precursor to staged decontamination. A test was designed to determine if a simple plastic barrier could be rapidly installed into a subway tunnel and provide an adequate barrier for contamination control. The barrier installation was accomplished by in-house NYCT emergency response teams. Once installed, the barrier was subjected to smoke and pressure tests. The tests determined that such barriers, if properly constructed, could withstand minimal pressure gradients consistent with that achieved for asbestos abatement. Methods for improving the installation process were captured for inclusion into the next generation of deployable countermeasures.

Efforts to use the wrapping of rail cars and the installation of barriers in subway tunnels in NYCT proved potentially effective as steps in controlling contamination from an RDD. More detailed and comprehensive tests are needed before these methods can be considered deployable.

Being able to (1) isolate portions of subway systems and (2) fix contamination on rail cars so that they can be relocated for decontamination is critical to developing return-to-service strategies. The strategies outlined here take advantage of capabilities already in place in the transit systems.

Question and Answer Period

Conference participants posed no questions at the conclusion of the presentation.

3.6 Bio-Response Operational Testing and Evaluation (BOTE)

Shannon D. Serre, EPA, National Homeland Security Research Center

The BOTE Project is a collaborative effort between EPA, DHS, CDC, DOD, and the Federal Bureau of Investigation (FBI) designed to operationally test and evaluate biological (anthrax) incident response from public health/law enforcement response through environmental remediation. The project will involve coordination between On-Scene Coordinators and Special Teams, EPA researchers from NHSRC, and several EPA Program Offices to demonstrate the restoration of a facility at full scale after the wide-area release of a biological threat agent. The project will assess the effectiveness of numerous decontamination methods within the facility and include establishment of an Incident Command System, sampling, decontamination including waste treatment and disposal (solid and liquid), facility clearance (including risk assessment/communication), and economic analysis. This project is currently being planned by a cross-agency/cross-government project team, and testing is expected to be conducted in September 2010 at a facility located at Idaho National Laboratories.

The BOTE Project has four main objectives:

- To exercise and evaluate coordination of an interagency response to a biological agent release indoors.
- To conduct and evaluate field-level studies of various biological agent decontamination technologies/protocols.
- To conduct and evaluate sampling strategies and plans.
- To conduct an economic analysis of the incident response.

This presentation will focus on the planning aspects of Objective 2.

Question and Answer Period

- *If decontamination were ineffective, how would the facility be restored for subsequent testing rounds?*
  Post-decontamination sampling will be used to assess the reduction in spore levels and efficacy. The spore level, however, should be similar from round to round.

- *What sampling was proposed at the onset of the study to establish a baseline and between testing rounds to assess efficacy?*
  The facility had been cleaned after a recent project, so no baseline sampling was planned before testing began. Serre noted that the participant had raised a good point, which the researchers will consider, about the need to establish a baseline for comparison.

- *What pre- and post-sampling methods were planned? What were the method detection limits?*
  Pre- and post-sampling methods have not yet been defined and the test plan is under development.

- *What was the proposed method for depositing spores in the test facility?*
  A group with previous experience in the facility will conduct the deposition. The specific deposition method—point source or HVAC system—will be discussed with this group.

4 Cross-Cutting Recovery Activities

4.1 National Homeland Security Research Center Water Treatment and Infrastructure Decontamination Research

Scott Minamyer, EPA, NHSRC

The Water Infrastructure Protection Division of EPA's NHSRC conducts research to enhance the nation's ability to detect, mitigate, and recover from chemical, radiological, or biological contamination in drinking water and wastewater systems. This presentation provides an overview of several NHSRC studies focused on treating water and decontaminating water system infrastructure contaminated by biological and chemical agents. NHSRC water treatment and decontamination research is intended to (1) increase knowledge regarding the treatability of chemical, biological, and radiological contaminants most likely to be used to contaminate drinking water supplies; (2) identify which priority contaminants will adsorb and persist on wetted water infrastructure surfaces; and (3) determine the capabilities of water treatment and decontamination technologies to remove or destroy biological and chemical contaminants that do persist.

Question and Answer Period

- *To experience an effect, the consumer would need to contact a high concentration of toxins. Was this level of exposure possible?* Available research regarding biotoxins indicated that the presence of biotoxins in the water supply was a concern.

- *Several specific inorganic contaminants, including arsenic and mercury, were mentioned. Using a generic treatment approach, such as flushing or changing pH to address arsenic contamination, resulted in low decontamination levels, which was not surprising. Contaminant-specific technologies such as precipitation technologies were available for arsenic and were much more effective,. Would future research include more contaminant-specific technologies*?
  Minamyer agreed that more effective decontamination methods exist. This project evaluated typical decontamination methods. Additional research into contaminant-specific decontamination methods, the method requirements, and the method efficacy is underway.

- *Has a tool or method been developed to determine the level of dirt and/or rust in an old pipe? This kind of tool would be useful.* Minamyer said that no such tool has been developed. He thought that developing such a tool would be impossible because of the differences in water pipes around the nation (e.g., age, pipe material, pipe size).

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

Marissa Lynch, EPA, Office of Water

Contamination of a drinking water, wastewater, or storm water system with chemical, biological, or radiological contaminants may require water utilities to contain and/or dispose of large amounts of water. In 2008, the Critical Infrastructure Partnership Advisory Council Water Sector Decontamination Working Group identified the need for guidance on containment and disposal of decontamination waste, including large amounts of water and associated solid wastes for the water sector. In response, EPA is developing a draft support guide for water utilities on containment, treatment, and disposal of large amounts of water to help utilities respond to all-hazards contamination event(s). The decontamination and recovery process for a water system following a contamination incident will vary on a case-by-case basis. Therefore, water utilities need information that can be adapted to specific situations and incidents, as appropriate, during planning and rapid decision-making.

EPA's Water Security Division leveraged existing information, including current guidance, relevant regulations, response tools, technologies, ongoing research efforts, relevant research reports, and case studies to develop the draft support guide for water utilities. This information was compiled and evaluated for applicability to water sector decontamination. The draft guide includes the following:

- An overview on containment, treatment, and disposal of contaminated water from a CBR event.
- Types of containment, treatment methods and disposal options.
- Decision trees that can be adapted for containment, treatment, and disposal options depending on the nature of the contamination incident.
- Information on applicable regulatory requirements.

Four contaminant classes are addressed in the draft support guide:

- **Chemical contaminants,** including petroleum and hydrophobic compounds, chemical warfare agents, heavy metals, and pesticides.
- **Biological contaminants,** including bacteria, viruses, and protozoa
- **Biotoxin contaminants,** including plant toxins, bacterial toxins, algal toxins, and fungal toxins.
- **Radiological contaminants,** including alpha, beta, and gamma emitters.

In addition, the guide also provides a disposal checklist and summarizes risk communication needs during containment and disposal of large amounts of water.

This presentation will provide an update on EPA efforts to develop and disseminate this support guide to help prepare utilities to respond to all-hazards contamination events.

Question and Answer Period

- *Can users apply the guidelines to treatment of decontamination wastewater? If so, were specific treatment technologies suggested? This participant noted that offsite treatment is often a challenge and wondered what onsite treatment technologies were suggested.*
  Lynch indicated that the information contained in the guidelines could be applied to decontamination wastewater treatment. The guidelines provide specific suggestions for treatment technologies and examples could be identified by reviewing the guidelines.

4.3 Threat Agent Disposal: Disposal Issues Following a CBRN Incident Based on RDD and Anthrax Waste Disposal Workshops

Paul Kudarauskas, EPA, Office of Emergency Management

As part of EPA's continuing efforts to enhance the nation's readiness to handle the environmental impacts of terrorist use of chemical, biological, or radiological threat agents, EPA convened a Threat Agent Disposal work group to strengthen its understanding of the issues surrounding the disposal of threat agent-derived waste following a wide-area chemical, biological, or radiological terrorist event. Because disposal of threat agent–derived waste is one of the Agency's primary issues, EPA has initiated a series of efforts to engage stakeholders to help identify the issues and concerns that need to be considered in advance, not in the confusion surrounding an actual incident.

This presentation will summarize two workshops that discussed the transportation and disposal capabilities in the response to attacks involving (1) an RDD and (2) anthrax in an urban area. The first workshop was based on Liberty RadEx held in Philadelphia, Pennsylvania; the second was based on the

Interagency Biological Demonstration held in Seattle, Washington. Each workshop involved interviews and discussions with the private sector, state and local governments, and the federal government.

Question and Answer Period

Conference participants posed no questions.

4.4 Update on the Validated Sampling Plan Work Group

Dino Mattorano, EPA Office of Emergency Management

The Validated Sampling Plan Work Group is an interagency work group that was established to address concerns with sampling and analysis for *Bacillus anthracis.* Group participants include CDC, EPA, DOD, FBI, National Institute for Standards and Technology, and DHS. The Work Group's objectives are to develop guidance and a decision support process for selecting specific methodologies that provide a level of confidence in the sampling and analytical results during an incident.

This presentation will briefly describe the Validated Sampling Plan Work Group as well as its current and ongoing work, including an interagency environmental sampling strategy.

Question and Answer Period

- *Given the almost random nature of contamination in the Hart Senate Office Building, would the protocols be effective in characterizing random contamination and identifying outliers? At the Hart Senate Building, contamination was found in one office because a letter shared a mail bag with the letter that contained the spores.*
  In the test facility, the gradient ranged from 10^1 to 10^4. In the Hart Senate Office Building, high concentrations were found in the Daschle suite, and then concentrations tapered off. Mattorano noted that the method had succeeded in identifying contamination in the Hart Senate Office Building; however, investigators had information about the spore-containing letter and the movement of this letter.

- *Did the preferred sampling method depend on the inoculation method?*
  Wet versus dry dissemination mattered less than the surface material characteristics (e.g., carpet versus nonporous surface). For example, vacuum methods were best for collecting samples from carpets, whereas wipes were best for collecting samples from clean, dry surfaces.

- *Which sampling strategy was preferred—random or grid approach?*
  The size of the facility was one factor in selecting an approach. The grid approach worked well, but a random approach worked better when no information existed about the extent of contamination. Mattorano noted that establishing a grid in a facility could be simple. He felt no easy answer existed to the question of preferred strategy.

- *How did the number of samples collected in a specified area impact the confidence in clearance? This participant noted that Mattorano's presentation referenced 99 percent confidence that 95 percent of the spores had been cleared.*
  Mattorano noted that much of the confidence level was based on hot spots and the number of samples and the confidence level depended on the size of the hot spot. A smaller hot spot (e.g., 3 inches [7 centimeters] in diameter) required more sampling than a larger hot spot (e.g., 10 feet [3 meters] in diameter). Mattorano noted that results for small and large hot spots were similar. He also noted that some statisticians and others disagreed that a hot spot approach was appropriate.

- *What were the sampling efficiencies of the various sampling methods?*
  Quite a number of studies have evaluated the efficiencies of various sampling methods. Mattorano referenced a project that involved reviewing the published and unpublished data regarding sampling

efficiencies. Findings were summarized in a table, which he has a copy of, but the table has not been publicly released. Mattorano noted that the CDC Laboratory Response Network documents also include a summary table of this information.

4.5 Developing an Effective CBRN Decontamination Capability

Hasmitta Stewart, Government Decontamination Services

The Government Decontamination Service (GDS) is now part of the U.K.'s Food and Environment Agency and is responsible for ensuring that the U.K. has an effective decontamination capability to respond to chemical, biological, radiological, and nuclear (CBRN) attacks or major accidental releases of hazardous materials. Decontamination services are operationally delivered using a framework of private companies (suppliers) that work in a range of industrial sectors including nuclear decommissioning, clinical decontamination, oil exploration, remediation of industrial spills and the demolition of industrial sites. As releases of CBRN materials are rare, GDS leads a program of work to develop operational capabilities within the U.K. and its protectorates using a combination of theoretical case studies, learning from industrial accidents, exercises, CBRN incidents, and scientific research and development projects. As no one country has practical experience of all areas of CBRN decontamination in civilian environments, active international collaboration is of central importance to GDS's capability development strategy. Although a decontamination capability is in place, continued research and development coupled with clear exploitation plans and exercises are required to drive forward both the capacity and capabilities likely to be required in the recovery phase of an incident.

Question and Answer Period

- *GDS and EPA have worked together and shared information for many years. EPA is a response agency with a research function, the participant felt, whereas the recent GDS move seems to have positioned GDS's response functions within a research facility. Did this move change GDS's ability to collaborate with researchers and affect research projects?*
  Stewart replied that GDS's relationship with researchers remains a work in progress.

- *The pathways for addressing chemical agents appeared straightforward. The pathways for addressing biological agents, however, presented a number of issues. Examples of options for addressing biological agents included medical countermeasures, prophylactics, vaccines, and PPE. How does GDS plan to address biological agents?*
  At the moment, GDS is focused on assessing supplier deployment of response technologies. The biological agent pathway certainly needs additional attention and consideration.

- *In working with U.S. contractors, EPA has found a reluctance to use prophylactics. EPA has strongly recommended vaccines and antibiotics, but overcoming this reluctance has been difficult.*
  In the U.K., research laboratories have been asking questions about obtaining and using prophylactics, which implies an interest in using these methods to address biological concerns.

4.6 U.S.-Canada Bilateral Technical Working Group (TWG) for CBRN Response and Recovery

G. Blair Martin, EPA, Air Pollution Prevention and Control Division

DHS and EPA have collaborated to develop a draft charter for a Technical Working Group (TWG) to serve as the basis of negotiations of bilateral agreements with other countries. The TWG would provide a mechanism for sharing both response and research and development (R&D) expertise and experience in the event of a CBRN incident.

The concept of a TWG was initiated and developed during the 2001 anthrax incidents in the United States. The membership of each

TWG was tailored to provide appropriate support to the incident commander for the particular situation. Some of the same expertise has been engaged in response to the "natural anthrax" incidents in the United States and United Kingdom. As a result, the TWG concept has been expanded to consider its potential to engage the expertise of multiple countries in the event of other CBRN incidents. DHS and the Canadian Defense Research and Development Command have negotiated a bilateral agreement for mutual assistance in response to CBRN incidents. As a part of this agreement, a U.S.–Canada TWG was formed. The TWG membership includes representatives from both the response and R&D community, with a permanent co-chair from each of the two communities. The TWG will have a core group from each community to provide continuity. However, other members may be added or substituted to address a specific CBRN issue most effectively. This presentation will describe the present state of development and membership of the TWG. The presentation concludes that the TWG is a useful approach for mutual cooperation in the event of a CBRN incident.

This is the first bilateral agreement to establish a TWG for support of CBRN response and restoration from a CBRN incident. The agreement establishes the relative roles for both the response and R&D communities to work collaboratively to support such an effort. DHS anticipates negotiating bilateral agreements with other countries, including the United Kingdom and Australia, based on this model.

Question and Answer Period

- *Given the complexities of response and recovery efforts, a participant asked if Martin recommended creating TWGs that specialized in chemical, biological, and radiological issues or creating a single TWG that covered all issues.*
  EPA's ORD designed the TWG to cover all concerns—chemical, biological, radiological, and measurement. The individuals on the TWG would have access to experts in a variety of subject areas. In response to an event, the TWG could then convene expert subgroups that could address issues and identify appropriate responses.

- *Has EPA had the opportunity to use the TWG?*
  Martin noted that the TWG is beginning to form and has not responded to an incident. However, the St. Johns Hospital fumigation (conducted in August 2008) provides an example of an effective TWG. The TWG, which included experts from outside government, was on site during the fumigation and addressed both regulatory and technical issues as they arose. As a next step in developing the TWG, Martin suggested that the group conduct a tabletop exercise that more fully discusses the specifics of a response action. A meeting participant agreed that a number of tabletop exercises existed and would benefit from TWG input.

5 Tools and Guidance Development

5.1 Analysis of Decontamination Strategies Following a Wide-Area Biological Release in a Metropolitan Area

Robert Knowlton, Sandia National Laboratories

National Planning Scenario number 2 concerns a wide-area release of a biological agent used as a weapon of mass destruction to impart casualties in a major metropolitan area. Anthrax is a potential agent, as it may be released as an aerosol, has the potential to be persistent in the environment, is not easily detected, and may cause significant casualties and fear. The anthrax letter attacks in 2001 are an example of the consequences that can occur from even a relatively small amount of the material released into the air. The cleanup effort for the 2001 anthrax attacks cost hundreds of millions of dollars and took several years in some cases to reoccupy the contaminated facilities. A wide-area metropolitan release can be devastating, and the need to optimize the time and minimize the cost of the response and recovery effort is great.

To plan for the restoration and recovery efforts that would follow a potential wide-area release of anthrax in a metropolitan area, Sandia National Laboratories has developed a decision support tool called the Analyzer for Wide-Area Restoration Effectiveness, or AWARE. AWARE is a comprehensive software product that facilitates the development of cost and timeline estimates for the restoration and recovery efforts. The activities accounted for in the AWARE toolset include: initial screening sampling and laboratory analysis; characterization of sampling and laboratory analysis; decontamination processes, including surface treatment and fumigation, waste handling, and disposal; and clearance sampling and laboratory analysis. Critical inputs to the model are the resources available to perform these activities, such as the number of sampling teams available, the laboratory throughput capacity, the rate of application of surface decontamination treatments, the number of fumigation units available, the number of decontamination teams available, and the costs associated with these activities and labor rates.

An analysis of different hypothetical anthrax release scenarios will be presented. Tradeoffs related to decontamination strategies will be analyzed, such as varying the amount of surface treatment versus fumigation in the cleanup process and the optimal number of decontamination resources necessary to reduce the timeline for restoration. Chokepoints in the system will be identified and discussed. An analysis of homeowner-implemented decontamination methods in residential areas will also be presented.

Results of these studies should be of value to those decision-makers who may be faced with the burden of planning a response and recovery effort following a wide-area anthrax release in a metropolitan area.

Question and Answer Period

- *EPA Regions III, IV, and V have completed a gap analysis for a similar response scenario. A participant suggested that Knowlton compare the Sandia National Laboratory (SNL) effort to the EPA effort. The two groups approached decontamination differently and applied different assumptions. This participant thought that a comparison of assumptions and findings would be useful. The EPA regions concluded that the decontamination effort would take two years.*

  This participant provided specific comments on the SNL assumptions regarding sample collection and decontamination approach. The SNL effort assumed that 2 million samples would be required during decontamination efforts. The Brentwood Postal Facility, which consisted of 14

million cubic feet of interior space, required only 4,000 environmental clearance samples, which did not provide 95 percent coverage. All 4,000 samples were negative. This participant felt that the assumption of 2 million samples could be greatly reduced. The participant also noted that the EPA regions assumed collection and analysis of 2,000 samples per day. The SNL approach assumed that all exterior decontamination would be complete before interior decontamination began. This participant felt that exterior decontamination would be conducted to create corridors that allowed movement without causing further contamination. Interior decontamination would then begin and occur simultaneously to additional exterior decontamination. Exterior decontamination might also include exclusion zones or satellite zones that would become smaller as decontamination progressed.

Knowlton stated that the SNL effort was intended as a planning tool. He agreed that the concerns raised should be addressed during use in an operational setting.

5.2 Interactive Decision Framework for Consequence Management

Robert Greenwalt, Lawrence Livermore National Laboratory

In May 2009, EPA and DHS jointly released a draft document *Planning Guidance for Recovery Following Biological Incidents,* developed by the Subcommittee on Decontamination Standards and Technology, Committee on Homeland and National Security, within the Biological Decontamination Standards Working Group of the National Science and Technology Council. Included is a description of the biological agent incident-response decision process in the form of a flowchart that "arranges the response activities in a specific sequence and provides the decision-maker … with a guide to key decisions … and tasks … that need to be accomplished during a response." In addition, the Interagency Biological Restoration Demonstration (IBRD) Program has developed an extended framework, also in flowchart form, that provides additional details for selected steps within the general decision process.

This presentation demonstrates a Web-based, multiuser, interactive implementation of the extended decision process flowchart. The presentation provides decision-makers with a tool to document decisions as they are made, to inquire what decisions are outstanding, and generally to track progress of the response. The process can be viewed in several ways, including the basic flowchart form and by incident command system role. The decision-making process can also be customized "on the fly," should this be necessary.

The multiuser Web interface uses a standard Web browser, communicating with a database back end, to present current status information and let the user update incident status information. The tool will lead the management and technical staff through the tasks that need to be accomplished and record rationale and information available for each decision.

Using this tool can help decision-makers work in accord with a national-level consensus document, as well as synchronize actions and progress across all involved agencies.

Question and Answer Period

Conference participants posed no questions.

5.3 Optimization Approaches and Issues Associated with Late-Phase Recovery Following Radiological or Nuclear Events

S.Y. Chen, Argonne National Laboratory

Following the terrorist acts of September 11, 2001, preparations for responding to similar future activities have been underway throughout the world. For radiological or nuclear events, response scenarios focus on the use of RDDs or Improvised Nuclear Devices (INDs). In 2008, DHS issued a series of Protective Action Guides to address all response phases (i.e., early, intermediate, and late phases). These guides recognize the need for a process to "optimize" a

multifaceted approach to late-phase (long-term) recovery for affected communities. This paper discusses optimization approaches and possible issues associated with the recovery process.

Events associated with RDDs or INDs have been extremely rare, and they offer very limited relevant information. Yet it is possible to gain some insight into possible response scenarios by reviewing some large-scale nuclear incidents of the past. These events include the Three-Mile-Island nuclear event of 1979 in the United States, the Chernobyl nuclear event of 1986 in Ukraine (former Soviet Union), and the cesium source accident of 1987 in Goiânia, Brazil. Releases from these events and the subsequent responses offer insights into the potential cleanup issues associated with the aftermath of RDD or IND events.

While DHS's "optimization" approach is reasonable for addressing late-phase recovery activities, extensive effort is needed to develop more specific stepwise guidance, including: (1) formulating applicable national policies, (2) advancing research and development in characterizing contamination and cleanup technologies, (3) improving understanding and ascertaining potential radiological impacts and implications, (4) developing effective decision-making processes, and (5) opportunities for stakeholder involvement. These elements must be considered when developing a robust optimization framework.

This work suggests a path toward optimization of environmental cleanup activities in the aftermath of an RDD or IND event (that will be directed to specific event-related situations). This process will also bring about a harmonious and consistent approach that considers other non-event-related situations that are addressed under current statutory requirements (including the EPA's Superfund Program). The future results are intended to complement the DHS Protective Action Guides on radiological response to events involving RDDs or INDs.

Question and Answer Period

- *What were the most important factors in determining the time and cost requirements for remediation efforts?*
  Chen noted that lower cleanup limits resulted in higher costs. Optimization works to balance competing factors such as lower cleanup limits and higher costs. Chen noted that the Superfund program has a funding mechanism, so lower cleanup levels could be achieved without a direct impact to taxpayers. No such funding mechanism exists for addressing remediation after a terrorist event. Chen felt there is a need to establish priorities regarding health concerns and funding.

6 Fate and Transport Research Activities Informing Recovery (Cross-cutting)

6.1 Transport of *Bacillus Thuringiensis* var. *Kurstaki* (Btk) from an Outdoor Release into Buildings

Kristin Omberg (presenting for Sheila Van Cuyk, Los Alamos National Laboratory)

Understanding the fate and transport of biological agents in the environment will be critical to recovery and restoration efforts after a biological attack. Los Alamos National Laboratory (LANL) conducted experiments in the Seattle, Washington, and Fairfax County, Virginia, areas to study agent fate in urban environments. As part of their gypsy moth eradication efforts, Washington State and Fairfax County have sprayed *Bacillus thuringiensis* var. *kurstaki* (Btk), a common organic pesticide, for a number of years. Because Btk shares many physical and biological properties with *Bacillus anthracis,* the results from these studies can be extrapolated to a bioterrorist release. Many of the spray zones are located in or near urban areas.

Work in Fairfax County, Virginia, in 2008 showed viable Btk in buildings near spray areas. The 2009 study will present the combination of modeling and experimentation used to assess methods to determine whether a building is contaminated after spraying Btk. We have collected samples from within nine buildings located inside or immediately adjacent to a spray block. A strategy of combined probabilistic sampling and targeted sampling was used, with a goal of reducing numbers of samples while still allowing a determination with reasonable confidence that a building is contaminated. The goal is to rapidly "rule in" a building as contaminated.

Several different types of buildings were sampled, including older commercial buildings with relatively "leaky" construction and HVAC systems and newer commercial buildings with more recent, "tight" construction and newer HVAC systems. In addition, a commercial building was sampled that did not have an HVAC system; this building pulled in no air from the outside.

The results from experimental data and simulations from the sampled buildings will be presented to gain insights into infiltration into buildings as a function of building type and meteorological and land use variables. By using available indoor models for contaminant transport, an understanding of the importance of human tracking of materials sprayed outside the building into the building is identified.

This work will present a summary of the results from building samples collected adjacent to Btk spray areas, as well as a methodology for collecting samples in order to determine rapidly whether a building is contaminated following a biological attack. We will present strategies that will allow confidence in sampling results with fewer samples than the traditional probabilistic approach. In addition, we have developed "rules of thumb," elucidated from the data, based on key building characteristics.

Question and Answer Period

- *Were templates used to ensure consistent sample sizes?*
  Omberg used templates for swipe samples. For irregularly shaped vacuum samples, Omberg used measuring tapes to outline sampling areas.

- *What evidence supports the conclusion that the HVAC system was responsible for spore movement? Only a limited number of samples were collected within the building.*
  Modeling results supported the conclusion that the HVAC system was responsible for spore movement. Assuming a perfect HVAC filter and spore infiltration at the building entries, the model predicted eventual spore

dispersal throughout the building by the HVAC system.

- *Was the model verified? If not, what evidence supports the modeling results?* Omberg answered that the model had not been verified but is based on NIST's CONTAM model. She mentioned additional samples that were collected during the study, but were not included in the presentation. In rooms without people or HVAC vents (e.g., fire suppression rooms, telecommunications rooms), samples were negative. In rooms with only the HVAC system or tracking by people as a source (e.g., interior bathrooms), samples were positive. However, Omberg could not distinguish between spore transport via the HVAC system versus tracking.

- *Was any air sampling conducted?* Omberg collected outdoor air samples along the sides and roofs of the buildings, but did not collect air samples inside the buildings.

- *What was the sample size for each of the different sample types collected?* Omberg collected four types of samples. The bootie samples consisted of individual booties. The vacuum sock samples averaged 7 square meters (m^2) and were no larger than 9 m^2. The swipe samples were 100 square centimeters (cm^2). For the 3H trace evidence collection filters, study participants collected as much of the HVAC filter as possible, up to 2 tablespoons of dirt.

6.2 Transport of Bioaerosols into a Regional Transport System

Michael Dillon, Lawrence Livermore National Laboratory

Intentional and controlled releases of Btk to control gypsy moth infestations have provided an opportunity to test characterization equipment and sampling methodologies, as well as gain information on movement of this species within the environment. This study took advantage of these natural experiments to characterize how Btk was transported to and penetrated into an urban regional transit system. A particular focus of this study was to improve the scientific understanding of the fomite/vector pathway (transport on objects and people)—including this pathway's contribution to measurable airborne concentrations within the transit vehicles. This experiment also provided an initial assessment of Btk contamination characteristics in transit stations, including a limited comparison of the efficacy of different sample types in detecting station contamination.

Airborne measurements of total particulates and aerosol size distributions were made with Anderson Impactors, total particulate samples, and Personal Sampling Units (PSUs). Surface samples were made with swipes and settling plates. Over 600 total samples were collected. Sample processing followed protocols established and vetted in previous DHS–sponsored gypsy moth studies.

Mass transit stations and vehicles can be contaminated via a wide area release. Significant airborne contamination appears to be possible via fomite/vector transport. Correlation between presence of surface contamination and detection based on aerosol sampling was not always good.

This work demonstrates that distant releases can contaminate transit stations and that fomite transport may play an important role in the spread of contamination. The observation that aerosol collectors did not always detect areas with measurable surface contamination suggests that transit system characterization should include a variety of measurement methods and that surface sampling or other more aggressive methods should be considered.

Question and Answer Period

- *What was particle size distribution?* Obtaining information about particle size was difficult because the sample signal was low. Sampling indicated that viable spores were present, but overall results were inconclusive. Dillon hopes to conduct additional sampling.

- *Was the spore preparation treated to enhance or alter transport?*
  Dillon responded that the spore preparation, which was used for outdoor releases, was not altered. This preparation was likely designed to fall quickly and to remain in place. Previous study findings, however, indicated that this type of spore preparation aged and resuspended over time.

- *A participant noted that the study probably used spores in a pesticide preparation. This participant felt that data on particle decay are critical. How were conclusions regarding aerosols drawn in the absence of particle decay data?*
  Dillon did not analyze the aerosols as they were released from the spray bottles, but hoped to do so in the future. He agreed that analysis of quantitative data was not possible. This study examined qualitative information and found that some degree of airborne transport occurred. In a train car with one contaminated person, positive samples were found even though no direct contact occurred between the contaminated person and the sampler. This observation indicated that, at a minimum, a short-term aerosolization pathway existed. Similarly, but less conclusively, positive samples were also found in locations not likely to be directly contacted by people or objects.

- *Did the lack of a correlation between air and surface sampling results provide further evidence that transport occurred by fomites and not aerosolization?*
  Dillon agreed that the study suggested that fomites were a concern. The study, however, was not designed to provide a definitive conclusion about transport, either for the specific study scenario or for more broad applications. Evidence indicated that fomites and people were major transport pathways that were not currently addressed. Dillon noted that the contamination patterns found during this study indicated that some level of airborne transport was occurring and strongly pointed to fomites as a concern.

6.3 Mitigation and Containment of Contaminant Spread

Jacky Rosati, EPA, NHSRC

The purpose of the containment research conducted by EPA's NHSRC, Decontamination and Consequence Management Division, is to provide information on the behavior, fate, and transport of contaminants. This information can be used to minimize the spread of contamination, minimize exposure to the public and responders, and support the development of decontamination techniques and disposal decisions.

We are investigating outdoor dispersion, deposition, adhesion, and reaerosolization of particles as well as their subsequent infiltration into buildings. We are also investigating the indoor resuspension and tracking of indoor particles, a particularly important way that contamination was spread throughout the Hart Senate Office Building. We are evaluating bioaerosol samplers to determine how effective these samplers are at detecting the presence and spread of biological contaminants. We are investigating the infiltration of particles into residential and commercial buildings, both in the field and in the laboratory. We are also trying to determine the forces and environmental conditions that cause particles to adhere and release from surfaces.

This research will inform remediation measures, as well as sampling techniques, and can be used to help mitigate spread and exposure in future incidents.

Question and Answer Period

- *Was contaminant spread via vehicle tires considered?*
  Rosati noted that this study did not evaluate contaminant spread from vehicles. She hoped, however, to include vehicles in future work.

- *If different decontamination efficacies were examined, how would the result from this study be integrated into definitions of efficacy?*

Rather than discuss decontamination efficacy, Rosati noted the importance of appropriate sampling in decontamination. Collection of characterization samples from the wrong location could result in incomplete remediation of the contaminated site. Rosati hoped that this study would provide data to better define the extent of contamination. In responding to the World Trade Center, EPA received questions about the methods used to determine contamination spread. For example, how did EPA know that contamination did not reach Brooklyn? Rosati aimed to provide data that supported EPA's responses to these types of questions. If EPA were able to define the extent of contamination better, then less decontamination might be required.

6.4 The Brooklyn Traffic Real-Time Ambient Pollutant Penetration and Environmental Dispersion (B-TRAPPED) Study

Russell Wiener, EPA, NHSRC

The B-TRAPPED study sought to develop a better understanding of the transport of airborne particulate pollutants in a heavily populated urban neighborhood, from the sources on the streets, down the street canyon, and into and within the adjacent buildings. Concerns about homeland security have resulted in a need for better understanding of urban dispersion near an accidental or intentional release of hazardous materials on a nearly instantaneous timescale. This study was designed to help develop a simplified model of urban aerosol transport relevant to human exposure in the near field of a release.

Components of the B-TRAPPED study included laboratory evaluations of the sampling technologies, wind tunnel studies of the atmospheric boundary layer flows in a simulated neighborhood, a modest micro-scale urban field study, and comprehensive theoretical modeling of the major mechanisms of particulate matter (PM) source release, transport, dispersion, surface flux, and infiltration processes. The B-TRAPPED field study was conducted in the residential Sunset Park neighborhood of Brooklyn, New York, in May 2005. The study site was chosen to represent a typical urban population center where high-density housing is in close proximity to major traffic arteries. The study applied spatially and temporally synchronized and concurrent observations of PM concentration and meteorological variables in multiple monitoring locations within a busy metropolitan urban residential area.

This study sought to measure dispersion in the street canyon, infiltration into the adjacent buildings, and concentrations within the structures simultaneously. Urban dispersion, contaminant infiltration, and indoor exposures are closely related phenomena. The results intend to accomplish the following:

- Delineate and visualize how a plume that is generated by customary (e.g., traffic), accidental (e.g., spill), or intentional (e.g., terrorist attack) means near or on the major roadway travels downwind and presents potential inhalation hazards at various locations and in both outdoor and indoor environments.

- Determine how time-series data of aerosol concentrations measured at a fixed site can be used to discern and describe the characteristic ‘‘wave’’ forms of plumes generated at a source (major roadway) traveling to downwind receptor locations in an urban environment when temporal autocorrelation analysis is applied.

- Determine the infiltration flux rate that can predict the degree of indoor exposure risk for certain harmful materials of outdoor origin using cross-correlation analyses of concurrent indoor–outdoor concentration time series.

- Characterize temporal and spatial PM concentration fluctuation and distribution patterns in the urban street canyon and their relationship to reference wind patterns and investigate their potential implications in exposure risk assessment.

- Determine the influence of meteorological variables on the transport, dispersion, and infiltration processes.
- Characterize the relationships between the building parameters and the infiltration mechanisms and identify the dominant mechanisms involved in the infiltration process.
- Evaluate the effectiveness of a shelter-in-place area for protection against outdoor-released PM pollutants.
- Use wind tunnel and computational fluid dynamics simulations to determine the predominant airflow and pollutant dispersion patterns within the neighborhood.

Question and Answer Period

Conference participants posed no questions.

7 Activities to Support Wide-Area Biodecontamination

7.1 Assessment of Liquid and Physical Decontamination Methods for Surfaces Contaminated with *Bacillus* Spores

Shawn P. Ryan, EPA, NHSRC

This intra-agency collaborative project was conducted to evaluate the effectiveness of a decontamination strategy, both individual and combined steps, used to successfully remediate a wooden shed contaminated with *Bacillus anthracis* spores. The contamination was the result of a drum maker working with untreated, contaminated animal skins. The overall objective was to develop practical, easy-to-perform decontamination procedures that might be useful during a wide-area response and recovery event due to contamination with *B. anthracis* spores.

The study was designed to assess the effectiveness of several liquid and physical methods for decontaminating porous and nonporous materials that had been contaminated with a specific amount (approx. 7-log) of *B. atrophaeus* spores (a surrogate for *B. anthracis*) via dry aerosol deposition. The decontamination treatment steps were applied individually and in combination. The full procedure tested involved the following sequence of steps: (1) vacuuming surfaces with a wet/dry vacuum containing a HEPA-rated filter; (2) wetting the surface with a liquid decontaminant and reapplying as necessary to maintain wetness for a period of 10 minutes; (3) scrubbing the surface using a brush (or sponge for painted wallboard) wetted with a detergent solution; (4) rinsing the surface with water using a garden hose (or sponge for painted wallboard); (5) vacuuming residual standing water from horizontal surfaces with the wet/dry vacuum containing a HEPA-rated filter; (6) completely covering the surface with the same liquid decontaminant used in Step 2 for the desired contact time (e.g., 30 to 60 minutes); (7) rinsing the entire surface with water using a garden hose (or sponge for painted wallboard); and (8) vacuuming residual standing water from horizontal surfaces with the wet/dry vacuum containing a HEPA-rated filter. Chemical decontaminants tested included a pH-adjusted bleach solution (about 6,000 ppm available chlorine and pH of 6.5–7.0) and Clorox® Clean-Up® disinfectant cleaner with bleach. The procedures were tested on coupons (14-inch by 14-inch pieces of bulk material) positioned either horizontally (h), representing a floor or ceiling, or vertically (v), representing a wall. The materials included latex-painted wallboard (h, v), carpet (h), rough-cut wood (v), sealed deck wood (h), and concrete (h, v). Sampling was done using wet wipes or vacuum socks in accordance with field sampling protocols.

The full decontamination procedure (Steps 1–8) or a truncated procedure (Steps 1–5), which included the use of pH-adjusted bleach, resulted in a greater than 6-log reduction in detectable viable spores (with the exception of concrete in the vertical position). The vacuuming step alone (Step 1) resulted in a slight measurable reduction in spores from the materials' surfaces. Rinsing with water (Step 4) or scrubbing with a detergent solution followed by rinsing (Step 3 and 4, and 5 for horizontal surfaces) resulted in a 1- to 4-log reduction in spores from the surfaces, and all of the removed spores were found viable in the rinsate. The use of Clorox® Clean-Up® in place of pH-adjusted bleach when using the eight-step decontamination procedure resulted in a greater than 6-log reduction in the spore population, with a high percentage of viable spores found in the rinsate (i.e., minimal sporicidal activity of the chemical decontaminant at the conditions tested, especially on vertical surfaces).

The study demonstrated that the greatest spore reductions from the coupon surfaces were achieved by using the eight-step procedure with a 30-minute contact time for the pH-adjusted bleach application (Step 6), or the first five decontamination steps (or four for horizontal surfaces). In all tests, viable spores were found in the rinsate. Within these tests, the 10-minute

application of pH-adjusted bleach (Step 2) appeared to be the single most effective step. Although the effectiveness of the pH-adjusted bleach spraying was not determined individually in this study, Step 2 apparently produced at least a 3- to 4-log reduction of spores on all materials under the application conditions used. The addition of other physical removal methods (i.e., HEPA vacuuming, washing with a detergent solution and rinsing) resulted in slight to modest levels of decontamination, but also transferred contamination across media. However, even though the vacuuming step (Step 1) was determined to reduce spore load by less than 1-log (considerably less in some cases), the materials tested here were pre-cleaned before use in the study (i.e., they did not contain soil and grime). Accordingly, in field applications, vacuuming may provide the benefit of reducing background soil and grime, which would probably reduce the sporicidal activity of the chemical decontaminants.

This study determined the effectiveness of practical, easy-to-perform decontamination procedures for surfaces contaminated with *B. anthracis* spores. These results are intended to inform the development of decontamination strategies for wide area response and recovery if the need arises. Additional laboratory work employing these results at larger-scale is currently ongoing to develop field-relevant, readily accessible decontamination options for indoor and outdoor areas. The results have recently been used in the development of a recommended decontamination strategy by EPA Region 1 for the remediation of a facility on the University of New Hampshire campus contaminated with natural *B. anthracis* spores resulting from the use of drums made with untreated animal hides.

Question and Answer Period

- *A participant asked Ryan to comment on mixing bleach and detergent.*
  Ryan noted that the procedure moving forward includes mixing bleach and detergent, specifically TSP. Preliminary studies indicated that the bleach-TSP mixture was at least as sporicidal as pH-adjusted bleach alone.

- *Vacuuming resulted in less than a log reduction in spores. Could you explain the vacuuming procedure?*
  A vacuum with a 10-inch squeegee attachment was pulled down each coupon three times. An up-and-down or back-and-forth motion was not used.

- *What was the range of spore concentrations on the coupons after the first exposure?*
  Ryan targeted concentrations within a log of 10^7, so the typical range was 5×10^6 to 5×10^7 with a few outliers at higher concentrations.

- *How was the laboratory decontaminated after each release and treatment?*
  Coupons were inoculated and treated in a stainless steel spray chamber, which was decontaminated with pH-adjusted bleach between tests. Initially, chlorine gas off-gassing was an issue. Researchers wore respirators to prevent exposure. Ryan noted that everything required decontamination, including water tanks.

- *In the 2001 responses, bleach decontamination on personnel resulted in some burns. As a result, EPA relied on mechanical decontamination with soap and water. Did an opportunity exist to apply findings from this study to field operations, particularly decontaminating personnel leaving a hot zone?*
  This study found that soap and water alone resulted in limited spore load reductions. However, Ryan noted that the spore loading in this study was high. During field operations, the suit material would impact efficacy, with some materials more easily decontaminated than others. Overall, soap and water rinsing, without scrubbing, was insufficient for full spore removal. A follow-on study is evaluating amended bleach and length of time for full removal and inactivation of spores. A participant noted that mechanical removal simply moves spores from one location to another, so spore tracking is a concern when setting up mechanical decontamination.

7.2 Evaluation of COT Products for Decontamination of *Bacillus* Spores

Jason Edmonds, U.S. Army

A significant gap in technology preparedness exists with regard to federal response to a wide-area release of biological agents such as *B. anthracis* spores. In 2001, release of just a few letters containing anthrax spores resulted in the contamination of several building interiors, including U.S. Postal and Distribution Centers in Brentwood, District of Columbia; Trenton, New Jersey; and American Media Inc. in Boca Raton, Florida. Despite heavy contamination levels of several building interiors, remediation was achieved successfully by fumigation with chlorine dioxide or vaporous hydrogen peroxide (VHP). A wide-area release and contamination of outdoors and building exteriors is likely to consume the entire U.S. remediation capacity, requiring years to clean up and resulting in incalculable economic losses due to a lack of effective cleanup response. Additional rapid, effective, and economical decontamination methodologies with the capability to be employed in wide areas (indoor and/or outdoor) are required to meet future challenges and national preparedness goals. In addition to well-documented fumigation-based cleanup efforts, agencies responsible for mitigating contaminated sites have employed alternative methods for decontamination, including combinations of disposing of contaminated items, vacuuming, and employing a shared set of mechanical and chemical approaches (scrub/wash and pH-adjusted bleach). If proven effective, a pressure-wash-based removal of anthrax spores in the runoff from building surfaces using readily available equipment will significantly increase the nation's readiness to meet the restoration and cleanup challenges resulting from a wide-area biological release.

We have begun investigating the efficiency and efficacy of three commercial off-the-shelf (COT) decontamination products to decontaminate large 4 foot by 4 foot panels composed of exterior materials common to building structures: pressure treated lumber, brick, and stainless steel. The large panels are seeded with biological agent and then undergo a decontamination process, maintaining a contact time of 30 minutes with the COT product. The brick, and pressure-treated lumber panels are then processed by vacuum (or wiped with a Dacron wipe in the case of stainless steel). Colony-forming units (CFU) are then counted and statistical analysis is performed to determine the amount of agent killed and/or removed from the panels by using the spray system.

Our preliminary data suggest that the degree of efficacy is dependent on the building material as well as the biological agent being removed, and we are witnessing a six-log reduction in CFU collected after the decontamination process.

Question and Answer Period

- *Was an amended bleach solution used?*
  Edmonds responded that a pH-adjusted amended bleach solution was used.

- *Did the reported log reductions account for spores in the rinsate? How was the runoff neutralized?*
  The reported log reductions included the inactivated spores and the spores in the rinsate. Edmonds noted that researchers were unable to grow culturable colonies from the spores in the runoff. The required decontaminant amounts changed daily based on factors such as temperature and RH, and, in turn, the required amount of neutralization buffer changed daily. A decision was made to forgo a neutralization buffer and instead collect samples as quickly as possible after the initial runoff.

- *How did the differences in the* B. globigii *and* B. subtilis *spore impact decontamination?*
  Edmonds referred this question to Rastogi. Rastogi responded that the material preparation technique resulted in a large number of nonviable *B. globigii* spores—only 10 percent of *B. globigii* spores were viable. Rastogi noted that extraneous materials were present in the preparation. He did not know how these extraneous

materials impacted decontamination. The material preparation technique for *B. subtilis*, however, resulted in only a small number of nonviable *B. subtilis* spores—approximately 99 percent of *B. subtilis* spores were viable. Rastogi noted that regardless of the surface material, studies found greater *B. globigii* spore recovery compared to *B. subtilis*.

- *A participant asked if Edmonds or others had tried excising or abrading the surface to improve recovery.*
  Edmonds had considered methods for improving recovery by dislodging spores, similar to a carpet cleaner. To his knowledge, however, these technologies were not available.

7.3 Evaluation of Peroxide-Based Solutions for Facility Decontamination by Owner/Occupants

Paula Krauter, Sandia National Laboratories

In support of the IBRD program, we are evaluating methods that may be useful for decontamination of residences, small businesses, and other small facilities that are not heavily contaminated and are a low-level priority for cleanup. The remediation of a large number of contaminated facilities will likely be a limiting step in the recovery of an urban area following a wide-area release of a biological warfare agent due to the limited number of resources. A potential option for remediation of residences and small businesses is to provide training, resources, and instructions for using a simple liquid decontamination material. EPA has developed and evaluated the use of pH-amended bleach for self-decontamination; we are evaluating another common household cleaning agent—peroxide.

Several peroxide materials were evaluated for efficacy against *Bacillus atrophaeus*, including 3, 4, 6, and 7.9 percent hydrogen peroxide; solutions of 3, 4, 6, and 7.9 percent hydrogen peroxide with buffer and activator, and STERIS SporKlenz™. Neutralizers for the peroxide materials were identified and basic efficacy tests were conducted to select the two best peroxide materials to test in the aerosol chamber. SporKlenz™ and a simple activated-peroxide formula (4 percent H_2O_2 with an activator) were chosen for further evaluation. Decontamination products will probably need to be supplied in bulk quantities from the manufacturer during an incident and, potentially, a simple formulation could be requested and provided to neighborhoods. An aerosol chamber was equipped with ceramic tile, vinyl tile, stainless steel, plastic, and a table and chair. *B. atrophaeus* spores were dispersed throughout the test chamber by a fluidized-bed generator. All surfaces in the test chamber were sprayed with the decontamination solutions using a garden sprayer. Following a 30-minute contact time, samples were taken from the various surface materials and evaluated for viable spore concentration. Air samples were taken from the test chamber to determine the concentration of aerosolized spores during cleanup and whether any airborne spores remained following the decontamination procedure.

Our intent was to evaluate the application of the decontamination material in a room-size aerosol chamber while monitoring the concentration of airborne spores during the decontamination procedure. Activated peroxide solutions and H_2O_2/peracetic acid solutions are effective sporicides on nonporous surfaces and are reasonable materials for owner/occupant decontamination. However, important issues surrounding the safety of those conducting the decontamination process and the thoroughness of the process remain. Spore-particle movement in air currents and/or thermals confounded the settling velocity predictions. Without suitable secondary containment, airborne spore particles will potentially increase the contaminated zone. Workers should be aware of the potential for tracking spores out of the contamination zone. An important consideration for owner/occupant decontamination is to provide decontamination workers with knowledge and materials to protect themselves while limiting the spread of contaminants.

Question and Answer Period

- *What is the shelf life of peroxide once activated?*
  The solution we used was only evaluated for a single, same-day use. Stabilizers may prolong its activity.

- *Were samples collected outside the sample chamber?*
  No samples were collected outside the chamber, but Krauter would like to collect these samples in the future. Krauter noted that the chamber had a standard entry zone.

- *How was the chamber decontaminated between experiments?*
  The chamber was lined with spray nozzles. After an experiment, the nozzles sprayed the chamber with DF-200. The DF-200 spray was followed by a rinse and full dry.

- *Was fogging considered to minimize exposure?*
  Krauter agreed that fogging was a good idea. She noted that the area size and mixing mechanism are important for fogging. For this study, Krauter wanted to evaluate a simple technology, so decontamination was conducted with a garden sprayer.

- *In neighborhoods, how important is outdoor decontamination?*
  Outdoor decontamination remains a substantial concern. Fate and transport, Krauter felt, will inform outdoor decontamination decisions. However, data gaps in understanding fate and transport remain, such as how tightly spores stay on the ground or the air flow required to move spores. Indeed, Krauter felt that many questions regarding outdoor decontamination remain. A participant noted that most people spend 80 to 90 percent of their time in controlled indoor environments. In general, office environments are more controlled than home environments. Considering outdoor exposure is important, but outdoor contaminant concentrations decrease rapidly due to factors such as dilution. Although indoor concentrations are likely lower initially, the exposure times would be much longer.

- *Were other peroxide formulations considered? A participant noted the different characteristics of various peroxide formulations.*
  Krauter stated that she was interested in gathering more information about the different formulations, which implied that she had not considered these formulations in selecting a decontamination agent.

7.4 Inactivation of *Bacillus Anthracis* Spores on Indoor and Outdoor Building Surfaces using Commercially-Available Liquid Sterilant Technologies

Worth Calfee, EPA, NHSRC

Two research efforts were conducted to evaluate the efficacy of commercially available liquid or foam-based sporicidal technologies to decontaminate building materials dosed with spores of *Bacillus anthracis* and/or *Bacillus subtilis*. The technologies tested include DioxiGuard™, Calcium polysulfide, Oxonia Active®, Minncare® Cold Sterilant, SanDes, pH-adjusted bleach, CASCAD™ Surface Decontamination Foam, Decon Green®, EasyDECON 200, SporKlenz RTU®, and Peridox®. The building materials tested include industrial-grade carpet, decorative laminate, galvanized metal ductwork, painted wallboard paper, painted cinder block, bare wood, stainless steel, glass, aluminum, porcelain, granite, concrete, brick, asphalt, treated wood, topsoil, and butyl rubber. Technologies were tested against a ≥7 log challenge of *Bacillus* spores. Methods of spray, application rates, and contact times were determined according to vendor-specific recommendations.

Application methods, contact times, neutralization data, and efficacy data for these technologies will be presented. Briefly, efficacy values ranged from <1 log reduction to ≥7 log reduction (total kill) on these materials. Nonporous materials were generally more easily decontaminated than porous materials. For the

majority of technologies, spore inactivation was most challenging on treated wood, bare pine wood, and topsoil. Liquid sterilants with hydrogen peroxide, hydrogen peroxide plus peracetic acid, or hypochlorous acid/hypochlorite as active ingredients were most efficacious. Technologies with chlorine dioxide or calcium polysulfide as the active ingredient were least effective at inactivating *Bacillus* spores.

Data presented here were generated to give decontamination professionals valuable input for decisions regarding remediation of outdoor areas contaminated with infectious biological agents such as *Bacillus anthracis* spores.

Question and Answer Period

- *Were spores characterized for physical traits (e.g., adhesion properties)? This participant also noted that 30 percent spore recovery from brick was unusual.*
  Calfee noted that Battelle prepared the spores following standard operating procedures. Standard operating procedures were also followed for the test methods used for this study (which were peer-reviewed and accepted methods). Calfee noted that sonication was used to improve spore recovery.

- *Did a correlation exist between material compatibility with the decontaminants and efficacy?*
  All of the decontaminants were compatible based on a qualitative evaluation of material effects. The technologies had no effect on the materials themselves. Calfee noted that the material surfaces (e.g., asphalt, concrete) affected decontamination.

- *What were the technology application methods?*
  The application methods varied based on the technology, though they followed manufacturer recommendations.

- *Why were different decontamination methods used for the indoor and outdoor tests? This participant thought that comparing a single technology in an indoor and outdoor setting would have been useful*.
  Calfee referred this question to Wood. Wood responded that indoor and outdoor tests were different projects funded by different sources. EPA internally funded the indoor materials test and the decontamination technologies were selected with stakeholders' input. Wood noted that the indoor tests began approximately 1 year before the outdoor test.

7.5 Inactivation of Bioagents through Natural Attenuation, Liquid Decontamination, or Fumigation

Harry Stone, Battelle

EPA's NHSRC investigated persistence of *Brucella suis, Francisella tularensis,* vaccinia virus (a surrogate for the smallpox virus), and *Yersinia pestis* on various materials, and the decontamination efficacy including the same bioagents with the addition of *Bacillus anthracis* Ames spores. For efficacy testing, four fumigation technologies (chlorine dioxide, two brands of hydrogen peroxide, and methyl bromide) and four liquid technologies (pH-adjusted bleach, chlorine dioxide solution, and two brands of hydrogen peroxide–phosphoric acid solutions) were evaluated with regard to their ability to decontaminate various materials that were spiked with bioagent. The persistence of viable bioagents and the decontamination efficacy of various technologies were evaluated by comparing the bioagent recovered from building materials after treatment (passage of time or decontamination) to bioagent recovered from building materials at time zero or a positive control condition.

The methods used include the following steps:

- The bioagent is prepared.

- Material coupons (generally 1.9 by 7.5 centimeters) are inoculated with approximately 1.0×10^7 culturable bioagent per coupon, generally applied as 10×10 microliter droplets.

- The coupons are allowed to sit for various specified times under specified environmental conditions.

- Decontamination test coupons are exposed to the fumigant or liquid decontamination for specified contact times at specified environmental conditions.

- Decontamination is halted by aeration of the chamber (fumigants) or chemical neutralization (for liquids).

- Coupons are extracted, the extracts serially diluted, the dilutions cultured, and the colony- or plaque-forming units are enumerated.

- Efficacy is evaluated by comparing the enumerated bioagent recovered from positive control coupons (or time zero for persistence) to the enumerated bioagent recovered from test coupons.

The persistence of the bioagents on various building materials varied by organism and material type. All bioagents persisted at least seven days (168 hours) on at least one building material. While only low levels (10^1 CFU) of *F. tularensis* and *Y. pestis* were recovered from any material after seven days, 10^6 CFU of *B. suis* and 10^5 plaque-forming units of vaccinia virus were recovered at seven days from computer keyboard keys.

All of the fumigant and liquid technologies tested were efficacious against all of the bioagents tested. For many, but not all, decontamination technology–material–bioagent combinations, no viable bioagent was recovered after decontamination at the tested conditions.

Scientifically defensible persistence and decontamination efficacy data for a range of bioagents are useful to inform planning for response and decontamination after natural occurrences or intentional releases of bioagents. The results also show that both persistence and decontamination of bioagents are influenced by environmental conditions and the materials with which the agents are in contact.

Question and Answer Period

- *A participant asked for clarification regarding the units for the reported fumigant concentrations*.
  Stone noted that the values represented concentration times time (CT). A value of 9,000 parts per million by volume (ppmv) represented a three-hour contact time at 3,000 ppmv. Stone agreed that typically CT values were reported as ppmv-hr.

- *What was basis for selecting particular ppmv values for each technology?*
  For the most part, EPA worked with the manufacturers to identify target ppmv values. For methylene bromide, the target ppmv value was based on previous EPA testing.

- *A participant noted that RH was important for decontamination, but the data for the STERIS hydrogen peroxide system did not include RH information.*
  Stone responded that the STERIS system included a built-in humidity control system that dehumidified the room and kept the RH below the microcondensation level.

7.6 High/Low Tech Approaches to HVAC Decontamination

Brian Attwood, EPA, NHSRC

The aim of this work is to evaluate the decontamination efficacy as well as the economic costs associated with several methods of cleaning the HVAC system of a building contaminated with *Bacillus anthracis* (commonly known as anthrax) spores. The high-tech method employed will be fumigation with hydrogen peroxide vapor (and possibly chlorine dioxide gas). The low-tech method will involve mechanical cleaning and liquid sporicide application based on techniques currently used in the commercial duct cleaning sector.

A section of galvanized metal ductwork will be assembled in EPA's Research Triangle Park facility for decontaminant testing. The configuration of the ductwork will be chosen to

represent a typical commercial building HVAC. Selected sections of the ductwork will be contaminated with aerosol-deposited bacterial spores.

The ductwork will then be subjected to the different decontamination methods, after which the contaminated sections of ductwork will be sampled to determine how many viable spores remain. Sections not initially contaminated will also be tested for cross-contamination. In addition to looking at the decontamination efficacy of each method, other factors such as the cost of application and the logistical feasibility of a large-scale application of the method will be evaluated. Provided that efficacy is proven in the spot contamination tests, the project will culminate in an actual aerosol release within the ductwork to provide a more realistic decontamination challenge.

In the event of a wide area release of a biological agent, the choice of decontamination method will depend on the clearance, costs, and time goals for that scenario. The results of this work will provide information on how the above-mentioned high- and low-tech methods can be employed to meet those goals.

Question and Answer Period

- *Historically, mold remediation efforts used different methods for decontamination, such as chlorine dioxide and ozone. Were the lessons learned from this industry considered?*
  Attwood noted that chlorine dioxide and ozone fumigation are sophisticated technologies, and initially testing focused on low-tech options. Mold remediation historically included mechanical cleaning followed by treatment with biocides, which were biostatic. Attwood thought that mechanical cleaning could apply to spore removal. The biocides, however, have not been proven effective for anthrax spores. For the immediate future, testing will focus on proven sterilants. Wood noted that initial screening of spore treatment with ozone has been completed. A report summarizing findings is available and additional testing with ozone is planned.

- *Are there plans to evaluate a dirty duct?*
  For the moment, testing involves clean ducts. Attwood agreed that testing a dirty duct would provide comparison information and should be considered.

8 Persistence of Biological Agents and Other Bio-related Decontamination and Disposal Research

8.1 Persistence of Selected Biological Agents

Joseph Wood, EPA, NHSRC

The data on how long certain biological threat agents may persist under various environmental conditions are sparse. Persistence is affected by RH, temperature, sunlight, and the material with which the agent is associated. In the event of a release of a biological agent, having an understanding of how long the agent may survive in the environment can assist officials in making decisions about decontamination.

Although *Bacillus anthracis* is known to survive in the environment for decades, laboratory tests were conducted to determine how simulated sunlight (UVA/UVB) affects its persistence on different materials. Tests were also conducted to determine the persistence of *Brucella suis* (a Category B Centers for Disease Control agent) and freeze-dried vaccinia virus (a surrogate for the variola virus, which causes smallpox) under various environmental conditions and materials.

In general, the agents were inoculated (~10^7 to 10^8 organisms per coupon) onto 1.9 x 7.5 cm coupons, or in the case of soil, 1 cm high by 3.5 cm diameter Petri dishes. The contaminated materials were then exposed to the environmental condition being examined (a combination of low or high RH, ambient or low temperature, with or without simulated sunlight) for a particular time period. The agent was then extracted from the test coupons and quantified via plating techniques. To benchmark the results, the agents were also recovered from positive control coupons at time zero, or in the case of the *B. anthracis* tests, after the same time period as the test coupons, but without UVA/UVB exposure.

Tests with simulated sunlight were conducted with *B. anthracis* and *B. suis* at levels of ~70 microwatts UVB/cm^2, ~100 microwatts UVA/cm^2, and no UVC. These tests were conducted with UV lamps alternating 12 hours on and off to simulate diurnal conditions.

In the tests with *B. anthracis* using simulated sunlight at ambient conditions, viable agent was recovered on topsoil, concrete, and wood at the longest elapsed time point tested (56 days). Less than a one log reduction was observed for topsoil at 56 days. Although the agent was least persistent on glass, there were still a few coupons from which anthrax was recovered after 28 and 56 days' exposure to simulated sunlight.

For the *B. suis* tests, the agent persisted beyond 28 days at both room and low temperature conditions (with no simulated sunlight) on aluminum, glass, and soil but was less persistent on bare concrete. With simulated sunlight, the persistence of *B. suis* diminished on all materials, but the effect was less pronounced on soil.

In the vaccinia tests, the agent was most persistent at the low temperature and low RH conditions. At the low temperature/low RH condition, the virus persisted beyond 56 days on all four materials tested (glass, galvanized metal, painted cinder block, and carpet).

These tests confirm that these agents can persist for extended periods of time depending on the environmental conditions and materials, and that decontamination may be necessary.

Question and Answer Period

- *What type of bulb was used to simulate light? This participant noted that metal halide bulbs simulate ultraviolet light best, but they become very hot.*
  The study used ReptiSun® bulbs (used in reptile terrariums) as the UV-A and UV-B source. Three bulbs were placed about 1 foot

above the test coupons. UVC was also measured.

- *Could the instability of the virus at a high RH be related to the use of a freeze-dried preparation?*
  Wood noted that this study did not evaluate the mechanisms contributing to instability, but the results were consistent with work completed by Shawn Ryan, which indicated that RH was a more important factor than temperature.

8.2 Disinfection of Mobile Equipment after an Emergency Poultry Disease Outbreak

Eric R. Benson, Department of Bioresources Engineering and Department of Animal and Food Science, University of Delaware

The main stages involved in managing an emergency poultry disease outbreak for avian influenza, exotic Newcastle disease, and other highly contagious poultry diseases include surveillance, quarantine, depopulation, disposal, and disinfection. Agricultural tractors, skid steer loaders, and other equipment are extensively used during the depopulation and disposal portions of the response. Movement of contaminated equipment has been implicated in the spread of disease in previous outbreaks. One approach to equipment disinfection is to power-wash the equipment, treat it with a liquid disinfectant, change any removable filters, and let it sit idle for several days. Experimental results show that liquid-applied disinfectants may not be suitable for this application.

In this project, multiple disinfectant strategies were individually evaluated for their effectiveness at inactivating Newcastle disease virus on mechanical equipment seeded with the virus. A small gasoline engine was used to simulate typical mechanical equipment. A high titer of LaSota strain Newcastle disease virus was applied and dried onto a series of metal coupons. The coupons were then placed on both interior and exterior portions of the engine.

Liquid disinfectants were not effective at disinfecting the engine and positive virus samples were recovered. Placing the equipment in a tent and applying the disinfecting agent via indirect thermal fog showed a decrease in overall virus titer. A combination of direct and indirect thermal fog was more effective than liquid-applied or indirectly-applied thermal fog. Cold fogging and electrostatic fogging were also tested and shown to have some reductions in virus titer, but neither method was entirely satisfactory. Only one combination of test agent and application method (direct fog Virocid®) was able to reliably disinfect interior and exterior surfaces of equipment.

Test data show that current methods recommended for agricultural disease response are not sufficient. One combination of test agent and application method has significant health concerns and would not be recommended for field use. Additional research is required to provide effective recommendations for the field.

Question and Answer Period

- *As a point of reference, if decontamination of the virus was attempted with high temperatures and humidity alone, what temperature and contact time would be needed for successful decontamination?*
  At 56 degrees Celsius (°C), only a few seconds were needed for inactivation of avian influenza and similar viruses. As the temperature decreased, additional time would be required. Benson noted that the study was conducted in ambient temperatures ranging from 70 degrees Fahrenheit (°F) to 90 °F.

- *If heat alone was successful at decontaminating the virus, why was surface scrubbing necessary? Was harnessing the heat from a vehicle's engine or placing heaters in buildings a viable option? This participant wondered about the need to introduce chemical decontamination if heat was sufficient.*
  Benson noted that a typical engine compartment is greasy with high organic loads, which complicates decontamination.

In other areas of a vehicle, temperatures are closer to ambient levels. Accordingly, decontamination beyond heating was necessary. Using chemicals reduced the time needed to complete decontamination. Initially, researchers considered simply letting the temperature rise in a building, but allowing a building to heat takes time. Depopulation equipment needed to be cleaned and moved as fast as possible to the next location.

- *What concentration was achieved in the tents?*
  Chlorine dioxide concentrations were approximately 200 ppm. Benson did not have the ppm concentrations for the other fumigants.

- *In developing protocols for farm equipment decontamination, a participant noted, the Canadian Food Inspection Agency had issues dealing with the dirt load, manure, and equipment size (e.g., front loaders, skid steers, dump trucks). This participant noted that a recent response included three days to simply clean a skid steer to remove the grime, grit, and dirt embedded in the treads before decontamination could occur.*

- *Another participant noted that a person from the U.S. Army research laboratory had recently visited the EPA laboratory. This person described prototype testing conducted using a large chamber designed to decontaminate tanks. This participant felt that the technology might be useful for agricultural or wide-area decontamination.*
  Benson noted that states often oversee low pathogen responses, so funding and resource availability is often a concern. In a high-pathogen response, federal agencies are more likely to be involved and military resources are more accessible. A participant mentioned an advanced technology demonstration that examined vehicle decontamination methods beyond labor-intensive scrubbing methods. This participant believed that the U.S. Army is testing a technology that resembled a large mobile car wash. The mobility of this technology, however, is limited.

- *A participant commented that the porous surfaces found in agricultural settings are a substantial problem. Was porous surface testing conducted?*
  Some porous surface testing was completed approximately two years ago. Benson agreed that porous surface decontamination is difficult. Only a citric acid decontaminant reliably meets the test objectives for both porous and nonporous materials. Benson noted that the impact of poor recovery on the results was unclear. Observed decreases in pathogen concentrations may have been the result of decontamination or poor recovery.

8.3 Testing Sporicidal Efficacy of Six Disinfectants on Carrier Surfaces Contaminated With *B. Atrophaeus* Spores

Bruce Hinds, Defense Threat Reduction Agency

This presentation will discuss a decontamination technology study supporting the IBRD program.

The DISCRETE Zeus study employed a three-step method (TSM) to test the sporicidal efficacy of six disinfectants on two different carrier surfaces contaminated with *Bacillus atrophaeus*. The carrier surfaces used were stainless steel and ceramic. The disinfectant/test articles used were Peridox®, CASCAD®, SporKlenz RTU®, EasyDECON®, Decon Green®, and MDF-200®. Microbiology-grade water was used as a negative control and pH-amended bleach (pH 7 ± 0.1) was used as the positive control. Qualification of the spore suspension was achieved by conducting acid resistance and microscopic analysis tests. The carriers were inoculated with the test spores (1.10 x 107 CFU to 2.80 x 107 CFU) using a spore suspension. The carriers were then dried overnight (at least 12 hours at room temperature). The exposure time for the TSM was 30 minutes, and the carriers went through three different steps to recover any spores. The results of the testing

indicated that when using the stainless steel carrier, the log kill of all test articles and positive control was within 7 ± 0.5, and these values were not significantly different from each other (ANOVA, a = 0.05). For the ceramic carrier, the values of log kill were statistically significant as a group. Further pair-wise comparison using Tukey's Honestly Significant Difference Test and Fisher Least Significant Difference Test was done to identify pairs that were statistically significant or otherwise.

Study data will aid the IBRD program in making informed decisions regarding wide area decontamination technologies

Question and Answer Period

Conference participants posed no questions.

8.4 Development of a Novel Bioassay for Detection of Functional Ricin

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

Ricin toxin, found in the bean of the castor plant, is one of the most toxic and easily produced plant toxins. Ricin is a lectin consisting of two polypeptide chains, the A chain and the B chain, linked by a disulfide bond. The active A chain can catalytically remove adenine on the 28S RNA subunit of eukaryotic ribosomes, resulting in cessation of protein synthesis and cell death. Current methods for detection of ricin include immunological, *in vitro* translation inhibition, and general cellular toxicity assays. The present study was initiated with the objective of developing a novel bioassay for detection of functional ricin. Recently, a cell-based assay expressing green fluorescent protein under the control of cytomegalovirus promoter was reportedly used for detecting low levels of ricin (Halter et al. 2009, *Assay and Drug Dev. Tech.* 7: 356–365). However, this assay has not been developed as a high-throughput method.

An engineered mammalian HeLa cell line (with an inducible gene expression system) was stably transfected with a luciferase gene, resulting in inducible expression of the gene. The expression of luciferase in the engineered cell line was repressed in the presence of the antibiotic doxycycline, and in its absence was induced by >1,000-fold. A typical assay in a 96-well plate contained 10E4 cells in a volume of 100 microliters and an aliquot (25 microliters) of ricin, which was added at the start of luciferase induction. Luciferase was assayed after a 24-hour incubation at 37 °C, and its expression was inhibited by the presence of very low levels of ricin (20 to 50 picograms per 125 microliters). Utility of the cell-based assay was investigated following decontamination of steel coupons contaminated with crude ricin (<1 percent active ricin by weight). No active ricin was detected after a 30-second exposure with a 1:20-diluted bleach or 250 ppm chlorine dioxide. However, about 80 percent ricin was detected following treatment with 1 percent hydrogen peroxide under the same conditions.

A novel cell-based assay for detection of functional ricin has been developed. This assay can be used to determine the efficacy of disinfectants used for ricin contamination.

Cellular toxicity is elicited only in presence of functional holo-ricin. Current immunological and other chain-based methods do not provide conclusive evidence for the presence of functional ricin. Availability of the novel bioassay developed in this study will permit detection and the development of a high-throughput method for detecting very low amounts of functional ricin (<0.4 nanograms per milliliter), and this assay could be used as a confirmatory test in ricin decontamination studies.

Question and Answer Period

- *Was the assay specific to ricin? The presentation indicated that the assay could be applied to other dual component toxins.* The assay was specific to binary toxins that had a binding component event followed by inhibition that caused changes in protein synthesis, either by breaking the elongation factor or disrupting the ribosome.

- *Were other biotoxins tested?* This study evaluated only ricin.

- *What were the effects of the decontamination agent on the assay? Field applications would not include a neutralization step.*
  Rastogi indicated that neutralization served as a control for the contact time. Rastogi also found that without a 1:50 dilution, the cells were affected. He also noted that the decontamination agent itself was toxic to the cells. Some degree of dilution was therefore necessary before conducting the assay. Even with a 1:50 dilution, Rastogi noted that the assay sensitivity was approximately 0.2 nanograms per milliliter.

- *Was dilution conducted after neutralization?*
  Rastogi confirmed that dilution occurred after neutralization.

- *Was heat inactivation of ricin studied?*
  Rastogi had not conducted research regarding heat inactivation of ricin. He agreed that heat would likely destroy the three-dimensional structure and result in loss of function.

- *How was the known amount of ricin determined for the calibration?*
  The crude ricin was compared to a known sample of pure ricin to determine the amount of ricin in the crude sample.

- *Would cells uptake protease, for example, and would that uptake interfere with the assay?*
  Rastogi had not evaluated whether proteins were readily transported across the cell membrane. He speculated that protein transfer across the cell membrane would not occur.

- *Why was a HeLa cell line used in the study?*
  The study considered human toxicity issues, and therefore involved use of a human cell line. Rastogi noted that other researchers were examining nonhuman cell lines.

- *A participant noted the importance of using sound cell lines and cell cultures. How stable was the manipulated cell line? How many subcultures were possible before degradation occurred?*
  Rastogi noted that the cells remained stable as long as subculturing was possible. The HeLa cell line has been stable for about 60 years: it originated in the 1950s and researchers continue to use it in 2010. A cycle of growing cells, freezing, growing, and freezing was possible. Approximately one to two weeks were required to move from frozen to usable cells.

8.5 Biotoxin Test Method Development

Linda C. Beck, Naval Surface Warfare Center, Dahlgren Division

The Naval Surface Warfare Center, Dahlgren Division, has been working to develop standardized test methods for determining the efficacy of liquid decontaminants against bio-warfare agents on hard or porous surfaces. The method requirements include testing liquid contaminants at an increased challenge level with reduced contact times, testing on a wide range of materials, and testing with minimal manipulation of the sample. The need for reproducible assays and standard methods for testing is recognized within the DOD and EPA test communities. The objective of this project is to develop, standardize, and verify a method for evaluating the efficacy of liquid decontaminants on surfaces and coatings for select biological toxins. The Center's recently developed test method for the evaluation of the efficacy of liquid and gaseous decontaminants on bacterial spores was modified and applied to develop the biotoxin sampling procedure. The differences between spores and biotoxins were considered prior to modification of the protocol.

Electrochemiluminescence immunoassay was selected as the method of analysis for the protein biotoxins and enzyme-linked immunosorbent assay was used for the molecular toxins. Analysis of the data generated: (1) standard curves; (2) baseline recovery data on four military-relevant surfaces; (3) percent recovery of *C. botulinum* Type A toxin complex, ricin, aflatoxin, and T-2 mycotoxin on four surfaces

after treatment with the liquid decontaminants 10 percent bleach, DF-200, or HTH. The procedures were verified and validation testing was performed. Verification was successfully completed by repetitive sampling and analysis. Preliminary testing for validation was accomplished by comparing the reproducibility of the test results using a different method of analysis, liquid chromatography/mass spectrometry, at an alternate laboratory (Dugway Proving Ground). The method generated provides a standard for efficacy testing of liquid decontaminants against biotoxins that will be recommended for incorporation into the TOP 8-2-061. The results could also impact the concept of operations for the decontamination of protein and molecular biotoxins and could be leveraged by additional hazard mitigation projects.

Question and Answer Period

- *How were the decontaminant liquids applied to the coupons?*
  The decontaminant liquids were placed on the coupons with micropipettes.

- *Were analyses (i.e., liquid chromatography/mass spectrometry [LC/MS]) of the disinfection results conducted at Dugway Proving Ground facilities?*
  Beck followed a standard process for removing the biotoxins from the coupons. Beck analyzed resulting samples using electrochemiluminescence and ELISA immunoassay methods. Beck also provided samples to Dugway Proving Ground, where they were analyzed by LC/MS.

- *Were any indications of disinfection byproducts identified?*
  This study did evaluate disinfection byproducts.

- *A participant noted that hand application of extremely toxic substances seemed dangerous and potentially countered Occupational Safety and Health Administration (OSHA) regulations. Was hand application the preferred method?*
  Beck noted that the study used only very small concentrations of the toxic substances. Concentrations were: 2 nanograms/milliliter (ng/mL) ricin, 10 ng/mL botulinum toxin, 16 ng/mL aflatoxin, and 10 ng/mL T-2 mycotoxin. Researchers conducted testing under a hood and wore appropriate PPE. Overall, they followed regulations for worker safety.

- *What was the mass of the toxins applied to each coupon?*
  The toxins were applied by volume—50 microliters. Calculations were necessary to translate the volume into a mass.

- *Was the ELISA immunoassay method commercially available or developed for this study?*
  The ELISA immunoassay was commercially available through AgraQuant.

- *Most of the tests were conducted with pure preparations. How would inorganics interfere with results?*
  Beck did not have information about inorganic interferences.

8.6 Development of Test Methods for Determining the Efficacy of Disinfectants against Foreign Animal Disease Viruses on Nonporous Surfaces

Peter W. Krug, Foreign Animal Disease Research Unit, Agricultural Research Service, U.S. Department of Agriculture

Foreign animal disease (FAD) agents are a major economic threat to the United States that could potentially cost billions of dollars in lost revenue, culled livestock, and environmental cleanup if FAD agents are introduced into U.S. agriculture. Preventing the accidental or intentional introduction of these agents into the country is vital, but once introduced, rapid response and recovery from FAD outbreaks requires effective disinfection of contaminated premises and equipment. Standardized methodologies for testing disinfectant efficacy

against FAD agents on surfaces and fomites are lacking.

To develop and validate basic methodologies for evaluating disinfectant efficacy, we selected three representative viruses: foot and mouth disease virus (FMDV), a small, nonenveloped RNA virus; classical swine fever virus (CSFV), a small, enveloped RNA virus; and African swine fever virus (ASFV), a large, enveloped DNA virus. In our approach, high-titer virus stocks (10^7 to 10^8 50 percent tissue culture infective dose) are dried on nonporous surfaces and exposed to a liquid disinfectant. After a predetermined contact time, the disinfectant is neutralized and the virus is titered on susceptible cells to detect infectious virus post-disinfection. FMDV and ASFV were both recovered with minimal titer loss when dried on stainless steel and plastic surfaces. In contrast, CSFV titers decreased by up to three orders of magnitude as a result of the drying process. Next, we tested various concentrations of three disinfectants against each virus on nonporous surfaces. Sodium hypochlorite was efficacious for all three viruses at specific concentrations and contact times. Citric acid was effective against FMDV and ASFV but did not disinfect CSFV at the tested concentrations. As expected, the surfactant sodium dodecylbenzene sulfonate was ineffective against the nonenveloped FMDV.

A concentration of 1000 ppm sodium hypochlorite applied for a 10-minute contact time is an effective antiviral disinfectant on stainless steel and polystyrene surfaces. Under the same conditions, 2 percent citric acid is effective against FMDV and ASFV.

This methodology enables standardized testing of disinfectants against FAD viruses from nonporous surfaces. Optimization of virus recovery from wood is the focus of our current research on porous surface disinfection. These techniques will be used for testing disinfectants against other high-priority FAD viruses on porous and nonporous surfaces.

Question and Answer Period

- *Was the percent recovery from the neutralized disinfectants evaluated?* When conducting a disinfection assay, all recovery controls were conducted with a mixture of the disinfectant and neutralizing agent. The values presented represent the percent recovery from the mixture.

8.7 Destruction of Spores in a Bench-Scale Landfill Flare System

Dana Wimsatt, EPA, NHSRC

Incinerators and hazardous waste landfills are unlikely to be able to accept all the building decontamination residual (BDR) from a large-scale bioterrorism attack. As a result, BDR will likely be sent to municipal solid waste landfills. The concern with BDR disposal in these landfills is that the BDR may contain viable spores that can become reaerosolized in landfill gas systems, pass through landfill gas flares, and be emitted to the atmosphere. Therefore, it is imperative to determine under what conditions landfill gas flares will destroy these spores.

A bench-scale landfill flare system was developed to study the behavior of *Geobacillus stearothermophilus* spores, a surrogate for *Bacillus anthracis*. In this system, spores in solution are aerosolized using a collision nebulizer. The aerosolized spores go through a diffusion dryer and into a chamber where they are mixed with nitrogen. An SKC Biosampler is used to obtain a pre-flare spore concentration. Methane is then introduced to the system to create simulated landfill gas. This mixture enters a flare housed in an open top Pyrex enclosure with an integral stainless steel exhaust system. The exhaust system with associated HEPA filter and pump cools the exhaust, dilutes any released methane with outside air, and collects remaining spores in a second Biosampler to obtain a post-flare spore concentration.

Information regarding the design of the flare system, problems encountered, sampling methods, spore losses throughout the system, and preliminary spore destruction results will be presented. Specific issues encountered include:

drying of phosphate buffer saline that clogged the Biosampler nozzles and decreased sampling efficiency; flow limitations due to flare size; and fluid breakthrough from the Biosampler into the mass flow meter.

The reduction of *G. Stearothermophilus* spores in this bench-scale landfill flare system will help decision-makers recommend potential disposal options.

Question and Answer Period

- *Was evidence of destroyed spores found?*
  No evidence of destroyed spores was found.

- *If the landfill gas was not flared, would a hazard exist?*
  A researcher—Morton Barlaz—at North Carolina State examined reaerosolization of spores in building waste. He found that spores could reaerosolize if building wastes were placed in a situation where landfill gas formed. Wimsatt thought that reaerosolization was possible if the landfill gas was not flared.

8.8 Development of an Aerosol Deposition Method for *Bacillus* Spores

Sang Don Lee, EPA, NHSRC

A method was developed to deposit *Bacillus* spores onto various material surfaces for biological decontamination and detection studies using a metered dose inhaler (MDI). These spores were deposited onto common indoor and outdoor surfaces, and the deposition amount and repeatability were measured. The MDI was loaded with *Bacillus subtilis* spores (0.05 and 0.5 wt percent), which served as a surrogate for *Bacillus anthracis*. A separate apparatus was developed to reproducibly deposit spores from an MDI onto surfaces of various sizes and material types with control over the location and amount deposited. Five different material surfaces (aluminum, galvanized steel, wood, carpet, and painted wallboard paper) were tested for *B. subtilis* spore deposition. These tests showed that more than 10^6 viable spores could be deposited onto surfaces with less than a 50 percent coefficient of variation, depending on the surface types. The current method can be varied to produce the wide range of spore deposition amounts from 10^5 to 10^8 spores per cm^2. Benchtop decontamination and detection experiments will benefit from this spore particle deposition method.

Question and Answer Period

Conference participants posed no questions at the conclusion of the presentation.

9 Radiological Recovery Research Activities

9.1 Simulated Cesium Radiological Dispersal Devices for Deposition, Dose, and Decontamination Studies

Mark Sutton, Lawrence Livermore National Laboratory

Nonradioactive cesium was explosively dispersed to simulate a cesium-137 RDD. Unique facilities at Lawrence Livermore National Laboratory enabled indoor and outdoor explosive testing combined with physical, chemical, and dose-related analysis. Cesium deposition and diffusion studies allowed dose to be examined as a function of particle size distribution, surface loading, distance from the explosion, and depth of penetration into concrete.

Sampled urban building material (particularly relating to mass transit systems) and surrogates were characterized using a full suite of chemical and surface analyses. The samples were then positioned in both vertical and horizontal planes and explosively contaminated with stable solid cesium chloride. Cesium deposition and diffusion were measured using laser ablation inductively coupled plasma mass spectrometry. Cesium diffusion into concrete pores was comparable with hydrated concrete, suggesting that RH greatly affects diffusion. While urban grime did not affect cesium speciation and migration into surfaces, urban grime could physically block or hinder transport below the concrete surface. The presence of grime did not chemically affect cesium speciation or mobility, but results did show that grime could physically hinder cesium transport to the concrete surface below. We have studied the dose consequences from deposited ground-shine, as well as the reduction in dose with respect to both the distance from ground-zero and the diffusion of contaminants into concrete surfaces.

This work may aid in decision-making between destructive and nondestructive decontamination techniques to minimize residual dose consequences during restoration-phase response activities. In addition, by understanding the contamination at the surface and below, we were able to better understand the behavior of selective chelating agents. Such decontamination agents effectively bind radionuclides while leaving infrastructure intact, resulting in more rapid return-to-service, waste minimization, and decreasing exposure times for decontamination workers.

Question and Answer Period

- *Specific chelators for cesium were not mentioned. Is information about the modeled chelators available for release?*
  Specific information regarding the chelators is unavailable due to a pending patent application.

- *Are any cesium chelators available commercially?*
  Sutton noted that cesium is difficult to chelate. Some research has evaluated sorbing cesium onto a material, but Sutton did not have specific information about the chelating material.

- *Were particles larger than 10 microns measured?*
  No particles larger than 10 microns were measured.

- *Was cesium diffusion through the concrete expected at a pre–Manhattan Project building?*
  Sutton indicated that the observed diffusion was due to RH and not precipitation.

- *When using a chelator, how much time was needed for the chelator to penetrate 1 centimeter (cm) into the material and bind with the cesium?*
  Time requirements depended on the application method. Sutton noted that

chelator medium also affected the time requirements. For example, media that could be pushed into the contaminated surface, foams, or clay poultices to draw out moisture more readily penetrated the contaminated surface. Sutton noted that drawing the chelators back out of the surface was also necessary.

- *Are any HotSpot data available?*
  Sutton did not have immediate access to these data, but they are available.

9.2 EPA Spectral Photometric Environmental Collection Technology: Gamma Emergency Mapper Project

John Cardarelli, EPA, Office of Emergency Management

The EPA Airborne Spectral Photometric Environmental Collection Technology (ASPECT) program provides assistance to the first responder by providing an aerial tool to collect photographic, chemical, and physical (infrared and gamma radiation) information quickly and to relay this information directly to decision-makers in the field. Since 2001, ASPECT has assisted the response community in over 100 incidents ranging from ammonia releases to recent radiological deployments supporting Region 2 and Region 6. The ASPECT aircraft is located near Dallas, Texas, and is "wheels-up" within one hour of activation. Up to six 2-inch by 4-inch by 16-inch NaI(Tl) detectors and two 3-inch by 3-inch $LaBr_3$(Ce) detectors are among the suite of detectors mounted in the aircraft.

EPA initiated the ASPECT Gamma Emergency Mapper (GEM) project in 2008 to improve airborne gamma-screening and mapping capability for ground-based gamma contamination following a wide-area RDD, fallout from an IND attack, or an effluent release following a nuclear power plant disaster. This essential asset can support Homeland Security in events of national significance and assist EPA with environmental surveys for potassium, uranium, and thorium at Superfund sites. The ASPECT GEM committee consists of members from the EPA special teams, academia, Region 2, and the Department of Energy. This presentation provides (1) the preliminary report on at least one Superfund site in Region 2 and a brief summary of a recent survey of abandoned uranium mines in New Mexico (Region 6), (2) specifics about the technology's radiological (and chemical) detection capabilities, (3) minimum detectable activities, and (4) limitations.

Question and Answer Period

- *DOE calibrated their systems by flying over test ranges with known radiation levels at 1 meter above the surface. How did EPA calibrate this system?*
  EPA followed the DOE flight patterns over Lake Mohave near Las Vegas. EPA also conducted tests at another lake bed. EPA conducted pressurized ion chamber and soil sample characterization at this site to estimate background levels.

- *Had EPA considered using a helicopter instead of a plane?*
  Operating a plane was more cost-effective. By flying over an area two or three times, a fixed-wing plane achieved the same minimal detectable activity as a helicopter.

9.3 Radiological Decontamination of Urban Surfaces using Selective Isotope-Sequestering Agents

Konstantin Volchek (presenting for Pervez Azmi, Environment Canada, Emergency Sciences and Technology Section)

This study focused on the identification and evaluation of sequestering agents that could be used to improve the radiological decontamination efficiency of an existing commercial decontamination product. More specifically, the work was performed to develop a decontamination formulation that would be effective for the removal of cesium, strontium, and cobalt from a variety of common urban surface materials.

Several sequestering agents were selected for the study, including polycarboxylic acids for cobalt and strontium and ammonium salts and ferrocyanides for cesium. Liquid-phase tests were conducted first to determine binding efficiencies of the sequestering agents towards Cs, Sr, and Co. Based on results of these tests, decontamination experiments on urban material surfaces were conducted using material coupons spiked with each target contaminant. Concrete, painted steel, ceramic tile, dry wall, marble, granite, anodized aluminum, and galvanized steel were on the list of the tested surfaces. All experiments were conducted using nonradioactive surrogates. Analysis was performed by inductively coupled plasma/mass spectrometry. Test results revealed an improved effectiveness when the sequestering agents were added to the formulation. The next step in the development of the product will be to perform tests using radiological isotopes.

A benefit of this formulation is that it can be incorporated into a commercial product used for chemical and biological decontamination. The resulting mixture can therefore be used to deal with the chemical, biological, and radiological agents at once.

Question and Answer Period

- *How were the coupons prepared? Were coupons treated with the isotope surrogates? How long were contaminants present on the coupon surface prior to decontamination?*
  The coupons consisted of urban materials in 5 cm by 5 cm squares. These coupons were spiked with cesium, cobalt, and strontium solutions in pre-determined concentrations. Aqueous solutions were used for "wet" contamination and methanol-based suspensions were used to mimic "dry" contamination. After a 24-hour drying period, decontamination was performed. Consistent with current surface decontamination protocols for foam, the foam remained in contact with the contaminated surface for 30 minutes. The coupons were rinsed with water and then analyzed for contaminants. Volchek noted that the effects of both the drying time and the exposure time on decontamination efficacy have been evaluated.

9.4 Performance Evaluation of Decontamination Technologies for Dirty Bomb Cleanup

John Drake, EPA, NHSRC

A primary EPA responsibility is cleaning up and restoring urban areas affected after an accidental or intentional release of radiological materials. These releases could include terrorist incidents, such as an RDD or "dirty bomb." To prepare for such an event, EPA's NHSRC is conducting performance evaluations of commercial, off-the-shelf radiological decontamination technologies. NHSRC's Technology Test and Evaluation Program recently completed a series of performance tests of five mechanical technologies to gauge their effectiveness in the removal of cesium from concrete. NHSRC is now in the process of testing five chemical-based technologies and is also evaluating the efficacy of common household cleaners for decontamination of surfaces typically found in residential settings. The emphasis is on "low-tech" methodologies, which tend to be simple, low-cost, and easy to use, and can be transported and deployed quickly, requiring only minimal support services or infrastructure. The experimental procedures used and the results of the completed tests will be presented, as well as a status report for two ongoing projects. The results of these evaluations are also being made available to the larger homeland security community for use in developing cleanup guidance and to support decisions concerning the selection and use of decontamination technologies for large outdoor environments contaminated with specific radiological threat agents.

For each evaluation, 15 cm × 15 cm unpainted concrete coupons were contaminated with cesium-137 at a level of approximately 1 microcurie per coupon, measured by gamma spectroscopy, and then placed in a test stand designed to hold nine coupons in a vertical orientation to simulate the wall of a building.

Each technology was applied to the wall, so that each coupon was treated for approximately 15 seconds. The coupons were then removed from the wall and the residual contamination was measured.

The decontamination efficacy attained by each technology was determined in terms of percent of contaminant removed and decontamination factor, which compares the surface contamination measured before versus after using the equipment.

Deployment-related parameters measured included the rate at which the technologies can be used to decontaminate a vertical surface, level of production of secondary waste, the effect of the technology on the texture or finish of the concrete surface, and utility and operator skill requirements. A limited evaluation of cross-contamination was performed.

The decontamination factor for technologies tested ranged from 1.6 to 41.0, with a decontamination rate from 1 to 5 m^2/hr. The impact on the surface finish of the concrete substrate ranged from "no impact" to "noticeable roughness."

The work produced data that can be used by response planners and operations personnel to make scientifically informed decisions regarding decontamination feasibility and methods.

Question and Answer Period

- *Was resuspension from pressure washing assessed? Were the device controls sufficient to prevent contaminant migration to clean wall surfaces?*
  The study included control coupons, including blank coupons for assessing cross-contamination. Little cross-contamination was observed on the blank coupons.

- *Was redeposition of radionuclides on the ground surface considered?*
  No data were included in the report. However, swipe samples were collected during tent decontamination, which occurred between the different technology tests.

- *Did the vacuum hoses become hot?*
  The vacuum collection vessels, but not the hoses, became hot. Drake indicated that this was an operational consideration.

- *How was the exhaust air from the vacuum treated?*
  A cascade of HEPA filters was used to treat the exhaust air. Drake indicated that these filters were effective.

- *How long did the contamination remain on the coupons prior to decontamination?*
  A study of the residence time for cesium chloride applied by wet deposition reported no measurable difference in decontamination efficacy between seven and 28 days. This study used a seven-day residence time.

- *Were environmental conditions controlled?*
  Testing was conducted in a dry climate. The coupons were kept at a known temperature and RH throughout the process.

- *Were publicly available cleaners (i.e., cleaners that could be purchased at a grocery store or hardware store) evaluated?*
  Studies of publicly available cleaners are beginning, said Drake. These studies aim to inform the public about actions they can take to minimize exposure when they return to their homes.

- *Have discussions about scaling up these technologies occurred? For example, automation might make the technologies available for cleaning a large building.*
  Current application rates are not acceptable for implementing these technologies in a real-world RDD response. Drake indicated that more information is needed before these technologies can be scaled up.

9.5 The Evolution of Radiological Decontamination at DRDC Ottawa

Marc Desrosiers, Defense Research and Development Canada

Defence Research and Development Canada (DRDC) Ottawa has been involved in radiological decontamination operation and research for several years for the Canadian Forces. We are now using our expertise and unique facilities to investigate the problem of large-area contamination that could be a result of an RDD; the lessons learned in this research on either the civilian or the military side can be beneficial to either, due to the similarity of the problems.

DRDC Ottawa, with its partners, has continued to develop procedures, techniques, and testing protocols for simulating various situations faced during radiological decontamination. The work started with radiologically-contaminated liquid solutions and small test plates and progressed to larger test plates and structures (vehicles and houses) and the use of fine (respirable) dry particles. The progression and use of the different contaminants is shown through a description of the following experiments: military vehicle decontamination, urban decontamination, absolute decontamination efficacy, "Little House in the Prairie," and decontamination of sensitive Canadian military equipment.

During the progression of these experiments, DRDC Ottawa has continued to develop its procedures for processing (grinding and separation based on particle size), contaminating (contamination of test plates), and detecting (surface vs. subsurface) a variety of short-half-life radioisotopes.

This work may lead to new decontamination techniques, optimization of existing techniques, and development of new modeling tools such as the Decontamination Decision Tool to support the Canadian Forces in choosing the best approach for decontamination in the field. (This tool is also proposed to be used by first responders and to be expanded to serve as a radiological assessment tool.)

The above work is leading to a databank of information on contaminated environments and factors that can affect radiological cleanup. DRDC Ottawa is using this information to support a variety of projects and initiatives, such as the Canadian Forces decontamination project team and RDD contamination Interaction with Urban Surfaces CRTI projects.

Question and Answer Period

- *A participant asked if the data regarding contaminant residence time are available.* Contaminant residence time was examined. Desrosiers indicated that he would provide these data to this participant.

- *Would follow-on work consider waste generation concerns?* Waste generation was not considered for this study, but follow-on work planned to examine waste generation. Desrosiers noted that, based on mission objectives, waste generation was typically not as important to the military. When creating a tool for first responders in a civilian population, waste generation is a consideration.

9.6 Persistence of Surrogate Radioisotopes on Drinking Water Infrastructure and the Effectiveness of Decontamination Methods

Jeff Szabo, EPA, NHSRC

The persistence of cesium, cobalt, and strontium on common drinking water infrastructure has not been thoroughly examined. Furthermore, it is unknown whether these compounds can be decontaminated if they do persist. Therefore, bench-scale research was undertaken to understand how surrogate isotopes for cesium, strontium, and cobalt associate with drinking water pipe material. Mechanisms of attachment and the efficiency of decontamination methods were examined.

Drinking water infrastructure surfaces were conditioned in biofilm annular reactors with Cincinnati tap water. Unlined iron coupons were

allowed to corrode before contact with the surrogate isotopes. Surrogate cesium, cobalt, and strontium solutions were pulse-injected and allowed to contact the coupons for one hour. The reactors were flushed and coupon samples were harvested over the next month to establish persistence. Coupon and bulk phase samples were analyzed with inductively coupled plasma. If persistence was observed, decontamination was undertaken with methods such as flushing, increasing disinfectant levels, and changing water quality parameters.

Cesium was not detected on the coupons, but cobalt formed an insoluble precipitate which was difficult to decontaminate. Lowering pH was the only method that resulted in significant decontamination, but lowering pH also dissolved some of the pipe scale. Strontium was observed to persist on corroded iron, but the mechanisms at work and decontamination methods are still being determined. Strontium experiments will be completed in August 2010.

Cesium persistence on the iron coupons was not observed, but cobalt formed an insoluble precipitate that was difficult to remove. Strontium experiments are ongoing, but association with iron coupons has been observed. Persistence on cement-lined material, which is another common form of drinking water infrastructure, will be examined in the future.

This work is significant because the persistence of radioisotopes on drinking water infrastructure needs to be well understood, so that decontamination techniques can be formulated in the event of contamination.

Question and Answer Period

- *Did the study consider a range of pHs for removing the cobalt from the coupons?*
  Decontamination experiments were conducted at high and low pH, but cobalt was removed only at a low pH.

- *A participant noted that removing the coupons from the biofilm reactor changed the oxidation environment. How was this change addressed?*
  Szabo noted that drinking water with a disinfectant present provides a stronger oxidative environment than air, but air contact could not be completely avoided. Szabo minimized contact with air as much as possible during sample transport and storage.

- *Was cesium adherence to silt considered?*
  A great deal of literature regarding cesium adherence to silt is available from sources such as DOE. For example, studies have examined cesium in ground water and its association with clays and silts. Szabo was interested in cement-lined pipes because similarities between adherence in pipes and ground water are possible.

9.7 Evaluating Cesium Contamination of Urban Building Materials: Two Instrumental Approaches

Julia Barzyk, EPA, NHSRC

Cesium contamination is an issue after nuclear power plant accidents, RDD events, and IND events. We are conducting a series of experiments to investigate the interactions of cesium chloride with a variety of urban surface materials. A potential method of decontamination will also be evaluated.

Radioactive cesium is used in medicine and industry. Our work uses stable cesium-133 in the form of cesium chloride to contaminate powdered building material samples such as concrete, asphalt, brick, and limestone. Questions of interest are: (1) Is the nature of contamination acquired on each material time-dependent? (2) What are the mechanisms of cesium adsorption to surface materials? (3) Is rinsing contaminated materials with water an effective method of decontamination?

Powdered building material of each variety will be suspended in a solution of 0.05M cesium chloride for one-day, one-week, five-week, and 10-week time intervals before separation by filtration. Additionally, a portion of each of the 10-week samples will be rinsed with water. All

resulting samples will be analyzed using time-of-flight secondary ionization mass spectrometry (TOF-SIMS). This technique allows the relative quantification of cesium concentrations among samples. Supporting data may be collected using x-ray photoelectron spectroscopy (XPS), which provides information on the bonding status of cesium in material samples. Because powdered samples can be analyzed on both TOF-SIMS and XPS, no processing of the samples after equilibration and separation is required.

Completion of this work will provide information directly relevant to decision-making regarding cesium contamination such as the effects of material type and time on the magnitude and nature of cesium contamination and the effectiveness of water decontamination.

Question and Answer Period

- *A participant noted that Barzyk had described adsorption by mass, for example, milligrams of cesium per kilogram of crushed brick. In real-world decontamination events, adsorption is based on surface area. How does adsorption expressed as a mass relate to adsorption expressed as a surface area? For example, what is the surface area associated with 1 gram of powdered brick?*
  Barzyk prepared samples by crushing the materials to create a powder and then passing the powder through a series of sieves. This process generated uniform samples with similar surface areas and allowed for comparison of cesium adsorption across materials. The powder form reduced mass transfer impacts and allowed Barzyk to focus on chemical reactions. A participant added that surface area is an important factor in cesium adsorption, but this study focused on the differences in cesium bonding based on chemical reactions rather than differences in surface area.

9.8 Impact of RDD Decontamination Strategies on Quantities and Characteristics of Resulting Waste and Debris

Paul Lemieux, EPA, NHSRC

Determining waste characteristics and disposal pathways for waste and debris resulting from an RDD and subsequent waste management activities will probably contribute a significant portion of the overall remediation effort in terms of time and costs. Selected decontamination techniques, whether they involve chemical treatment, strippable coatings, abrasive removal, or aqueous washing will influence the amount and types of waste generated and the rate at which the waste is generated. The aim of this effort is to examine the effect of mitigation decisions on waste disposal activities.

This presentation describes a methodology to develop a waste inventory based on commercially available Geographical Information System software, overhead satellite imagery analysis, and a spreadsheet tool that allows the impact of different decontamination approaches on resulting waste quantities to be investigated. Based on the aforementioned waste estimation methodology, a sensitivity analysis shows the impacts of decontamination strategies on waste quantities and characteristics.

The ultimate goal of this effort is to provide a simplified framework that could be used in the early stages of an RDD response so that an integrated decision-making approach that includes both decontamination and disposal considerations can be used to formulate remediation strategies.

Question and Answer Period

- *A participant noted that the study did not include a cleanup level. This participant suggested that Lemieux consider cleanup levels in the analysis. As previously mentioned during the conference, cleanup levels are a substantial factor in determining decontamination costs. Using a cleanup level approach, Lemieux could assume that some material with low-level contamination would remain in place, which would reduce disposal costs.*

- *The cost information considered only disposal costs, and not transportation costs. A participant noted the importance of transportation when comparing disposal costs at a Resource Conservation and Recovery Act (RCRA) facility to disposal costs at a local facility. Adding transportation costs could double or triple the overall disposal costs. This participant thought that including transportation costs in estimates would provide useful information.*
  Lemieux agreed and noted that the disparity between RCRA disposal costs and low-level waste disposal costs is due to the range of activities required for addressing different types of waste.

- *A participant noted that Nuclear Regulatory Commission (NRC) requirements drove clean-up costs associated with radiological wastes. Recently, NRC began evaluating blended waste streams based on limitations associated with low-level radioactive waste sites. This step, felt the participant, represented NRC's recognition of the need to evaluate more options for radiological waste disposal.*

9.9 Treatment of Liquid Wastes from Radiological Decontamination

Konstantin Volchek, Environment Canada

The decontamination of soil, water, or buildings following either an industrial accident or sabotage involving hazardous CBRN agents usually results in the generation of contaminated wastes. Many of the decontamination technologies currently available use water-based formulations. The volumes of wastewater can be quite large. These wastewaters may contain residual toxic agents, their degradation byproducts (which may also be toxic), surfactants, suspended solids, and other materials that may not be suitable for discharge into the environment. This situation would normally require transportation of the wastewater to an offsite treatment facility. The transportation of large volumes of hazardous liquid waste has inherent risks and expenses. The larger the volume of the wastewater, the greater the factors associated with offsite treatment. The goal of this study was to investigate the feasibility of an onsite concentration of liquid decontamination wastes to reduce the volume and make transportation for final treatment or disposal easier.

The authors conducted a series of tests for the removal of radionuclide and other hazardous components from liquid decontamination wastes. A combined membrane filtration/adsorption process was shown to be effective in treating waste streams containing various contaminants. Based on test results, a mobile treatment process was developed. Process performance is discussed and recommendations for future development are given.

An alternative to offsite treatment would be to process the wastes on site using mobile treatment systems. Such systems would concentrate the contaminants of liquid wastes and minimize waste volumes.

The logistics of reducing the volume of wastewater generated from CBRN decontamination activities using a mobile on-site process has been shown to be feasible. The reduced volume of wastewater ensures safer transport to the final waste treatment facility and decreases final disposal costs.

Question and Answer Period

- *What throughput could be achieved with these membranes?*
  Volchek noted that the membranes had large pore sizes. He recorded a throughput of up to 250 liters per square meter per hour. At this rate, a 2 m^2 membrane would have a throughput of approximately 0.5 cubic meters (m^3) of mechanically pretreated water per hour. Much lower throughputs would occur with untreated water.

- *For the surfactant technology, detectors are needed to monitor changing isotope*

concentrations in water and to allow for adjustments in the surfactant flow to meet these changes. Does this type of sophisticated detector exist?
This study did not evaluate techniques to detect isotope concentrations and adjust surfactant flow accordingly. Rather, data were available to determine how much rejection was expected at given surfactant levels and optimize the system. For example, if the optimal surfactant level was 1 to 2 grams, but only 0.5 grams were present, then surfactant could be added to the system to achieve optimal conditions. Volchek felt that future research could evaluate the use of modeling and detection technologies to select optimal surfactant concentrations

10 Operational Considerations for Decontamination

10.1 Impact of CT and Relative Humidity on Efficacy and Material Effects of Chlorine Dioxide

John Y. Mason, Sabre Technical Services, LLC

Historical research has shown that achieving and maintaining 75 percent RH is critical for the effectiveness of chlorine dioxide gas against spore-forming microorganisms when decontaminating structures. Although chlorine dioxide is considered by many to be the standard for decontamination of structures, achievement of this parameter can be difficult and has been associated with corrosive effects on certain steels and soft metals. The objective of this work was to evaluate whether RH can be lowered without impacting the sporicidal effectiveness of chlorine dioxide gas and to evaluate any associated corrosive effects.

Exposure studies were conducted in a laboratory chamber capable of maintaining target RH and chlorine dioxide levels, as well as during 10 full-scale building decontaminations. RH conditions were measured throughout the duration of each exposure by HOBO® Model U12-011 temperature and RH data loggers manufactured by Onset Computer Corporation. Chlorine dioxide levels were monitored by a gas sample collection method that is a modification of OSHA Method ID-202 and a titration method that is a modification of Method 4500-ClO_2-E APHA.AWWA from *Standard Methods for Water and Wastewater,* 20th edition. Sporicidal efficacy was evaluated using commercially-produced *Bacillus atrophaeus* spore strips, environmental antimicrobial efficacy was evaluated using drywall coupons with bacteria embedded in the gypsum core, and material effects on corrosion coupons were evaluated qualitatively and quantitatively via visual inspection and gravimetric analysis.

A series of exposure studies showed that as RH levels decrease, the CT needed in order to reach 100 percent sporicidal efficacy increased following a second order polynomial standard curve. At the lowest RH level tested (45 percent RH), 100 percent kill of spore strips and embedded environmental vegetative organisms was achieved at a CT of 12,000 ppmv-hours. Corrosion effects were found to be independent of CT but RH-dependent. At RH values of less than 48 percent, corrosion was not observed on even the most sensitive test samples at CT values exceeding 12,000 ppmv-hours. The demonstrated ability to decontaminate buildings at RH levels below 48 percent with no observable corrosive effects broadens the applicability of chlorine dioxide gas as a sterilant or decontaminant.

Question and Answer Period

- *There is a strong push to remove and replace drywalls in homes. Is fumigation an option?*
  Only a few people believe that bacteria are an issue. Mason noted several conditions pointing to bacteria as a possible source: calcium sulfate, organic matter, increased biogenic gas concentrations with increased RH and temperature, and findings in cultured samples. Mason is working to gather evidence supporting a bacterial source.

- Mason noted that Sabre was working on a project at an approximately 250,000-square-foot condominium complex with roughly 200 units. Removal and replacement of the drywall would require an estimated 2.5 years. For comparison, Sabre fumigated and repopulated a hospital in less than 10 days.

- *A participant noted that Mason had presented data on the efficacy of a lower RH and an increased CT on bacteria in drywall. What is the applicability of a lower RH and increased CT to spores? Has standard testing been conducted?*

Mason has not tested a low RH and increased CT approach to decontaminating spores. He noted that others have conducted low RH testing.

- *Sabre is working on a prototype system that could fumigate a 5 million cubic foot structure. Do those 5 million cubic feet assume a big, box-shaped building or a more complex building with many small spaces (e.g., office, hotel)?*
  This technology applies to more complex spaces, such as apartment buildings. Mason referred to a Sabre project at a six-story condominium complex with roughly 200 units and many small spaces. The piping and electrical trains also required treatment, which added to the complexity of the project. Sabre is also working on a project at a 47-story condominium complex.

- *Did the costs presented include waste management and disposal?*
  The type of response influences the waste management and disposal costs. A virulent pathogen is handled differently than bacteria, Mason noted. When working in private homes, people have valuable belongings that must be recovered. However, impacts to porous materials are unpredictable. Valuables are removed from homes and treated outside, a labor-intensive process. For virulent pathogens, removal is unnecessary because treatment damages materials one way or another. Mason noted that Sabre has achieved a CT of 100,000 in a 75,000-cubic-foot structure. Accordingly, he felt, chlorine dioxide fumigation of weaponized spores is plausible.

10.2 Methodology for Quantitative Analysis of the Impact of Decontamination on Electronic Equipment

G.E. Derkits, Alcatel-Lucent

Principal goals of the work at Alcatel-Lucent were to introduce reproducibility, quantitative methods, and traceability into the study of decontamination impacts on electronic equipment, in order to provide objective information to the agencies of the U.S. government responsible for decontamination oversight.

The methods used were adapted from best practices in the field of electronic and telecommunication system environmental testing. Specific methods applied to this investigation included:

- Standard test vehicles. Personal computers were chosen as test vehicles because they are highly standardized. High competition among computer vendors provides up-to-date technology and well-characterized equipment. Low unit cost allows an experiment to use enough replicates to reduce the effects of random variation. Standard industry software is available to precisely characterize hardware failures.

- Quantitative correlative information. The use of pure metal coupon process monitors was adapted from ASTM standard test methods for calibrating mixed flowing gas test chambers for environmental testing of electronic equipment. The materials of the coupons are source-traceable. The effect of each exposure was measured by the weight gain of coupons of aluminum, copper, tin, and silver using a precision microbalance calibrated using National Institute of Standards and Technology–traceable methods and a reproducibility and repeatability study. The corrosion mass gain of the coupons was then used as a quantitative measure of the harshness of exposure conditions that could be related to a figure of merit derived from chamber test conditions.

- Quantitative failure data. Objective assessment of system failure was performed using industry standard PC Doctor® software, which applies software-driven tests to each subsystem of the PC to define "failure." Use of this software replaces a subjective opinion with a reproducible objective datum: "Pass = 0" or "Fail = 1."

- Replacing visual inspection with high-resolution photographs of a pre-specified set of test points covering major subsystems and the full span of relevant materials allowed an objective visual comparison from unit to unit and throughout the test duration. For some degradation modes, such as cut-edge corrosion, this practice also resulted in quantitative information, as the position of the edge of the corrosion pattern with respect to the stamped metal edge can be measured and the degree of corrosion over time can be compared with the results of similar images of samples exposed to more typical harsh environments such as salt-fog tests.

- Damage progression was quantitatively assessed by performing the PC Doctor® test protocol repeatedly at regular intervals over an extended period of time to gauge the repeatability of the assessment and to look for progressive degradation, which is known to occur in corrosion. The number of failed tests per month was tracked over six months after the exposure; it was shown, in the case of chlorine dioxide decontamination, to be a monotonically increasing function of time, with a slope related to the harshness of the exposure represented as a figure of merit equal to the concentration of chlorine dioxide multiplied by the exposure time and the RH or, alternatively, to the coupon mass gain.

- Root cause analysis was adapted from industry protocols. In our method, a complete destructive physical analysis of failed subunits down to the materials level was performed to establish the root cause of failure.

The adoption of standard industrial practices for environmental reliability studies to assess the impact of decontamination using chlorine dioxide and hydrogen peroxide has resulted in a set of data and conclusions that can be quantified and are demonstrably repeatable and objective.

This work provides a description of the methodology used to create a quantifiable objective assessment of the impact of biological agent decontamination on electronic equipment. Until this study, the results in this field were qualitative and subjective. We have advanced the state of art of biodecontamination studies and improved the quality of information used by U.S. government agencies for the evaluation of fumigant technologies.

Question and Answer Period

- *Were smaller test volumes considered, for example testing circuit boards rather than whole computers?*
  For this study, Derkits wanted to evaluate a whole system. The metal coupon testing conducted as part of this study provided more detailed information. In addition, PC Doctor® software was available for the whole system to identify failure points. Derkits also collected data regarding specific subsections on a circuit board. For example, chlorine dioxide at a high RH strongly attacked tin-based solder. Derkits stated that a great deal of detailed data existed, so he was more interested in the larger issues.

- *To what extent did just-in-time manufacturing impact the study variables and results?*
  Just-in-time manufacturing meant that Dell received deliveries from different vendors, each of which used different designs. For example, one of the DVD players evaluated was clearly designed differently than the others, even though all the test computers were ordered together. However, the basic form was similar regardless of design, so the impacts of these design differences were smaller than might be expected. A participant noted that 2,700 Dell computers delivered to a hospital in a single shipment included a number of design differences.

- *Will future work include power-off conditions to prevent thermals?*
  The experiments reported included both power-off and power-on conditions. Derkits

agreed that power-off is a more controlled state and recommended turning off electronics during practical fumigations. He noted that the computers turned themselves off for a number of uncontrollable reasons (e.g., different thermal detectors, various subsystems).

10.3 Assessment of the Impact of ClO_2 and H_2O_2 Decontamination on Electronic Equipment

M.L. Mandich, Alcatel-Lucent

DHS's Science and Technology Directorate and the Environmental Protection Agency's National Homeland Security Research Center are interested in the effects of decontamination technologies on electronic equipment under multiple fumigation conditions. This work provides extensive information on the impact of fumigation with chlorine dioxide (ClO_2) or hydrogen peroxide (H_2O_2) on prototypical complex electronic equipment.

Test vehicles consisting of Dell computers and exposure coupons were subjected to chlorine dioxide and hydrogen peroxide vapor using an exposure test matrix designed to investigate the effects of CT, RH, and equipment power state under conditions suitable for each fumigation technology. This test matrix included two different hydrogen peroxide technologies—STERIS VHP® and BIOQUELL HPV—plus gaseous chlorine dioxide generated using a ClorDiSys Solutions Inc. gas generation system.

Test vehicles exposed to both chlorine dioxide and hydrogen peroxide exhibited fumigation-induced degradation at the system and subsystem level. Results of post-exposure performance monitoring using objective pass/fail criteria showed that the number of hard and intermittent failures increased over a timeframe of months following fumigation. Visual inspection revealed corrosion of multiple materials, including aluminum, steel, silver, and plated copper, as well as bleaching of cables and extensive particulate formation in chlorine dioxide–exposed computers. Hygroscopic corrosion products were formed, posing both immediate and long-term reliability problems. No obvious corrosion was observed visually for the hydrogen peroxide–fumigated computers. For chlorine dioxide, there was a marked correlation of the extent of damage with CT and RH conditions. Very high humidity conditions ($\geq$ 85 percent RH), outside of normal use for chlorine dioxide fumigation, were particularly deleterious.

Extensive failure mode analyses were performed for observed subsystem failures, especially those associated with connectors and optical disk drives. These failure mode analyses revealed: (1) many gold-plated connectors were heavily corroded as a result of chlorine dioxide decontamination, and (2) both fumigants, particularly hydrogen peroxide, caused deleterious damage to passive optics, especially those fabricated with plastic optical materials. In both examples, the use of COT components in the test computers contributed to their vulnerability to fumigation.

Significant, in-depth data are now available on the impact of chlorine dioxide and hydrogen peroxide fumigation on electronic equipment. Both fumigants caused damage that was observed to have deleterious short- and long-term effects on hardware performance, as well as on the reliability of key components. This damage was observed under normal-use conditions for both fumigants; however, the most significant impact was seen for harsher chlorine dioxide fumigation conditions. On this basis, chlorine dioxide fumigation in >75 percent RH conditions should be avoided, provided biological agent kill can be achieved. Material choices used in these test computers were a significant reason for the extent of fumigation-induced damage. In many cases, these choices are made for cost-saving reasons in the COT market.

This work provides an objective assessment of chlorine dioxide and hydrogen peroxide fumigation–induced damage of electrical components, materials, and subsystems typical of complex electronic equipment. These results can be used to estimate potential outcomes in a field decontamination scenario for equipment such as computers, telecommunications

equipment, and data servers, as well as civilian and military equipment using complex electrical and optical components. The results also can be used to guide material, design, and fabrication choices for electronic equipment where robustness to harsh fumigants is required.

Question and Answer Period

- *What scrubbing agent was used for the chlorine dioxide?*
  EPA conducted the scrubbing and could provide this information.

- *Based on the reported results, a participant suggested adding data recovery as a step in the decontamination. This participant also suggested disposing of electronic equipment as an e-waste stream.*

- *Hard drive failures were not mentioned. Were data stored on hard drives recoverable?*
  Some hard drive failures were found five to seven months after fumigation. The failures tended to occur in areas where data were stored. Frequent use areas on the drive were more susceptible to failure.

- *What technology was used to generate chlorine dioxide? Was free chlorine measured?*
  A ClorDiSys system generated the chlorine dioxide. Monitoring for chlorine gas occurred. No detections were reported.

- *Were some of the plastic polymers more susceptible to the fumigants than others?*
  Reverse-engineering the plastics and evaluating their susceptibility was beyond the project scope. Mandich noted that the optical plastics industry uses a large number of different plastics, so differences in susceptibility to fumigants are a concern. Mandich speculated that the type of plastic would influence susceptibility.

- *Have research findings been compared to results from real-world fumigations events?*
  Mandich did not have information regarding equipment impacts observed after fumigation. A participant noted that a paper has been published regarding hydrogen peroxide and chlorine dioxide exposures in a pharmaceutical plant. EPA's Office of Pesticide Programs allows restricted access to this paper.

- *Limited anecdotal data are available regarding equipment operation in postal facilities after decontamination, noted a participant. In Trenton, the mail-sorting equipment was replaced and the damage from fumigation was compared to exposure to sea salt. The participant noted that computers are easily replaced, but postal facilities and hospitals contain high-value equipment. How is this equipment protected?*
  In the telecommunications industry, equipment has a 20- to 25-year life expectancy. Some conditions hasten failure (e.g., high sulfur, sea salt). This study found highly accelerated degradation conditions associated with fumigation, even compared to high sulfur and sea salt environments. To Alcatel-Lucent, these findings raised important concerns for infrastructure preparedness. Mandich noted that the fumigants essentially created highly accelerated stress tests.

11 Chemical Warfare Agent Recovery Research

11.1 Evaluating Strategies for CWA Decontamination of Indoor Facilities

Adam H. Love, Consultant to Lawrence Livermore National Laboratory

Executing an efficient restoration and recovery process after a civilian facility is contaminated with a chemical warfare agent (CWA) requires understanding the full range of decontamination strategies and where these strategies are expected to be most effective. As part of a DHS-funded effort to improve the preparedness for facility restoration after a chemical release, a range of relevant decontamination strategies has been evaluated experimentally for surfaces contaminated by vapor and/or liquid sarin (GB), mustard agents (HD), and VX.

Experiments at Lawrence Livermore National Laboratory have applied actual CWA to surfaces at controlled-vapor or liquid-surface loading and then measured the residual contamination following a series of different decontamination approaches on a selection of typical indoor surfaces. Volumetric decontamination approaches evaluated utilized both hot air ventilation and hot/humid air ventilation. Liquid and foam decontaminant surface treatments (bleach, DF-200, CASCAD, and DeconGreen) were evaluated for their ability to reduce the residual surface contamination. Control experiments with no active decontamination were also performed to evaluate the relative benefit of the decontamination strategies versus the no treatment option.

While each of the decontamination strategies is effective under some specific conditions, there is no one universal decontamination approach that is effective and efficient for the entire facility restoration process. Therefore, an efficient facility restoration will likely employ a range of decontamination strategies based on an understanding of agent/substrate interaction and the efficacy of the decontamination approaches for the event-specific contamination conditions.

Improving the understanding of the efficacy of various decontamination strategies for a range of indoor materials greatly facilitates the restoration process by:

- Identifying materials that are easily decontaminated.
- Identifying materials that should be removed.
- Determining the most appropriate decontamination approach for the contamination scenario and agent/material combination.
- Understanding what is necessary for waste disposal.

Applying this information to a well-organized and thoughtful Remediation Action Plan enables a more rapid and economical facility restoration.

Question and Answer Period

- *Were tests conducted for agents that entered the material surface, but were released weeks later?*
  Love noted that polymer diffusion generally followed a pattern of penetration and slow release. The liquids placed on a material surface penetrated the polymer. A two-phase diffusion process then occurred. In the first phase, the liquid near the surface was released. The second phase included the diffusion-limited release of the agent that had penetrated further into the polymer.
- *What was the extraction process?*
  Love covered the coupons with a methylene chloride solution, then sonicated the coupon and solution for 15 minutes.

11.2 Test Methodology for the Assessment of Chemical Warfare Agent Decontamination Performance on Porous or Complex Surfaces

Paul Brister, Clean Earth Technologies, LLC

Currently, there are no accepted methods available to test CWA decontaminant performance on porous materials. Conventional panel (surface) methods typically assess either contact or vapor hazards post-decontamination and provide information on the effectiveness of the application method rather than the efficacy of a particular decontaminant. Current panel testing methods need to be improved to allow the best achievable result, providing a better understanding of parameters that affect decontamination performance on varying surfaces, particularly porous or complex surfaces.

Clean Earth Technologies, LLC, has developed a chemical testing methodology for the assessment of decontaminant performance on porous or complex surfaces. The presented method introduces a new approach for evaluating decontaminant performance on porous materials. The method can be used in parallel with conventional testing methodology (e.g., stirred reactor or panel testing) or used independently to assess performance on porous or complex surfaces. The design of the experiment gives "best case" efficacy data for a decontaminant, which will provide aid in selection of decontaminants for a given scenario/surface or give baseline, or best achievable, data for CONOPS development. The method was designed to control variables to ensure that decontamination performance/efficacy is the dependent variable. Control of variables is achieved by eliminating the dependence of critical parameters such as decontamination loading rates and challenge levels and focusing on decontamination performance parameters (penetration and neutralization rates).

Experimental data showed that conventional decontamination application rates are not sufficient for removal of CWAs from porous materials, due to varying localized concentrations of contaminant (high challenge levels). The new method eliminates this variable by supplying the decontaminant in excess, allowing a determination of how a decontaminant penetrates and neutralizes a challenge. The presented method was tested against varying porosities, materials, decontaminants, chemical simulants, and agents, and at varying reaction times. Those data and subsequent conclusions will be presented.

By providing scientifically defensible test methodology to quantitatively evaluate CWA decontaminant efficacy on porous surfaces, the end user is in a better position to compare products and processes. resulting in more efficient testing, easier data interpretation for the user, and lower cost.

Question and Answer Period

- *A participant asked for clarification about decontaminant- versus diffusion-limited reactions, as described by Brister. This participant thought that reactions occurring in the stir reactor were decontaminant-limited.*
  Brister agreed that reactions occurring in the stir reactor were not diffusion limited. Brister and the participant disagreed that slow reductions after a single application of the decontaminant represented a diffusion-limited reaction and more rapid reductions after multiple decontaminant applications represented decontaminant-limited reactions.

11.3 Basic Research Needs in Decontamination

Jennifer Becker, U.S. Army Research Office

The battlefield environment is highly complex and diverse, and the war fighter needs integrated protection from chemical hazards—chemical and biological warfare agents as well as common hazardous chemicals, which might include combustion products, radioactive materials, and heavy metals. Innovative research

concepts combined with novel procedures in many different areas of chemical and biological defense and decontamination can be leveraged to provide new capabilities for protecting the war fighter and first responder. For years the Army and DOD have invested in fundamental research in catalysis, surface chemistry, and organized assemblies. The goal of the Army Research Office's Organic and Inorganic Chemistry program is to seed scientific and far-reaching technological discoveries in chemistry that enhance Army and DOD capabilities. The program has a balance of opportunity-driven research and needs-based research focused on the development of a molecular-level understanding of catalytic reactions, functionalized surfaces, and organized assemblies that will provide the foundation for creating new materials and processes to protect the soldier from hazardous chemicals and materials. This research has led to the development of new catalysts for destruction of hazardous materials, an understanding of reaction mechanisms on surfaces, and novel colloids and assemblies for decontamination. Recent work has also focused on the development of multi-functional, biomimetic, and higher-ordered materials. These research investments in fundamental science have led to novel biotechnology-based and nanotechnology-based materials that are now being investigated in chemical and biological defense research programs. The new technologies and lessons learned can be used to design revolutionary new capabilities.

An overview of current basic research programs in decontamination and transitions of basic research efforts will be described.

Question and Answer Period

Participants posed no questions.

11.4 Knockdown and Neutralization of Aerosolized Chemical Agent Simulants using Charged Decontaminant Sprays

Rita Betty, Sandia National Laboratory

The purpose of this work was to demonstrate rapid, effective knockdown and neutralization of CWA simulant aerosol releases using electrostatically-charged decontaminant sprays, and to explore and optimize spray system parameters that will improve aerosolized CWA simulant knockdown and neutralization.

Modeling of threat agent release conditions has produced a comprehensive understanding of airborne threat vapor/particle distribution and concentrations and particle fallout over time. Potential airborne exposure levels can be compared to target safe exposure levels to determine orders of magnitude reduction in initial threat agent exposure level required to attain safe exposure levels, i.e., required neutralization efficacy.

Aerosolized test method: A 14.5-cubic-meter aerosol test chamber is filled with aerosolized chemical/biological warfare agent simulant for long enough to achieve airborne aerosol concentrations at customer-defined threat densities. Aerosol samples are collected throughout the simulant charging process, using aerosol samplers (impingers) with iso-octane as the collection medium. An electrostatically charged DF-200 spray is deployed for a set duration—one or two minutes—using pre-determined spray system parameters such as nozzle air pressure, liquid pressure, etc. Test spray parameters are based on results of nozzle spray characterization profiles. Charged decontaminant spray droplet sizes are an average of 30 micrometers, dispersed at a spray density of about 120 grams per cubic meter. Aerosol simulant concentrations are again measured immediately after the end of the charged DF-200 spray deployment, and at selected times following the charged spray deployment. Sampled aerosolized CWA simulant will solubilize in the organic iso-octane collection medium phase, thus separating from the aqueous

DF-200, quenching the decontamination reaction, and providing an aerosolized simulant concentration measurement representative of the timeframe from which the sample was collected. Chemical agent simulant collected in the iso-octane is analyzed by gas chromatography. Results are reported as aerosol concentration (gm/m^3) and plotted versus test time (minutes). All spray system parameters are monitored and tracked electronically by a data acquisition system.

Experimental testing demonstrates rapid, effective knockdown and neutralization of aerosolized chemical/biological warfare agent simulants from initial, high-threat levels, decreasing by orders of magnitude corresponding to inhalation exposure levels below the LD_{50}. Results demonstrate a decrease greater than three orders of magnitude in aerosolized CWA simulant (diphenylchlorophosphate) concentration within five minutes of charged DF-200 spray deployment.

In progress is an initial toxicological survey to assess the potential respiratory effects of inhalation exposure to aerosolized DF-200 spray densities and droplet sizes representative of those deployed by this technology. Preliminary results may be available for presentation at this conference.

Sandia has demonstrated rapid, effective knockdown and neutralization of aerosolized CBW agent simulants using charged DF-200 sprays. The technology may be applied to provide protection and minimize contamination in a variety of military and civilian venues.

Of significance is the potential use of this fundamental technology in numerous applications including mitigation and neutralization of chemical/biological weapon releases. A release mitigation spray safety system will remove airborne contaminants from an accidental or intentional release to protect personnel and limit the spread of contamination.

Question and Answer Period

Participants posed no questions at the conclusion of the presentation. The presenter utilized the full duration allotted for this presentation and Q&A.

11.5 Study of the Release of Pesticides from Building Materials

Geneviève Thouin, SAIC Canada

Decontamination of impacted facilities may be necessary following terrorist attacks or industrial accidents to enable safe reoccupancy. Very limited information and no suitable standards exist, however, for determining safe contamination levels for reoccupancy. As part of a project to set decontamination standards for buildings and structures affected by chemical and biological terrorism, this work focused on studying the fate and behavior of chemical agents of concern on building surfaces and in the surrounding air.

In order to assess the health hazards linked to specific decontamination limits, a series of experiments involving the release of four pesticides from different surface materials was studied under different conditions. The relation between their concentration on the surface and their concentration in the air was investigated as a function of temperature, surface concentration, and construction material. The release of toxic byproducts was also monitored and analyzed. Several evaporation, sublimation, and desorption models were applied to the data.

The highest concentrations detected in the vapor phase were similar to the ideal saturation concentrations for lindane, diazinon, and malathion. Results obtained for carbofuran, however, were 500 times greater than the ideal saturation concentrations based on the vapor pressure data found in the literature. Vapor-phase concentrations exceeded the time-weighted averages for lindane, diazinon, and malathion.

The levels of decontamination required to establish a “safe” working environment were estimated based on the experimental results. A

model for ventilated work environments was developed based upon Nielsen's evaporation model and experimental data to provide vapor-phase concentration and time estimates.

The contamination of a small surface with semivolatile toxic organic compounds can lead to levels of concern in the air of an enclosed space. The levels of decontamination required to ensure safe concentrations in the air may have to be extensive. Though some compounds show saturation behaviors close to ideal, others, such as carbofuran, present interactions with surfaces that are very nonideal. Vapor-phase concentrations of such compounds can be several orders of magnitude greater than what would be expected based on their sole vapor pressure. It is therefore very hard to predict the behavior of compounds of concern based only on usual physicochemical properties without specific compound-surface interaction data.

The results of this study are used in conjunction with complementary studies to establish cleanup standards for chemical agents. Once the experimental and modeling work has been developed into standards, a broad range of personnel from first responders to top-level decision makers will use these standards. Special emphasis will be placed on using standards and associated models for post-remediation clearance of facilities and for determination of potential usage of facilities following a contamination event. Consequently, standards will be made available in condensed format for use in emergency response scenarios.

Question and Answer Period

- *Were control samples collected?* Control samples were collected. No pesticides or compounds that would interfere with results were detected.

11.6 Assessment of Fumigants for Decontamination of Surfaces Contaminated with Chemical Warfare Agents

Emily Snyder, EPA, National Homeland Security Research Center

The aim of this work was to evaluate steam and vaporous hydrogen peroxide modified with ammonia (mVHP®) for decontamination of four different indoor building material surfaces (decorative laminate, industrial-grade carpet, galvanized metal, and ceiling tile) contaminated with one of four selected chemical warfare agents (HD, GB, VX, and thickened soman [GD]). This work investigated this efficacy as a function of operational conditions (two generation or flow rates for each fumigant and two concentrations of mVHP®) and determined the material compatibility of these technologies.

A test chamber was designed and fabricated to accommodate the two decontamination systems. Approximately 1 milligram of agent was applied to 2- by 5-centimeter sample coupons, and these coupons were placed into the test chamber for decontamination. During the positive control tests, fumigant was not introduced into the test chamber. Samples were removed from the chamber at specified time periods and analyzed for the amount of residual agent remaining on or within the sample. All decontamination efficacies were calculated relative to the positive controls.

Results from the steam efficacy testing indicate that for both feed rates (1.5 and 3 kilograms per hour), steam was efficacious (>99 percent efficacy for most material-agent-exposure time combinations) in removing the surface contamination for all agents; however, detectable amounts of GB, thickened GD, and VX were found in the condensate. In addition, the steam impacted both the carpet and the ceiling tile materials, most significantly dissolving the ceiling tile.

The mVHP® fumigant was very effective at removing HD from the surfaces and removed a significant portion of the VX from the surfaces tested (81 to 89 percent efficacy at 400 minutes

exposure time). The efficacy of mVHP® against HD appeared to be affected by flow rate of the fumigant (34 versus 340 liters per minute) through the chamber more than the fumigant concentration (250 vs. 350 ppmv of VHP). Lastly, the mVHP® fumigant did not impact the appearance of most of the materials, only causing a white residue to form on the galvanized metal.

Steam was effective at removing every agent tested from the selected materials, but scaling up this fumigation technology could be problematic due to the presence of the GB, thickened GD, and VX in the condensate. The presence of these agents in the condensate indicates that if the steam fumigation were used to decontaminate the interior of a facility or section of a facility, there would likely be re-distribution of these agents onto other surfaces. However, the nondetectable levels of the agents on the procedural blanks directly adjacent to the test coupons indicate that steam might be a suitable decontamination method if it were used in small areas where the condensate could be collected, such as a steam cleaner.

These tests indicate that mVHP® is efficacious against HD surface contamination, but presence of the agent in the vapor indicates that the HD may not be completely reacting with the mVHP® during fumigation. Longer exposure times need to be tested to determine if this fumigant can be efficacious against VX.

This work provides an assessment of how steam and mVHP® performed under certain operational conditions that are representative of what would be used in the field. This work also provides insight on how these technologies could best be implemented in the field. EPA decontamination teams will use this information when providing technical assistance to states and localities when they are selecting remediation technologies for a contaminated site. This work also provides insight into how these technologies should be implemented in the field.

Question and Answer Period

- *What kind of carpet was used for testing?* An industrial-grade nylon carpet was used.

Appendix A Agenda

United States
Environmental Protection Agency
Decontamination and Consequence Management Division and National Decontamination Team

2010 U.S. EPA Decontamination Research and Development Conference

Hilton Raleigh Durham Airport
Durham, NC

Agenda

DAY 1: TUESDAY, APRIL 13, 2010

PLENARY SESSION

Protecting Human Health and the Environment through Innovation..... *Dr. Paul Anastas, Assistant Administrator, EPA/ORD*

Plenary Speaker..... Honorable David Price, Congressman, 4th District, North Carolina

FIELD ACTIVITIES AND LARGE SCALE DEMONSTRATIONS

Case Study: Decontamination of a Community Building Containing Low Concentrations of *Bacillus Anthracis* Spores, Durham, New Hampshire ..... *Ted Bazenas, EPA/Region 1*

Decontamination of a Facility and HVAC System Ductwork using Chlorine Dioxide Gas.....*Mark Czarneski, ClorDiSys Solutions Inc.*

Source Reduction Following the 2001 Anthrax Attacks: Lessons Learned..... *Dorothy Canter, Dorothy Canter Consulting LLC*

An Overview of the Chemical Restoration Operational Technology Demonstration (OTD) Project .. *Mark D. Tucker, Sandia National Laboratories*

Two Recent Proof of Principle Tests of Deployable Countermeasures to Support Recovery of Critical Mass Transit Facilities ..... *Robert Fischer, Lawrence Livermore National Laboratory*

DAY 1: TUESDAY, APRIL 13, 2010 (Continued)

FIELD ACTIVITIES AND LARGE SCALE DEMONSTRATIONS (continued)

Bio-Response Operational Testing and Evaluation (BOTE) ..... *Shannon D. Serre, EPA/ORD/NHSRC*

CROSS-CUTTING RECOVERY ACTIVITIES

National Homeland Security Research Center Water Treatment and Infrastructure Decontamination Research ..... *Scott Minamyer, EPA/ORD/NHSRC*

Containment and Disposal of Large Amounts of Water: A Support Guide for Water Utilities ..... *Marissa Lynch, EPA/OW*

Threat Agent Disposal: Disposal Issues Following a CBRN Incident Based on RDD and Anthrax Waste Disposal Workshops ..... *Paul Kudarauskas, EPA/OSWER/OEM*

Update on the Validated Sampling Plan Work Group ..... *Dino Mattorano, EPA/OSWER/OEM*

Developing an Effective CBRN Decontamination Capability ..... *Hasmitta Stewart Government Decontamination Service (Fera)*

US-Canada Bilateral Technical Working Group (TWG) for CBRN Response and Recovery ..... *G Blair Martin, EPA/ORD/APPCD*

TOOLS AND GUIDANCE DEVELOPMENT

Analysis of Decontamination Strategies Following a Wide-Area Biological Release in a Metropolitan Area ..... *Robert Knowlton, Sandia National Laboratories*

Interactive Decision Framework for Consequence Management ..... *Robert Greenwalt Lawrence Livermore National Laboratory*

DAY 2: WEDNESDAY, APRIL 14, 2010

TOOLS AND GUIDANCE DEVELOPMENT (continued)

Optimization Approaches and Issues Associated With Late-Phase Recovery Following Radiological or Nuclear Events ..... *S.Y. Chen, Argonne National Laboratory*

FATE AND TRANSPORT RESEARCH ACTIVITIES INFORMING RECOVERY (CROSS CUTTING)

Transport of *Bacillus Thuringiensis* var. *Kurstaki* (Btk) From an Outdoor Release into Buildings ..... *Kristin Omberg for Sheila Van Cuyk, Los Alamos National Laboratory*

Transport of Bioaersols into a Regional Transit System—Implications for Characterization..... *Michael Dillon, Lawrence Livermore National Laboratory*

Mitigation and Containment of Contaminant Spread..... *Jacky Rosati, EPA/ORD/NHSRC*

The Brooklyn Traffic Real-Time Ambient Pollutant Penetration and Environmental Dispersion (B-TRAPPED) Study ..... *Russell Wiener, EPA/ORD/NHSRC*

ACTIVITIES TO SUPPORT WIDE AREA BIODECONTAMINATION

Assessment of Liquid and Physical Decontamination Methods for Surfaces Contaminated With *Bacillus* Spores ..... *Shawn P. Ryan, EPA/ORD/NHSRC*

Evaluation of COT Products for Decontamination of *Bacillus* Spores..... *Jason Edmonds, DOD, U.S. Army*

Evaluation of Peroxide-Based Solutions for Facility Decontamination by Owner/Occupants..... *Paula Krauter, Sandia National Laboratories*

Concurrent Sessions	
ACTIVITIES TO SUPPORT WIDE AREA BIODECONTAMINATION	**RADIOLOGICAL RECOVERY RESEARCH ACTIVITIES**
Inactivation of *Bacillus anthracis* Spores on Indoor and Outdoor Building Surfaces Using Commercially-Available Liquid Sterilant Technologies *Worth Calfee EPA/ORD/NHSRC*	**Simulated Cesium Radiological Dispersal Devices for Deposition, Dose, and Decontamination Studies** *Mark Sutton, Lawrence Livermore, National Laboratory*
Inactivation of Bioagents by Natural Attenuation, Liquid Decontamination, or Fumigation *Harry Stone, Battelle*	**EPA Spectral Photometric Environmental Collection Technology: Gamma Emergency Mapper Project** *John Cardarelli, EPA/OSWER/OEM/NDT*
High/Low Tech Approaches to HVAC Decontamination *Brian Attwood, EPA/ORD/NHSRC*	**Radiological Decontamination of Urban Surfaces Using Selective Isotope-Sequestering Agents** *Konstantin Volchek for Pervez Azmi, Emergency Sciences and Technology Section, Environment Canada*
PERSISTENCE OF BIOLOGICAL AGENTS AND OTHER BIO-RELATED DECONTAMINATION AND DISPOSAL RESEARCH	**Performance Evaluation of Decontamination Technologies for Dirty Bomb Cleanup** *John Drake, EPA/ORD/NHSRC*
Persistence of Select Biological Agents *Joseph Wood, EPA/ORD/NHSRC*	**The Evolution of Radiological Decontamination at DRDC Ottawa** *Marc Desrosiers, Defense Research and Development*
Disinfection of Mobile Equipment after an Emergency Poultry Disease Outbreak *Eric R. Benson, Department of Bioresources Engineering and Department of Animal and Food Science, University of Delaware*	**RADIOLOGICAL RECOVERY RESEARCH ACTIVITIES (Cont'd.)**
Testing the Sporicidal Efficacy of Six Disinfectants on Carrier Surfaces Contaminated with *B. Atrophaeus* Spores *Bruce Hinds, Defense Threat Reduction Agency*	**Persistence of Surrogate Radioisotopes on Drinking Water Infrastructure and the Effectiveness of Decontamination Methods** *Jeff Szabo, EPA/ORD/NHSRC*
Development of a Novel Bioassay for Detection of Functional Ricin *Vipin K. Rastogi, R&T Directorate, US Army–ECBC*	**Evaluating Cesium Contamination of Urban Building Materials: Two Instrumental Approaches** *Julia G. Barzyk, EPA/ORD/NHSRC*
Biotoxin Test Method Development *Linda C. Beck, Naval Surface Warfare Center, Dahlgren Division*	**Impact of RDD Decontamination Strategies on Quantities and Characteristics of Resulting Waste and Debris** *Paul Lemieux, EPA/ORD/NHSRC*
Development of Test Methods for Determining the Efficacy of Disinfectants against Foreign Animal Disease Viruses on Nonporous Surfaces *Peter W. Krug, Foreign Animal Disease Research Unit, Agricultural Research Service, United States Department of Agriculture*	**Treatment of Liquid Wastes From Radiological Decontamination** *Konstantin Volchek, Environment Canada*

DAY 3: THURSDAY, APRIL 15, 2010

PERSISTENCE OF BIOLOGICAL AGENTS AND OTHER BIO-RELATED DECONTAMINATION AND DISPOSAL RESEARCH

Destruction of Spores in a Bench-Scale Landfill Flare System (20 min.).....*Dana Wimsatt, EPA/ORD/NHSRC/DCMD*

Development of an Aerosol Deposition Method for *Bacillus* Spores.....*Sang Don Lee, EPA/ORD/NHSRC*

OPERATIONAL CONSIDERATIONS FOR DECONTAMINATION

Impact of CT and Relative Humidity on Efficacy and Material Effects of Chlorine Dioxide.....*John Y. Mason, Sabre Technical Services, LLC*

Methodology for Quantitative Analysis of the Impact of Decontamination on Electronic Equipment (30 min.).....*G. E. Derkits, Alcatel-Lucent*

Assessment of the Impact of ClO_2 and H_2O_2 Decontamination on Electronic Equipment.....*M. L. Mandich, Alcatel-Lucent*

CHEMICAL WARFARE AGENT RECOVERY RESEARCH

Evaluating Strategies for CWA Decontamination of Indoor Facilities.....*Adam H. Love, Consultant to Lawrence Livermore National Laboratory*

Test Methodology for the Assessment of Chemical Warfare Agent Decontaminant Performance on Porous or Complex Surfaces.....*Paul Brister, Clean Earth Technologies, LLC*

Basic Research Needs in Decontamination.....*Jennifer Becker, U.S. Army Research Office*

Knockdown and Neutralization of Aerosolized Chemical Agent Simulants Using Charged Decontaminant Sprays.....*Rita Betty, Sandia National Laboratories*

Study of the Release of Pesticides from Building Materials.....*Geneviève Thouin, SAIC Canada*

Assessment of Fumigants for Decontamination of Surfaces Contaminated With Chemical Warfare Agents.....*Emily Snyder, EPA/ORD/NHSRC*

EPA FACILITY TOURS

Appendix B List of Participants

United States
Environmental Protection Agency
Decontamination and Consequence Management Division and National Decontamination Team

2010 U.S. EPA Decontamination Research and Development Conference

Hilton Raleigh Durham Airport
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Appendix C Presentation Slides

Case Study: Decontamination of a Community Building Containing Low Concentrations of *Bacillus Anthracis* Spores, Durham, New Hampshire

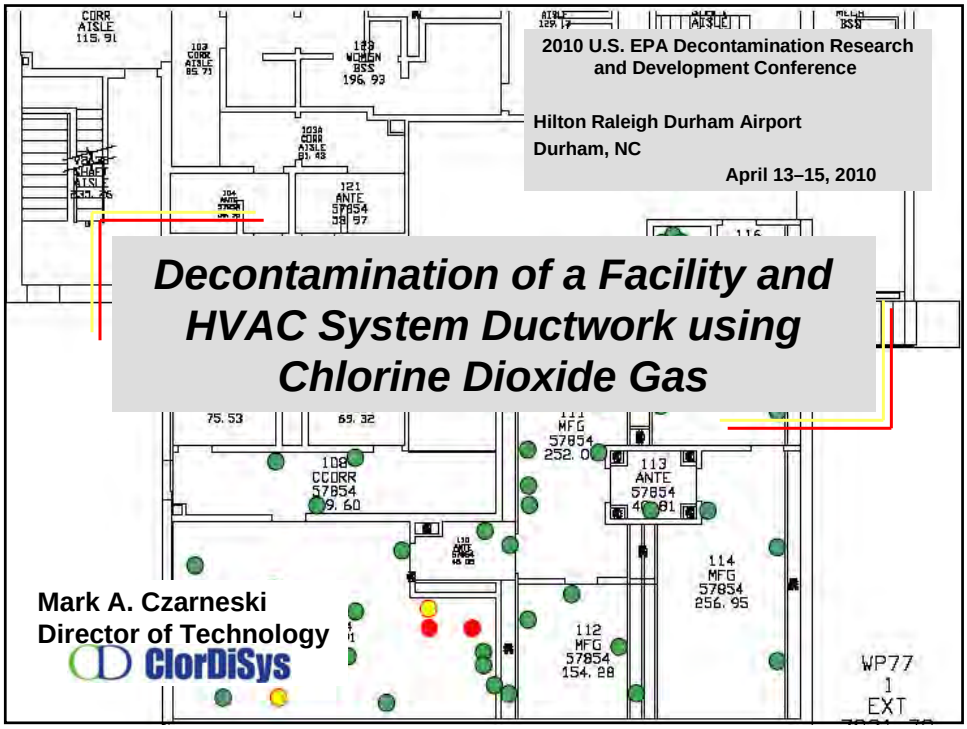
Ted Bazenas, EPA/Region 1

Presentation not available for distribution

Decontamination of a Facility and HVAC System Ductwork Using Chlorine Dioxide Gas

Mark Czarneski, ClorDiSys Solutions Inc.

Mark Czarneski
ClorDiSys Solutions, Inc



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Overview

1. **Registration / Background**
2. **Reasons, Requirements & Choices**
3. **Equipment / Facility Setup**
4. **Pictures of Setup**
5. **Readings**
6. **Concerns & Conclusions**

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Mark Czarneski
ClorDiSys Solutions, Inc

ClorDiSys

Current Sterilizer (Sporicides) Registration with US-EPA as of January 2009

More than 5000 antimicrobial products are currently registered with the US-EPA.
Only 40 agents are registered as a Sterilant.

Agent	Quantity
Ethylene Oxide	24
Sodium Chlorite (chlorine dioxide)	4
Hydrogen Peroxide Based	12
Total	40

http://www.epa.gov/oppad001/chemregindex.htm

3

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Current Sodium Chlorite (Chlorine Dioxide) Sterilizer Registration

Company	Produce Name	Registration #	Ingredient %	Sterilization Use
Alcide Corp	Alcide Exspor 4:1:1 – Base	1677-216	1.520%	Immerse in solution for 10 hours @ 20 deg C
ClorDiSys Solutions, Inc.	CSI CD Cartridge	80802-1	72.8%	Follow System Operations Guide Chlorine Dioxide gas @ 10 mg/L for 15 min
Englehard Corp	Aseptrol S10-Tab	70060-19	20.8%	Immerse or soak in 1000 ppm solution for min 1 hour
Pharmacal Research Laboratories Inc	CLIDOX-S BASE	8714-8	0.85%	1:3:1 Dilution for 5 hours @ 25 deg C

For Anthrax cleanup Under Section 18 of FIFRA, EPA exempted Sabre Technologies from any provision of EPA registration requirement for sale or use.

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http://www.epa.gov/oppad001/chemregindex.htm

Mark Czarneski
ClorDiSys Solutions, Inc

ClorDiSys

http://www.epa.gov/oppad001/chemregindex.htm

Current Hydrogen Peroxide Based Sterilizer Registration

Company	Produce Name	Registration #	HP %	Other	Use
Arkema Inc	Peroxal 70 Bio	335-233	70%	None	Not listed on label
Advanced Sterilization Products	Sterrad Hydrogen Peroxide	71871-3	59%	None	see equipment manual
Clean Earth Technologies	Peridox	81073-1	24%	1.2% Peroxyacetic acid	Immerse in 4% solution for 45 minutes
Ecolab Inc	Oxonia Active	1677-129	27.5%	5.8% Peroxyacetic acid	Circulate, coarse spray or flood 5 % solution for 6 hours @ 20 deg C, 20 min @ 50 deg C or 5 min @ 80 deg C
Ecolab Inc	Vortexx	1677-158	6.9%	4.4% Peroxyacetic acid and 3.3% Octanoic acid	Circulate, coarse spray or flood solution for 30 min @ 20 deg C followed by sterile or potable water rinse
Minntech Corp	Actril Cold Sterilant	52252-7	0.8%	0.06% Peroxyacetic acid	Immerse in solution for 5.5 hours @ 20 deg C
Minntech Corp	Minncare Cold Sterilant	52252-4	22%	4.5% Peroxyacetic acid	Immerse in 100X dilution solution for 11 hours @ 20 deg C
Steris Corp	**Steris-Hydrogen Peroxide Sterilant**	**58779-3**	**31%**	**none**	**For sterilization of empty, pre-cleaned, sealed enclosures up to 40 ft^3 apply 2.2 grams of product per minute for 90 minutes**
Steris Corp	Spor-Klenz RTU Cold Sterilant	1043-119	1.0%	0.08% Peroxyacetic acid	Hold in sterilizing solution for minimum of 5.5 hrs
Steris Corp	GW002 Tertiary Blend	1043-121	35%	none	Hold in sterilizing solution for minimum of 8 hrs
Steris Corp	**Vaprox Hydrogen Peroxide Sterilant**	**58779-4**	**35%**	**none**	**see equipment manual (Dec 2002) (May 2000 said same as above)**
Steris Corp	**Vaprox Hydrogen Peroxide Sterilant**	**1043-123**	**59%**	**none**	**see equipment manual**

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Reasons for Decontamination

- Penicillin work performed in facility
- Change Facility function
- Some people allergic to penicillin residues
- Positive samples in 2 labs + throughout the HVAC system
- Option 1
  - DEMOLISH - costly to demolish entire building then rebuild $$$$$$$$$
- Option 2
  - DECONTAMINATE – under $100,000

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ClorDiSys Solutions, Inc

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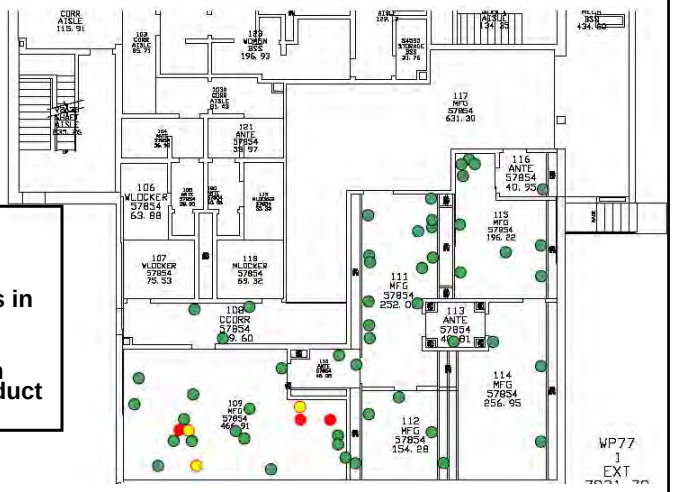
Facility Layout and samples



- 90 sample taken
- 6 Positive Swab tests in room areas
- 7 Positive samples in supply and exhaust duct work

- Negative Results
- Results above LLD (0.115 Results above LLD (0.115 mcg/wipe), but less than LOQ
- Results above LOQ (0.386 mcg/wipe)

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Equipment and Costs

- 41,000 cu ft (1161 cu m)
- 12 generators
- 40 chlorine cylinders
- 40 Fans
- 15 steam generators
- 1 EMS CD Gas Sensor Module
- 3/8" gas inject tubing
- ¼" gas sample tubing
- Extension Cords
- Duct Tape
- 2 ft Wide Tape
- 4 people
- 3 day on site
- 2 day off site

Total Decontamination Cost $ *72,694*

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Requirements for Decontamination

- Previous studies demonstrated penicillin (beta lactam) inactivation with 7000 ppm-hrs.
- Achieve medium concentrations levels

  3mg/L (1086ppm)
- Hold for long time to achieve minimum 7000 ppm-hrs

  7 hours
- Decontaminate production area and HVAC system (supply and exhaust)

  Have NO positive samples when complete

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Time Line (How Long is the whole Process?)

- Day 1 arrive in morning
  - Uncrate generator & sensors
  - Place Fans & Humidifiers
  - Run injection tubing
  - Run sample tubing
  - Seal all entry /exit areas
  - Place signage
- Day 2 arrive in morning

Start RH humidification	9:00am
Start CD gassing	9:50am
Reach minimum target (3mg/L)	12:45pm
Maintain / increase / hold	5:30 pm
Aerate start	5:30 pm
Finish Decon, Safe to enter	7:45pm

- Day 3 arrive in morning
  - Clear area (less than 0.1ppm)
  - Remove equipment and re-crate

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CD Gas Generation Technology

$Cl_{2(g)} + 2NaClO_{2(s)} \longrightarrow 2ClO_{2(g)} + 2NaCl_{(s)}$

- Performed in solid phase (no liquids)
- Gas generated on demand
- Gas generated at 100mg/L (36,200 ppm)
- Use concentration 0.1mg/L – 100mg/L
- Easily scalable to ANY volume
- Simple to replace consumables
- Small, Medium and Large portable generators

- Photometric measurement of concentration at multiple points
- Real Time
- Repeatable
- Accurate
- US-EPA Validated Measurement

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Injection and Sample Points

Sample Point #	12 Sample Point Location
1	Inside room 109
2	Inside room 110
3	Inside room 113
4	Inside room 117
5	Inside room 120
6	Inside room 104
7	Inside room 102
10	Inside room 115
14	Inside room 114
15	Inside room 117
16	Inside a HVAC return vent in room 115
17	Inside a HVAC supply vent in room 103

24 Injection Points
3 Injects inside room 109
Inside room 112
3 injects inside room 117
2 injects inside room 114
Inside room 115
Inside room 116
2 injects inside room 111
2 injects inside room 130
Inside room 103
In-between rooms 118 and 119
Inside room 121
Inside room 103A
Inside room 103
Inside room 107
Inside room 102
Inside room 128
Inside room 123

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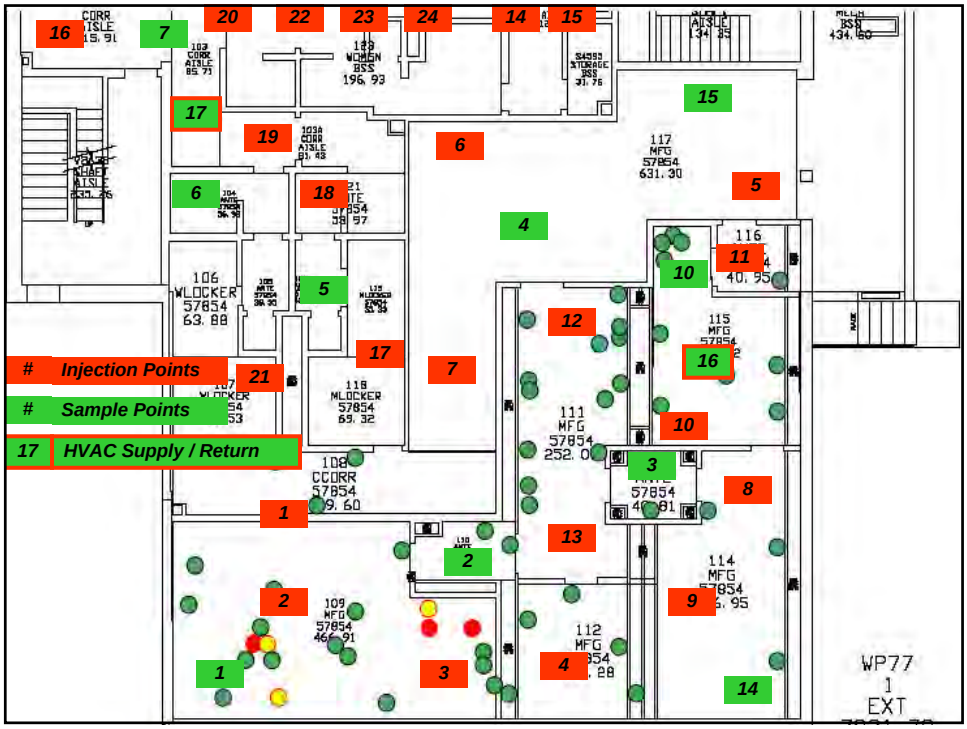
Mark Czarneski
ClorDiSys Solutions, Inc



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Readings in mg/L

Time	SP#1	SP#2	SP#3	SP#4	SP#5	SP#6	SP#7	SP#10	SP#14	SP#15	SP#16	SP#17
10:50 AM	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
11:15 AM	0.5	0.5	0.6	0.5	0.2	0.2	0.5	0.1	0.8	0.7	0.7	0.4
11:45 AM	1.8	1.8	2.1	1.9	1.9	1.9	1.8	0.9	2.0	1.9	1.9	1.6
12:15 PM	2.8	2.9	2.8	3.0	3.0	3.0	2.8	1.9	2.8	2.7	2.6	2.5
12:45 PM	3.4	3.3	3.6	3.4	3.4	3.4	3.1	2.3	3.4	3.2	3.3	2.5
1:15 PM	3.9	3.9	3.9	3.9	3.9	3.9	3.5	2.9	3.4	3.4	3.2	3.3
1:45 PM	4.2	4.2	4.3	4.1	4.1	4.2	3.6	3.0	4.2	3.7	3.7	3.6
2:15 PM	4.5	4.6	4.6	4.3	4.3	4.4	4.0	3.4	4.3	4.1	3.7	4.1
2:45 PM	5.0	4.9	5.4	4.6	4.6	4.8	4.1	4.8	5.0	4.5	5.0	4.5
3:15 PM	5.0	4.9	5.1	4.8	4.6	4.7	4.2	4.3	5.0	4.6	4.8	4.4
3:45 PM	5.0	5.0	5.2	4.8	4.6	4.8	4.2	4.0	5.0	4.5	4.6	4.6
4:15 PM	5.1	5.1	5.1	4.5	4.6	4.5	4.1	3.9	4.8	4.1	4.1	4.5
4:45 PM	5.1	5.1	5.2	4.5	4.6	5.0	4.2	3.9	5.2	4.2	4.5	4.7
5:15 PM	4.9	4.9	5.0	4.2	4.4	5.0	4.2	4.0	5.2	4.0	4.5	4.7
5:30 PM	4.7	4.7	4.8	3.9	4.2	4.9	4.1	4.1	5.1	3.7	4.5	4.7
5:45 PM	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
6:15 PM	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
6:45 PM	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0

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Reading in PPM-Hrs

Time	SP#1	SP#2	SP#3	SP#4	SP#5	SP#6	SP#7	SP#10	SP#14	SP#15	SP#16	SP#17
11:15 AM	45.3	45.3	54.3	45.3	18.1	18.1	45.3	9.1	72.4	63.4	63.4	36.2
11:45 AM	208.2	208.2	244.4	217.2	190.1	190.1	208.2	90.5	253.4	235.3	235.3	181.0
12:15 PM	416.3	425.4	443.5	443.5	443.5	443.5	416.3	253.4	434.4	416.3	407.3	371.1
12:45 PM	561.1	561.1	579.2	579.2	579.2	579.2	534.0	380.1	561.1	534.0	534.0	452.5
1:15 PM	660.7	651.6	678.8	660.7	660.7	660.7	597.3	470.6	615.4	597.3	588.3	524.9
1:45 PM	733.1	733.1	742.1	724.0	724.0	733.1	642.6	534.0	687.8	642.6	624.5	624.5
2:15 PM	787.4	796.4	805.5	760.2	760.2	778.3	687.8	579.2	769.3	705.9	669.7	696.9
2:45 PM	859.8	859.8	905.0	805.5	805.5	832.6	733.1	742.1	841.7	778.3	787.4	778.3
3:15 PM	905.0	886.9	950.3	850.7	832.6	859.8	751.2	823.6	905.0	823.6	886.9	805.5
3:45 PM	905.0	896.0	932.2	868.8	832.6	859.8	760.2	751.2	905.0	823.6	850.7	814.5
4:15 PM	914.1	914.1	932.2	841.7	832.6	841.7	751.2	715.0	886.9	778.3	787.4	823.6
4:45 PM	923.1	923.1	932.2	814.5	832.6	859.8	751.2	705.9	905.0	751.2	778.3	832.6
5:15 PM	905.0	905.0	923.1	787.4	814.5	905.0	760.2	715.0	941.2	742.1	814.5	850.7
5:30 PM	868.8	868.8	886.9	733.1	778.3	896.0	751.2	733.1	932.2	696.9	814.5	850.7
5:45 PM	425.4	425.4	434.4	353.0	380.1	443.5	371.1	371.1	461.6	334.9	407.3	425.4
6:15 PM	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
6:45 PM	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
7:15 PM	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
7:45 PM	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Total PPM-hrs	10117.9	10099.8	10443.7	9484.4	9484.4	9900.7	8760.4	7873.5	10172.2	8923.3	9249.1	9068.1

9465 average ppm-hrs

Highest Exposure time

Lowest Exposure time, this sets overall exposure time

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Concerns During the Process

- **Reaching all areas of HVAC supply and exhaust**
  - **Bumped HVAC blower every 30-60 minutes**
- **Leakage in HVAC room**
- **Room 117 (raw concrete and untreated surfaces)**

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Conclusions

- No physical residue observed
- Had Leakage from HVAC units to HVAC room
- No visible indication of material degradation on any electronics
- No affects to HVAC system (blowers, condenser coils, heating elements, control dampers, duct work material, diffusers, duct mounted smoke detectors)
- Had some material corrosion (some scissors & tape dispenser)
- Medium Chlorine Dioxide Concentrations
  - Average concentration 3-5mg/L (3200 – 1800 ppm)
- 7873 Lowest PPM-Hrs
- 10,443 Highest PPM-Hrs
- 9465 Average PPM-HRs

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ClorDiSys

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Revision Date: March 30, 2010

18

Source Reduction Following the 2001 Anthrax Attacks: Lessons Learned

Dorothy Canter, Dorothy Canter Consulting LLC

Source Reduction Following 2001 Anthrax Attacks: Lessons Learned

EPA Decontamination Research and Development Conference

April 13, 2010

Raleigh Durham Airport, NC

Dorothy A. Canter, PhD
Carlton Kempter
Richard Rupert

Overview

- Background on source reduction
- Source reduction at four facilities following 2001 anthrax attacks
- Comparison of processes at facilities
- Lessons learned

Source Reduction

- Source reduction is the process for decreasing the amount of contamination in a facility prior to main decontamination activities
- Goals of source reduction are to:*
  - reduce the number of items and/or materials present
  - ensure that any matter that might inhibit decontamination is removed, and
  - generally reduce the levels of contaminant that may be present

***DHS-EPA. 2009. "Planning Guidance for Recovery Following Biological Incidents." p. 101.**

Source Reduction

Main Activities

- Removal and off-site treatment of essential items for eventual re-use by owners
- Removal of non-essential items for ultimate off-site treatment/disposal either as waste or through re-cycling
- Pretreatment of identified hot spots within facility

Determining Extent of Source Reduction Activities

Key factors

- Degree of contamination in specific areas of facility
- Amount of materials within contaminated areas needing removal
  - Essential items
  - Non-essential items that may decrease effectiveness of decontamination activities (e.g., porous materials)
- Nature and degree of remediation to be performed
- Resources/time frame allotted for cleanup

Essential Items

Examples

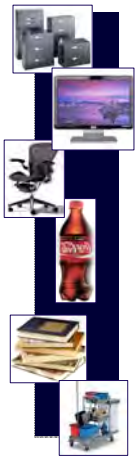
- Irreplaceable electronic files stored only in contaminated facility
- Irreplaceable documents
- Items of significant historic or monetary value
- High value works of art
- Designated personal property
- Certain vehicles

Non-essential Items

Examples

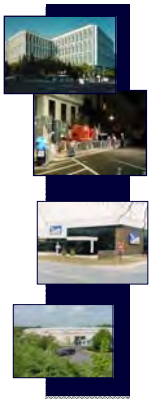
- Recyclable (e.g., metal items, batteries, fluorescent lights)
- Non-recyclable
  - Site debris (includes items selected on basis of cost/benefit analysis)

    Office equipment, furnishings, carpeting, tools, books/catalogues, foodstuffs, janitorial supplies, etc.
  - Industrial chemicals



Source Reduction Activities at Four Facilities with Fumigations

- Capitol Hill Anthrax Site
- US Department of Justice (DOJ) Mail Facility
- US Postal Service (USPS) Trenton Processing & Distribution Center (P&DC)
- US Department of State (DOS) Mail Facility



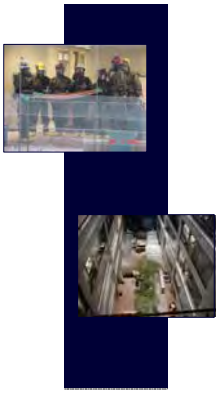
Fumigations were performed in all four facilities but differed in extent, fumigant used, approach to conducting fumigations

Capitol Hill Anthrax Site

- Essential items
  - Items critical to Congressional business operations, personal items of significance (self-selected)
    - Treatment: Off-site in ethylene oxide (EtO) sterilization chamber
    - Amount: 3250 bags
    - Cost: ~784K
    - Duration: ~10 weeks
  - Packages, private mail (e.g., FedEx) large office items, mail equipment, etc.
    - Treatment: Off-site in trailer using chlorine dioxide fumigation
    - Amount: 4300 packages
    - Cost: ~ $615K
    - Duration: 6-7 weeks

Capitol Hill Anthrax Site

- Essential items (continued)
  - High value artwork
    - Treatment: hand cleaned, HEPA-vacuumed, cleared by environmental sampling
  - Drummed mail
    - Sent to US Postal Service facility in Lima, OH, for irradiation
  - Vehicles
    - HEPA-vacuumed, then treated with bleach solution



Capitol Hill Anthrax Site

- Non-essential items
  - Debris/solid waste, PPE, decontamination water
  - Treatment

    Fort Detrick military base (under special exemption from State of MD)

    Medical waste incineration (most items)/municipal waste incineration (large objects, PVC-containing materials) -- 300,000 lbs

    Wastewater treatment followed by steam sterilization of decontamination water

    Cost: $127K (treatment plus transport costs)

    Commercial medical waste incineration at facility in VA (mainly furniture) – 300 cu. yds.

    Steam sterilization of metal items at FL facility followed by recycling

DOJ Mail Facility

- Essential items
  - FOIA documents, certified mail receipts, CFRs, computer disks, notebooks, rubber stamp inserts for Omation machine
  - Treatment: Off-site in EtO sterilization chamber
  - Amount: 12 Gaylord boxes
- Non-essential items
  - Porous items (mainly paper, but also modular work stations and furniture)
  - Off-site medical waste incineration
  - Amount: 5 truckloads
- Duration: 1.5 mos. (entire remediation took 2.5 mos.)
- Total cost: $120K ($464K for entire cleanup)

USPS Trenton P&DC

- Materials for re-use (mail, personnel items) sent off-site for ion beam or gamma irradiation
  - Did not use EtO sterilization process
- PPE and items sent for off-site treatment in
  - Medical waste incinerator (preferred)
  - Autoclave
- Large metal soffit panels under roof removed prior to fumigation process sent to hazardous waste landfill
- Cost and duration data not available

DOS Mail Facility

- Nearly all materials, including HVAC system, removed from facility prior to fumigation with vaporized hydrogen peroxide
  - Decision following cost-benefit analysis of treatment options
- Surfaces of large fixed items and interior of facility then pre-treated prior to fumigation
- Five different decontamination technologies used for removed essential and non-essential items
- Duration: 9 mos. (16 mos. for entire remediation)
- Cost: $4.3M ($8.6M for entire cleanup)

Disposition of Items Removed from DOS Mail Facility

Item				Decontamination Technology	Final Disposition
Type	Category	Subcategory	Description		
Essential	Irreplaceable documents, diplomatic mail pouches			Treatment in ethylene oxide sterilization chamber	Returned for reuse
Nonessential	Recyclable items	Metal items	Carts, HVAC components, machines, piping, files systems, desks		Recycling facilities
		Universal wastes	Batteries, fluorescent lights	On-site treatment with SporKlenz®, environmental sampling	
	Non-recyclable Items	Industrial chemicals	Paraformaldehyde, flammable liquids (hazardous waste)	Hazardous waste incineration	Subtitle C landfill
			Ammonium bicarbonate, ethylene glycol (non-hazardous waste)		
		Site debris	Small items (PPE, wood, paper, computers)	Medical waste incineration	Subtitle D landfill
			Large items (insulation, furniture, carpeting)	Steam sterilization	

Comparison of Source Reduction Activities

Process	Capitol Hill Anthrax Site	DOJ mail facility	Trenton P&DC	DOS mail facility
Off-site irradiation	+		+	
Off-site EtO sterilization	+	+		+
Off-site chlorine dioxide fumigation	+			
On-site decontamination followed by clearance environmental sampling	+			+
Medical waste incineration	+	+	+	+
Municipal waste incineration	+			
Steam sterilization	+			+
Hazardous waste incineration				+
On-site pretreatment/placement in hazardous waste landfill			+	
Cost	>$1.53M	$120K	NA	$4.3M

Lessons Learned from 2001 Anthrax Attacks

- Source reduction is often a very time-consuming process
- Need for stringent consensus definition for essential items, including exhaustive list of non-essential items
  - Important and highly cost-effective preparedness activity
- Need for consistent plans for essential item identification, removal, treatment and return as separate mission within overall remediation process
  - Important to take needed time to do it right
  - Value in having independent quality control contractor perform essential item inventory

Lessons Learned from 2001 Anthrax Attacks

- Key role of electronic data management in addressing essential items
  - Photographing, tagging/bagging, tracking, returning items
  - Positioning of biological indicators in containers undergoing EtO sterilization and results from their culture after treatment
- Need for increased supervision of, and coordination among, teams performing source reduction activities
- Requirement to transport all items (essential and non-essential) removed from site in compliance with DOT requirements

Ultimate Lesson Learned

Limit Removal of Non-Essential Items Prior to Main Decontamination Process

(Optimum decontamination approach will significantly reduce extent/duration of source reduction)

Special Thanks

Richard Orlusky, US Postal Service
Thomas Sgroi, US Department of State

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Questions?

An Overview of the Chemical Restoration Operational Technology Demonstration (OTD) Project

Mark D. Tucker, Sandia National Laboratories

Presentation not available for distribution

Two Recent Proof of Principal Tests of Deployable Countermeasures to Support Recovery of Critical Mass Transit Facilities

Robert Fischer, Lawrence Livermore National Laboratory

LLNL-PRES-427147

Lawrence Livermore National Laboratory

Two Recent Proof of Principle Tests of Deployable Countermeasures to Support Recovery of Critical Mass Transit Facilities

April 13, 2010

2010 US EPA Decontamination

Research and Development Conference

Robert Fischer (LLNL), Annmarie Wood-Zika (LLNL), Dr. Charles Burrus (NYCT), Michael Gemelli (NYCT) Michael Metz (NYCT), Anne Kirsch (MNR), William Welch (MNR), Igor Grahovac (DOHMH)

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  - New York City Transit
    - Department of Security
    - NYCT WMD HazMat Team
- Vendors
  - InstaCote Inc.
  - CT Packaging Systems Inc.

The Subway Safety Initiative Project Mission – Rapid Return to Service

- Actions to be taken to prevent the spread of contamination
- Identification of methods to isolate sections of the transit system to contain the spread of contaminants
- Identification of process to install barriers and filtration systems
- Identification and evaluation of tunnel sealing devices
- Offsite locations for the decontamination of equipment
- Recommendations for first responder actions that will speed the recovery process

Provide MTA the information, plans, and equipment recommendations to help ensure a rapid return to service of the NYC metropolitan region transportation network

Subway Safety Initiative – Proof of Principle Demonstrations

Metro-North Railroad

Rolling Stock Stabilization

New York City Transit

NYCT Tunnel Barrier Installation

Train car stabilization proof of principle test

Metro-North Railroad

- Test was conducted on June 25th and 26th, 2009
- Participants: LLNL, MNR RESORT, Vendor Reps
- Location: Stamford Rail Maintenance Facility
- Primary Objectives:
  - Test ability to wrap a rail car in shrinkable plastic for transportation to a designated recovery facility
  - Demonstrate qualitatively the efficacy of two stabilization techniques
- Motivation:
  - The remediation of contaminated and potentially contaminated rolling stock is an important aspect of transit agency return to service strategy

Metro North Railroad

- MNR is the second largest regional railroad in the U.S.
- Daily ridership of 281,000
- Grand Central Terminal is the destination of more than 80% of all passengers
- 1,229 rail cars
- 120 stations
- 384 route miles

Metro North RESORT Team

Metro-North Railroad

Railroad
Equipment
Specialized
Onsite
Response
Technicians

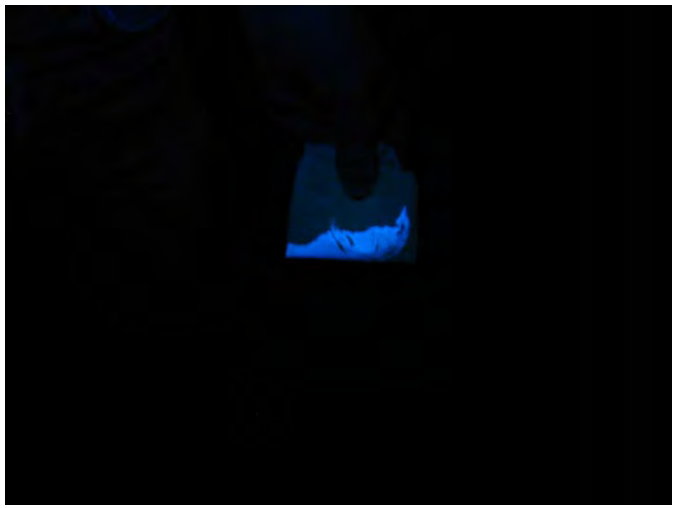
- An integral part of the test was to use MNR response personnel
- The RESORT Team is comprised of MNR volunteers that have specialized knowledge to secure and shutdown critical MNR equipment and facilities
- Team is trained to perform operations in a variety of hazardous environments

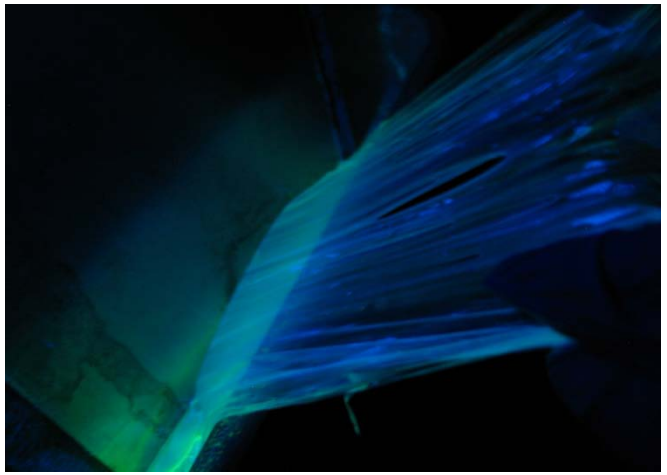
Two stabilization agents were selected for testing

- InstaCote – CC Wet
  - Non permanent wetting agent designed to stabilize particulate contamination
- InstaCote – CC Strip
  - A vinyl acrylic latex strippable coating
  - Designed to be used alone or in combination with CC Wet

UV active contamination simulation powders were used to evaluate effectiveness of stabilization techniques

- Two types of UV active contamination simulation powders manufactured by Risk Reactor were used
  - PDT-06 - larger heavier particulate simulant
  - PXT-07 – lighter smaller particulate simulant





Shrink wrap was used to completely encapsulate the rail car

- Commercially available Durashield shrinkable polyethylene sheeting (7 mil)
- Heat sensitive tape for seams
- Purchased in a 40 foot wide 150 foot long roll

Rolling Stock Stabilization: Applied to M-6 Multiple Unit (MU) Rail Car

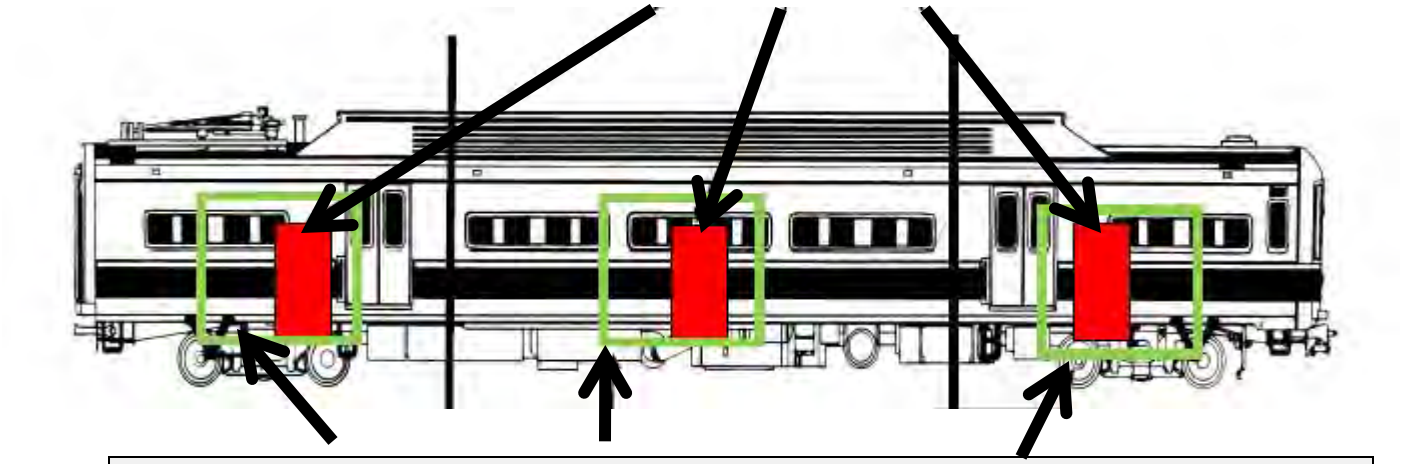
- Used on MNR New Haven Line
- 48 in use
- Manufactured in1993
- Middle car selected because pantograph expected to create wrapping challenges

Rolling stock stabilization proof of principle process

- Setup contamination surrogate test areas on car
- Apply stabilization agents
- Wrap car
- Unwrap car
- Evaluate stabilization agent effectiveness
- Remove stabilization
- “Survey”/inspect surfaces and surrounding areas

Contamination simulation zones– side to be stabilized

Contamination Areas (red)



Target area for application of stabilization agents (green)

Zone 1	Zone 2	Zone 3
CC Wet	CC Wet 1st Followed by CC Strip	CC Strip

Applying contamination simulant to rail car for stabilization tests

Zone # 3

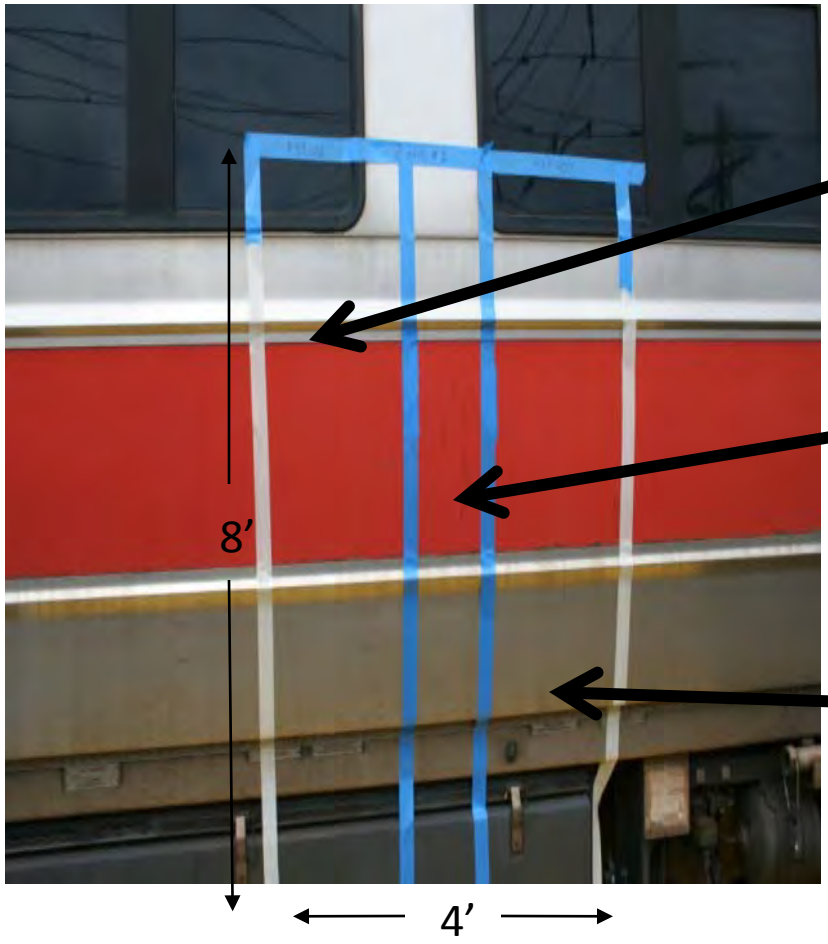
Zone # 2

Zone # 1 Behind Plastic Tarp (not shown)

Contamination Control Plastic

Simulant was brushed on to car surface

Contamination zones were created to test a variety of surfaces and two different simulants

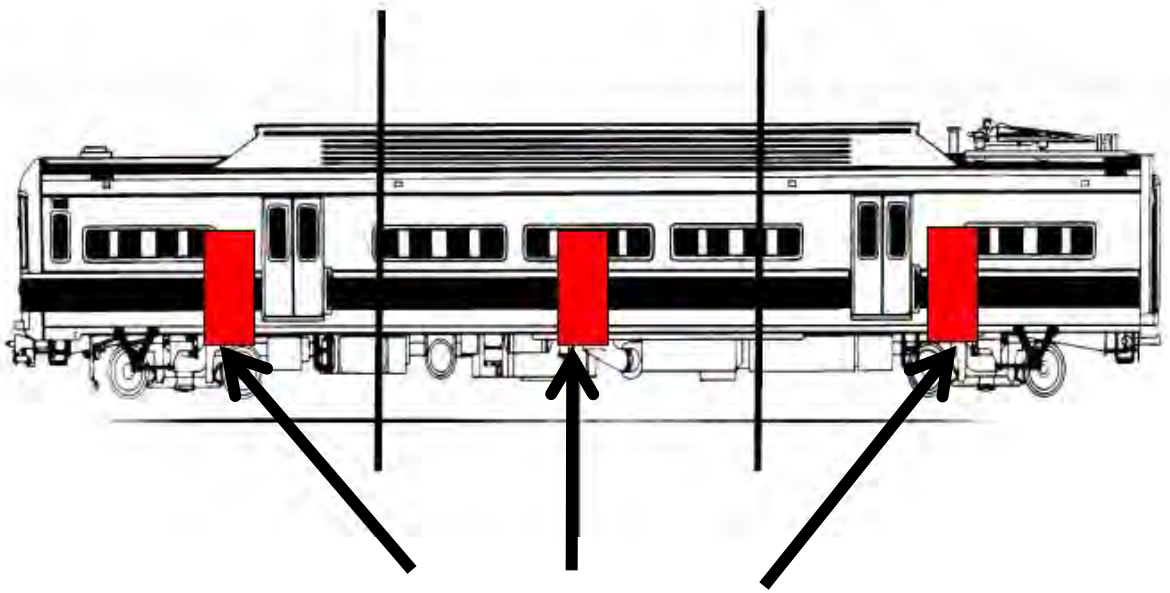


PXT-07 contamination simulant applied

Buffer area no simulant applied

PDT-06 contamination simulant applied

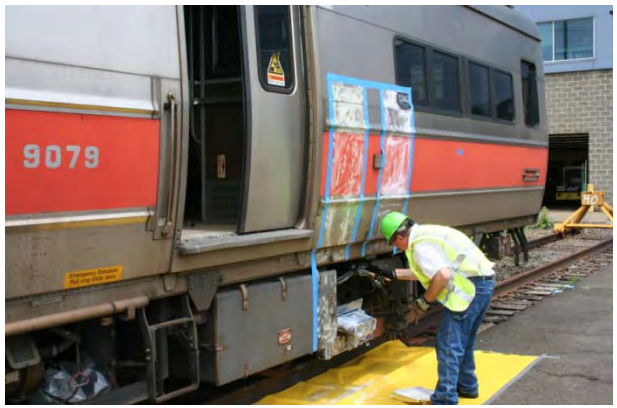
Contamination simulation zones (untreated side) no stabilization agents to be applied

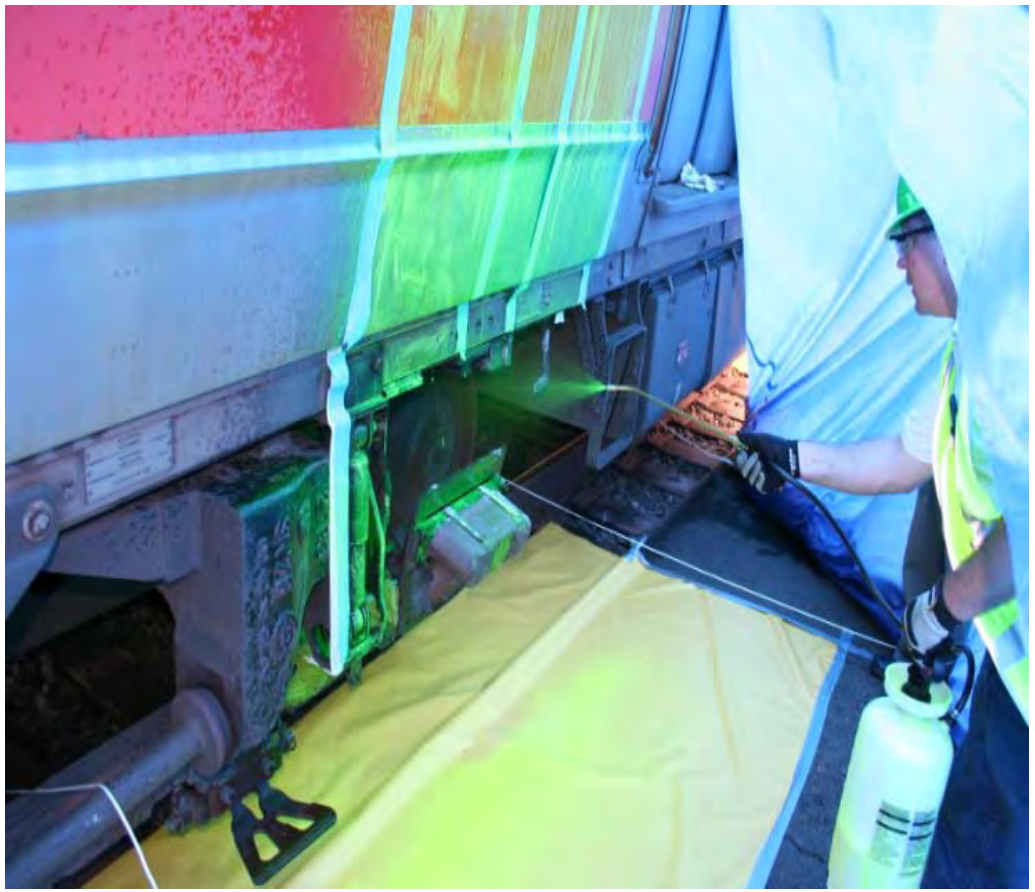


Contamination simulation powder applied to three areas of roughly the same dimension and location as the treated side of car

Application of Stripcoat (CC Strip) and Wetting Agent (CC Wet)

Application of Stripcoat





Application of Wetting Agent

Wrapping process

Layout of wrap

Placement of Guides

Lifting wrap into place

Securing wrap on far side of car

Wrapping process - continued

Covering car

Securing with strapping

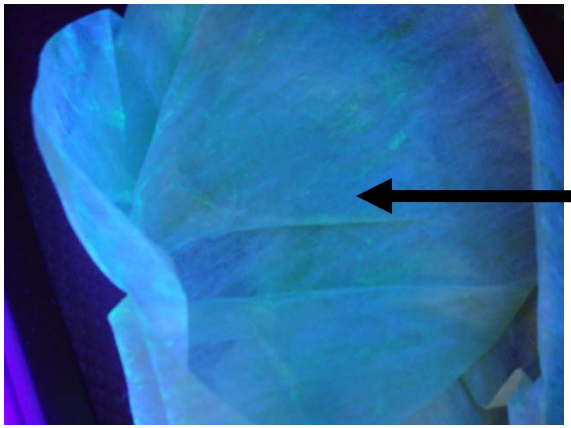
Securing ends

Using propane heat gun to seal seams

Wrapping process - completed

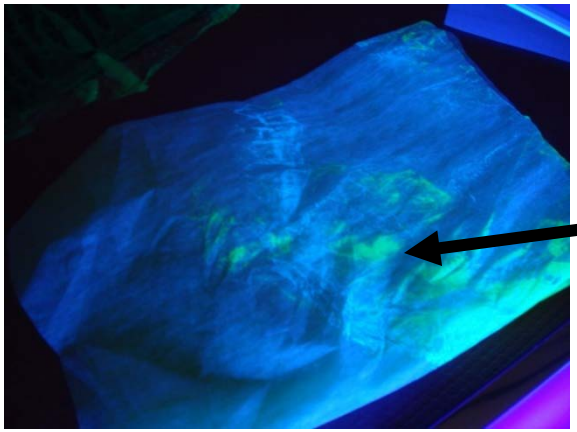
Stabilization techniques significantly reduced contaminant transfer

Zone 1 (Treated Side) interior plastic surface wipe



Very little simulant transfer observed on plastic from treated side of car

Zone 4 (Untreated Side) interior plastic surface wipe

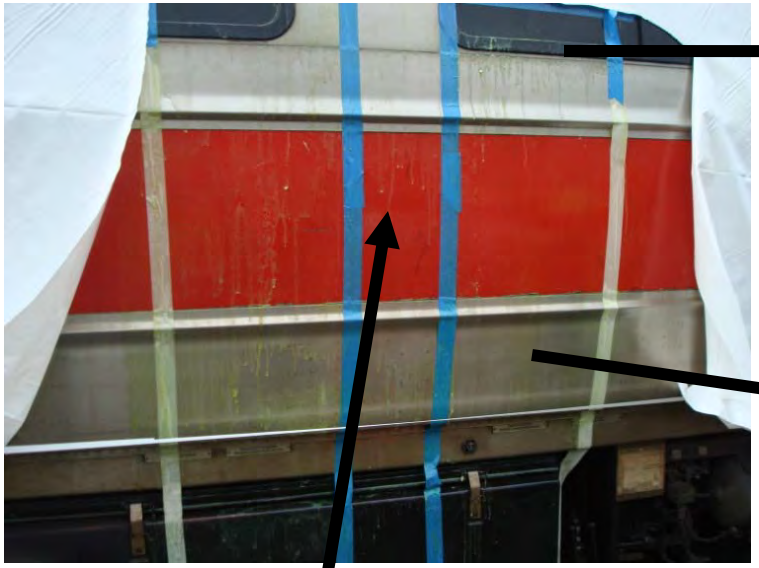


Substantial simulant transfer from surface of car to plastic on untreated side of car

Test methods

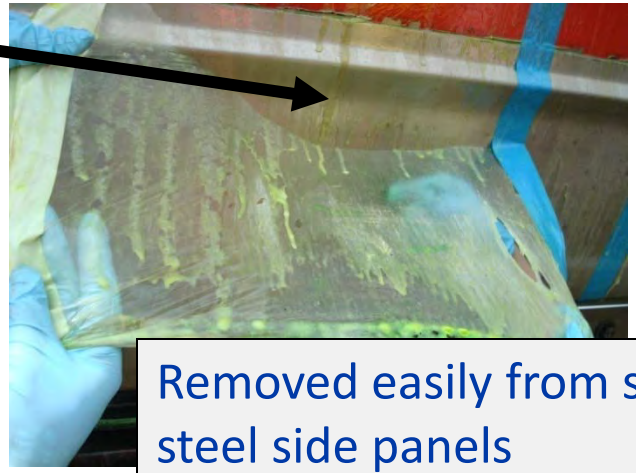
- **Swipes from inside of plastic wrap (shown)**
- **Vibration test**
- **Large area wipes from plastic sheeting**

Car surface materials interacted differently with strippable coating



The stripcoat adhered tenaciously to the red panel

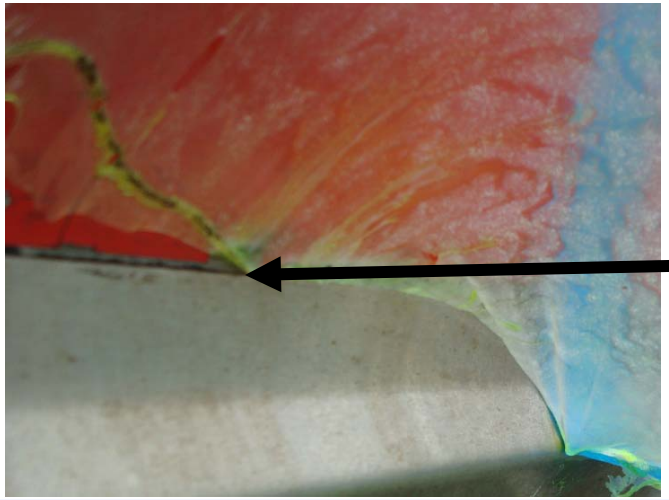
Difficult to remove from window gasket



Removed easily from stainless steel side panels

Pre-treatment had a positive affect on removal efficiencies

In area without pretreatment (zone 1) a substantial amount of simulant was observed in joint area after removal of stripcoat



Pretreatment with CC Wet resulted in a complete removal of strip coat (and simulant) from joint in zone 2 without tearing

Rolling stock stabilization proof of principle conclusions

- Shrink wrapping a rail car appears to be feasible
- Application of fixative prior to wrapping greatly reduces the potential for contamination to migrate
- Strippable coating behaved differently on various surfaces
- Strippable coatings used with wetting agents showed better coverage and penetration of cracks and crevices
- Use of UV active simulants as contamination surrogates was useful determining effectiveness of stabilization agents

Tunnel barrier deployment proof of principle test

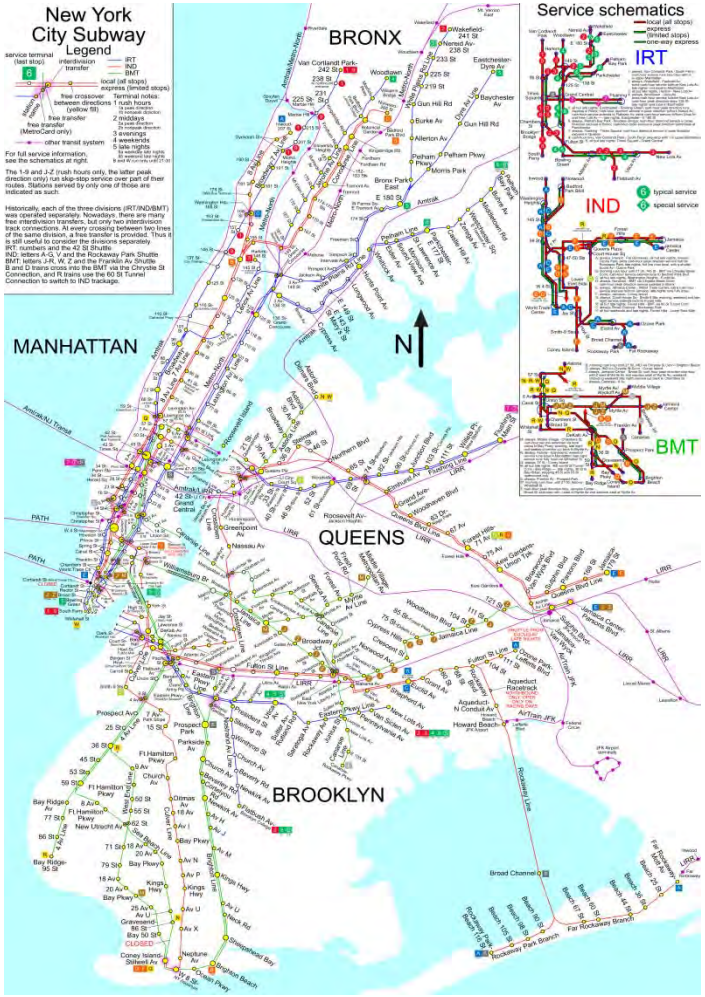
New York City Transit

- Test was conducted on August 5th, 2009
- Participants: LLNL, NYCT WMD HazMat Team
- Location: NYCT Ninth Ave Station
- Primary Objectives:
  - Construct a plastic contamination control barrier in NYCT tunnel utilizing readily/commonly available materials
  - Test the efficacy of the constructed barrier
- Motivation:
  - Post event achievement of positive contamination control will be required prior to restart of transit operations

The New York City Subway System

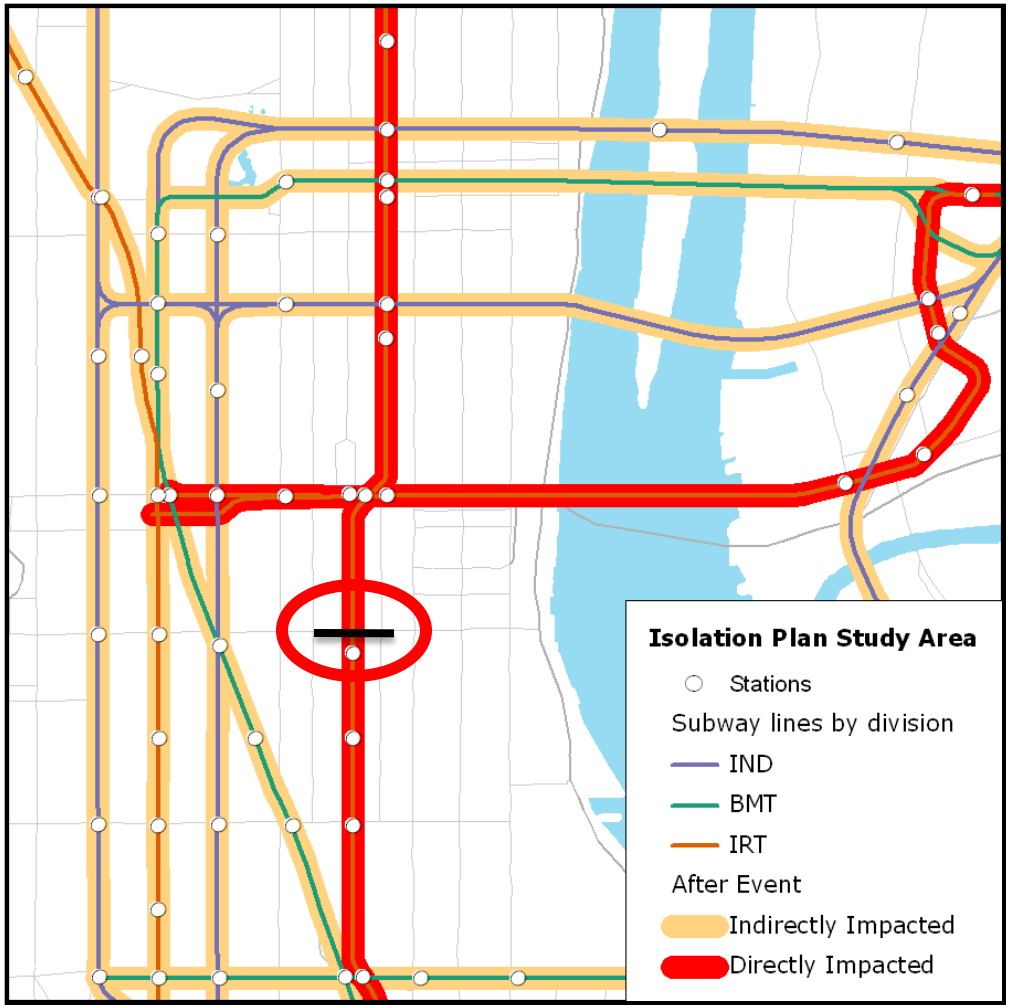
New York City Transit

- World's 4th largest subway system
- Average daily ridership of 5.2 million
- 6,400 subway cars
- 26 service lines run over 600 miles of track
- 468 stations
- Operates 24/7-365



NYCT barrier placements to mitigate further system contamination

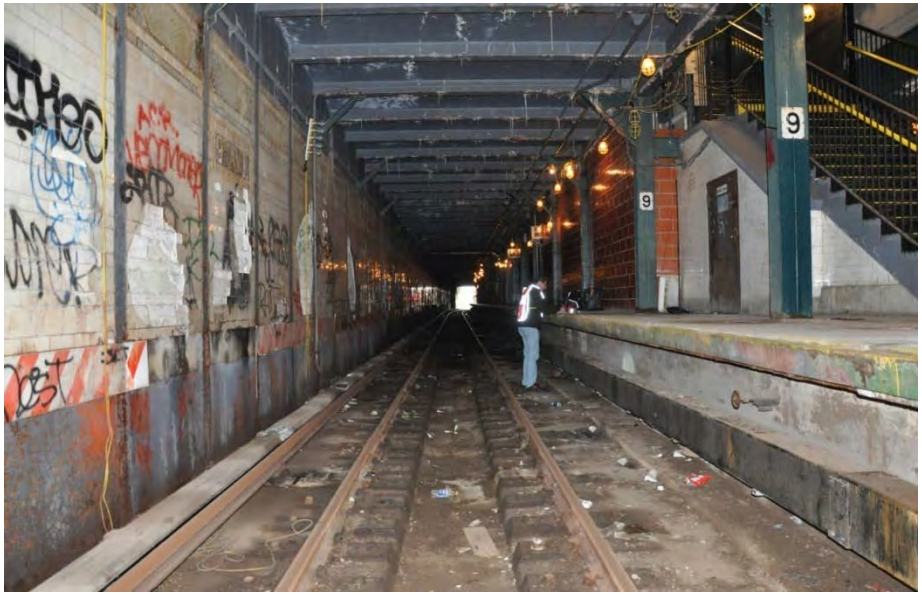
- Strategically placing barriers in tunnels to prevent the spread of contamination or to isolate parts of the system
- Place tunnel barriers at key locations on directly impacted lines
- Locations pre-selected



NYCT WMD HazMat Team

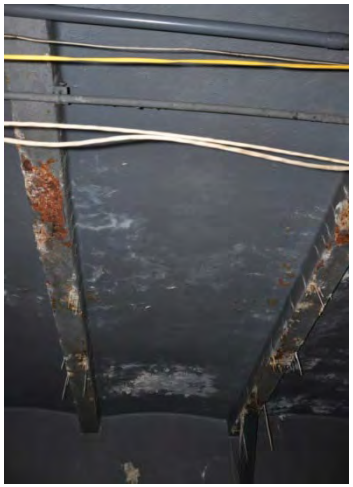
- Comprised of more than 100 volunteers from several departments within NYCT
- Trained to respond to WMD events that may impact the NYCT system
- Team members receive extensive training in hazardous materials response
- Participate in frequent drills and exercises

A station no longer used for passenger service was selected as the test site (NYCT 9th Avenue Station)



- Single track
- Construct two barriers approximately 15 ft. apart
- After construction the space between the barriers was to be pressurized and filled with smoke
- Differential pressure to be measured

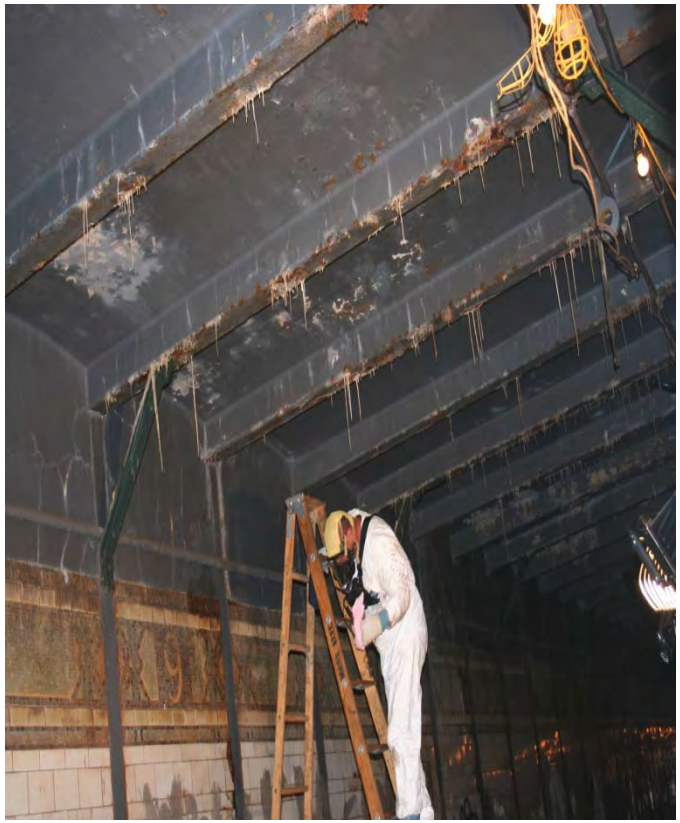
Location specific challenges typical of NYCT tunnels



- Multiple utility lines
- Third rail
- Roadbed
- Cableways
- Less than pristine conditions
- For safety reasons no wall penetrations allowed (Test Constraint)

In a subway environment the preparation of surfaces proved to be extremely important

- Walls cleared of any large debris
- Cleaning solution applied to surfaces
- Grime and particles made it challenging to get an effective bond with the tape
- A tape seal applied to the walls



The interface between the barrier and roadbed is a key sealing point

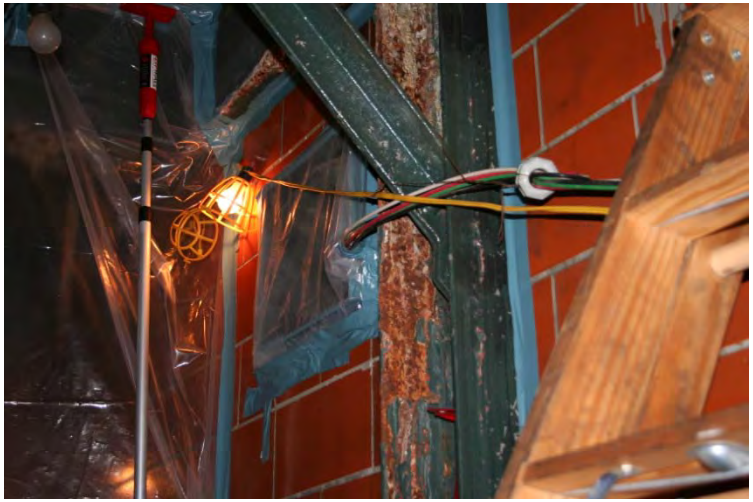
- A major challenge was creating a base for the barrier where it intersected with the road bed
- A wood foundation was constructed to create the base for the barrier to be attached
- NYCT Hazmat crews displayed amazing ingenuity and creativity in solving this complicated problem

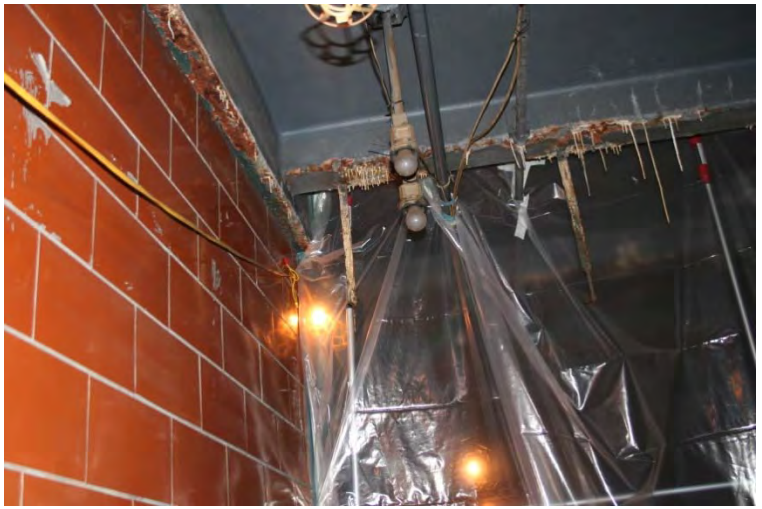
Creating a temporary support structure to span the width of the track

- The wall had to span a distance of about 15 feet wide by a height of 16 feet
- To provide a readily adaptable wall support zip poles were used
- This technique is widely used in the asbestos abatement industry

Subway tunnels contain a wide variety of utility conduits

- A variety of utilities pass through tunnel areas
- Ventilation pathways must also be sealed
- An effective barrier needs to allow for multiple penetrations
- Creating an effective seal in these conditions can be challenging





All primary sealing surfaces were checked and reinforced

- Expanding foam was added to any open space
- All equipment removed

In order to establish whether a seal had been established the space between the walls was pressurized

- A smoke generator was placed between the barriers
- A blower was connected to the barrier wall
- A differential pressure gage probe was inserted into the wall
- The smoke generator was turned on and the pressure rise was monitored

Barrier was successfully tested to a differential pressure of .085 column inches (water gauge)

- NYC standard for asbestos containments is -0.02 inches
- The barrier ultimately failed in a location where water was constantly seeping onto a tape seal
- The ability of the barrier to survive pressure changes is critical in the subway environment

NYCT barrier proof of principle conclusions

- Successfully demonstrated that a containment barrier can be placed into an NYCT tunnel
- Long term survivability of barrier not tested
- Total time to build
  - First barrier 3.5 hours
  - Second barrier 2 hours
- Numerous operational improvements were captured
- Additional testing of barriers recommended
  - More complicated tunnel section
  - The use of inflatable barriers

SSI proof of principle conclusions

- Proof of principle demonstrations provide a valuable real world check on remediation techniques
- Great benefit in combining decontamination science with the operational know how possessed by transit agencies
- Fills the gap between science based efficacy testing and operational applicability

Back-up Slides

Untreated side of car was used to compare relative effectiveness of stabilization

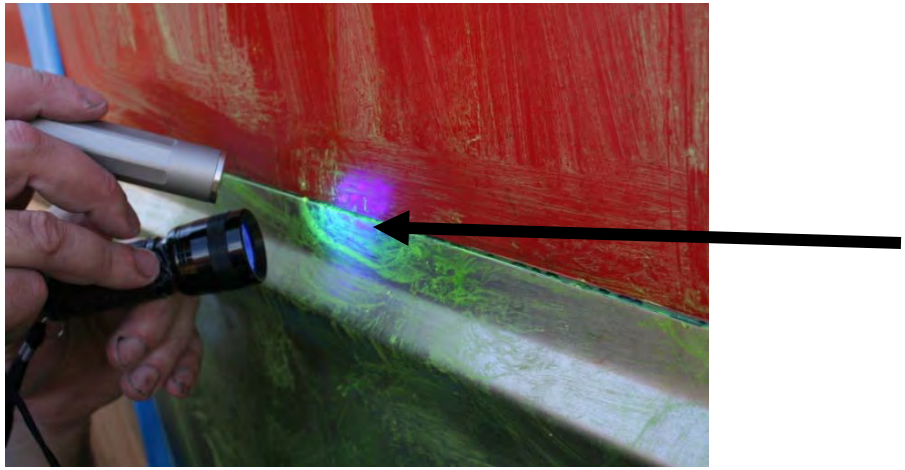
Zone 6

Zone 5

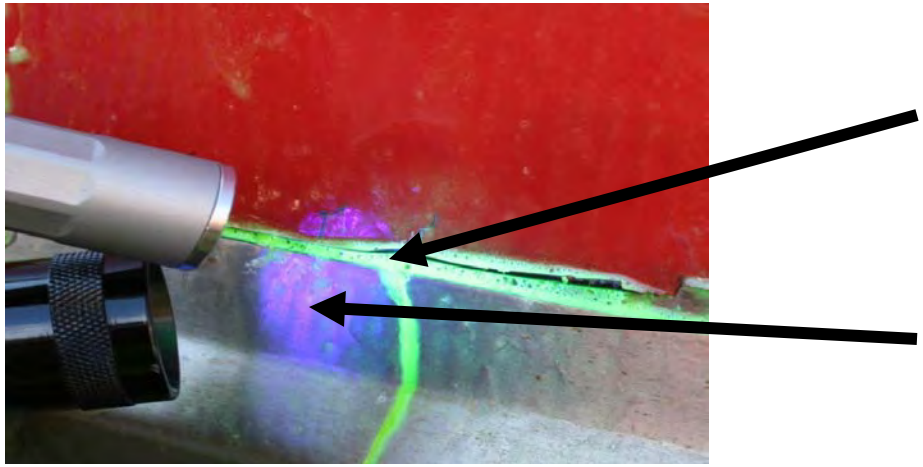
Zone 4

Contamination control plastic removed after application

Two different application techniques were tested and then results were compared



Zone #3 PDT-06 Simulant in interface between painted surface and aluminum after treatment with strip coat
Note incomplete penetration of joint area as compared to wetting agent below



Zone #2 Green color is from dye in wetting agent indicating good penetration in interface region

Simulant PXT-07 showing bright white under UV light

Preparing to shrink wrap car

Plastic sheeting to “catch” contamination resuspended during wrapping exercise

Control swipes taken to monitor migration from target areas

Protecting shrink wrap from tearing during covering

Pantograph down and in locked position

Roof top insulators

Plastic tarp to cover pantograph

Rolling stock stabilization proof of principle conclusions

- Use of UV active contamination simulants
  - Choice of simulant very important
    - One simulant used did not adhere to car body
  - Good for qualitative use only, hard to draw any major efficacy implications without further testing
    - Chemical interaction
    - Concentration used
    - Representativeness to actual contaminant

Barrier construction techniques based on common industry designs for D&D projects

- Since no nailing was allowed focus was on the selection of tapes and glues
- Expanding foam used as sealant
- Telescoping pressure sensitive poles used to form support frame

NYCT barrier proof of principle conclusions

- Additional testing of barriers recommended
  - More complicated tunnel section
  - The use of inflatable barriers
  - Ability to withstand changing pressure gradients over time

- Operational considerations
  - In real emergency tracks may be removed
  - Nailing in walls and ceilings permitted

Bio-Response Operational Testing and Evaluation (BOTE)

Shannon D. Serre, EPA/ORD/NHSRC

EPA United States Environmental Protection Agency

Bio-Response Operational Testing and Evaluation (BOTE)

Shannon D. Serre

April 13, 2010

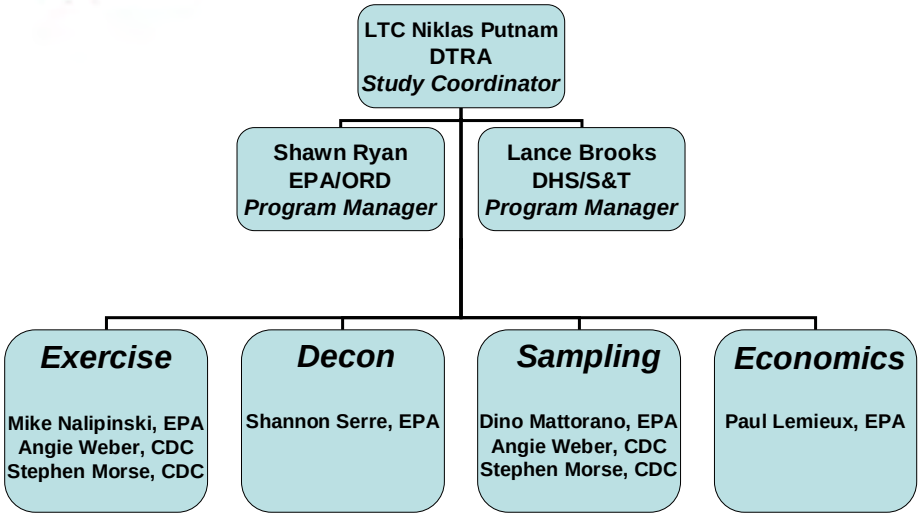
Office of Research and Development
National Homeland Security Research Center, Decontamination and Consequence Management Division

EPA United States Environmental Protection Agency

Collaborators

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

Key Participants

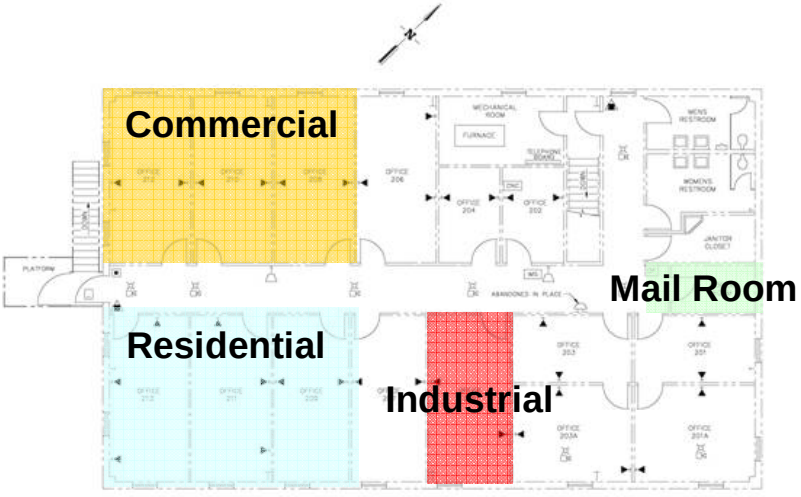


Overall Objective

The overall objective of the ***Bio-Response Operational Testing & Evaluation*** Project is to operationally test and evaluate biological incident response from health/law enforcement response through environmental response (remediation).

INL Facility

Floor Schematic



Decon Assessment Study

Objective

- To conduct and evaluate field-level facility remediation studies of various decontamination technologies/protocols over 3 Rounds.

A Round is defined as:

- –Facility contamination/distribution of spores
- –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

Decon Assessment Study Round 1

Contamination

- First Floor – 10^2 spores/ft^2
- Second Floor – 10^6 spores/ft^2

Round 1 – Medium Tech/Capacity

- Lead time to get supplies
- Specialized equipment and expertise

Decon Assessment Study
Round 2

Contamination
- First Floor – 10^2 spores/ft^2
- Second Floor – 10^6 spores/ft^2

Round 2 – Low Tech/Capacity
- Relatively simple to implement
- Supplies are readily available
- Minimal prep time
- Minimal skill required

Decon Assessment Study
Round 3

Contamination
- First Floor – 10^2 spores/ft^2
- Second Floor – 10^6 spores/ft^2

Round 3 – High Tech/Capacity
- Full facility approach
- Highly specialized equipment and expertise

Waste/Wash Water Decon

- Waste/wash water may be generated
  - –Decon technologies
  - –PPE Decon line
- One or two decontamination methods will be selected and tested
- Test sampling strategies and analysis
- Develop a testing strategy to verify that the water is disinfected prior to disposal
- Generate a lessons learned document on collection, sampling, storing and treatment of the washwater

Post-Test Analysis

- Efficacy of decontamination methods
- Documentation of operational parameters
  - –Time requirements
  - –Labor hours
  - –Waste generation
  - –Adverse impacts on the facility
- Economic Analysis
  - –Capture data from studies
  - –Assessment of cost of application of technology
  - –Estimator for future events

Conclusions

- BOTE exercise will provide:
  - Information on the efficacy of several decontamination methods
  - Information on the time requirements, labor requirements, waste generated, and adverse impacts on the facility
  - 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

National Homeland Security Research Center Water Treatment and Infrastructure Decontamination Research

Scott Minamyer, EPA/ORD/NHSRC

National Homeland Security Research Center

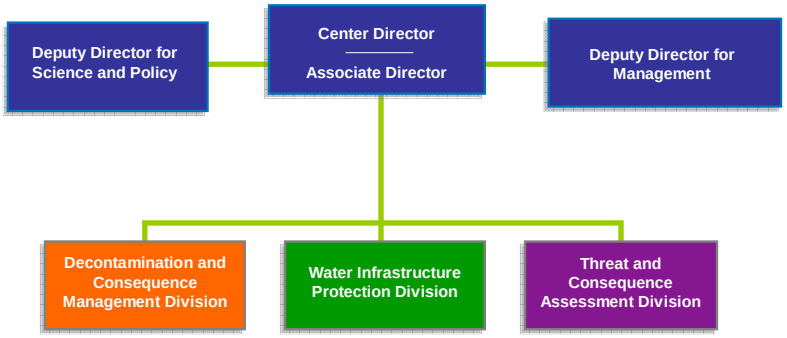
Water Treatment and Infrastructure Decontamination Research

Scott Minamyer, Kim R. Fox, Hiba S. Ernst

US EPA Decontamination Research and Development Conference

April 13, 2010

National Homeland Security Research Center



Science...

- Chemistry/Physical Sciences
- Toxicology/Physiology
- Mathematical Modeling
- Engineering
- Biology/Microbiology
- Radiation Sciences
- Public Health
- Environmental Sciences
- Communication

...Applied to Solve Problems

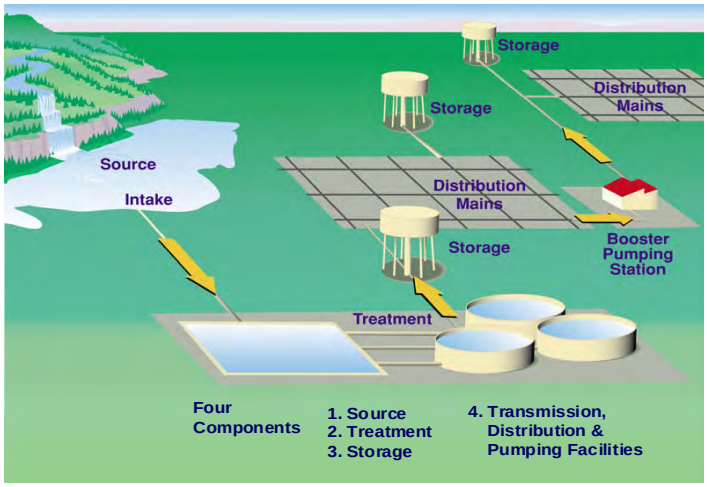
- Water Security
- Detection
- Decontamination
- Disposal
- Exposure Assessment
- Threat and Hazard Assessment
- Risk Assessment/Cleanup Goals
- Analytical and Sampling Methods
- Technology Testing and Evaluation

Cincinnati, OH Research Triangle Park, NC Washington, DC Las Vegas, NV

Water Infrastructure Protection Division

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

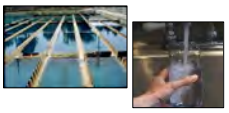
Public Water Systems



Treatment Versus Decontamination

- If a contamination event occurs, it may be necessary to treat water, decontaminate infrastructure, and dispose of wastes/residuals from any response activity

Treatment refers to the removal, inactivation, or destruction of contaminants in water



Decontamination refers to the removal or destruction of residual contaminants adhered to wetted surfaces in the drinking water plant, distribution system, or post-service connections such as building plumbing, water heaters, and filtration devices

Impacts of Contamination Events

- Chemical, biological, or radiological contamination events or attacks on drinking water and wastewater infrastructure could have devastating public health, economic, and social impacts

- Consequences may include denial of water for additional vital services such as firefighting, food preparation, sanitation, agriculture, and industry

Potentially Impacted Resources

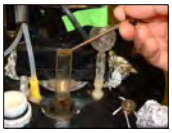
- Introduction of harmful agents into a drinking water distribution system has the potential to contaminate:
  - Drinking water over a relatively large service area
  - Storage tanks
  - Pipes and pumps used to convey the water
  - Service connections to buildings
  - Water-consuming appliances, such as water heaters
- Attacks could also impact drinking water treatment plants, wastewater treatment facilities, and storm and sewer systems

Biofilms and Corrosion

- Complicating decontamination is the propensity of some contaminants to adhere to corroded pipes or biofilms on the pipe walls, potentially prolonging the impact of the contamination by sloughing off into the water over time after the incident

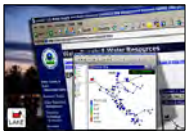
Treatment and Decontamination Research

- Identify which priority chemical, biological, or radiological (CBR) contaminants will attach to wetted surfaces and how they can best be remediated
- Determine the efficacy of typical water infrastructure decontamination technologies to destroy or remove chemical and radiological contaminants
  - Dr. Jeff Szabo Presentation on ***Persistence and Decontamination of Surrogate Radioisotopes from Drinking Water Infrastructure*** (Weds 3:50 PM)
- Determine inactivation and removal capabilities of typical water treatment and disinfection technologies for biological contaminants



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



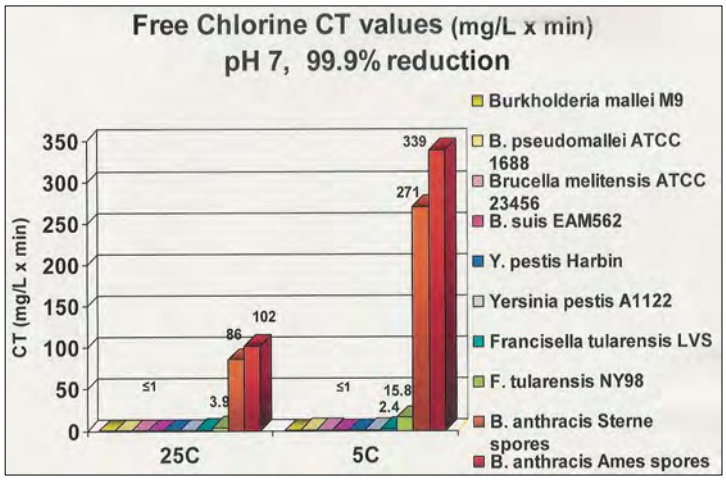
Treatment and Decontamination Research Multi-Year Planning

- For current multi-year planning (next 3-5 years) the Division is considering potential new research to address five areas of need:
  - Agent fate and transport research and modeling
  - Persistence of contaminants on pipes and infrastructure
  - Decontamination and treatment protocols and technologies
  - Appropriate cleanup levels and verification methodologies
  - Treatment/disposal of wastewater associated with the decontamination process

Water Treatment
Inactivation of Bacterial Bioterrorism Agents

- Studies conducted in collaboration with U.S. Centers for Disease Control
- Screening studies of chlorine inactivation:
  - ***Bacillus anthracis***
  - ***Brucella*** spp.
  - ***Burkholderia*** spp.
  - ***Francisella tularensis***
  - ***Yersinia pestis***
- Studies on the effect of strain variability on resistance to chlorination:
  - ***Burkholderia pseudomallei***
  - ***Francisella tularensis***

Inactivation of Bacterial Bioterrorism Agents Cont.



Chlorine Inactivation of Anthrax Spores in Decontamination Wash Water

- Bench-scale study to determine the effectiveness of chlorine to inactivate ***anthrax*** spores in wash water generated during building decontamination activities
- The National Response Team has recommended a procedure for the chlorine treatment of wash water containing ***anthrax*** spores:
  - Bleach and vinegar at doses resulting in a solution containing 1% hypochlorite and having a pH of 7
  - The procedure was established based on results of previous studies using distilled water
  - Wash water represents a different matrix for which the effectiveness of chlorine is not well known

Chlorine Inactivation of Anthrax Spores in Decontamination Wash Water Cont.

- Wash water may contain components that increase chlorine demand--impacting the inactivation of ***B. anthracis*** spores
  - For previous incidents and in some locations, wastewater treatment plants would not accept the wash water even after treatment
- Inactivation study will be conducted using wash water that represents incident cleanup activities
- Will be field-tested as part of the BOTE Project

Pilot-scale Adherence and Decontamination Study

- Pilot-scale evaluations conducted at the EPA Test and Evaluation Facility in Cincinnati
- Tested adherence and various decontamination approaches for five contaminants (arsenic, mercury, ***Bacillus subtilis,*** diesel fuel, and chlordane)
- Cement-lined ductile iron pipe coupons
  - With and without biofilm
- Various flow rates and parameters
- All tested contaminants have a strong tendency to adhere to cement-lined ductile iron pipe surfaces

Pilot-scale Adherence and Decontamination Study Results

Contaminants	Decontamination Method	Decontamination Efficiency	Qualitative Performance Rating
Arsenic	Water flushing	-7 – 51%	Average
	Low pH	6 – 36%	Average
	Phosphate buffer	-24 – -16%	Poor
	Acidified potassium permanganate	54 – 61%	Good
	NW-310/NW-400	46 – 65%	Good
	Floran Biogrowth Remover / Catalyst	63 – 67%	Good
	Floran Top Ultra / Catalyst	23 – 68%	Average
Mercury	Water flushing	19 – 46%	Average
	Low pH	21 – 23%	Average
	Acidified potassium permanganate	72 – 96%	Excellent
Bacillus subtilis	Water flushing	-29 – -11%	Poor
	Shock chlorination	94 – 96% (1.2-1.4 log removal)	Average
Diesel fuel	Water flushing	36 – 38%	Average
		74% (for clear PVC pipe)	Good
	Surfonic TDA-6	> 91%	Excellent
		78% (for clear PVC pipe)	Good
Chlordane	Surfonic TDA-6	89 – 91%	Excellent
		99% (for clear PVC pipe)	Excellent

Building Plumbing System Decontamination

- Interagency project with National Institute for Standards and Technology (NIST)
- Studied both adherence and decontamination of chemical and biological contaminants in plumbing materials in bench scale, pilot scale, and full scale setups
- Numerous tests conducted:
  - Various combinations of contaminants and plumbing system materials
  - Different flow conditions and configurations
  - Coupons, small pipe sections, full-scale pipe loops, and water heater tanks

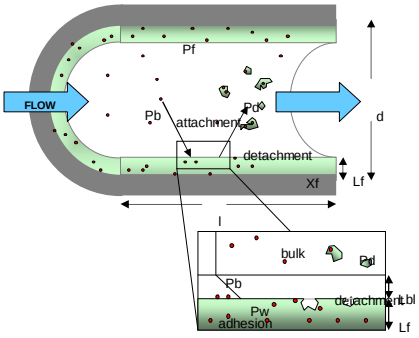
Building Plumbing System Decontamination Cont.

- Contaminants tested included diesel fuel, gasoline, toluene, strychnine, cyanide, phorate, mercuric chloride, ***E. coli***, ***Bacillus anthracis, Bacillus thuringiensis***, and Ricin
- Plumbing system materials were copper, galvanized iron, PVC or chlorinated polyvinyl chloride (CPVC), rubber, and brass

- Surfaces included water pipes (with and without scale and/or biofilm), fittings, valves, and water-using appliances
- Final reports are being edited for publication

Water Quality Modeling Research

- Research objective
  - –Develop accurate mathematical models for contaminant transport to inform decontamination decisions
- Products
  - –Models for adsorption/desorption
  - –Models for attachment to biofilms
  - –Models for reaction with chlorine
- Impact
  - –Tools will be available to help support decontamination research
  - –New models will improve consequence assessment modeling and sensor placement optimization



Schematic of pipes showing pipe wall layer where contaminants can adsorb to corrosion products or attach to biofilms

NHSRC Water Treatment and Decontamination Research Summary

- Presented a snapshot of water security treatment and decontamination studies conducted by NHSRC
- Research results support:
  - The water sector, including drinking water and wastewater utilities
    - Improved ability to deal with crisis incidents
    - Multiple benefits for standard operations
  - Office of Water and Department of Homeland Security
- The Center is continuing CBR water treatment and infrastructure decontamination research, with input from key stakeholders

Questions ?

minamyer.scott@epa.gov

NHSRC Web Site

www.epa.gov/nhsrc

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

Marissa Lynch, EPA/OW

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

2010 U.S. EPA Decontamination Research and Development Conference
Durham, NC - April 13, 2010

Marissa Lynch
U.S. Environmental Protection Agency, Office of Ground Water and Drinking Water

Laura Jones, Kimberly Ogren, and Shalini Jayasundera
CSC

Overview

Problem statement:

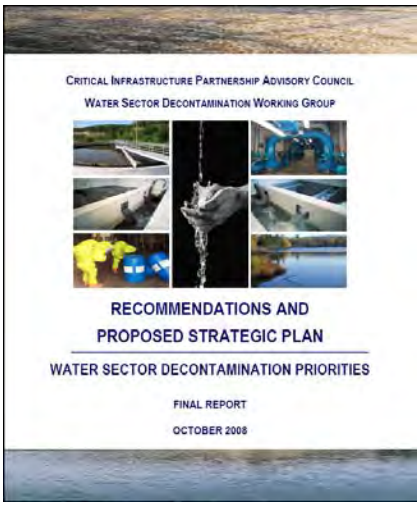
- The Water Sector has identified gaps in decontamination tools, guidance, and research as related to water security

Objectives:

- Provide background on CIPAC Water Sector Decontamination Strategy
- Provide an overview of WSD efforts - Development of ***Containment and Disposal of Large Amounts of Water: A Support Guide for Water Utilities*** in response to Issue 1, Recommendation 2 of the CIPAC Water Sector Decontamination Strategy

CIPAC Water Sector Decontamination Recommendations

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



Priority Decontamination Issues

1. Containing and/or disposing of large amounts of water
2. Near-term, practical solutions
3. Decontamination procedures for infrastructure in treatment plants
4. Decision-making frameworks for decontamination
5. Decontamination procedures for distribution system

Priority Decontamination Issues, continued

6 Outreach and training to utilities, partners, and stakeholders

7 Utility communications to the public and others on decontamination

8 Cleanup levels

9 Treatment procedures for contaminated water and wastewater

10 Agent fate and transport

Priority Decontamination Issues, continued

11 Clarifying roles and responsibilities for decontamination and treatment

12 Process for regulatory waivers/suspensions

13 Resources and assets for decontamination and treatment

14 Laboratory analysis

15 Health and safety assessment for water and wastewater treatment plant staff

16 Overarching decontamination needs*

* Identified by the Working Group but not included in recommendations

Disposal Guidance for the Water Sector

CIPAC Decontamination Strategy Issue 1, Recommendation 2

- **Issue:** Water Sector needs guidance on containment and/or disposal of large amounts of contaminated water
- **Recommendation:** Revise existing guidance or develop new guidance for containment and disposal of decontamination waste, including large amounts of water and associated solid waste

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

Development Progress

- **White Paper**
  - Completed March 2009
  - Reviewed by Internal Work Group
- **Annotated Outline**
  - Reviewed by Internal Work Group and Stakeholders (Remediation & Recovery Workshop)
- **Draft Guide**
  - Select chemical, biological, and radiological (CBR) contaminants
    - Completed October 2009
    - Reviewed by Internal Work Group
  - Additional chemical contaminant groups and biotoxins
    - In progress
    - Reviewed by Internal Work Group

Internal Work Group

- Work Group established in early 2009 to review and contribute to development of the guide.
- Members include personnel from:
  - OW
  - OHS
  - ORD - NHSRC
  - OSWER – NDT, ORCR
  - ORIA
  - EPA Regions – Region 3
  - OGC
  - OSCs – Region 3 & Region 7

Support Guide Overview

Scope

- Decision-making framework for disposal of CBR-contaminated water
- Overview of containment, treatment, and disposal options for drinking water, wastewater, and stormwater systems
- Reference guide for development of a system-specific disposal plan for contaminated water
- Disposal of solids not included - sufficient guidance available from other EPA offices

Audience

- Primary - drinking water, wastewater, and stormwater utilities
- Secondary - decision makers involved with planning and disposal at the federal, state, local, and tribal levels

Organization of the Guide

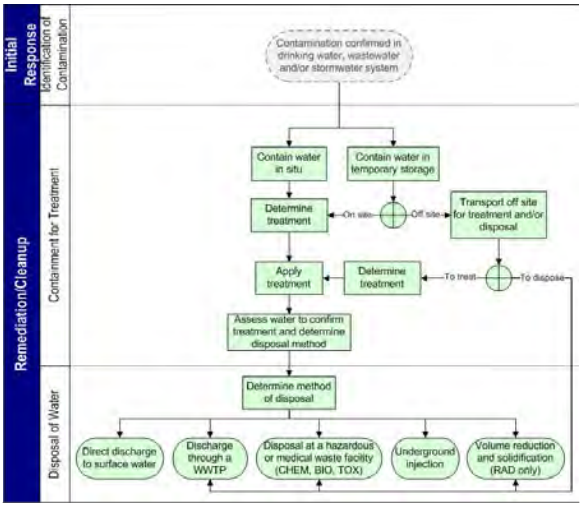
1. Introduction
2. Containment and Disposal as Part of Remediation and Recovery
3. Containment and Treatment of Water
4. Disposal of Water
5. Storage and Transportation

Appendices:

A. Risk Communication
B. Potential Treatment Methods
C. Sample Disposal Checklist
D. Resources
E. Summary of Applicable Laws and Regulations
F. References

Flowcharts

- Overview flowchart of containment, treatment, and disposal
- Separate, expanded decision trees for drinking water systems and wastewater/ stormwater systems are in the guide



Contaminants Included

- Sixty-nine contaminants of concern to the Water Sector
  - Chemical
  - Biological
  - Biotoxin
  - Radiological
- Selection of Contaminants
  - Reviewed other areas in water security to identify appropriate contaminants
  - Received input on contaminants at the Remediation and Recovery Workshop

Contaminants Included, continued

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

Next Steps

- Completion of internal review
- Review by external stakeholders - NACWA, WEF, ASIWPCA, AWWA
- Determination of appropriate release
  - Web site
  - Access restrictions
- Projected completion in July 2010

Thank You

Thank you for your time and attention.

If you have any questions, please contact me at:
Lynch.Marissa@epa.gov
202-564-2761

Threat Agent Disposal: Disposal Issues Following a CBRN Incident Based on RDD and Anthrax Waste Disposal Workshops

Paul Kudarauskas, EPA/OSWER/OEM

US Environmental Protection Agency
Office of Emergency Management

Threat Agent Disposal

Disposal Issues Following a CBRN Incident

Based on RDD and Anthrax Waste Disposal Workshops

Paul G. Kudarauskas
National Decontamination Team
Deconologist and T&D Specialist

April 13-15, 2010
2010 Decontamination Conference
EPA NHSRC – RTP, NC

Agenda

- EPA Roles & Responsibilities
- Threat Agent Disposal Work Group
- Waste Disposal Workshops
- Workshop Findings
  - IBRD (Anthrax)
  - Liberty RadEx (RDD)
- Discussion

EPA's Roles and Responsibility

- CBR threats are considered real risks to U.S. security
- EPA-specific responsibilities regarding decontamination and disposal
- Authorities:
  - Homeland Security Presidential Directives
    - HSPD – 10: Biodefense for the 21st Century
    - HSPD – 22: Domestic Chemical Defense ***(classified)***
  - National Response Framework
    - ESF 10 – Oil and Hazardous Materials Response

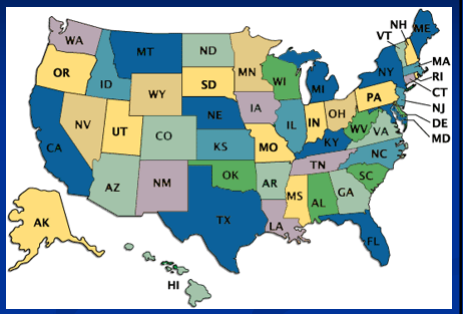
Threat Agent Disposal Workgroup

THREAT AGENT DISPOSAL WORKGROUP

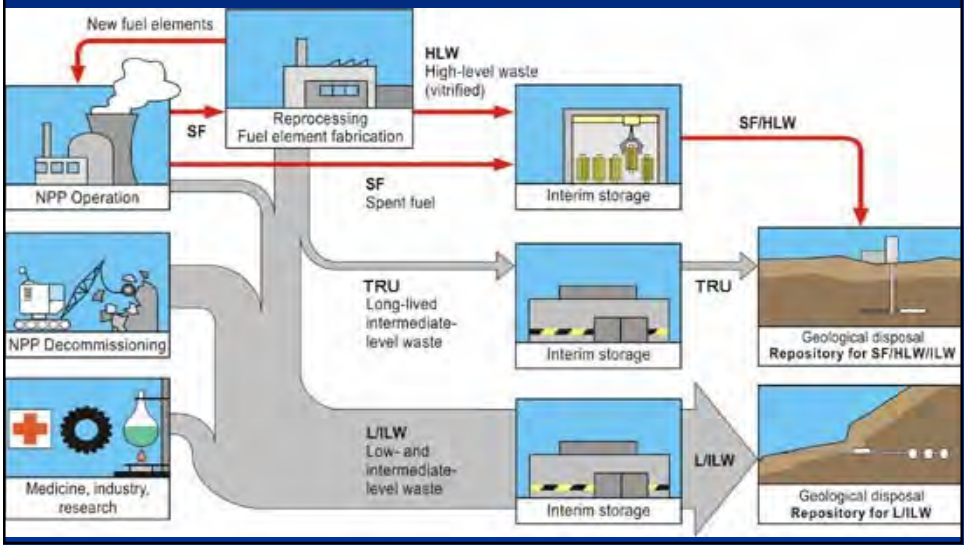
- EPA has identified three preparedness gaps related to terrorist events involving chemical, biological or radiological (CBR) threat agents
  - ***Decontamination, Laboratory, and Disposal capacity***
- Summer 2008 EPA convened the Threat Agent Disposal (TAD) workgroup to examine the issue of disposal after a CBR event
- Significant barriers to disposal given the volume of waste resulting from a wide-area and/or multiple simultaneous attacks
- The TAD workgroup, lead by OHS & ORCR was comprised of representatives from several EPA offices and regions

WASTE DISPOSAL

- State regulated
- Case-by-Case



TYPICAL SOURCES OF WASTE



Situations we have little or no experience with

≠

TAD Working Group Overview

- **Purpose:**
  - ***Examine the issue of disposal after a CBR-threat agent event***

- **Objectives:**

1. Identify the **types and quantities** of wastes typically generated in CBR threat agent events,
2. Examine existing **disposal options** for that waste based on current statutory and regulatory conditions, and
3. Examine **barriers** that the EPA encounters in disposing waste

THREAT AGENT DISPOSAL WORKGROUP

- Developed rough estimates of the order of magnitude of wastes that would be generated in a "typical" CBR event.
- In order to examine the barriers to disposal of waste generated in a wide-area terrorist attack, the TAD workgroup established general categories of waste based on an operational field approach

Category	Definition of Waste
I	Uncontaminated Waste (Solid Waste)
II	Verified Decontaminated/Treated Waste
III	Not Verified Decontaminated/Treated Waste
IV	Contaminated Waste
V	Decontamination Effluent/By-Products
VI	Problematic Waste

Barriers to Treatment & Disposal

- The release of CBR agents introduces a host of challenges related to the treatment and disposal of waste contaminated with these agents.

- Potential barriers and associated definitions identified for this effort include:
  - ***Regulatory / Statutory***
  - ***Policy / Guidance***
  - ***Technical / Scientific***
  - ***Socio-political***
  - ***Capacity***

Threat Agent Disposal Workshops

Workshop Approach

- Key waste facility owners, haulers, waste associations, and service providers and relevant officials at the local, state, and federal levels
- Representation of waste-disposal ecosystem that included transportation, disposal, treatment, and regulatory components
- Include representatives from all relevant organizations, companies, and agencies involved with the handling and disposal of all forms of waste in order to provide a comprehensive picture of waste management from the initial response phases through the recovery phase.
- Baseline Assessment Interviews

Workshops

- A series of three workshops
- Each workshop focused on a specific stakeholder group:
  1. Waste facility owners, haulers, associations;
  2. State and local agencies; and
  3. Federal agencies
- Identify and prioritize major concerns of each group
- Identify major concerns and needs to support recovery and restoration efforts

Threat Agent Disposal Workshop

Anthrax – Based on the IBRD Scenario

Anthrax Workshop Objectives

- Current state of preparedness for disposal of anthrax-contaminated materials;
- Capabilities, requirements, and limitations to respond to and recovery from an anthrax incident;
- Issues of and barriers to disposal of biological agent-contaminated waste; and
- Develop a prioritized list of issues to be addressed.

Workshop w/ Waste Facility Owners, Haulers, Associations, and Service Providers

The individuals invited to the workshop represent the private sector and a small cross section of local public sector waste management and regulatory authorities in the Seattle urban area.

Priority Issues:

- Planning
- Regulatory status of waste
- How is "clean verified"
- Education/Training

Workshop w/ State and Local Participants

Six state and local agencies represented the City of Seattle, King County, Snohomish County, and the State of Washington participated

Priority Issues:

- Regulatory Ownership
- Behavior of Anthrax in Landfill Environment
- Lessons Learned
- Treatment in Place

Workshop w/ Federal Participants

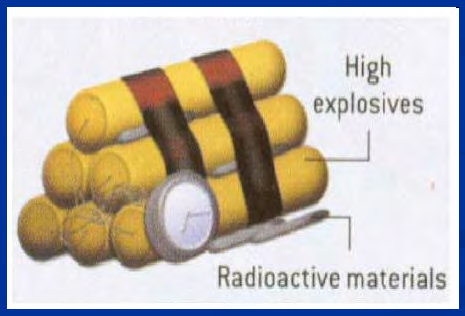
- Representatives from Fort Lewis, EPA Headquarters and the Region 10 Office, and the U.S. Department of Agriculture (USDA) participated in the Federal Workshop.

Priority Issues:

- Template/Decision Framework
- Research
- Waste Treatment and Disposal Pathway/ Regulations on Decontamination Agents

Threat Agent Disposal Workshop

RDD – Based on the Liberty RadEx Scenario



Workshop Objectives

- Understand the current state of preparedness (including roles and responsibilities) in waste management and disposal in the case of a RDD urban incident
- Identify the issues and barriers of transportation, treatment, and disposal of RDD waste (short- and long-term) and priorities for addressing those issues
- Develop a template for a City of Philadelphia waste disposal management plan in case of a RDD urban incident
- Provide valuable information on waste disposal for the Liberty RadEx

Issues for Private Sector Participants

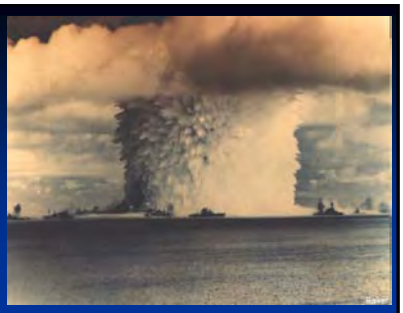
- ***Regulatory Restrictions/Agreements/ Exceptions Issues***
- ***Response Pre-planning***
- ***Scientific/Technological Issues***
- ***Communications***

Issues for State and Local Participants

- *Waste Disposition Jurisdiction Issues*
- *Regulatory Restrictions/Agreements/ Exceptions Issues*
- *Scientific/Technological Issues*
- *Ultimate Disposition Capacity Issues*
- *Communications Issues*

Issues for Federal Participants

- *Waste Disposition Jurisdiction Issues*
- *Regulatory Restrictions/Agreements/ Exceptions Issues*
- *Scientific/Technological Issues*
- *Ultimate Disposition Capacity Issues*



Conclusion

Discussion

- Need/Interest for an interagency effort to finalize issues/gaps, including through possible interagency efforts?
  - ***Disposition Capacity***
  - ***Regulatory Restrictions/Agreements/ Exceptions***
  - ***Waste Disposition Jurisdiction Issues***
  - ***Scientific/Technological Issues***
- Need/Interest to address the dispo issues in other exercises?
- Suggestions for future considerati or collaboration of the TAD WG?

Contact Information

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Questions?
Comments?
Criticisms?

Update on the Validated Sampling Plan Work Group

Dino Mattorano, EPA/OSWER/OEM

Update on the Validated Sampling Plan Work Group

Dino Mattorano, MS, CIH
CDR/USPHS
National Decontamination Team
Office of Emergency Management

Dr. Randolph Long
Deputy Division Director
Chemical and Biological Division
Science & Technology Directorate

Validated Environmental *B. anthracis* Sampling Efforts

Matterano

- May 2006 hearing on Anthrax was conducted before a House Subcommittee
  - Based on GAO Report on Anthrax Detection (GAO-05-251)
- DHS assumed leadership role
  - in developing interagency sampling strategy
- Interagency working group (Validated Sampling Plan WG)
  - DHS, EPA, CDC, DOD, FBI, NIST, and National Lab representatives.
- Draft strategic plan outlines:
  - agency responsibilities, milestones, required funding
  - develop validated guidance for environmental bio sampling/analysis across all phases of response

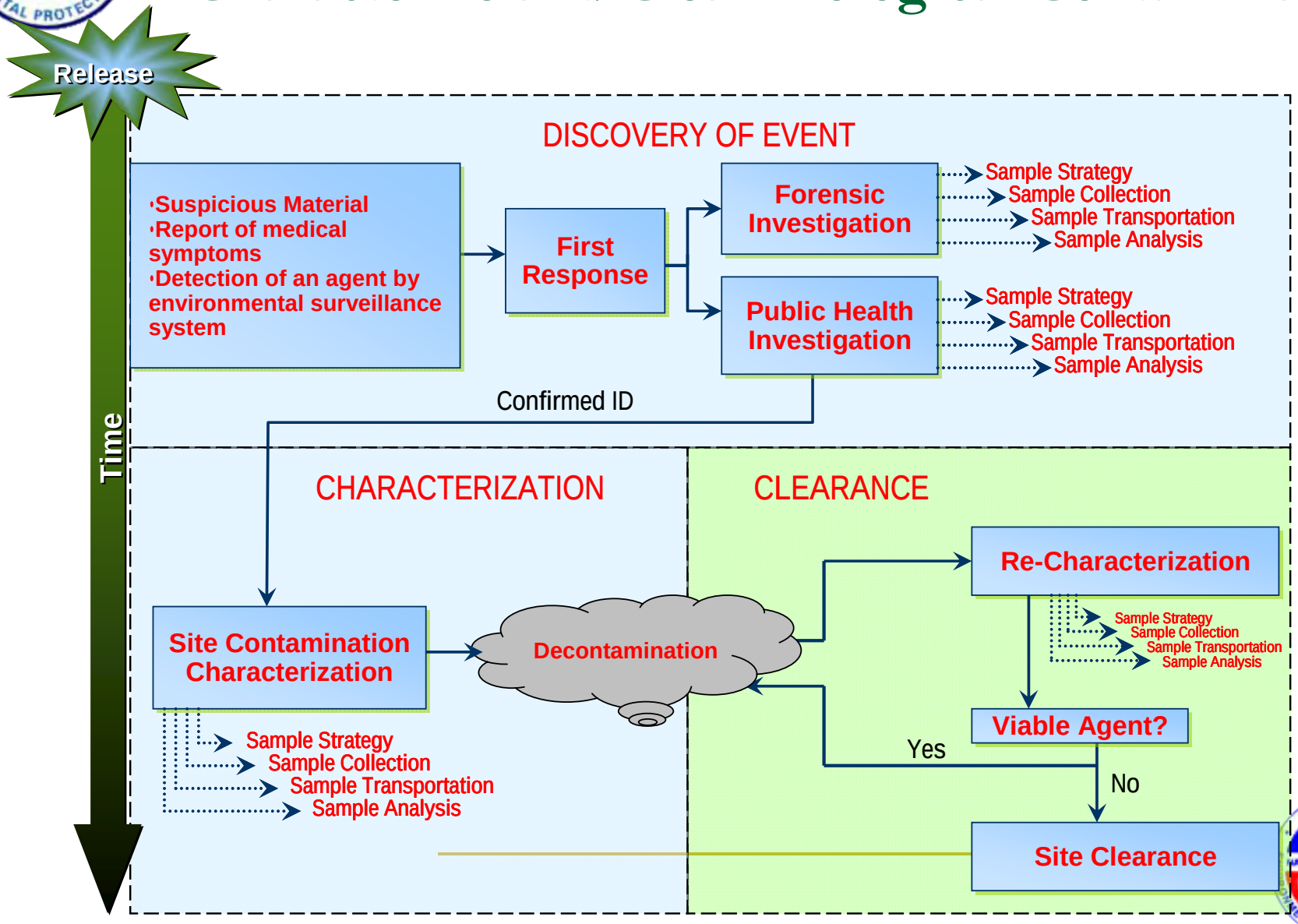
General Structure of Strategic Plan

Plan addresses the following major categories of activity:

- Sample collection methods for surface and air,
- Maintain sample integrity during transportation/storage
- Sample processing and analysis
- Sampling strategy
- Sampling and analysis plan exercise
- External peer review

Sample Collection Methods and Strategies to Characterize and Clear Biological Contamination

Mattorano



Consensus VSP WG Definitions

- **Validation**
  - "Validation is the confirmation by examination and the provision of objective evidence that the particular requirements for a specific intended use are fulfilled." (ISO 17025)
- **Sampling Strategy**
  - a set of operating precepts and diagnostic tools
    - including sample collection methods; packaging and shipping protocols; recovery, extraction, and analytical methods; and statistical analysis packages
    - combined to confidently answer specific hypotheses
    - sampling strategy describes general guidance informed by a decision support process
- **Sampling Plan**
  - a documented approach for field execution that captures
    - specific combination of operating precepts
    - diagnostic tools used for a given scenario to answer a specific hypothesis.
    - sampling plan, collection, recovery, transport (sample integrity), extraction and analysis refer to specific methodologies.

Status of Sampling Strategy

- Joint EPA-CDC product (approx 100 pp)
- Edition 1 has been completed (fall 09):
  - Response roles and responsibilities
  - Development of sampling plan
  - Worker safety and health
  - Sample collection
  - Sample documentation and data management
  - Interface with laboratory networks
  - Implementation of sampling plan
- Edition 2 (targeted for July 2010 completion) will:
  - Incorporate sampling decision trees via contextual vignettes
  - Improve organization
  - be more robust tool for responders

Sampling Plan Exercise

VSP WG adopted as definition of "sampling plan:"

a documented approach for field execution that captures the specific combination of operating precepts and diagnostic tools used for a given scenario to answer a specific hypothesis." A sampling plan is an executable plan of action that addresses the sampling and analytical requirements of a specific situation and is formulated in accordance with the guidance of the sampling strategy.

- Objective: contaminate building, develop and execute sampling plan in accordance with sampling *strategy*, assess adequacy of approach
- Conducted exercise with *B. atrophaeus* at INL Sep 2007 and Sep 2008
- Enabled exercise of tools such as Visual Sample Plan and BROOM

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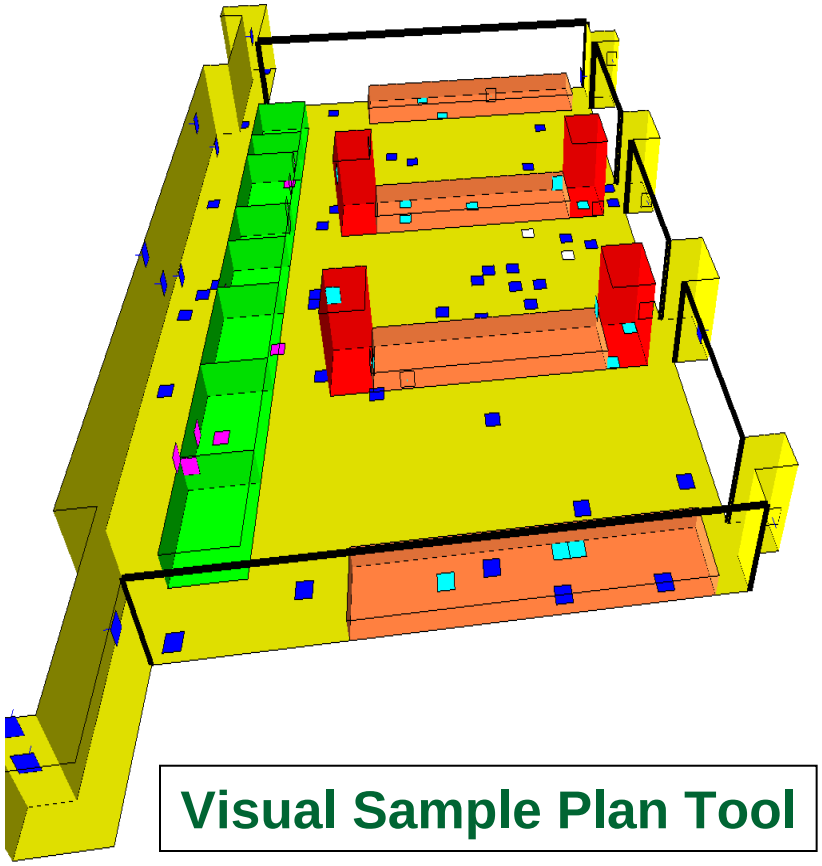
Statistically Defensible Sampling

Problem:

- How Many Samples Are Needed?
- What is the Optimal Sampling Approach?

To:

- Characterize magnitude and extent of contamination?
- Evaluate effectiveness of decontamination?
- Confidently demonstrate cleanliness?



Visual Sample Plan Tool

Visual Sample Plan (VSP)

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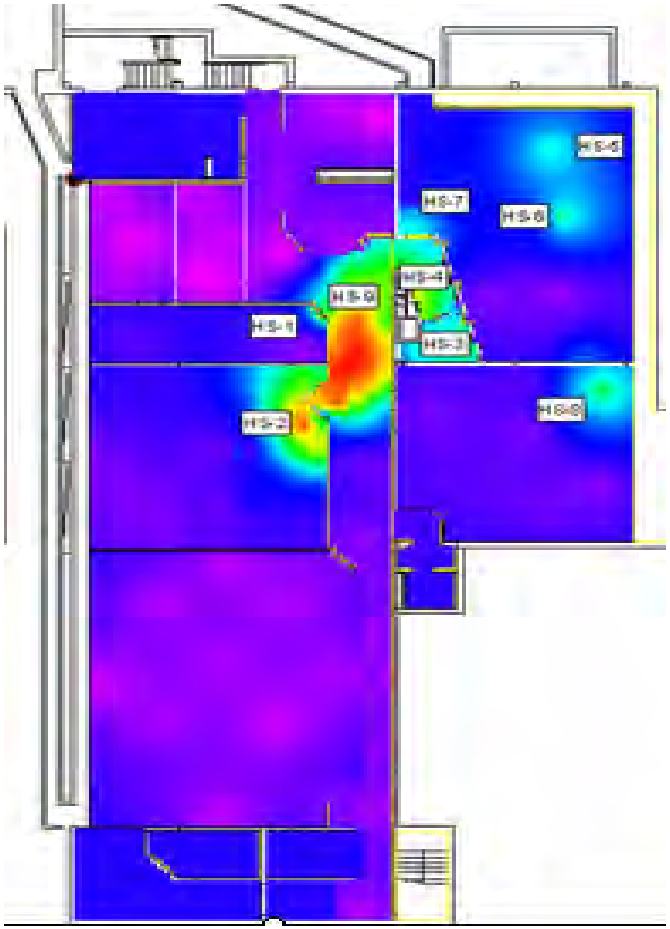
Data Quality Objectives (DQO) based systematic planning software:

- to determine number and location of samples
- to ensure confident, statistically defensible decisions
- to perform statistical and data quality assessment in support of decision making process.



- Sponsored by DHS, DOE, EPA, DoD, UK, CDC
- Free VSP Download at http://dqo.pnl.gov/vsp

Building Restoration Operations Optimization Model (BROOM)

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Software to improve the efficiency of restoration operations and enhance decision making

- Desktop
  - Design Sampling Plans
  - Access Sampling Results
  - 2D and 3D Visualization
  - Contamination Maps
  - Confidence Maps
- PDA
  - Display Facility Floor Plan
  - View Sampling Plan
  - Collect Surface, Bulk, and Filter Samples

BROOM and VSP Integration

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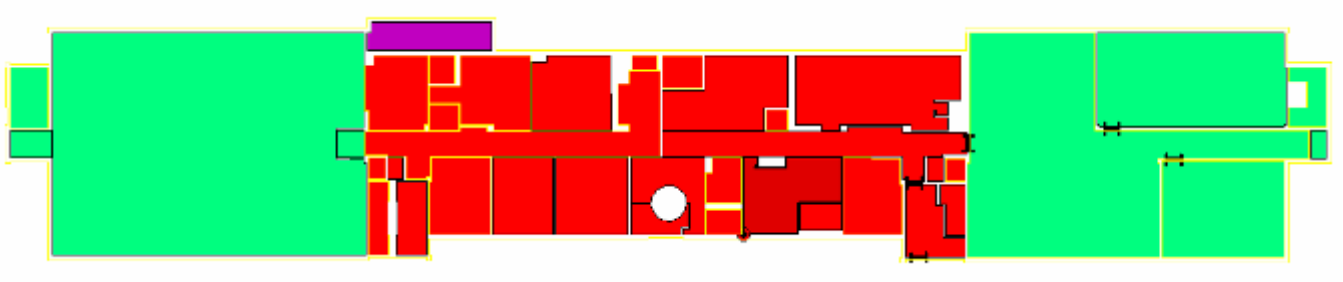
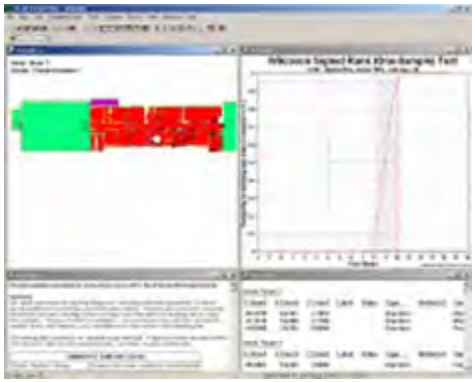
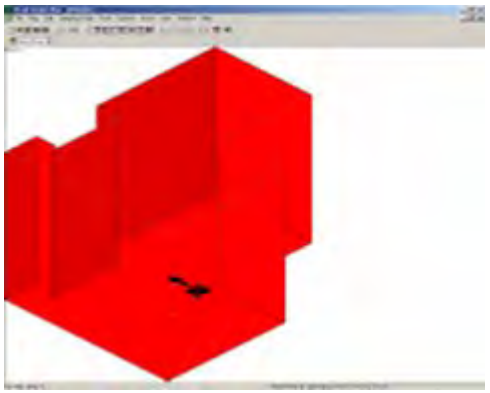
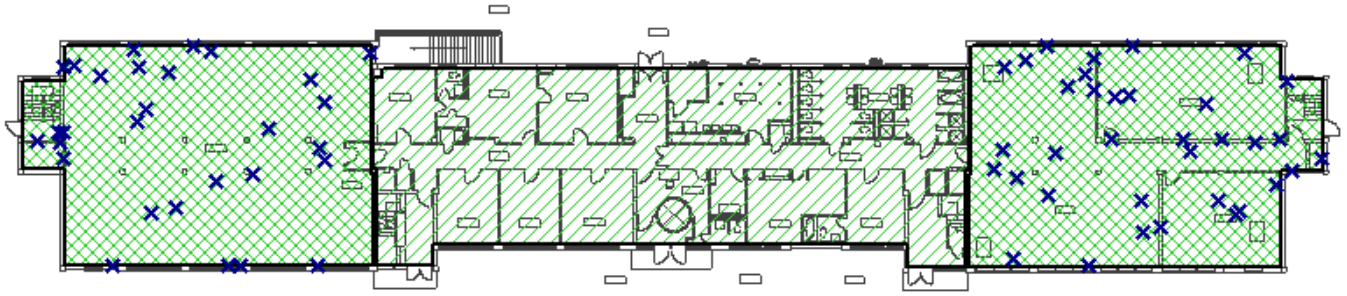






BROOM



Sampling plans and aids evaluated in practice (2007 and 2008)

Abandoned but functional building used for tests

Civil Support Teams and First Responders trained to conduct sampling

Characterization sampling Test 4

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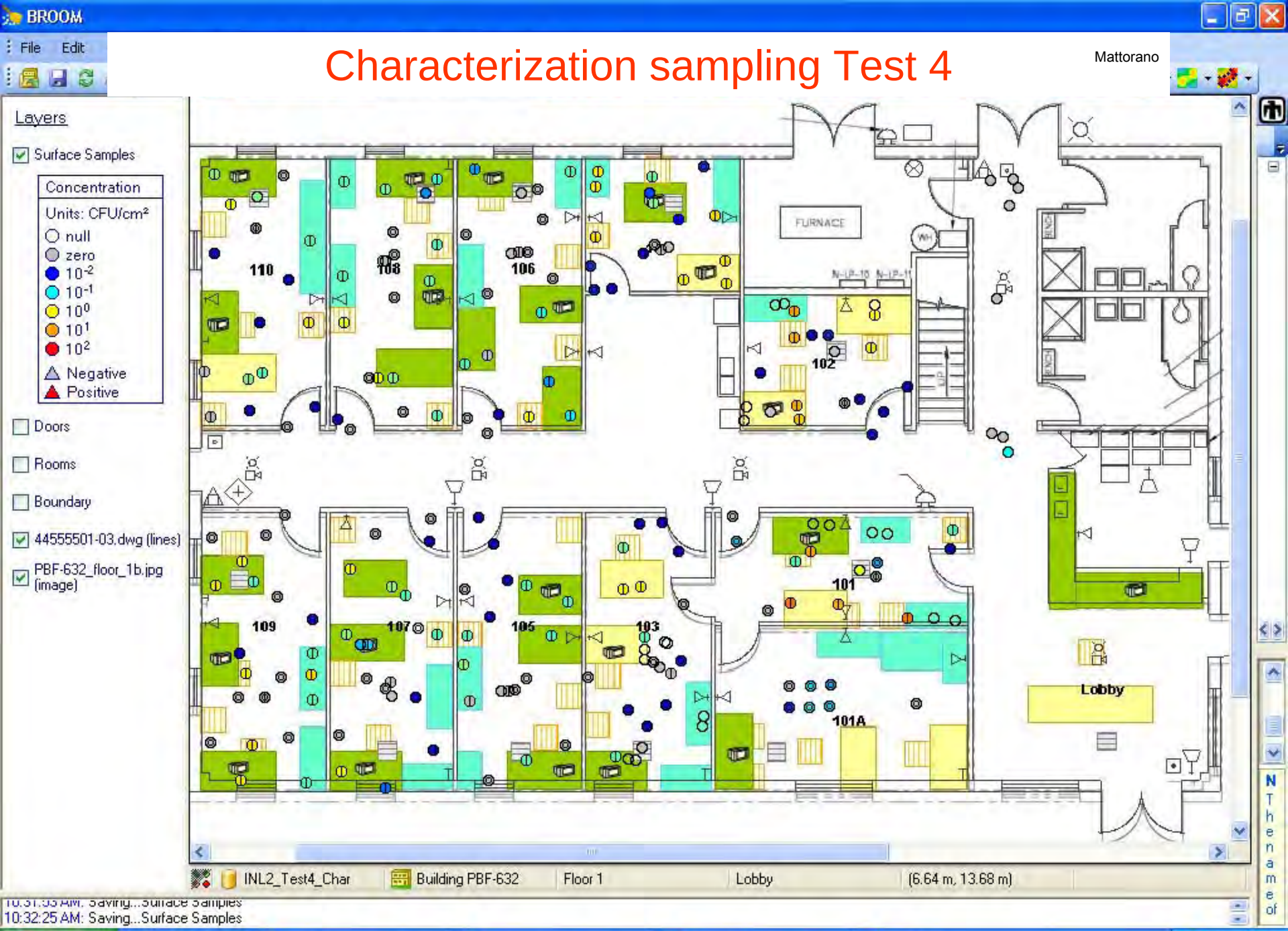

Clearance sampling Test 4

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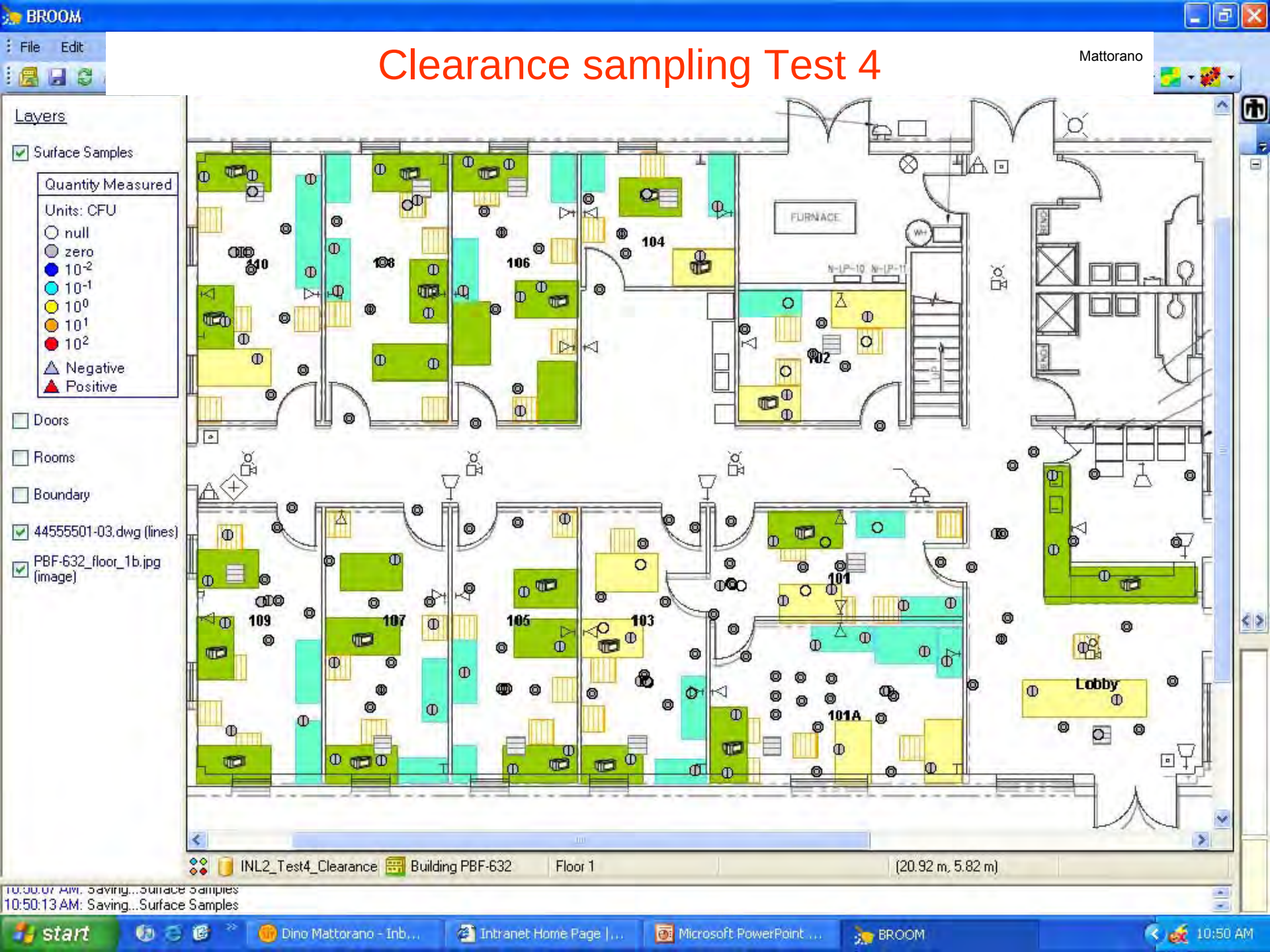

Overall

- Collected 3,000 samples in 3 weeks
- 60 CST / first responders
- Analysis done on-site by DOD 9th AML
  - Both culture and pcr (10%)
- Some samples sent to CDC LRN (50 total)
- Successfully achieved dissemination gradient
- Successfully characterized contamination
- Successfully demonstrated decontamination of facility

Observations from previous studies and events

- EPA summarized *Bacillus anthracis* related sampling and decontamination efforts based on available published and unpublished literature.
  - 15 historical events were summarized
  - Lessons learned from each event were captured
- PNNL and NIST summarized previous *Bacillus anthracis* (or simulant) chamber and controlled studies, and provided recommendations for a future controlled study.
  - Purpose was to characterize performance of methods for collecting, storing and/or transporting, extracting, and analyzing samples from surfaces contaminated by *Ba* or related simulants.
  - Summary of previous studies shows significant gaps in the performance information.

On-going Activities

- Controlled chamber study to improve statistics on swab/wipe sampling limit of detection
- Development of algorithm to estimate uncertainty across entire sampling and analysis process
- Studies on sample transportation and storage protocols
- Improved sampling and analysis methods
- Refinement of sampling strategy document

Sampling and analysis data are only part of the solution

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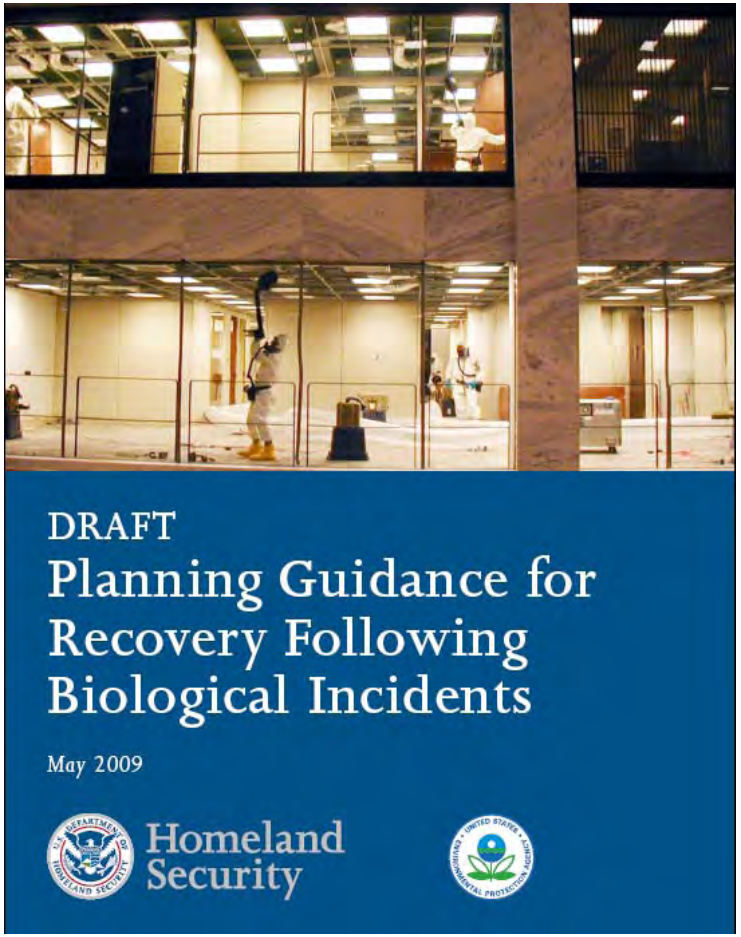
- Sampling data are acquired to inform decisions
- Decision makers must assess risk pursuant to decisions
- DHS and EPA completed in 2009 document outlining risk optimization and management approaches to guide response and recovery efforts



Developing an Effective CBRN Decontamination Capability

Hasmitta Stewart, Government Decontamination Service (Fera)

Developing an Effective CBRN Decontamination Capability

U.S. EPA Decontamination Research & Development Conference

April 2010

Dr Hasmitta Stewart

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Contents

- Background to Fera and GDS
- GDS Specialist Supplier Framework
- Development of decontamination capability

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GDS Background

- GDS established as an Executive Agency of DEFRA in October 2006
- Merged with Central Science Laboratory and three other Defra regulators in April 2009 to form the Food and Environment Research Agency
- Extensive network of contacts throughout UK science base (Central Government, Dstl, HPA, universities, private industry)

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GDS Primary Functions

1. **To provide advice, guidance and assistance on decontamination related issues to responsible authorities** in their contingency planning for, and response to, CBRN (and HAZMAT) incidents;

2. **To maintain and build on the GDS Framework of specialist suppliers** and ensure that responsible authorities have access to their services if the need arises;

3. **To advise central Government on the national capability** for the decontamination of buildings, infrastructure, transport and open environment, be a source of expertise in the event of a CBRN incident or major release of HAZMAT materials.

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Drivers for GDS

- UK Counter-terrorism Strategy (CONTEST)

http://security.homeoffice.gov.uk/news-publications/publication-search/science-technology/Science-Technology-strategy/index.html

- National Risk Assessment (NRA)

http://www.cabinetoffice.gov.uk/media/348986/nationalriskregister-2010.pdf

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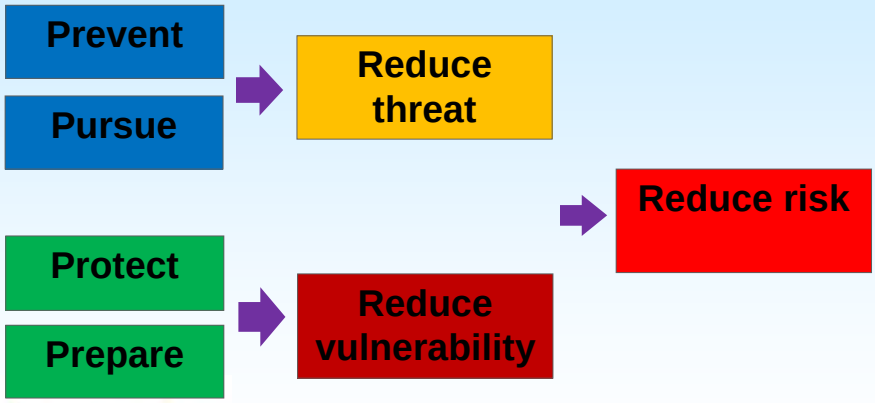
CONTEST - The 4 Pillars



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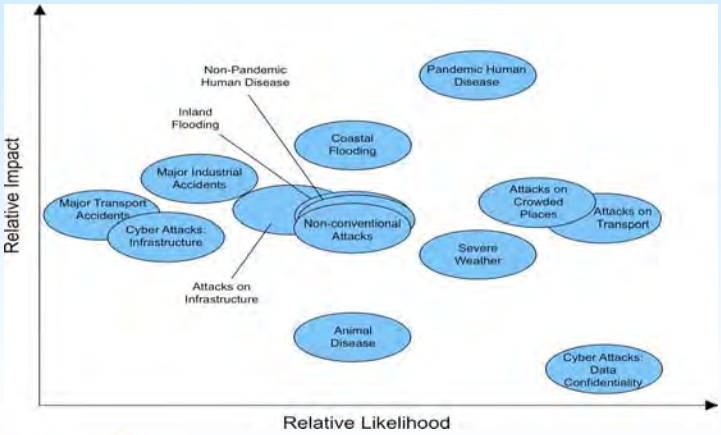
National Risk Assessment



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Development of Specialist Supplier Framework

- 12 Specialist Suppliers with capabilities across the CBR spectrum;
- Technologies routinely deployed in commercial use
- 24 / 7 emergency response
- Security clearance (Company specific)

Challenge is to move these contractors from their civil environments to CBRN environment (also major HAZMAT)

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Development of Specialist Supplier Framework

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

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Stages in the Development Decontamination Capability

1. Routine work
2. Counter-terrorism paper-based exercises
3. Counter-terrorism practical exercises
4. Addressing gaps in Framework

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Routine Work

Specialist Supplier Framework
Chemical

•Chemical contractors routinely deal with chemical spills and routine HAZMAT incidents

• Some specialised decontamination technologies available – current response limited to hazardous material containment and removal

•Demolition of contaminated buildings and industrial sites

•PPE capability

Specialist Supplier Framework

- Relative of a deceased man contacted Health Protection Agency
- GDS received a request from a local authority
- Employment history indicated access to potential hazardous chemicals
- Back garden chemistry laboratory

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GDS paper-based exercises

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GDS scenarios

- Based on National Risk Assessment and CBRN scenario vignettes
- Real world
- Paper based exercises
- Practical exercises
- Operational analysis

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GDS paper-based exercises

- Ex HYDRATION - Vesicant release inside sports stadium
- Ex STREETWISE - Radioisotope release in a busy city centre
- Ex PIPE CLEAN - Vesicant release in underground rail system
- Ex MAY FIRST- G Nerve agent release in enclosed space
- Ex WOOLSORTER - Biological release in enclosed space

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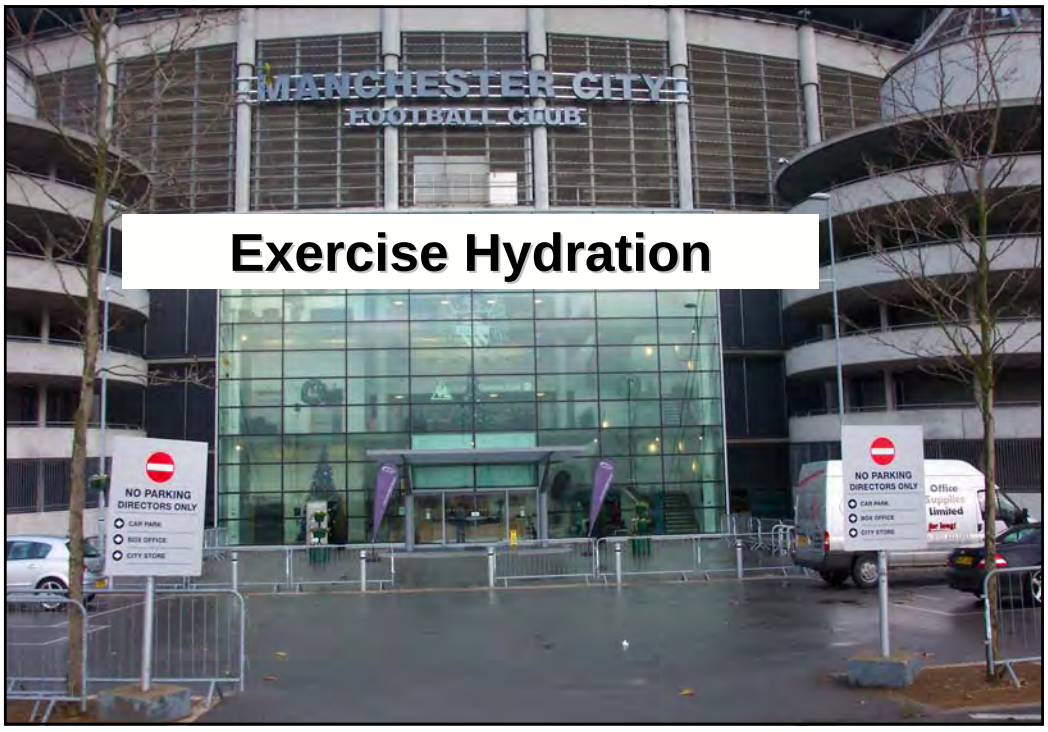

Exercise Hydration

- Sunday 2nd December 2007.
- 43,000 fans attending Premiership soccer game.
- Broadcast live by Sky TV throughout the world.
- Three incidents occur just before half time.

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Exercise Hydration cont.

Sulphur Mustard released from soft drink bottles in three different areas in the stadium causing extensive contamination

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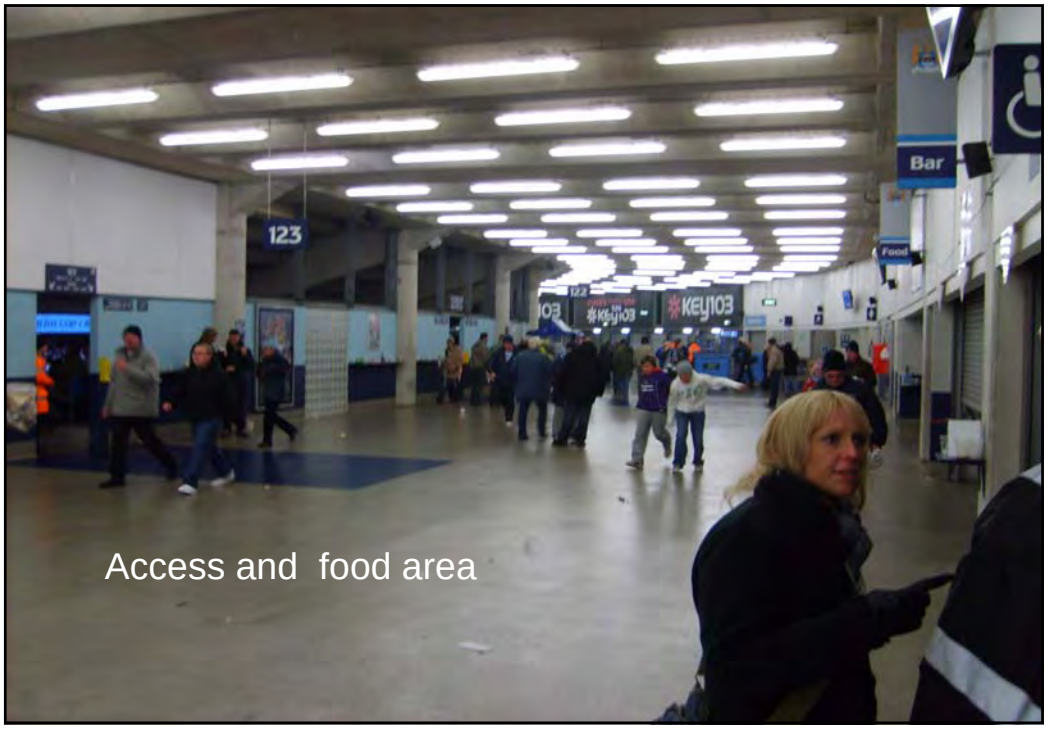
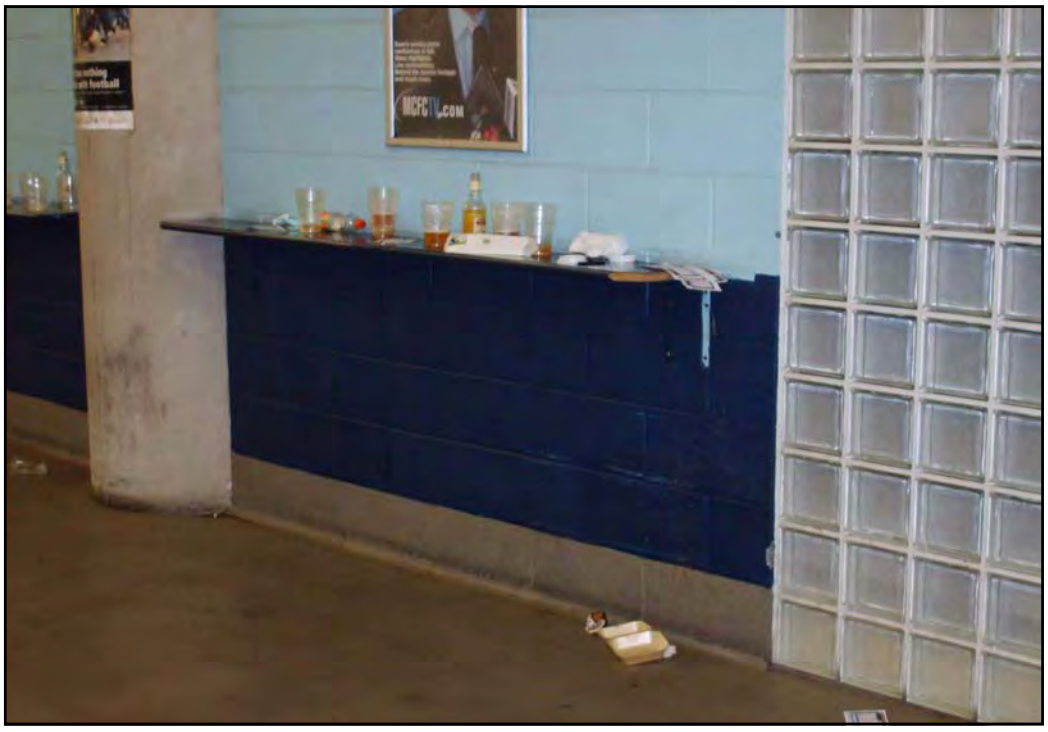
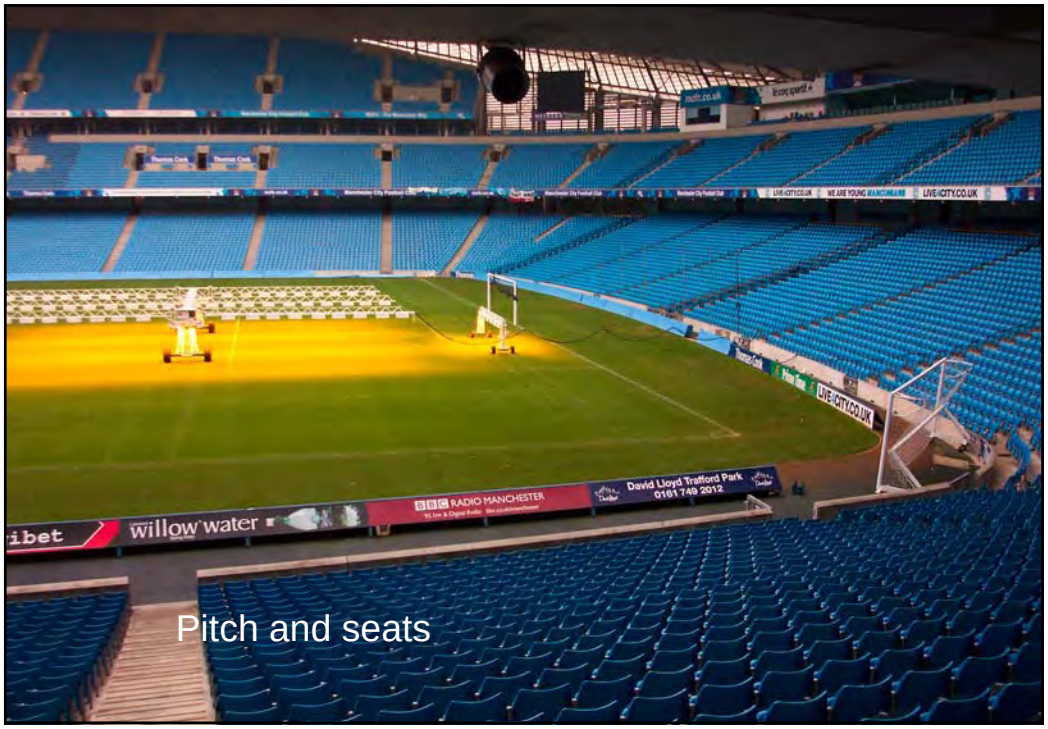

123
Bar
Food
#KEYNOTE
Access and food area


MUFC TV.com


Seating Area



Pitch and seats

Exercise Hydration cont.

Gap	Effect	Action
Management, transport & disposal of chemical wastes.	Delays remediation and significantly increases costs	A specific Waste management contractor recruited on the GDS Framework who has sufficient resource and capacity to be able to deal with this issue
Limited knowledge of the interaction of H with common building surfaces	Inability to assess: production of toxic by-products; depth of H penetration Inaccurate assessment of risk to environment and human health	R& D projects assessing CWA absorption onto common building surfaces
Limitations of current detection equipment	No confidence in ascertaining if decontamination has been effective	To be addressed by the counter terrorism CBRN S & T programme

Exercise Hydration cont.

Specific Recovery Issues

- Sampling and monitoring data from the emergency phase
- Tolerability of Residual Hazards
- Availability of technical solutions from industry
- Use of military assets (assumed by contractors)
- R&D to close capability gaps

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General Recovery Issues

Irrespective of the nature of the incident, the following issues always come up:-

- Who pays?
- Lack of adequate insurance cover
- Waste management
- Multi-agency information sharing
- Media handling
- Management of expectations around the decontamination process, cost and timescale

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GDS Practical Exercises

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Support to First Responders

- Mass decontamination structures
- Emergency service high-value assets

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GDS Practical Exercises

In preparation

- Release of G- nerve agent simulant in office environment
- Release of *Bacillus anthracis* surrogate in office environment
- Underground train systems – proposed C,B and R

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Filling in gaps to the Framework

- Supply chain resilience
- Support directory

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Supply Chain resilience

Objectives

- Assess and hopefully improve supply chain resilience in relation to each supplier's ability to respond to a CBRN incident.
- Map the supply chain of each supplier (in respect of equipment/PPE, services and staff),
- Identify any overlap between suppliers, and recommend appropriate further action in response to the risks and issues identified.

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Support Directory

The directory is intended to identify companies who have a role in the Chemical, Biological or Nuclear Industries who can offer support and assistance, or who work in a critical area of decontamination such as laboratory analysis or contaminated waste storage, transportation or disposal.

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Filling the gaps!

Science/Technology

Capability

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Thank you

- Questions?

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For Information
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US-Canada Bilateral Technical Working Group (TWG) for CBRN Response and Recovery

G Blair Martin, EPA/ORD/APPCD

U.S. – Canada Bilateral Technical Working Group on CBRN Response and Recovery

By: Lance Brooks, Department of Homeland Security
Norman Yanofsky, DRDC Canada
G. Blair Martin, U.S. EPA, Office of Research and Development
John Cardarelli, U.S. EPA, National Decon Team

Presented at: 33rd AMOP Technical Seminar on Environmental Contamination and Response
Halifax, Nova Scotia
June 7-9, 2010

BACKGROUND

- Concept of the TWG developed during 2001 ***B. antrhacis*** (B.a.) response
- Provided advice to:
  - Incident Commander
  - On-Scene Coordinator
  - Program Offices
- The TWG provided advice in four ways
  - Document review
  - Periodic meetings and teleconferences
  - Recommendation of special studies
  - On-site observation of the fumigation

BACKGROUND

- Document review
  - Federal Insecticide Fungicide and Rodenticide Act (FIFRA)
    - Remediation Action Plan (RAP)
    - Sampling and Analysis Plan (SAP)
    - Ambient Air Monitoring Plan (AAMP)
  - RAP - process and treatment conditions
  - SAP - process parameters and indicators
  - AAMP - ambient health and safety monitoring
- Meetings and teleconferences
  - Document comment resolution
  - Process issue resolution

BACKGROUND

- Recommended special studies
  - Process conditions
  - Equipment design and functionality
  - Performance issues
- On-site support during fumigation
  - Pre-fumigation assessment of facility
  - Observation of process installation
  - Evaluation of comments on RAP and SAP
  - Monitored progress of fumigation
  - Provided advice on issue resolution
  - Consultation with the Incident Commander
  - Post-fumigation assessment of facility

TWG OBSERVATIONS

- Whole is greater than the parts
  - Diverse backgrounds provide innovative thinking
  - However, challenging to forge a working solution
  - Compromise and creativity necessary
  - But don't try to think too far outside the box
- Communication is a key
  - Face to Face meetings are ideal, but present logistic and scheduling challenges
  - Direct orientation on building characteristics is essential
  - Teleconferences can resolve some issues
  - On-site document review expedites communication

TWG OBSERVATIONS

- TWG Membership
  - Provide relevant expertise in 8 to 12 members
  - Prior TWG experience desirable
  - Scientific and technical support for clients
  - Response expertise essential
- On-site TWG provides many benefits
  - Understanding of process implementation
  - Ability to advise Incident Commander on technical issues
  - Advice on response to regulatory issues
  - Direct interface with regulators, if necessary
  - Suggest remedial actions when process conditions difficult

FUTURE ROLE OF THE TWG

- For an Incident of National Significance a permanent TWG could provide valuable assistance
- Ideally TWG should be on site for the duration of the event – or at critical periods
- DHS/DTRA meeting with Australian CBRN counterparts
  - Concept of bilateral TWG discussed
  - Provide a greater range of resources for a response
  - EPA representative asked to take lead
  - Developed draft charter with Australian lead
  - Discussed with Australia, UK and Canada
- DHS lead in developing international agreements

FUTURE ROLE OF THE TWG

- U. S. - Canada Agreement on Cooperation in Science and Technology for Critical Infrastructure protection and Border Security
  - Chemical and Biological Detection and Defense Cooperative Activity Agreement – June 1, 2004
  - Technical Annex 2, January 31, 2010:
    - CBRN Technical Working Group (TWG) for Remediation
    - Incorporates draft TWG Charter
    - Biennial meetings rotating geographically
    - Coordinate with other meetings
    - Provides access to both R&D and response experts
- Potential for other agreements:
  - Bilaterals: United Kingdom or Australia
  - Consequence Management Group of the QUAD

FUTURE ROLE OF THE TWG

- Project Points of Contact
  - United States:
    - Lance Brooks, DHS, S&T
    - Debbie Dietrich, EPA, OHS
    - Cindy Sonich-Mullin, EPA, ORD
  - Canada:
    - Norman Yanofsky, DRDC Center for Security Science
- EPA technical co-leads
  - John Cardarelli, EPA, NDT
  - Blair Martin, EPA, ORD

FUTURE ROLE OF THE TWG

- First meeting held before Decon Conference
  - April 12, 2010
  - EPA facility at Research Triangle Park, NC
- Initial TWG Members – core group to guide efforts
  - U.S.
    - Shawn Ryan, EPA, ORD – biological decon
    - Emily Snyder , EPA, ORD – chemical and radiological decon
    - Paul Lemieux, EPA, ORD – waste disposal
    - Hiba Ernst – water issues
    - Tonya Nichols – risk assessment
  - Canada
    - Patrick Lambert, Environment Canada
    - Konstantin Volchek, Environment Canada
- Membership will be expanded to provide additional expertise on the specific CBRN issue

Analysis of Decontamination Strategies Following a Wide-Area Biological Release in a Metropolitan Area

Robert Knowlton, Sandia National Laboratories

Analysis of Decontamination Strategies Following a Wide-Area Biological Release in a Metropolitan Area

Robert Knowlton, Wayne Einfeld, and Mark Tucker

Sandia National Laboratories
Albuquerque, New Mexico

Sandia National Laboratories

Sandia is a multi-program laboratory operated by Sandia Corporation, a Lockheed Martin Company, for the United States Department of Energy under Contract DE-AC04-94AL85000.

Problem Statement

National Planning Scenario 2 deals with one or more aerosol releases of anthrax in one or more large metropolitan areas. There may be 10's of thousands of people affected, thousands of buildings impacted, 10's of square kilometers contaminated, and billions of dollars in economic consequences.

Decontamination will be a significant challenge.

National Response to the 2001 Anthrax Letter Attacks Was Costly and Time Consuming

- Postal facilities, senate buildings, and news organizations were contaminated
- Very little experience decontaminating large indoor facilities
- CDC reports that over 125,000 samples were tested at LRN laboratories costing $25-30 mil.
- Many facilities were closed for years and restored at great cost
  - Capitol Hill (4 mo, $42 mil.)
  - Brentwood (26 mo, $130 mil.)
  - US Postal Facilities (3+ yr, $800M)

A National Planning Scenario 2 response would be extremely complex and costly

Interagency Biological Restoration Demonstration (IBRD) for Wide-Area Biological Release

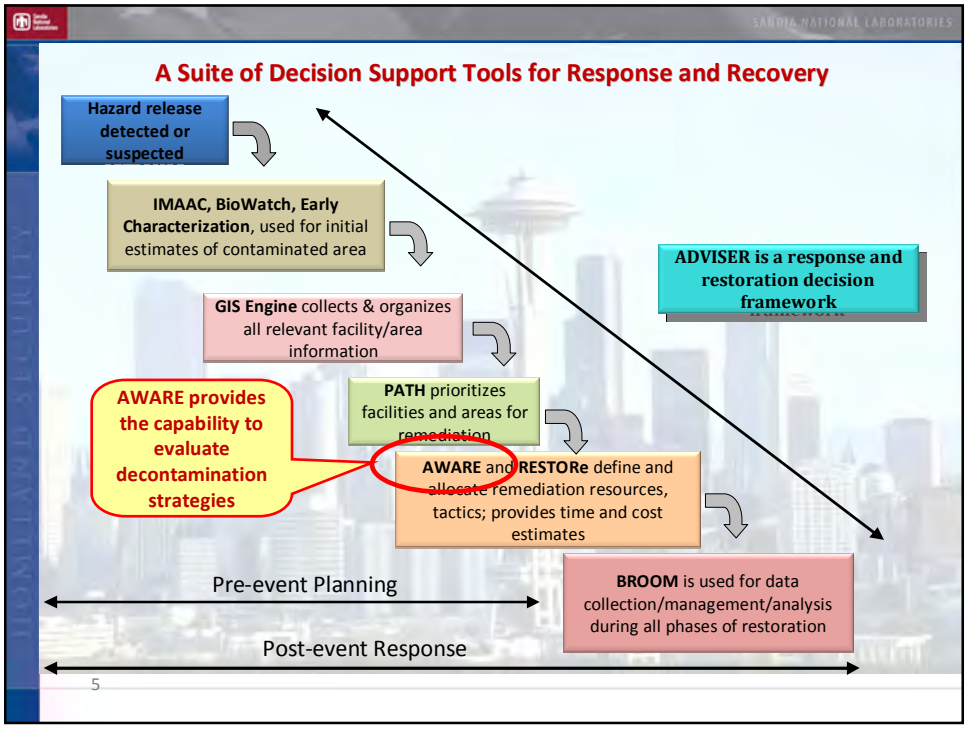
The IBRD project has the following objectives:

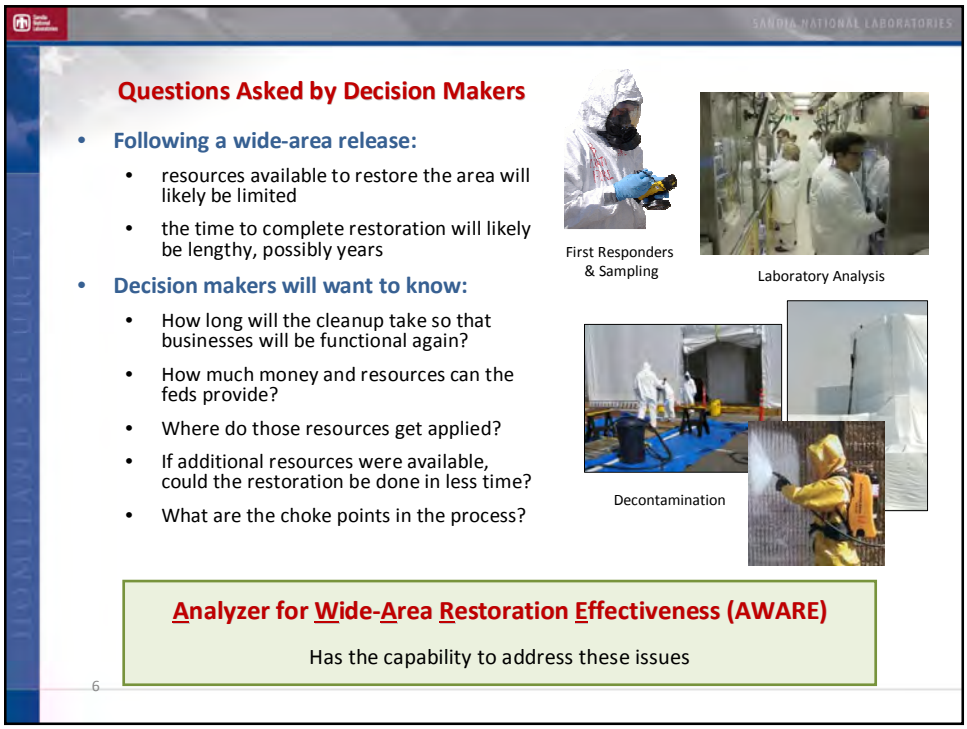
- Develop comprehensive guidance for restoration and recovery following a National Planning Scenario 2 attack, considering civilian/military cooperation
- Evaluate the technology gaps that exist today
- Develop technology, where appropriate, to fill these gaps, with an emphasis on saving time and money in the restoration process
  - **Decision support tools have provided valuable capability**

IBRD Program Managers:
- Lance Brooks, DHS-S&T
- Ryan Madden, DoD-DTRA

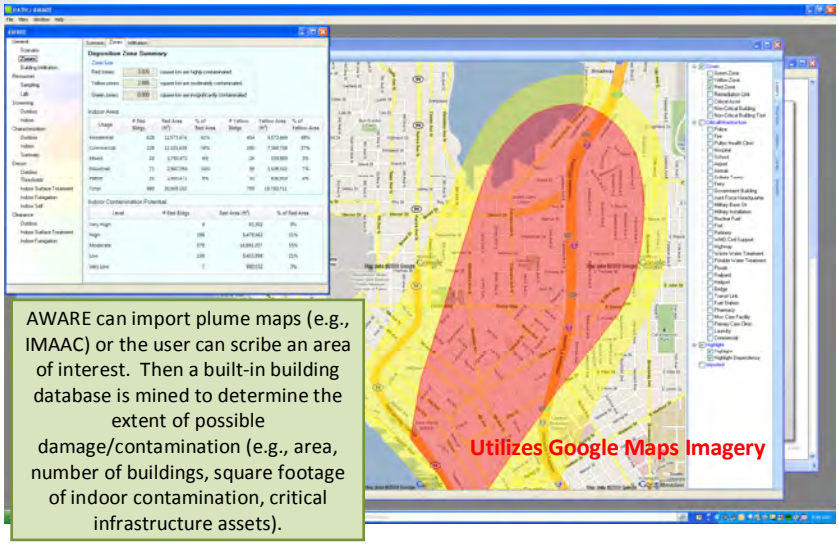
Laboratory Participants:
- Sandia National Laboratories
- Lawrence Livermore National Laboratory
- Pacific Northwest National Laboratory

Project funded by the Department of Homeland Security - Science & Technology and the Department of Defense - Defense Threat Reduction Agency


SANDIA NATIONAL LABORATORIES
A Suite of Decision Support Tools for Response and Recovery
Hazard release detected or suspected
IMAAC, BioWatch, Early Characterization, used for initial estimates of contaminated area
GIS Engine collects & organizes all relevant facility/area information
PATH prioritizes facilities and areas for remediation
AWARE and RESTORe define and allocate remediation resources, tactics; provides time and cost estimates
BROOM is used for data collection/management/analysis during all phases of restoration
ADVISER is a response and restoration decision framework
AWARE provides the capability to evaluate decontamination strategies
Pre-event Planning
Post-event Response
5


SANDIA NATIONAL LABORATORIES
Questions Asked by Decision Makers
Following a wide-area release:
resources available to restore the area will likely be limited
the time to complete restoration will likely be lengthy, possibly years
Decision makers will want to know:
How long will the cleanup take so that businesses will be functional again?
How much money and resources can the feds provide?
Where do those resources get applied?
If additional resources were available, could the restoration be done in less time?
What are the choke points in the process?
First Responders & Sampling
Laboratory Analysis
Decontamination
Analyzer for Wide-Area Restoration Effectiveness (AWARE)
Has the capability to address these issues
6

AWARE Capability



AWARE can import plume maps (e.g., IMAAC) or the user can scribe an area of interest. Then a built-in building database is mined to determine the extent of possible damage/contamination (e.g., area, number of buildings, square footage of indoor contamination, critical infrastructure assets).

AWARE Capability

- AWARE addresses the Consequence Management phase of response and recovery, encompassing the following activities:

Initial screening sampling (consistent with BioWatch Phase 2 sampling)

Characterization does not begin until screening is complete

Once a site has been sampled, the sampling teams can move on to the next site even though the lab results are not complete

Characterization (including the ability to use confidence-based statistical sampling design)

Decontamination does not begin until all laboratory analyses are complete

Surface treatment vs fumigation is prescribed by the user based on degree of contamination

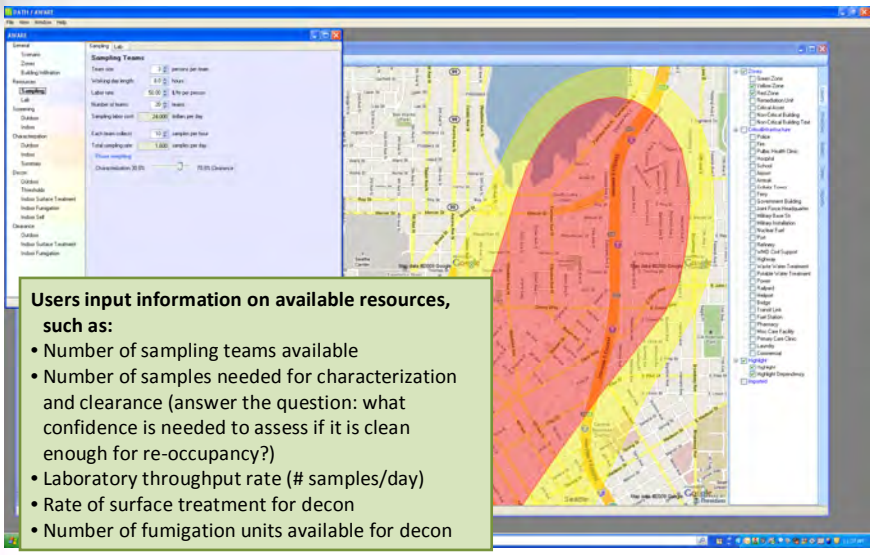
Decontamination (including surface decon, fumigation & waste disposal)

Clearance sampling does not begin until decon is complete

Clearance (including the ability to use confidence-based statistical sampling design)

Decision rules are applied within the AWARE resource allocation and timeline algorithms

AWARE Capability



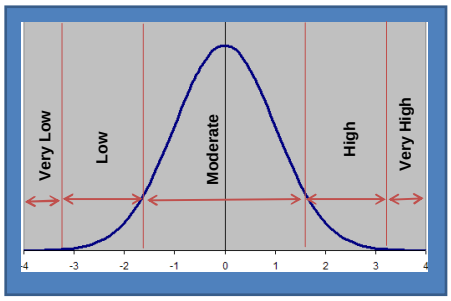
Users input information on available resources, such as:

- Number of sampling teams available
- Number of samples needed for characterization and clearance (answer the question: what confidence is needed to assess if it is clean enough for re-occupancy?)
- Laboratory throughput rate (# samples/day)
- Rate of surface treatment for decon
- Number of fumigation units available for decon

9

AWARE Capability

- The approach to decontamination planning has the following assumptions:
  - Outdoor decon occurs before indoor decon (to limit fomite transport)
  - Buildings are characterized as small, medium or large for the purpose of scoping fumigation resources and time (the user sets the specifications)
  - The degree to which a building is contaminated is assumed to have some relationship with whether surface treatment or fumigation will be employed
  - The relative degree of contamination in buildings is assumed to be a normal statistical distribution
  - User supplied metrics determine the selection of surface treatment vs fumigation based on degree of contamination



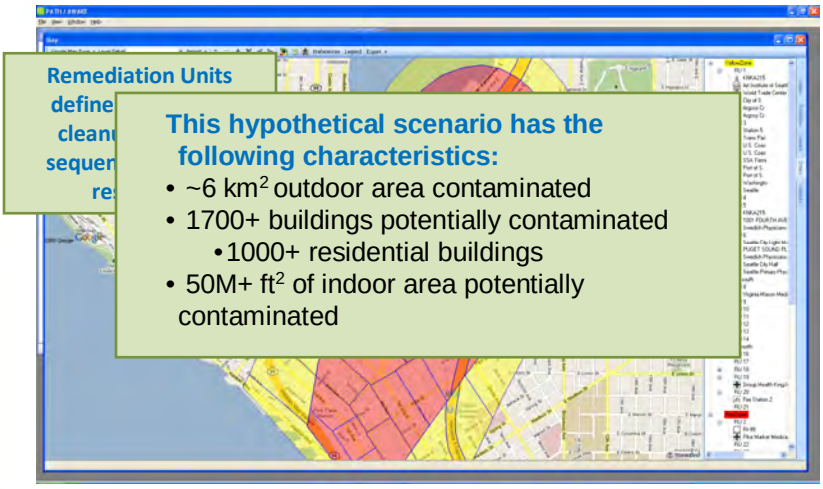
Relative Degree of Contamination in Buildings

The amount of spore infiltration into buildings is highly uncertain

10

Case Study A

- Hypothetical release scenario for Seattle



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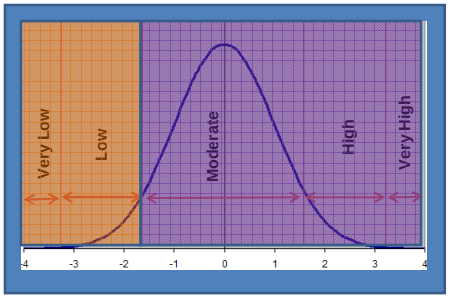
Case Study A

- Reasonable assumptions for resource allocations were assigned to this scenario (e.g., only judgmental sampling during characterization, confidence-based sampling during clearance (95% confidence that 95% of the area is safe for re-occupancy))
- A key decon parameter input relates to the fact that only 3 large-scale fumigation units exist in the US at this time

The apportionment of surface treatment vs fumigation is shown at right



Relative Degree of Contamination in Buildings

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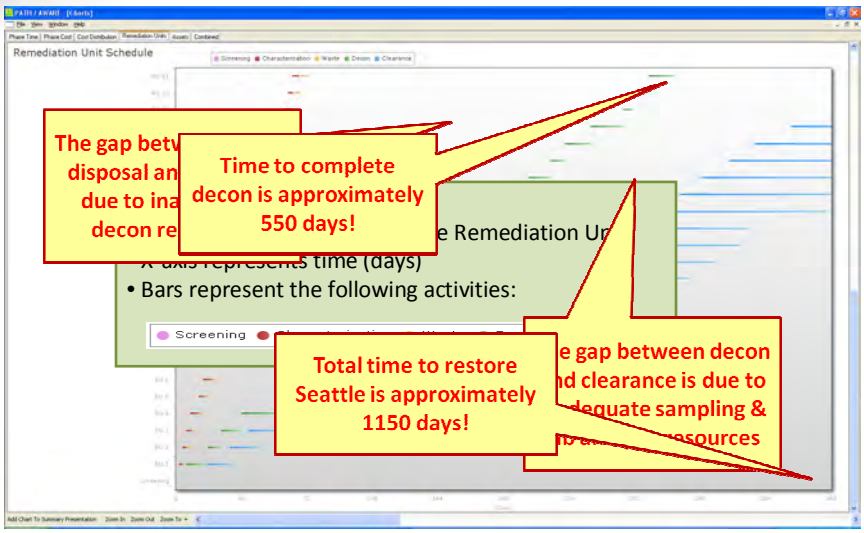
Case Study A



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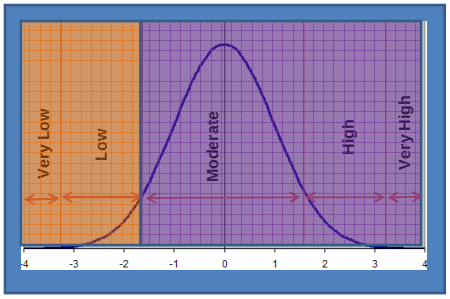
Case Study B

- All other parameters were kept the same as Case Study A, with the exception that the number of fumigation units was increased by a factor of 4

The apportionment of surface treatment vs fumigation is shown at right

Surface Treatment

Fumigation



Relative Degree of Contamination in Buildings

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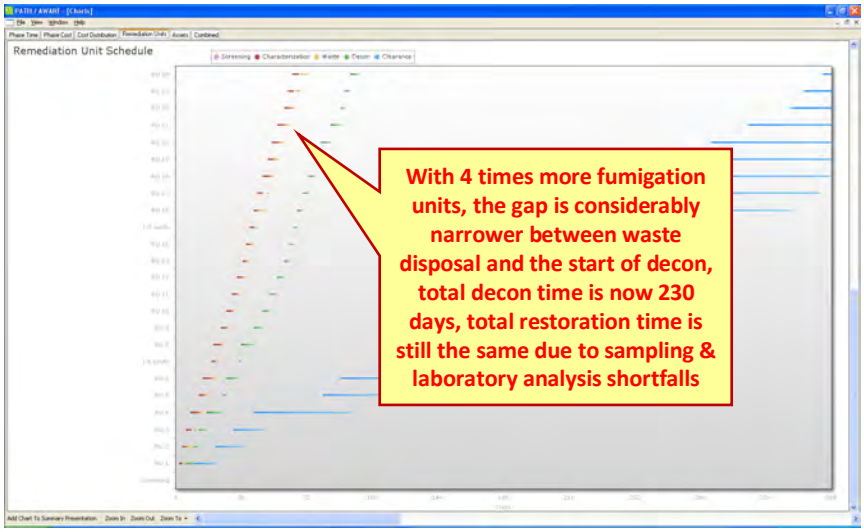
Case Study B



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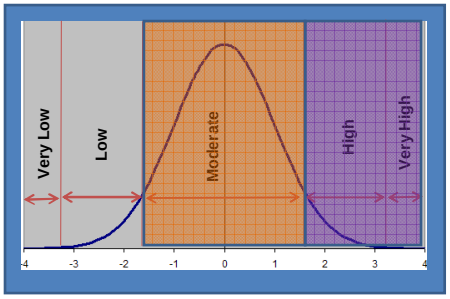
Case Study C

- What if there were a risk-based standard for anthrax cleanup that was greater than "zero culturable growth on all environmental samples"?
- What if fumigation was only warranted for highly contaminated areas?
- All other parameters kept the same as in Case Study B

The apportionment of surface treatment vs fumigation is shown at right

Surface Treatment

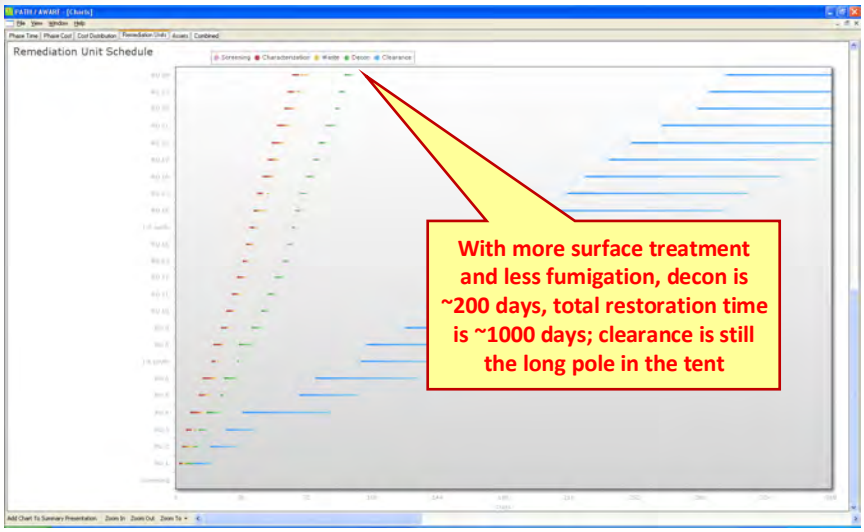
Fumigation



Relative Degree of Contamination in Buildings

16

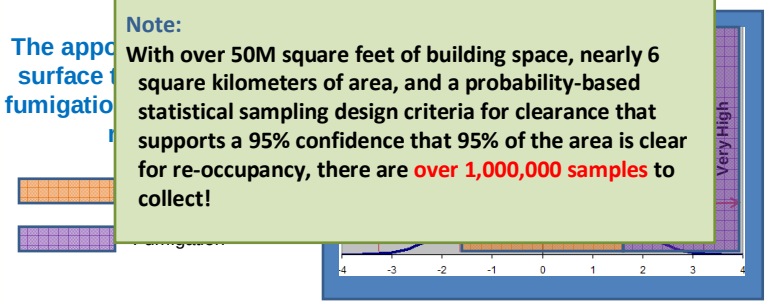
Case Study C



Case Study D

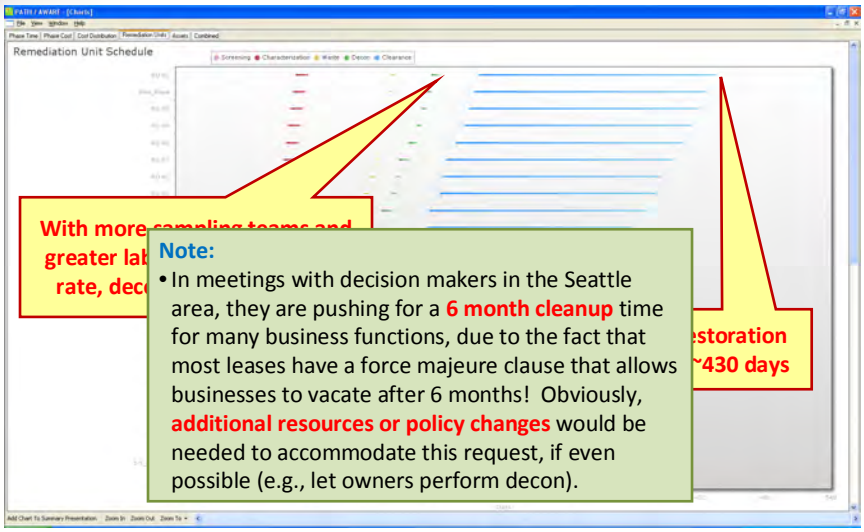
- What if more sampling teams were available and the laboratory throughput rate were increased , how would that affect the schedule?
- For this scenario, 4 times more sampling teams (120 total) and 4 times the laboratory throughput rate (1200 samples per day) were assumed
- All other parameters kept the same as in Case Study C

Note:
With over 50M square feet of building space, nearly 6 square kilometers of area, and a probability-based statistical sampling design criteria for clearance that supports a 95% confidence that 95% of the area is clear for re-occupancy, there are over 1,000,000 samples to collect!



Relative Degree of Contamination in Buildings

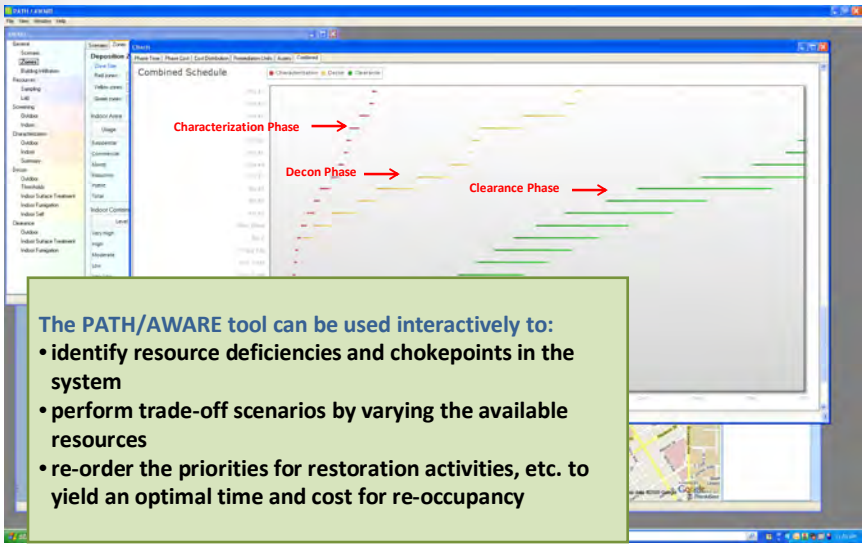
Case Study D



Note:

- In meetings with decision makers in the Seattle area, they are pushing for a **6 month cleanup** time for many business functions, due to the fact that most leases have a force majeure clause that allows businesses to vacate after 6 months! Obviously, **additional resources or policy changes** would be needed to accommodate this request, if even possible (e.g., let owners perform decon).

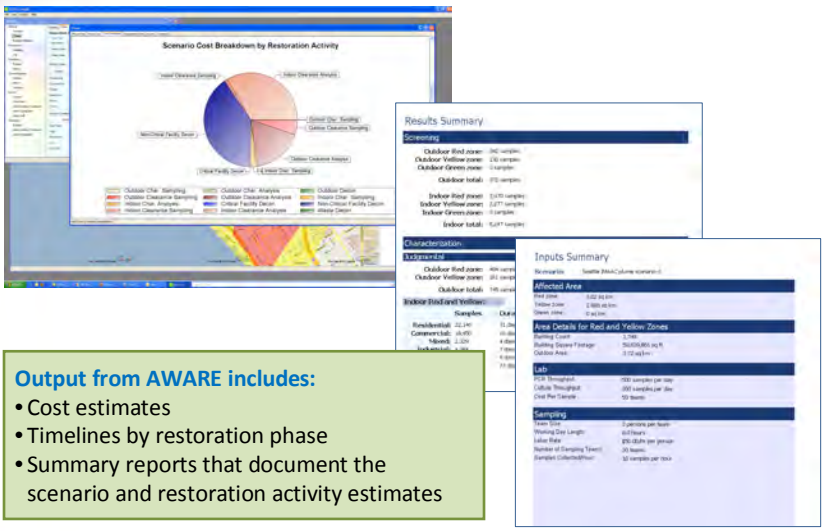
Decontamination Scenario Analysis



The PATH/AWARE tool can be used interactively to:

- **identify resource deficiencies and chokepoints in the system**
- **perform trade-off scenarios by varying the available resources**
- **re-order the priorities for restoration activities, etc. to yield an optimal time and cost for re-occupancy**

Additional AWARE Capabilities



Output from AWARE includes:
- Cost estimates
- Timelines by restoration phase
- Summary reports that document the scenario and restoration activity estimates

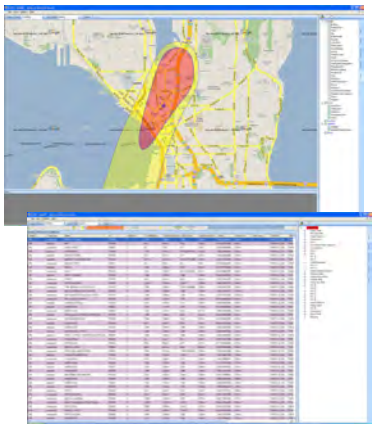
Take Away Message

- Response and recovery following a National Planning Scenario 2 incident will be quite costly and time consuming
- The PATH/AWARE decision support tool provides insight to decision makers, for pre-planning and post-incident consequence management activities
- These tools provide a means of estimating resource requirements (e.g., number of fumigation units needed, laboratory throughput capacity, etc.) and may provide the basis for a more efficient response and recovery effort (e.g., reducing cost and time)
- Analyses with tools like PATH/AWARE may lead to policy changes
- These tools would be beneficial to decision makers in multiple jurisdictions and agencies/departments; however, a transition pathway has yet to be defined and supported

Backup Slides

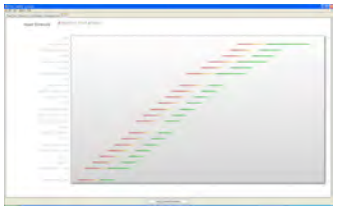
GIS and Database Capabilities in PATH/AWARE

- **Think Geo Geographical Information System (GIS)**
  - Fully-functional GIS
  - Utilizes Google map suite
  - Custom graphical user interface (GUI) elements
- **Microsoft's Structured Query Language (SQL) database**
  - Secure network access
  - Large data storage
  - Tax assessor data, HSIP data, HAZUS data, etc.
- **Enabling software chosen not only for functionality, but also so there are no licensing costs to end users**



PATH Capabilities

- **The PATH module allows decision makers to prioritize critical infrastructure for restoration**
- **Critical infrastructure objectives associated with restoration include:**
  - Maintain public health
  - Maintain public safety
  - Maintain economy
  - Minimize environmental impact
  - Maintain national security
  - Protect property
- **Prioritization is performed by weighting objectives and associated functions while considering dependencies and special conditions (e.g., work-arounds)**
- **Reporting results in a number of formats, including:**
  - Graphical
  - Summary PowerPoint presentation



The PATH methodology may be used for any hazard, not just bio

Interactive Decision Framework for Consequence Management

Robert Greenwalt, Lawrence Livermore National Laboratory

Presentation not available for distribution

Optimization Approaches and Issues Associated With Late-Phase Recovery Following Radiological or Nuclear Events

S.Y. Chen, Argonne National Laboratory

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NCRP National Council on Radiation Protection & Measurements

Optimization Approaches and Issues Associated with Late-Phase Recovery Following Radiological or Nuclear Events

Presented at
2010 US EPA Decontamination Research and Development Conference
April 12-15, 2010
Durham, North Carolina

S.Y. Chen, PhD, CHP
Environmental Science Division
Argonne National Laboratory, Argonne, IL

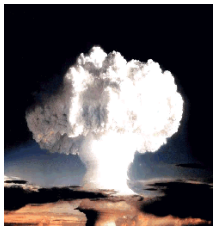
T.S. Tenforde, PhD
National Council on Radiation Protection and Measurements, Bethesda, MD

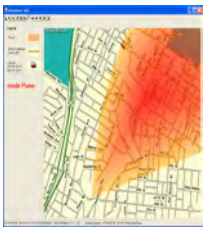
RDD and IND May Derive from Many Sources

NCRP National Council on Radiation Protection & Measurements

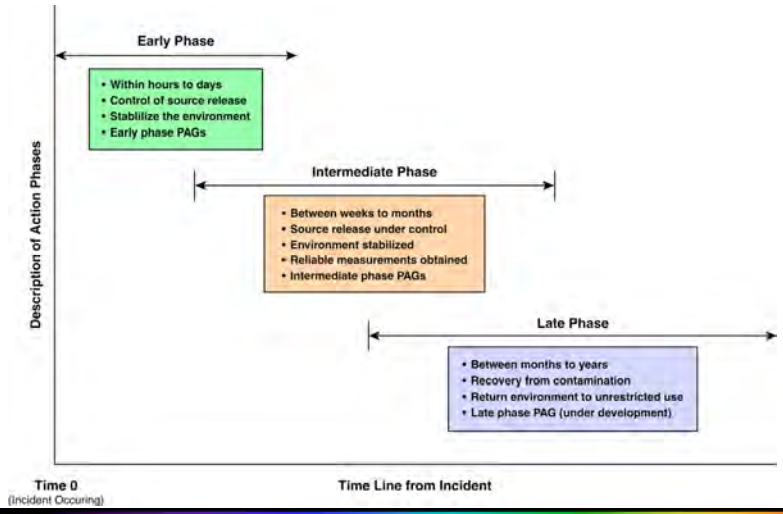
"**Radiological Dispersal Device**" (RDD) refers to any method used to deliberately disperse radioactive material in the environment in order to cause harm.

"**Improvised Nuclear Device**" (IND) refers to any device incorporating radioactive materials designed to result in the dispersal of radioactive material or in the formation of nuclear-yield reaction.





The Radiological Emergency Response and Management Are Represented in Three Sequential Phases



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3

Guidelines on Radiological Consequence Management Are Being Developed

Protective Actions

Activities that may be conducted in response to a nuclear incident in order to reduce or eliminate exposure to members of the public to radiation or other hazards.

Protective Action Guides (PAGs)

The projected dose(s) to a reference individual from an accidental release of radioactive material at which a specific protective action to reduce or avoid that dose is expected to be warranted.

Operational Guidelines

Operational guidelines are levels of radiation or concentrations of radionuclides that can be accurately measured by radiation detection and monitoring equipment, and then related to Protective Action Guides to quickly determine if actions for protection of the public need to be implemented.

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*Latest Protective Action Guides (PAGs) Issued By the Department of Homeland Security for RDD and IND**

PHASE	Protective Action	PAG
Early	Sheltering-in-place or evacuation of the public	1 to 5 rem projected dose
	Administration of prophylactic drugs – potassium iodine	5 rem projected dose to child thyroid
	Administration of other prophylactic drugs or decorporation agents	
Intermediate	Relocation of the public	2 rem projected dose first year. Subsequent yeas, 0.5 rem/y projected dose.
	Food interdiction	0.5 rem projected dose or 5 rem to any individual organ or tissue in the first year, whichever is limiting.
	Drinking water interdiction	0.5 rem projected dose in the first year

*The final version of the guidance, ***Planning Guidance for Protection and Recovery Following Radiological Disposal Device (RDD) and Improvised Nuclear Device (IND) Incidents***, was published by DHS in ***Federal Register***, Vol. 73, No.149 (August 1, 2008). It is to be noted that it does not contain a PAG for the Late Phase.

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The DHS Guidance Lacks A PAG for the Late Phase

- **What is needed:** Guidance on long-term (late-phase) cleanup following an event
- **What is recommended:** Site-specific optimization process for reaching the cleanup criteria (in lieu of a specific PAG)
- **Why:** Extreme flexibility needed to address wide-range impacts and effort for the cleanup in various scenarios
- **How:** Involving stakeholders in reaching acceptable cleanup criteria
- **Remaining issues:** In need of specific framework and mechanism to support the optimization process

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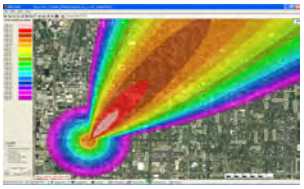
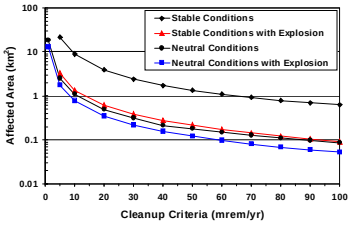
The "Optimization" Process Requires A Multi-Faceted Effort

- **Key Considerations**
  - Pubic Health
  - Social Economics
  - National Security
  - Public Welfare
  - Communication
- **Decision Process**
  - A Graded Approach
  - Qualitative and Quantitative Assessments
  - Evaluation of Remedial Options
    - ***Cost-Benefit Analysis***
    - ***Technology Evaluation***
    - ***Short- and Long-Term Feasibility***
    - ***Land Use Options***
  - Stakeholder Involvement
  - Implementation of the Decision

Assessing Potential Impacts for the Late-Phase Actions Involves Many Complex Issues





Relevant Issues and Competing Factors

- Wide-area cleanup issues
- Availability of effective cleanup technologies
- Non-specific cleanup criteria (long-term health risks)
- Accommodation with existing cleanup statutory requirements
- Waste generation and disposal issues
- Potential cleanup costs
- Inexperience in managing the late-phase activities
- Competing priorities of the society

Recent Reports on Long-Term Recovery

- GAO Report (JAN 2010) – Report to Congressional Committees
  "***COMBATING NUCLEAR TERRORISM – ACTIONS NEEDED TO BETTER PREPARE TO RECOVER FROM POSSIBLE ATTACKS USING RADIOLOGICAL OR NUCLEAR MATERIALS"***
- Homeland Security Affairs Journal, Paper (JAN 2010) – S.Y. Chen and T.S. Tenforde
  "***OPTIMIZATION APPROACH TO DECISION MAKING ON LONG-TERM CLEANUP AND SITE RESTORATION FOLLOWING A NUCLEAR OR RADIOLOGICAL TERRORISM INCIDENT"***

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Issues Identified

- The Nation's current preparedness for recovery phase is deficient
- Inadequate research focus on radiological events
- Existing technology base, although extensive, does not necessarily address event-specific situations
- Current decision-making process for recovery (i.e., site cleanup) may not be well suited for event situations
- The "optimization" approach will need to incorporate many factors to reach (multi-faceted) cleanup decisions
- Need to develop a national disaster recovery strategy

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Cleanup of Urban Area Presents Special Challenges

- Statutory cleanup requirements such as CERCLA have applied mostly to non-urban areas
- No clear federal guidance on long-term recovery phase
- Policy on radioactive waste disposal may not be applicable
- Recovery effort faces competing priorities
- Returning the society to "normalcy" becomes the top priority

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Technology for Wide-Area Cleanup Is Yet to Be Fully Tested and Proven

Key Considerations

- Applicability
- Availability
- Efficacy
- Efficiency
- Reliability
- Life-Cycle Costs
- Secondary Waste Generation
- Long-Term Considerations

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12

Lessons Learned from Past Events

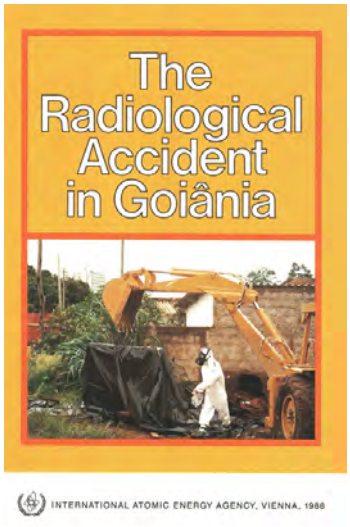
Level 7 **Large offsite release with widespread health and environmental effects. Example: Chernobyl Event (1986), Ukraine.**

Level 6 **Significant offsite release requiring full implementation of planned countermeasures. Example: Kyshtym event at Mayak (1957), former Soviet Union.**

Level 5 **Limited offsite release requiring partial implementation of planned countermeasures. Example: Three Mile Island accident (1979), United States**

International Nuclear Event Scale (IAEA)

Past Experiences Offer Valuable Lessons



Goiania, Brazil

- Incident occurred in 1987, involving
- Cs-137 as source
- Total 1,375 Ci; 1,200 Ci recovered
- 4 deaths and many injured
- Total waste volume 3,500 m3
- Took 3 months to complete
- decontamination on main area of 0.4 mi2 (or 1 km2)
- 7 houses demolished
- Contaminated soils removed
- 42 houses decontaminated
  - High pressure water jet outside
  - Vacuum cleaning inside
  - Various chemical methods used

Past Experiences Offer Valuable Lessons (Cont'd)

(Source: BBC News)

Chernobyl, Ukraine

- Nuclear power plant accident in 1986
- About 380 MCi released (43 MCi I-131 and 2.3 MCi Cs-137); 400 times the atomic bomb release at Hiroshima, Japan in WWII
- 56 people died and 4,000 estimated latent cancer deaths
- Very widespread contamination
- Cs contamination presented a major challenge
- About 90% Cs retained in soil for the first 5 years
- High-pressure washing reduced doses by 10–40%
- Other technologies showed various levels of effectiveness

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Further Developments Needed

- **Policy Development - Need to Address Emergency Situation**
  - Property Condemnation
  - Economic Assistance
  - Radioactive Waste Generation, Storage and Disposal
  - Cleanup Requirement against Current Statutory Policies
- **Scientific Research and Technology Development**
  - Short-Term vs. Long-Term Contamination
  - Environmental Fate and Transport in Urban Setting
  - Technology Involving the Wide-Area Contamination
  - Understanding the "Real World" Problems
- **Potential Impacts and Implications**
  - Assessing Magnitude of Impacts
  - Impacts Implications on Land-Use, Technical Feasibility, Costs, Cost-Effectiveness, and Public Acceptance
- **Stakeholder Involvement**
  - Desire to Return Life to Normalcy in Timely Manner
  - Perception of Residual Radioactivity
  - Potential Cleanup Costs Involved

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16

Current Federal Cleanup Guidance Is Part of the Optimization Process

- Current Cleanup Guidance
  - EPA CERCLA (i.e., Superfund) cleanup
  - NRC License Termination Rule (10 CFR 20, Subpart E)
  - DOE cleanup of nuclear weapons complex
- Major Differences with Event-Related Situations
  - Incident vs. non-incident situations
  - Urban vs. rural contamination
  - Above ground vs. subsurface contamination
  - Cleanup costs and funding mechanisms
  - Applicability of current regulatory requirements
  - Allocation of other priorities vs. long-term health risks
  - Involvement of different stakeholder groups

More Recovery Exercises Needed

Lead Agency: EPA (ESF #10)

Liberty RadEx...what is it?

Liberty RadEx is a national exercise sponsored and designed by the US Environmental Protection Agency (EPA) to practice and test federal, state and local assessment and cleanup capabilities in the aftermath of a radiological dispersion device (also known as a RDD or "dirty bomb") incident in an urban environment. Most exercises only focus on the first hours and days of a response. Liberty RadEx is unique in that participants will practice their "post-emergency" phase responsibilities and coordination, and work with stakeholders and the public to plan for community recovery. Liberty RadEx provides the opportunity to share information and procedures while strengthening relationships among federal, state and local partners in Pennsylvania and adjoining states.

EPA Mobile Command Post

Cleanup and assessment

Exercising the National Response Framework (NRF):

Unfortunately, disasters can happen anywhere. The NRF was written to ensure a consistent national response and coordinate the roles and responsibilities of the local, state, and federal government during large and small disasters. The Department of Homeland Security National Exercise Program (NEP) is designed to test the nation's ability to respond to natural and man-made disasters.

pennsylvania

US Army Corps of Engineers

Liberty RadEx

...and) of the incident;
...ing radiological assessment, hazardous
...re, infrastructure restoration, public
...and hazardous materials response; and
...nity recovery.

Related NCRP Publications

Reports Published

- Report No.138, ***Management of Terrorist Events Involving Radioactive Material*** (2001)
- Commentary No. 19, ***Key Elements of Preparing Emergency Responders for Nuclear and Radiological Terrorism*** (2005)
- Commentary No. 20, ***Radiation Protection and Measurement Issues Related to Cargo Scanning with Accelerator-Produced High-Energy X Rays*** (2008).
- Report No.146, ***Approaches to Risk Management in Remediation of Radioactively Contaminated Sites*** (2004)

Report Under Development

- Report on ***Responding to Radiological and Nuclear Terrorism: A Guide for Decision Makers.***

Recommendations

- **Develop Further Guidance on for Optimization Process**
  - Principles and Approach to Optimization
  - Key Components and Parameters
  - Technical Basis and Requirements
  - Implementation Procedures
  - Develop Case Examples
  - Develop National Disaster Recovery Strategy
- **Identify and Address Relevant Issues**
  - Address Policy Needs
  - Fill Technical Gaps and Provide Assessment Tools
  - Vet the Issues through Recovery Exercises (for RDD)
    - ***Liberty RadEx (April 2010, Lead by EPA)***
  - Obtain Lessons Learned

Transport of *Bacillus Thuringiensis* Var. *Kurstaki* (Btk) From an Outdoor Release Into Buildings

Kristin Omberg for Sheila Van Cuyk, Los Alamos National Laboratory

Transport of *Bacillus thuringiensis* var. kurstaki (*Btk*) from an Outdoor Release into Buildings

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svancuyk@lanl.gov

April 14, 2010

LA-UR 10-02013

Gypsy Moths

The culprit …

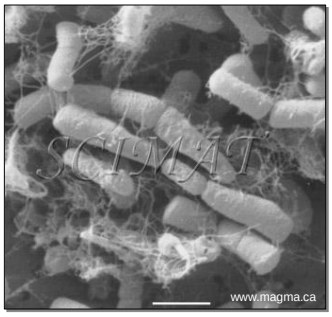
… looks pretty harmless.

Images from www.acgov.org and www.forestryimages.org

Consequences of gypsy moths

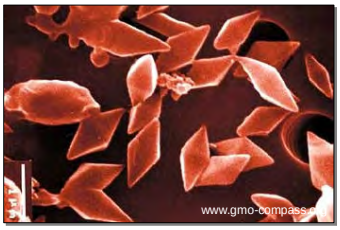
Biological warfare (on gypsy moths)

Bacillus thuringiensis
var. ***kurstaki*** (***Btk***)



1 m

Bt toxin crystals



Btk spraying provides a unique opportunity to study environmental fate following a biological release

- ***Btk*** shares many physical and biological properties with ***Bacillus anthracis***
- Bounding scenario—other agents likely less persistent
- May not be an ideal release scenario
  - Droplets are very large
  - Droplet size distribution estimated (log-normal assumed)
  - Clumping is desirable
  - Wind speed, direction only known at regional scale; conditions unstable; local wind fields and turbulence not known
- Adequate for evaluating environmental fate

Interagency Biological Restoration Demonstration (IBRD)

- US Department of Homeland Security & Defense Threat Reduction Agency
- Develop policies, approaches, methods, plans and applied technologies to restore large urban areas, Department of Defense installations and critical infrastructure following the release of a biological agent
- Los Alamos National Laboratory (LANL) is using spraying for gypsy moth control in Fairfax, VA to characterize long-term fate of ***Btk*** in urban environments
  - How long does the agent remain viable at detectable levels?
  - What is the approximate magnitude and duration of resuspension?
  - Does the agent transport into buildings?

LANL is using Fairfax, VA gypsy moth to characterize long-term fate of *Btk* in urban environments

- Fairfax, VA, 2008
  - Does ***Btk*** enter buildings?
- Fairfax, VA, 2009
  - Develop a method to (rapidly) determine if a building has been contaminated

Building infiltration studies in Fairfax, VA, 2009

Evaluate sampling strategies to determine building infiltration and contamination

Develop a method for the rapid triage (rule-in) of buildings for remediation

- Collect building samples within one week after spraying
  Sample types:
  - vacuum sock (primarily floors)
  - 3M trace evidence filter (HVAC)
  - swipes (elevator buttons, monitors, other targeted locations)
  - booty (shoe covers from samplers)
- One-time sample collection
- BROOM used to generate floor sample locations
- Tracking of samples using BROOM (when possible)
- CONTAM (Sandia National Lab) used to model building contamination
- PSUs placed on or near five buildings. Designed to be a positive control (turned on before spraying, turned off during building sampling)
- Samples cultured with B.t. selective media, confirmed as ***Btk*** by PCR

National Wildlife Federation

- 11100 Wildlife Center Drive, Reston, VA
- Built in 2000
- Modern/green construction
- Rooftop HVAC system (2 AHUs)
- Three floors
- PSU placed on roof

48 Total samples
- Booty (4)
- Swipe (6)
- Vacuum sock (36)
- 3M trace evidence (2)

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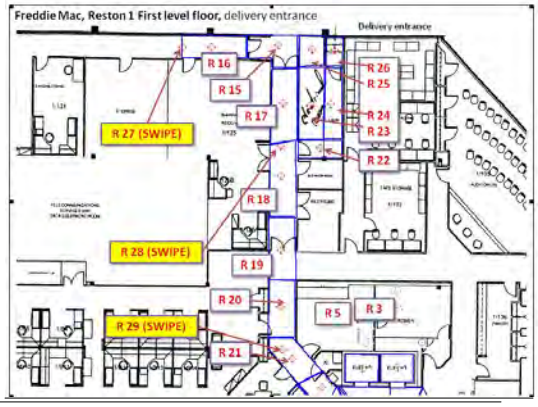
NNSA

Freddie Mac, Reston 1

- 1771 Business Center Drive, Reston, VA
- Built in 1980s
- Approximately 300-400 occupants and visitors to this location daily
- Three floors and six rooftop HVAC systems
- No windows open
- Approximately 68,000 ft^2

37 Total samples
- Booty (1)
- Swipe (8)
- Vacuum sock (26)
- 3M trace evidence (2)



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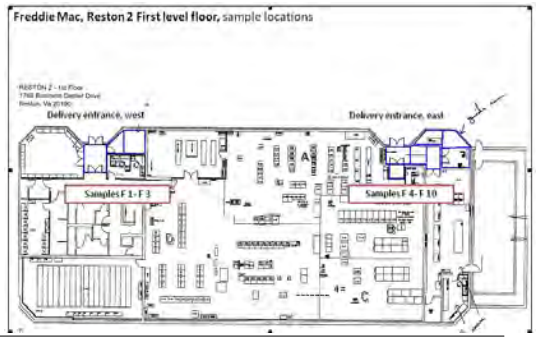
NNSA

Freddie Mac, Reston 2

- 1769 Business Center Drive, Reston, VA
- Built in 1980s
- Approximately 50 occupants
- Three floors and two rooftop HVAC systems
- No windows open
- Approximately 35,000 ft^2
- PSU placed on ground

22 Total samples
- Booty (1)
- Swipe (1)
- Vacuum sock (18)
- 3M trace evidence (2)



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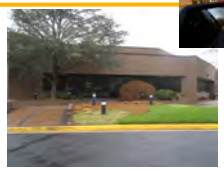
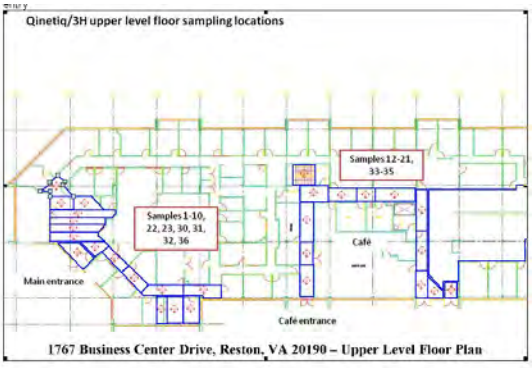
NNSA

3H/QinetiQ



- 1765 and 1767 Business Center Drive, Reston, VA
- Built in 1984
- Approximately 150-180 occupants
- Two buildings in one structure, two floors connected by stairwell
- Rooftop HVAC system (2 AHUs)
- No windows open
- Approximately 40,000 ft^2
- PSU placed on roof

52 Total samples
- Booty (4)
- Swipe (7)
- Vacuum sock (39)
- 3M trace evidence (2)



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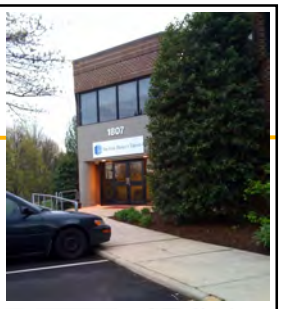
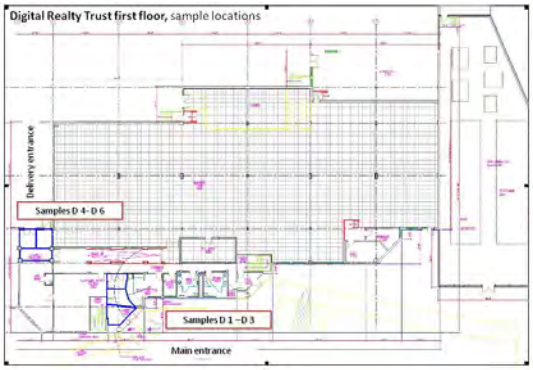
NNSA

Digital Realty Trust



- 1807 Michael Faraday Court, Reston, VA
- Built in 1980s
- 2 occupants, with occasional drop-in staff
- Two floors
- No HVAC system
- No windows open
- PSU placed on roof



17 Total samples
- Booty (1)
- Swipe (3)
- Vacuum sock (13)

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NNSA

Engineering Building

- Business Center Drive, Reston, VA
- Built in 1980s
- 4 occupants
- One floor with large truck bay
- Rooftop HVAC system
- Windows open

14 Total samples
- Swipe (3)
- Vacuum sock (5)
- 3M trace evidence (6)

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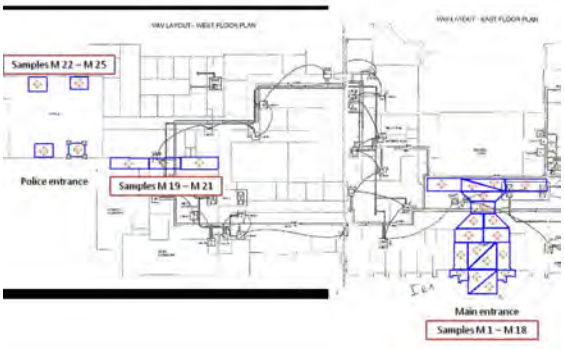
NNSA

Mason Governmental Center

- 6507 Columbia Pike, Annandale, VA
- Built in 1980s
- Open 24-hrs
- Community rooms and Fairfax County Police Headquarters
- One floor
- Four rooftop HVAC system
- Windows open
- PSU place at ground level

32 Total samples
- Booty (2)
- Swipe (5)
- Vacuum sock (22)
- 3M trace evidence (3)



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2009 Building Infiltration Results

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NNSA

Building Samples Results: by sample type

	Total number of samples	Number of positive samples	Percent positive
Total	224	149	66.5
3M	18	16	88.9
Booty	13	6	46.2
Swipe	33	17	51.5
Vacuum sock	160	110	68.8

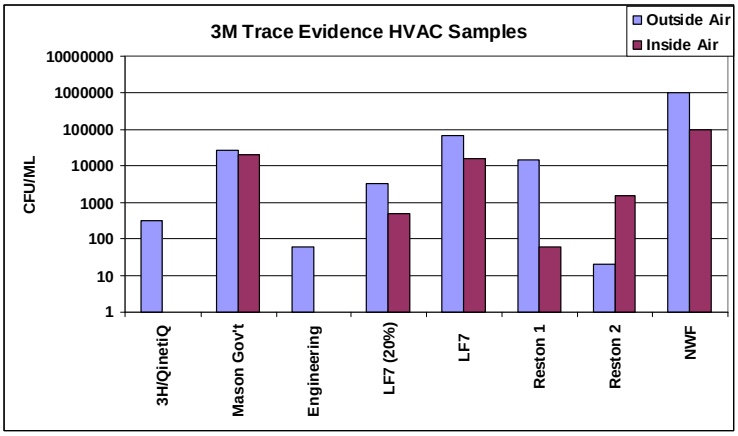
Building Samples Results: by location

Percent positive

	3H QinetiQ	Freddie Mac/ Reston 1	National Wildlife Federation	Mason Government Building	Freddie Mac/ Reston 2	Engineer - ing Building	Digital Realty Trust
All samples	46.2	67.6	81.3	68.8	77.3	64.3	64.7
Booty	50.0	0	50.0	0	100	n/a	100
Wipe	42.9	37.5	83.3	60.0	0	0	100
Vacuum sock	46.2	76.9	83.3	72.7	77.8	80.0	53.8
3M filter	50.0	100	100	100	100	83.3	n/a

n/a indicates no samples of this type were taken from this location

3M Trace Evidence: Inside vs. outside air by building



Comparison of inside air side of HVAC filter (concentration in CFU/ML) and outside air concentration of 3M trace evidence samples from buildings (note y-axis logarithmic scale).

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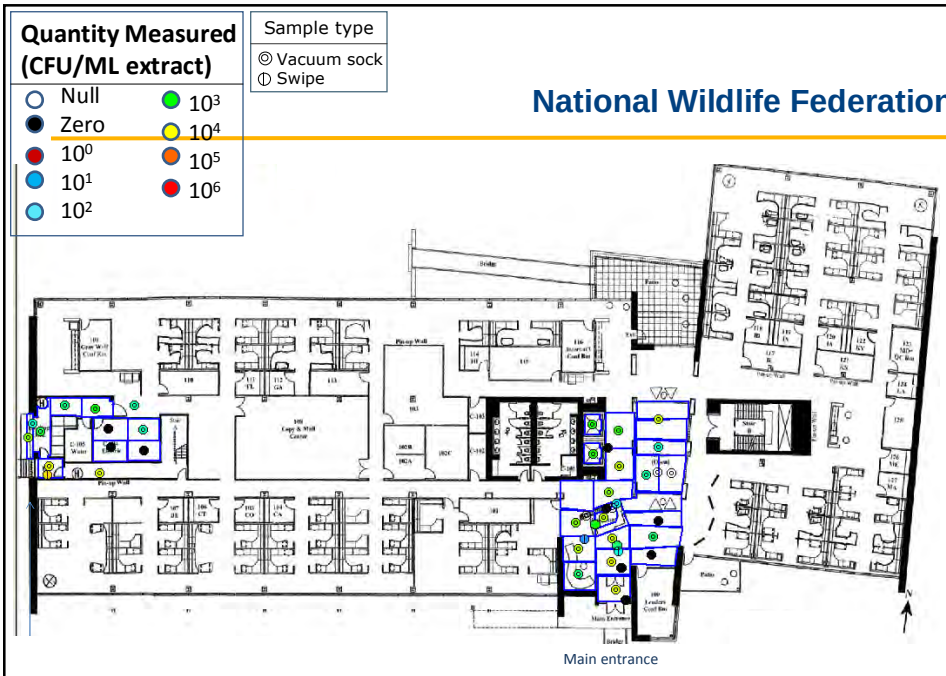
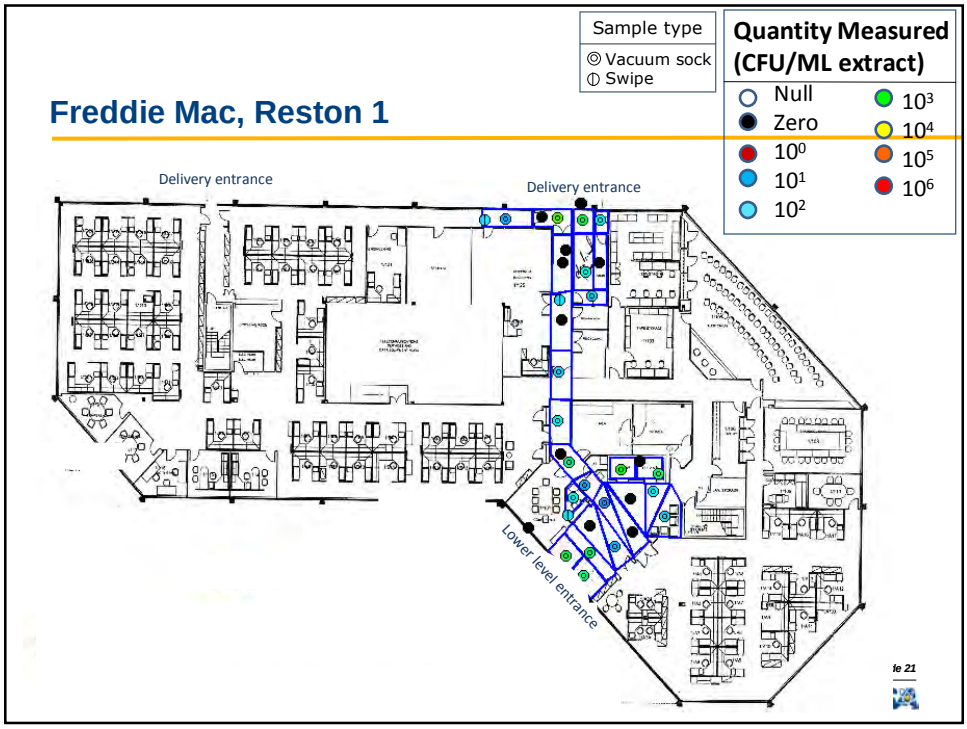
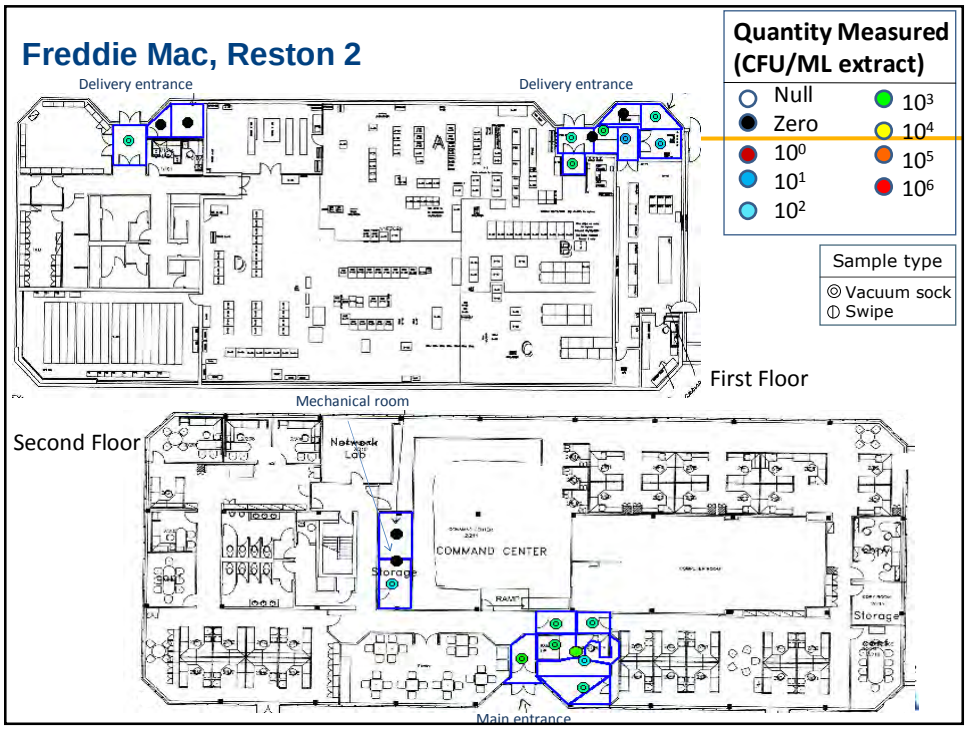
Slide 19

NNSA

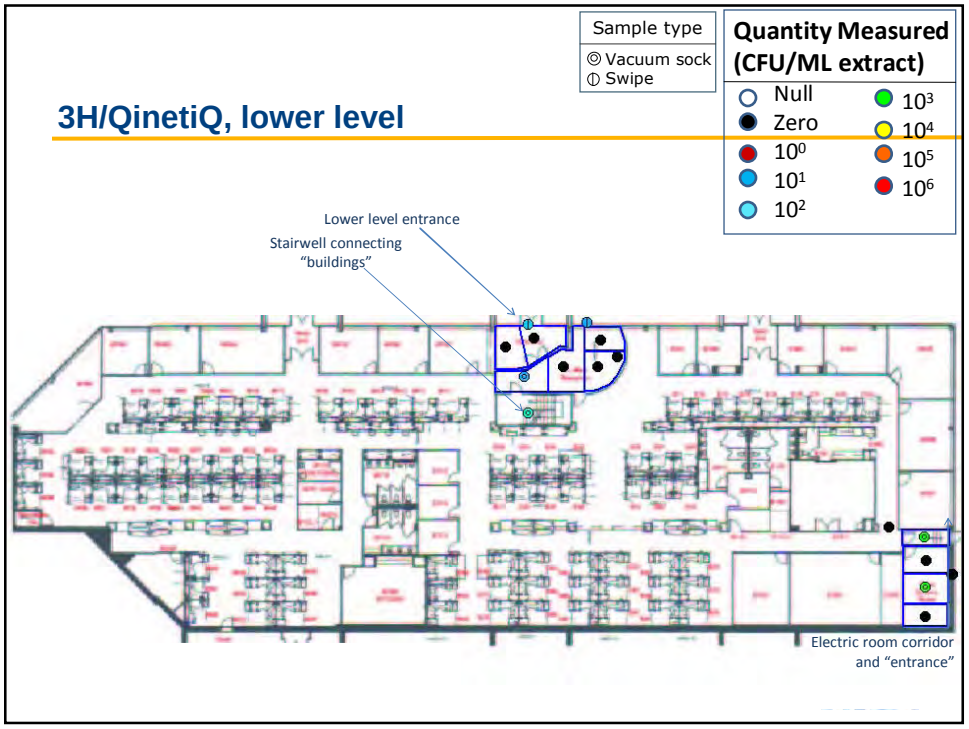
National Wildlife Federation



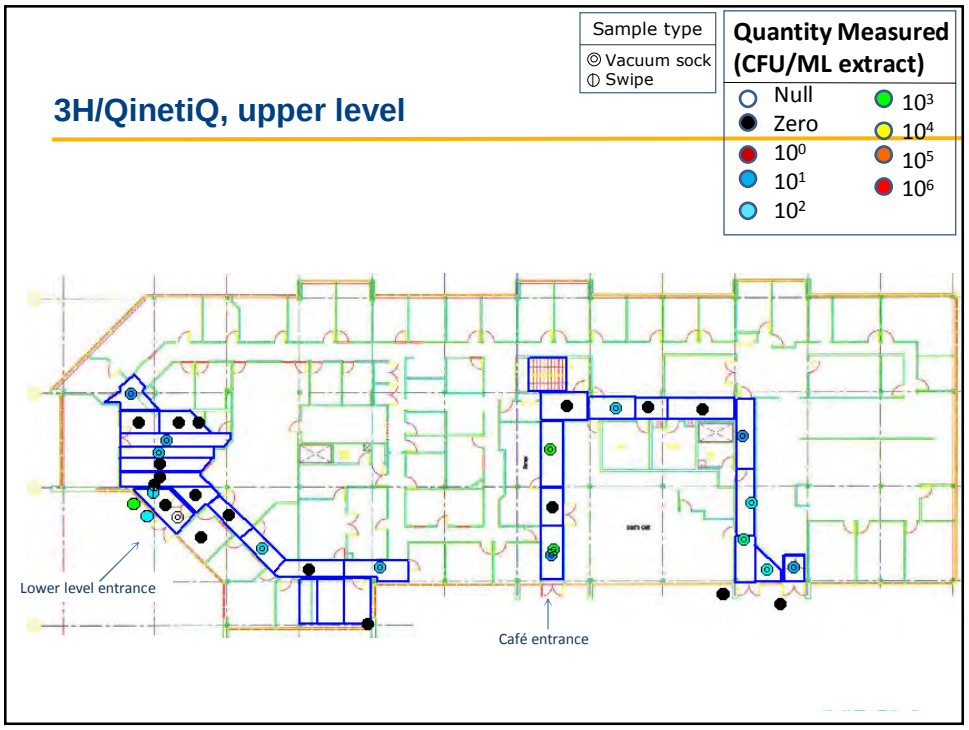

Sample type
Vacuum sock
Swipe
Quantity Measured (CFU/ML extract)
Null
Zero
10^0
10^1
10^2
10^3
10^4
10^5
10^6
Freddie Mac, Reston 1
Delivery entrance
Delivery entrance
Lower level entrance


Freddie Mac, Reston 2
Quantity Measured (CFU/ML extract)
Null
Zero
10^0
10^1
10^2
10^3
10^4
10^5
10^6
Sample type
Vacuum sock
Swipe
Delivery entrance
Delivery entrance
Mechanical room
First Floor
Second Floor
Network Lab
COMMAND CENTER
Storage
Storage
Main entrance

3H/QinetiQ, lower level



3H/QinetiQ, upper level

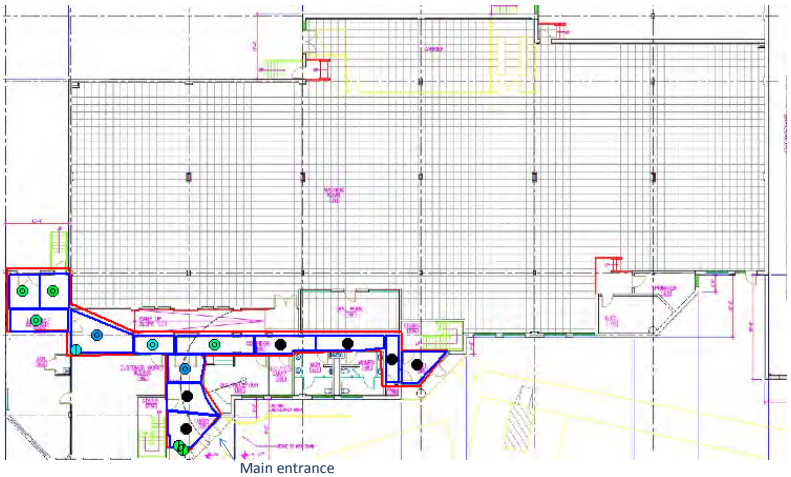


Digital Realty Trust

Sample type
◎ Vacuum sock
ⓘ Swipe

Quantity Measured (CFU/ML extract)

Null	10^3
Zero	10^4
10^0	10^5
10^1	10^6
10^2	



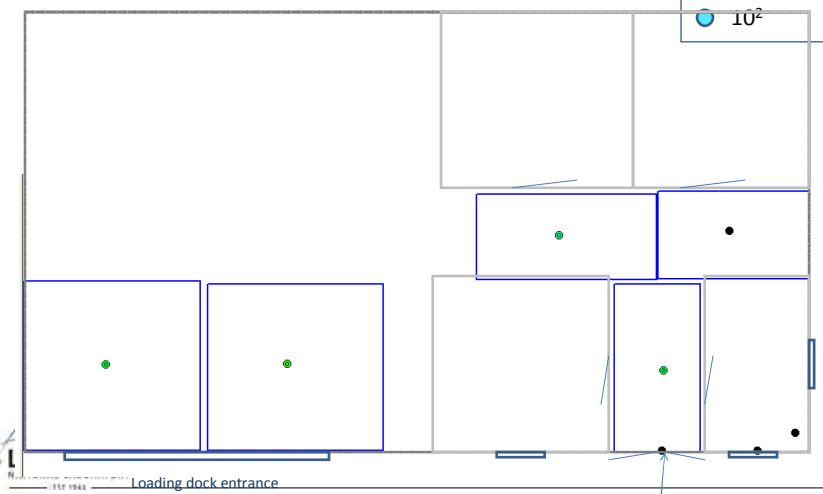
Engineering building

(not to scale)

Sample type
◎ Vacuum sock
ⓘ Swipe

Quantity Measured (CFU/ML extract)

Null	10^3
Zero	10^4
10^0	10^5
10^1	10^6
10^2	



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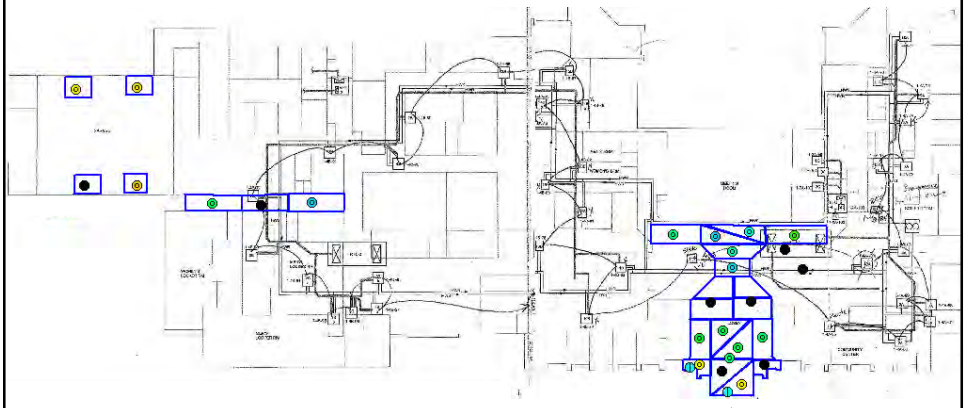
NNSA

Mason Governmental Center

Sample type
◎ Vacuum sock
◐ Swipe

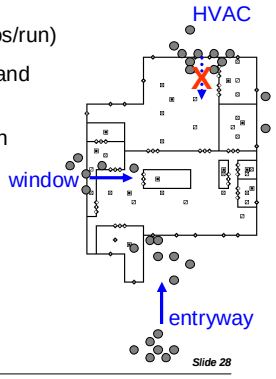
Quantity Measured (CFU/ML extract)

- Null
- Zero
- 10^0
- 10^1
- 10^2
- 10^3
- 10^4
- 10^5
- 10^6



Modeling and Simulation

- Sandia National Laboratory: FacDAC model of deposition in buildings
- Modeled 3H/QinetiQ facility accounting for entryway, window, walls, and HVAC flow paths
- Each infiltration mechanism was isolated by fixing relevant parameters (e.g., increasing filter efficiency of HVAC)
- Simulations run using Monte Carlo techniques (1000 scenarios/run)
- Characterized deposition in terms of extent of contamination and integrated deposition
- Simulated experimental release and identify primary infiltration mechanisms
- Correlated infiltration mechanism with building characteristics



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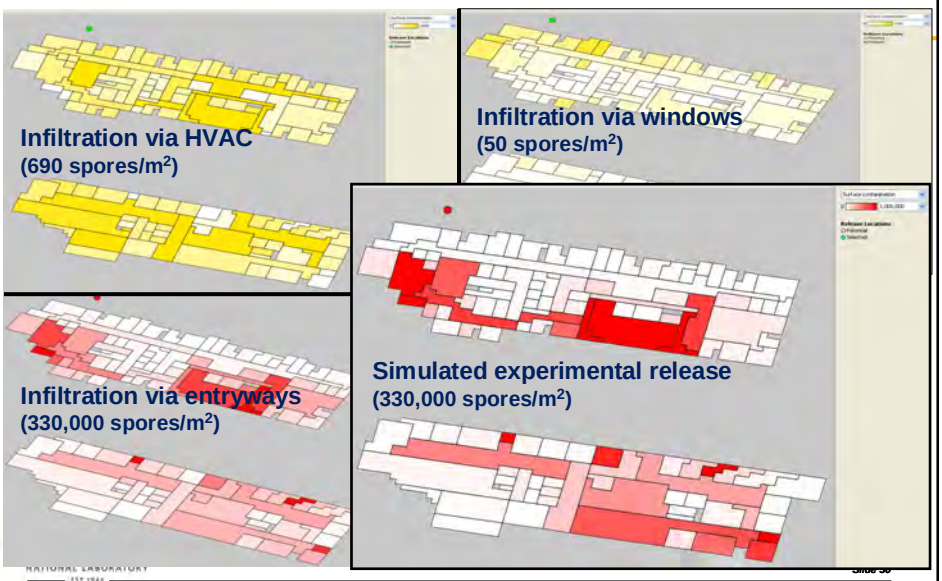
Slide 28

NNSA

Simulation parameters

- Experimental measurements and QUIC generated plume maps were used to define key parameter values
- Limited to modeling infiltration from initial release, does not account for tracking or re-aerosolization
- Ambient Conditions
  - Temperature = 53 – 74°F
- Release characteristics
  - Large particle agglomerates, homogenous concentrations (large, elevated release)
    Mean Particle size = 60µm (Low = 20µm, High = 80µm)
  - 3H facility exposed to steady concentrations of $5x10^{-5}$ g/m3 for ~8 minutes
- Variables
  - HVAC settings (e.g., mixing, return and exhaust schedules)
  - Door status = 0 – 0.2 (% open)

Modeling indicates entryways are predominant contamination mechanism



Btk scenario results and conclusions

- Entryways are most likely the dominant mechanism for building infiltration (tracking may also significantly contribute)
- Areas adjacent to entryways and well connected zones (e.g., reception areas, hallways are high probability locations for surface contamination)
- HVAC systems act as effective distribution systems but are a poor mechanism for infiltration
- Inoperable windows do not pose a significant risk of infiltration
- Results are representative of the experimental release conditions only. For a weaponized release, additional experiments are needed
- With decrease particle size, models predict increased infiltrations, increased HVAC contribution to infiltration, and decreased deposition within building

Building sampling "rules of thumb"

- Where to sample to rapidly determine if a building is contaminated
  - Entryway(s)
    - Primary entryways should be sampled
    - Large area vacuum sock sample
  - HVAC filter(s)
    - If small number of HVAC, sample all filters
    - If large number of HVAC or access limitations
      - Sample based on operational information (HVAC system on?)
      - Sample based on locations (lower level HVAC first, then higher)
    - Sample inside air side if HVAC is designed for biological filtration (e.g., HEPA)
    - Sample outside air side of all other or if unknown
    - Sample > 1 m^2 area using 3M trace evidence filter

Summary

- Experimental testing shows ability to collect viable sample from all entryways using vacuum sock sampling
- Modeling and testing support entryways as dominant mechanism of infiltration following agent release
- Rules of thumb for sampling of buildings allow for a rapid method to quickly “rule in” a building as contaminated following a bioagent release
  - Vacuum sample large area of main entryways
  - Sample HVAC filter (outside air side of filter unless HEPA, then inside air side)

Acknowledgements

- Defense Threat Reduction Agency, Chemical & Biological Defense Applied Technologies Division
- Los Alamos National Laboratory
  - Alina Deshpande
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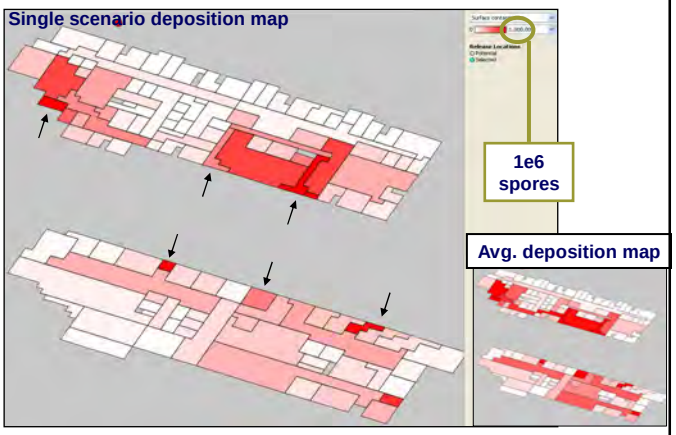
- Sandia National Laboratories
  - David Franco
  - Nate Gleason
  - Bob Knowlton
  - Brad Melton
  - Nerayo Teclemariam
- Pacific Northwest National Laboratory
  - Brent Pulsipher
- Fairfax County, VA
  - Mr. Troy Shaw, Mr. Frank Finch and Mr. Larry Nichols
- National Wildlife Federation
  - Mr. Steve Johnsen
- 3H Technologies/QinetiQ
  - Mr. Dan Ayed
- Freddie Mac
- Digital Realty Trust
  - Mr. Bobby Lambert

Thank you

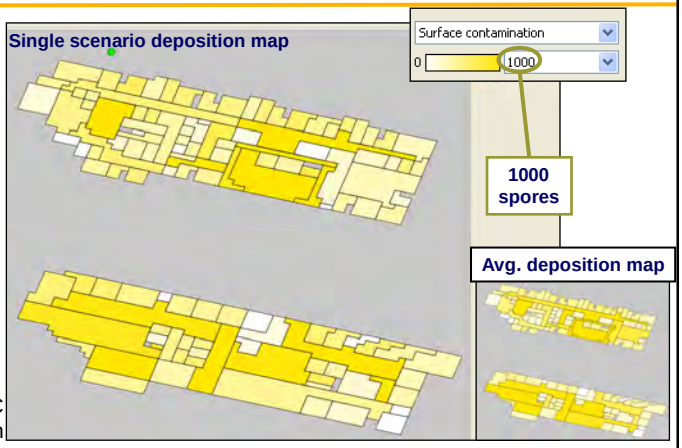
Simulation Results: Deposition map of 3H for infiltration via entryways

- Avg. integrated concentration = 330,000 spores/m^2
- High levels of contamination (multiple entryways, minimal filtration effects)
- Widespread contamination (multiple entryways)
- Infiltration via entryways results in significant levels of interior contamination



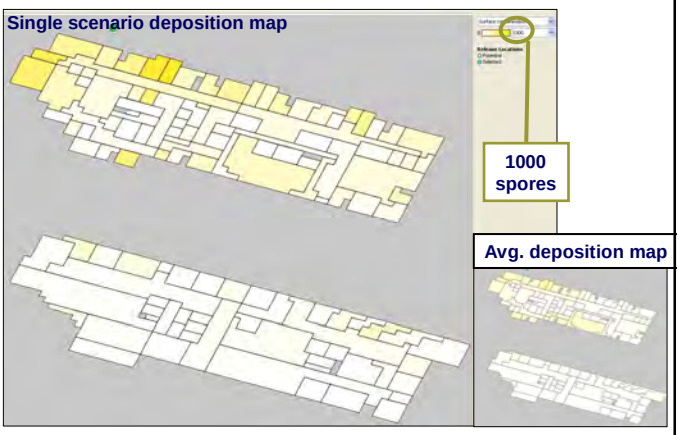
Simulation Results: Deposition map of 3H for infiltration via the HVAC system

- Avg. integrated concentration = 690 spores/m^2
- Low levels of surface contamination (large particles are effectively filtered out)
- Widespread contamination in well connected areas
- Infiltration through the HVAC may significantly contribute to indoor contamination; the HVAC is an effective distribution system



Simulation Results: Deposition map of 3H for infiltration via windows

- Avg. integrated concentration = 50 spores/m^2
- Low levels of contamination (inoperable windows, large particles)
- Localized contamination in locations with large window areas
- Infiltration through windows does not significantly contribute to building contamination



T**ransport of Bioaersols Into a Regional Transit System—Implications for Characterization**

Michael Dillon, Lawrence Livermore National Laboratory

Presentation not available for distribution

Mitigation and Containment of Contaminant Spread

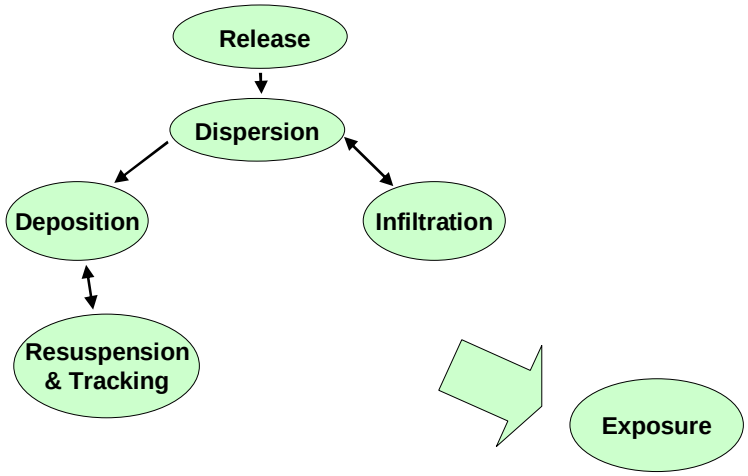
Jacky Rosati, EPA/ORD/NHSRC

Mitigation and Containment of Contaminant Spread

Jacky Ann Rosati and Russ Wiener
U.S. Environmental Protection Agency
National Homeland Security Research Center
Decontamination and Consequence Management Division

August 19, 2010

Movement of a Particle based Agent



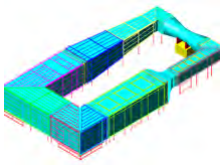
Release & Dispersion

Controlled Release Studies (wind tunnel)

- Large scale PM based contaminant release
- Outdoor conditions (wind, dew, etc)

- Deposition & reentrainment on outdoor surfaces
- Efficiency of ambient samplers

Release & Dispersion



100' x 60'
(4m x 4m cross-section)

Release & Dispersion

Field Studies

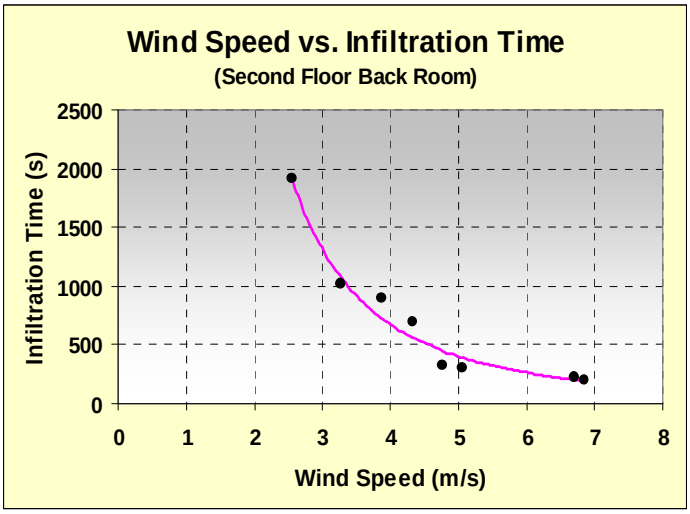
- Traffic emissions surrogate for outdoor released agent
- Characterize concentration movements with varied distance from highway

- Model urban transport, dispersion, and infiltration
- Determine extent of decontamination required

Release & Dispersion

Field Study Site in Brooklyn, NY

Release & Dispersion



Infiltration

- How is infiltration to the indoors affected by:
  - Building design,
  - Ambient conditions
  - Building shell

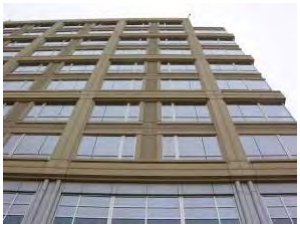
- Determine best way to mitigate penetration
- Minimize human exposure and decontamination

EPA United States Environmental Protection Agency

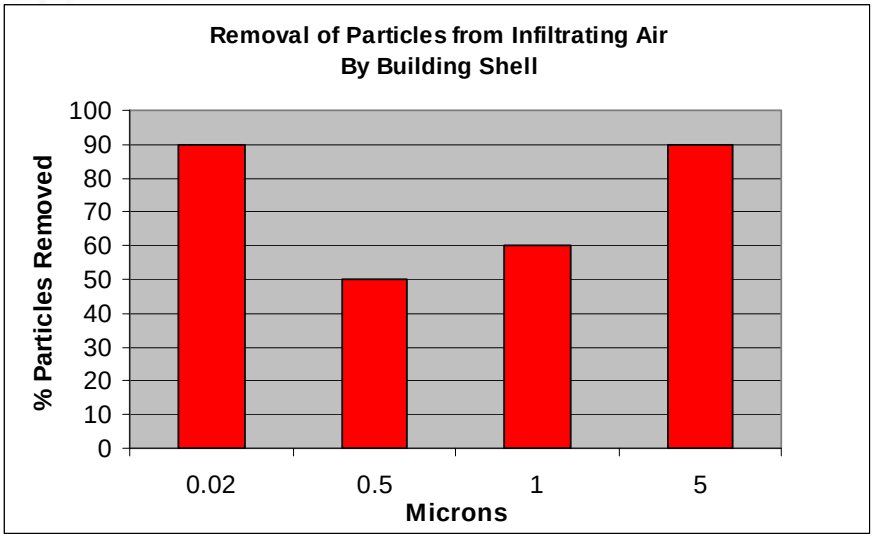
Two Compartment Chamber for Infiltration Studies

EPA United States Environmental Protection Agency

Infiltration



Exterior commercial walls to separate the compartments



Surface Deposition

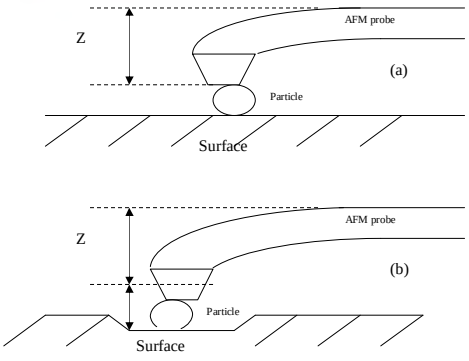
- Understand how materials deposit on and adhere to surfaces:
  - Outdoor (bldg materials, road, vegetation, soil)
  - Indoor (flooring, windows, walls)

- Speed of clean up (likelihood of resuspension)
  - Likelihood of tracking
  - Sampling method
  - Decontamination method

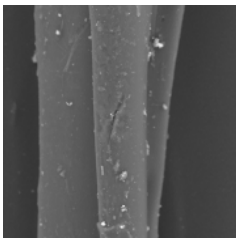
Adhesion

- Atomic Force Microscopy (AFM) used to determine particle adhesion forces to complex surfaces.
- Surface roughness data obtained.
- Data correlated to develop removal and sampling efficiencies

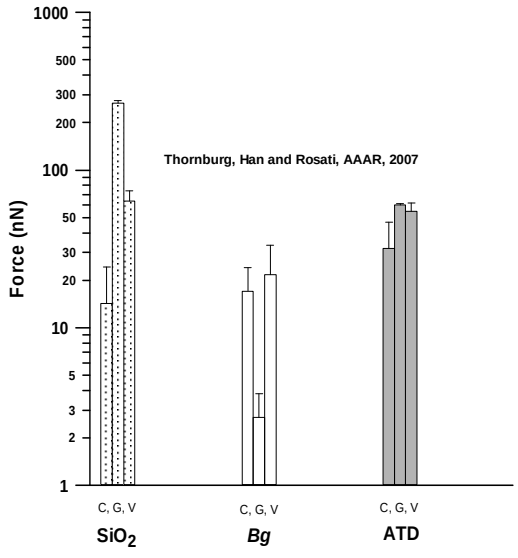
- Advise appropriate sampling methods.
- Assess reaerosolization and exposure risk



AFM tip with particles adhered



Surface roughness, elasticity



Combined electrostatic
and
van der Waals forces

- Silicon dioxide (SiO2) and Arizona Test Dust (ATD) adhesion forces mainly meniscus van der Waals forces.
- ***Bacillus globulii (Bg)*** spores and polystyrene latex spheres - lowest forces due to negative surface charge and hydrophobic nature
- SiO2 and ATD adhesion to glass high due to material similarity

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Resuspension and Tracking

• Resuspension and tracking of particulate matter (PM) primary modes of movement indoors – e.g., anthrax attack/cleanup at Hart Senate Office Building

• Experiments conducted to characterize:
  • resuspension and tracking
  • impact of environmental conditions

• Computational particulate fluid dynamics (CPFD) model developed from experimental data

Guide response to particle based release

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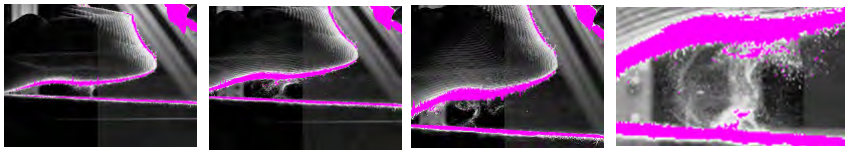
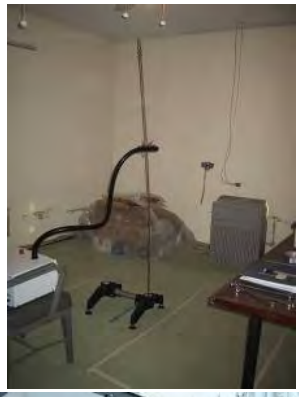
Stepping on Particle Contaminated Surface



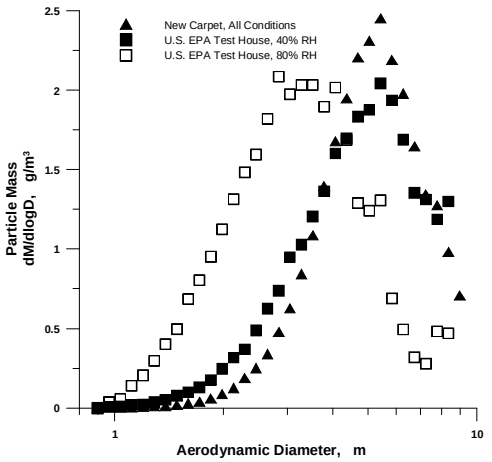
- **Particles picked up by foot surface during uplift**
- **Dust falls from bottom of foot/shoe surface**
- **Rotating motion causes turbulence under foot**
- **Flow rapidly moves toward front of foot**
- **Cotton socks and Tyvek booties pick up significantly more particles than rubber soled shoe.**
- **More particles adhesion/drop - more re-entrainment**



Resuspension

Field and Chamber Tests

- Used real world 'dirty' carpet, seeded carpet and seeded flooring surfaces.
- Walking and concurrent sampling.

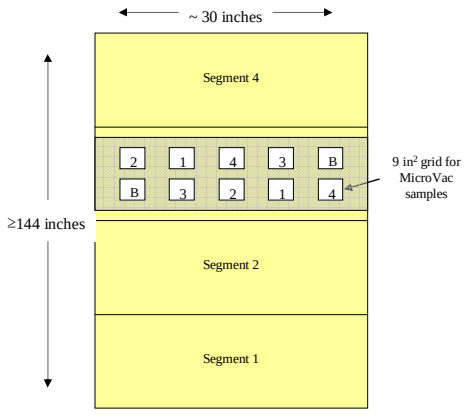


Rosati, Thornburg and Rodes, AS & T, 2008

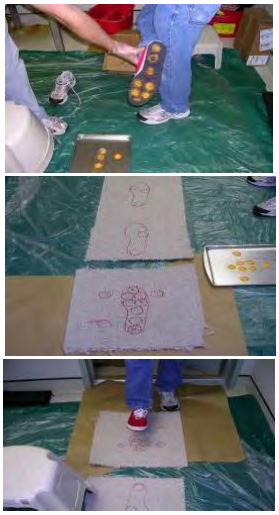
Tracking

- Characterize tracking of particles from outdoors to indoors
- Determined how non-airborne materials move around and become 'available' for resuspension

Field Work - Evaluation of tracking at indoor sites using 'track-off' carpet at entrances.



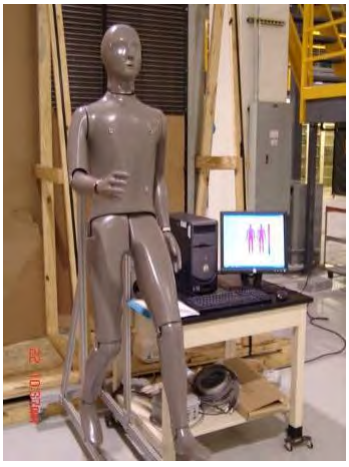
Chamber Work – Similar setup to field work but controlled environment with 'seeded' shoes.

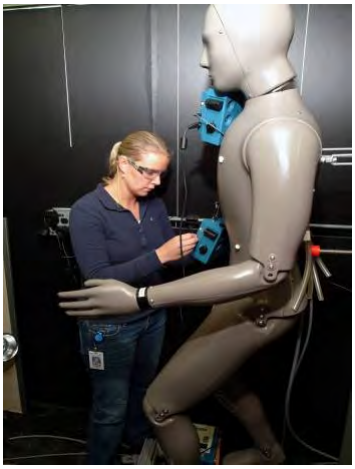


Tracking

- 40-80% of mass on shoe transferred to carpet on first step after loading
- Subsequent steps transfer ~ 2% each
- ~1% of mass in carpet transferred to shoe at each step
- PM tracking dependent on weather conditions, i.e., wetness of tracked material.

Exposure

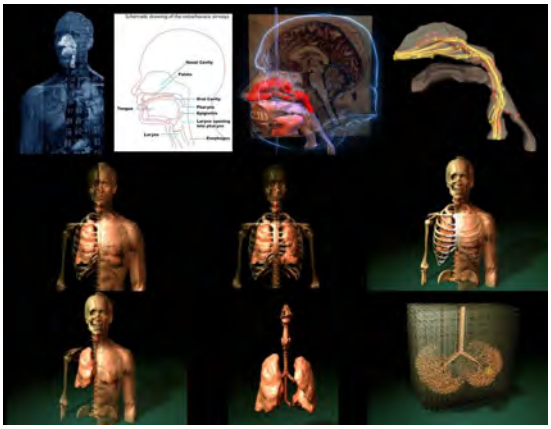


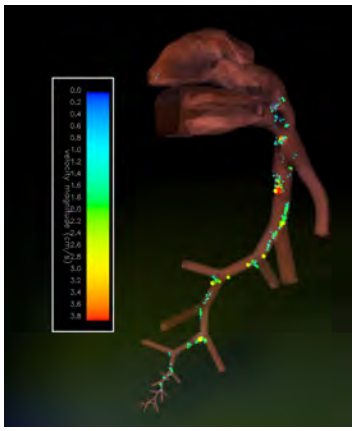


Heated breathing mannequin

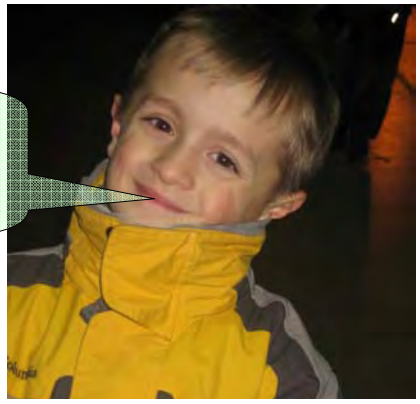
Exposure

3-D model of human respiratory system





Questions??



By working in multiple areas - comprehensively gather data to answer questions about contaminant spread, spread mitigation and public protection

DISCLAIMER:

The views expressed in this presentation are those of the authors and do not necessarily reflect the views or policies of the U.S. EPA

The Brooklyn Traffic Real-Time Ambient Pollutant Penetration and Environmental Dispersion (B-TRAPPED) Study

Russell Wiener, EPA/ORD/NHSRC

EPA United States Environmental Protection Agency

The Brooklyn Traffic Real-Time Ambient Pollutant Penetration and Environmental Dispersion (B-TRAPPED) Study

Themed issue: A real-time study of airborne particulate dispersion in urban canyons.

JEM 11:12:2113–2206 (Dec. 2009)

Russell W. Wiener, Ph.D.

The 2010 US EPA Decontamination Research and Development Conference, April 14, 2010, Raleigh, NC

EPA United States Environmental Protection Agency

The Brooklyn Traffic Real-Time Ambient Pollutant Penetration and Environmental Dispersion (B-TRAPPED) Study

Russell W. Wiener, Ph.D.

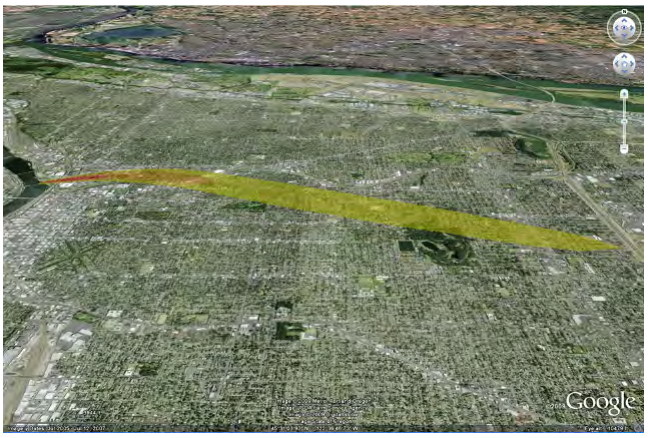
Disclaimer:

Although this work has been funded wholly by the United States Environmental Protection Agency, it does not necessarily reflect the views of the Agency. Mention of trade names or commercial products does not constitute endorsement or recommendation for use.

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

3-D View of Plume 100 µCi/m² Zone

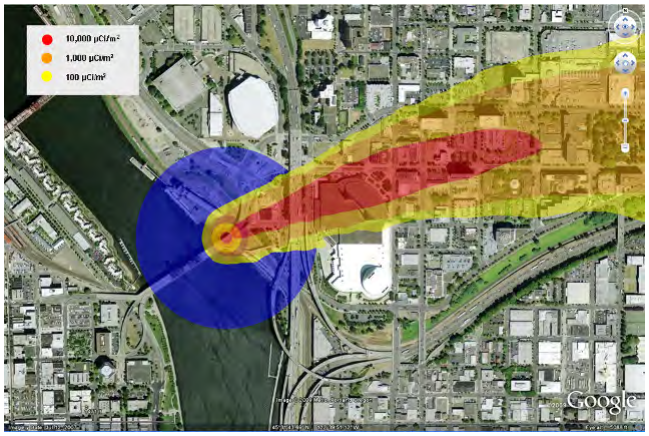
TOPOFF4 National Level Exercise FRMAC



Source: TOPOFF4 National Level Exercise FRMAC

TOPOFF4 RDD Event Plume

TOPOFF4 National Level Exercise FRMAC



Source: TOPOFF4 National Level Exercise FRMAC

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Brooklyn Traffic Real-Time Ambient Pollutant Penetration & Environmental Dispersion Field Study Site

SUNSET PARK

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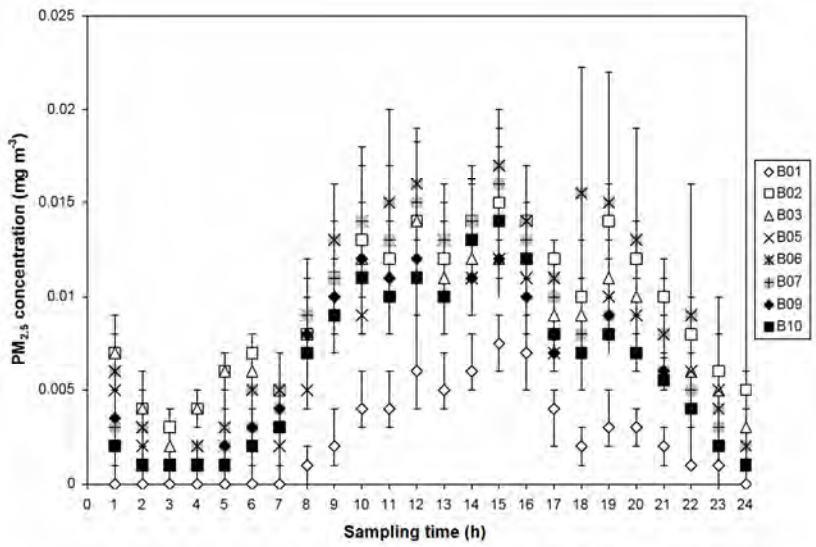
Sampling Locations

Google Earth

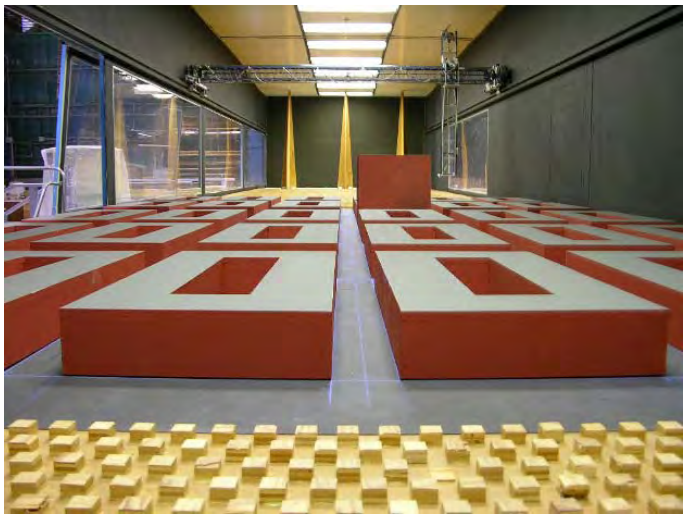
Sampling Locations

Google Earth

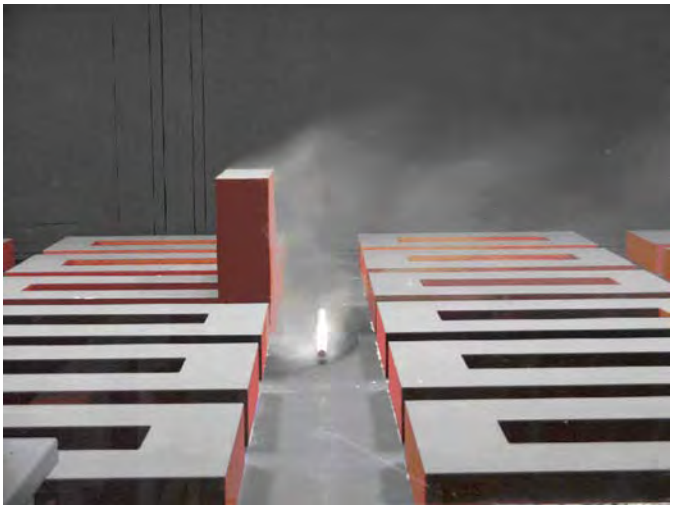
Concentration distribution by time and location



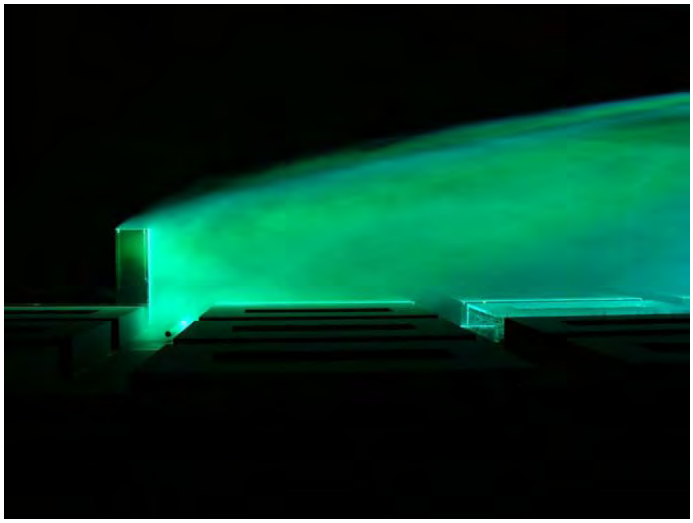
Atmospheric Boundary Layer Wind Tunnel with Neighborhood Model



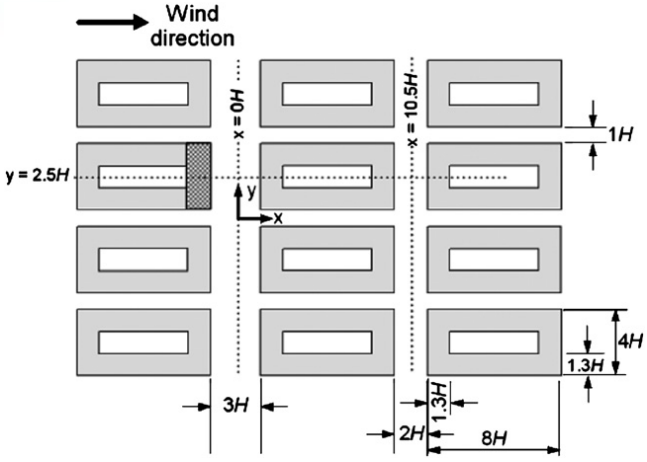
Atmospheric Boundary Layer Wind Tunnel with Neighborhood Model



Atmospheric Boundary Layer Wind Tunnel with Neighborhood Model - Laser Light Sheet



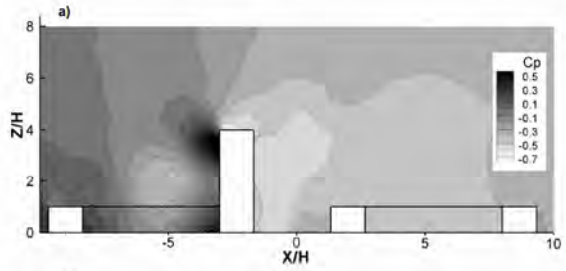
CFD Model Layout



Note: H is the height of the 3 story building

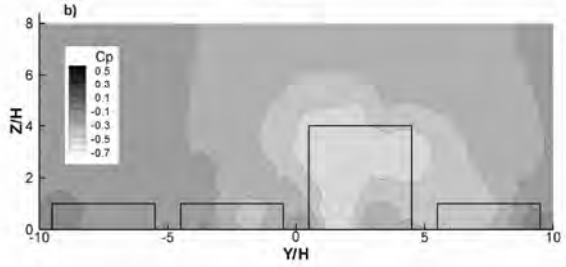
Coefficient of Pressure from CFD in the (A) y/H ¼ 2.5 Plane and (B) x/H ¼ 0 plane

A

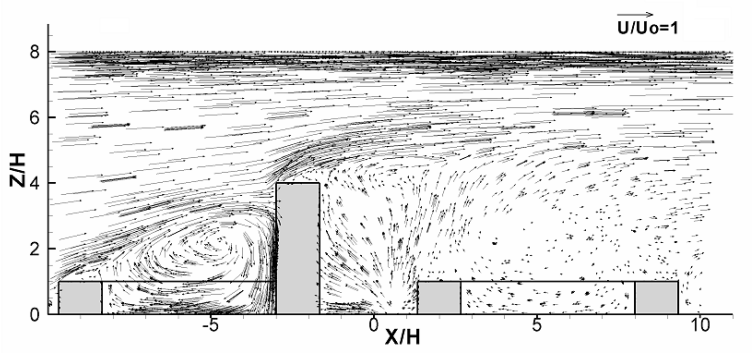


$$C_p = 1 - \left(\frac{V}{V_\infty}\right)^2$$

B

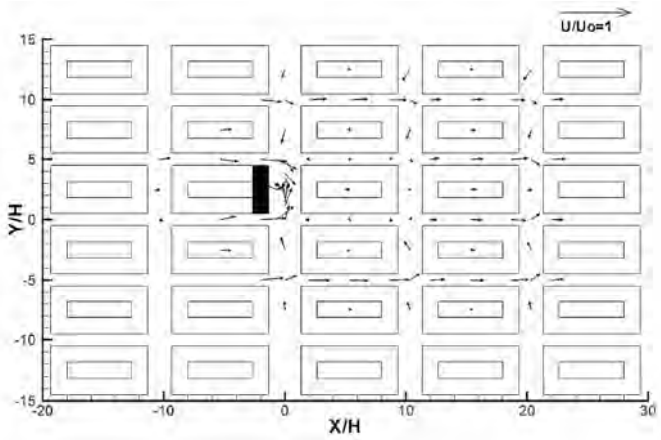


Computational Fluid Dynamic Dispersion Modeling Performed on Neighborhood Simulation



Mean velocity vectors measured using LDV

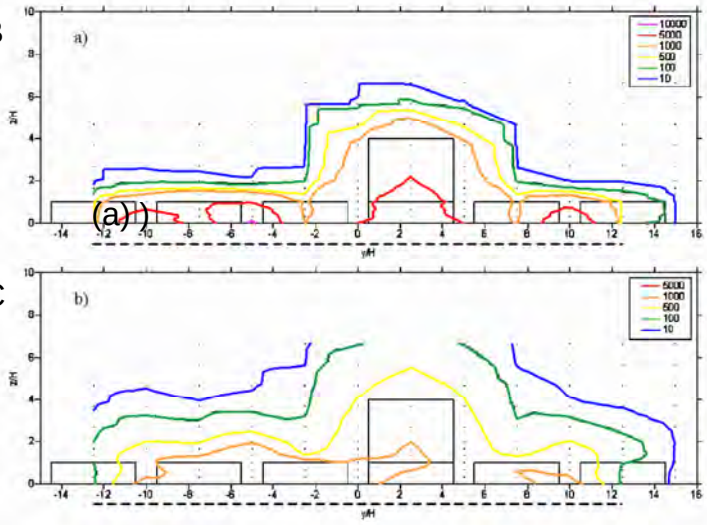
at z/H = 0.5



''Infinite'' Line Source Concentration

A) Avenue B
(x = 0.67H)

B) Avenue C
(x = 10.3H



(a))

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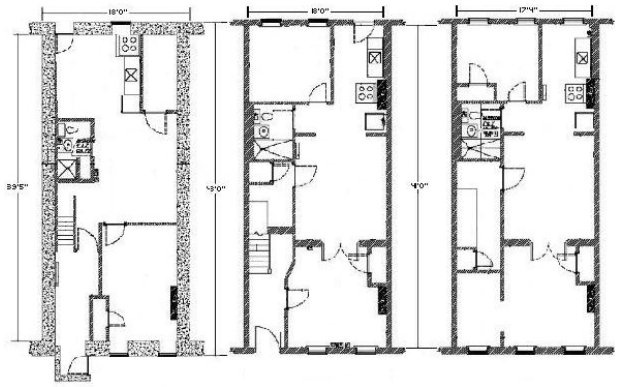
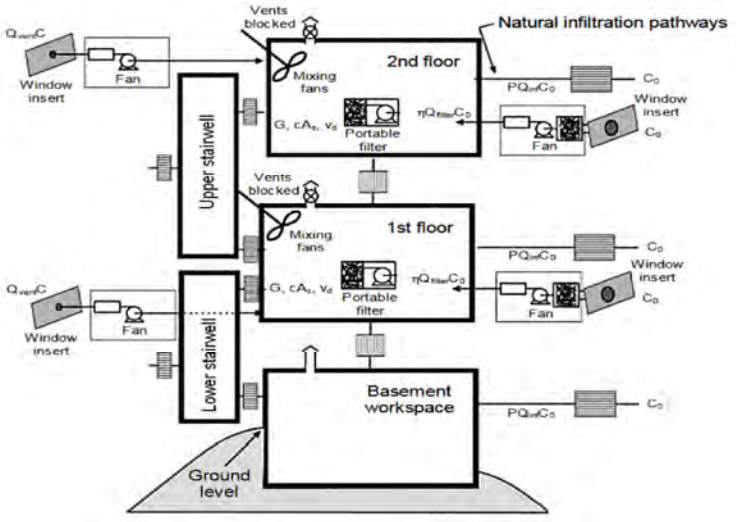
Townhouse Schematic by floor

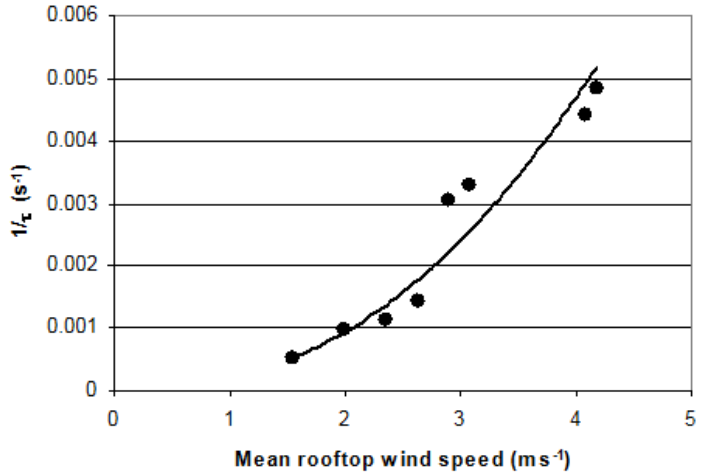


EPA United States Environmental Protection Agency

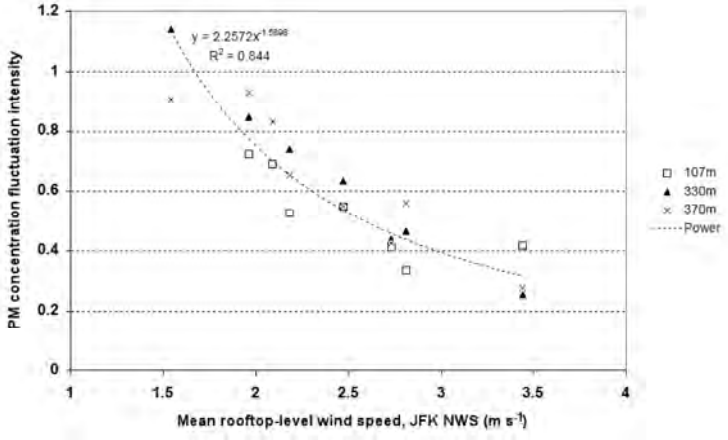
Vertical Profile of Townhouse



Infiltration Rate vs Rooftop Wind Speed

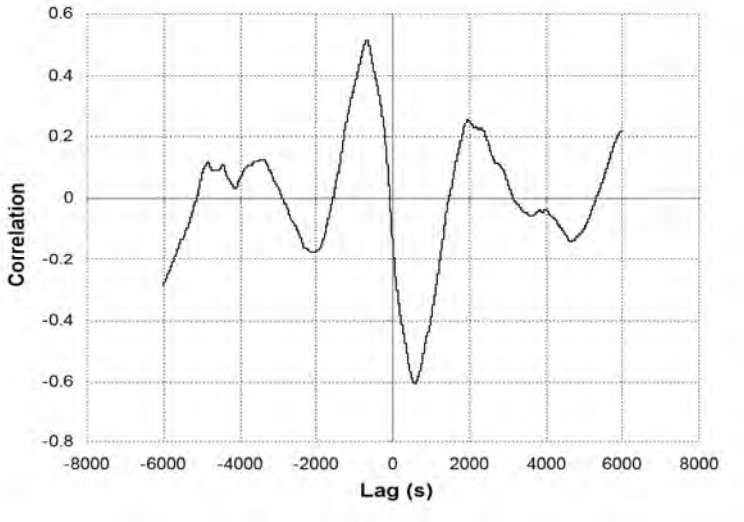


Mean rooftop-level wind speed vs. PM concentration fluctuation Intensity

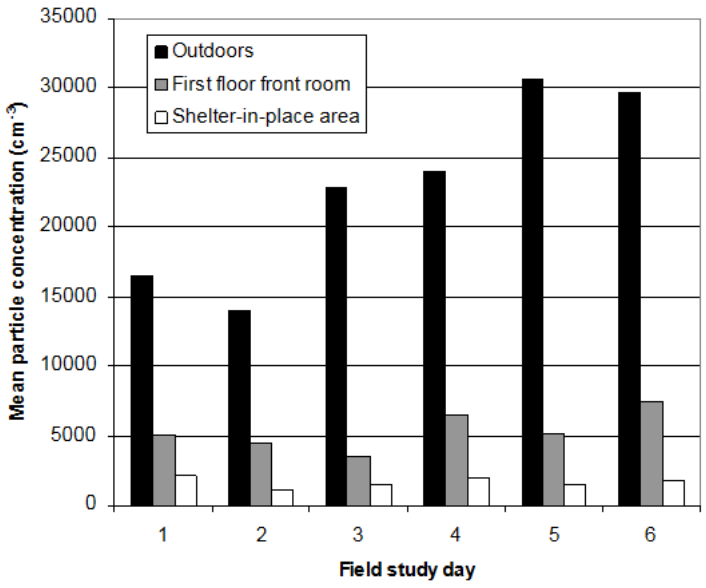


Concentration fluctuation intensity is the ratio of the standard deviation (SD) of the concentration time-series data to the time-averaged mean concentration

Lag Time for Infiltration of Particles into Townhouse



Particle Concentrations



US EPA's Aerosol Test Facility (ATF)

at Research Triangle Park, NC

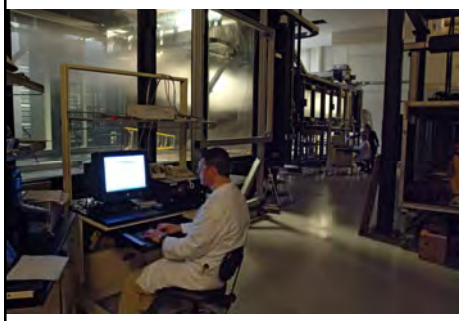
- Wind tunnels, chambers, and laboratories aerosol testing.
- Responsible for $PM_{2.5}$ Standard
- BTRAPPED
  - Brooklyn Traffic Real-Time Ambient Pollutant Penetration and Environmental Dispersion Study

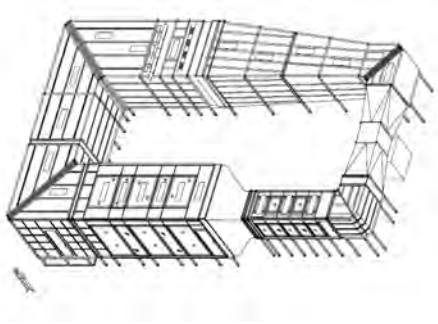
US EPA's Aerosol Test Facility

(at Research Triangle Park, NC)

- **Why do we need an ATF?**
  - **Develop quantitative standards for aerosol measurement**
    - **Biological, Toxic, or Radiological particles**
    - **Quality assurance for existing methods**
  - **Develop and evaluate dispersion models to determine human exposure**
  - **Provide predictive models for wide area contamination and decontamination**
    - **Development**
    - **Validation**

Aerosol Wind Tunnel

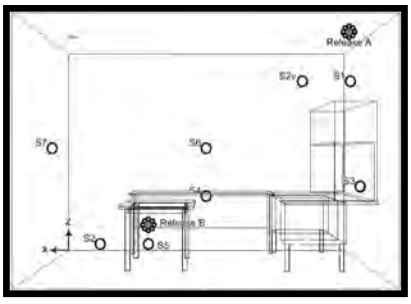


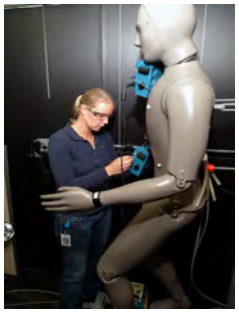


US EPA's Aerosol Test Facility at Research Triangle Park

Aerosol Test Facility Research Areas

- **Human exposure measurement**
- **Indoor Air Studies**
- **Ambient Air and Field Studies**
- **Exposure Simulation**
- **Aerosol infiltration and penetration studies**





Human Exposure Test Dummies

Partnership Opportunities

- Study fluid and aerosol motion to base scientific decisions
  - Only large aerosol wind tunnel in the US
  - Scaled for adult human exposure testing using heated-breathing manikins
- Ability to design and test
  - Monitors and Sampling Technologies
  - Models of human exposure
  - Dispersion models
  - Field and laboratory studies for wide area decontamination and prediction

Assessment of Liquid and Physical Decontamination Methods for Surfaces Contaminated With *Bacillus* Spores

Shawn P. Ryan, EPA/ORD/NHSRC

Assessment of Liquid and Physical Decontamination Methods for Environmental Surfaces Contaminated with *Bacillus* Spores

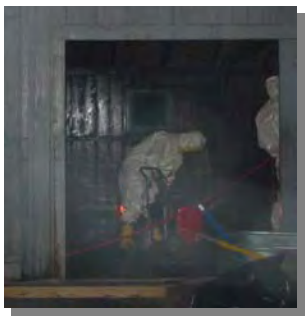
***Shawn P. Ryan*[1], *M. Worth Calfee*[1], *Leroy Mickelsen*[2], *Stephen Tomasino*[3], *Carlton Kempter*[3], *Mike Nalipinski*[4], *Curtis Snook*[2], *Ted Bazenas*[4], *Dahman Touati*[5], *Stella Payne*[5], *and Matt Clayton*[5]**

1 US EPA/ORD/National Homeland Security Research Center
2 US EPA/OSWER/OEM/National Decontamination Team
3 US EPA/Office of Prevention, Pesticides and Toxic Substances
4 US EPA/Region 1 (New England)
5 ARCADIS-US, Inc.

April 14, 2010

Capability Enhancement: Effective Surface Decon Procedures

- How effective are surface decontamination procedures for materials contaminated with ***Bacillus*** spores?

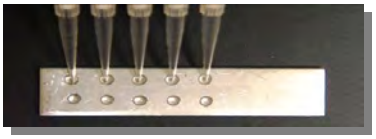


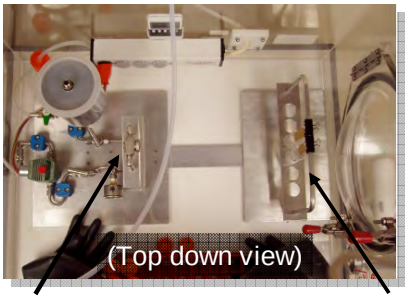
Project Purpose/Objectives

- Challenge/Need:
  - Decontamination of complex surfaces using liquid disinfectants/sterilants and physical methods
- Objectives:
  - Quantitative measurement of residual viable spores
    - Surfaces
    - Rinsate
    - Air samples
  - Determination of log reduction (LR)
  - **Development of a combination of procedural steps providing the desired effectiveness and applicability**

General Laboratory Sporicidal Efficacy Studies – Other Studies

- Spore suspension
- Liquid inoculation
- Treatment
  - Spray application
  - Immersion
  - Fumigation
- Neutralization
- Extraction
- Analysis of colony forming units
- Calculation of log reduction



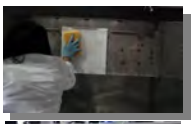


Field Application of Surface Decontamination Methods

- Combinations of methods
  - Surface decontamination
  - Fumigation
- Field Decontamination
  - Danbury, CT shed (surface)
  - Danbury, CT house (surface/fumigation)
  - Capitol Hill (surface/fumigation)
  - AMI facility (fumigation)
  - P&DC's (surface/fumigation)

Surface Decon Procedure Based upon Danbury, CT Shed

1) Vacuum
2) Wet with pH-adjusted bleach solution (10 minutes)
3) Wash with detergent solution (TSP)
4) Rinse with water
5) Vacuum standing water
6) Maintain wet with pH-adjusted bleach solution (e.g., 30 or 60 minutes)
7) Rinse with water
8) Vacuum standing water

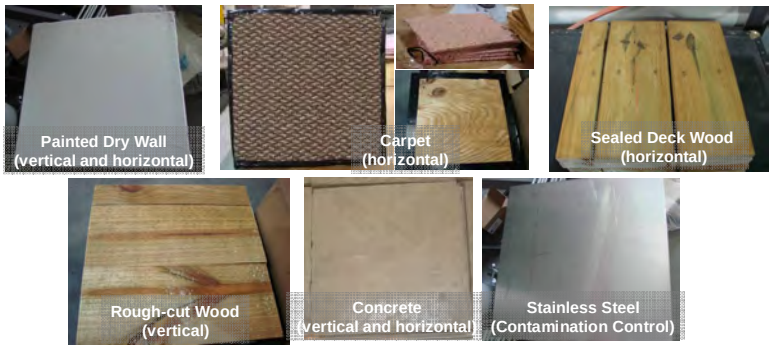


Surface Decon Procedure: Field → Lab

- Complex application procedures
  - Quality Assurance/Quality Control (QA/QC)
    - Data quality indicators for vacuuming, bleach spraying, rinsing with water and scrubbing with a brush or sponge
    - Repeatability
    - Reliability
- Development of novel test methods
  - Aerosol deposition of spores on surfaces
  - Spray chamber for controlled decon application
  - Collection of rinsate and air sampling
  - Use of field sampling methods
  - Material coupon sizes suitable for decon and field sampling methods

Test Materials

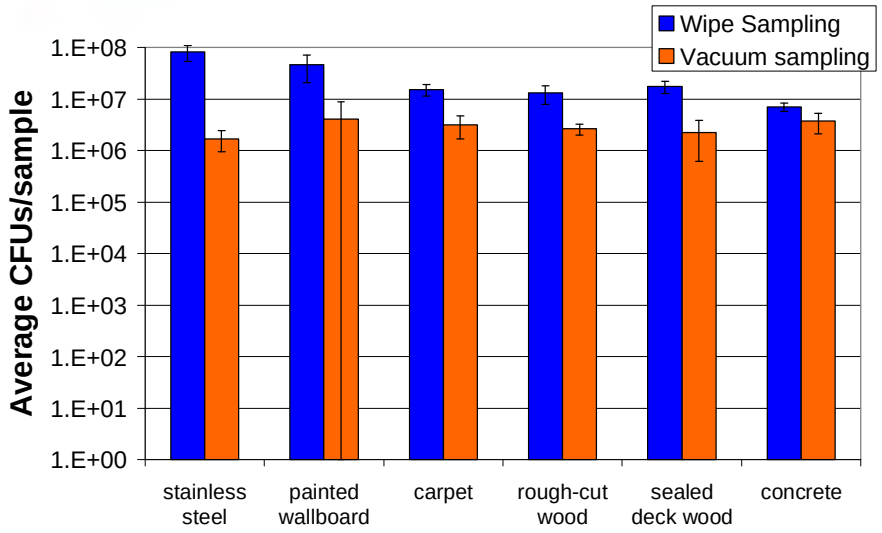
- Contamination:
  - ***Bacillus*** atrophaeus (ATCC 9732) spores deposited onto surfaces
    - Spore preparation as cited in Brown et al., ***App. Environ. Microbiol.*** 2007, 73 (3) 707.
  - Target recovery of 1E7 viable spores/sampled area (1 sq ft)
- Materials (14 in x 14 in):



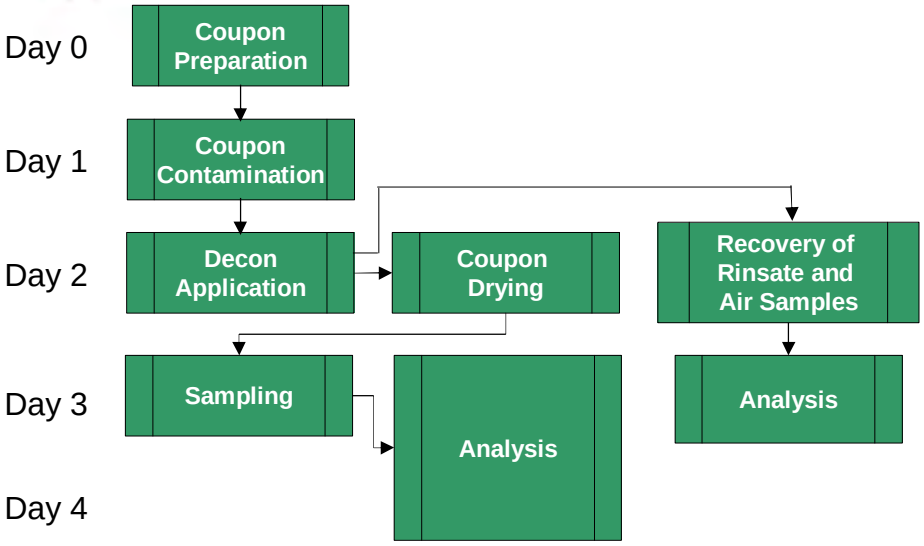
Sampling Methods?

- Vacuum sock
- Wet wipe (PBS with 0.05% Tween-20)
- Complex materials
  - Porous
    - Rough
    - Smooth
  - Hard, non-porous (smooth)

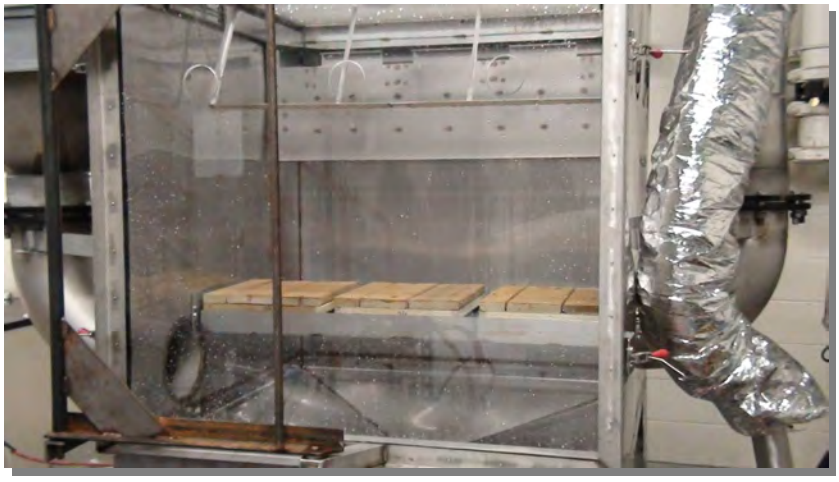
Sampling Method Comparison for Aerosol Deposition



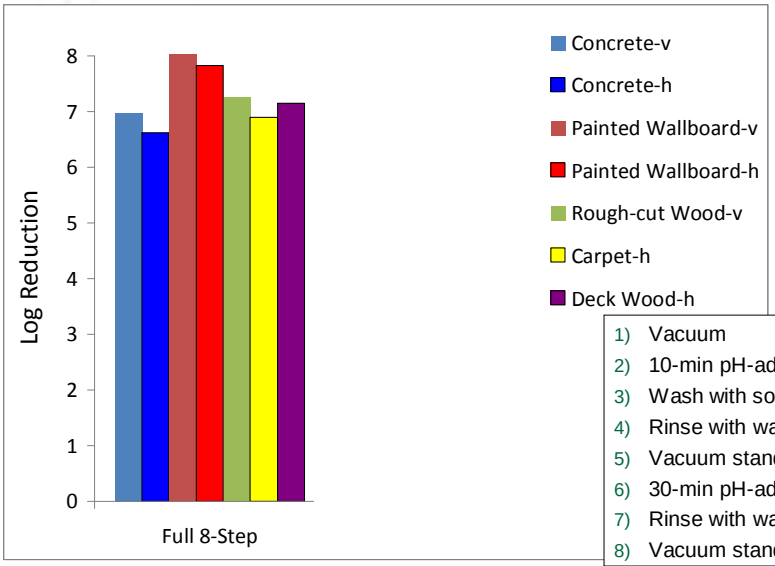
Experiment Timeline



Spray Chamber

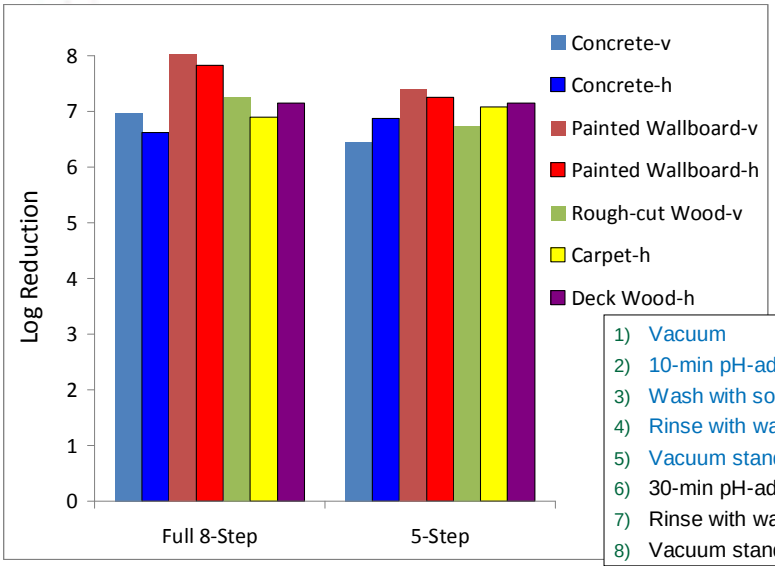


Full 8-Step Surface Decon Procedures Results



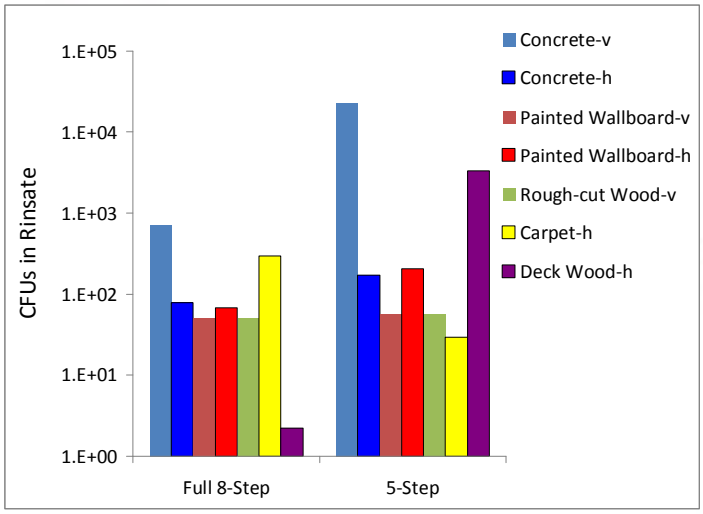
1) Vacuum
2) 10-min pH-adjusted bleach
3) Wash with soap and water
4) Rinse with water
5) Vacuum standing water
6) 30-min pH-adjusted bleach
7) Rinse with water
8) Vacuum standing water

Full 8-Step and 5-Step Surface Decon Procedures Results

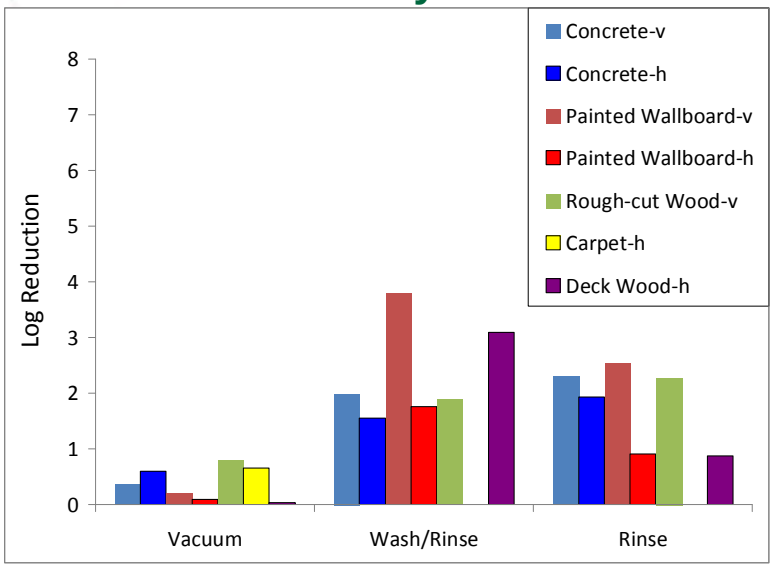


1) Vacuum
2) 10-min pH-adjusted bleach
3) Wash with soap and water
4) Rinse with water
5) Vacuum standing water
6) 30-min pH-adjusted bleach
7) Rinse with water
8) Vacuum standing water

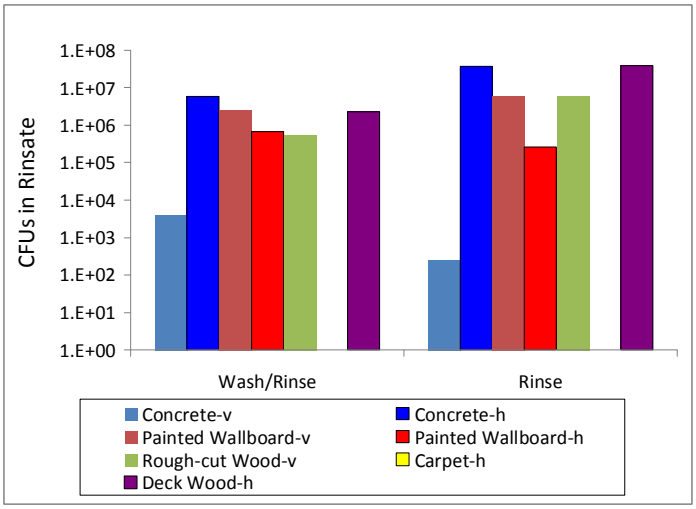
8-Step and 5-Step Surface Decon Procedures: Rinsate



Surface Decon Procedural Step Results: Physical Methods



Surface Decon Procedural Step Results: Rinsing or Washing/Rinsing



Surface Decon Procedural Step Results: Vacuuming

- All wet/dry vacuums were fitted with a HEPA-rated filter
- Air samples were taken from vacuum exhausts
- In 50% of tests, viable spores were detected in the exhaust samples

Summary

- 8-step and 5-step procedures effective for surface decontamination for materials tested (>6 log reduction; no viable spores from surfaces)
- 10 minute pH-adjusted bleach step determined to produce the highest log reduction on the surfaces, but only a 2- to 4- log reduction
  - Viable spores recovered in the rinsate (rinse or wash/rinse after bleach)
- Vacuuming resulted in minimal (<1 log) reduction in surface contamination
  - Potential to aerosolize spores (spread contamination)
  - Potential usefulness to remove gross contamination (e.g., dirt)
- Rinsing resulted in a 1- to 3- log reduction; washing (with detergent solution) resulted in minimal or no added log reduction, in general
  - Clean materials used in this study

Next Steps

- Effective surface decontamination demonstrated; however, viable spores in air samples and rinsate provide potential for spread of contamination
- Focus of additional testing:
  - Revised procedure to attempt to increase spore inactivation (use of detergent plus pH-adjusted bleach solution)
  - Reduce number of steps, time, and labor
  - Testing at larger scale with aerosol release

Future Testing

- Optimization of pH-adjusted bleach/surfactant solution spray application rate and frequency
  - Objective: complete inactivation of viable spores; decrease labor time/cost
- Effectiveness as a function of surface contamination amount
  - Does a 2 log reduction starting from 1E7 spores correlate to complete inactivation when starting loading is <1E2?
- Assessment of re-aerosolization on surface decontamination methods
  - Need for air cleaning or fumigation?
- Scale-up testing on facility
  - Biological-response Operational Test and Evaluation (BOTE) Project

Questions?

The Wide-area Perspective

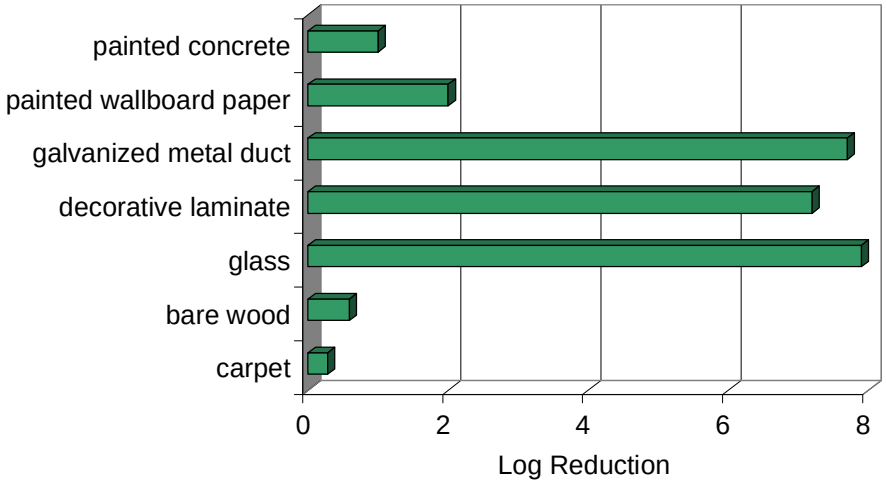
- ***B. anthracis*** spore contamination in 23 public facilities
  - Timeline of restoration: years
  - Cost or restoration: reported upwards of $1B

- Advancements in decontamination capabilities
- Significant data gaps for wide area consequence management

Example of Material Preparation: Concrete

Inactivation of *Bacillus anthracis* Ames Spores

Spraying with pH-adjusted bleach (10 min contact time)



Evaluation of COT Products for Decontamination of *Bacillus* Spores

Jason Edmonds, DOD, U.S. Army

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Evaluation of COT Products for Decontamination of *Bacillus* Spores

Jason Edmonds, Jonathan Sabol, and Vipin Rastogi
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04/13/2010

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- How well does laboratory testing predict effectiveness of COTS decon technologies for field or exterior surface decontamination?
  - Interagency Biological Restoration Demonstration

- Are quantitative methods permitting efficient and effective decontamination of large surfaces available for efficacy assessment?

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Sealing buildings and irregular objects is common

Tug boat

Whole neighborhoods

Multi-level apartment building

Department stores

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Enclosing a larger area for gassing is much more difficult than it looks

- Logistical issues:
  - Evacuating millions of people
  - Sealing individual buildings both exterior and interior
  - Gassing large volumes of space and objects

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Spraying building exterior surfaces with high pressure decontaminants poses special issues as well

- Volume of chemicals needed
  - Environmental impact
- Large surface area
- Contact time
    - Many manufacturers recommend several hours of contact time for effective decontamination

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- 4 foot X 4 foot panels
  - Brick veneer
  - Stainless steel
  - Pressure Treated (PT) lumber
- Decon Solutions
  - Ultra Clorox Germicidal Bleach (0.6% Sodium hypochlorite)
  - Peridox (3.8% Hydrogen peroxide, 0.2% Peroxyacetic acid)
  - CASCAD (9.5% Dichloroisocyanuric acid)
- Application on panels with use of a low pressure backpack sprayer
  - Think “fine mist” setting at car wash
  - Contact time of 30 continuous* minutes

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- OSB backing
- 1X6 boards cut to 48” long
- Secured to OSB via 1.25” deck screws on both ends of board

Secured to holder with clamps

Sits on acrylic shelf

Soln. collects under the panel in a tray

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- OSB backing
- T-304 NO. 2B Finish 20 GA stainless steel
- 1X2 foot panels
- Secured to OSB via liquid nails

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- King William brick veneer
  - Brick-it
- OSB backing
- Metal grid secured to OSB via liquid nails
- Brick veneer secured to metal grid via liquid nails

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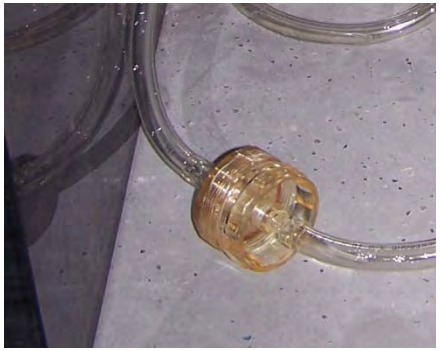

Filter for capturing spores removed from panels

Carboy for recording volume of decon solution used on each panel

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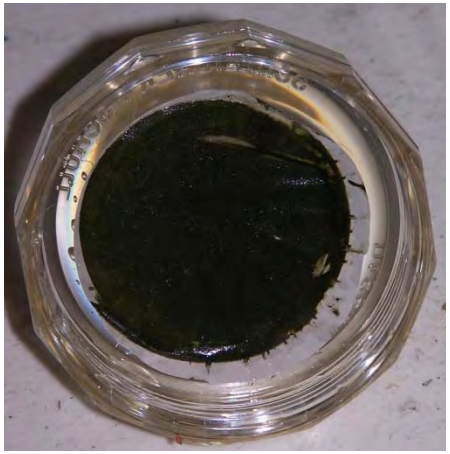
Crushed Carboy

Plugged Filter



Standing Soln.

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- Vacuum crushes carboys due to debris clogging filters
- New protocol for counting CFUs which have been removed from the panels via run-off
  - 25 ml removed from collection tray
    - From 1-3L total depending on panel type and solution
  - Sample pushed through filter & washed with water to remove decontaminant
  - Spores extracted and plated

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Sample Flow Chart

$10^{\wedge 9}$ spores seeded onto panels

Dry Sampling control

Water/Decon treatment

Panel alone is sampled without any treatment. No run-off.

25 mL sample from 1-3 L total volume of run-off is collected

Panel is sampled after treatment and after dry time.

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Control Preliminary Results

Total *B. subtilis* spores seeded onto panels

- 2.94E+09
- 1280 individual 10μl droplets
  - 2.83E+06 spores per droplet

<u>Spore collection</u>

- Vacuum socks for lumber and brick
- Polyurethane wipes for steel

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Control *B. subtilis*

Log CFU Recovered

	Steel Panel	PT Lumber Panel	Brick Veneer Panel
Positive Control (Sampling Only)	**2.90E+07**	**3.80E+02**	**1.07E+03**
Water control (Spraying)	**7.49E+06**	**5.27E+04**	**5.00E+02**

- *B. subtilis* spores seeded onto each panel - 2.94E+09
- Recovery from lumber and brick by sampling from no spray controls is low (<0.01%) - not conducive to decon efficacy measurements

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Control *B. atrophaeus* sub *globigii* (BG)

	Steel Panel	PT Lumber Panel	Brick Veneer Panel
Positive (No spraying)	**1.7E+09**	**3.1E+07**	**2.1E+07**
Water control (Spraying)	**1.7E+09**	**3.3E+07**	**4.4E+08**

- 2.94E+09 Total *BG* spores seeded onto each panel
- Sampling efficiency 1 - 90%

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Bacillus atrophaeus sub. *globigii*
Dry panel control

Spores Recovered Untreated Panels

	% Recovery	Spores Recovered
Steel	76%	1.7E+09
Brick	1%	2.1E+07
Lumber	1%	3.1E+07

Spores Inoculated onto panel 2.3E+09

- Purpose of the Dry Control is to determine recovery efficiency of untreated panels
- Recovery from untreated panels is sufficient to allow for 6 log reduction (LR)
- Poor recovery from porous surface - 1% or 2-logs less
    - Inaccessible or very poor recovery efficiency of vacuum socks

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Bacillus atrophaeus sub. *globigii* Run-off *Recovery*

Spores Recovered from Runoff

	% Recovery	Spores Recovered
Steel	24%	5.5E+08
Brick	8%	1.7E+08
Lumber	16%	3.8E+08

Spores Inoculated onto panel 2.3E+09

- Presence of high number of viable spores in the run-off demonstrates their removal from the panels
- Spraying action (no decontaminant) mechanically dislodges spores from the panels

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Sample Flow Chart

$10^{\wedge 9}$ spores seeded onto panels

Dry Sampling control

Water/Decon treatment

Panel alone is sampled without any treatment. No run-off.

25 mL sample from 1-33 L total volume of run-off is collected

Panel is sampled after treatment and after dry time.

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Bacillus atrophaeus sub. *Globigii* Water Treatment

Spores Seeded onto Panels	Total Spores Recovered from Steel	Reduction in Recovery from Steel	Total Spores Recovered from Brick	Reduction in Recovery from Brick	Total Spores Recovered from Lumber	Reduction in Recovery from Lumber
2.3E+09	1.7E+09	0.1 Log	4.4E+08	0.7 Log	3.3E+07	1.8 Log

- Virtually no reduction in CFU recovery from steel and brick panels post water treatment
- Slight reduction in CFU recovery from lumber panels after water treatment
  - Not a result of run-off

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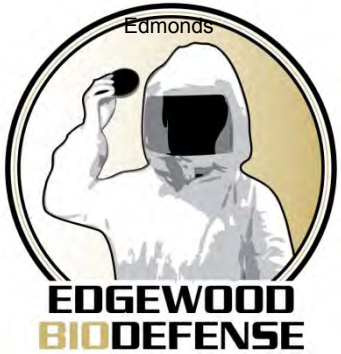

Bacillus atrophaeus sub. *Globigii* Bleach Treatment

Spores Seeded onto Panels	Total Spores Recovered from Steel	Reduction in Recovery from Steel	Total Spores Recovered from Brick	Reduction in Recovery from Brick	Total Spores Recovered from Lumber	Reduction in Recovery from Lumber
2.2E+09	1.0E+04	5.8 Log	5.0E+01	8.7 Log	2.6E+04	5.9 Log

- Approximately 6-LR in number of viable spores from stainless steel and lumber
- >8-LR in number of viable spores from brick panels by bleach treatment

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Bacillus atrophaeus sub. *Globigii* Peridox Treatment

Spores Seeded onto Panels	Total Spores Recovered from Steel	Reduction in Recovery from Steel	Total Spores Recovered from Brick	Reduction in Recovery from Brick	Total Spores Recovered from Lumber	Reduction in Recovery from Lumber
2.0E+09	4.2E+03	6.3 Log	6.8E+01	9.2 Log	1.8E+01	8.1 Log

- 5-LR in number of viable spores from stainless steel after Peridox treatment
- Eight and nine log reductions in CFUs recovered from lumber and brick panels respectively

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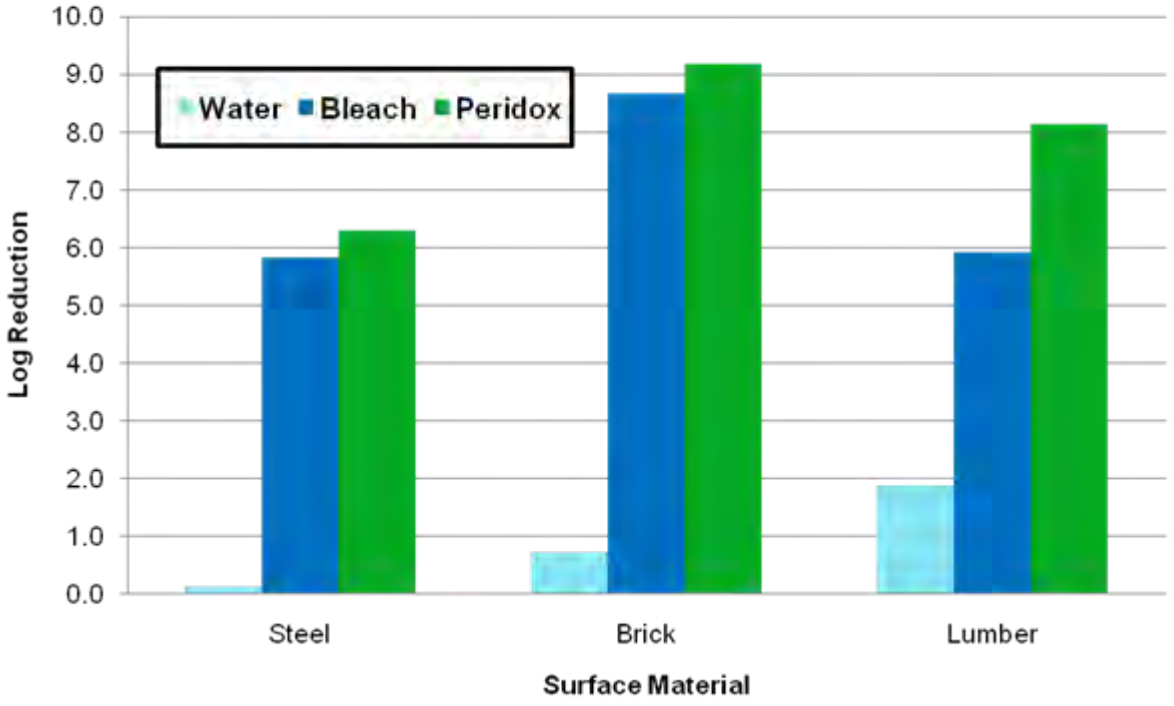
Reduction in Available Spores for Recovery After Decontamination Treatment



Reminder: Higher the Number – Fewer the spores recovered from panels

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Efficacy measurements

- Multiple means of measuring efficacy and efficiency.
  - Relative to initial panel after seeding
    - Numbers presented in this presentation
  - Relative to theoretical panel contamination levels after subtracting water treatment
  - Relative to dry sampling which takes into consideration recovery efficiency of available technologies

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FAQs

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- Stainless steel is a non-porous, flat surface, why do you see less decontamination from stainless steel than from brick and lumber?
  - It is necessary to distinguish between decontamination and availability
  - There are fewer recoverable spores/CFUs available on brick and lumber panels after treatment
    - Spores (viable and non-viable) are pulled into cracks and crevices of brick and lumber and are not recovered
    - Poor sampling/recovery technology for porous materials
    - Deposition method may provide protective factor for spores
    - Difficulty in keeping stainless steel continuously wet
      - Not as applicable to our study compared to larger areas such as buildings
    - All of the above

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FAQs

- If spores are not recoverable, are they viable or non-viable dead?
- How much risk does the unrecoverable spores pose?
  - Currently developing experimental approaches to determine the viability of unrecoverable spores
  - The number of unrecovered spores may change as technology advances in coming months and years

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Summary

•Efficacy efficiencies can only be accurately measured using species specific spores.

•We do observe a six log decrease in recoverable CFUs from stainless steel panels using either bleach or Peridox.

•On porous materials, Peridox out performs bleach under our pre-determined conditions and constraints not consistent with manufacturer's recommendations.

- •Eight log and nine log reduction respectively on lumber and brick panels for Peridox compared to six and 8.7 log reductions for bleach respectively.

•Decontamination attempts similar to our design could potentially be used as a short term mitigation technique.

•There is a need for an improvement in sampling technology for porous materials.

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Support

- Dr. Vipin Rastogi
- Jonathan Sabol
- Stephen Blum
- Maegan Lay

Defense Threat Reduction Agency

Department of Homeland Security

Evaluation of Peroxide-Based Solutions for Facility Decontamination by Owner/Occupants

Paula Krauter, Sandia National Laboratories

Evaluation of Peroxide-Based Solutions for Facility Decontamination by Owner/Occupants

2010 US EPA Decontamination Research and Development Conference

April 13-15, 2010

Sandia National Laboratories

Paula Krauter, Mark Tucker, Wayne Einfeld, Mollye Wilson, Matt Tezak, Ashley Allen, Dan Lucero, Brandon Servantes & Andres Sanchez

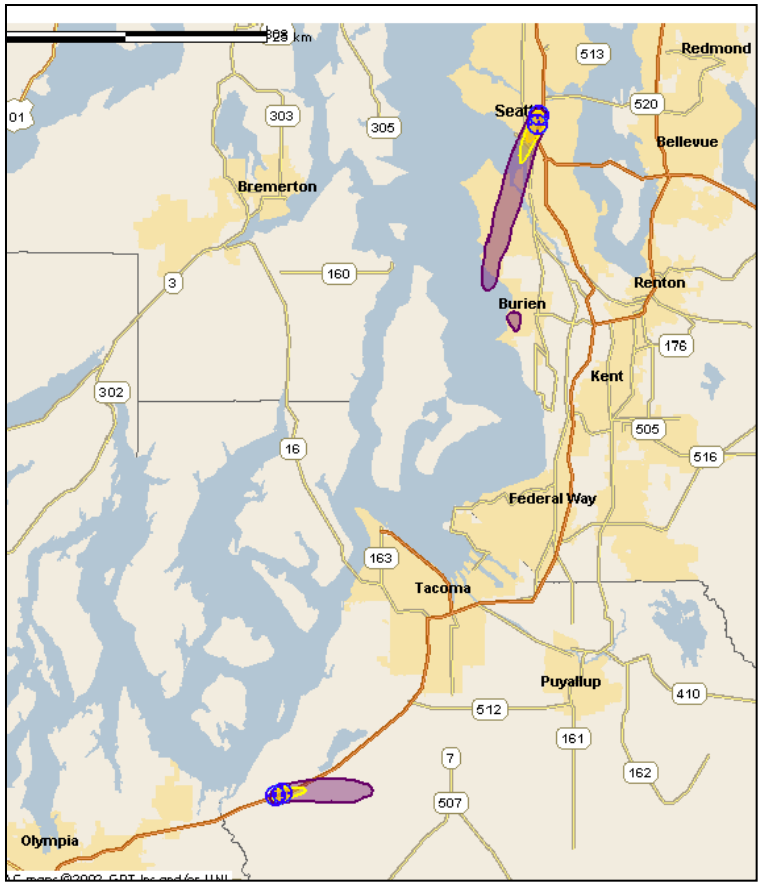
Sandia is a multiprogram laboratory operated by Sandia Corporation, a Lockheed martin company, for the United States Department of Energy's National Nuclear Security Administration under contract DE-AC04-AL8500

The American National Standards Institute: 9/11 Commission Report

Stated that "the private sector, which controls 85% of the critical infrastructure in the nation, remains largely unprepared for a terrorist attack. In the event of a large-scale outdoor bioterrorism incident, resources will become limited and self-decontamination, that is, decontamination and remediation by non- professional contractors, may become necessary." 2002

National Exercise Planning Scenario #2

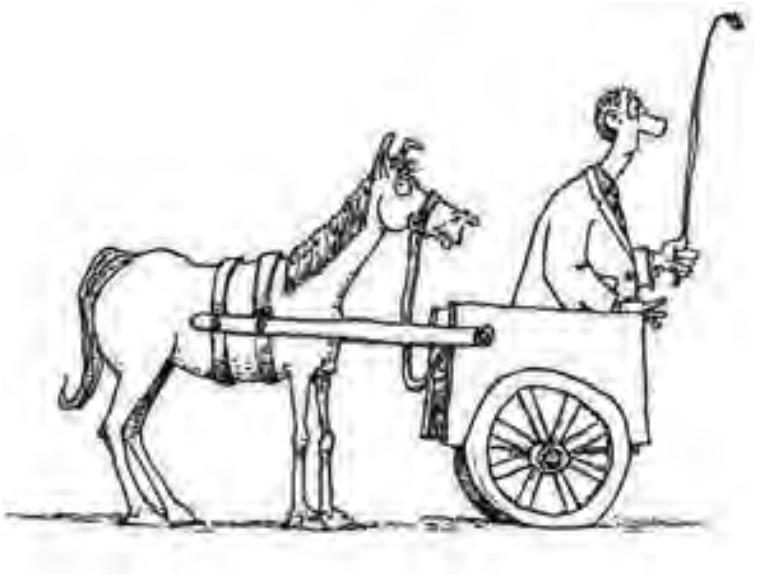
- Two aerosol releases of weaponized *Bacillus anthracis* spores: one in metropolitan Seattle and another just off the Fort Lewis installation.
- The plumes are modeled by the National Atmospheric Release Advisory Center facility using weather conditions.
- The IBRD scenario encompasses a large, diverse environment: hundreds of indoor and outdoor areas require decontamination



The Operations section of the Unified Command is faced with a large number of potentially contaminated buildings which would overwhelm available resources

Objective

Objective: To conduct a small-scale demonstration of the occupant-performed decontamination



To implement occupant-performed decon several issues need to be resolved:

- **Criteria for selection of facility**
- **Mechanism to train workers**
- **Documented procedure**
- **Decon materials availability**
- **Method to judge success**

Outline

- Investigate Self-Decon Approaches
  - Identify alternative decontaminants to bleach
    - Conduct decontaminant screening tests
    - Develop self-decon procedure for alternative decontaminant
- Conduct Self-Decon Demonstration
    - PPE
    - Materials
    - Evaluate self-decon procedure
    - Measure impact of decon on spore resuspension & tracking

Investigate self-decon approach

1. *Define requirements* for an efficacious peroxide-based material
   -Verify the concentration of the active ingredient in the decon material

2. As a precursor (agent qualifier) for the chamber test we tested decon material efficacy against spores with appropriate neutralizer to separate biostatic from biocidal decon materials

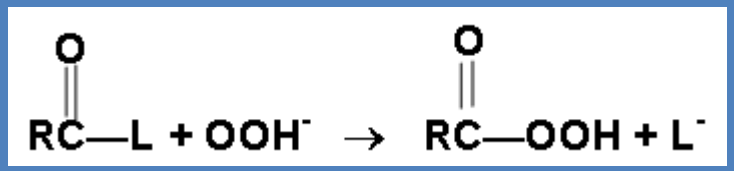
3. Presume a contamination level lower than ~10^6 spores/cm^2 for self-decon application.

Identify alternatives to bleach that are efficacious, readily obtained, safe and easy to use

Peroxide Solutions Were Chosen as a Alternative to pH amended-Bleach

Krauter

Activated peroxide is formed from the reaction of hydrogen peroxide and an activator (tetraacetylethylenediamine, TAED):



The result is two sporicidal species:

- **Hydrogen peroxide (low efficacy)**
- **Peracetyl compound e.g., peracetic acid (high efficacy)**
- **"Tide™ with Bleach" is an example of a commercial product utilizing this chemistry**

- The breakdown products are oxygen and water
- Less corrosive than bleach
- Used in detergents and other products
- Activated peroxides are simple and commercially available.

D. Martin Davies and Michael E. Deary "Kinetics of the hydrolysis and perhydrolysis of tetraacetylethylenediamine, a peroxide bleach activator" J. Chem. Soc., Perkin Trans. 2, 1991, pages 1549 - 1552. DOI: 10.1039/P29910001549

Krauter

Screening Tests: SporKlenz™ and activated peroxide were efficacious against 10^6 *B. atrophaeus* spore concentrations

Decon agent composition	With Decon Agent (CFU log (10)/mL ± SD)	With Decon Agent + neutralizer (CFU log (10)/mL ± SD)
3% H_2O_2	6.44 ± 0.06	6.43 ± 0.03
4% H_2O_2	6.43 ± 0.04	6.45 ± 0.03
6% H_2O_2	6.15 ± 0.01	6.40 ± 0.002
7.9% H_2O_2	5.61 ± 0.06	6.53 ± 0.02
3% H_2O_2 + activator+buffer	0 ± 0	6.41 ± 0.01
4% H_2O_2 + activator+buffer	0 ± 0	6.43 ± 0.01
6% H_2O_2 + activator+buffer	0 ± 0	6.42 ± 0.006
7.9% H_2O_2 + activator+buffer	0 ± 0	6.41 ± 0.03
SporKlenz™	0 ± 0	6.12 ± 0.02

- An activator is necessary for efficacy
- A simple peroxide-based material includes 3-4% H_2O_2, activator (TAED) and buffer
- Ready to use SporKlenz™
- Other commercially available peroxide-based products include but are not limited to Peridox™, Cascad SDF™, Easy Decon 200™, MinCare™ and Oxonia™

Chemical Hazards Considerations

- **Hydrogen peroxide Airborne Exposure Limits:**
  - -OSHA Permissible Exposure Limit: 1 ppm (TWA).
  - -ACGIH Threshold Limit Value: 1 ppm (TWA).

- **Acetic acid airborne exposure limits:**
  - -OSHA: 10 ppm (PEL)
  - -ACGIH: 15 ppm (STEL)

Ventilation System: A system of local and/or general exhaust is recommended to keep employee exposures below the Airborne Exposure Limits.

For this test the decon material usage rate ~1L per 12 m^2
Exposure time ~7-10 min

Workers must meet environmental safety & health standards

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- hazardous waste operations and emergency response training as required in 20 Code of Federal Regulations (CFR) 1910.120,
- medical surveillance as required in 20 CFR 1910.120 (b),
- respirator protection required in 20 CFR 1910.134,
- biological/chemical agent training,
- be familiar with decontamination procedures, and
- use certified personal protective equipment as specified by National Institute for Occupational Safety and Health (NIOSH).

Outline

- Investigate Self-Decon Approaches
  - Identify methodology to select appropriate facilities
  - Identify alternative decontaminants to bleach
    - Conduct decontaminant screening tests
    - Develop self-decon procedures for alternative decontaminant
- Conduct Self-Decon Demonstration
    - Location
    - Materials
    - Evaluate self-decon procedure
    - Measure impact of decon process on spore resuspension & tracking

Decon Process Using Peroxide-Based Solutions

We used the following decon process for our demonstration:

- HEPA filters for 1 μm particles were placed in ventilation system.
- Test chamber was equipped with ceramic tiles, vinyl tiles, stainless steel tiles, desk and chair.
- Non-essential materials and porous materials were removed.
- HEPA-filtered vacuum was used to pre-clean all surfaces. Filters were disposed of as hazardous waste.
- Selected a peroxide-based decon material.
- Sprayed the interior of the building with the solution according to the manufacturer's direction.
- Kept the surfaces wet with the decon solution for manufacturer's recommended time period (30 minutes). No rinsing.
- Pending results of post-treatment sampling decontamination might need to be repeated in some locations.

USEPA/NDT DECONTAMINATION ANALYTICAL AND TECHNICAL SERVICE (DATS) CONTRACT NUMBER: EP-W-06-089 TDD No. TO-02-07-10016. After Action Report Danbury Anthrax Incident. September 19, 2008. Kelly Smith (Dynamac Corp.)Michael J. Nalipinski, EPA/OSC

Aerosol Chamber

The aerosol chamber was chosen because of available instrumentation and ability to disperse a well mixed spore cloud (~4 log (10))

Surface Area~ 35.7 m^2

Volume~ 14.5 m^3

The chamber was outfitted with vinyl, ceramic and stainless steel tiles and a table and chair

Decon Process- HEPA Vacuum

Pre-cleaned all surfaces using a HEPA-filtered vacuum. Filters were disposed of as hazardous waste.

Decon Process- Liquid spray application

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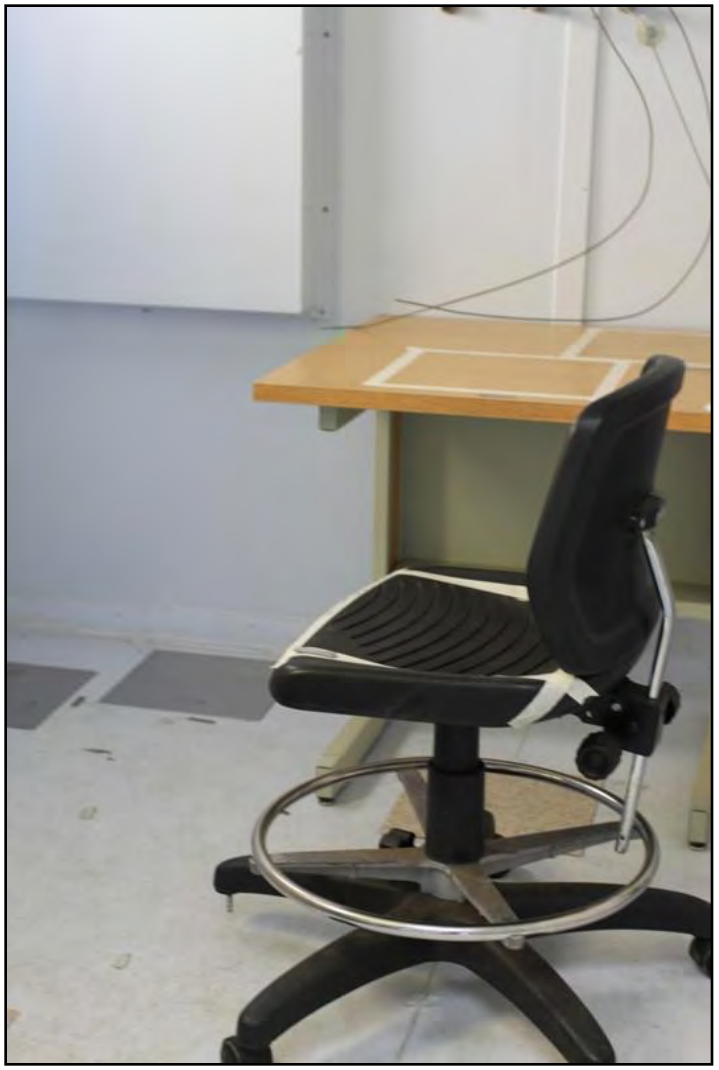
Spray the interior of the chamber with the solution using a garden sprayer.

One application kept the surfaces wet for 30 minutes.

Usage rate ~ 1L per 12 m^2

Post-treatment wipe samples



•Wipe samples were collected 30 min after the decon materials was applied.

•The wipes were placed into a sterile neutralizer solution.

Both peroxide-based solutions were efficacious

SAMPLE TYPE	PRE-DECON CONTROL (activated peroxide) CFU log (10)/ cm^2	Activated-peroxide POST-DECON CFU log (10)/ cm^2	PRE-DECON CONTROL (SporKlenz™) CFU log (10)/ cm^2	SporKlenz™ POST-DECON CFU log (10)/ cm^2
Vinyl	4.49 ± 0.11	0 ± 0	4.35 ± 0.15	0 ± 0
Ceramic	4.47 ± 0.18	0 ± 0	4.48 ± 0.09	0 ± 0
Stainless steel	4.60 ± 0.07	0 ± 0	4.31 ± 0.08	0 ± 0
Chair	4.49	0 ± 0	4.43	0 ± 0
Desk	4.43 ± 0.26	0 ± 0	4.26 ± 0.03	0 ± 0

Decon Personnel Contamination

ACTIVITY	PERSON 1 CFU log (10)/ cm^2	PERSON 2 CFU log (10)/ cm^2
Before start of test	0	0
After spore deposition and 20 h settling. After collecting positive control samples.	1.68	2.70
After vacuuming chamber	2.50	3.34
After applying decon spray to chamber	1.98	2.59
After collecting test samples. Clean Tyvek suits worn to collect test samples.	0.69	0.07

Exposure Hazards: Spore counts in chamber air

ACTIVITY	CEILING (CFU log (10)/L air)	CENTER (CFU log (10)/L air)	BOTTOM (CFU log (10)/L air)
Background	0.03	0	0
After dispersion & 20 h settling. Chamber closed.	3.13	2.33	3.07
After collection of reference samples	1.16	1.09	0.81
During beginning of vacuuming, ventilation on	0.77	0.57	0.20
Near ending of vacuuming, ventilation on	0	0.03	0.03
15 min after decon spraying	0	0	0
During beginning of sample collection, ventilation on	0	0	0
Near ending of sample collection, ventilation on	0	0	0.63

- Temperature differences from inside (21.3 °C) and outside (20.2 °C) the test chamber may have kept some spores from settling
- Opening the chamber door caused air-mixing and airborne spores migrated outside the chamber
- Ventilation system should be on to maintain a negative pressure in the room

Conclusions

- Temperature differences between inside and outside the building and electrostatics will keep a proportion of spores from settling.
- Turning on ventilation systems and keep negative pressure will keep spores in building.
- Workers can become contaminated and transport the contamination into a clean area.
- Peroxide-based solutions are effective sporicides for non-porous surfaces.

Issues that need consideration in future demonstrations

Grauter

- **Air quality, biological**: evaluate spore-particle movement while conducting self-decontamination procedure
  - Personnel exposures
  - Evaluate air concentrations inside & outside facility during process
- **Air quality, chemical**: monitor air during recommended process for concentrations of chemical compounds
- Test self-decon protocols on additional materials e.g., **porous materials**
- **Persistence** of decontamination reagent
  - Protection from secondary contamination

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DHS, Science and Technology (Lance Brooks, Program Manager)

This project was funded by DTRA

Inactivation of *Bacillus anthracis* Spores on Indoor and Outdoor Building Surfaces Using Commercially-Available Liquid Sterilant Technologies

Worth Calfee EPA/ORD/NHSRC

EPA United States Environmental Protection Agency

Inactivation of *Bacillus anthracis* Spores on Indoor and Outdoor Building Surfaces using Commercially-Available Liquid Sterilant Technologies

M. Worth Calfee and Joe Wood, US EPA

T. Kelly, J. Rogers, Y. Choi, Battelle

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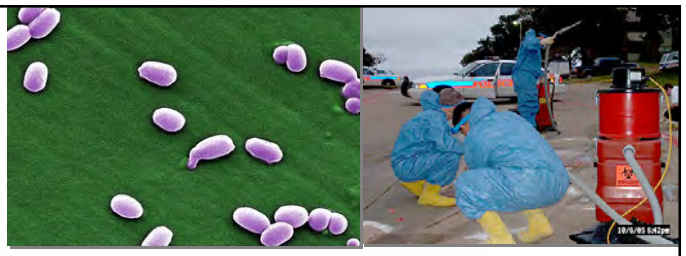


How effective are currently-available liquid sporicides at decontaminating materials contaminated with Anthrax spores?

Overview and Objectives

- Wide-area bioterror attack
- Evaluate liquid sporicides
- Decon of surfaces
- ***Bacillus anthracis*** (Ames)

Outline

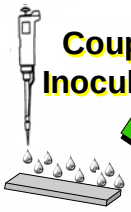
- Test methods
  - Inoculation, neutralization, extraction, samples, data
- Part 1 – Indoor Material Tests
  - Coupon Materials
  - Liquid sterilant technologies
  - Chemistry and spray/application approach
  - Results
- Part 2 – Outdoor Material Tests (DTRA Funded)
  - Coupon Materials
  - Liquid sterilant technologies
  - Chemistry and spray/application approach
  - Results
- Conclusions

Test Methods - Overview

Coupon Inoculation

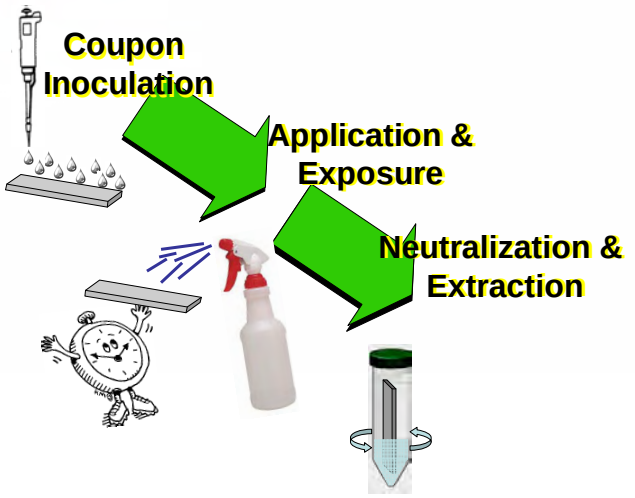
Test Methods - Overview

Coupon Inoculation

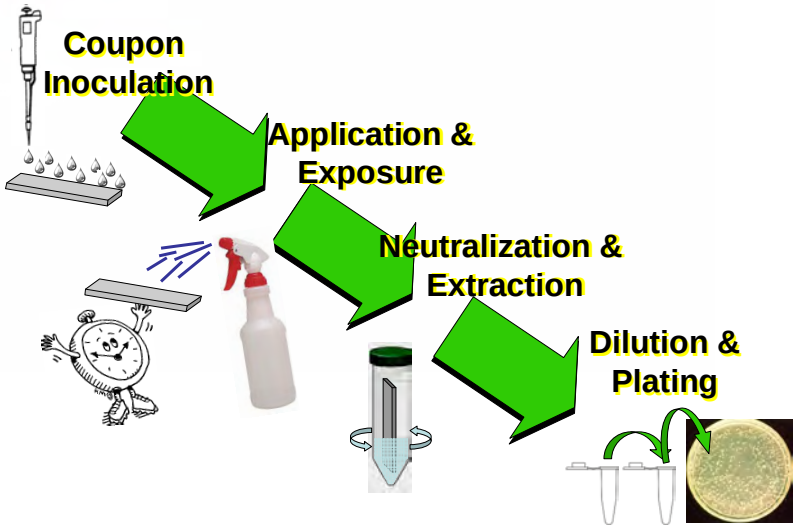


Application & Exposure

Test Methods - Overview



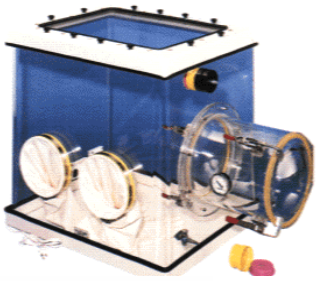
Test Methods - Overview



Technology Spray Devices

Test Methods – Exposure & Extraction

- Tests conducted in ~317 liter glove box at ~ 23ºC and < 70% RH



- Extractions: After contact time, coupons and runoff placed in 50 mL conical tube containing 10 mL phosphate buffered saline (with 0.1% Triton X-100) and neutralizer, orbital shaker 15 minutes, 200 rpm.
  - Except brick, asphalt, granite, concrete: sonicated for 45 minutes

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Test Methods - Neutralization

- Neutralization of sporicidal chemical
  - **Step 1** – Determine the volume of each sporicide retained by each coupon material

***CASCAD* – Sporicide Volume**

Test Material	Average Deposition/Runoff Weight (g)
Non-Porous	
Stainless Steel	0.11
Glass	0.23
Aluminum	0.23
Porcelain	0.56
Granite	0.28
Average	***0.28***
Porous	
Concrete	0.75
Brick	1.40
Asphalt Paving	0.60
Treated Wood	1.59
Butyl Rubber	0.46
Average	***0.96***

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Test Methods - Neutralization

- Neutralization of sporicidal chemical
  - **Step 2** – Incremental testing of neutralizer with the previously-determined volume

***CASCAD* – Neutralization Panel**

		Bacillus anthracis Ames				
Code	Treatment	Inoculum (CFU)	Observed (CFU/mL)	Total (CFU)[bc]	Avg Total (CFU)	% of Control
A1	CASCAD SDF + Spores-1[a]	9.47E+07	0.00E+00	0.00E+00	0.00E+00	0.00%
A2	CASCAD SDF + Spores-2[a]	9.47E+07	0.00E+00	0.00E+00		
A3	CASCAD SDF + Spores-3[a]	9.47E+07	0.00E+00	0.00E+00		
A4	CASCAD SDF + PBS + Triton X-100 + Spores-1[a]	9.47E+07	0.00E+00	0.00E+00	0.00E+00	0.00%
A5	CASCAD SDF + PBS + Triton X-100 + Spores-2[a]	9.47E+07	0.00E+00	0.00E+00		
A6	CASCAD SDF + PBS + Triton X-100 + Spores-3[a]	9.47E+07	0.00E+00	0.00E+00		
A7	Triton X-100 + Spores (**Control**)-1	9.47E+07	9.40E+06	9.40E+07	1.04E+08	-
A8	Triton X-100 + Spores (**Control**)-2	9.47E+07	1.07E+07	1.07E+08		
A9	Triton X-100 + Spores (**Control**)-3	9.47E+07	1.10E+07	1.10E+08		
A10	CASCAD SDF + 0.5% STS + Spores-1[a]	9.47E+07	9.80E+06	1.01E+08	1.06E+08	102.14%
A11	CASCAD SDF + 0.5% STS + Spores-2[a]	9.47E+07	1.02E+07	1.05E+08		
A12	CASCAD SDF + 0.5% STS + Spores-3[a]	9.47E+07	1.09E+07	1.12E+08		
A13	CASCAD SDF + 1.0% STS + Spores-1[a]	9.47E+07	9.87E+06	1.01E+08	9.24E+07	89.15%
A14	CASCAD SDF + 1.0% STS + Spores-2[a]	9.47E+07	8.63E+06	8.87E+07		
A15	CASCAD SDF + 1.0% STS + Spores-3[a]	9.47E+07	8.47E+06	8.71E+07		
A16	CASCAD SDF + 1.5% STS + Spores-1[a]	9.47E+07	9.43E+06	9.69E+07	9.46E+07	91.23%
A17	CASCAD SDF + 1.5% STS + Spores-2[a]	9.47E+07	8.77E+06	9.02E+07		
A18	CASCAD SDF + 1.5% STS + Spores-3[a]	9.47E+07	9.40E+06	9.66E+07		

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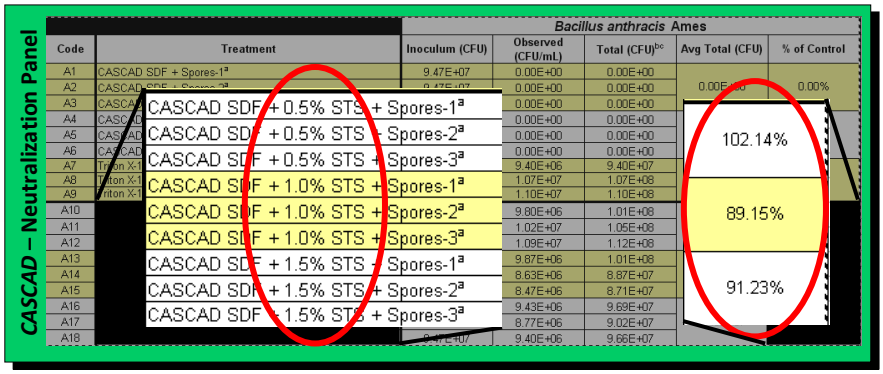
Test Methods - Neutralization

- Neutralization of sporicidal chemical
  - **Step 2** – Incremental testing of neutralizer with the previously-determined volume



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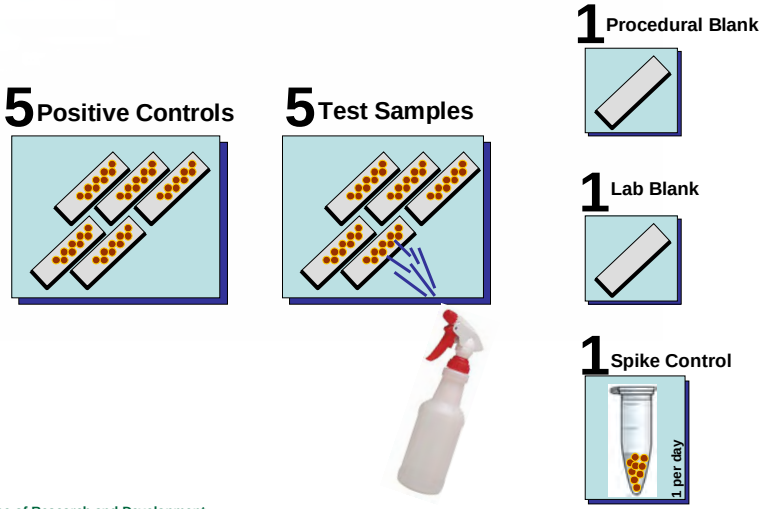
Test Methods - Samples



Test Methods - Data

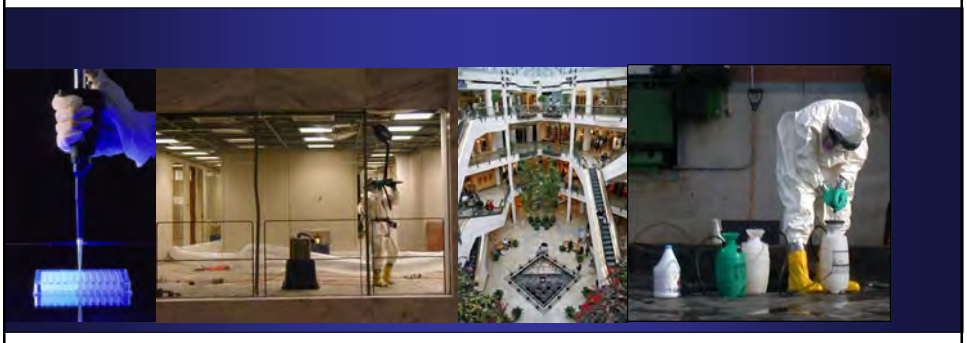
- Percent Recovery (positive controls): spores recovered / spores spiked

$$Recovery = \frac{CFU_{Control}}{CFU_{Inoculum}} \times 100$$

- Efficacy (log reduction) calculation: mean of log values for positive controls – mean of log values for test coupons

$$Efficacy = \overline{(\log CFUc_{ij})} - \overline{(\log CFUt_{ij})}$$

Part 1 – Indoor Materials



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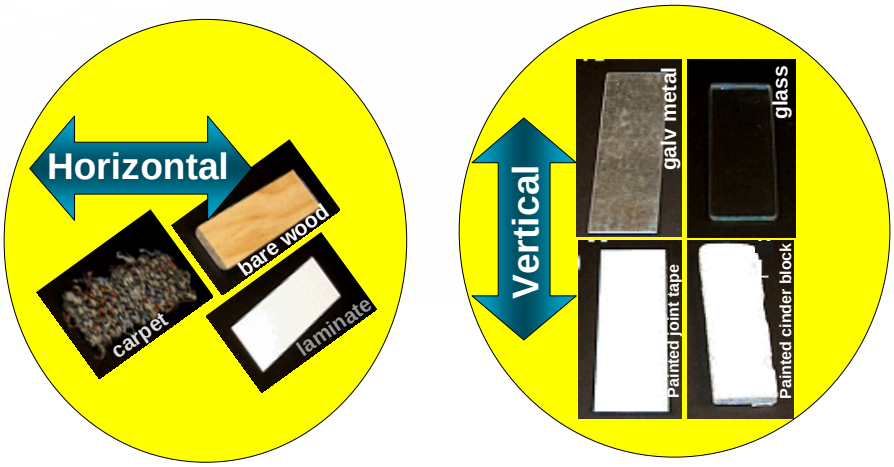
Coupon Materials and Orientation



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Liquid Sterilant Technologies

Technology	Vendor
• DioxiGuard™	Frontier Pharm.
• pH-Adjusted Bleach	Clorox Corp.
• Calcium Polysulfide	VGS, Inc.
• CASCAD™ SDF	Allen Vanguard
• Oxonia Active	Ecolab Inc.
• Minncare® Cold Sterilant	Minntech Corp.
• SanDes	DTI-Sweeden AB

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Chemistry and Application

Technology	Chemistry	Contact time	
		Non-porous	Porous
DioxiGuard	Chlorine dioxide	10	10
pH-adjusted Bleach	Hypochlorite, hypochlorous acid	60	60
Calcium polysulfide	Calcium polysulfide	60	60
CASCAD SDF	Hypochlorite, hypochlorous acid	30	30
Oxonia Active	Peroxide, peracetic acid	60	60
Minncare Cold Sterilant	Peroxide, peracetic acid	10	30
SanDes	Chlorine dioxide	70	70

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Results – Recovery from Indoor Materials

Material	Average Percent Recovery	
	B. anthracis	*B. subtilis*
Carpet	98	46
Decorative Laminate	72	52
Galvanized Ductwork	73	49
Painted Wallboard Paper	66	15
Painted Cinder Block	95	36
Bare Pine Wood	18	4
Glass	66	49

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B. anthracis
Log Reduction – Indoor Materials

Test Material	Sporicidal Technology						
	DioxiGuard	pH-Adjusted Bleach	Calcium Polysulfide	CASCAD SDF	Oxonia Active	Minncare Cold Sterilant	SanDes
Carpet	1.8			7.4	7.0	≥ 7.8	0.1
Laminate	2.6			7.4	≥ 7.6	≥ 7.6	0.2
Ductwork	1.0			≥ 7.6	≥ 7.9	≥ 7.8	0.1
Wallboard	0.7			4.8	≥7.4	≥ 7.5	0.2
Painted Block	1.8	7.3		≥ 7.8	≥ 7.9	≥ 8.1	0.3
Bare Wood	0.8	0.8	0.1	2.8	4.6	5.4	0.4
Glass	2.5		-0.0	≥ 7.9	≥ 7.7	≥ 7.8	4.7

Complete Kill

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B. subtilis
Log Reduction – Indoor Materials

Test Material	Sporicidal Technology						
	DioxiGuard	pH-Adjusted Bleach	Calcium Polysulfide	CASCAD SDF	Oxonia Active	Minncare Cold Sterilant	SanDes
Carpet	0.9			≥ 7.6	≥ 7.4	≥ 7.9	0.6
Laminate	0.3			≥ 7.3	≥ 7.7	≥ 7.9	1.4
Ductwork	-0.7			≥ 7.6	≥ 7.6	≥ 7.9	0.8
Wallboard	0.7			≥ 6.1	≥ 6.7	≥ 7.46	0.6
Painted Block	-0.5	≥ 7.2		≥ 7.1	≥ 7.3	≥ 7.9	0.5
Bare Wood	0.3	0.7	-0.1	1.3	5.2	6.0	0.7
Glass	0.3		0.3	≥ 7.5	≥ 7.0	≥ 8.0	0.2

Complete Kill

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B. anthracis vs. *B. subtilis* – Indoor Materials

Test Material	Sporicidal Technology						
	DioxiGuard	pH-Adjusted Bleach	Calcium Polysulfide	CASCAD SDF	Oxonia Active	Minncare Cold Sterilant	SanDes
Carpet							
Laminate						★	
Ductwork					★	★	
Wallboard					★		
Painted Block				★	★	★	
Bare Wood							
Glass					★	★	

LR of *B.a.* < *B.s.* — No data — ★ Complete kill for both *B.a.* & *B.s.*

LR of *B.a.* > *B.s.* — LR of *B.a.* = *B.s.*

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B. anthracis vs. *B. subtilis* – Indoor Materials

Test Material	Sporicidal Technology						
	DioxiGuard	pH-Adjusted Bleach	Calcium Polysulfide	CASCAD SDF	Oxonia Active	Minncare Cold Sterilant	SanDes
Carpet							
Laminate							
Ductwork							
Wallboard							
Painted Block							
Bare Wood							
Glass							

LR of *B.a.* < *B.s.* — No data

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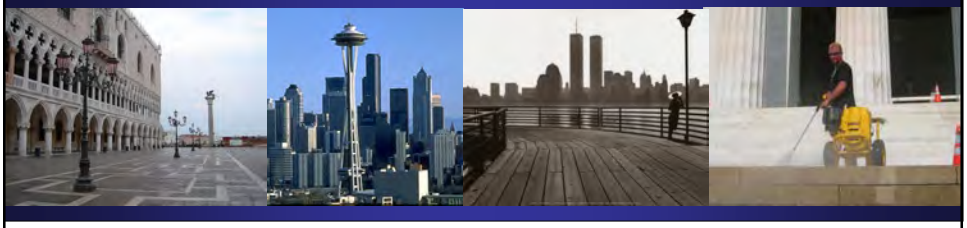
Part 2 – Outdoor Materials



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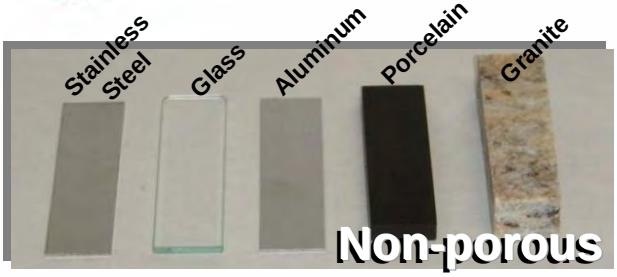
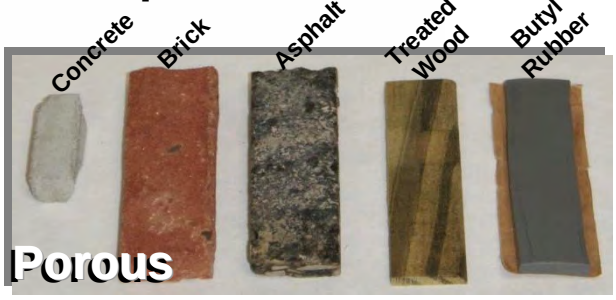
Coupon Materials





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Liquid Sterilant Technologies

Technology	Vendor
• pH-adjusted Ultra-germicidal Bleach	Clorox*
• CASCAD SDF	Allen Vanguard
• Decon Green	STERIS*
• EasyDECON	EFT Holdings Inc.
• Spor-Klenz RTU	STERIS*
• Peridox RTU	Clean Earth Technologies

* no vendor agreement
all liquids sprayed from a distance of 12 inches

EPA United States Environmental Protection Agency

Chemistry and Application

Technology	Chemistry	Contact time	
		Non-porous	Porous
pH-adjusted Germicidal Bleach	Hypochlorite / hypochlorous acid	60	60
CASCAD SDF	Hypochlorite / hypochlorous acid	30	60
Decon Green	Peroxide	60	60
Easy Decon 200	Peroxide	30	60
SporKlenz RTU	Peroxide, peracetic acid	30	60
Peridox	Peroxide, peracetic acid	30	60

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Results – Recovery from Outdoor Materials

	Material	Percent Recovery (*B. anthracis*)
Non-porous	Stainless steel	64
	Glass	77
	Aluminum	76
	Porcelain	70
	Granite	59
Porous	Concrete	11
	Brick	31
	Asphalt	56
	Treated wood	10
	Butyl rubber	30

EPA United States Environmental Protection Agency

Results Summary

	Test Material	Quantitative Efficacy (log reduction)					
		Clorox Ultra Germicidal Bleach (60 minutes)	CASCAD SDF (30/60 minutes)	Decon Green (60 minutes)	Easy DECON 200 (30/60 minutes)	SporKlenz RTU (30/60 minutes)	Peridox (30/60 minutes)
Non-porous	Stainless Steel	≥ 7.7	≥ 7.7	≥ 7.6	≥ 7.6	7.3	≥ 6.7
	Glass	≥ 7.8	≥ 7.7	≥ 7.8	≥ 7.8	7.4	≥ 7.8
	Aluminum	≥ 7.9	≥ 7.8	≥ 7.8	≥ 7.8	7.2	≥ 7.8
	Porcelain	≥ 7.8	≥ 7.7	≥ 7.7	≥ 7.8	≥ 7.7	≥ 7.7
	Granite	≥ 7.6	≥ 7.6	≥ 7.3	≥ 7.5	≥ 7.6	≥ 7.4
Porous	Concrete	6.3	≥ 6.9	4.0	≥ 7.1	1.0	1.4
	Brick	≥ 6.9	≥ 7.4	≥ 7.5	≥ 7.3	≥ 7.3	4.0
	Asphalt Paving	3.6	≥ 7.6	3.0	1.6	2.6	7.2
	Treated Wood	1.9	≥ 7.0	1.9	0.8	6.1	≥ 7.0
	Butyl Rubber	≥ 7.0	≥ 6.8	≥ 6.9	≥ 7.0	≥ 7.4	≥ 6.7

Complete Kill

EPA United States Environmental Protection Agency

Conclusions

- Spore recovery is dependent upon material type
- Efficacy is dependent upon material type
- Differences in technology effectiveness are most apparent on 'difficult to decon' materials
- ***B. subtilis*** is a good (not perfect) surrogate for ***B. anthracis*** decon studies, could be dependent upon decontaminant
- Minncare (10 or 30 min) demonstrated the highest efficacy on indoor materials, CASCAD (30 or 60 min) on outdoor materials

Simulated Cesium Radiological Dispersal Devices for Deposition, Dose, and Decontamination Studies

Mark Sutton, Lawrence Livermore, National Laboratory

Lawrence Livermore National Laboratory

Simulated Cs Radiological Dispersal Devices for Deposition, Dose and Decontamination Studies

April 14th 2010

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Presentation

- Background
- LLNL Capabilities
- Explosive tests
- Deposition and fate
- Dose
- Decontamination
- Acknowledgements

Background

- The rapid and efficient cleanup after an RDD is crucial to subsequently limit the potential for panic, fear and economic disruption, and to decontaminate the affected area for potential reuse.
- Not only will the decontamination of surfaces be necessary, but also the consideration of the release of radiation into the water supply or in aerosolized form into the air.
- First responders and HazMat cleanup teams must be prepared to decontaminate infrastructure, environments and the population.
- The longevity of some radionuclides in the environment deems that large areas would require eventual decontamination and/or demolition.
- Post-RDD cleanup and demolition costs would be very high, estimated in excess of several billion dollars.

Cs-137

- Produced from uranium fission in reactors
- Undergoes beta decay (1.18 MeV), half-life of 30.1 years.
- Found in radiotherapy devices, thickness and density gauges, food irradiators and gemstone treatment equipment,
- Activities typically range from 1 to 1,000 Ci.
- Most sources contain highly soluble cesium chloride (CsCl) powder, incorporated in disks, rods, seeds or lead containers.

$^{137}CsCl$

- Dissolves to form Cs^+ ions that are behave conservatively, i.e. highly mobile in fractured material.
- Soluble under all pH regimes and generally does not precipitate in natural systems.
- May undergo ion exchange with other cations in zeolite materials, and may be incorporated into layered mica sheets over long time periods.
- May be transported deep inside porous urban building material, where it may become trapped and difficult to remove.

Cs RDD

- Researchers at LLNL have investigated the chemistry and material science of urban materials, including grime and carbonation layers present in urban transit systems.

- Deposition and fallout from a Cs-137 RDD may present an immediate danger to first responders and clean up teams, as well as persons within the vicinity. A fraction of the Cs-137 particles formed during the event may be respirable.

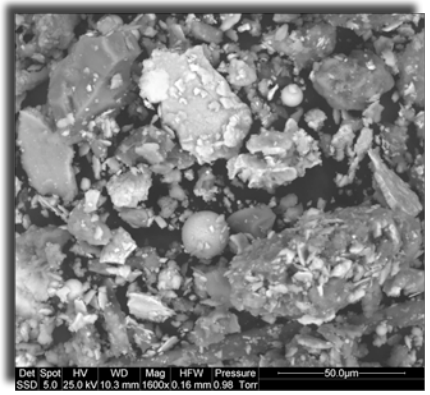
- In order to simulate and better understand the processes involved in deposition, dose and surface interactions of Cs RDDs in urban environments, non-radioactive Cs-133 has been used at unique LLNL facilities that enable indoor and outdoor explosive testing combined with physical, chemical and dose related analysis.

LLNL Explosive Test Capabilities

- LLNL's Site 300 experimental test site is situated in foothills approximately 15 miles from the main Laboratory site.
- 7,000 acres, used since 1955 to perform high explosive research in support of LLNL missions.
- In addition to outdoor testing, the site also houses a 28,000 sq-ft indoor explosive testing facility (Contained Firing Facility).

LLNL Explosive Tests

- Sampled urban building material, grime layers (particularly relating to transit systems) and surrogates were characterized using a full suite of chemical and surface analyses.



- Samples were then loaded into holders and attached to blast shields in both vertical and horizontal planes.

LLNL Explosive Tests

- The samples were located at 10, 20 and 30 feet from the device containing approx 1 kg ^{133}CsCl(s) and C-4 explosive.

Additional LLNL Explosive Tests

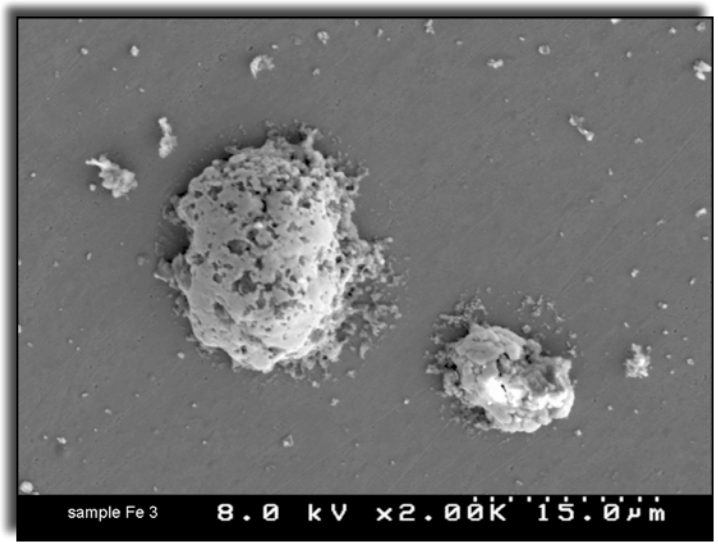
- We have also performed outdoor RDD simulations with Cs-133 that allow the study of weather conditions and greater deposition distances. These outdoor tests contained more cesium and more C-4 than the indoor test compared to indoor tests.

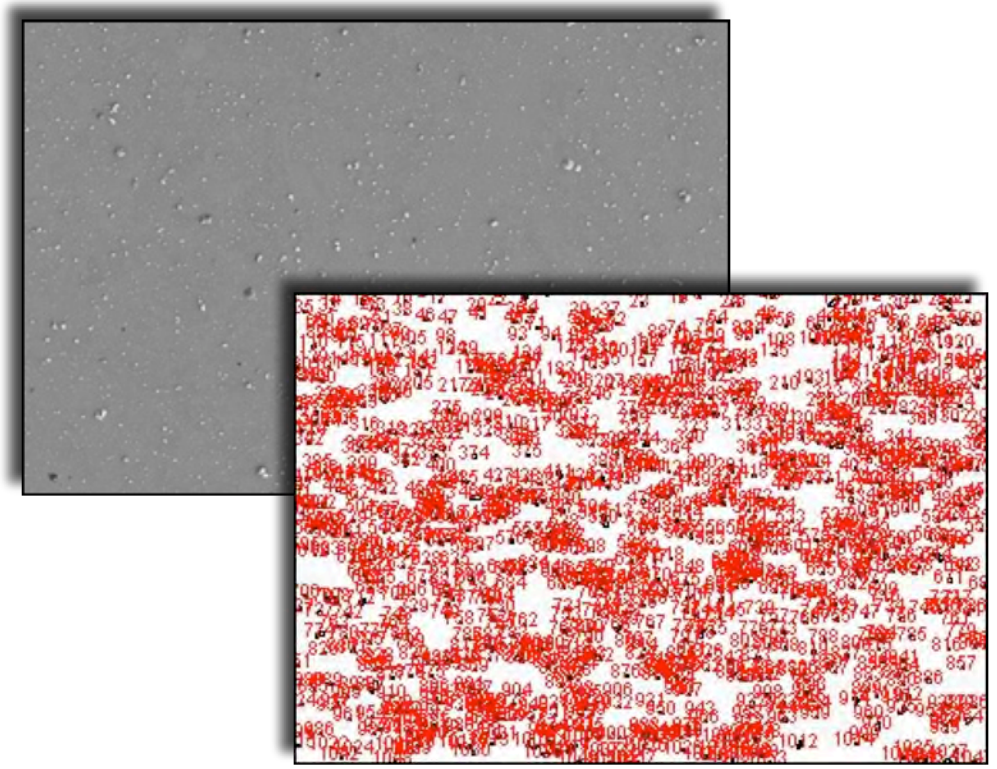
Deposition

- Cs deposition and diffusion data were measured using SEM/EDS and laser ablation inductively coupled plasma mass spectrometry (LA-ICP-MS).
- Cs diffusion into concrete pores was comparable with hydrated concrete, suggesting relative humidity greatly affects diffusion.
- The presence of grime did not chemically affect Cs speciation or mobility (as determined by sorption experiments), but results did show that grime could physically hinder Cs transport to the concrete surface below.

Deposition

- SEM/EDS results showed a particle density of approx 9,500 particles/mm^2, with an average diameter of 6 microns.





SEM/EDS images of contaminated surfaces CsCl deposition, particle density, and false color image for particle counting

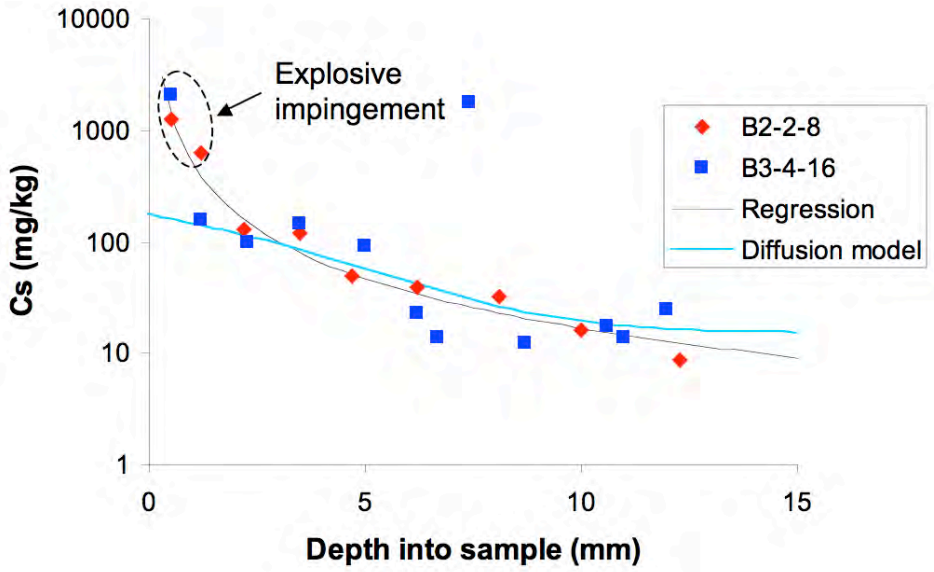
Fate and Transport

- The cement core samples were cut vertically, and transverse laser ablation was performed to investigate the depth of penetration into the concrete.

- Cesium was detected beyond 1 cm depth after samples had equilibrated for 32 days between deposition and analysis.

Fate and Transport

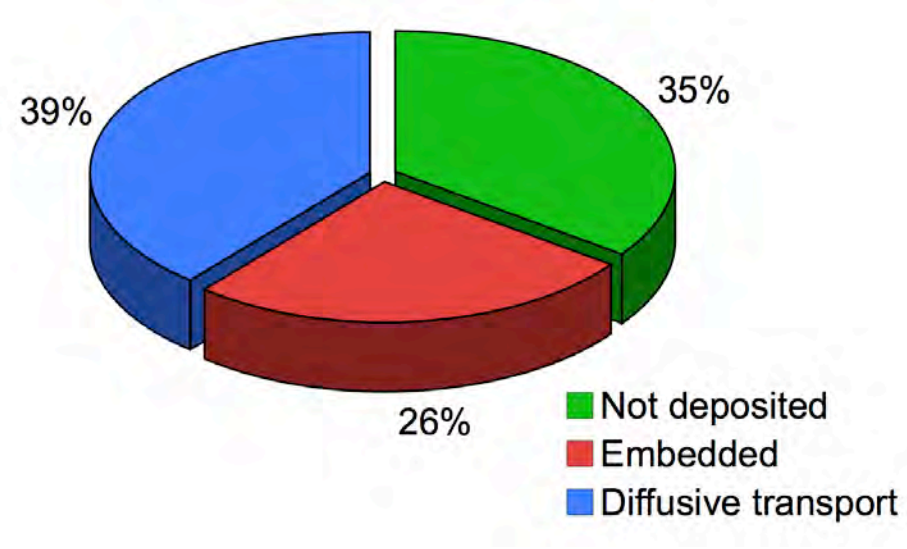
- Diffusion was modeled to fit experimental data and the difference between the regression and diffusion model was assumed to be embedded Cs from the explosion.



- The migration into the concrete is believed to be due to diffusion, with Cs^+ carried in to the pores by the ambient relative humidity present between deposition and analysis (21-99 %RH over 32d).

Fate and Transport

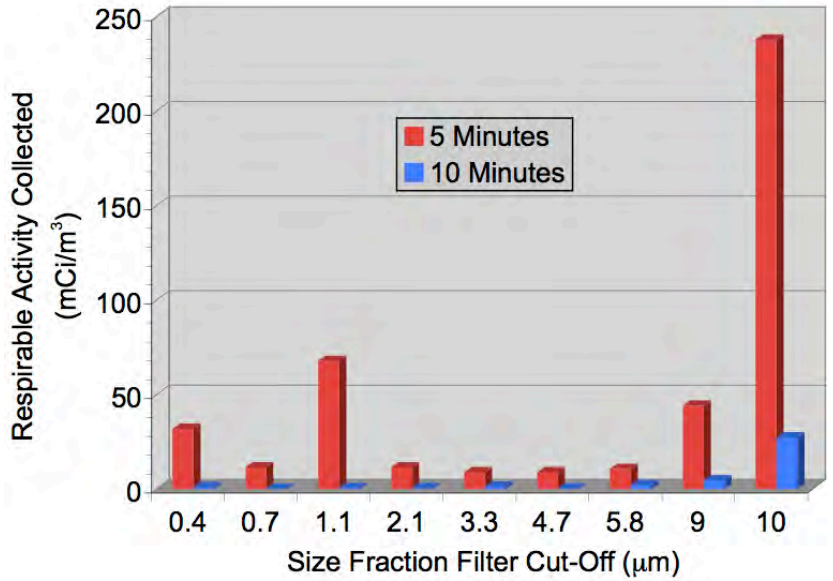
- By understanding the diffusive transport fraction, embedded fraction and original cesium load from the explosion, we were able to calculate the air-suspended fraction.



- One third of the cesium was suspended, one quarter was explosively driven into the cement, the remainder underwent diffusion into the concrete, making decontamination problematic.

Dose

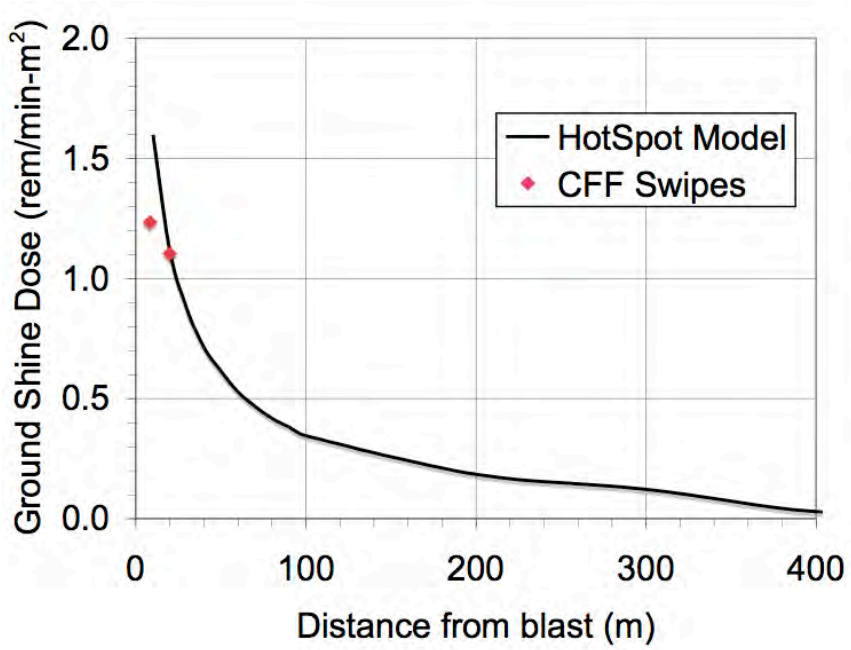
- A 9-stage cascade impactor was used to sample air from the CFF chamber both 5 and 10 minutes after the explosive test.
- The results were converted from mg/m^3 Cs to activity using a specific activity of 88 Ci/g (thus allowing contamination estimates to be made from a non-radioactive test).
- The results show a significant portion of the respirable particles are within the 9-10 um range.



Dose

- LLNL's HotSpot model was used to examine ground shine depostion and dose variation with distance.

- Swipe samples taken from the explosive test were converted to dose values and plotted similarly (DCF from FGR 11, 12, ICRP-30).

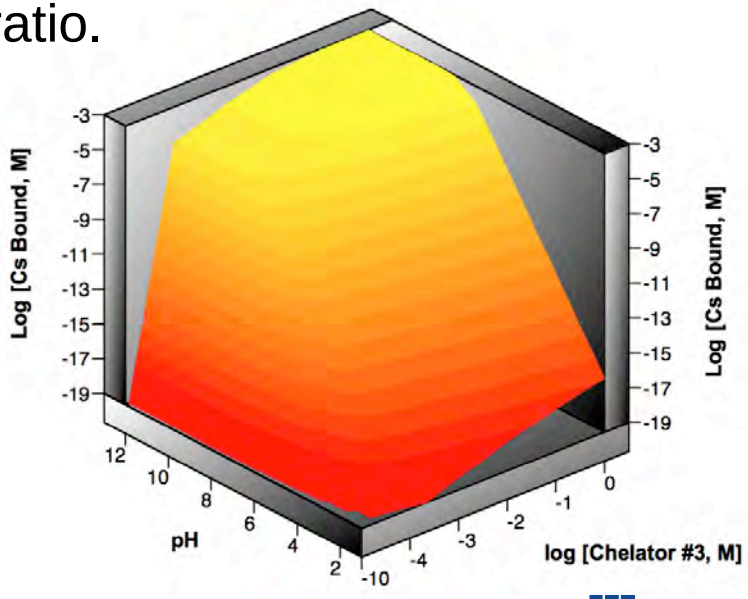


Decontamination Development

- Separately, chemical thermodynamic and structural modeling has aided in the determination of more effective decontamination agents.

- Such agents are capable of binding radionuclides to a higher degree of selectivity when compared to traditional chelating technology, over a wide pH and decon ratio.

- The use of selective chelators allows for the rapid and efficient removal of radionuclides, while also leaving infrastructure intact, reducing waste generation, dose and exposure time.



Caveat and Summary

- While our non-radioactive Cs RDD simulation was perhaps unrealistically large with respect to total Cs-137 activity, the work does provide insight into the science of surface interaction, deposition, dispersion, dose and decontamination needed to prepare for protection and response against such a device.

- The work aids decision making between destructive and non-destructive decontamination techniques to minimize residual dose consequences during restoration-phase response activities

- The work also provides experimental data that is used to validate models.

Acknowledgements

Hotspot: National Atmospheric Release Advisory Center, LLNL

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Inactivation of Bioagents by Natural Attenuation, Liquid Decontamination, or Fumigation

Harry Stone, Battelle

Inactivation of Bioagents by Natural Attenuation, Liquid Decontamination, or Fumigation

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2

Biological Agents, Materials, and Decontamination Technologies

Biological Agents (5)

- ***Bacillus anthracis*** Ames spores
- ***Brucella suis*** Biotype I
- ***Francisella tularensis*** LVS
- Vaccinia virus ATCC VR119
- ***Yersinia pestis*** CO-92

Materials (11)

- Aluminum
- Keyboard keys (computer)
- Carpet
- Painted joint tape
- Decorative laminate
- Galvanized metal
- Painted concrete
- Wood
- Glass
- Ceiling tile
- Cellulose

Decontamination Technologies (10)

Fumigant technologies (5)

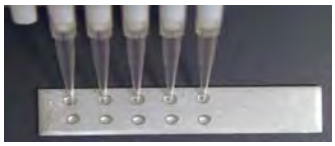
- Sabre: ClO_2
- STERIS VHP®: H_2O_2
- BIOQUELL Clarus® C: H_2O_2
- BIOQUELL Clarus® S: H_2O_2
- Methyl bromide

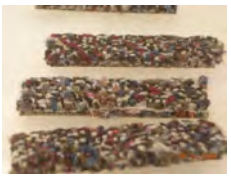
Liquid technologies (5)

- pH amended bleach
- Exterm: ClO_2 (aqueous)
- Oxonia Active®: H_2O_2 / peroxyacetic acid
- Spor-Klenz Ready-to-Use: H_2O_2 / peroxyacetic acid
- DuPont Virkon® S: potassium peroxomonosulfate, sodium dodecylbenzene sulphonate, and sulfamic acid

Internal Standard Operating Procedure for Efficacy Testing

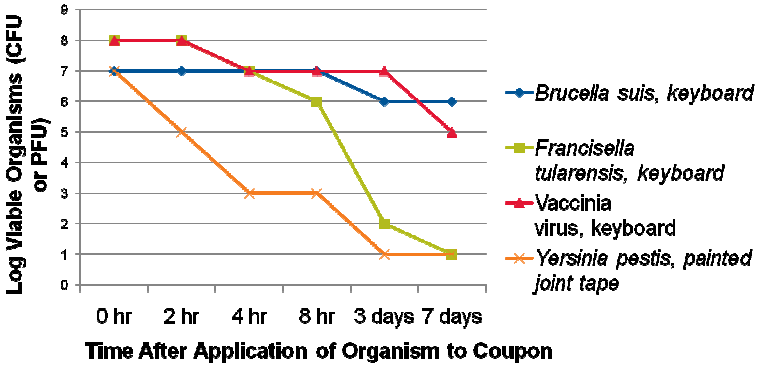
- Coupons: ~1.9 x 7.5 cm (except keyboard key, small glass, and cellulose)
- Inoculation: 10 x 10 µL drops, ~1 x 10^7 viable organisms/coupon (except vaccinia ~1 x 10^8);
  - persistence measured from application
  - dry one hour (except spores dried overnight) before decontamination





- Expose to decontaminant
- Extract coupons with 10 mL of PBS (spores, add 0.1% Triton X-100), agitated for 15 minutes
- Serial dilution and plating to determine CFU or PFU
- Efficacy: log reduction equals the mean log density of control carriers minus the mean log density of test carriers

Attenuation of Biological Organisms Over Time



- Persistence was at ambient laboratory conditions (21.5˚C ± 3.5˚C; 24% to 60% RH)
- At laboratory conditions tested, viable ***Brucella suis***, ***Francisella tularensis***, vaccinia virus, and ***Yersinia pestis*** were recovered from at least one material at 7 days
- ***Brucella suis*** and vaccinia virus were most persistent (highest residual viable organisms over time) at the conditions tested

5

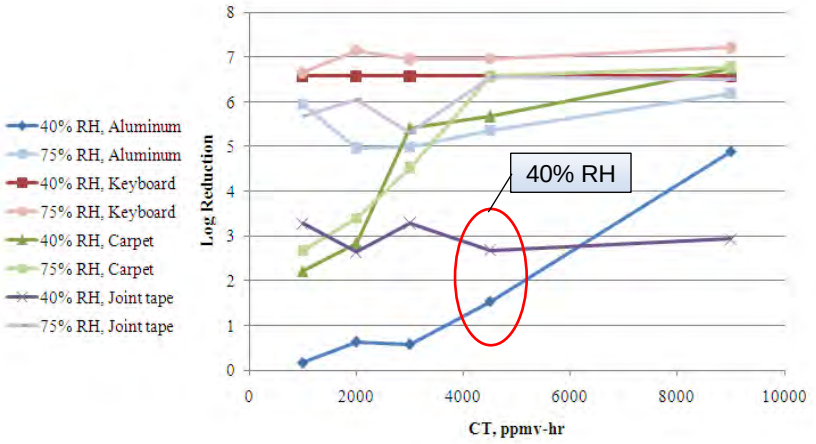
B. anthracis Ames: Sabre ClO_2 Fumigation (3000 ppmv x 3 hr, 24°C–25°C, 85% - 95% RH)

Material	Control Mean CFU (SD)	Decon Mean CFU (SD)
Glass (5 mm x 5 mm), 1x 10^7 spores applied	4.70 x 10^6 (1.13 x 10^6)	0
Painted Concrete, 1x 10^8 spores applied	3.89 x 10^7 (1.18 x 10^7)	6.61 x 10^2 (1.48 x 10^3)
Galvanized Metal, 1x 10^8 spores applied	4.68 x 10^6 (2.00 x 10^6)	0
Decorative Laminate, 1x 10^8 spores applied	3.58 x 10^7 (1.18 x 10^7)	0
Cellulose Insulation, 1x 10^8 spores applied	4.83 x 10^7 (2.13 x 10^7)	5.07 x 10^2 (3.24 x 10^2)
Particle Board, 1x 10^8 spores applied	3.53 x 10^6 (3.25 x 10^6)	0
Industrial Carpet, 1x 10^8 spores applied	4.31 x 10^7 (8.43 x 10^6)	0
Plate Glass, 1x 10^8 spores applied	3.90 x 10^7 (9.24 x 10^6)	0

- Sabre ClO_2 at 3000 ppmv for 3 hr (high humidity) is efficacious against ***B. anthracis*** Ames spores on all materials tested with no viable spores recovered from most materials tested

6

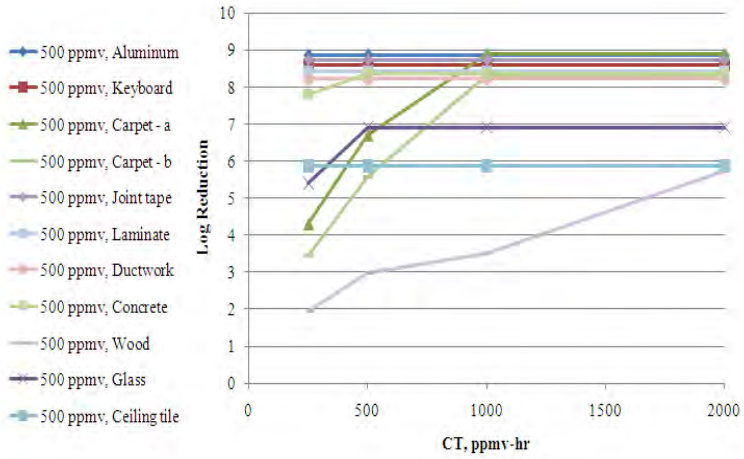
B. anthracis: Sabre ClO_2 Fumigation



- ClO_2 has lower efficacy at low RH (40%) than at higher RH (75%) against ***B. anthracis*** Ames spores on certain materials; carpet may retain moisture

7

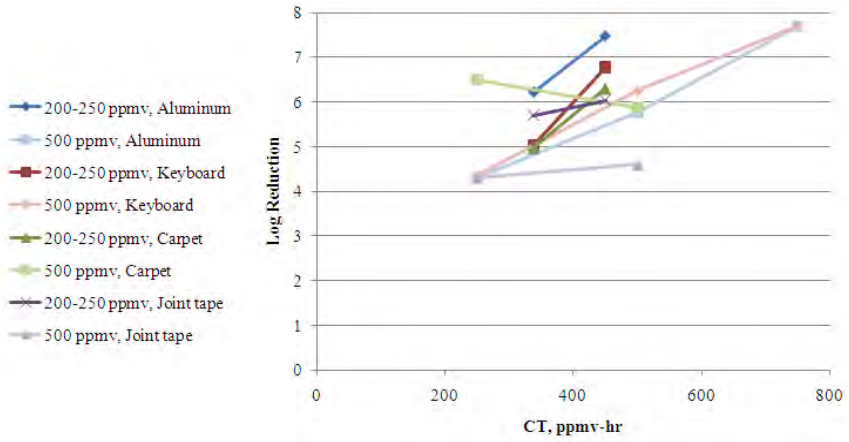
STERIS VHP® 500 ppmv HP Fumigation Results for *B. anthracis*



- Steris VHP fumigation yields high log reductions of ***B. anthracis*** from all materials tested in 4 hours with a 500 ppmv fumigation cycle

8

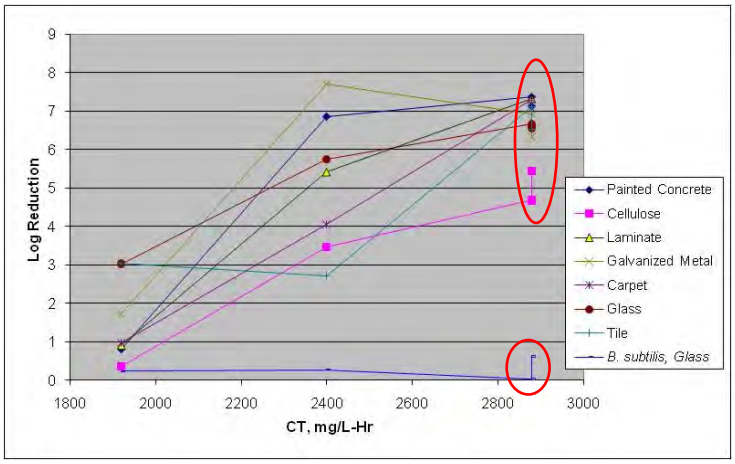
B. anthracis: STERIS VHP Fumigation Results for at the 200-250 ppmv compared to 500 ppmv



- Effectiveness of STERIS VHP fumigation of ***B. anthracis*** spores in the range tested appeared to be independent of how CT was achieved (whether concentration or time was varied).

9

B. anthracis: Methyl Bromide 320 mg/L Fumigation (36˚C, 75% RH)



- At 320 mg/L for 9 hours contact time, methyl bromide was efficacious against ***B. anthracis*** – but not against ***B. subtilis*** for materials and conditions tested

10

B. anthracis: BIOQUELL Clarus C 150 ppmv HP Fumigation, 180 min Contact Time

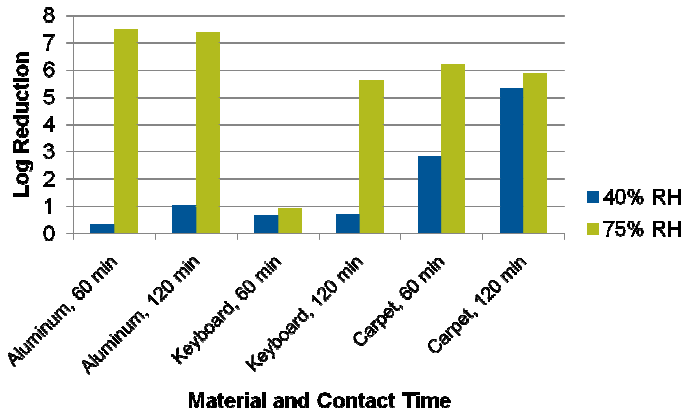
- Spike amount 1.08 x 10^7 CFU/coupon
- Fumigate 10 min at 8 g/min; dwell at 0.8 g/min (150 ppmv cycle)

Material	Mean Recovered *B. anthracis* (CFU/coupon) Positive Control	Test Coupon	Mean Log Reduction
Laminate	7.18 ± 3.60 x 10^6	0.00 ± 0.00	6.86 ± 0.00
Ductwork	2.86 ± 1.71 x 10^6	0.00 ± 0.00	6.46 ± 0.00
Carpet	5.42 ± 0.75 x 10^6	8.63 ± 16.6 x 10^4	4.68 ± 2.84
Concrete	8.51 ± 2.94 x 10^6	4.99 ± 10.6 x 10^3	5.46 ± 2.07
Wood	5.25 ± 1.46 x 10^5	7.95 ± 9.18 x 10^3	2.16 ± 0.64
Glass	6.17 ± 0.72 x 10^6	0.00 ± 0.00	6.79 ± 0.00
Ceiling tile	6.66 ± 1.63 x 10^5	0.00 ± 0.00	5.82 ± 0.00

- Clarus C 150 ppmv HP fumigation – complete kill of ***B. anthracis*** on nonporous materials and greater than 6-log kills at 180 min
- Viable spores recovered from some porous or absorbent materials after fumigation

11

B. suis: Sabre Fumigation Results for 50-100 ppmv ClO_2 (23°C)



- Sabre ClO_2 fumigation at 50 – 100 ppmv at 120 min contact time is efficacious against ***B. suis*** at 75% RH
- 75% RH for ClO_2 fumigations results in higher log reduction against ***B. suis*** than 40% RH

12

B. suis: STERIS VHP 500 ppmv Fumigation Results

Contact Time	Material	Mean Recovered *B. suis* (CFU/coupon) CFU/coupon (Spike amount 7.03×10^7 - 8.80×10^7) Positive Control	Test Coupon	Mean Log Reduction
60 min	Aluminum	$3.76 \pm 1.62 \times 10^7$	$2.40 \pm 2.73 \times 10^2$	5.76 ± 1.11
	Keyboard	$3.32 \pm 0.51 \times 10^7$	$8.68 \pm 9.31 \times 10^1$	6.25 ± 1.17
	Carpet	$7.43 \pm 3.65 \times 10^5$	0.00 ± 0.00	5.87 ± 0.00
	Joint tape	$4.02 \pm 2.01 \times 10^4$	0.00 ± 0.00	4.60 ± 0.00
90 min	Aluminum	$5.06 \pm 0.59 \times 10^7$	0.00 ± 0.00	7.70 ± 0.00
	Keyboard	$5.01 \pm 1.05 \times 10^7$	0.00 ± 0.00	7.70 ± 0.00

- Steris VHP fumigation at 500 ppmv – complete kill of ***B. suis*** on all materials tested at 90 min

B. suis: BIOQUELL Clarus C 150 ppmv HP Fumigation Results

Contact Time	Material	Mean Recovered *B. suis* (CFU/coupon) (Spike amount 3.5×10^7) Positive Control	Test Coupon	Mean Log Reduction
180 min	Aluminum	$1.50 \pm 0.64 \times 10^7$	0.00 ± 0.00	7.18 ± 0.00
	Keyboard	$2.24 \pm 0.93 \times 10^7$	0.00 ± 0.00	7.35 ± 0.00
	Carpet	$7.06 \pm 1.30 \times 10^6$	0.00 ± 0.00	6.85 ± 0.00
	Joint tape	$2.17 \pm 0.25 \times 10^6$	0.00 ± 0.00	6.34 ± 0.00

- Clarus C 150 ppmv HP fumigation – complete kill of ***B. suis*** on all materials tested at 180 min contact time

F. tularensis: Sabre 50-100 ppmv ClO_2 (23°C, 75% RH) Fumigation Results

Contact Time	Material	Mean Recovered *F. tularensis* (CFU/coupon) (Spike amount 6.77 x 10^7)		Mean Log Reduction
		Positive Control	Test Coupon	
120 min	Aluminum	2.39 ± 1.41 x 10^6	0.00 ± 0.00	6.38 ± 0.00
	Keyboard	3.86 ± 0.82 x 10^4	0.00 ± 0.00	4.59 ± 0.00
	Carpet	7.01 ± 9.14 x 10^5	0.00 ± 0.00	5.85 ± 0.00
	Joint tape	0.00 ± 0.00	0.00 ± 0.00	Not calculable

- Sabre ClO_2 fumigation at 50 – 100 ppmv, 75% RH, is efficacious against ***F. tularensis***
- High natural attenuation was observed on certain materials over the period of testing

F. tularensis: STERIS VHP 200-250 ppmv HP Fumigation

Contact Time	Material	Mean Recovered *F. tularensis* (CFU/coupon) (Spike amount 1.91 x 10^8)	
		Positive Control	Test Coupon
90 min	Aluminum	2.18 ± 0.91 x 10^6	0
	Keyboard	5.55 ± 1.57 x 10^5	0

- STERIS VHP 200 – 250 ppmv HP fumigation – complete kill on both materials tested at 90 min contact time

F. tularensis: Bioquell Clarus S 150 ppmv HP Fumigation Results

Contact Time	Material	Mean Recovered *F. tularensis* (CFU/coupon) (Spike amount 1.65 – 1.77 x 10^8) Positive Control	Test Coupon	Mean Log Reduction
30 min	Carpet	3.00 ± 0.69 x 10^6	0.00 ± 0.00	6.48 ± 0.00
	Joint tape	4.01 ± 4.82 x 10^3	0.00 ± 0.00	3.60 ± 0.00
	Aluminum	6.63 ± 2.76 x 10^4	0.00 ± 0.00	4.82 ± 0.00
	Keyboard	1.30 ± 1.21 x 10^6	0.00 ± 0.00	6.11 ± 0.00

- Clarus S 150 ppmv HP fumigation – complete kill of ***F. tularensis*** on all materials tested at 30 min contact time

Vaccinia: Sabre 250 ppmv ClO_2 Fumigation with 30 min Contact Time (22˚C, 76% RH)

Material	Control Mean PFU (SD)	Decon Mean PFU
Glass (small)	3.22 x 10^4 (3.12 x 10^3)	0
Painted Concrete	3.25 x 10^5 (5.45 x 10^4)	0
Galvanized Metal	2.95 x 10^5 (9.11 x 10^4)	0
Decorative Laminate	2.32 x 10^5 (1.53 x 10^4)	0
Cellulose Insulation	3.67 x 10^5 (3.12 x 10^5)	0
Particle Board	1.10 x 10^5 (1.30 x 10^4)	0
Industrial Carpet	2.98 x 10^5 (8.74 x 10^4)	0

- No viable vaccinia virus was recovered from any material tested after Sabre 250 ppmv ClO_2 fumigation for 30 min contact time

Vaccinia: STERIS VHP HP 200-250 ppmv Fumigation Results

Contact Time	Material	Mean Recovered Vaccinia Virus (PFU/coupon) (Spike amount 5.99 – 9.64 x 10^6) Positive Control	Test Coupon	Mean Log Reduction
30 min	Aluminum	2.50 ± 1.59 x 10^6	1.42 ± 0.32 x 10^1	5.26 ± 0.11
	Keyboard	2.43 ± 0.60 x 10^5	1.49 ± 0.48 x 10^1	4.23 ± 0.16
	Carpet	1.34 ± 1.79 x 10^4	0.00 ± 0.00	4.13 ± 0.00
	Joint tape	1.75 ± 0.65 x 10^4	0.00 ± 0.00	4.24 ± 0.00
60 min	Aluminum	1.41 ± 0.22 x 10^6	1.25 ± 0.21 x 10^1	5.06 ± 0.08
	Keyboard	8.50 ± 1.37 x 10^4	0.00 ± 0.00	4.93 ± 0.00
120 min	Aluminum	1.64 ± 0.42 x 10^6	3.37 ± 0.67 x 10^1	4.70 ± 0.09

- STERIS VHP 200 – 250 ppmv HP fumigation – complete kill on all materials tested except aluminum at 90 min contact time
- Hypothesize that hydrogen peroxide may react with aluminum, reducing efficacy; near complete kill on aluminum at 120 min

Vaccinia: BIOQUELL Clarus C 150 ppmv HP

Contact Time	Material	Mean Recovered Vaccinia virus (PFU/coupon) (Spike Amount 3.52 – 9.64 x 10^7 PFU/coupon) Positive Control	Test Coupon	Mean Log Reduction
180 min	Keyboard	7.74 ± 3.90 x 10^5	0.00 ± 0.00	5.89 ± 0.00
	Carpet	3.93 ± 1.88 x 10^4	0.00 ± 0.00	4.59 ± 0.00
	Aluminum	1.59 ± 0.59 x 10^7	0.00 ± 0.00	7.20 ± 0.00
	Joint tape	1.09 ± 0.45 x 10^5	0.00 ± 0.00	5.04 ± 0.00
	Glass	1.60 ± 0.54 x 10^7	0.00 ± 0.00	7.20 ± 0.00

- No viable vaccinia virus was recovered from any material tested after Clarus C 150 ppmv HP fumigation for 180 min contact time

Y. pestis: Sabre ClO_2 Fumigation Results

Contact Time	Material	Mean Recovered *Y. pestis* (CFU/coupon) (Spike Amount 1.56 – 2.30 x 10^7 CFU/coupon) Positive Control	Test Coupon
0 min	Aluminum	9.54 ± 5.52 x 10^3	Not applicable
	Keyboard	6.16 ± 6.09 x 10^3	Not applicable
	Carpet	5.04 ± 2.64 x 10^6	Not applicable
	Joint tape	0.00 ± 0.00	Not applicable
30 min	Aluminum	0.00 ± 0.00	0.00 ± 0.00
	Keyboard	4.00 ± 7.24 x 10^1	0.00 ± 0.00
	Carpet	1.05 ± 1.10 x 10^6	0.00 ± 0.00
	Joint tape	0.00 ± 0.00	0.00 ± 0.00

- Sabre ClO_2 fumigation at 50 – 100 ppmv, 75% RH: no viable ***Y. pestis*** recovered from any material after a 30 min contact time

21

Y. Pestis: STERIS VHP 200-250 ppmv HP Fumigation

Contact Time	Material	Spike Amount (CFU/coupon)	Mean Recovered *Y. pestis* (CFU/coupon) Positive Control	Test Coupon	Mean Log Reduction
90 min	Aluminum	3.83 x 10^6	3.29 ± 0.52 x 10^4	0.00 ± 0.00	4.52 ± 0.00
	Keyboard	3.83 x 10^6	4.13 ± 1.57 x 10^2	0.00 ± 0.00	2.62 ± 0.00

- STERIS VHP 200 – 250 ppmv HP fumigation – complete kill of ***Y. pestis*** on both materials tested at 90 min contact time
- High levels of natural attenuation of ***Y. pestis*** result in low calculated log reductions

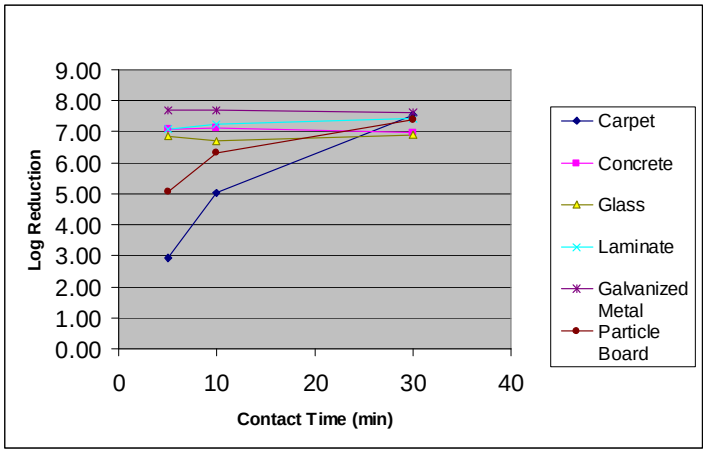
22

Y. pestis: BIOQUELL Clarus C 150 ppmv HP Fumigation

Contact Time	Material	Mean Recovered *Y. pestis* (CFU/coupon) (Spike Amount 9.07 x 10^6 CFU/coupon) Positive Control	Test Coupon	Mean Log Reduction
180 min	Aluminum	3.02 ± 0.71 x 10^4	0.00 ± 0.00	4.48 ± 0.00
	Keyboard	4.56 ± 1.53 x 10^5	0.00 ± 0.00	5.66 ± 0.00
	Carpet	2.14 ± 0.93 x 10^3	0.00 ± 0.00	3.33 ± 0.00
	Joint tape	4.29 ± 2.76 x 10^3	0.00 ± 0.00	3.63 ± 0.00

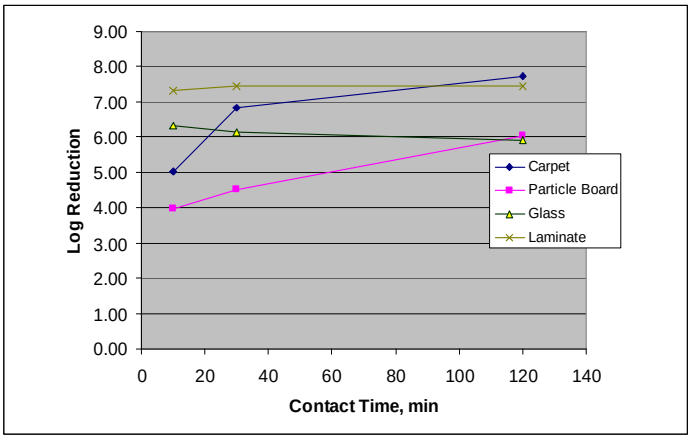
- No viable ***Y. pestis*** was recovered from any material tested after Clarus C 150 ppmv HP fumigation for 180 min contact time

B. anthracis Ames: pH Amended Bleach (5,000 ppm) Solution (20°C)



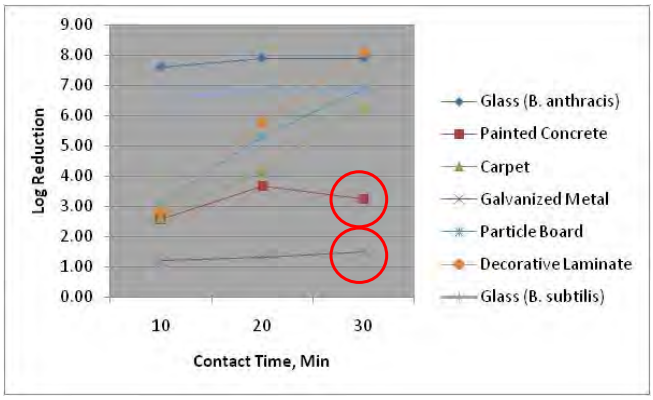
- pH amended bleach effective against ***B. anthracis*** Ames with 30 min contact time on all materials tested; contaminated surface was soaked in liquid

B. anthracis Ames: Exterm 1,000 ppm ClO_2 (20°C)



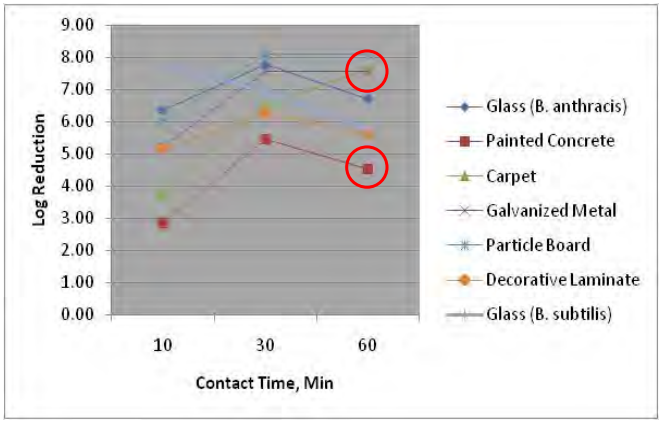
- Exterm ClO_2 solution effective against ***B. anthracis*** Ames with 120 min contact time on all materials tested; contaminated surface was soaked in liquid

B. anthracis Ames: Spore-Klenz Hydrogen Peroxide - Peracetic Acid (20°C)



- Spor-Klenz Ready-to-Use solution effective against ***B. anthracis*** Ames with 30 min contact time on some materials tested; limited effectiveness on galvanized metal and painted concrete; contaminated surface was soaked in liquid
- Preliminary results – data currently under review

B. anthracis Ames: Oxonia Active Hydrogen Peroxide - Peracetic Acid (20°C)



- Oxonia Active solution effective against ***B. anthracis*** Ames with 60 min contact time on most materials tested; limited effectiveness on painted concrete; contaminated surface was soaked in liquid
- Preliminary results – data currently under review

B. anthracis: Virkon S (1%) Decontamination Method Demonstration

Virkon S	Time	Neutralizer	Average Log Density (CFU/mL)	Average Log Reduction
No	30 min	None (tubes 1-3)	6.83	n/a
Yes	30 min	None (10-12)	6.97	-0.14
No	60 min	None (tubes 1-3)	6.16	n/a
Yes	60 min	None (10-12)	5.89	0.27

- Virkon S 1% solution not effective against ***B. anthracis*** Ames with 30 or 60 min contact time in suspension test

Summary

- At laboratory conditions tested, viable ***Brucella suis***, ***Francisella tularensis***, vaccinia virus, and ***Yersinia pestis*** were recovered from at least one material at 7 days
- ***Brucella suis*** and vaccinia virus were most persistent (highest residual viable organisms over time) at the conditions tested
- Application all fumigants (Sabre ClO_2, STERIS VHP, and BIOQUELL Clarus C and S) at conditions tested resulted in reduction in recovered viable ***B. anthracis, B. suis***, ***F. tularensis***, vaccinia virus, and ***Y. pestis***; exposure of ***B. anthracis*** to methyl bromide resulted in reduction in recovered viable organisms
- Fumigant efficacy varied from low to high, depending on concentration of the fumigant, contact time, materials on which agent was deposited, and conditions, e.g., temperature and RH
- Application of amended bleach, Exterm® were highly efficacious against ***B. anthracis*** under conditions and on materials tested; Oxonia Active®, Spor-Klenz Ready-to-Use were highly efficacious against ***B. anthracis*** under conditions tested for some, but not all, materials tested
- DuPont Virkon® S as tested was not efficacious against ***B. anthracis*** in 30 and 60 min suspension tests

EPA Spectral Photometric Environmental Collection Technology: Gamma Emergency Mapper Project

John Cardarelli, EPA/OSWER/OEM/NDT

EPA Airborne Spectral Photometric Environmental Collection Technology
Gamma Emergency Mapper Project

Decontamination Workshop
Research Triangle Park, NC
April 14, 2010

John Cardarelli II[1], Mark Thomas[1], Tim Curry[1], Scott Faller[2],
[1] National Decontamination Team
[2] Radiological Emergency Response Team

Outline

- Background: ASPECT Aircraft & Program
- ASPECT GEM Purpose and Goal
- GEM Team
- Radiation detection technology and survey
- Recent Surveys/MDA
- Accomplishments
- Future Work

Aircraft Platform

- **AeroCommander 680 FL/G Platform**
  - Base of Operation: Waxahachie, Texas
  - IFR/GPS Equipped
  - High Quality Filtered Power
  - STC Camera Holes in the floor
- **Crew: Two Pilots, One Operator, All Commercial/ATP Rated**
- **Speeds:**
  - Data Collection at 100 kts
  - Cruise at 180 – 200 kts
- **Range/Aloft Time:**
  - Range 1,100 NM
  - Aloft Time 4 – 6 hours
- **Service Altitude:**
  - Data Collection at 500 to 2,000 ft AGL
  - Cruise at 20,000 ft (with Supplemental Oxygen)
- **Ground Needs – Standard FBO**

Deployments and Responses

ASPECT Statistics

49 Emergency Responses

14 SEAR Deployments

12 NSSE Deployments

7 FEMA Activations

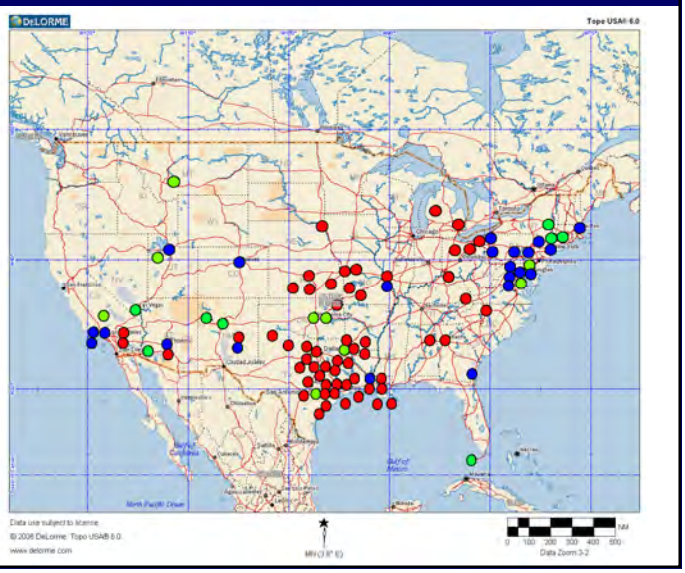
20 Special Projects

LEGEND

Responses

Deployments

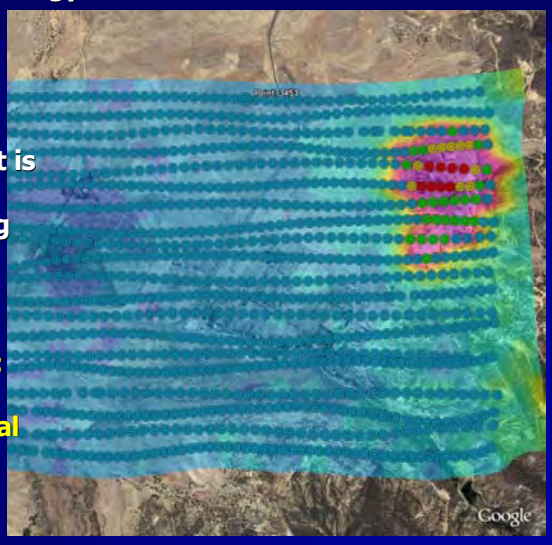
Special Projects



ASPECT

Airborne Spectral Photometric Environmental Collection Technology

- **The primary mission of ASPECT is to provide information to the first responder in a form that is timely, useful, and compatible with existing infrastructures.**
- **ASPECT can provide infrared & photographic images with geospatial chemical and radiological information.**



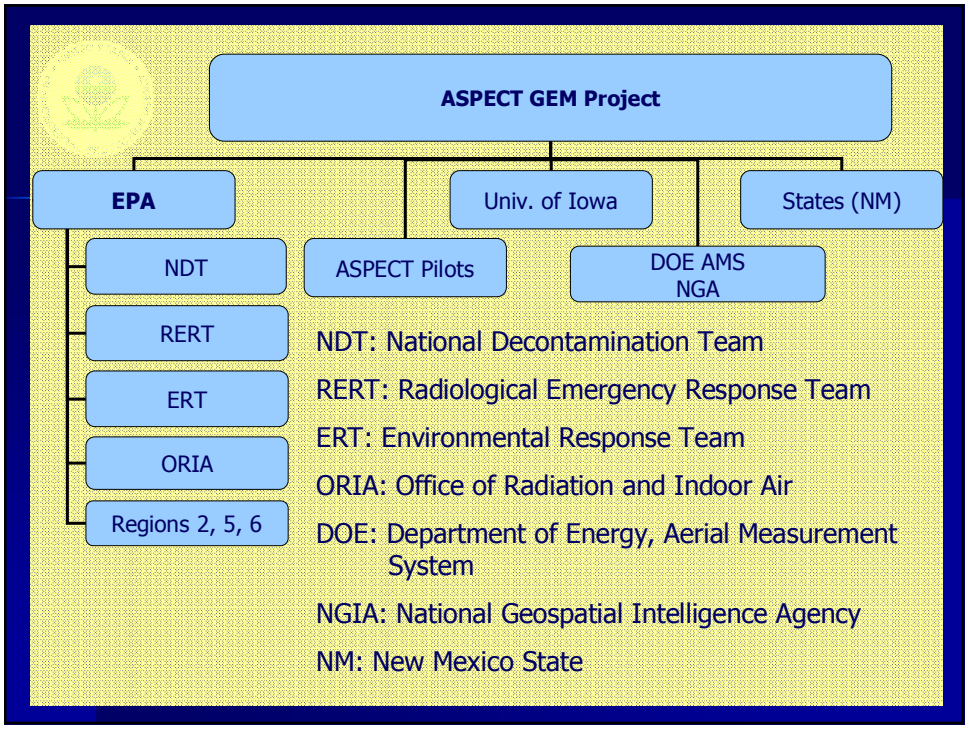
ASPECT GEM

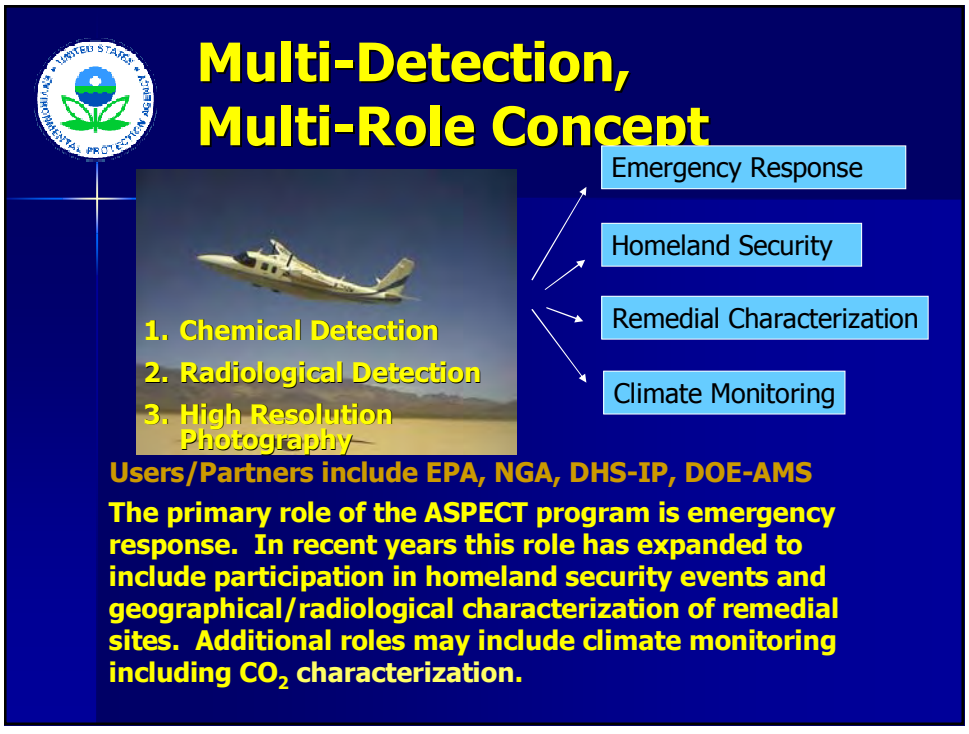
"Gamma Emergency Mapping" Project

Purpose: To improve the US EPA airborne ***gamma-screening and mapping*** capability of ground-based gamma contamination following a wide-area radiological dispersal device (RDD) or improvised nuclear detonation (IND) attack.

Goal: To develop the most advanced gamma-radiation detection capability mountable within an Aero Command 680 FL airframe.

www.epaosc.net/aspectgem

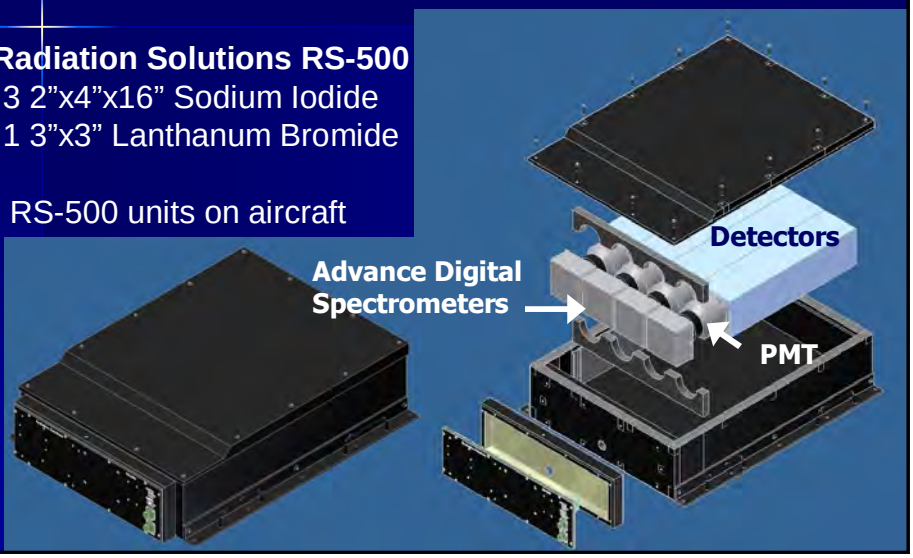

ASPECT GEM Project
EPA
Univ. of Iowa
States (NM)
NDT
ASPECT Pilots
DOE AMS
NGA
RERT
ERT
ORIA
Regions 2, 5, 6
NDT: National Decontamination Team
RERT: Radiological Emergency Response Team
ERT: Environmental Response Team
ORIA: Office of Radiation and Indoor Air
DOE: Department of Energy, Aerial Measurement System
NGIA: National Geospatial Intelligence Agency
NM: New Mexico State


Multi-Detection,
Multi-Role Concept
1. Chemical Detection
2. Radiological Detection
3. High Resolution Photography
Emergency Response
Homeland Security
Remedial Characterization
Climate Monitoring
Users/Partners include EPA, NGA, DHS-IP, DOE-AMS
The primary role of the ASPECT program is emergency response. In recent years this role has expanded to include participation in homeland security events and geographical/radiological characterization of remedial sites. Additional roles may include climate monitoring including CO_2 characterization.

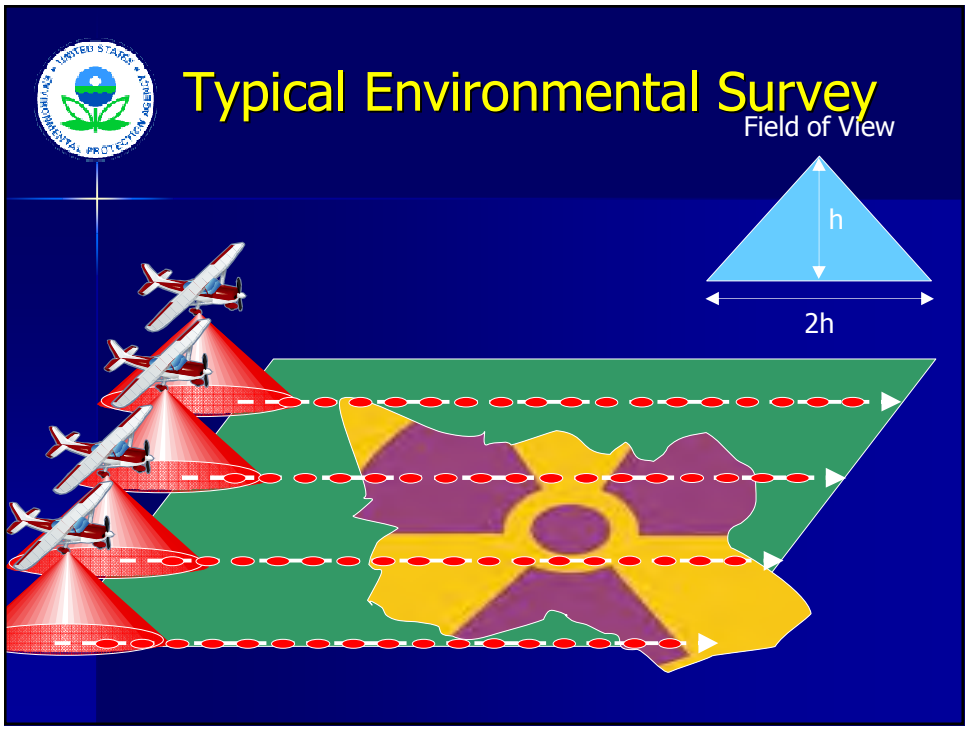
Radiation Detection Technology

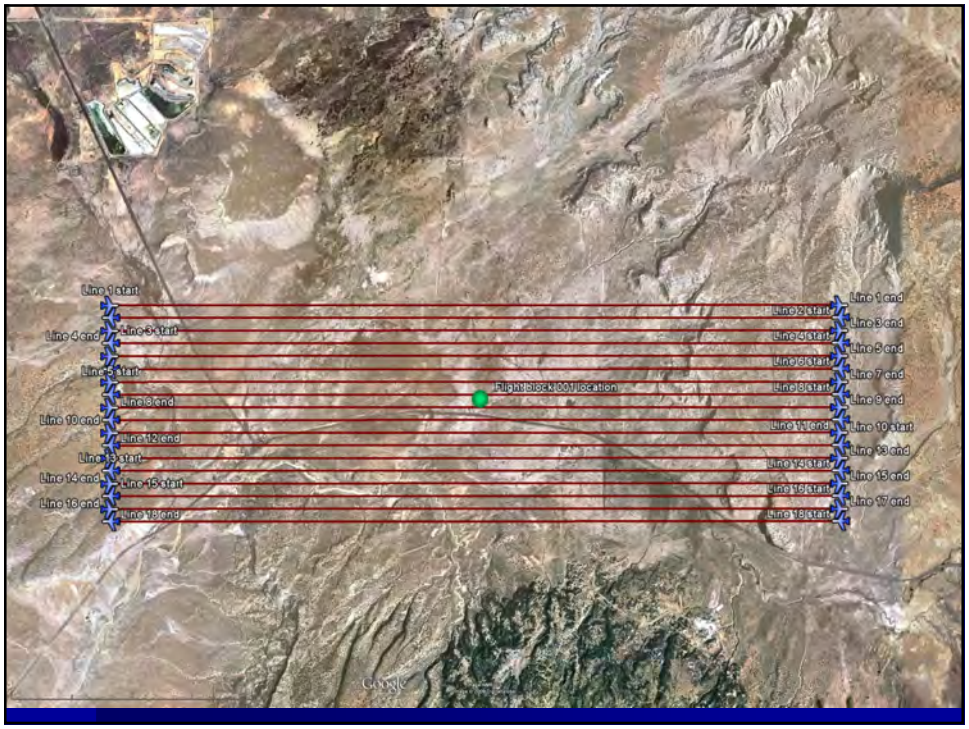
Radiation Solutions RS-500
- 3 2”x4”x16” Sodium Iodide
- 1 3”x3” Lanthanum Bromide

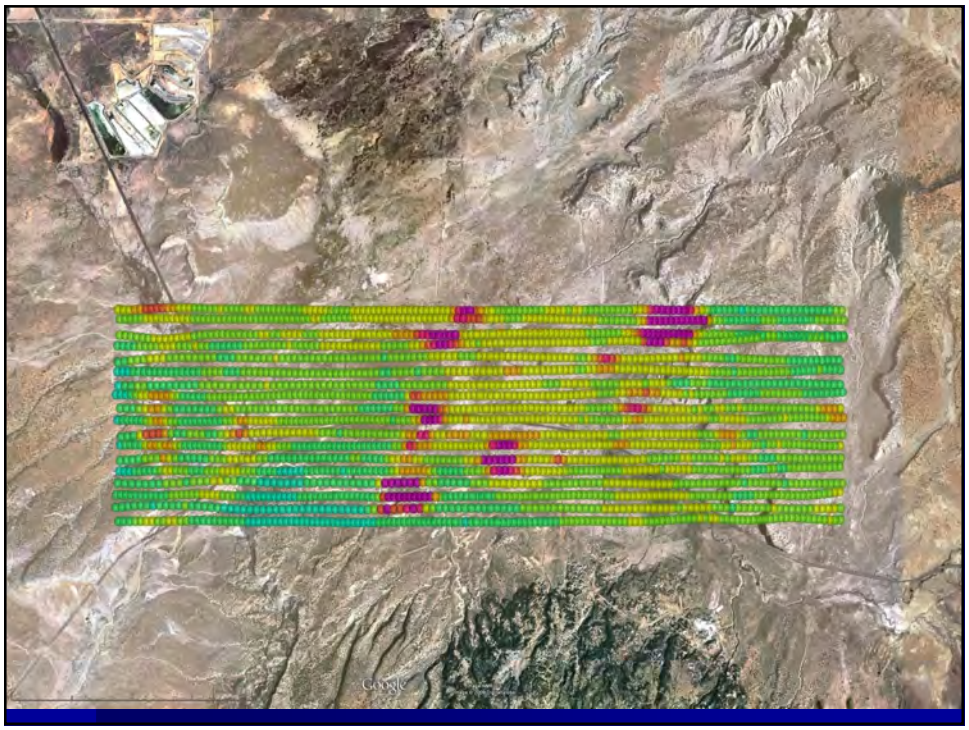
2 RS-500 units on aircraft

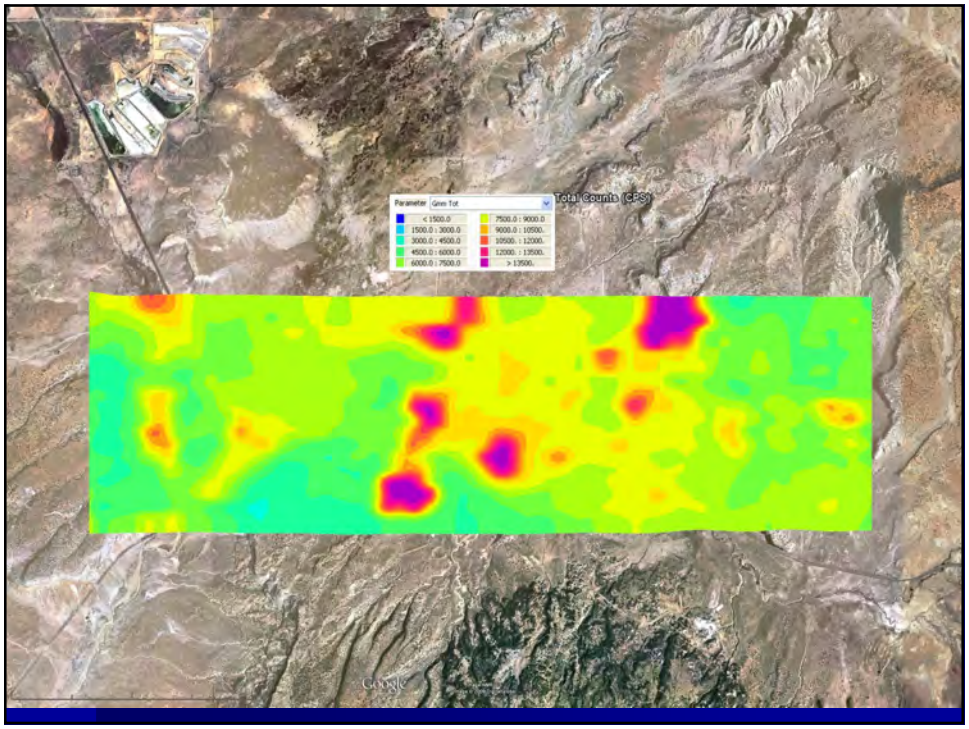


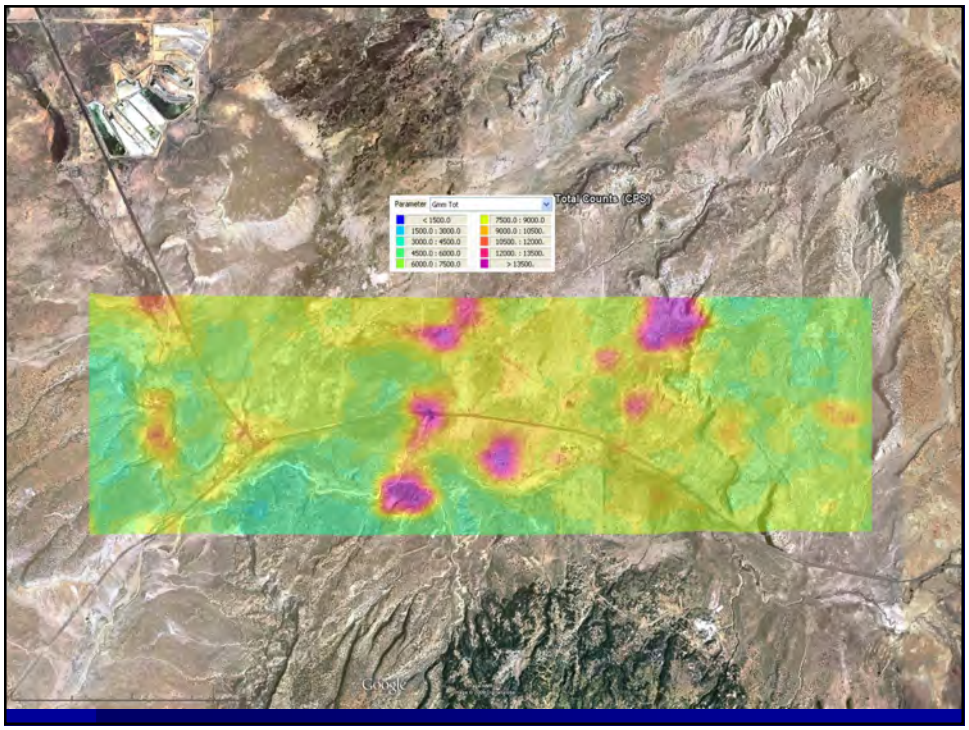
Typical Environmental Survey



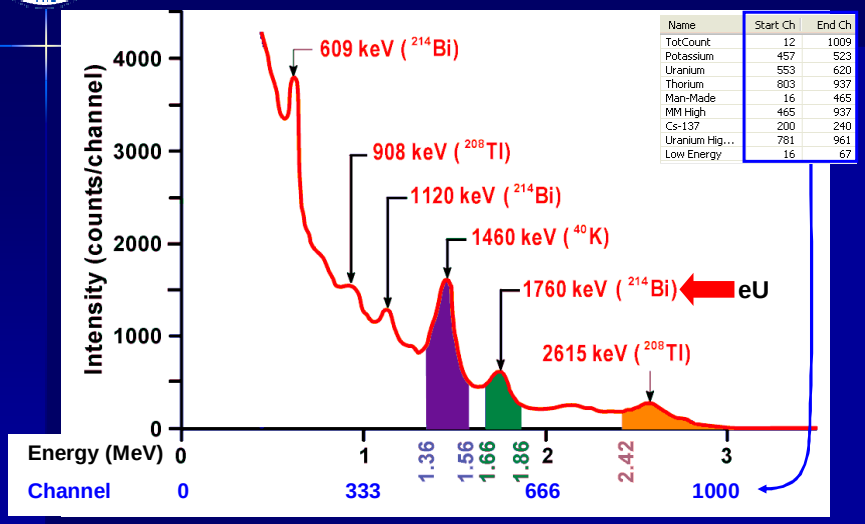

Line 1 start
Line 1 end
Line 2 start
Line 3 end
Line 4 end
Line 3 start
Line 4 start
Line 5 end
Line 5 start
Line 6 start
Line 7 end
Flight block 1001 location
Line 8 start
Line 9 end
Line 8 end
Line 10 end
Line 11 end
Line 10 start
Line 12 end
Line 13 end
Line 13 start
Line 14 start
Line 14 end
Line 15 start
Line 15 end
Line 16 start
Line 16 end
Line 17 end
Line 18 end
Line 18 start




Parameter Gmm Tot
Total Counts (CPS)
< 1500.0
1500.0 : 3000.0
3000.0 : 4500.0
4500.0 : 6000.0
6000.0 : 7500.0
7500.0 : 9000.0
9000.0 : 10500.
10500. : 12000.
12000. : 13500.
> 13500.
Google


Parameter Gmm Tot
Total Counts (CPS)
< 1500.0
1500.0 : 3000.0
3000.0 : 4500.0
4500.0 : 6000.0
6000.0 : 7500.0
7500.0 : 9000.0
9000.0 : 10500.
10500. : 12000.
12000. : 13500.
> 13500.
Google

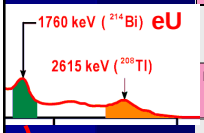
Typical Gamma-Ray Spectrum

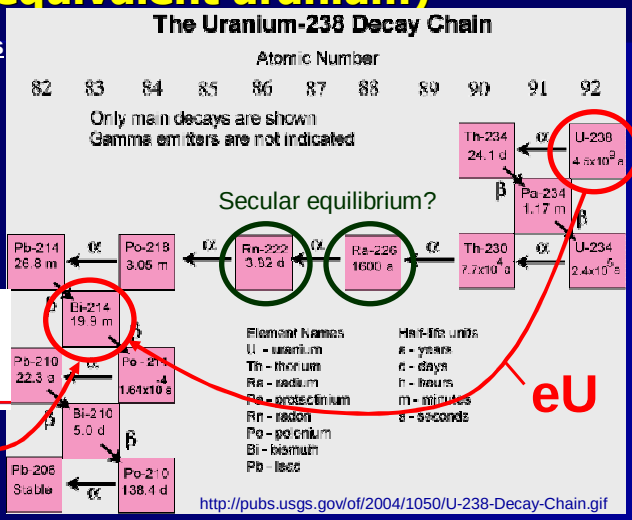


Uranium Decay Chain (equivalent uranium)

Bi-214 Gammas

keV	%
0.609	46.1
1.120	15.0
1.760	15.9
2.204	6.0



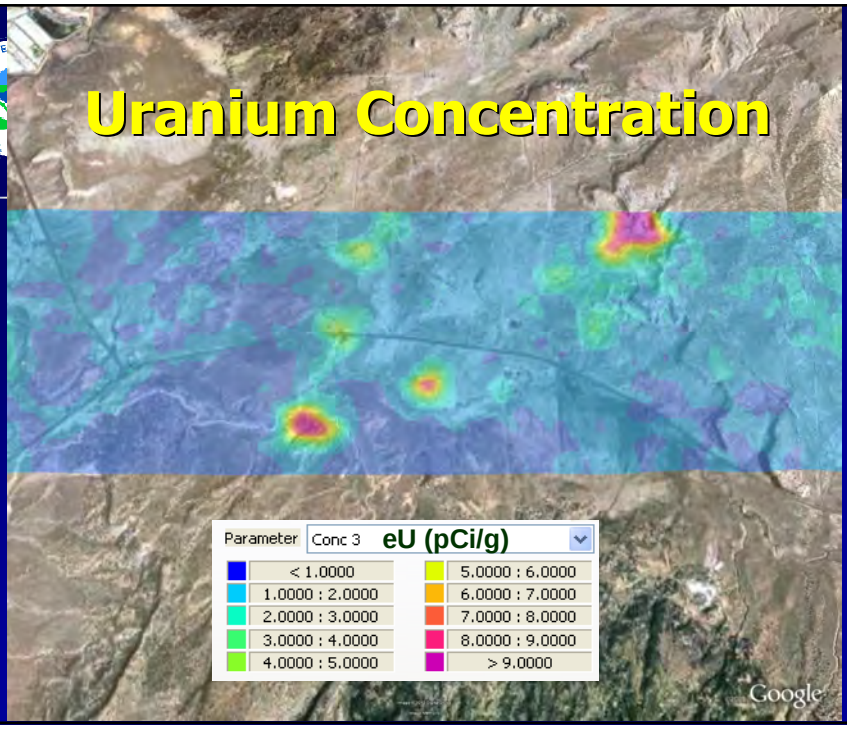


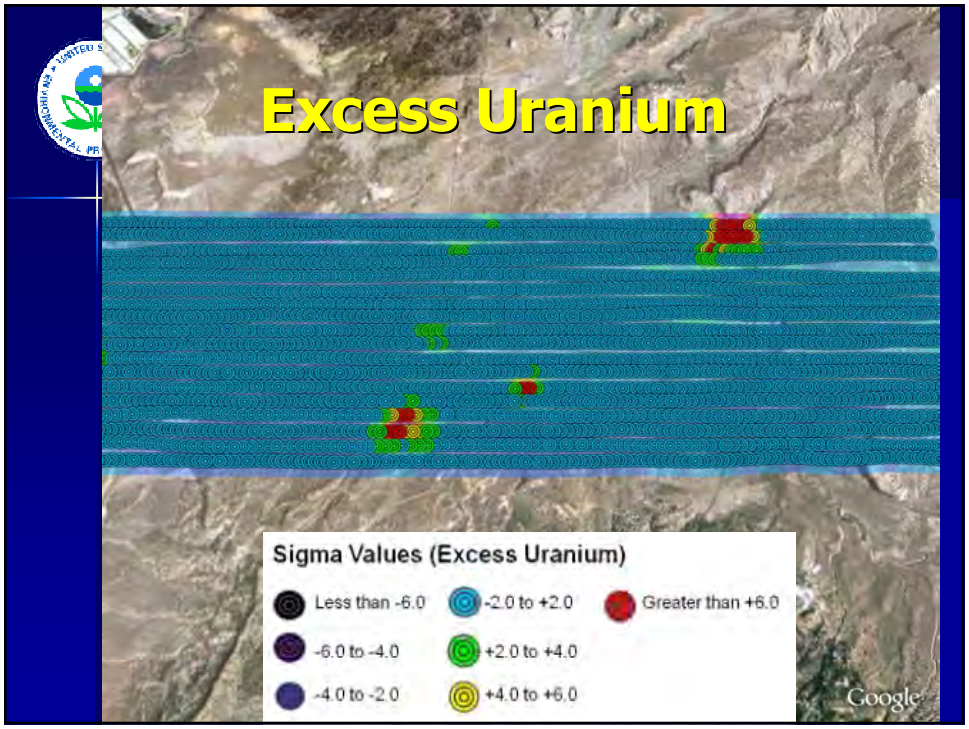
Average Concentrations

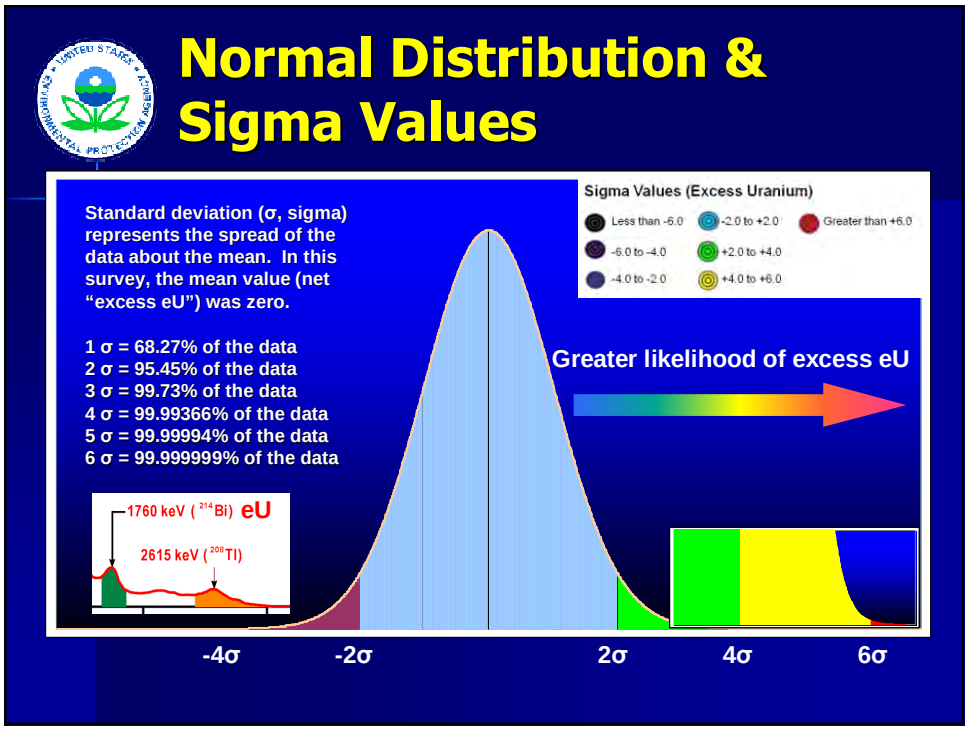
Material	Potassium (pCi/g)	Uranium (pCi/g)	Thorium (pCi/g)
Granite	32	1.7	0.22
Sandstone	11.2	0.2	0.19
Cement	6.4	1.2	0.57
Limestone concrete	2.4	0.8	0.23
Sandstone concrete	10.4	0.3	0.23
Wallboard	2.4	0.4	0.32
By-product gypsum	0.2	5.0	1.78
Natural gypsum	4	0.4	0.2
Wood	90	-	-
Clay brick	18	3	1.2
U deposits in Grants area		600 to 2,000	

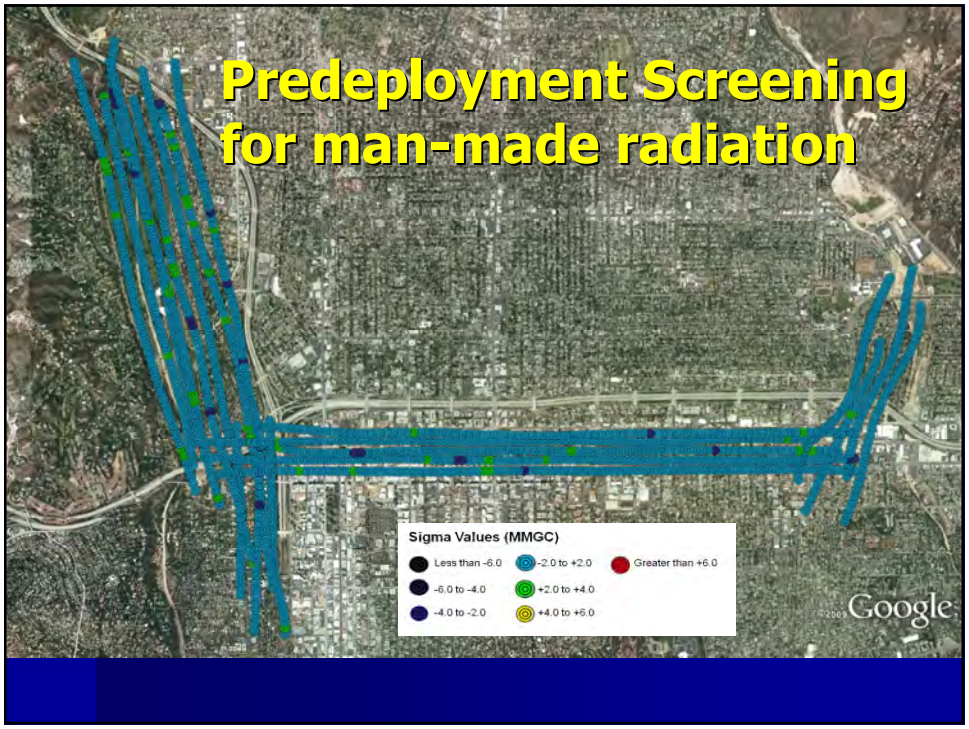
27 pCi ≈ 1 Bq

Uranium Concentration




Excess Uranium
Sigma Values (Excess Uranium)
Less than -6.0
-6.0 to -4.0
-4.0 to -2.0
-2.0 to +2.0
+2.0 to +4.0
+4.0 to +6.0
Greater than +6.0
Google

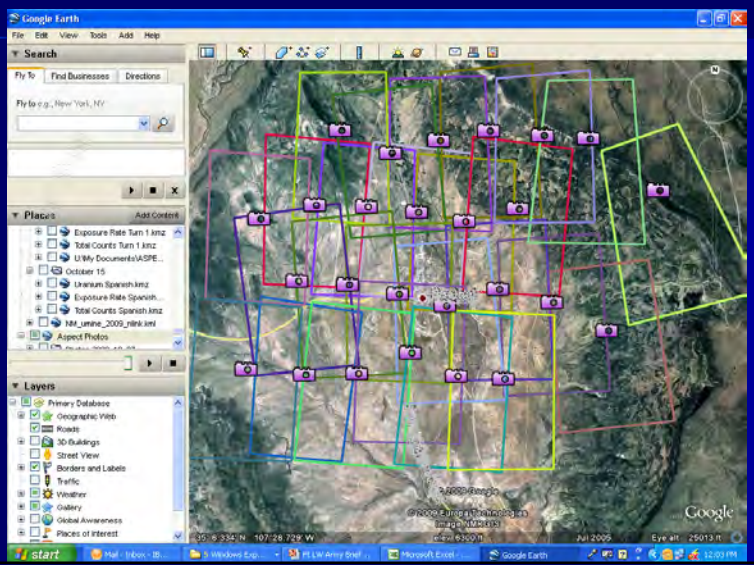

Normal Distribution & Sigma Values
Standard deviation (σ, sigma) represents the spread of the data about the mean. In this survey, the mean value (net "excess eU") was zero.
1 σ = 68.27% of the data
2 σ = 95.45% of the data
3 σ = 99.73% of the data
4 σ = 99.99366% of the data
5 σ = 99.99994% of the data
6 σ = 99.999999% of the data
Sigma Values (Excess Uranium)
Less than -6.0
-6.0 to -4.0
-4.0 to -2.0
-2.0 to +2.0
+2.0 to +4.0
+4.0 to +6.0
Greater than +6.0
Greater likelihood of excess eU
1760 keV (214Bi) eU
2615 keV (208Tl)
-4σ
-2σ
2σ
4σ
6σ


Predeployment Screening
for man-made radiation
Sigma Values (MMGC)
Less than -6.0
-6.0 to -4.0
-4.0 to -2.0
-2.0 to +2.0
+2.0 to +4.0
+4.0 to +6.0
Greater than +6.0
Google

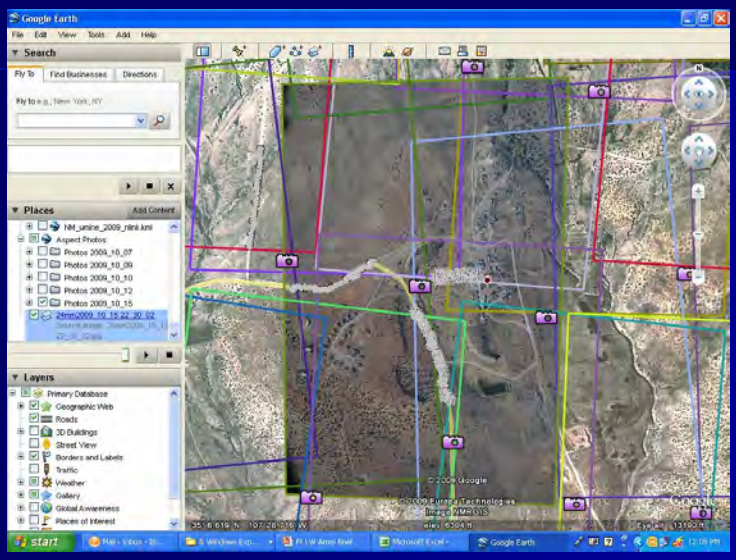

Google Earth Display
Google Earth
EPA U Mine Flights Oct 2009
Google

Google Earth Display – Main Menu

Google Earth Display – Aerial Photo Menu



Google Earth Display – Individual Color Aerial Photo Selection



Minimum Detectable Activity

110 knots	300 ft AGL + 3 s sliding avg				500 ft AGL + 5 s sliding avg			
	3 sigma activity (mCi)	Exposure at 1m (mR/hr)	6 sigma activity (mCi)	Exposure at 1m (mR/hr)	3 sigma activity (mCi)	Exposure at 1m (mR/hr)	6 sigma activity (mCi)	Exposure at 1m (mR/hr)
Cs-137	**2.6**	**0.84**	**5.2**	**1.7**	**10**	**3.2**	**20**	**6.4**
Co-60	**1.4**	**1.8**	**2.8**	**3.6**	**5.2**	**6.7**	**10.4**	**13.5**

1 mCi = 37 MBq

1 mR ≈ 0.01 mSv

6 2x4x16 NaI Detectors

2 3x3" LaBr Detectors

Average background exposure rate ranges between 0.005 to 0.020 mR/hr

Typical Cs-137 & Co-60 Sources/Applications

Application	Isotope	Min Activity (mCi) 1mCi = 37MBq	Typical (mCi)	Max Activity (mCi)	IAEA Class
Moisture Density Gauge	Cs-137	8	10	11	5
Fill-level, thickness gauges	Cs-137	50	60	65	4
Brachytherapy - low dose rate	Cs-137	10	500	700	4
Well Logging	Cs-137	1,000	2,000	2,000	4
Spinning Pipe Gauges	Cs-137	2,000	2,000	5,000	3
Dredger Gauges	Cs-137	200	2000	10,000	3
	Co-60	250	760	2,600	3
Blast Furnace	Cs-137	1,000	1,000	2,000	3
	Cs-137	100	3,000	40,000	3
	Cs-137	1,000	5,000	5,000	3
	Co-60	100	5,000	10,000	3

Current ASPECT MDA

Cs-137	2.4 @ 3σ
Co-60	1.4 @ 3σ

What's a Dangerous Source?

1 mCi = 37 MBq

Radionuclide	Activity associated with a Dangerous Sources (mCi)
Co-60	800
Cs-137	3,000
Ir-192	2,000
Ra-226	1,000
Tc-99^{m}	2,100

A 'dangerous source' is defined by the IAEA as "a source that could, if not under control, give rise to exposure sufficient to cause severe deterministic effects."

Current ASPECT MDA

Cs-137	2.4 @ 3σ
Co-60	1.4 @ 3σ

Accomplishments
since January 2009.

- Signed MOU with DOE
- Pending MOUs with New Mexico, NGA and DHS IP
- 6 Radiological Deployments
  - Balloon Festival, Rose Bowl, Sugar Bowl, Uranium Surveys, Superfund sites
- Procured additional equipment
- Expanded technology to ground-based activities
- Active applied R/D program
  - novel signal processing techniques; hybrid systems
- Lesson Learned corrections
  - LaBr gain shift, improved satellite transmission service, incorporated radar altimeter, faster product development, more flexible data management capabilities

Future Work

- **Calibrate system with 8 NaI detectors**
- **Cross calibrate ASPECT GEM with DOE**
- **Accelerated data exchange products (e.g. real-time contour mapping)**
- **Communicating uncertainties with maps**
- **Strengthen ground-based systems to be consistent with ASPECT GEM capabilities**
- **Strengthen deployment protocol with DOE on Homeland Security missions**

ASPECT Contact Information

Primary Contact

Mark Thomas (Primary Contact) Thomas.markj@epa.gov	816-718-4271
Tim Curry (Primary Contact) Curry.timothy@epa.gov	816-718-4281
John Cardarelli (GEM Contact) Cardarelli.john@epa.gov	513-487-2423
National Decontamination Team	800-329-1841

Regional Contacts

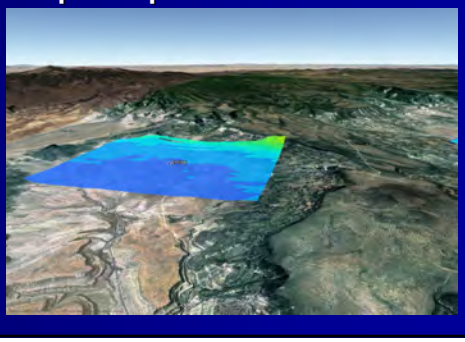
Region I	617-223-7265
Region II	732-548-8730
Region III	215-814-9016
Region IV	404-562-8700
Region V	312-353-2318
Region VI	866-372-7745
Region VII	913-281-0991
Region VIII	303-293-1788
Region IX	415-744-2000
Region X	206-553-1263

Questions?

?

Considerations

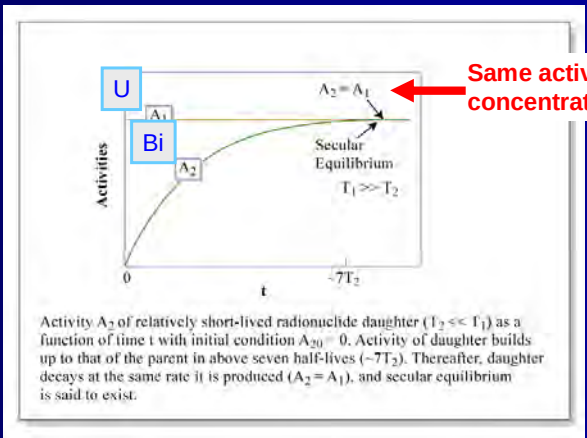
- Background radiation (radon)
- Secular equilibrium assumption
- Soil moisture and precipitation
- Topography
- Spatial effects



Comparing Results?

- Use *in-situ* measurement techniques
- Laboratory results not true comparison to airborne results due to the way the samples are processed.
- Ground-based exposure rates measurements must subtract cosmic radiation contribution to compare with airborne exposure rate measurements.

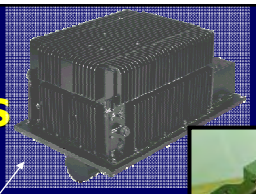
Secular Equilibrium (key assumption)



Same activity (cps) or concentration (pCi/g)

http://www.flickr.com/photos/mitopencourseware/3707241882/sizes/o/in/set-72157621182283632/

CURRENT SYSTEMS



- ASPECT Uses Five Primary Sensors/Systems:
  - An Infrared Line Scanner to image the plume
  - A High Speed Infrared Spectrometer to identify and quantify the composition of the plume
  - Two Gamma-Ray Spectrometer Packs for Radiological Detection
  - High Resolution Digital Aerial Cameras
  - A High Throughput Satellite Data System (SatCom)

Representative Compound Detection Limits

Compound	PEL (ppm)	IDLH (ppm)	Estimated LOD (ppm*M)	10 Meter Thick Plume (ppm)	30 Meter Thick Plume (ppm)
Acetone	1000	2500	87	8.7	2.9
Ammonia	50	300	24	2.4	0.8
1,3 Butadiene	1	2000	82	8.2	2.7
Ethylene Dibromide	20	100	42	4.2	1.4
Ethanol	1000	3300	100	10	3.3
Ethylene Oxide	1	800	70	7.0	2.3
Formic Acid	5	30	66	6.6	2.2
Hydrogen Chloride	5	50	40	4.0	1.3
Isopropanol	400	2000	158	15.8	5.3
Methanol	200	6000	68	6.8	2.3
Methyl Ethyl Ketone	200	3000	103	10.3	3.4
Methylene Chloride	25	2000	35	3.5	1.2
N-Butyl Acetate	150	1700	10	1.0	0.3

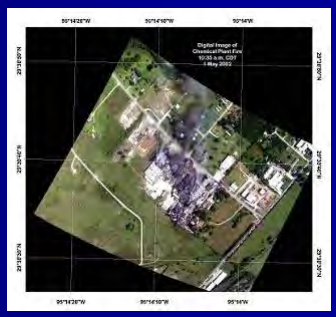
Representative Compound Detection Limits

Compound	PEL (ppm)	IDLH (ppm)	Estimated LOD (ppm*M)	10 Meter Thick Plume (ppm)	30 Meter Thick Plume (ppm)
Nitric Acid	2	25	73	7.3	2.4
Ozone	0.1	5	75	7.5	2.5
Phosgene	0.1	5	7.6	0.8	0.3
Propylene Oxide	100	400	169	16.9	5.6
Sulfur Hexaflouride	1000	Nd	1.0	0.1	0.03
Trichloroethylene	100	1000	34	3.4	1.3
Triethyl phosphate		Nd	4.5	0.5	0.2
Vinyl Chloride	1	Nd	150	15.0	5.0
GA (Tabun)	Very Low		13.5	1.35	0.45
GB (Sarin)	Very Low		9.0	0.9	0.3
GD Soman	Very Low		7.7	0.8	0.3
HD (Mustard)	Very Low		40	4.0	`1.3
HN (Mustard)	Very Low		45	4.5	1.5

Program ASPECT

Aerial Photography

- 12.5 MPixel High Resolution Digital Camera
- Independent and/or Slaved to IR Data Collection
- Rectified for Inclusion into GIS



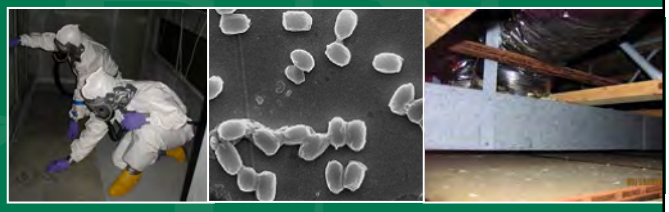
High/Low Tech Approaches to HVAC Decontamination

Brian Attwood, EPA/ORD/NHSRC

EPA United States Environmental Protection Agency

High/Low Tech Approaches to HVAC Decontamination

Brian Attwood



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

EPA United States Environmental Protection Agency

Introduction

What is the best way to decontaminate a biologically contaminated building, specifically the HVAC system?

Introduction

- How to define the “best” solution?
- Is it the:

cheapest $$$

fastest 

safest 

Possible Approaches

“High tech” - fumigation

“Low tech” - mechanical cleaning and disinfection

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High Tech vs Low Tech

- low waste
- turn-key solution
- low availability
- high tech costs

- high availability
- high labor cost
- high waste
- under development

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Decontamination Challenge

Efficacy Data on Galvanized Metal

- pH-amended bleach – 10 minute contact time (1)
- VHP – 250 ppm for 90 min? (2)
- Chlorine dioxide – 9000 ppm-hr (3)

[1] EPA (2006), ***Evaluation of Spray-Applied Sporicidal Decontamination Technologies***, EPA 600-R-06-146

[2] STERIS VHP registration label

[3] EPA (2006), ***Evaluation of Sporicidal Decontamination Technology: Sabre Technical Services Chlorine Dioxide Gas Generator***, EPA 600-R-06-048

Lab Experiments

- Contaminate short duct run with bacterial spores, e.g. ***Bacillus subtilis***
  - all orientations contaminated
  - aerosol deposition

Lab Experiments

Apply decontamination procedure

- Apply pH-adjusted bleach using garden sprayer keeping wet for 10 minutes
- Fumigate with VHP at 250 ppm for 90 minutes
- Fumigate with ClO_2 at 3000 ppm for 180 minutes

Lab Experiments

- Sample for residual contamination
- Optimize decontamination procedure
  - re-wetting frequency
  - number of access points
  - concentration/flow rate of fumigant

Field Testing

- Full-scale testing at INL in the fall

Field Testing

- High tech
  - entire building fumigated
- Low tech
  - flexi-duct removed
  - rooms and ductwork deconned
- Sampling

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Conclusion

- The relative effectiveness of the two approaches will be evaluated
- The “best” approach will likely depend on the situation

Radiological Decontamination of Urban Surfaces Using Selective Isotope-Sequestering Agents

Konstantin Volchek for Pervez Azmi, Emergency Sciences and Technology Section, Environment Canada

Presentation not available for distribution

Performance Evaluation of Decontamination Technologies for Dirty Bomb Cleanup

John Drake, EPA/ORD/NHSRC

United States Environmental Protection Agency

Performance Evaluation of Decontamination Technologies for Dirty Bomb Cleanup

Decontamination Research and Development Conference
RTP, NC 13 April 2010

John Drake NHSRC/DCMD

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

United States Environmental Protection Agency

Evaluation of "Mechanical" Decontamination Technologies

- Focus on "mechanical" technologies with vacuum assist for effluent capture
- Built full scale test facility: 9x9 ft vertical wall holds 9 concrete coupons
- Tested five technologies
  - CS Unitec (sander)
  - River Technologies (rotating water-jet)
  - Empire Blast (abrasive blast)
  - Dust Director (wire brush)
  - Dust Director (diamond flap wheel)
- Dry run to adjust to tool behavior
- Data analyses completed
- Reports underway

The "Wall" under construction

United States Environmental Protection Agency

Experimental Approach

- Deposit contaminant on coupons
- Measure contamination levels before and after application of decontamination technology
- Apply decon technology in a realistic manner (e.g. using the same application techniques as would be used in the field)

- Evaluate
  - Decon Factor DF = A_o/A_f
  - Percent Removal %R = $(1-A_f/A_o) \times 100\%$
    - A_o = activity before application of decon technology
    - A_f = activity after application of decon technology
  - Speed (ft^2/hr)
  - Operational parameters (difficulty, infrastructure, skill level, etc)
  - Other (deployed cost, availability, shelf life, etc)

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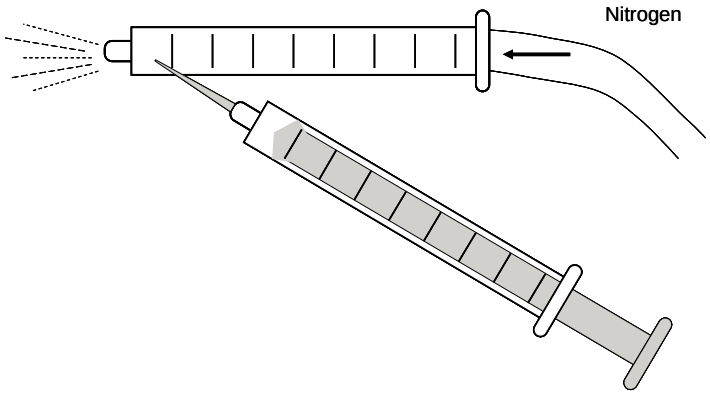
Cesium (Cs)-137 Deposition and Measurement



- Applied as mist of 2.5 mL of aqueous solution (2.6 mg/L)
- Target activity of 53 µCi/m^2 (µCi per coupon)
- Activity measured with intrinsic germanium detectors
- Perfect homogeneity not critical because total surface activity measured

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Full Scale Test Facility

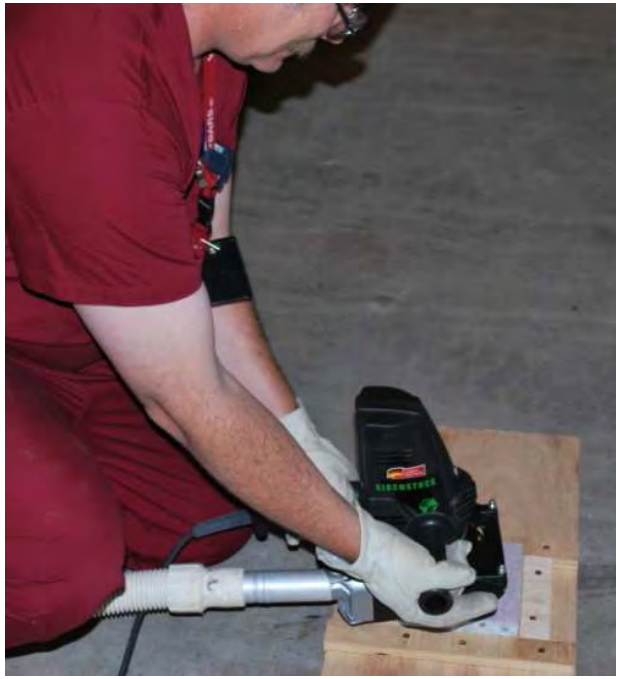
Radiological enclosure at INL

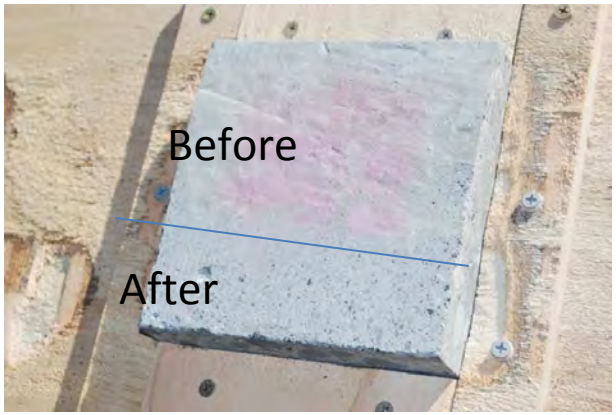
9x9 ft wall with inset coupons

United States Environmental Protection Agency

Dry run to adjust to tool behavior

- Each tool was used in a “dry run” to gain operator skill and adjust to appropriate pressure and traverse speed
- Blank coupons treated with dye before dry run for visual feedback during operation
- The same operator performed all dry runs as well as actual tests





Coupon with dye before/after dry run

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Dust Director – Steel Brush

Percent removed (avg): 38%
Decon Factor (DF): 1.6

United States Environmental Protection Agency

River Technologies (rotating water-jet)

Percent removed (avg): 36%
Decon Factor (DF): 1.6

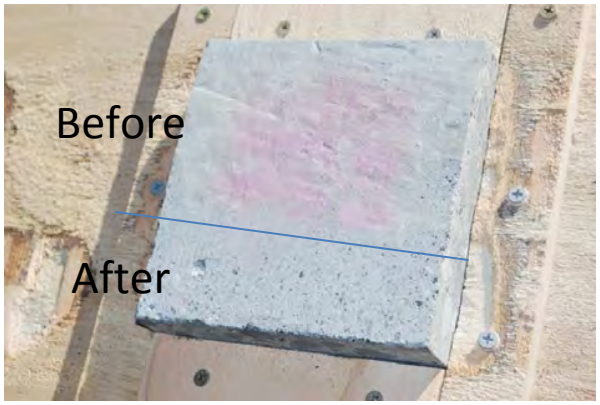
United States Environmental Protection Agency

CS Unitec (sander)

Percent removed (avg): 54%
Decon Factor (DF): 2.3

Dust Director – Diamond Wheel

Percent removed (avg): 89%
Decon Factor (DF): 14



United States Environmental Protection Agency

Empire Blast (abrasive blast)

Percent removed (avg): 96%
Decon Factor (DF): 41

United States Environmental Protection Agency

Summary of Results – 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

Summary of Results – Operational Performance

Parameter	*Grinding Technologies*	*Ablative Technologies*
Decontamination rate	Approximately 1-3 m^2/hr	Approximately 5 m^2/hr
Applicability to irregular surfaces	Irregularities kept some heads from making good contact with the surface; the more aggressive the head the greater the final contact area	Very applicable as surface is receiving a pressurized blast of abrasive or water; independent of surface terrain
Skilled labor requirement	Brief training session	Brief training session
Utilities required	110v for both grinder and vacuum	High pressure air compressor, hot water pressure washer
Extent of portability	Very portable	Equipment requirements more significant, hoses would allow access to most locations
Set-up time	30 minutes	2 days to assemble equipment, but once together set-up would be minimal
Secondary waste management	Very little waste; vacuum very effective in dust collection	Water spray control difficult; safety concern; grit blasting vacuum worked well
Surface damage	Sander & Wire Brush – minor visible surface damage, discoloration Diamond Flap Wheel – top 1-2mm of coupon removed leaving exposed aggregate	Rotating Water-jet – no visible surface damage Grit Blaster – 1-2 mm of coupon surface removed leaving exposed aggregate

Persistence of Select Biological Agents

Joseph Wood, EPA/ORD/NHSRC

Persistence of Select Biological Agents

EPA:
Joseph Wood

Battelle:
Tom Kelly, Harry Stone, Daniel Chappie, James Rogers, Young Choi, Morgan Wendling

Presented to US EPA Decontamination Research Conference
Research Triangle Park, NC
April 14, 2010

Acknowledgements

- Peer reviewers of quality assurance/test plans and test reports
- EPA National Decon Team
- TRIO (Task force on research to inform and optimize)
- Stakeholders

Outline

- Persistence of ***Bacillus anthracis*** with exposure to simulated sunlight
- Persistence of freeze-dried vaccinia virus
- Persistence of ***Brucella suis***

Why were these tests conducted?

- Data are sparse
- Quantify effect of relative humidity (RH), temperature, sunlight, and the material with which the agent is associated
- Understanding of how long the agent may survive in the environment will assist officials in making decisions about decontamination

Persistence of *B. anthracis* with exposure to simulated sunlight

Background for Anthrax Sunlight Tests

- Although ***B. anthracis*** is known to survive in soil for decades, minimal data are available to quantify the effect of sunlight over time on different materials
- Laboratory tests were conducted to determine/quantify how simulated sunlight affects its persistence on different materials, including soil

Anthrax Test Methods

- ***Bacillus anthracis*** (Ames) and ***Bacillus subtilis***
- Glass, bare pine wood, unpainted concrete, topsoil
  - –Coupon dimensions 1.9 x 7.5 cm (except soil – Petri dish)
- Four time points tested
- 10^8 CFU/coupon

Anthrax Test Methods

- Replicates, controls, and blanks
- Tests conducted in class III BSC glovebox at ~ 23ºC and < 70% relative humidity
- Extraction procedures
  - –Soil procedures: supernatant subject to heat shock following orbital shaker

Anthrax Test Methods

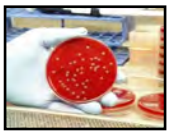
- Dilution plating of extraction liquid
- Loss of spores in terms of log reduction (LR)
  - –mean of log values for positive controls – mean of log values for test coupons

Anthrax Test Methods

Coupon inoculation

Exposure to UV-A/B to simulate sunlight

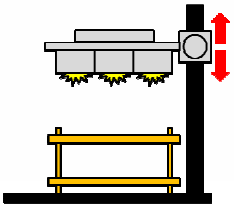
Extraction



Plating, Analysis

Anthrax Test Methods

- UV-A/B exposure: 12 hours on, 12 hours off each day
- UV-B level ~ 70 microwatts/cm^2
- UV-A level ~ 100 microwatts/cm^2

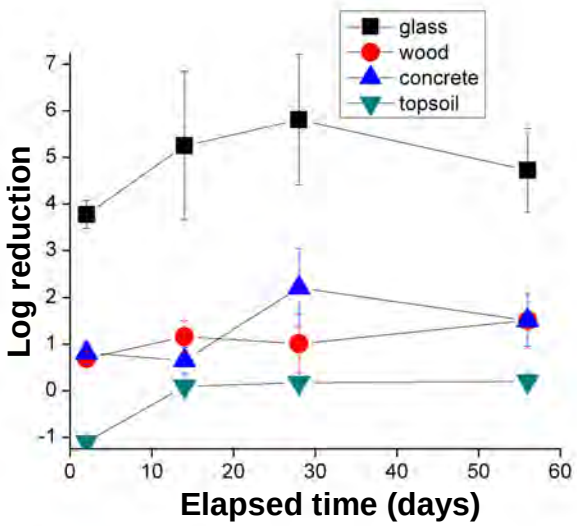


Figures from Choi, Y., Kelly, T., Rogers, J., and Wood, J. Effects of Simulated Sunlight on the Persistence of ***Bacillus anthracis*** Spores on Outdoor Materials, presented at American Society of Microbiology Biodefense and Emerging Diseases Meeting, Baltimore MD, 2010.

Log reduction of *B. anthracis* and *B. subtilis* after 56 days

	B. anthracis	***B. subtilis***
Glass	4.7 ± 0.9	5.3 ± 1.2
Wood	1.5 ± 0.6	1.3 ± 0.2
Concrete	1.5 ± 0.6	2.2 ± 0.1
Topsoil	0.2 ± 0.2	0.2 ±0.1

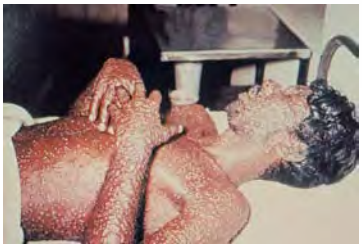
Log reduction *B. anthracis* exposure to simulated sunlight – all data



Persistence of freeze-dried vaccinia virus

Vaccinia - Variola Background

- Vaccinia virus is a surrogate for variola, the CDC Category A virus agent causing small pox
- Variola may be more stable and aerosolizable freeze-dried
- Often fatal (30%)
- Contagious, no known treatment, potential for epidemic



From CDC

Vaccinia Test Methods

- Materials: glass, galvanized metal, painted cinder block, industrial carpet
- Environmental conditions: room (~ 22 ºC) and low (~ 6 ºC) temperature at high (~ 90%) and low (~10%) relative humidity
- Four time points
- Inoculation: 10^7 PFU of vaccinia virus inoculated onto each coupon, kept at -80 ºC overnight, then freeze-dried (app. 2-4 h)
- Extraction: 15 minutes on orbital shaker w/ phosphate buffer solution

Vaccinia Test Methods

- Dilutions of extract on plates of African Green Monkey kidney cells
- Plaque Forming Unit (PFU) assay
- 5 positive control coupons, 5 test coupons, 1 lab blank, and 1 procedural blank; also 1 spike control per test day

Persistence of freeze-dried vaccinia virus (in days)

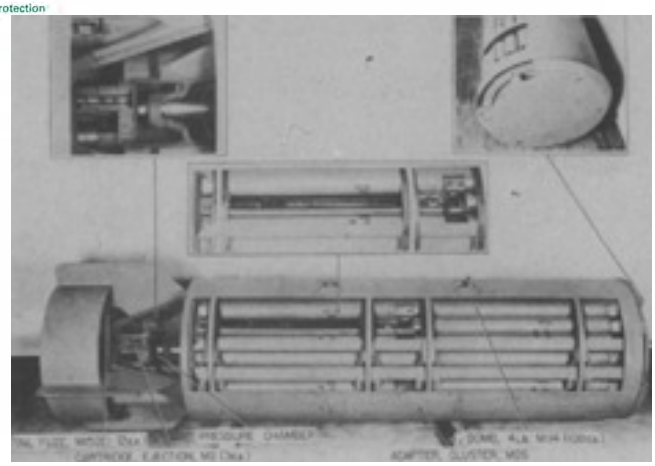
	Glass	Galvanized metal	Painted cinder block	carpet
Room temperature, low RH	**>42**	**>42**	>42	14-21
Room temperature, high RH	3-7	1-3	1-3	<1
Low temperature, low RH	**>56**	**>56**	**>56**	>56
Low temperature, high RH	14-21	7-14	21-42	21-42

< - not detected at shortest time interval tested
> - detected at longest time interval tested **data in red more than 10^3 PFU detected**

Persistence of *Brucella suis*

Background *Brucella suis*

- ***B. suis*** selected by TRIO workgroup
- CDC Category B agent
- Vegetative bacterium
- Naturally transmitted zoonotic disease (Brucellosis)
- Low infectious dose, easily aerosolized
- Low lethality, but hard to treat
- First standardized weaponry for biological agents by US military used ***B. suis***



The M33 500-lb biological cluster bomb, which held ***Brucella suis***.

From: Chemical and Biological Defense Command Historical Research and Response Team, Aberdeen Proving Ground, Md.

Persistence of *Brucella suis*

- Methods similar to tests with ***B. anthracis*** except as follows:
  - Brain heart infusion agar as growth medium
  - Materials: Aluminum, glass, unpainted concrete, topsoil, wood
  - Test matrix: Room and low temperature, with and without simulated sunlight

EPA United States Environmental Protection Agency

Persistence of *B. suis* (days)

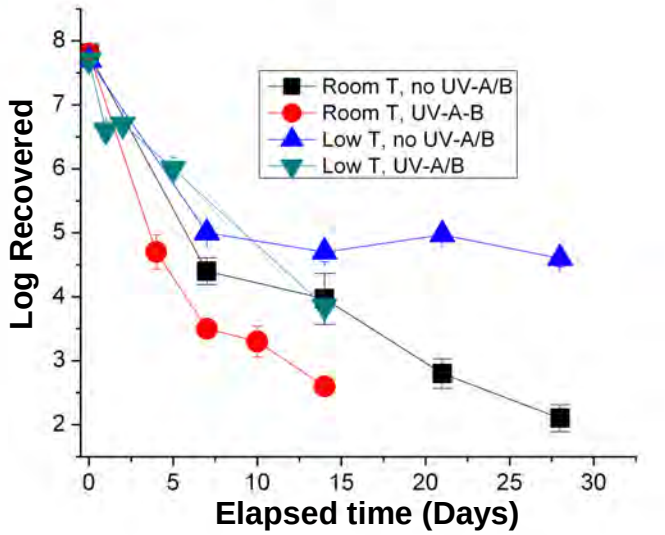
	Aluminum	Concrete	Glass	Soil	Wood
Room temperature	>28	<7	> 28	>28	< 21
Room temperature, UV-A/B	7-10	<1	1-2	>14	Not tested
Low temperature	**>28**	7-14	**>28**	**>28**	**>28**
Low temperature, UV-A/B	>5	<1	>2	>14	Not tested

< - not detected at shortest time interval tested > - detected at longest time interval tested

more than 10^4 CFU detected

EPA United States Environmental Protection Agency

Persistence of *B. suis* in soil



For more info

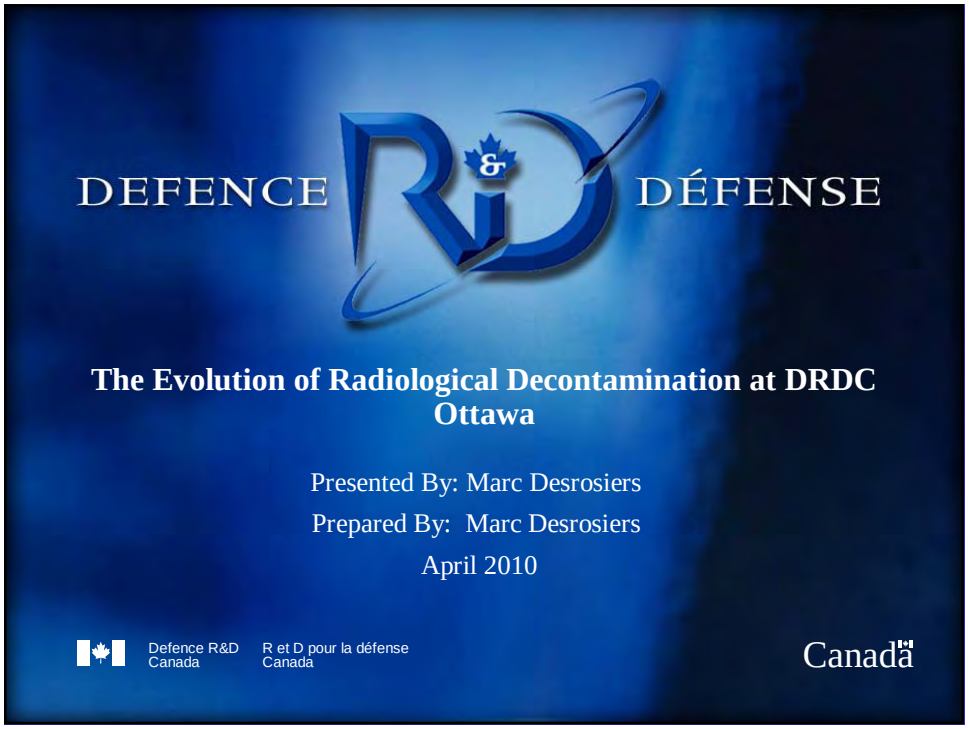
- See www.epa.gov/nhsrc for reports on these tests

Take Home Messages

- Persistence affected by material and environmental conditions
- For anthrax directly exposed to simulated sunlight for 56 days, essentially no impact when in soil, and less than 2 log reduction on wood and concrete
- Even with sunlight, higher temperatures and RH, ***B. suis*** and freeze dried small pox virus may still be viable up to a week or more on some materials
- With cold temperatures and no sunlight, ***B. suis*** may survive over a month, or months for variola

The Evolution of Radiological Decontamination at DRDC Ottawa

Marc Desrosiers, Defense Research and Development



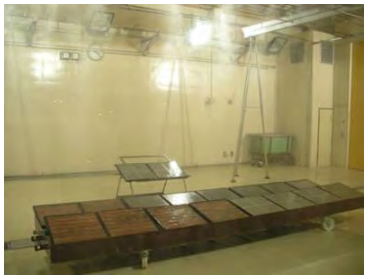
Introduction

- Size and complexity of experiments
- Measurement techniques
- Example of Results

Size and complexity

Urban Surfaces: Started with Small Surfaces

Moved to Larger Test Plates (RADPRO, WIS GER)



CF Decontamination of Sensitive Equipment (DOSE)

- Question: How do you decontaminate sensitive (fragile) equipment?
  - C7 Scope, Laptop and Blackberries
  - Some type of equipment have very special procedures for cleaning due to coatings
- Performed an experiment only looking at dry contamination.
  - Results showed that dry particles could be decontaminated using simple methods such as compressed air or vacuuming.
  - Also showed that wiping with wet cloth did not perform as well

CF DOSE

CF DOSE continued

- Forced us to develop protocols and procedures to deal with dry particle contamination.
  - Handling
  - Grinding
  - Sizing
  - “Concentration”

Vehicle Decontamination Experiments at DEP, Bourges France & FoA, Umea Sweden

Moved to a larger structure

32’ (9.8 m)

Measurement techniques

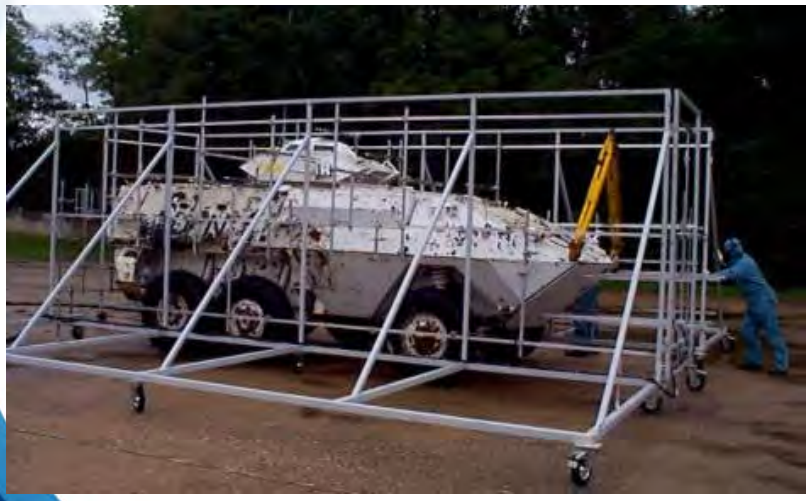
During the CF and Civilian (Urban) work continued to develop our Measurements Methods

- "One good thing about radiation it is easy to measure, one bad thing about radiation is that it is easy to measure"
- Started with simple instruments:
  - Beta/Gamma Contamination probes (pancake probes)
  - Dose rate probes

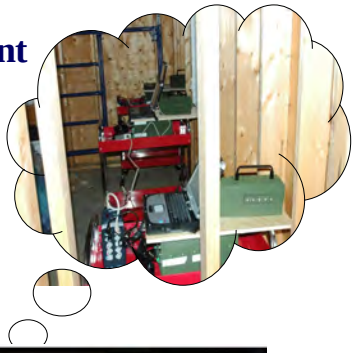
Current Measurement Techniques

- HPGe for pre and post gamma measurements
- Thermo SVG2 for pre and post beta measurement
  - Use gamma spectrometry or dose rate as a indication of total contamination "Fixed" and "Unfixed"
  - Use beta readings as indication of the surface contamination, "Unfixed"

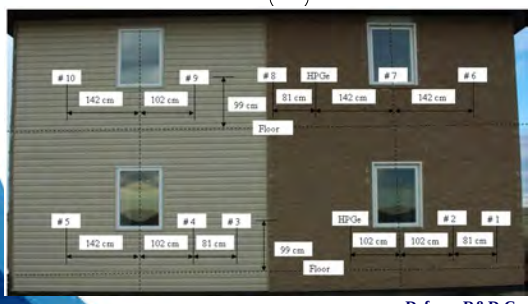
GM-tube Measurement "Cage" (DEP, Bourges France)



Measurement



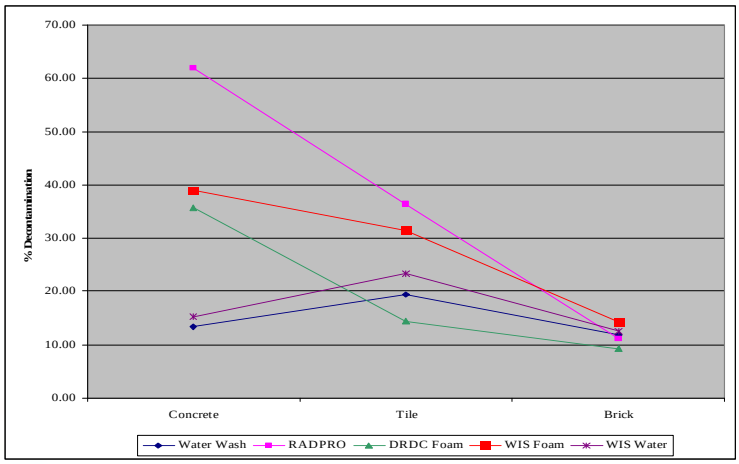
Mobile
Microspec
3”x3” NaI



HPGe and ISO-CART
Collimated Pb Shield

Results

Experimental Results: WIS Urban Material Decontamination and RADPRO Trial

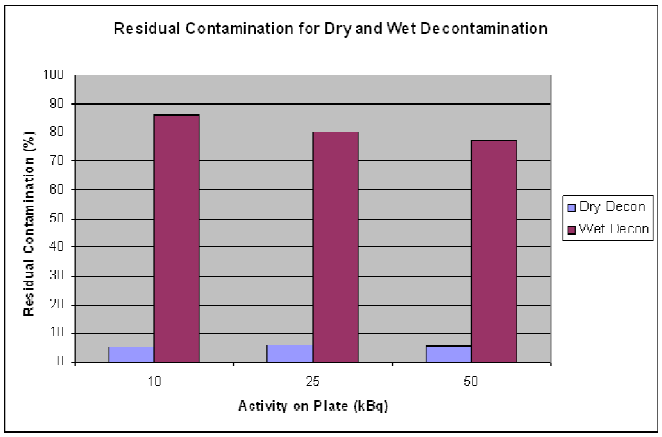


Experimental Results: RADPRO Trial Absorption of Wet Contaminants

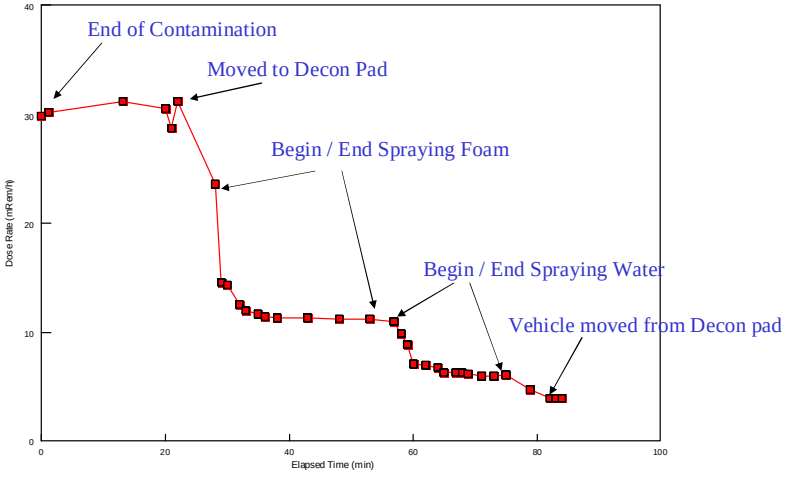
	Readings (µSv/hr)		
	Theoretical	Actual	Ratio
Brick	22.95	17.36	0.76
Concrete	22.95	4.65	0.2
Ceramic	22.95	1.4	0.02

Note: The above values were estimated by comparing the measured dose rate to the calculated dose rate expected for the amount of contamination being used. The contamination method for all three materials was identical, but not recorded.

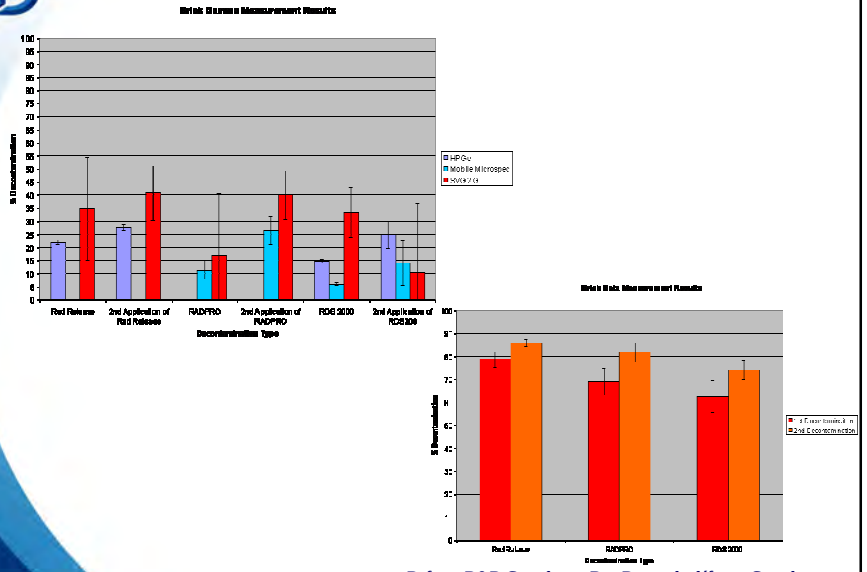
Experimental Results: ADEM Decontamination of Contamination (^{24}Na) applied Dry/Wet on Concrete



Vehicle (AMX-10) Decontamination DEP, Bourges France

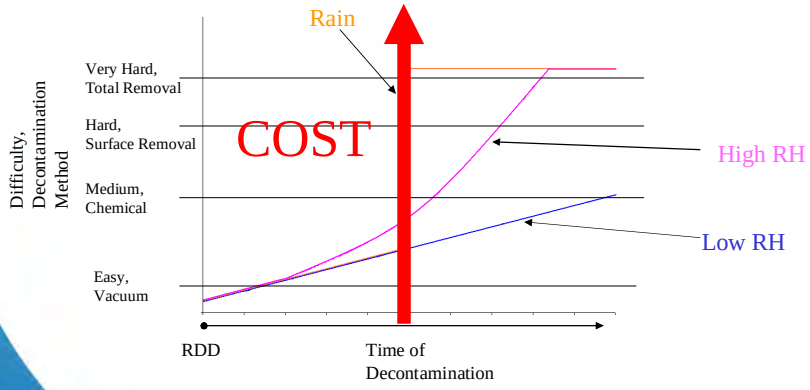


Little House on the Prairie: Brick



Radiological Dispersal Device (RDD) Contamination Interactions with Urban Surfaces (CRTI-06-0156RD)

- Dry RDD contamination that has not been affected by environmental conditions can easily be decontaminated to very low levels.
- However, below we see the combined effects of having a water soluble contaminate on a porous surface:



Conclusion

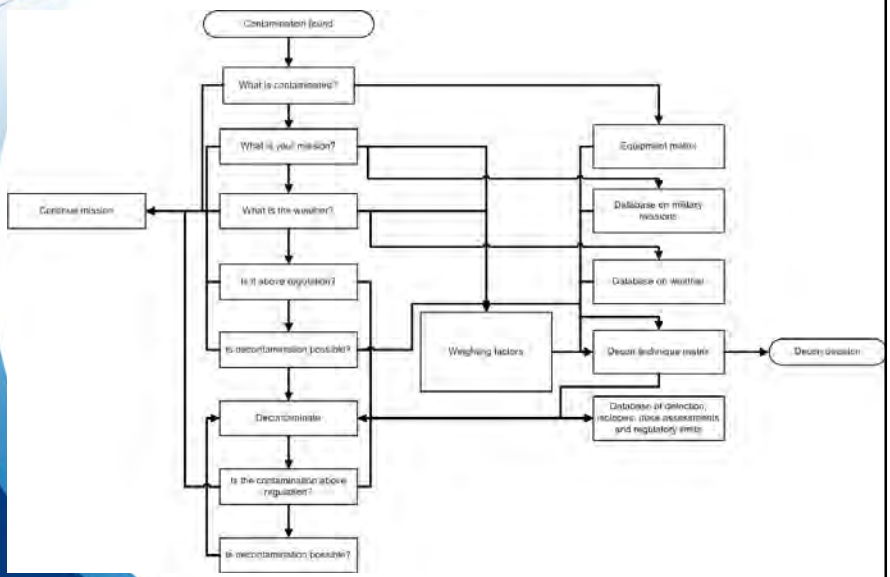
Important lessons learned from previous experiences that are important

1. Type of contamination is important
   - Chemical form
   - Activity (Bq) and Concentration (Bq/cm^2)
   - Particulate Size (physical size)
2. Material type/structure is important
   - Porous/non-Porous
   - Different chemical compositions
   - Surface conditions: clean, dirty, rough, vertical, horizontal
3. Environmental conditions
   - Dry, rain, humidity, snow
4. Measurements
   - Radiation is easy to measure, but do we have the right interpretation of the measurements?
   - Quantitative analysis of the results can get complicated
5. Regulatory Limits
   - Limits already exist but unclear how they would apply in a RDD situation

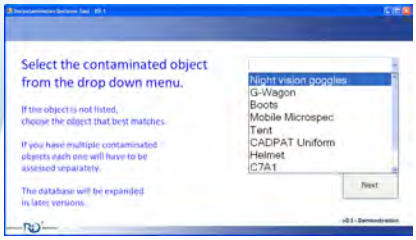
Decontamination Decision Tool (DDT)

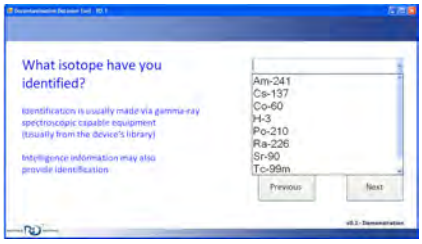
- Will be designed to help the soldier make decisions in the field to reduce the risks (i.e. health (dose) consequences) from contamination
- The desired specifications for the tool are:
  - Determine the characteristics of the contamination
  - Have information on CF Equipment, from aircraft to boots
  - Determine the health risk (dose) from the contamination
  - Determine the protective measures

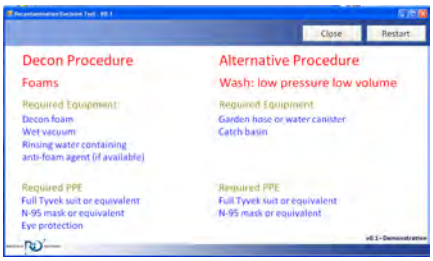
Future Flow Chart



DDT





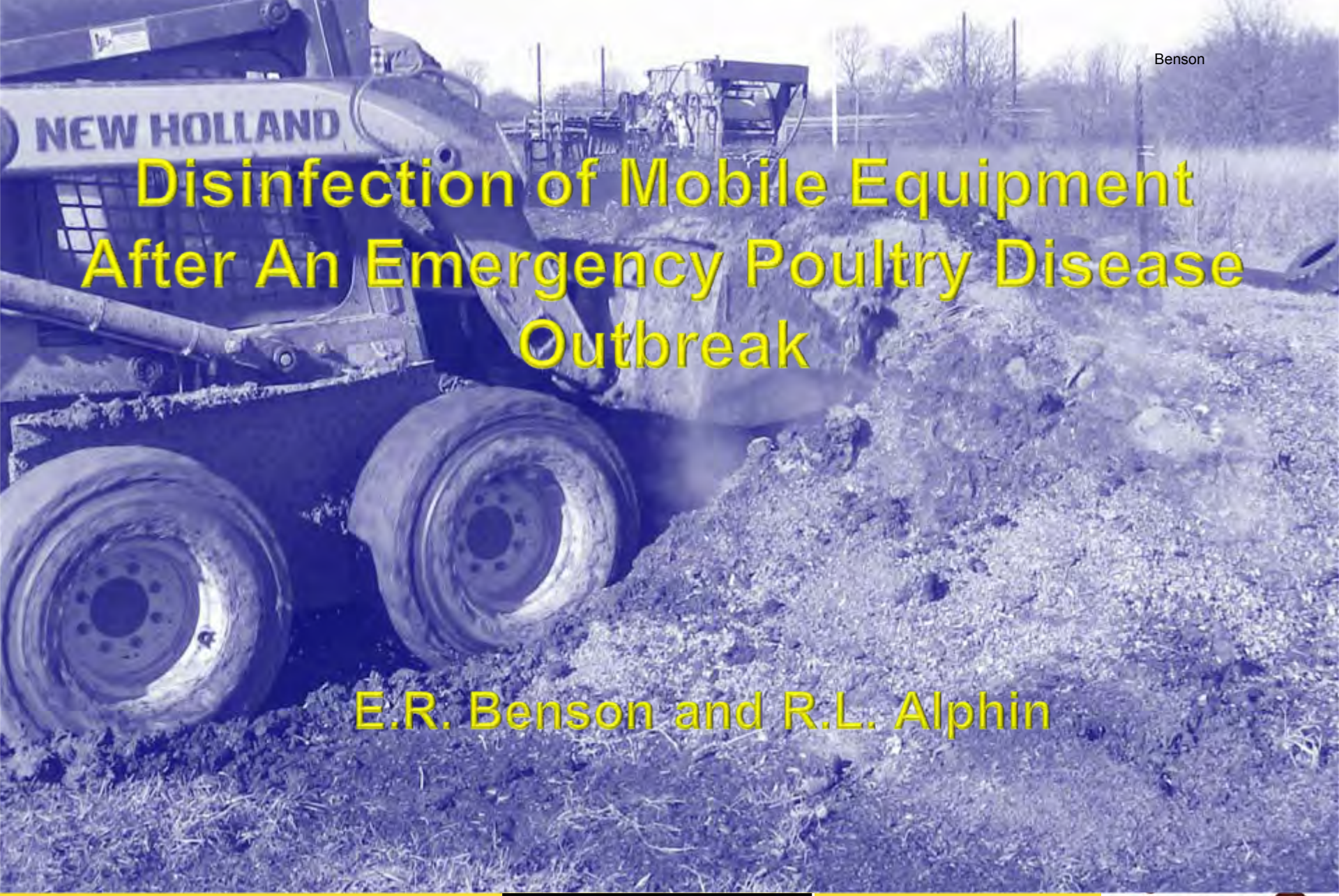


Summary

- Procedures and techniques have been developed and adopted internationally.
- These are also helping in the development of testing documents for NATO and other groups
- Work on the defining contamination and decontamination difficulties continues.
- DDT will be proposed for funding through Chemical, Biological, Radiological-Nuclear, and Explosives (CBRNE) Research and Technology Initiative (CRTI)

Disinfection of Mobile Equipment After an Emergency Poultry Disease Outbreak

Eric R. Benson, Department of Bioresources Engineering and Department of Animal and Food Science, University of Delaware



Disinfection of Mobile Equipment After An Emergency Poultry Disease Outbreak

E.R. Benson and R.L. Alphin

University of Delaware

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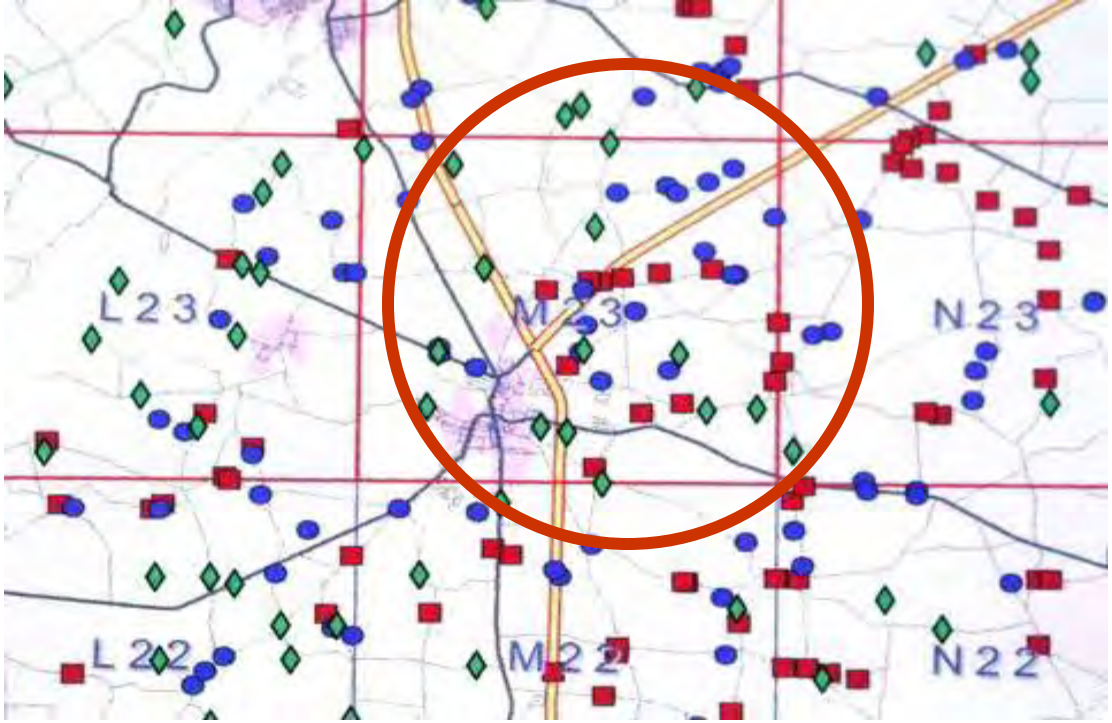
"When HPAI outbreaks occur in poultry, the preferred eradication and control methods are quarantine, enforcement of movement restrictions, and depopulation (culling) of all infected, exposed, or potentially infected birds, with proper disposal of carcasses and rigorous cleaning and disinfection of farms and surveillance around affected flocks. "

USDA APHIS VS EMD (2007)



Benson

- Control zone (3.2 km) around the farm
  - *Up to 50 farms*
- Average 2.5 houses / farm = 125 houses
- 20% inactive houses = 100 houses
- 25,000 birds x 100 houses = 2,500,000 birds
- *Note number of occupied houses in area!*

- Equipment is extensively used during response
  - Depopulation equipment
  - Skid steer loaders
  - Tractors
- Very limited numbers
- Decon prior to movement
- Difficult to effectively clean in field
  - Blind holes
  - Hidden areas

Benson

Skid steer loader constructing disposal windrow.

Excavator removing part of the roof to allow access.

- Performed as close to site as possible
- Remove all heavy mud and debris prior to decontamination
  - Concentrate on undercarriage
- Remove and replace select items
- Agents
  - Chlorine (0.5%) solution or soapy water
- Lubrication when complete

- Remove all filters
- Power wash to remove gross material
- Spray with liquid disinfectant
- Keep equipment in heated garage for 3 days
  - Inactivate virus
  - Idles equipment

- Objective
  - Test influence of disinfectant agent and application method on decontamination of NDV seeded equipment
- Disinfectant Agents
  - Citric Acid, Peroxygen, Glutaraldehyde, H_2O_2
  - Silver
- Application Methods
  - Liquid, Indirect thermal fog, Direct thermal fog, Electrostatic

- Engine model used to simulate equipment
  - Small scale, repeatable
  - Power washed prior
- Indicator strips and/or coupons
  - Indicator strip useful for disinfectant presence
  - Inoculated coupon for virus inactivation

Benson

Engine Model

- Place 12* NDV inoculated coupons
  - Interior / Exterior
- Apply treatment
- Remove coupons after 10 minutes
- Neutralization broth
- Thermal and positive controls
- Virus isolation

Benson

Removing samples from the engine

Egg inoculation

- Virus isolation used to assess presence
  - Pooled samples
  - Serial dilutions, dilutions inoculated into fve 9
    - 11 day old SPF eggs
  - Eggs candled for 5 days
- Hemagglutination activity assessed at termination

- Neutralization index used to compare effectiveness
- For a treatment to be effective
  - No recovered virus
  - Titer of positive control at least log 2.8 greater than the titer of treated groups
  - Titer of PC virus ≥ 4.0
  - Titer of treated groups <1.2
  - No recovered virus = $<10^{1.2}EID_{50}/mL$

(via Reed & Müench)

$$NI = t_{pc} - t_a$$

- Liquid sprayer used to apply disinfectant
  - Solo backpack sprayer
  - Time: 45 s
- Engine in tent
- Operator tried to ensure coverage of engine
- Agents
  - *Citric Acid (3%)*
  - *Peroxygen (1%)*
  - *H_2O_2 – Silver (5%)*

Benson

- Fogger directed into tent
  - Dramm Pulsfog
  - Time: 2 min
- Engine placed in tent
  - *No personnel in tent*
  - *SCBA*
- *Agents*
  - *Citric Acid (22.8%)*
  - *Glutaraldehyde (1%)*

Thermal fogging unit


Thermal fog discharge directed into tent.

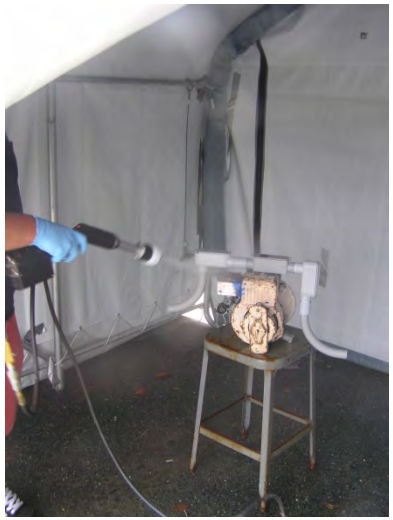
Thermal Fog Indirect

- Fogger directed at engine and allowed to fill tent
  - Dramm Pulsfog
  - Direct: 45 s
  - Tent: 75 s
- Engine in tent
  - *Personnel in tent*
  - *SCBA*
- *Agents*
  - *Citric Acid (22.8%)*
  - *Glutaraldehyde (1%)*
  - *H_2O_2 – Silver (5%)*

Directly applying the thermal fog to the engine.

- Electrostatic sprayer used for direct application
  - Electrostatic Spraying Systems
  - Time: 2 min
- *Agent*
  - *H_2O_2 – Silver (5%)*

Benson



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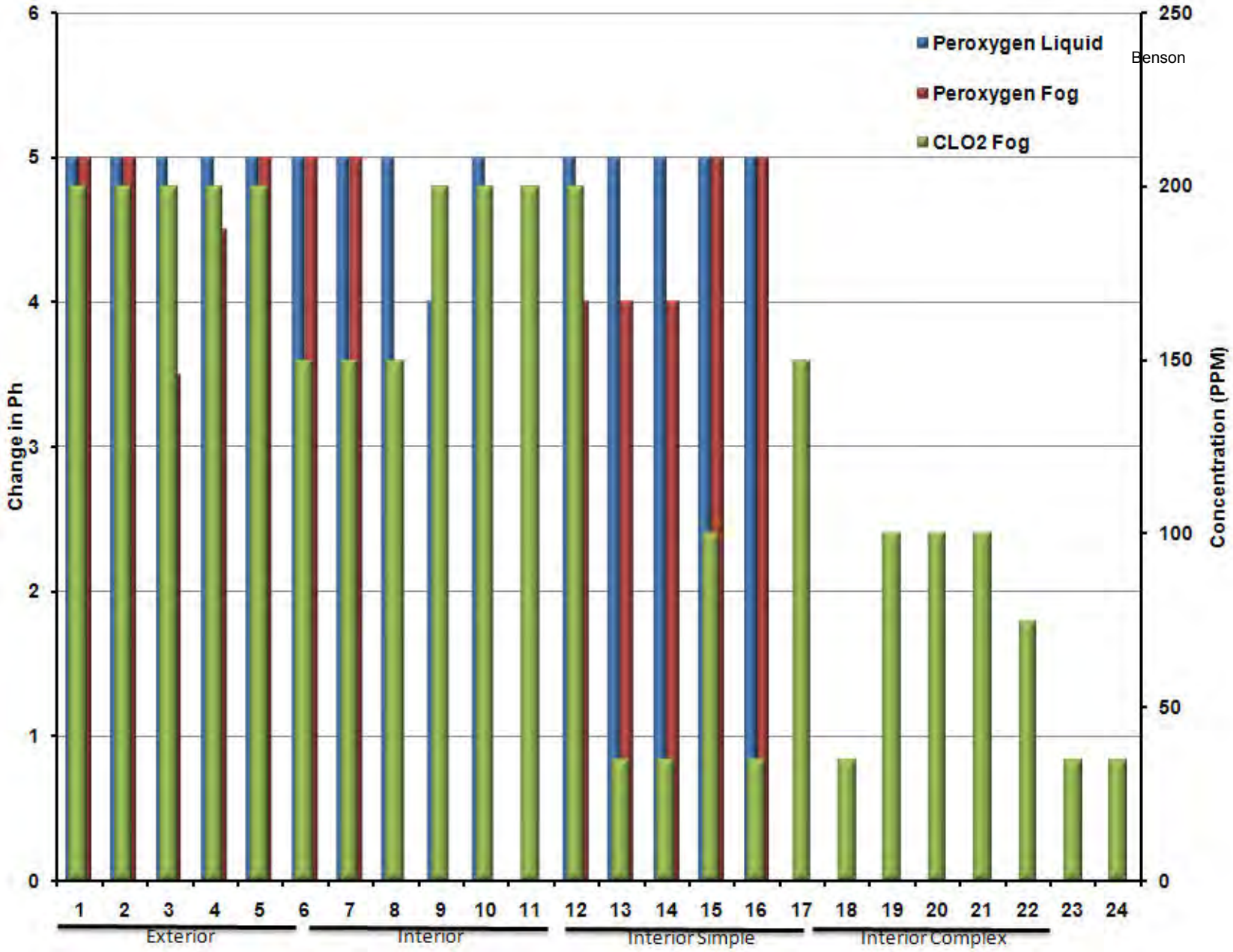

Indicator Strips

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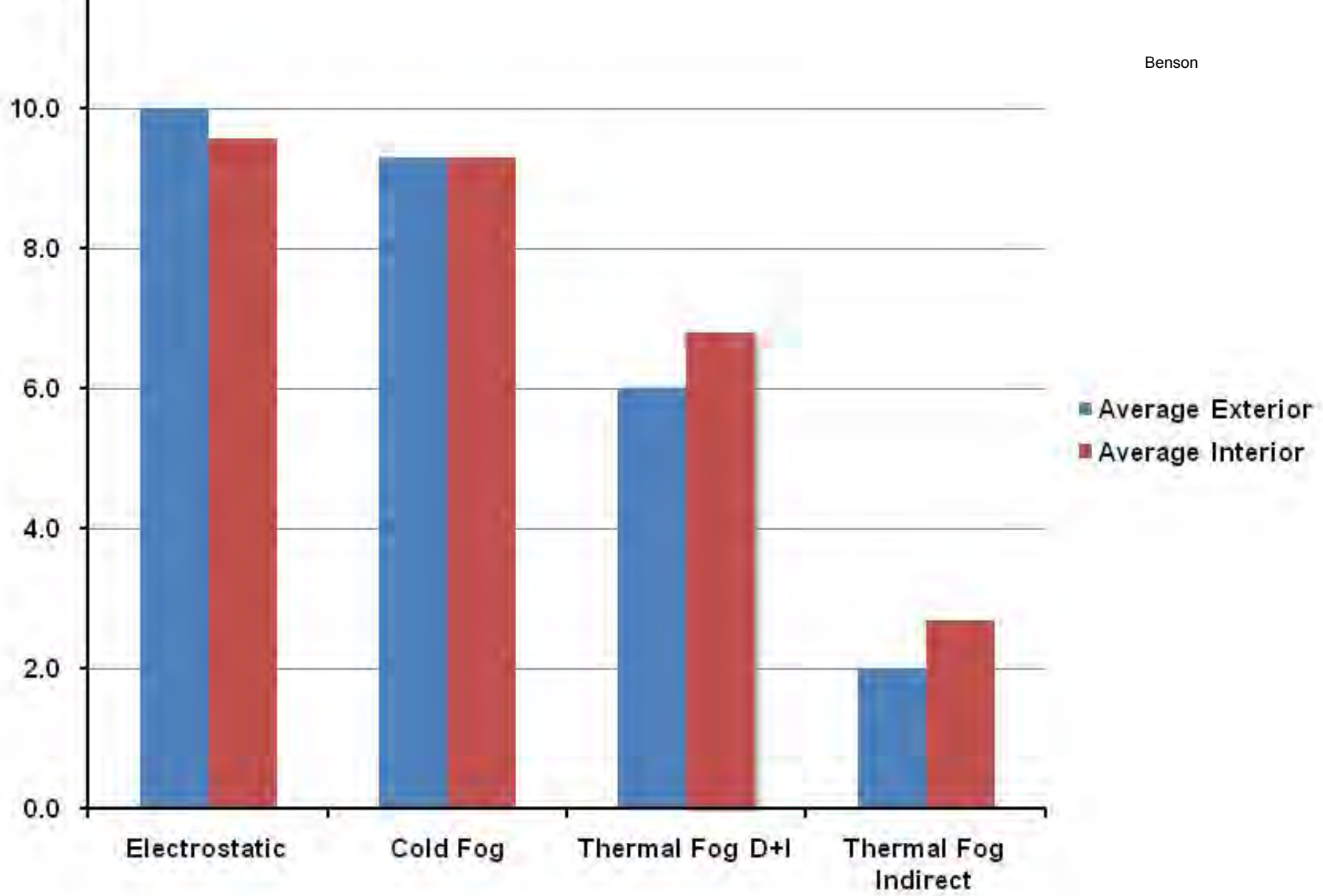
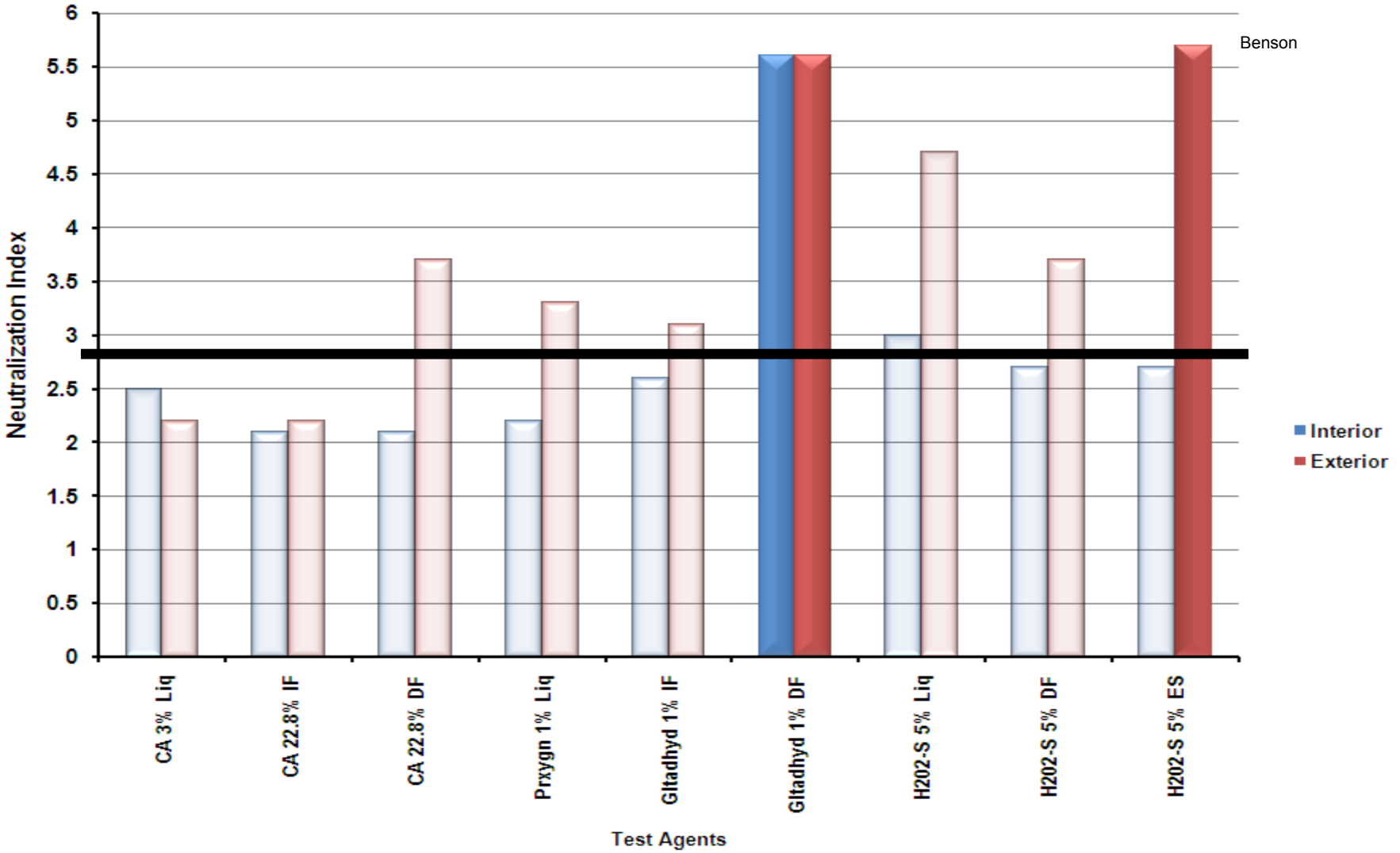


Application Method



Results

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- Equipment testing has shown that disinfection in the field may be a problem
  - Difficult to achieve reliable disinfection in hard to reach areas
  - Additional work required to achieve inactivation
- Liquid application may not be as suitable as initially thought
  - Difficult to get reliable access
- Tent based fogging method ideal, but does not provide suitable efficacy
  - Direct method raises exposure concerns

- Direct – indirect thermal fog applied glutaraldehyde current recommendation
- Direct fogging more effective than indirect fogging
  - Higher concentrations required
- Electrostatic sprayers may improve application, as noted with H_2O_2-Silver

Conclusions

- Any Questions?

- Dr. Eric Benson
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- Selected results were supported by the USDA AI CAP 2 program
  - Prevention and Control of Avian Influenza in the U.S.
- Selected results supported by USDA-APHIS Cooperative Agreement Award 06-9100-1044-CA.

USDA

Acknowledgements

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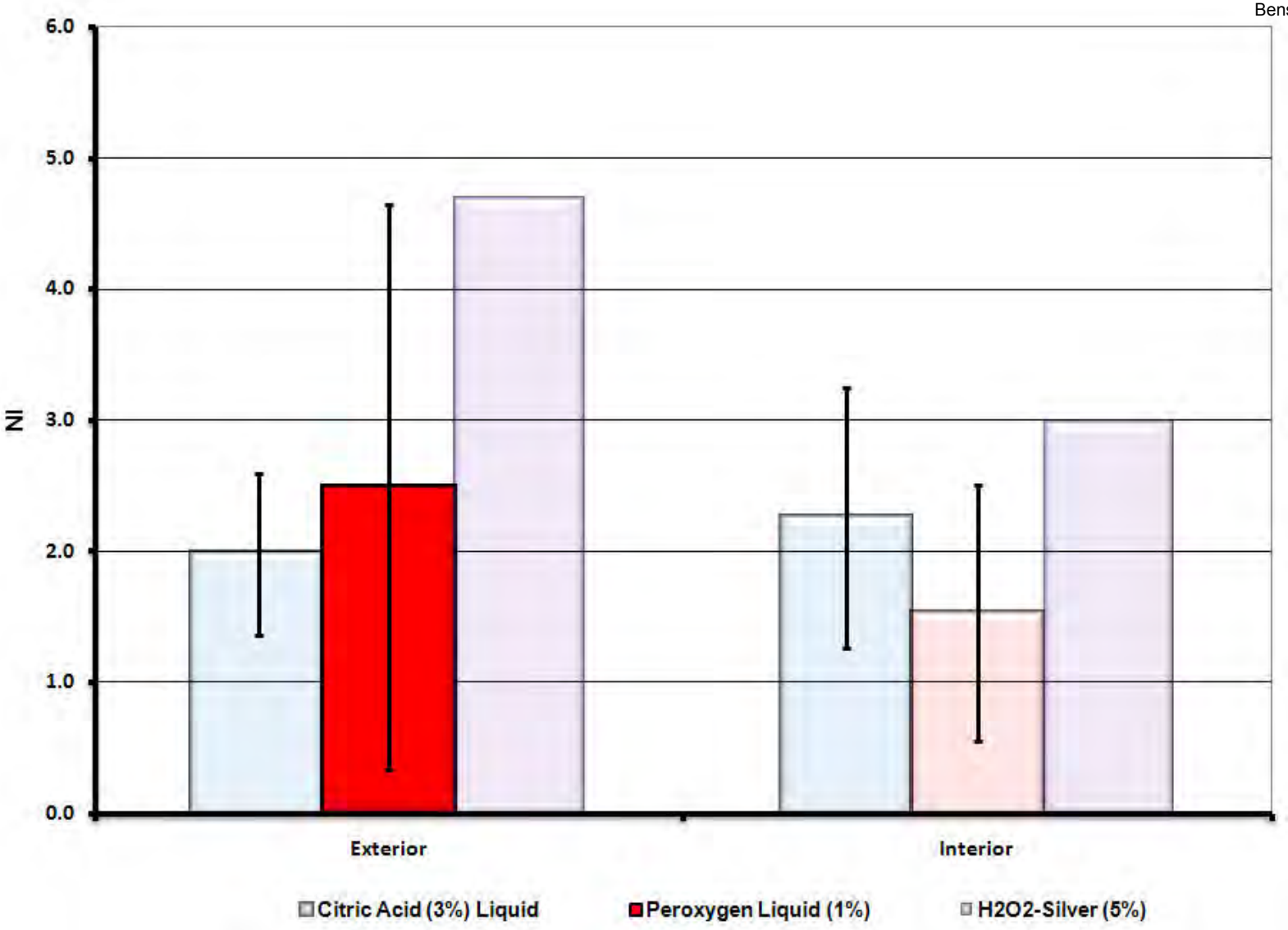
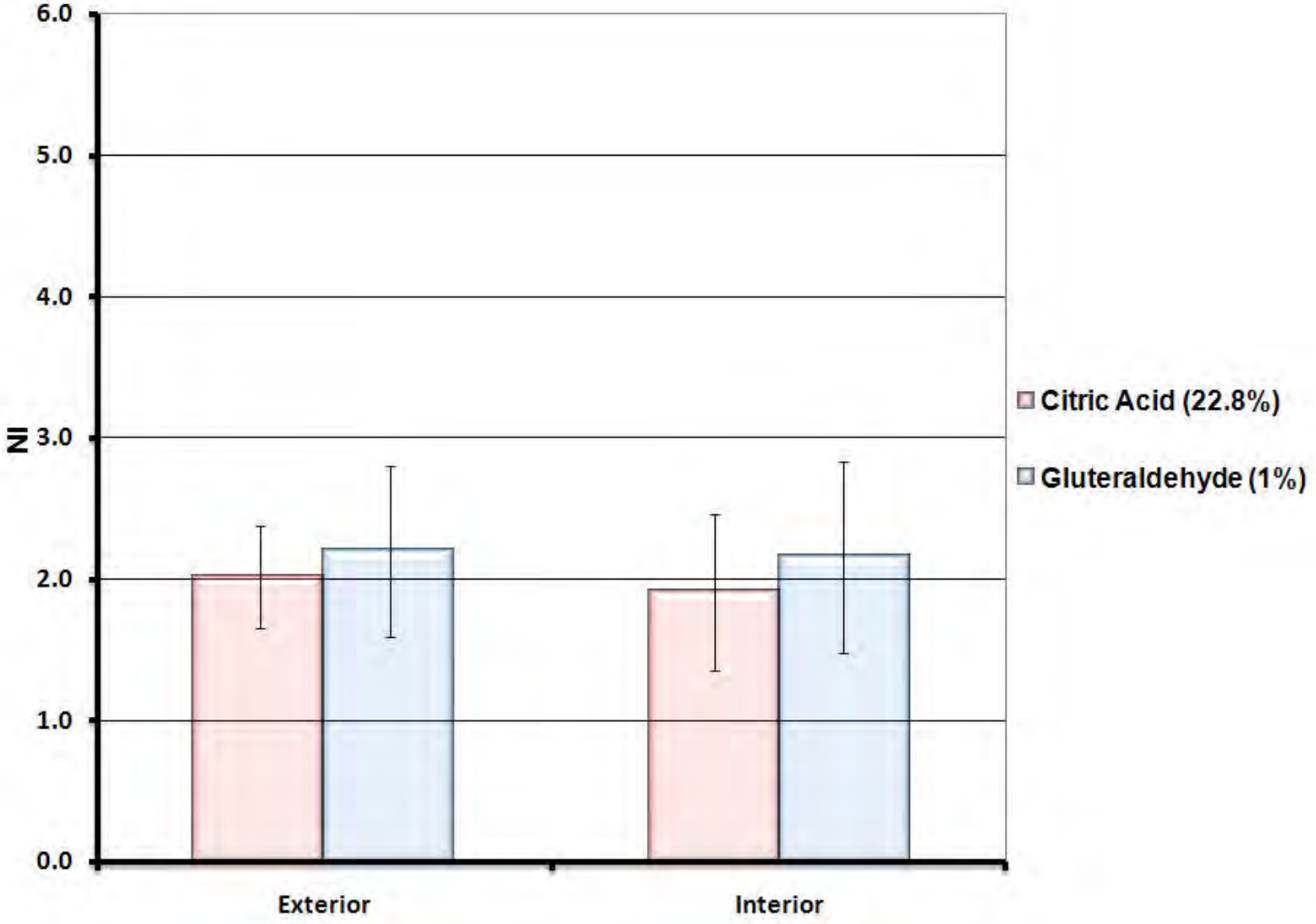
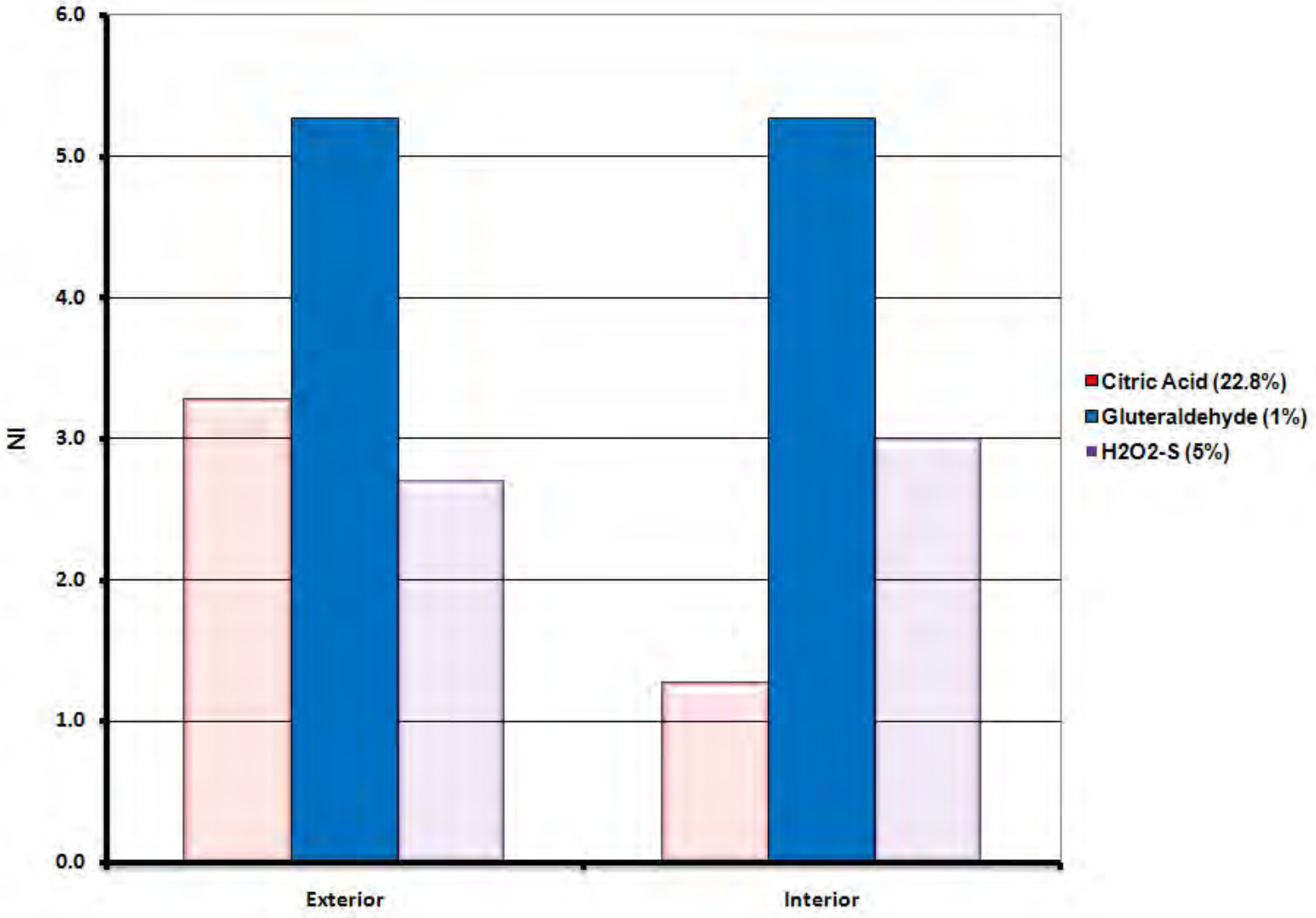


Liquid Treatment

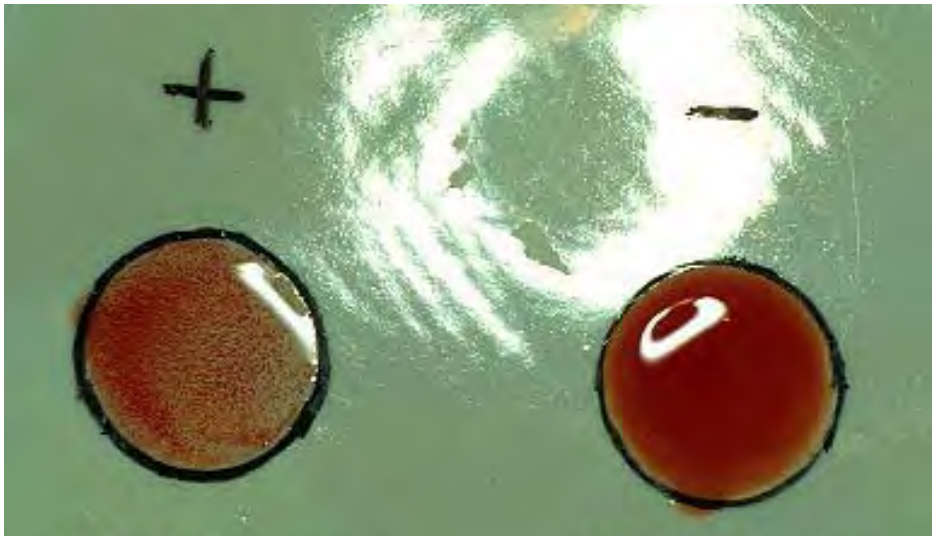


Thermal Fog Indirect



Thermal Fog Direct

- Embryo Inoculation
  - Broth from plates agitated and pooled
  - Fluid from plates diluted using three 10-fold serial dilutions
  - Positive control materials diluted with six 10-fold serial dilutions
  - Each dilution inoculated into five, 9-11 day old specific pathogen free (SPF) embryonated chicken eggs
  - Eggs candled daily for five days



Benson

Hemagglutination Positive **Hemagglutination Negative**

- Viral presence
  - Fluid collected from each egg
  - Examined for hemagglutination activity (HA) to determine viral activity

Testing the Sporicidal Efficacy of Six Disinfectants on Carrier Surfaces Contaminated With *B. Atrophaeus* Spores

Bruce Hinds, Defense Threat Reduction Agency

"Testing the Sporicidal Efficacy of Six Disinfectants on Carrier Surfaces Contaminated with B. atrophaeus Spores"

Mr. Bruce A. Hinds

Defense Threat Reduction Agency (DTRA)

Counter WMD Test Support Division - Diagnostics Branch (CXTD)

Study Overview

- Study was the Good Laboratory Practices (GLP) experiment designed to test the sporicidal efficacy of six disinfectants on carrier surfaces contaminated with *Bacillus Atrophaeus* (Bg)
- Lovelace Respiratory Research Institute (LRRI) conducted the GLP study; the contract vehicle was DTRA/RD-CXT's Test Operations, Technology and Test Support (TOTTS) contract with Applied Research Associates, Inc. (ARA)
- The LRRI GLP experimentation phase was conducted over the period 30 October 2008 to 9 January 2009
- The GLP study results indicated the decontamination efficacy varied by technology and carrier surface

Test Articles and Test System

- Six spray/foam-applied technologies were evaluated
- Two types of carriers were “contaminated” with BWA simulant
  - Carrier surfaces represented common non-porous and porous building materials found in an urban environment in the pacific northwest
  - BWA simulant was provided by Dugway Proving Ground

Test Article	Test System		
Decontamination Technology	**BWA Simulant Carriers**		**BWA Simulant**
Peridox®	Stainless Steel (non-porous)	Unglazed Porcelain (porous)	*B. Atrophaeus* (Bg)
CASCAD®			
SporKlenz RTU®			
EasyDECON®			
Decon Green			
MDF-200			

LRRI Facilities on KAFB

- The GLP study was conducted at the LRRI facility on Kirtland Air Force Base, NM

LRRI ‘s south facility, building 9200, Area Y, Kirtland AFB, NM

The GLP study was conducted in the laboratory inside Bldg 9255, located behind the main facility on KAFB

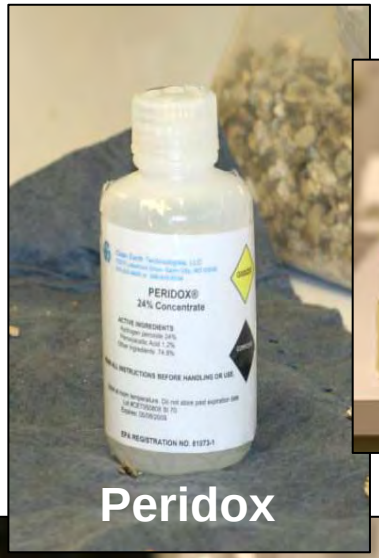
Secure Storage of Test Articles

- The decontamination system components were stored in the Test Article – Secured Material Storage (TA-SMS) room located inside the LRRI facility on KAFB
- Each decontamination system was assigned a unique TA number which was used throughout the GLP study

The DZ test articles (decon systems) were stored separately in these lockers

- **Access to the TA-SMS was strictly controlled**
- **An integrated monitoring system recorded all room entries and exits**
- **All entries/exits were crosschecked with the visitor log**

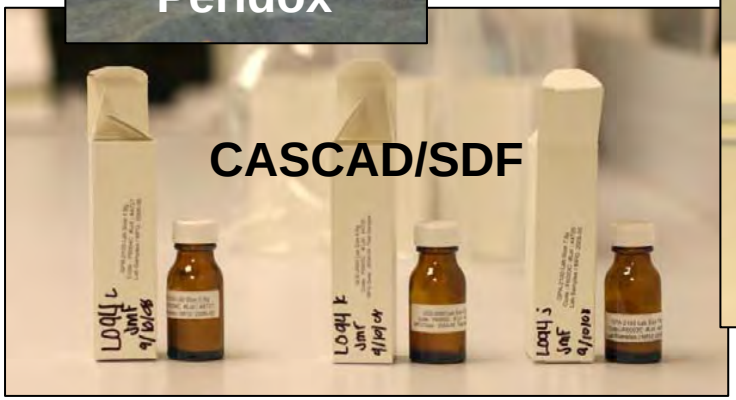
Test Articles (Decon Technologies)

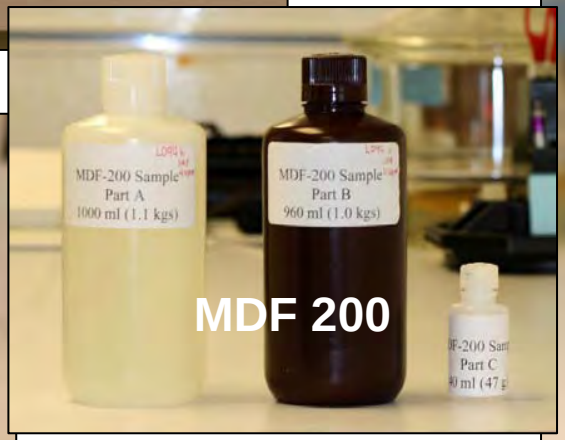


Peridox

Easy Decon

Decon Green


CASCAD/SDF



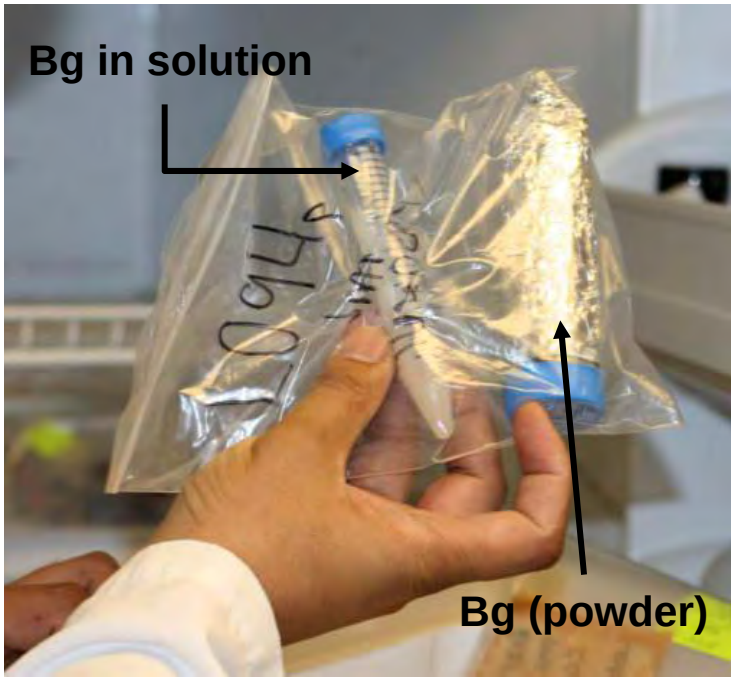
MDF 200

SporKlenz
RTU

Hinds

Secure Storage of Test Systems

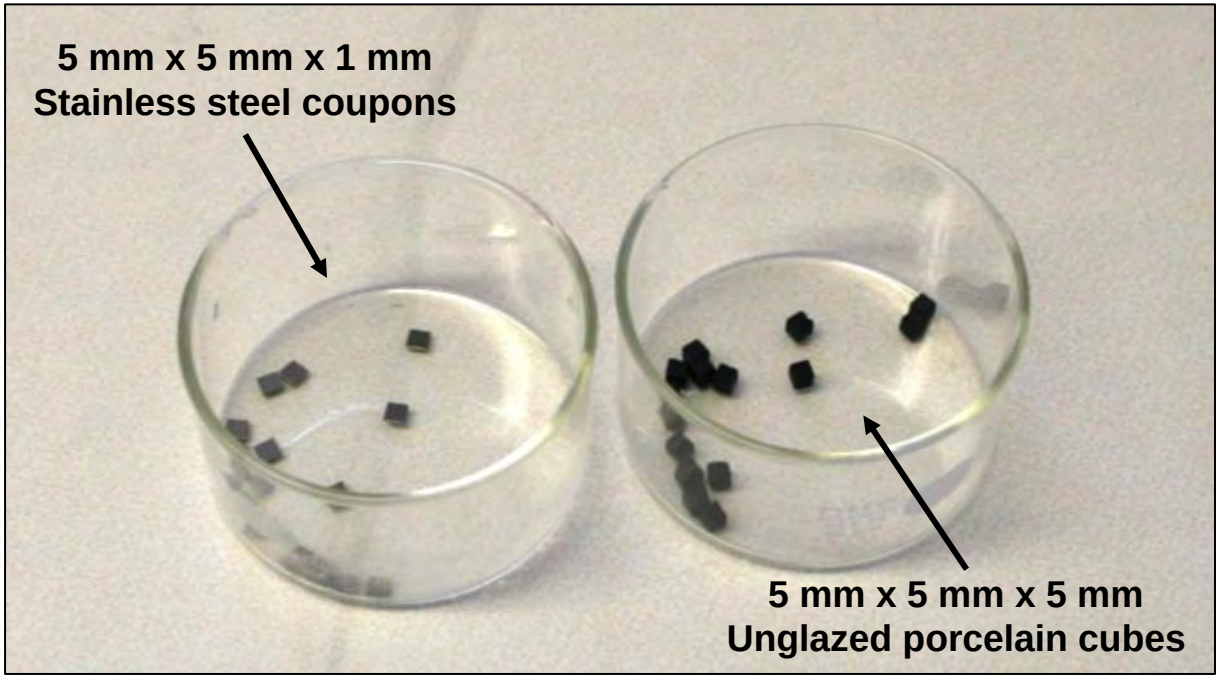
- The test system materials (Bg, carrier materials) were stored in the Secure Material Storage (SMS) room in the LRRI facility
- Test system materials were logged in/out through a computerized Inventory Management System



The Bg spores and Bg test solution were stored in a refrigerator located in the SMS

Bg Carrier Surfaces

- Non-porous surface – stainless steel coupons, grade 304 with 2B finish and 19 gauge (1 mm) thickness
- Porous surface – unglazed porcelain cubes, Brix Frammenti black mosaic tiles, reported porosity of ≤ 0.03%



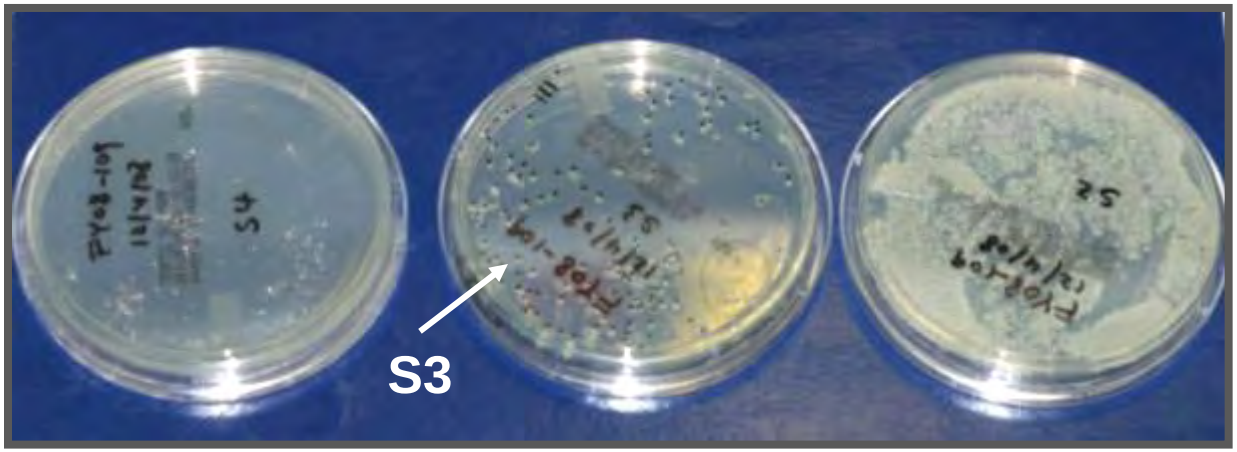
Experiment Design

- The study consisted of four main steps
  - Qualification tests of Bg
    - Microscopic and acid resistance tests were performed
  - Neutralizer testing
    - Neutralizers were chosen for their ability to stop the sporicidal action of the test article (decon technology)
  - Preparation of the test system
    - Carriers were inoculated with a suspension of Bg spores
  - Three-Step Method (TSM)
    - The TSM process was used to test the sporicidal efficacy of the test articles on porous and non-porous carries inoculated with Bg

Hinds

Preparation of the Spore Suspension

- The spore suspension contained between
  1×10^9 and 5×10^9 CFUs/mL
- The acceptable dilution ratio was determined for the stock solution



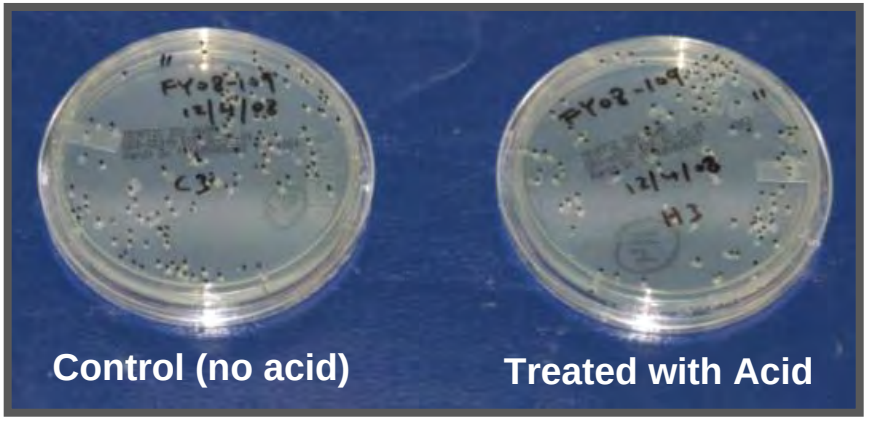
In this case, S3 was determined to have the appropriate dilution ratio

Hinds

Qualification Test of Bg Suspension

- Microscopic observation test
  - Spores were acceptable if less than 10% of the spores were vegetative cells (rod shaped)
- Two-minute acid resistance test
  - Spores were acceptable if the log reduction was in the range of 0 – 3 for a 2-min exposure
- Lesson Learned
  - Supply of acceptable Bg spores was limited
  - We may need to allow time to “grow our own” for future testing

Acid Resistance Test



Average log reduction for 2-min acid test was 0.363 ± 0.211 for 11 tests

Neutralizer Testing

- Reaction tubes were prepared for each neutralizer/decon material test:

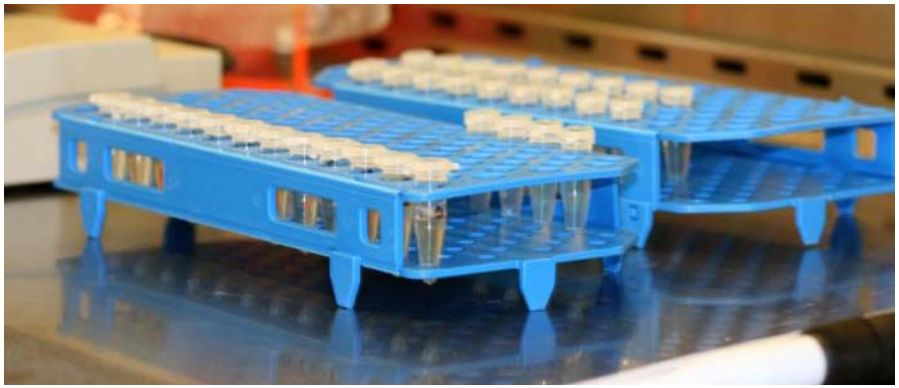
  Water + LB + Bg

  Neutralizer + water + Bg

  Neutralizer + test article + Bg

  } The neutralizer passed the test if these test solutions produced results that were within 1 log of each other

- <u>Lesson Learned:</u>
  - It is important to test neutralizers – even those specified by the decon technology vendors



Neutralizer Testing Results

Neutralizers tested for different test articles

Test Article	Neutralizer	Results
Peridox	Catalase (C-100, Sigma-Aldrich) in D/E Broth	PASS
CASCAD	Sodium Thiosulphate – Pentahydrate in LB Broth	FAIL
	Sodium Thiosulphate – Anhydrous in LB Broth	PASS
SporKlenz RTU	LB Broth	FAIL
	Catalase (IC-10042910, VWR/MP) D/E Broth	PASS
Easy DECON	LB Broth	FAIL
	Catalase (IC-10042910, VWR/MP) and Catalase (C-3155, Sigma) in D/E Broth	PASS
Decon Green	Sodium metabisulfite in microbiology grade water	PASS
MDF-200	LB Broth	FAIL
	Catalase (IC-10042910, VWR/MP) and Catalase (C-3155, Sigma) in D/E Broth	PASS

Three-Step Method Overview

- The acid test of the spore suspension was performed
- The bacterial spore suspension was deposited on the carriers and allowed to dry for at least 12 hours

Day 1

- The carriers were exposed to a sporicidal agent for a fixed time (30 min)
- The spores were removed from the carriers in three steps of increasing dislodging strength
  - Step 1: Fraction A – initial fraction
  - Step 2: Fraction B – sonication
  - Step 3: Fraction C – incipient germination
- Fractions A, B, and C, or their appropriate dilutions, were plated on agar and incubated (12 hrs at 37ºC)
- The Colony Forming Units (CFUs) were counted

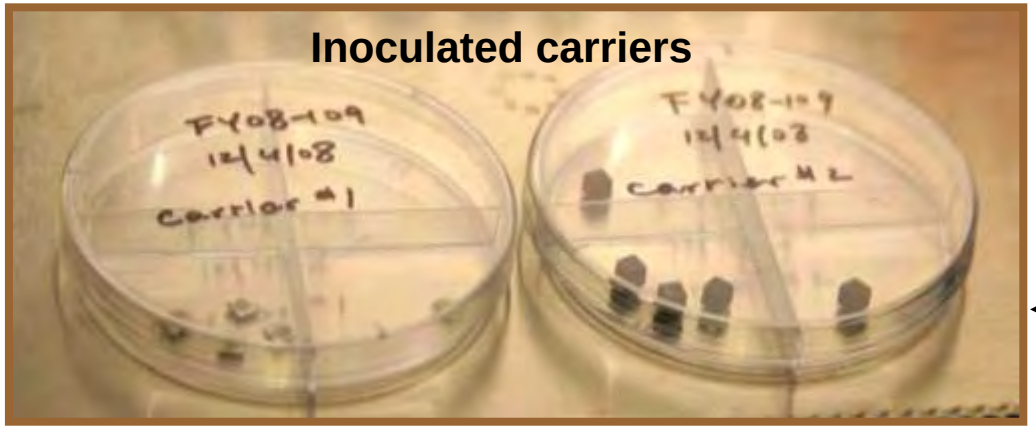
Day 2

Day 3

TSM Day 1 – Prepare the Test System

- Prepared the carriers
  - Unglazed porcelain cubes and stainless steel coupons
  - Washed with water and 95% ethanol, autoclaved
  - Performed the acid test of the spore suspension
- Inoculated carriers with 10µL of spore suspension
  - Microbial load of 1 x 10^7 to 5 x 10^7 spores per carrier
  - Covered and let dry overnight (at least 12 hours), inside the biological safety cabinet

Stainless steel coupons



Unglazed porcelain cubes

TSM Day 2 – Tests Performed

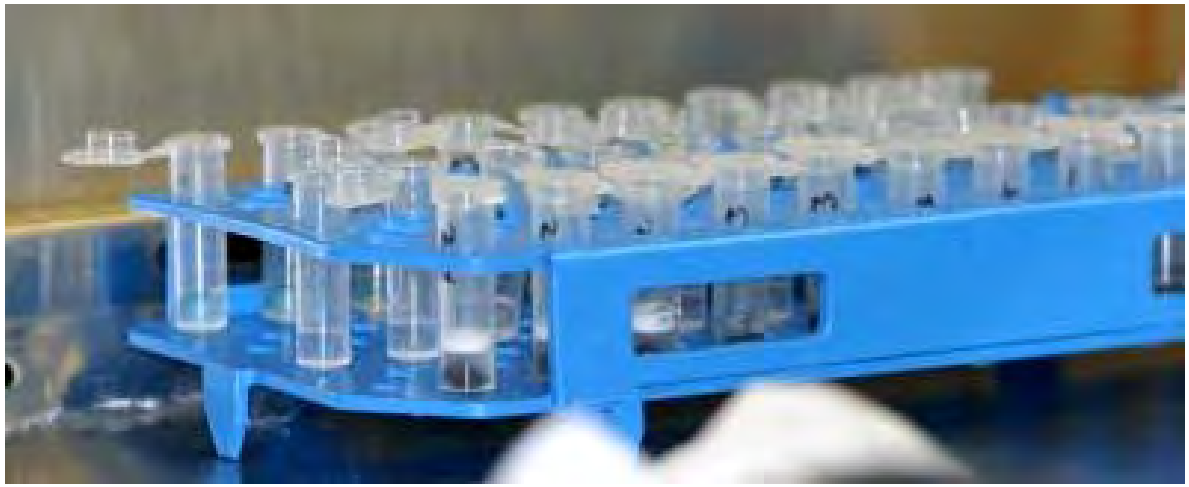
Hinds

- For each decontamination technology (test article) there were at least 14 laboratory tests performed
  - Two carrier types per test article (triplicate tests)
  - Negative control (microbiology grade water, triplicate tests)
  - Positive control (acidified bleach, pH 7, single test)
- The following table illustrates the minimum number of tests performed *for each test article*

Carrier	Test Article Tests	Negative Control Tests	Positive Control Tests	Total Tests	Fractions Plated & Counted
Stainless Steel	3	3	1	7	21
Unglazed Porcelain	3	3	1	7	21
Total	6	6	2	14	42

Apply the Decon Technology

- 400µL of the test article was added to the micro centrifuge tubes containing the inoculated carriers
- After 30 minutes exposure time 600µL of neutralizer was added to stop the sporicidal action of the disinfectant



Test article and controls were added to tubes containing inoculated carriers (porcelain cubes shown in photograph)

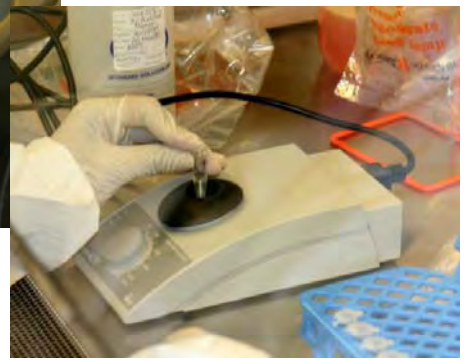
30-min exposure time

TSM – Steps 1 and 2

- Fraction A
  - Carrier was removed from the first solution of test article (or control) and neutralizer
- Fraction B
  - Carrier was placed in a second micro centrifuge tube containing 400µL microbiology grade water
  - Sonicated for 5 min
  - Added 600µL ice-cold LB broth and vortexed for 30 seconds

Sterile forceps were used to remove the carrier from Fraction A

Fraction B was sonicated for 5 min …



… and vortexed for 30 sec

TSM – Step 3

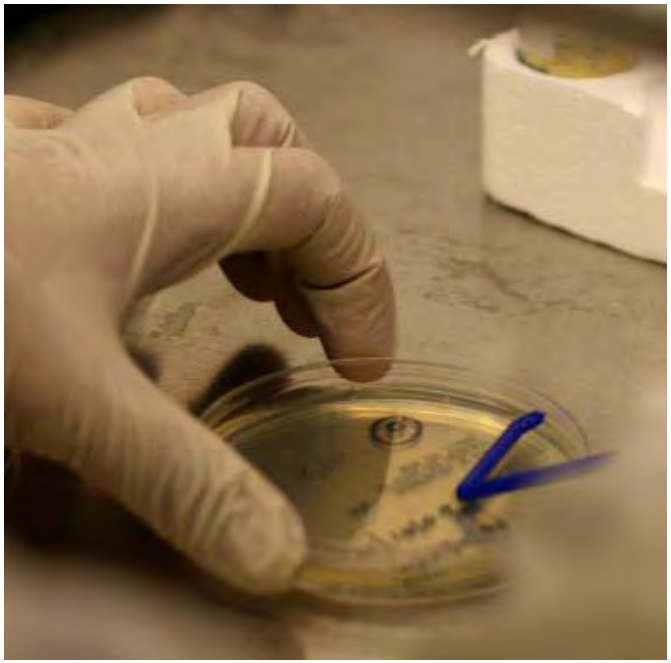
- Fraction C
  - Carrier was transferred to a third micro centrifuge tube containing 400µL room temperature LB broth
  - The tubes were placed in a rotator and incubated for 30 min at 37ºC

Fraction C was incubated in a rotator at 12 rpm

Hinds

Fractions A, B, and C were Plated

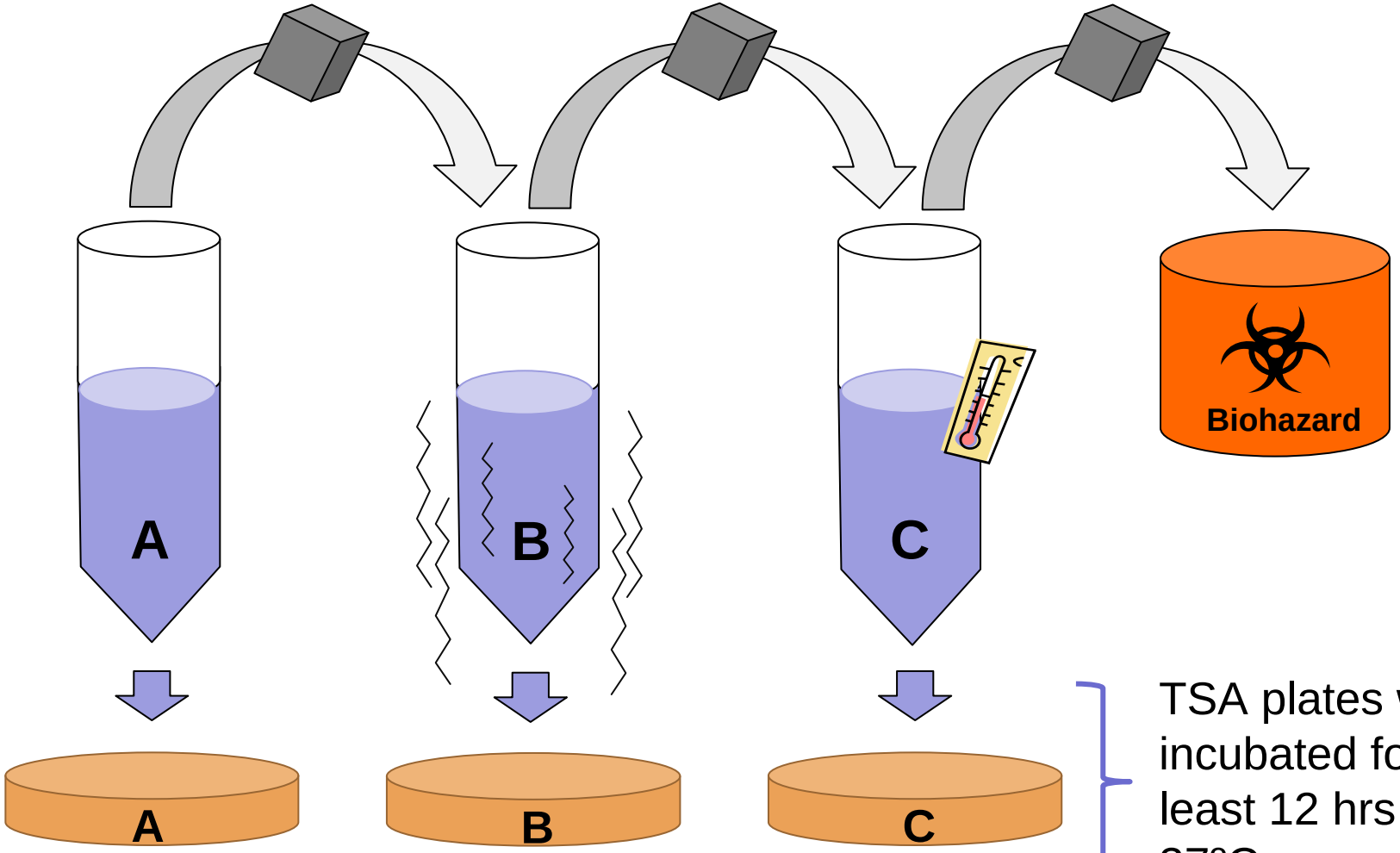
- Finally, the carrier was discarded and serial dilutions of Fractions A, B, & C were plated and incubated for at least 12 hours at 37ºC
- Dilution ratios resulting in 20 to 300 CFUs were typically used for the calculations
  - Plates with counts <20 were TFTC (too few to count)
  - Plates with counts >300 were TNTC (too numerous to count)
- For test articles and positive controls, any number of CFUs were counted



100µL of the diluted solution/concentrate was transferred to a Tryptic Soy Agar (TSA) media plate and distributed with a spreader

Hinds

Fractions A, B, and C were Plated



TSA plates were incubated for at least 12 hrs at 37ºC

TSM Day 3 – Count the CFUs

- The CFUs on each plate were counted
- The total viable spores per each carrier were obtained by adding the total CFUs in Fraction A, B, and C
- The Log Kill for each test article (or positive control) was calculated:

$$LK = LC - LS$$

Where

LC = Log of the average CFUs in the negative controls

LS = Log survival value (for test articles and positive controls)

LK = Log Kill (average of 3 LKs obtained from 3 replicates)

Results

Results

Hinds

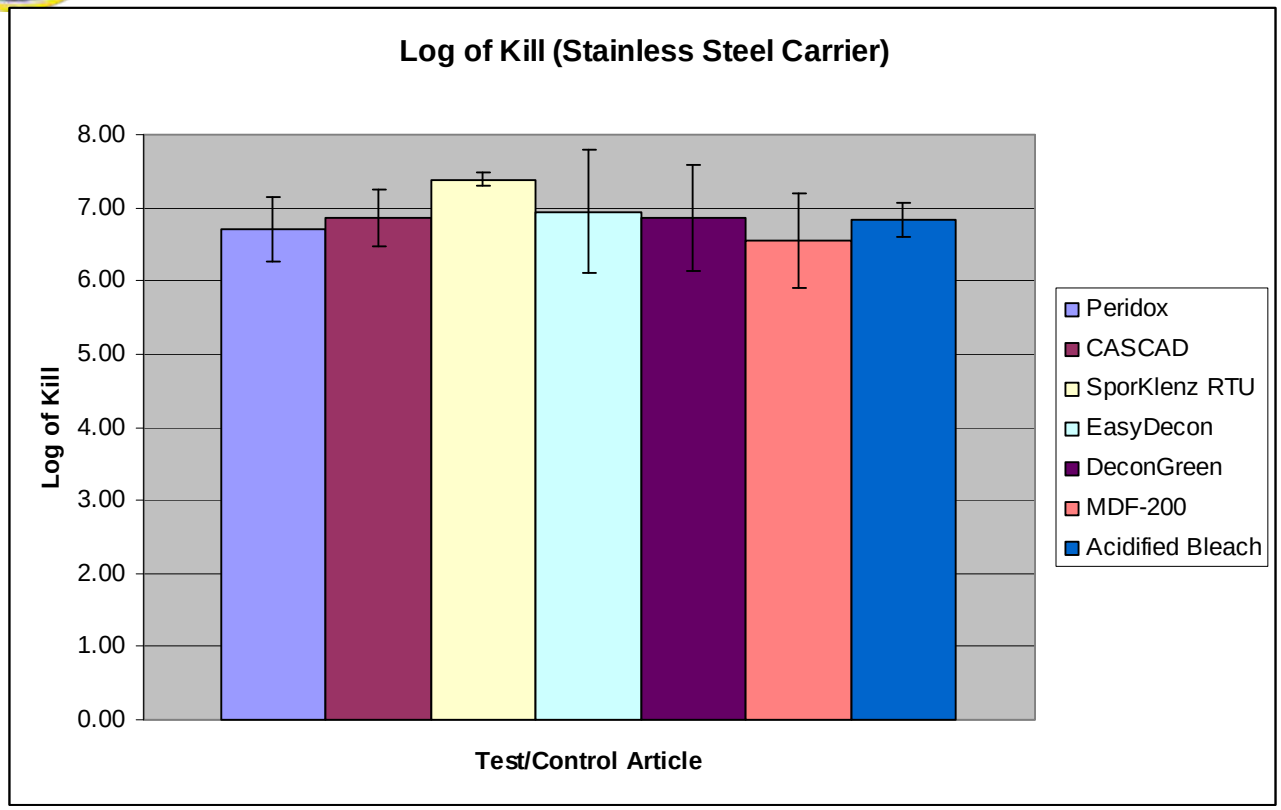
Log Kill – Stainless Steel Carrier

Log Kill for test articles and the positive control for stainless steel carrier

Test Article / Control	Test Number			Average	Standard Deviation
	I	II	III		
Peridox	6.52	7.2	6.4	6.71	0.43
CASCAD	6.44	7.19	6.95	6.86	0.38
SporKlenz RTU	7.35	7.49	7.33	7.39	0.09
EasyDECON	7.65	6.01	7.16	6.94	0.84
Decon Green	7.29	7.27	6.02	6.86	0.73
MDF-200	6.16	6.2	7.31	6.56	0.65
Acidified Bleach	6.87	6.60	7.05	6.84	0.22

Hinds

Log Kill – Stainless Steel Carrier



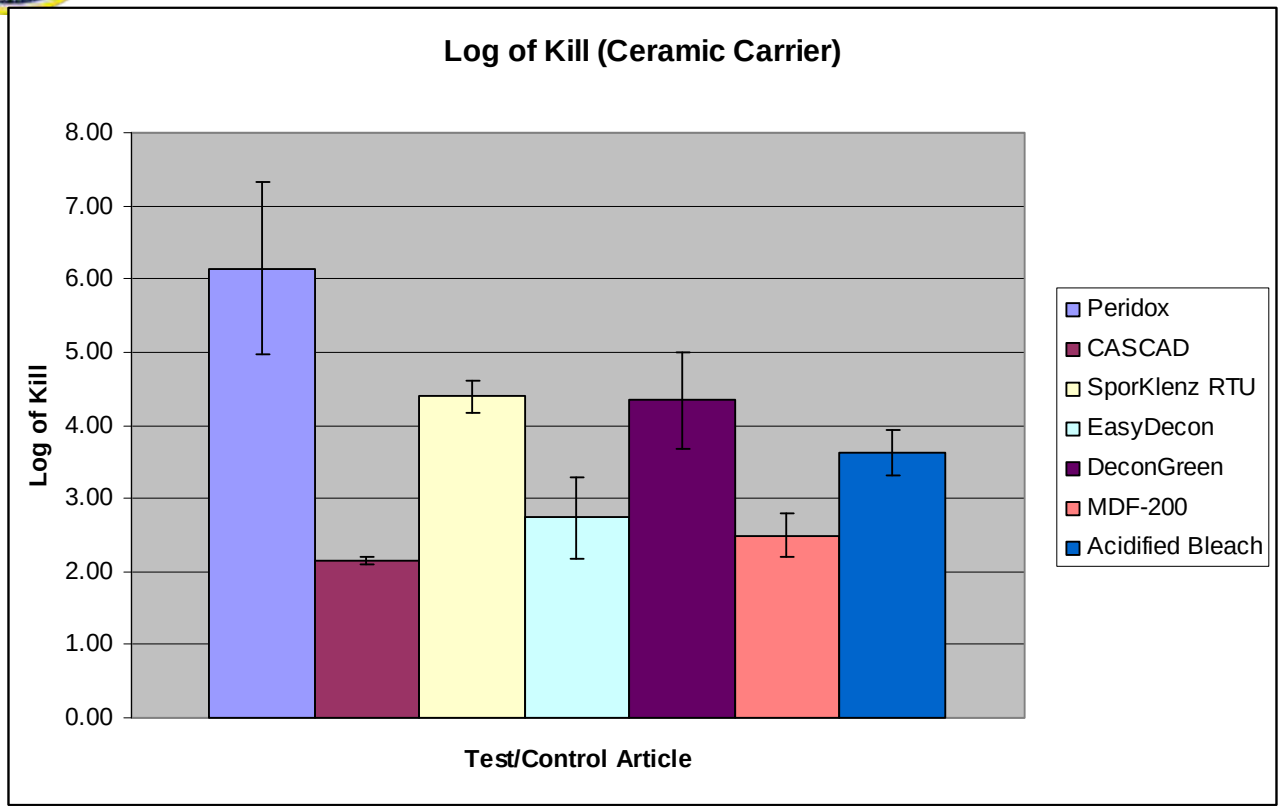
- Statistical analysis indicated there was no statistically significant difference between the LK of any of the test articles and the positive control (ANOVA, $\alpha = 0.05$)

Log Kill – Porcelain Carrier

Log Kill for test articles and the positive control for porcelain carrier

Test Article / Control	Test Number			Average	Standard Deviation
	I	II	III		
Peridox	7.3	6.18	4.96	6.15	1.17
CASCAD	2.15	2.2	2.09	2.15	0.06
SporKlenz RTU	4.65	4.27	4.25	4.39	0.23
EasyDECON	2.23	3.33	2.66	2.74	0.55
Decon Green	3.85	5.1	4.07	4.34	0.67
MDF-200	2.6	2.71	2.15	2.49	0.30
Acidified Bleach	3.88	3.29	3.71	3.63	0.30

Log Kill – Porcelain Carrier



- Statistical analysis indicated the values were statistically different when considered as a group
- Further statistical analysis was done

Tukey's HSD Test

Pair-wise analysis from Tukey's HSD Test

	Peridox	CASCAD	SporKlenz RTU	Easy DECON	Decon Green	MDF-200	Acidified Bleach
Peridox		S	S	S	S	S	S
CASCAD	S		S	NS	S	NS	NS
SporKlenz RTU	S	S		S	NS	S	NS
Easy DECON	S	NS	S		NS	NS	NS
Decon Green	S	S	NS	NS		S	NS
MDF-200	S	NS	S	NS	S		NS
Acidified Bleach	S	NS	NS	NS	NS	NS	

- Table shows combinations/pairs which were statistically significant (S=22) and those in which means were not statistically significant (NS=20)

Hinds

Fisher LSD Test

Pair-wise analysis from Fisher LSD Test (a more liberal analysis)

	Peridox	CASCAD	SporKlenz RTU	Easy DECON	Decon Green	MDF-200	Acidified Bleach
Peridox		S	S	S	S	S	S
CASCAD	S		S	NS	S	NS	S
SporKlenz RTU	S	S		S	NS	S	NS
Easy DECON	S	NS	S		S	NS	NS
Decon Green	S	S	NS	S		S	NS
MDF-200	S	NS	S	NS	S		S
Acidified Bleach	S	S	NS	NS	NS	NS	

- Table shows combinations/pairs which were statistically significant (S=28) and those in which means were not statistically significant (NS=14)

DISCRETE ZEUS Summary

- This Good Laboratory Practices (GLP) study employed a Three-Step Method (TSM) to test the sporicidal efficacy of six disinfectants on carrier surfaces contaminated with *Bacillus Atrophaeus* (Bg)
- The carrier surfaces were non-porous (stainless steel) and porous (unglazed porcelain) materials
- The disinfectants/test articles were Peridox, CASCAD, SporKlenz RTU, EasyDECON, Decon Green, and MDF-200.
  - Microbiology grade water was used as a negative control
  - Acidified bleach (pH 7) was used as a positive control
- The experimentation phase was conducted over the period 30 October 2008 to 9 January 2009
- The final report completed Feb 2009

Conclusions – Non-Porous Carrier

- Stainless steel:
  - The Log Kill of all test articles and the positive control were within 7±0.5
  - Based on the Analysis of Variation (ANOVA), there were no statistically significant differences between the test articles and the positive control

Conclusions – Porous Carrier

- Unglazed porcelain
  - Based on the average Log Kill

Peridox > SporKlenz RTU & Decon Green > Acidified Bleach

Acidified Bleach > CASCAD, EasyDECON, & MDF-200

  - Two additional statistical analysis methods were used to determine if the mean test article results were significantly different from those of the acidified bleach

Tukey's HSD & Fisher LSD: Peridox > Acidified Bleach

Fisher LSD: Acidified Bleach > CASCAD

Conclusions – Porous Carrier

Hinds

- Unglazed porcelain (cont'd)
  - Only 3 of 54 Fraction A solutions contained countable CFUs, however most of the Fraction B solutions indicated a large number of CFUs
  - This indicates the test articles have the capacity to kill the spores (with a high log kill) on the surface, but may not have sufficient wetting or penetration characteristics to adequately kill the spores inside the porous material
  - This phenomenon has been reported by others (*see note section for references*)

Acknowledgements

- Mr. Ryan Madden, DTRA-CB
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- Dr. Lucy Combs-Walker, Applied Research Associates, Inc.
- Mr. Joe Wood, EPA/HSRC
- Mr. Jeff Kempter, EPA/OPP
- Dr. Yung-Sung Cheng, Hammad Irshad and Dr. Yue Zhou, Lovelace Respiratory Research Institute

Backup

Backup Slides

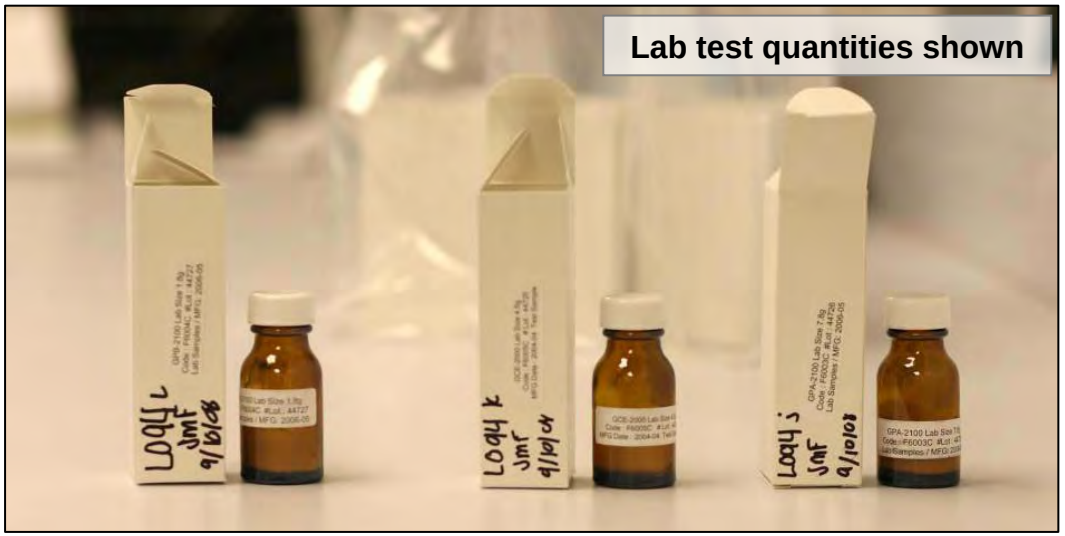
PERIDOX

- Clean Earth Technologies
- Distributed as a concentrate and diluted with water prior to use
  - Typically applied as a liquid or via the EDS (Electrostatic Decontamination System)
- Active ingredients:
  - Hydrogen peroxide
  - Peroxyacetic acid
- EPA registration as a sterilant/disinfectant

Concentrate – mix with water prior to use

CASCAD/SDF

- Allen-Vanguard Corporation
- Three components (A, B, and C) are mixed, and then water is added prior to application
  - Typically applied as a foam, but can be applied as a liquid
  - Use within 48 hours after mixing with water
- Active ingredient:
  - Dichloroisocyanuric acid
- No EPA registration



Four components – (A) active component, (B) buffering component, (C) surfactant, and water (not shown)

SporKlenz RTU

RTU – Ready to Use

- Steris Corporation
- “Ready to Use” (RTU) directly from the container
  - Typically applied as a liquid
  - Shelf life is 13 months from date of packaging
- Active ingredients:
  - Hydrogen peroxide
  - Peroxyacetic acid
  - Acetic acid
- EPA registration as a sterilant

EasyDECON

- EFT Holdings, Inc.
- Three components are mixed prior to application as a foam (recommended), liquid, mist or fog
  - Use within 8 hours after mixing
- Active ingredients:
  - Hydrogen peroxide
  - Benzalkonium chloride
- EPA registration as a disinfectant

Three components – (1) surfactant, (2) hydrogen peroxide, and (3) accelerator

Decon Green

- Steris Corporation
- Three components are mixed prior to application
  - Typically applied as a liquid, but can be applied as a foam
- Active ingredient:
  - Hydrogen peroxide
- No EPA registration

Three components – (A) surfactant, (B) hydrogen peroxide, and (C) activators and buffers

MDF-200 Foam

- Modec, Inc.
- Three components are mixed prior to application as a foam, liquid, spray or fog
  - Use within 8 hours after mixing
- Active ingredients:
  - Hydrogen peroxide
  - Benzalkonium chloride
- EPA registration as a disinfectant

Three components – (A) surfactant, (B) hydrogen peroxide, and (C) accelerator

Persistence of Surrogate Radioisotopes on Drinking Water Infrastructure and the Effectiveness of Decontamination Methods

Jeff Szabo, EPA/ORD/NHSRC

EPA United States Environmental Protection Agency

Persistence of Surrogate Radioisotopes on Drinking Water Infrastructure and the Effectiveness of Decontamination Methods

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National Homeland Security Research Center, Water Infrastructure Protection Division

August 20, 2010

EPA United States Environmental Protection Agency

Outline

- Motivation
- Experimental Design, Materials and Methods
- Experimental Results
- Conclusions
- Future Research

1

Motivation

- Decontamination of water infrastructure has become a research priority for WIPD in recent years
- Radioisotope persistence on drinking water infrastructure has been studied (U and Ra)
- Isotopes of homeland security interest are Cs, Sr and Co
- Data on Cs, Co and Sr persistence and decontamination is scarce in the open literature
  - –WRF project 2981 is a notable exception

2

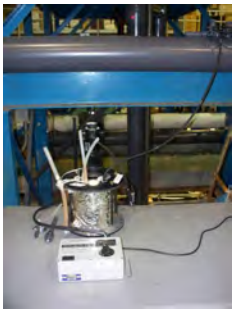
Experimental Design

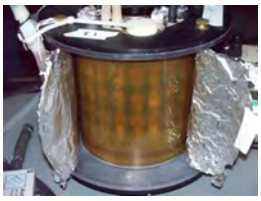
- Multiple options for simulating distribution systems at EPA's Test and Evaluation (T&E) facility
- Pilot and bench scale systems were available
- Chlorinated and chloraminated water is available

3

Experimental Design

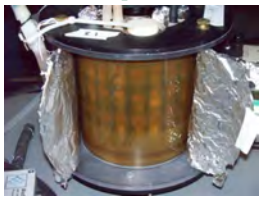
- Experiments were performed in a bench scale system: biofilm annual reactor
  - Allows for variation of shear independent of flow
  - 60 coupons available
  - Minimizes the mass of contaminant
  - Easier to clean between experiments and can be sterilized





4

Experimental Methodology-Persistence



- Condition iron coupons in tap water for 1+ months
- Spike reactors with stable soluble Cs, Co or Sr salts
  - CsCl, $CoCl_2$, $SrCl_2$
- Harvest coupon and bulk phase samples over time
- Analyze by ICP-OES
  - Coupon samples undergo microwave assisted digestion with nitric acid
- Persistence is monitored for one month or more

5

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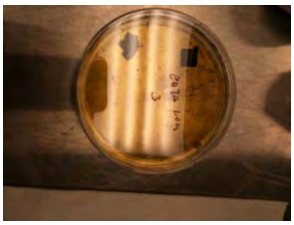
Experimental Methodology-Decontamination

- Flushing and increasing disinfectant concentration performed in the reactor
- Flushing is simulated by increasing the rotational speed of the reactor drum
- Decontamination by altering water quality was attempted:
  - High and low pH



6

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Experimental Methodology-ESEM

http://www.eng.uc.edu/amcc/EM.html

- Environmental Scanning Electron Microscopy (ESEM)
- Acquired images of the corrosion surface
- Used to confirm the presence or absence of cesium and cobalt on the coupon surfaces.
- “Maps” of cesium or cobalt on the coupon were made
- Also shows the spatial distribution of Cs or Co

7

Experimental Methodology-XAS

- Co and Sr were further analyzed at Argonne National Laboratory
- X-ray adsorption spectroscopy (XAS)
  - X-Ray Adsorption Near Edge Spectroscopy (XANES)
  - Extended X-Ray Adsorption Fine Structure (EXAFS)
- XANES=>valence/oxidation state
- EXAFS=>bonding

http://www.aps.anl.gov/

8

Results-Cesium

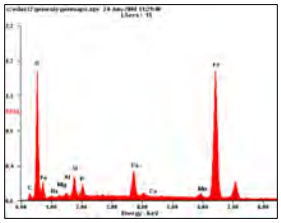
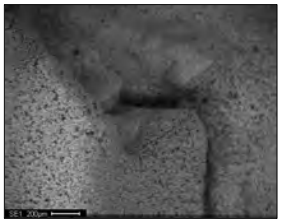
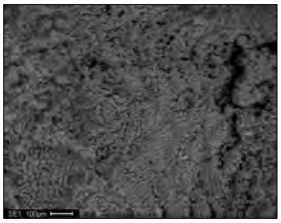
- Cesium was not detected on the coupons
- Initial bulk phase concentrations of 10 and 100 mg/L
- Bulk phase concentration was constant
  - Indicates no adsorption
- Lack of adsorption could be due to competing ions (i.e. Ca^{2+}, Mg^{2+})
- Literature shows that there could be very different results with concrete lined pipe

9

Results-Cesium ESEM

- Elemental mapping showed no cesium was present

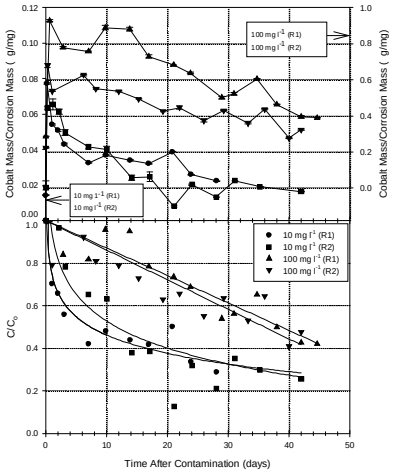


10

Results-Cobalt Persistence

- Cobalt persisted for 42 days
  - Likely longer
- Soluble $CoCl_2$ formed a precipitate upon introduction to chlorinated water
  - Online water quality sensor tests confirmed this
- A black film formed on the coupons one day after injection
  - Cobalt II or III?



11

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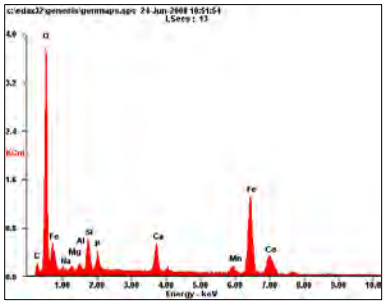
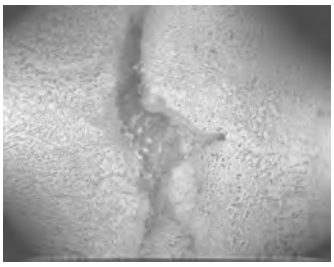
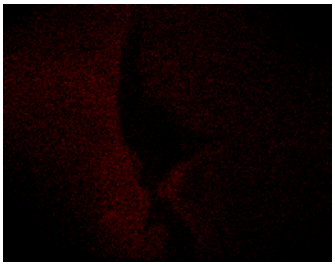
Results-Cobalt ESEM

- Cobalt was uniformly spread over the coupon surface





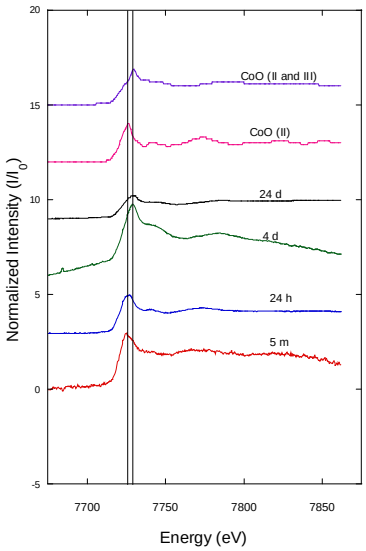


12

EPA United States Environmental Protection Agency

Results-Cobalt XAFS

- Cobalt on coupon samples immediately after injection and days after injection were compared
  - Standard also analyzed
- After one day in the reactor, cobalt was in the III oxidation state, not the II oxidation state
- Co(II) is very soluble
- Co(III) is very insoluble
- Free chlorine oxidized Co(II) to Co(III)



13

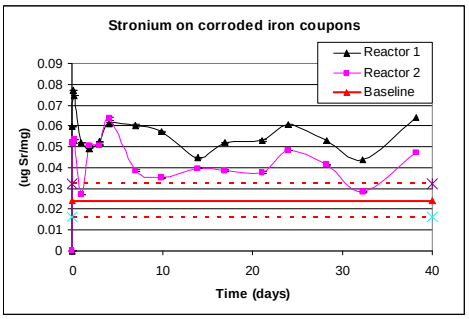
Results-Cobalt Decontamination

- XAS results informed the decontamination approach
- Co(III) compounds are soluble in acids (and not much else)
- Coupons exposed to ethanol, low pH (1.3) and high pH (14)
- Low pH removed 92% of the cobalt after 1 day of exposure
  - Sulfuric acid
- Cobalt and iron dissolution occurred

14

Results-Strontium

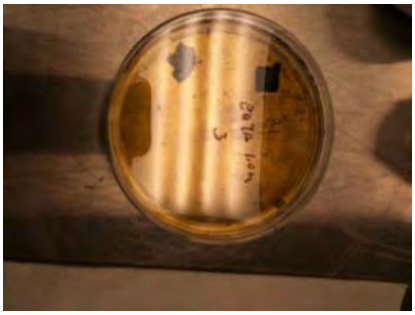
- Sr experiments are ongoing
- Sr is present in Cincinnati tap water at 0.2-0.4 mg/L
- This has made detection of injected Sr difficult
- It does show that strontium can adhere
  - What is it associating with?



15

Results-Strontium Decontamination

- Strontium coupons were exposed to calcium and EDTA (0.005, 0.05 and 0.5 M pH 8)
- Calcium was ineffective
- EDTA removed 20, 60 and 90% at 0.005, 0.05 and 0.5 M
- Removal was due to complexation of iron and disruption of the corrosion surface, not just removal of strontium



16

Results-Strontium XAS

- XANES and EXAFS data were collected
- XANES confirmed that Sr+2 was present, but this was not unexpected (doesn't oxidize)
- EXAFS data is not clear. Further analysis may be required
- Strontium is similar chemically to calcium
  - Ca and Sr are adjacent on the periodic table
- Dissolution of calcite deposits (lowering pH) may remove calcium and associated strontium

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Conclusions

- Cesium was not detected on the iron coupons
  - –Concrete lined may be a different story
- Cobalt did persist after oxidation
  - –Acid decontamination was effective, but is it a feasible decontamination option?
- Strontium appears to persist, but what it is persisting on is uncertain
  - –Changing water quality to dissolve calcite deposits is a possible decontamination strategy

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Future Work

- Mechanisms of Sr persistence will be examined
  - –This will inform the decontamination strategy
- Examine Cs, Sr and Co persistence on concrete lined coupons
- Repeat the same experiments in chloraminated water
  - –Sr work has used free chlorine and chloramines
- Decontamination may focus on cleaning or decontamination agents that meet NSF-60 standards

19

Development of a Novel Bioassay for Detection of Functional Ricin

Vipin K. Rastogi, R&T Directorate, US Army–ECBC

Development of a Novel Bioassay Detection of Functional Ricin

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1.U.S. EPA, ORD/NHSRC, RTP, NC
2.Biophysical chemistry Branch

Since 1917- A Tradition of Solutions.

Presented at the 2010 U.S. EPA Decontamination Research & Development Conference in Durham, NC on April 13-15, 2010

Outline and Scope

- Diversity of Bio-threat Agents
- Toxin Categories
- Ricin Toxin Characteristics and Mode of Action
- Approaches for Ricin Toxin Detection
  - Surface or Structure-based
    - Surface Epitopes - Immuno
  - Function-based
    - Protein Synthesis Inhibition
    - Ribosomal rRNA Cleavage
- Functional Ricin – Novel Bioassay
- Decontamination of Ricin

Since 1917- A Tradition of Solutions.

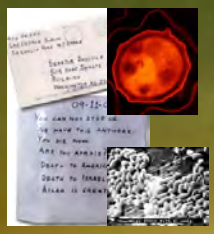
Bio-warfare Agents

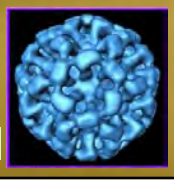
Replicating

Francisella tularensis

Yersinia pestis

Bacillus anthracis
Spores

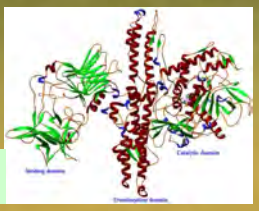




Viruses

Non-replicating - Toxins

Clostridium botulinum
(Botulinum Toxin)



Bio-weapon Toxin Characteristics

Soluble proteins produced by plants or bacteria capable of causing damage to the host by destroying cells or disrupt cellular metabolism

Toxin	Toxic Dose (mg)	Host
Botulism Type D	0.8×10^{-8}	Mouse
Tetanus	4×10^{-8}	Mouse
Shigella Neurotoxin	2.3×10^{-6}	Rabbit
Diphtheria	6×10^{-5}	Guinea Pig
RICIN	0.2-0.5	Human

- Resemble enzymes – denatured by heat, acids, and have high biological activity (most act catalytically) and exhibit specificity of action
- Many act intracellularly and consists of two subunits, chain A and chain B

Ricin – Ribosome Inactivating Toxins

- **Bacterial shiga (Stx), diphtheria (DT), *Pseudomonas* exotoxin (PE), and plant ricin are from diverse sources, but they inhibit protein synthesis and thereby result in cell death**
- **DT and PE causes inactivation of elongation factor – EF2**
- **Plant ricin and Stx act as N-glucosidase, cleaving adenine from rRNA and thus results in ribosome inactivation**
- **Ricin is extracted from castor bean (*Ricinus communis*) seeds**
  - **Average lethal dose is 0.2 - 0.5 mg/person**
  - **Twice as deadly as cobra venom**
  - **The most toxic protein toxin**
  - **Consists of two subunits joined by a disulfide bridge, chain B (262 residues, 34 kD, binds to cell membrane) and chain A (267 residues, 32 kD, internalized and serves as a ribosome inactivating protein)**
  - **No antidote and easy to produce and procure – bio-weapon**
  - **Chain A cleaves an adenine from 28S rRNA at 4324 position near the 3'-end**
  - **This deletion preclude binding of the EF-2 and thereby stops protein synthesis**

Ricin Detection – Structure-based

- **Immuno- or Antibody-based Detection**
  - Elisa
    - Limit of Detection (LOD) – 4 ng/mL
    - Takes several hours and requires trained personnel
    - Sandwich immunoassay LOD -1 ng/mL
- **Aptamers**
  - Oligonucleotides or peptides binding to specific target molecules
    - DNA or RNA - Bind to a variety of molecules with very high affinity
    - Using fluorescently-labeled RNA aptamers, LOD – 14 – 300 ng/mL
- **Analytical Methods and Mass Spectrometry**
  - High sensitivity, high specificity, and can identify and quantify ricin
  - LC-ES MS(MS) or HPLC/GC-Mass Spectrometry
    - High cost and sophisticated instrumentation
    - 10 pmol of ricin detected and in crude preparations

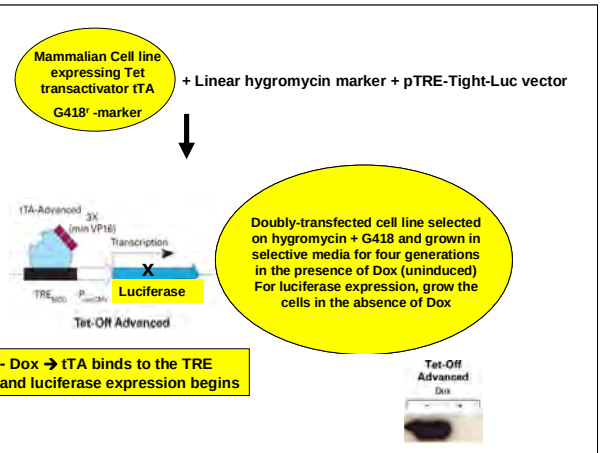
Ricin Detection – Function-based

- **Detection of Functional Catalytic chain A**
  - Release of adenine base from rRNA
  - LOD for adenine 2.4 ng/mL after conversion to a fluorescent derivative
  - HPLC-MS also used for detection of adenine
- **Inhibition of *In vitro* Protein Synthesis**
  - Because of high amplification, LOD in the range of 10 fg/mL
- ***In vitro* Transcription & Translation (IVT)**
  - Green fluorescent protein and luciferase gene vectors expressed using wheat germ kit
  - Ricin chain A resulted in inhibition of fluorescence
  - The ricin LOD – 0.3 ng/mL and detection performed in a microfluidic well-in-a-well device
  - Very powerful detection system relying on cessation of protein synthesis from expression vectors in the presence of chain
  - Does not assay for functional chain B or holo-ricin!

Ricin Detection – Cell-based

- ***In vivo* Protein Synthesis Inhibition**
  - Vero monkey cell line transfected with adenoviral vector expressing luciferase gene
  - Luciferase gene expressed in transduced cell line, which can be easily detected by light production using luminometer
  - Engineered cells not stable
- **General Cytotoxicity**
  - Vero monkey cell line along with MTT has been used
  - Low linear range for response to ricin
  - MTT assay relies on availability of reducing power, NADH
  - Ricin mode of action is via inhibition of protein synthesis, so toxicity is not related
- **Protein Synthesis-based Cytotoxicity**
  - Vero cell line engineered with a reporter gene, green fluorescent protein (GFP) under a constitutively expressing promoter, cytomegalovirus (CMV)
  - Response to ricin in 6 hours (IC_{50} = 1.8 ng/mL) with a LOD of 1 ng/ml

Bioassay Concept



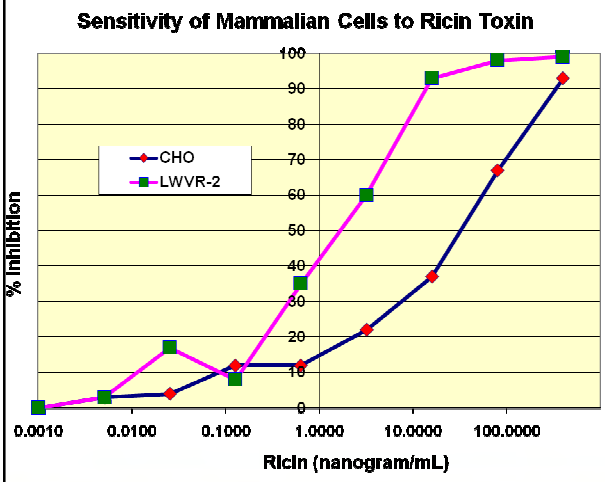
1. The host cell line, HeLa Tet-Off produces a Tet repressor and has a G418 resistance marker. The repressor binds to the promoter in the presence of Tet or Dox
2. pTRE plasmid with luciferase gene s into this cell line along with hygromycin linear marker into HeLa tet-Off cell line
3. Stable double transfectant selected and screened for luciferase expression or induction in the absence of Tet
4. Clone LWVR-2 selected on the basis of highest ratio of luciferase activity in the presence and absence of Tet

Clonal Selection

Clone #	UNINDUCED		INDUCED		Fold Induction
	Average RLU	SD	Average RLU	SD	
1-1	32	5	56	4	2
1-2	42	5	43434	10239	1040
1-3	36	6	38	11	1
1-4	35	6	37	3	1
1-5	26	3	28	6	1
1-6	29	7	75	102	3
1-7	17	4	30	9	2
2-1	36	5	92	10	3
2-2	31	3	525	464	17
2-3	42	6	33	5	1
2-5	25	4	23	3	1
2-6	32	3	16	5	0
2-7	44	44	23	5	1
2-8	93	132	24	7	0
2-9	23	2	21	5	1
3-1	95	21	6644	492	70
3-3	28	6	168	52	6
3-4	31	5	53	10	2
3-5	210	41	16149	899	77
4-1	34	9	337	47	10
4-2	28	8	6182	1227	221
4-3	30	3	113	19	4
4-5	29	6	45	31	2
4-6	39	18	35	8	1
4-7	29	8	42	18	1

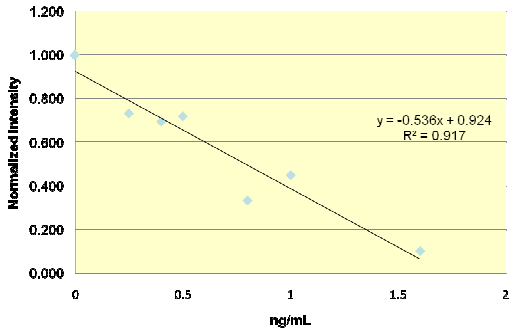
1. Clone LWVR-2 (1-2) exhibited the highest fold induction and was therefore selected for further analysis
2. The LWVR-2 clone was very stable, since even after passaging for 100 times, comparable degree of induction was observed
3. Cell seeding at 10^4 per 100 mL volume in a 96-well micro-titer plate, ricin addition at the time of cell seeding, and 24 hour induction, i.e. removal of Dox were selected as assay conditions

Ricin Sensitivity



- In comparison to the control CHO cell-line (IC50 = 16-24 ng/mL), the recombinant LWVR-2 clone is very sensitive to the presence of functional holo-ricin (IC50 = 3.2 ng/mL)
- Limit of detection by the recombinant HeLa cell line = 0.6 – 0.8 ng/mL
- Only two steps for the bioassay, seeding and luciferase detection within 24 hours

Bioassay Sensitivity



- Current assay based on luciferase expression in VRLW-2 cells can detect as low as 0.25 ng/mL ricin
- Response linear between .025 and 1.5 ng/mL
- The present assay is highly sensitive

Bioassay based Decon - Parameters

- Test decon solutions included 1% hydrogen peroxide, 1:20th diluted bleach, and 250 ppm chlorine dioxide solution
- Decon contact times were 30 sec or 1 min
- Test coupon types included steel (2x2-cm size)
- An aliquot of 7.5 mL test decon solution used per coupon
- An aliquot of 2.5 mL 2M sodium thiosulfate used as a neutralizer
- >80% ricin was recovered from the coupon
- Neutralized test decon solution used for ricin extraction from control coupons
- Extracted ricin needed to be diluted 1:50 before bioassay testing

Bioassay-based Decon Protocol

FLOW CHART

25 L Crude ricin (0.5%; 875 g total protein or 5 g ricin) spotted and dried over-night

↓

Add 7.5 mL of decon solution to test coupons in a 50 mL tube, tube and add 2.5 ml of 2M Na2S2O4

OR

10 mL of neutralized decon sol to control coupons in a 50 mL

↓

Extracted sampled diluted 1:50

↓

Performed an eight-series 1:2 serial dilutions and tested 25 L aliquot in a micro-titer plate well containing 100 L or ~10^4 LWVR-2 cells under induced condition (-DOX)

↓

Perform luciferase assay after 24 hours, and read luminescence intensity using a Promega GloMax luminometer

Ricin Decontamination

Test Decon Solution	Ricin Recovery (%)	Estimated Ricin Remaining (ng)	Comments
1:20 Diluted bleach	80	0	No pH adjustment
250 ppm CD Solution	97	0	No ricin detected (LOD = <0.2 ng)
1% H_2O_2	94	1900	Partial Decon

- **Approximately 4.8 g of crude ricin was dried per steel coupon**
- **The contact time was 30 seconds**
- **LWVR-2 recombinant cell line seeded at 10^4/well and an aliquot of 25 L diluted samples (ranging from 1:50 - 1:6400) added at the time of cell seeding**
- **Luciferase expression was analyzed 18-24 hour following ricin exposure**

Current ECBC-EPA Bioassay

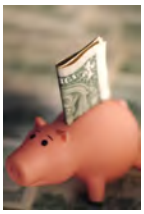
Unique Advantages

- **Detection Based on Functional Ricin Mode of Action**
- **Stable Recombinant Cell-line - with an inducible gene expression system**
- **High-throughput and Scalable – micro-titer format**
- **Simple Setup – requires only two steps**
- **Rapid Detection – GloMax plate reader scans the plate within minutes**
- **Decon Protocol Developed for Using Common Disinfectants**
- **Low Detection Limit (<0.2 ng/mL)**
- **Applicable to All Binary Toxins Affecting Gene Expression**
- **Can be Fully Automated**
- **Does Not Require Highly-trained Personnel**

Conclusions & Discussion

- A recombinant HeLa cell line, LWVR-2, expressing luciferase under an inducible Tet promoter was applicable for the ricin bioassay
- The cell-line was stable as luciferase expression was unchanged even after 100 passages
- The bioassay set up required only two steps
- The bioassay was very sensitive, as 0.2 ng/mL ricin detectable
- A decon protocol was optimized for common disinfectants
- Crude ricin was readily decontaminated with COTS disinfectants
- Future studies conducted in shortening the assay time from 18-24 h
- Additional decon solutions need to be tested
- Increase the shelf life of reagents and cell-line

ACKNOWLEDGEMENTS



- FUNDING

  EPA – NHSRC, Office of Research and Development, RTP, NC

  Future – ??

- Team

  Lalena Wallace, Saumil S. Shah, and Shawn Ryan

Evaluating Cesium Contamination of Urban Building Materials: Two Instrumental Approaches

Julia G. Barzyk, EPA/ORD/NHSRC

Presentation not available for distribution

Biotoxin Test Method Development

Linda C. Beck, Naval Surface Warfare Center, Dahlgren Division

Biotoxin Test Method Development

Linda C. Beck, PhD **Wynn Vo**
Elaine M. Strauss, PhD **R. Chris Hodge**

Naval Surface Warfare Center, Dahlgren VA

OUTLINE

- **Background**
- **Objective**
- **Materials and Methods**
- **Test Method Development and Results**
- **Conclusions**
- **Future Studies**

Biotoxin Test Method Development

Naval Surface Warfare Center, Dahlgren, VA

BACKGROUND

- DoD is working to develop standardized test methods for determining the efficacy of liquid decontaminants on bacterial spores and other biowarfare agents on hard and porous surfaces
- Biotoxins as weapons is an emerging threat.
- There is a need to assess the efficacy of decontaminants, originally developed for chem and bio warfare agents, as countermeasures against biotoxins.
- Accurate and precise test methods for sampling and measurement are needed for valid comparison.
- Test Operations Procedure (TOP) 8-2-061 document does not include methods of evaluations of decons used to mitigate biotoxin hazards.

Biotoxin Test Method Development

Naval Surface Warfare Center, Dahlgren, VA

OBJECTIVE

to develop, standardize, and verify a method for evaluation of the efficacy of liquid decontaminants against biotoxins on DoD relevant surfaces and coatings

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Biotoxin Test Method Development

Naval Surface Warfare Center, Dahlgren, VA

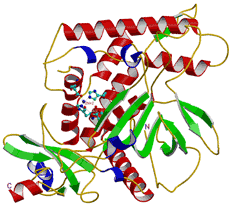
CBR CONCEPTS & EXPERIMENTATION BRANCH

MATERIALS

Biotoxins

Protein: Botulinum toxin and Ricin

Molecular: T-2 Mycotoxin and Aflatoxin



Botulinum Toxin

Coupons

Glass

Polycarbonate

JSGPM Mask Material

Aluminum 5052

CARC – Painted Steel

Fursarium toxin (T2)

Decontaminants

pH adjusted bleach	DF 200
HTH	10% Bleach

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Biotoxin Test Method Development

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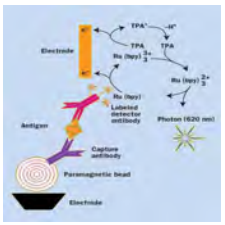
METHODS

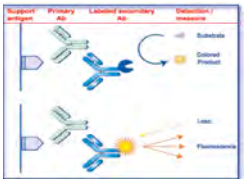
Assays to Evaluate the Biotoxins



1. Proteins

Electrochemiluminescence (ECL)

BioVeris M1M analyzer



2. Molecular

ELISA Immunoassay

Stat Fax 303

The % recovery was determined by comparison to the standard curve run in parallel with the test samples

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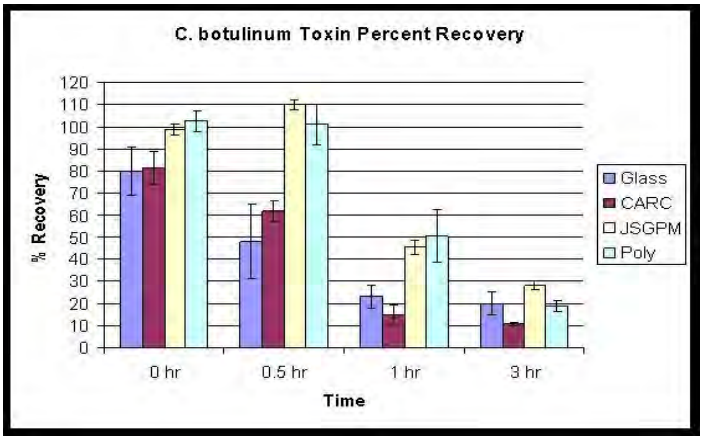
TEST METHOD DEVELOPMENT

Approach:

- Limit of Detection
- Time Course Experiments
- Baseline Recoveries
- Standard Curves
- Test Method

Biotoxin Test Method Development
Naval Surface Warfare Center, Dahlgren, VA



Time Course Experiments

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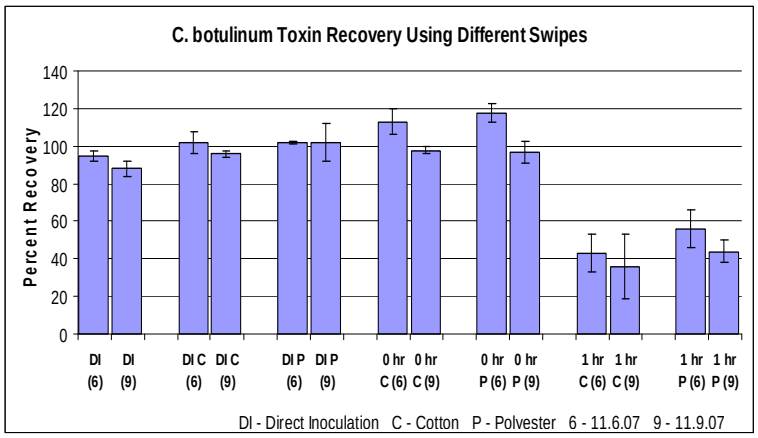
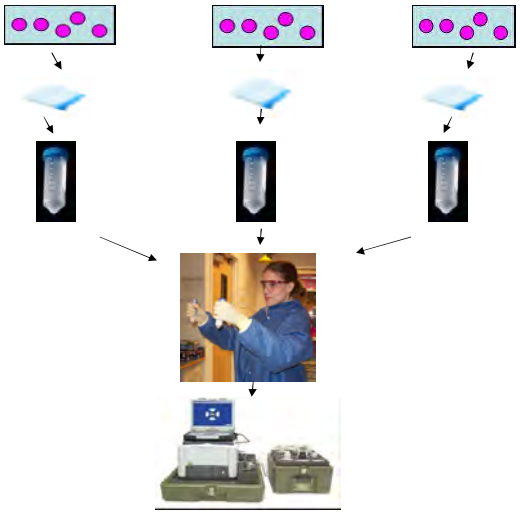


Cotton vs. Polyester

Biotoxin Test Method Development

Naval Surface Warfare Center, Dahlgren, VA



1. **Apply toxin to coupons (total 50 ul)**
2. **Wipe coupon surface with cotton swipe**
3. **Place cotton swipe in buffer**
4. **Handshake for 2 minutes**
5. **Analyze using ECL or ELISA**

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Biotoxin Test Method Development

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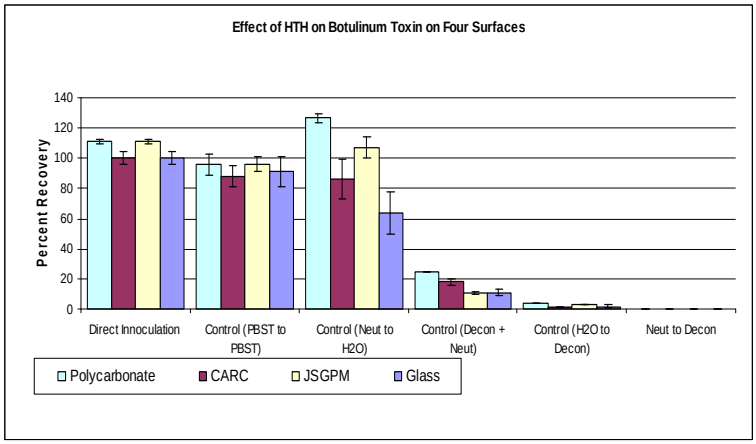

Botulinum Toxin: HTH

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Biotoxin Test Method Development

Naval Surface Warfare Center, Dahlgren, VA

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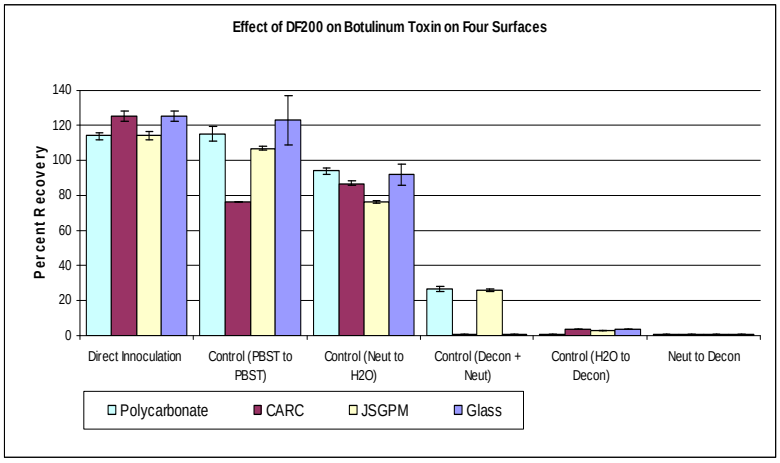


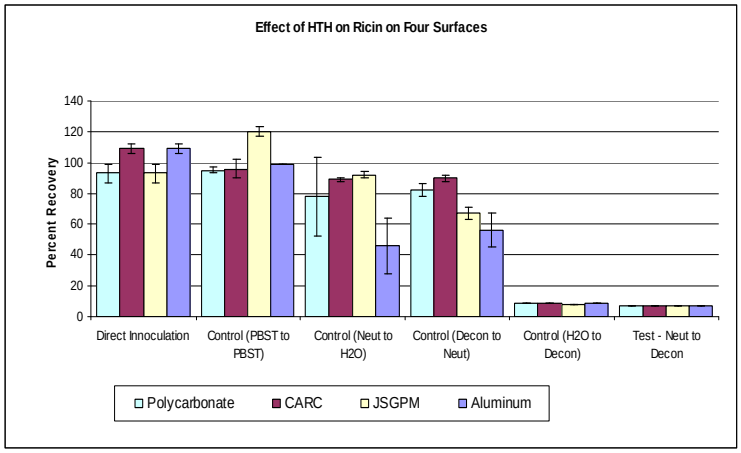
Botulinum Toxin: DF 200

NAVSEA WARFARE CENTERS DAHLGREN

Biotoxin Test Method Development

Naval Surface Warfare Center, Dahlgren, VA

CBR CONCEPTS & EXPERIMENTATION BRANCH



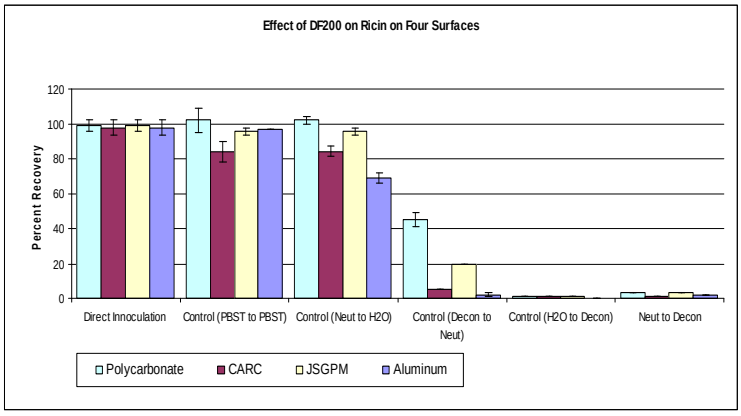
Ricin: HTH

NAVSEA WARFARE CENTERS DAHLGREN

Biotoxin Test Method Development

Naval Surface Warfare Center, Dahlgren, VA

CBR CONCEPTS & EXPERIMENTATION BRANCH



Ricin: DF 200

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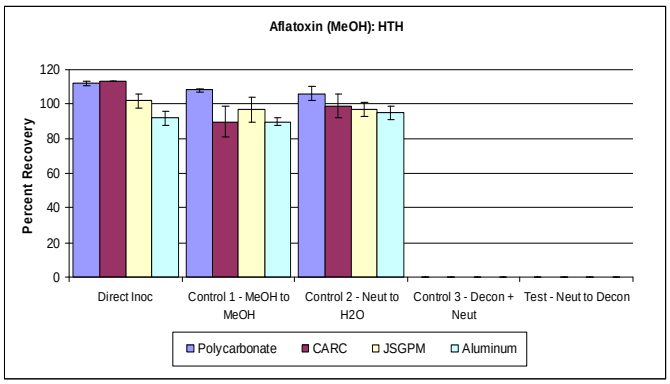

Aflatoxin: HTH

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Biotoxin Test Method Development

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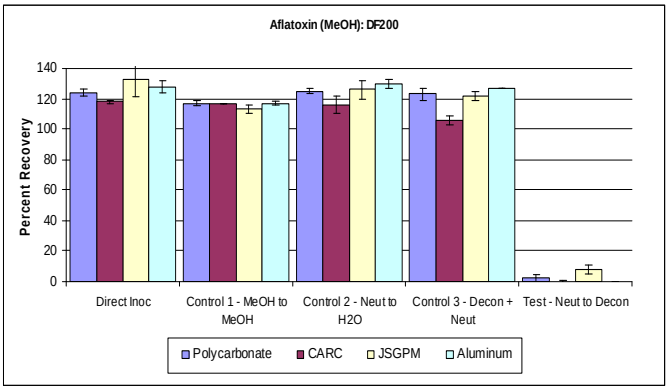

Aflatoxin: DF 200

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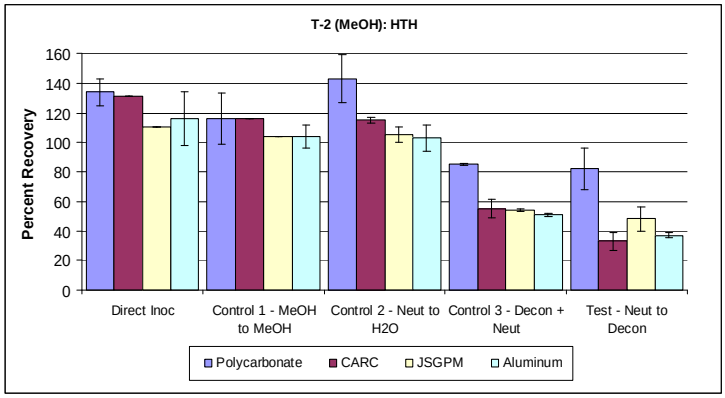


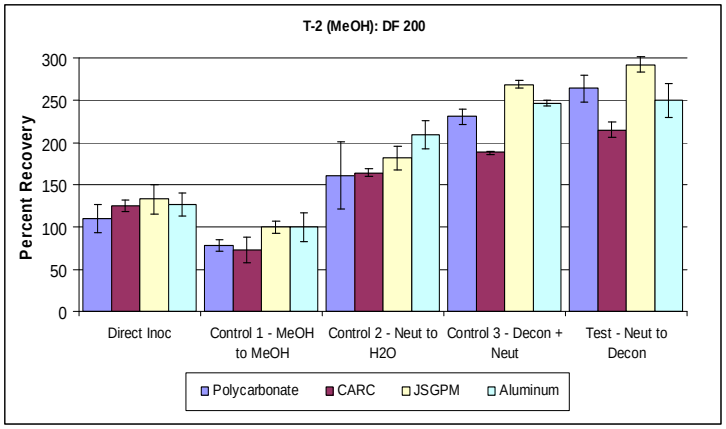
T-2: HTH

NAVSEA WARFARE CENTERS DAHLGREN

Biotoxin Test Method Development

Naval Surface Warfare Center, Dahlgren, VA

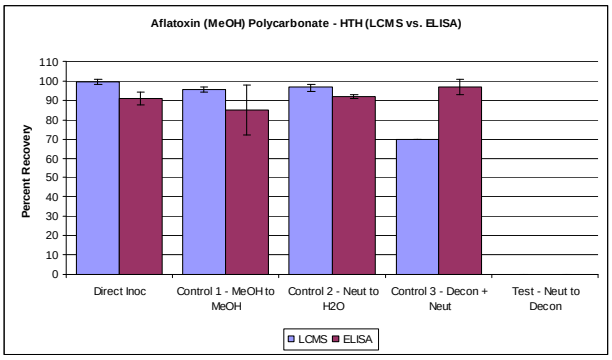
CBR CONCEPTS & EXPERIMENTATION BRANCH



T-2: DF 200

Biotoxin Test Method Development

Naval Surface Warfare Center, Dahlgren, VA



Percent Recovery of Aflatoxin by LCMS and ELISA after treatment with HTH on polycarbonate. The control data are the average of duplicate runs and the test data (neut to decon) are the average of 5 replicates.

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Biotoxin Test Method Development

Naval Surface Warfare Center, Dahlgren, VA

CONCLUSIONS

- **Time course experiments demonstrated that the percent recovery of Botulinum Type A Toxin Complex is reduced (10-28%) after 3 hours suggesting that the toxin may be denatured.**
- **Analysis of the data from the time course experiments suggest an optimum time of 15 minutes for the method development.**
- **Data from the protein biotoxin experiments and Aflatoxin trials show that the decontaminants are effective against the toxins and the data support our method development.**
- **Data from the T-2: DF 200 % recovery experiments are inconclusive because the 14 % SMS neutralizer appears to interfere with the T-2 assay. However, the control data from the T-2 experiments support our test methodology.**
- **The reproducibility of the sampling procedure and analysis by Liquid Chromatography Mass Spectrometry (LCMS) for aflatoxin suggest that this biotoxin test method is valid and indicates that LCMS may be a viable alternate method of analysis for the molecular toxins.**
- **The parameters for analysis of the T2 Mycotoxin by LCMS were not fully defined, so the data was not available for comparison.**

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FUTURE STUDIES

Our understanding of the biotoxin activity and byproducts produced after exposure of the toxins to the decontaminants is limited. Future studies to characterize the byproducts and analyze the toxin activity after decontamination would be advantageous.




Acknowledgements

This effort was sponsored by:

- Defense Threat Reduction Agency, S&T Office
- Joint Program Manager for Decontamination

We would like to thank our colleagues at NSWCDD for technical support, especially Max Lupton, Dan Shegogue Ph.D., Claire Wells, Lindsay Sobota

and

Richard M. Phan; William G. Davis US Army Dugway Proving Ground and Wesley D. Ercanbrack, Abbey L. Fausett, Jacobs Dugway Team

Impact of RDD Decontamination Strategies on Quantities and Characteristics of Resulting Waste and Debris

Paul Lemieux, EPA/ORD/NHSRC

Impact of RDD Decontamination Strategies on Quantities and Characteristics of Resulting Waste and Debris

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M. Ierardi
EPA/ORCR

Why We Are Doing This Work?

- **RDD waste issues linked with decontamination**
- **Waste management impacts restoration timeline**
- **Waste decisions need to be made early**
  - –Pre-selection of disposal options
  - –Identification for triage/staging/storage areas
- **Tool for Liberty RadEx to examine waste issues**

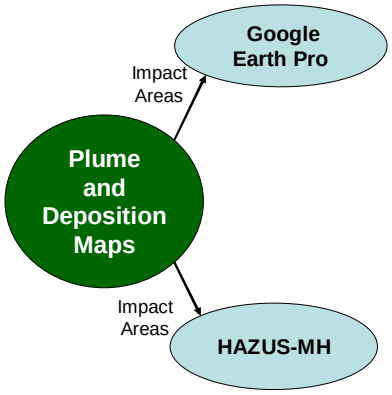
Outline

- Project objectives
- Methodology
- Results
- Conclusions
- Implications

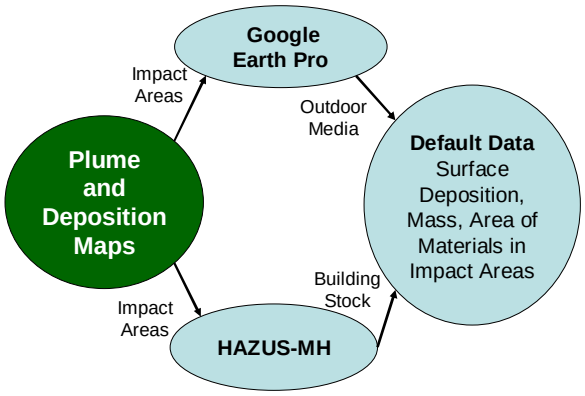
Project Objectives

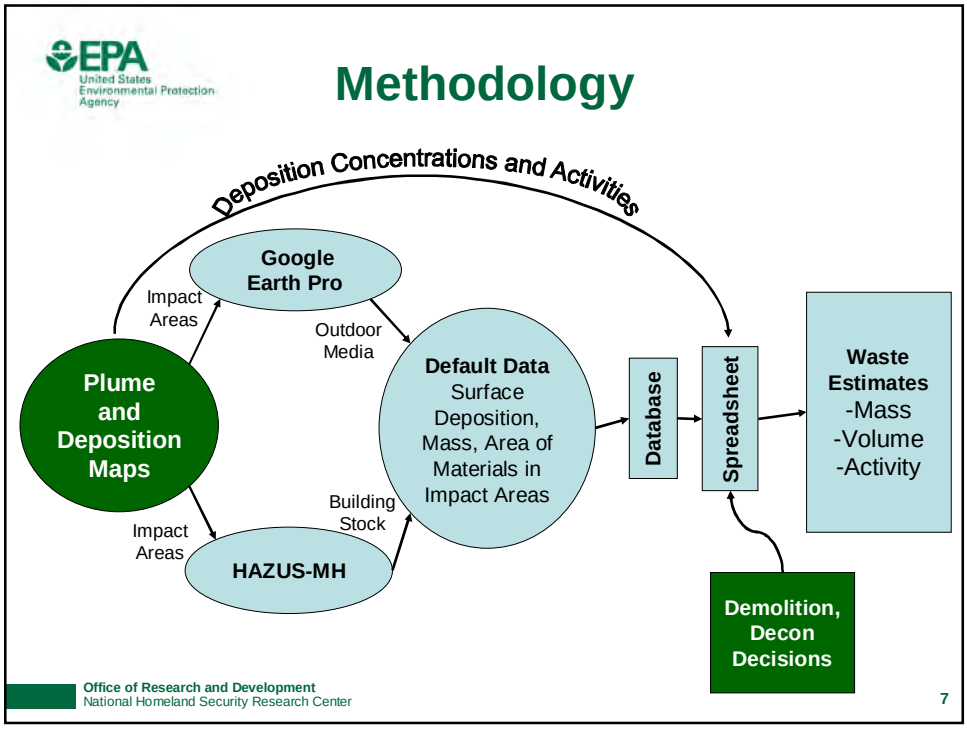
- 1st order estimate of waste from RDD event
- Use commercially available software/databases
- Adjust parameters based on decon options
- Develop generic methodology for any RDD event
- Perform sensitivity analysis

Methodology



Methodology




EPA
United States Environmental Protection Agency
Methodology
Deposition Concentrations and Activities
Google Earth Pro
Impact Areas
Outdoor Media
Plume and Deposition Maps
Default Data Surface Deposition, Mass, Area of Materials in Impact Areas
Database
Spreadsheet
Waste Estimates -Mass -Volume -Activity
Impact Areas
Building Stock
HAZUS-MH
Demolition, Decon Decisions
Office of Research and Development
National Homeland Security Research Center
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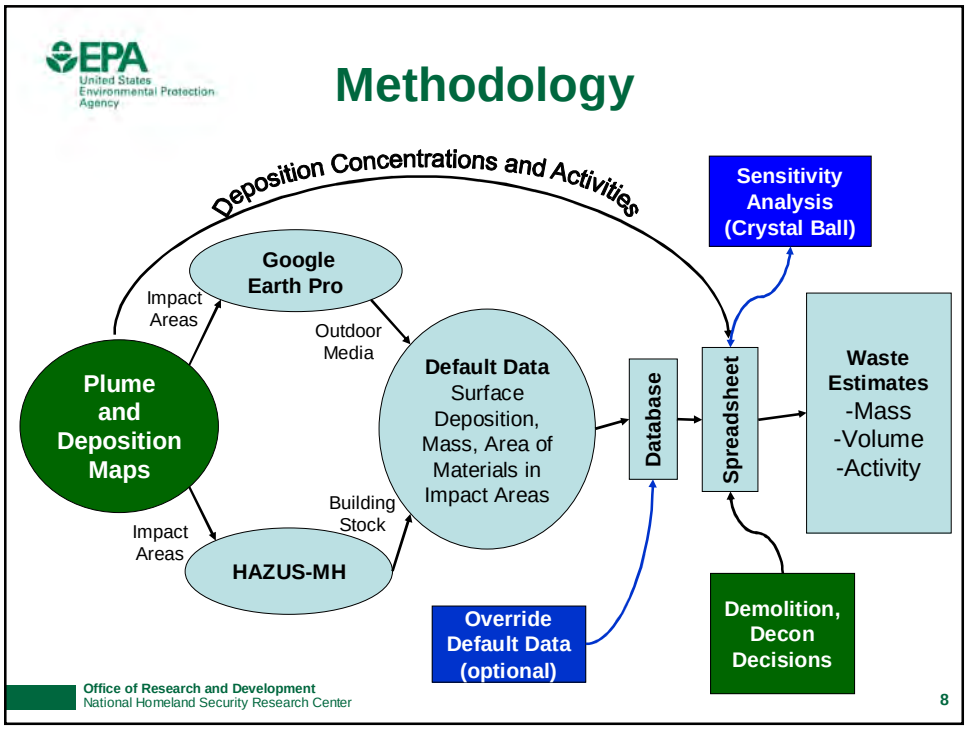
EPA
United States Environmental Protection Agency
Methodology
Deposition Concentrations and Activities
Sensitivity Analysis (Crystal Ball)
Google Earth Pro
Impact Areas
Outdoor Media
Plume and Deposition Maps
Default Data Surface Deposition, Mass, Area of Materials in Impact Areas
Database
Spreadsheet
Waste Estimates -Mass -Volume -Activity
Impact Areas
Building Stock
HAZUS-MH
Override Default Data (optional)
Demolition, Decon Decisions
Office of Research and Development
National Homeland Security Research Center
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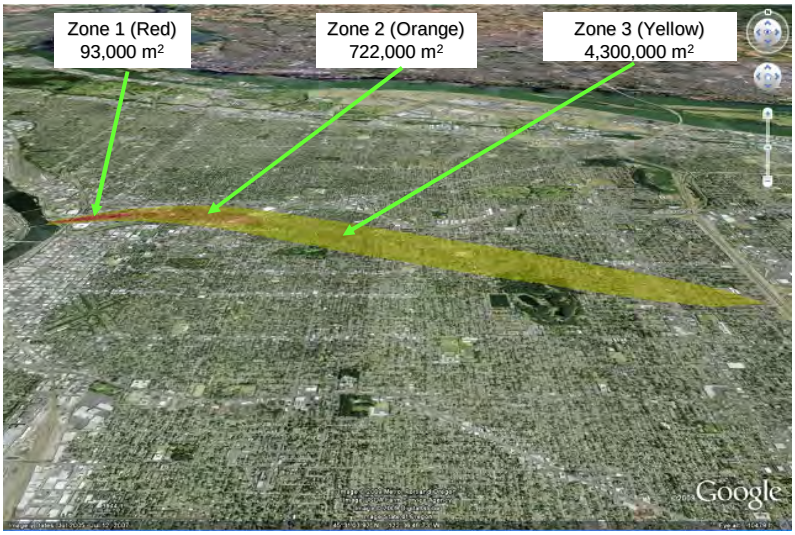
TOPOFF4 Scenario

- Simultaneous terrorist attacks in Portland, OR, Phoenix, AZ, and Guam
- Oklahoma City-style truck bomb with radioactive CsCl on board
- Exercise started at t=0 and continued until situation had stabilized
- Long-term restoration was not addressed

TOPOFF4 Plume Files



EPA United States Environmental Protection Agency

Results: Example Building Stock

General and Specific Occupancy Type	Zone 3	
	#	m^2
Residential	4,159	705,349
Commercial	324	120,481
Industrial	76	17,998
Government	4	2,233
Education	13	7,113
TOTALS	**4,576**	**853,174**

EPA United States Environmental Protection Agency

Results: Outdoor Areas (1000 m^2)

Media	Zone 1	Zone 2	Zone 3
Total Deposition Area	**93**	**722**	**4,300**
Asphalt	**37**	**280**	**655**
Concrete	**28**	**211**	**523**
Soils/Vegetation	**7**	**93**	**1,051**

Adjustable Parameters

- **Decisions available in tool**
  - Demolition/decontamination
- **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

Demolition/Decon Assumptions Used

- **Zone 1**
  - 90% demolition, 10% decontamination
- **Zone 2**
  - 10% demolition, 90% decontamination
- **Zone 3**
  - 10% demolition, 90% decontamination

EPA United States Environmental Protection Agency

Decon Assumptions Used

Media	Zone 1	Zone 2	Zone 3
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%

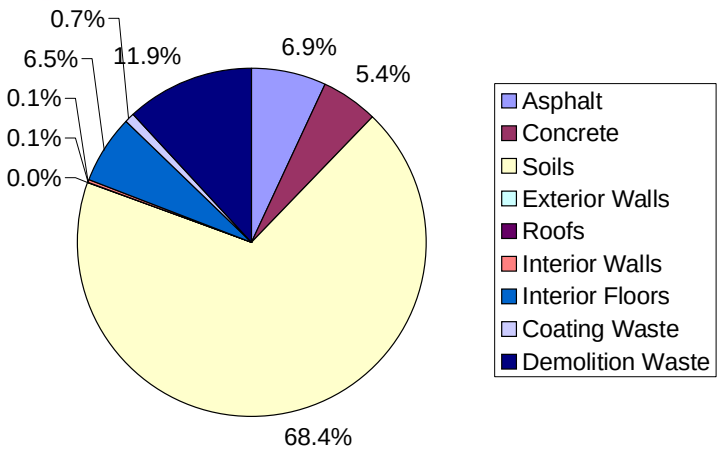
EPA United States Environmental Protection Agency

Results: Estimated Total Waste

Media	Zone 1	Zone 2	Zone 3
Outdoor Materials (1000 metric tons)	5.8	48	368
Building Demolition (1000 metric tons)	16	15	42
Building Decontamination (1000 metric tons)	0.2	15	27
Wastewater (billion liters)	0.013	2.1	11

This roughly equals 18 % of MSW generated in OR in 2007 and 6% of annual water usage in Portland

Waste Volume %



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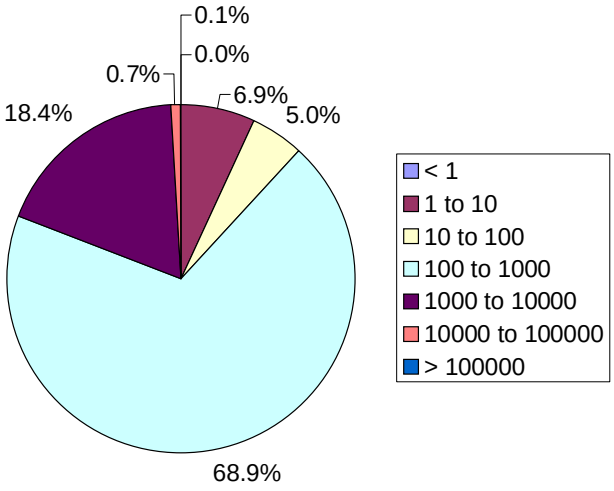
Est. Solid Waste Activity by Vol % (µCi/m^3)



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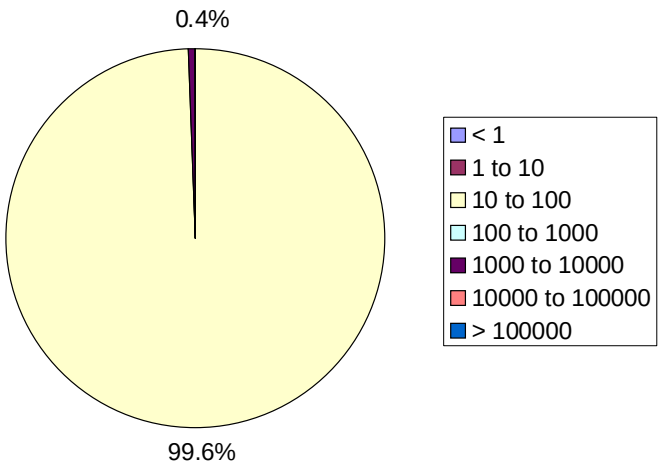
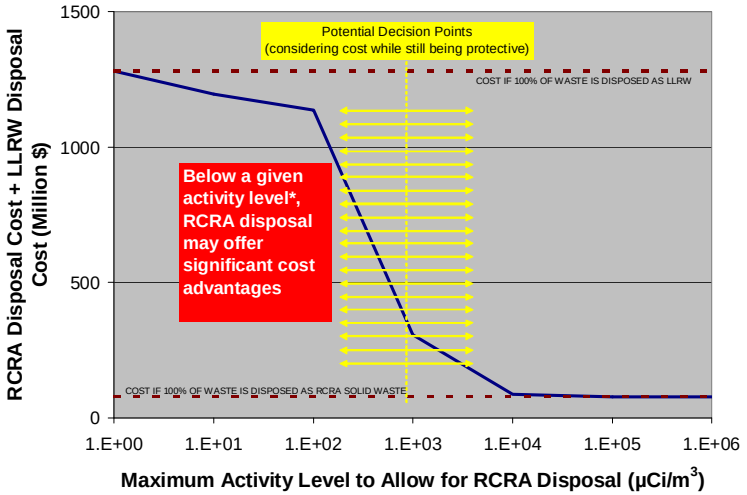
Est. Aqueous Waste Activity by Vol % (µCi/m^3)



EPA United States Environmental Protection Agency

Results: Cost vs. Disposal Option



NOTE: Assumed $300/m^3 for RCRA disposal and $5000/m^3 for LLRW disposal
* Where RCRA disposal is protective of public health and safety

Sensitivity Analysis: Description

- **"Crystal Ball" Monte Carlo simulation software**
  - 1000 Iterations
- **"Assumption" Variables**
  - % Demolition (Zones 1, 2, 3)
  - % Soil sent to on-site treatment (Zones 1, 2, 3)
  - Cutoff to allow waste disposal in RCRA facilities
- **"Forecast" Variables**
  - Amount of LLRW
  - Amount of RCRA solid waste
  - Combined cost of disposal in RCRA + LLRW facilities

Sensitivity Analysis: Contributions

- **Reduction in disposal cost achieved by**
  - Maximizing qty accepted by RCRA facilities
  - Minimizing demolition
  - Maximizing amt of soil not sent off as waste
- **NOTE: Decon costs & time not included in analysis – would interact with demolition effect**

Conclusions

- **RDD waste estimation methodology developed**
- **Uses commercial software packages**
  - GIS shapefiles based on plume models or sampling
  - Uses HAZUS-MH, CDMS, MS Access, MS Excel
  - User-adjustable parameters to assess mitigation methodologies
- **Potentially large quantity of solid & liquid waste**
  - Majority is low activity
  - Washwater requirements may overwhelm supply
  - Soil constitutes large fraction of solid waste
- **Clear cutoff point indicated for disposal option recommendations**

Potential Implications

- **Need to consider waste when selecting decontamination options**
- **Advantages of on-site treatment to reduce waste volumes**
  - Soil is prime candidate for on-site treatment
  - Soil washing technology inadequacies suggest research opportunity
- **Use of RCRA-permitted disposal facilities for minimally-contaminated materials**
- **Use of LLRW capacity for materials contaminated at higher levels**
- **Future Work: Include decon, transportation costs, time in analysis; improve waste activity estimates; additional radionuclides**

Development of Test Methods for Determining the Efficacy of Disinfectants Against Foreign Animal Disease Viruses on Nonporous Surfaces

Peter W. Krug, Foreign Animal Disease Research Unit, Agricultural Research Service, United States Department of Agriculture

Development of Test Methods for Determining the Efficacy of Disinfectants Against Foreign Animal Disease Viruses on Nonporous Surfaces

Peter W. Krug, Laura J. Lee and Luis Rodriguez

Foreign Animal Disease Research Unit, Agricultural Research Service, United States Department of Agriculture, Plum Island Animal Disease Center, Orient Point, New York 11957

Foreign Animal Diseases

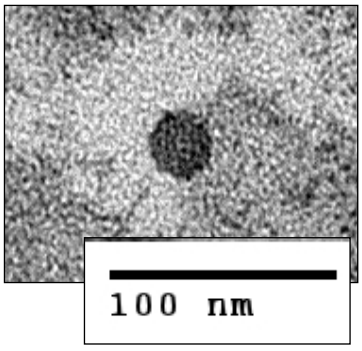
- Outbreaks are costly
  - FMDV outbreak in U.S. estimated > $5 Billion
    - >500,000 cattle estimated destroyed in CA alone
  - 1998 Netherlands CSFV eradication
    - $2.3 Billion, 12 million pigs culled
  - ASFV is currently moving through eastern Europe
- Prevention is critical - FMDV and CSFV are endemic in South America - threat to US livestock
- Need for disinfection in case of introduction
  - Limiting spread
  - Restoration of contaminated facilities
- Stability in environment varies
  - FMDV > ASFV > CSFV

Foreign Animal Diseases: FMDV

- FMDV is one of the most contagious viruses on the planet
- Mortality is low but morbidity is high, wide host range
- Seven FMDV serotypes: A, O, C, Asia, Sat1, Sat2, Sat3
- Vaccinations are not very cross-protective and do not offer long-term protection
- FMD is the major animal disease preventing world trade of animals and animal products
- High mortality associated with some control methods
- Rapid cleanup and quarantine response in a potential domestic outbreak could save $billions
  - 2001 UK outbreak cost over $16 billion
    - 7 million cattle and sheep killed
    - Tourism affected
    - Spread to other countries

Foot-And-Mouth Disease Virus

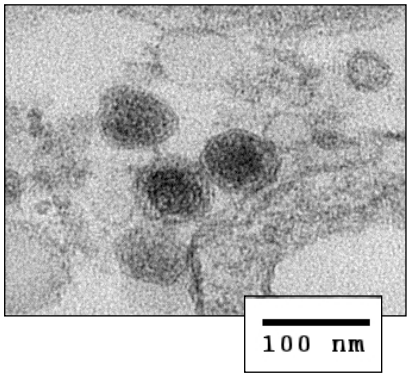
- **Family Picornaviridae**
  - genus aphtovirus
  - Non-enveloped, small RNA virus
- Stable in environment
- Resistant to surfactants
- Cell entry involves low pH fusion in endosomes
- Sensitive to high and low pH, chorine
- Not very stable in meat



Tom Burrage VCMI/DHS/S&T/PIADC

Classical Swine Fever Virus

- **Family: Flaviviridae**
  - genus: pestivirus
  - enveloped, small RNA virus
- Relatively fragile in the environment but very stable in meat
- Sensitive to surfactants, acids, and hypochlorite

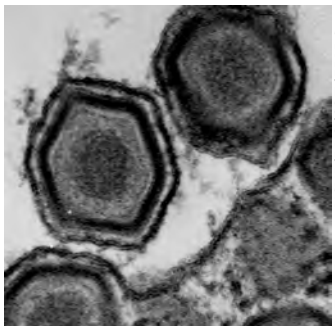


Tom Burrage VCMI/DHS/S&T/PIADC

African Swine Fever Virus

Family: Asfiviridae

- very large DNA virus (200 nm)
- double enveloped, encapsidated plus inner protein coat
- Intermediate stability in the environment and very stable in meat
- Sensitive to hypochlorite and Iodine



Tom Burrage VCMI/DHS/S&T/PIADC

EPA-ARS Interagency Agreement

- EPA/OPP has been funding an IA with USDA/ARS/PIADC for 2008-2011.
- Research follows a Basic Plan and an Advanced Plan

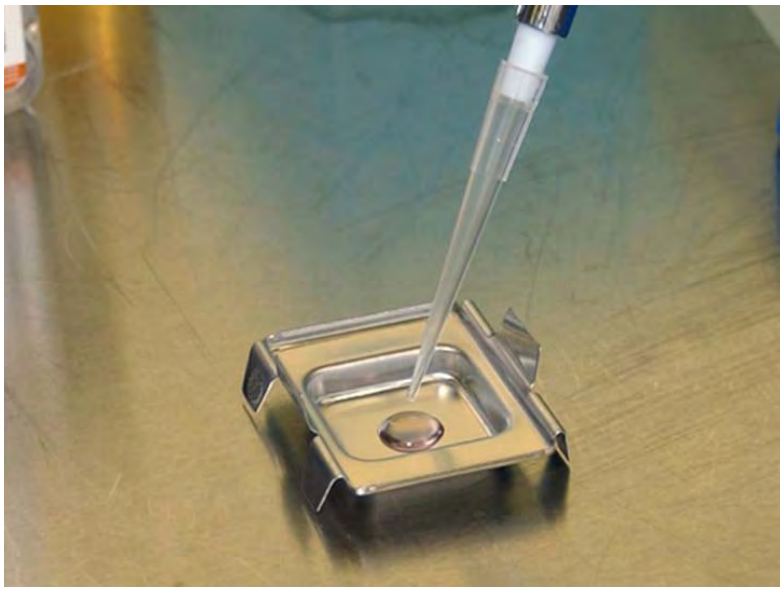
- Objective of Basic Plan
  - Develop an disinfection test method for hard, nonporous surfaces and to test selected chemicals against high priority FAD viruses.
  - Simple and Reproducible method

- Objectives of Advanced Plan
  - Develop an disinfection test method for porous surfaces
  - Test selected chemicals against FAD viruses on porous surfaces
  - Test variations in efficacy when certain parameters are changed (e.g., organic load, temperature, contact time, etc.)

Modeling Disinfection in the Lab

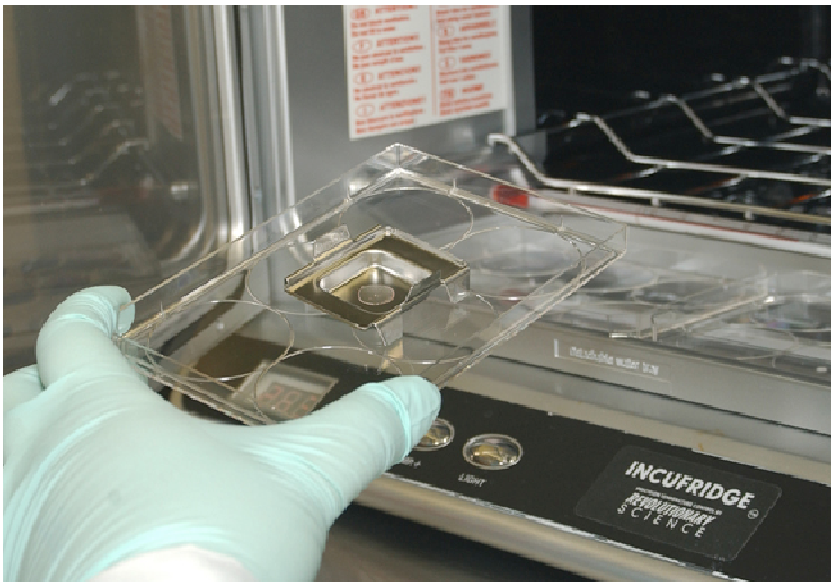
- Most published work done in suspension
- Surface disinfection by many groups
  - Many different methods
- Mostly non-porous surfaces
  - Issues of loss due to drying on porous surfaces
  - Extraction of virus from internal surfaces
  - High titer stocks can be difficult to make
    - virus dependent

Nonporous Methodology: Drying

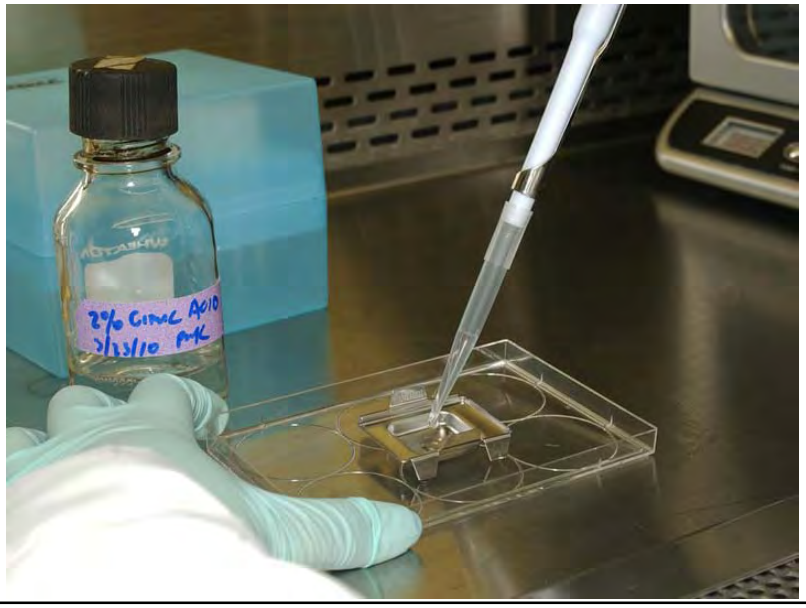


Nonporous Methodology: Drying

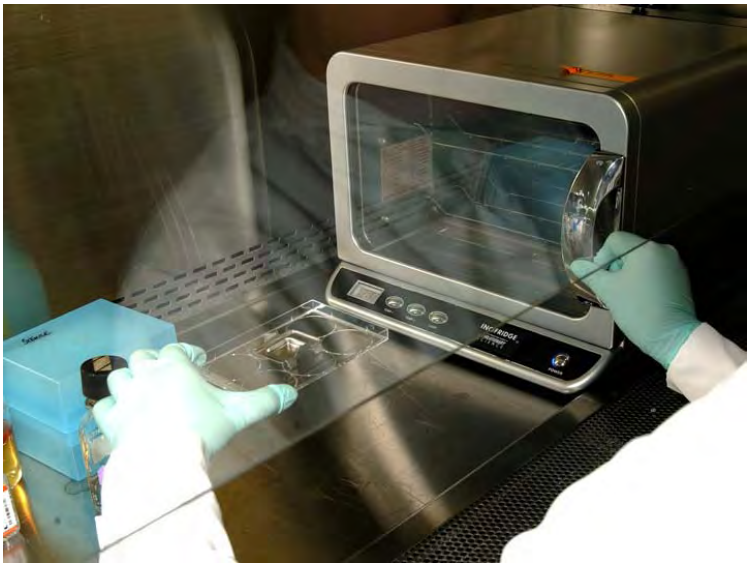
Nonporous Methodology: Drying



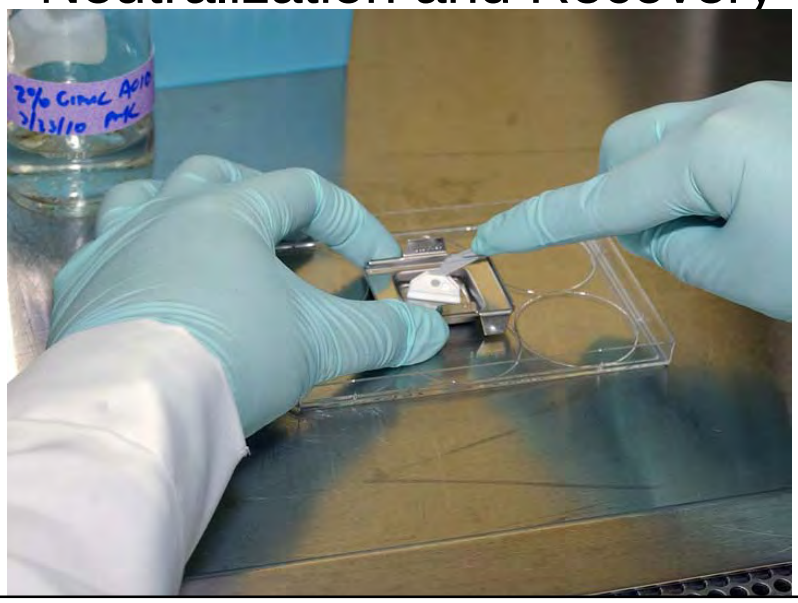
Nonporous Methodology: Disinfection



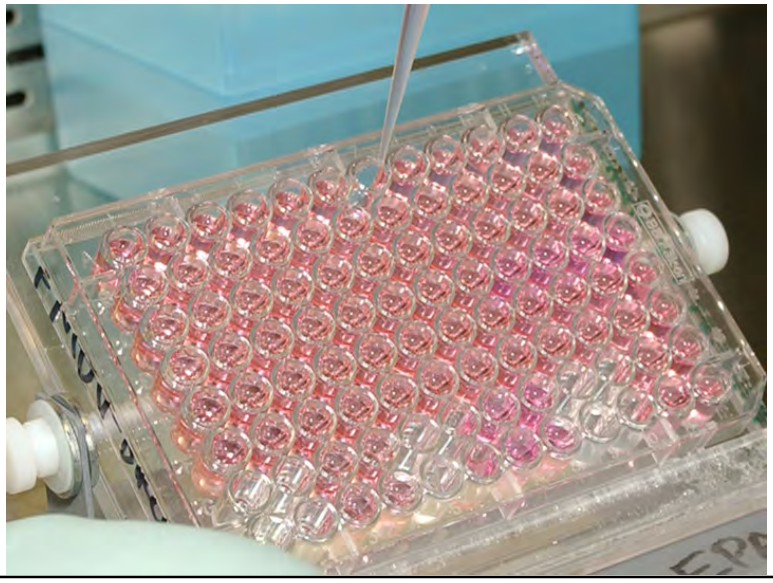
Nonporous Methodology: Disinfection



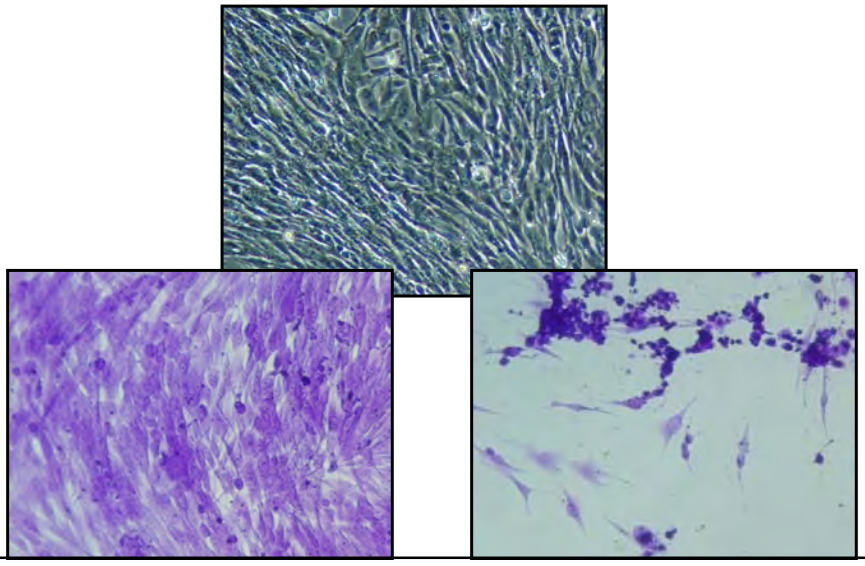
Nonporous Methodology: Neutralization and Recovery



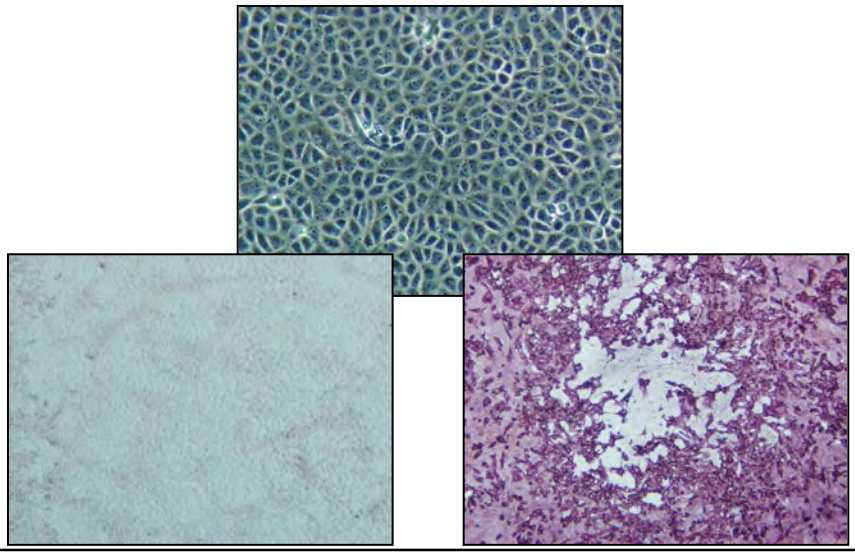
Nonporous Methodology: Inoculation of Cell Culture



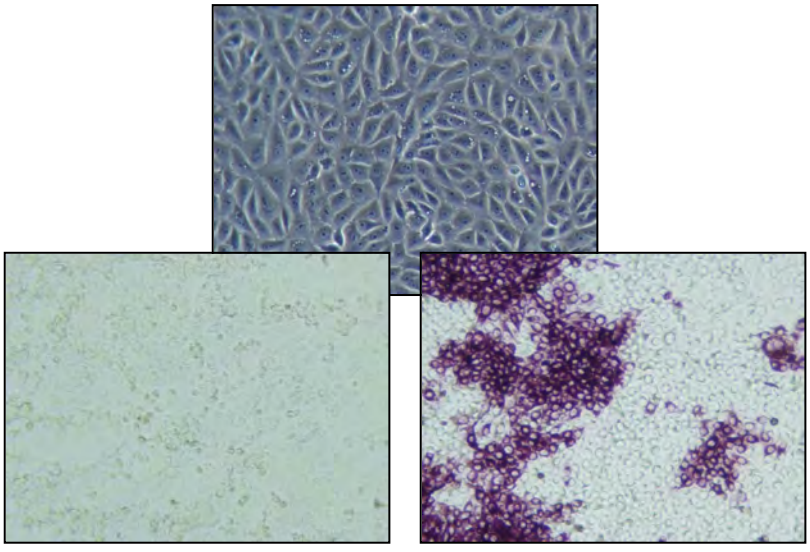
Nonporous Methodology: FMDV Detection



Nonporous Methodology: ASFV Detection

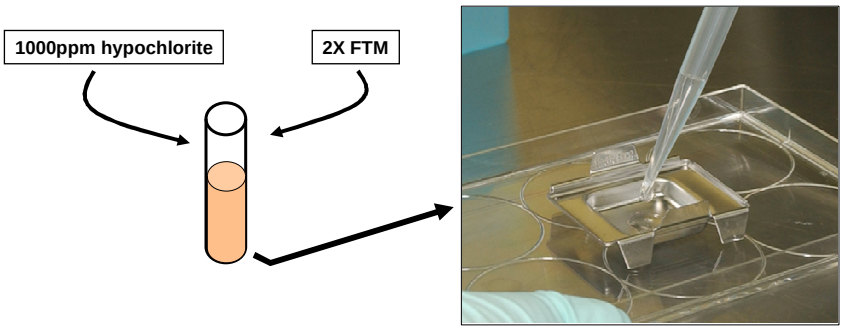


Nonporous Methodology: CSFV Detection



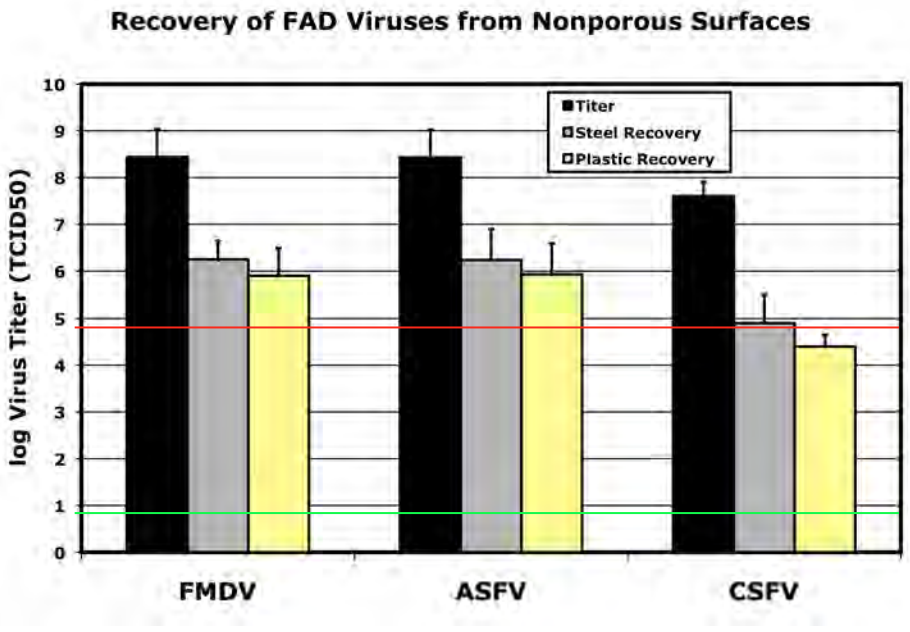
Nonporous Methodology: Controls

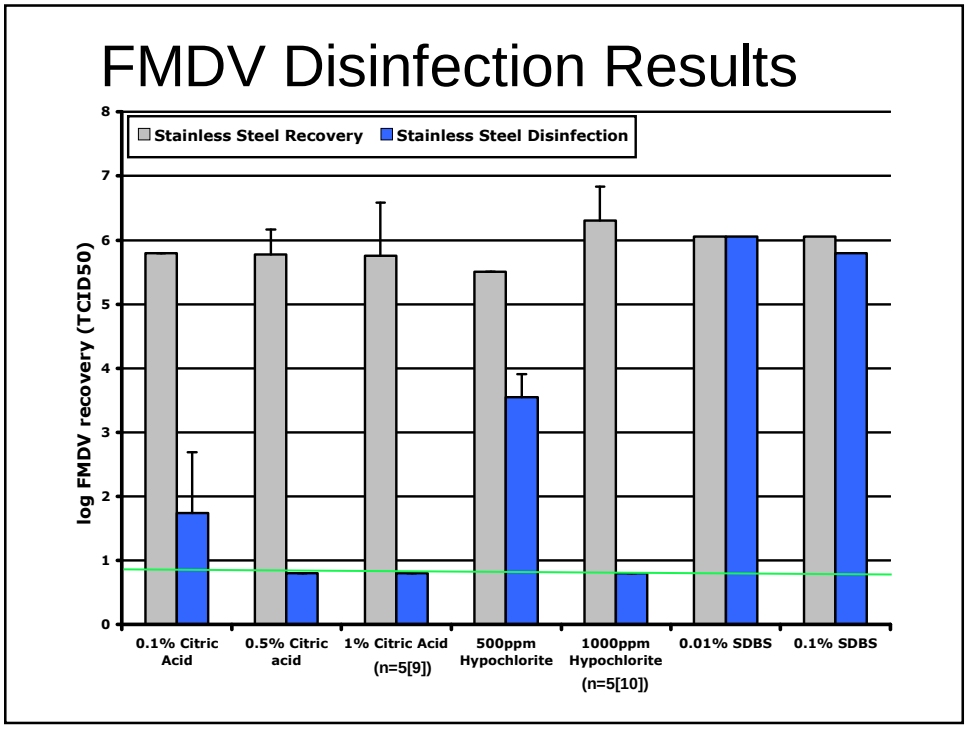
Disinfectant/Neutralizer mix Virus Recovery Control

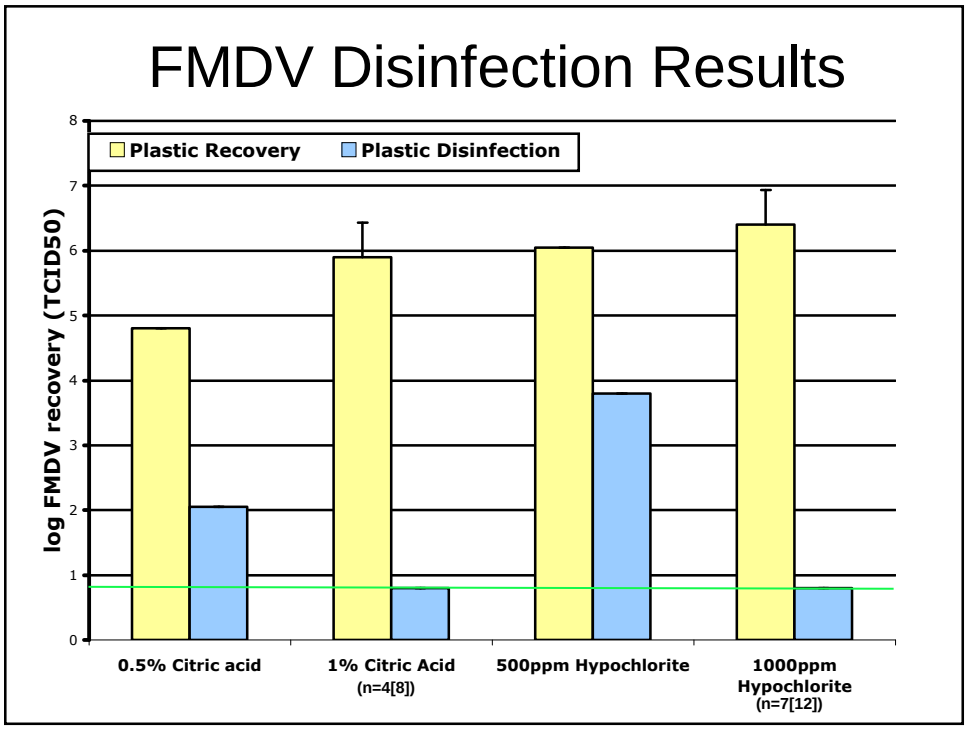


Hypochlorite neutralizer - Fluid Thioglycollate Medium
Citric Acid neutralizer - Sodium Bicarbonate
SDBS surfactant - Sephacryl S-400 HR spin columns*

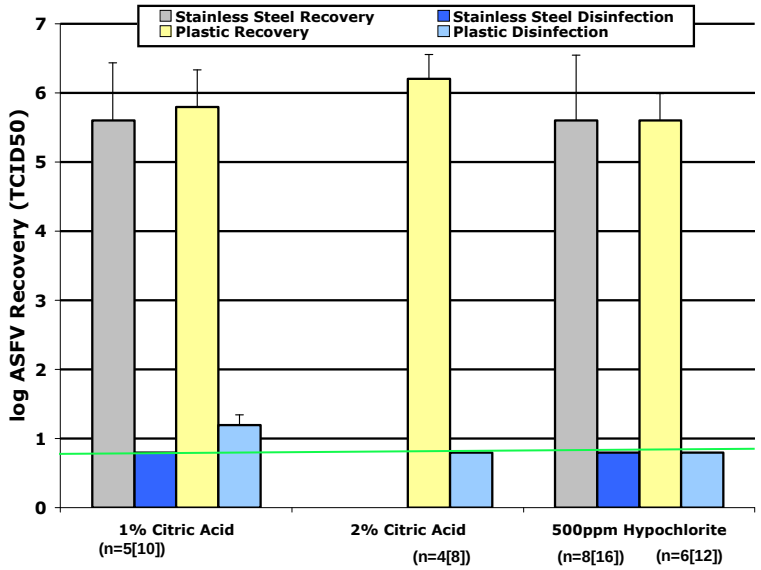
Controls for Disinfectant/Neutralizer/Media cytotoxicity and surface cytotoxicity included



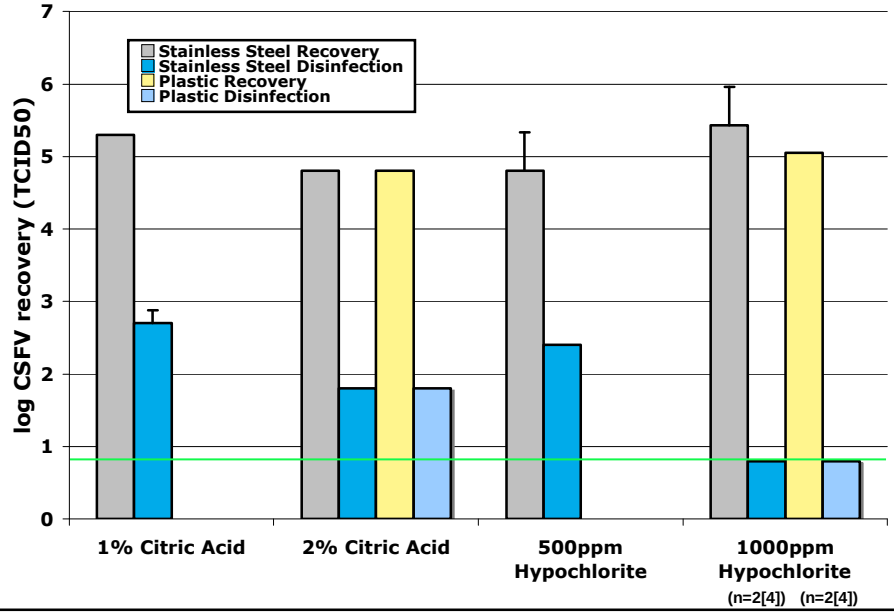

FMDV Disinfection Results
Stainless Steel Recovery
Stainless Steel Disinfection
log FMDV recovery (TCID50)
0
1
2
3
4
5
6
7
8
0.1% Citric Acid
0.5% Citric acid
1% Citric Acid (n=5[9])
500ppm Hypochlorite
1000ppm Hypochlorite (n=5[10])
0.01% SDBS
0.1% SDBS


FMDV Disinfection Results
Plastic Recovery
Plastic Disinfection
log FMDV recovery (TCID50)
0
1
2
3
4
5
6
7
8
0.5% Citric acid
1% Citric Acid (n=4[8])
500ppm Hypochlorite
1000ppm Hypochlorite (n=7[12])

ASFV Disinfection Results



CSFV Disinfection Results



Nonporous Disinfection Summary

- Dried FMDV and ASFV were recovered efficiently from both stainless steel and plastic surfaces (2-log loss due to drying).
- Dried CSFV was difficult to recover from either surface, with a 3-log loss due to drying.
- 1% citric acid consistently disinfected dried FMDV on both plastic (n=4[8]) and steel (n=5[9]) surfaces.
- 1000ppm (but not 500ppm) sodium hypochlorite inactivated dried FMDV on both plastic (n=7[12]) and steel (n=5[10]).
- As expected, the surfactant SDBS was not effective at inactivating FMDV.

Nonporous Disinfection Summary

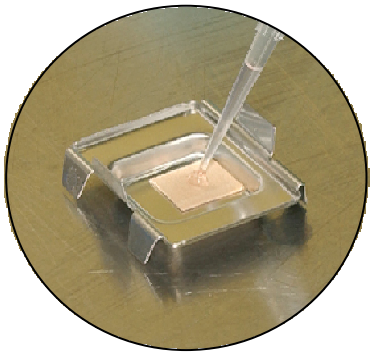
- 500 ppm sodium hypochlorite was able to disinfect ASFV on both plastic (n=6[12]) and steel (n=8[16]).
- 1% citric acid was able to disinfect dried ASFV on stainless steel (n=5[10]) but 2% citric acid was required to disinfect ASFV on plastic surfaces (n=4[8]).
- Dried CSFV was not completely disinfected by 2% citric acid on either plastic or steel surfaces.
- 1000ppm (but not 500ppm) sodium hypochlorite was able to disinfect dried CSFV from both stainless steel (n=2[4]) and plastic (n=2[4]) .

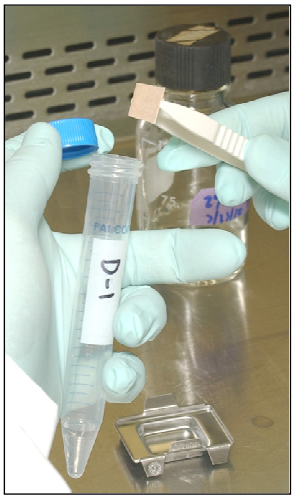
Porous Surface Disinfection

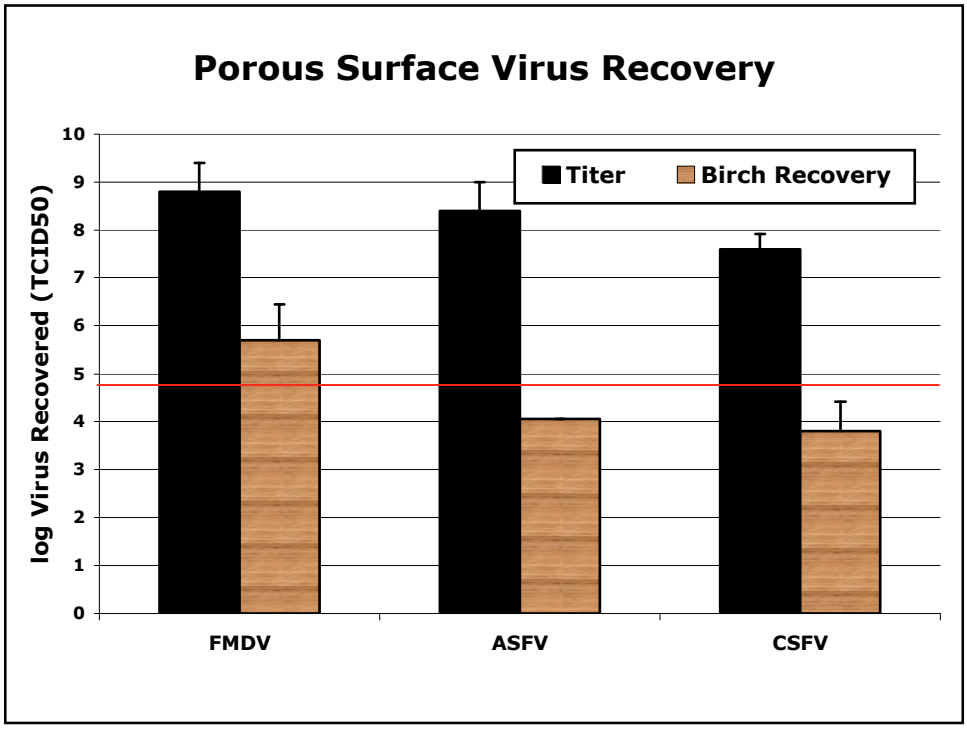
- Porous surfaces have been problematic
  - virus recovery
  - disinfectant penetration
  - Surface cytotoxicity

Porous Surface Methodology

- In development
- Similar to non-porous
- Birch Veneer Carriers







Overall Summary And Path Forward

- Nonporous surface methodology in place
- Disinfectant testing successful with representative viruses
- Porous surface methodology in development
  - Some success with Citric Acid against FMDV
- Plan to test disinfectants on other FAD viruses
  - AI, NDV, RPV,AHS, JEV*, VEEV*,RVFV*

Acknowledgments

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  - Luis Rodriguez (ARS)
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- **EPA**
  - Carlton Kempter
  - Jason Duncan
- **APHIS**
  - Nate Birnbaum
  - Lori Miller
  - Randall Levings

- Tom Burrage (DHS-S&T)
- Kathleen Apicelli (VIS)

Treatment of Liquid Wastes From Radiological Decontamination

Konstantin Volchek, Environment Canada

Presentation not available for distribution

Destruction of Spores in a Bench-Scale Landfill Flare System

Dana Wimsatt and Jacky Rosati, EPA/ORD/NHSRC/DCMD

EPA United States Environmental Protection Agency

Destruction of Spores in a Bench-Scale Landfill Flare System

Dana Wimsatt and Jacky Rosati

[1]University of North Carolina at Chapel Hill;
[2]US EPA National Homeland Security Research Center, Decontamination and Consequence Management Division

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Maryanne Boundy

Overview

- Background
- Objective
- Bench-Scale Landfill Flare System Design
- Results
- Future Work
- Conclusions

Background—Decontamination

- 2001 Anthrax attacks highlighted the need for effective decontamination and disposal methods of *Bacillus anthracis* spores
- Decontamination of buildings produced a significant volume of residue
- Much of the building decontamination residue will likely be disposed in municipal solid waste landfills

Background—Future Concerns

- Viable *Bacillus anthracis* spores could remain in the residue
- The potential exists for
  - viable spores to become re-aerosolized
  - partition into the landfill gases
  - pass through a landfill gas flare prior to emission
- A bench-scale system is needed to study the ability of landfill gas flares to destroy *Bacillus anthracis* spores

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Objective

To design, build, and test a bench-scale landfill flare system to establish that it operates as intended

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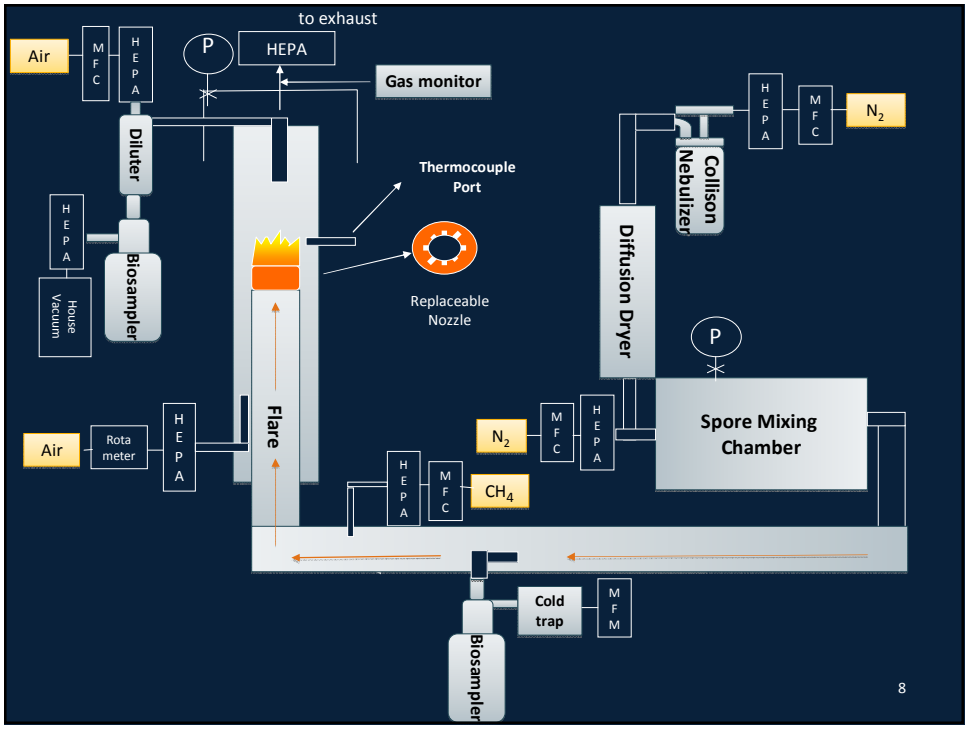
Geobacillus stearothermophilus

- Surrogate for *Bacillus anthracis*
- Similarities
  - gram-positive
  - rod-shaped bacterium
  - endospore forming
  - size
  - heat resistant

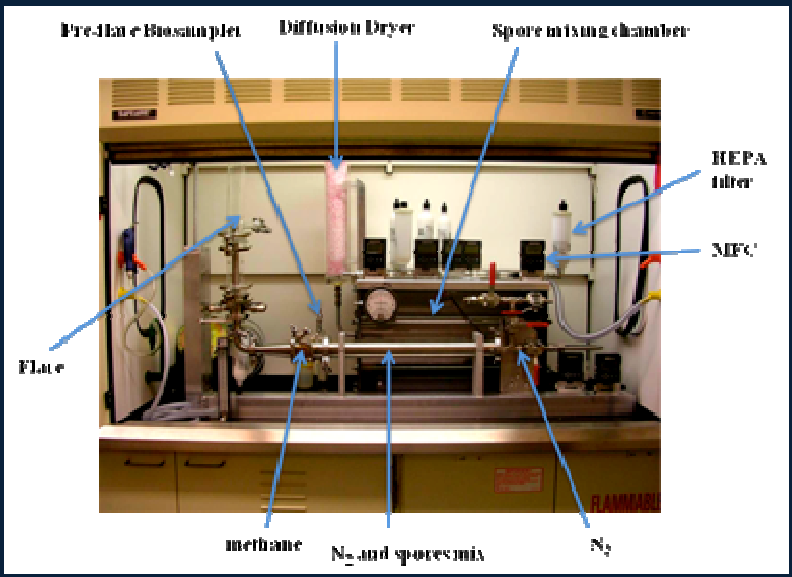
- One of the most heat-resistant spores, provides a "worst case" scenario for thermal resistance

7



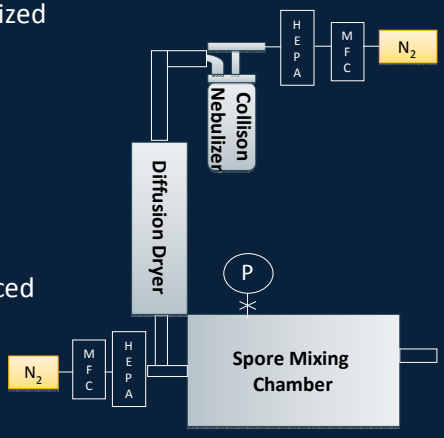
8

Bench-Scale System Photograph



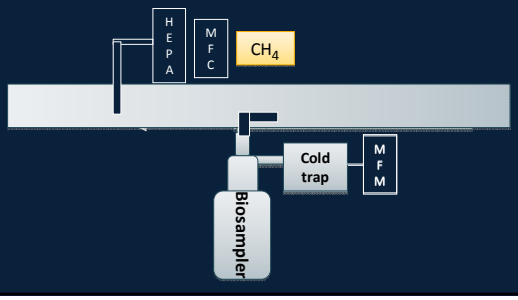
System Design: Aerosolization

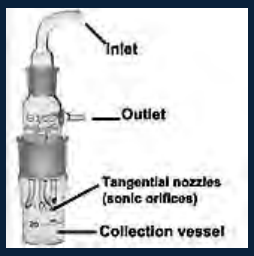
- Spores (2 x 10^6 CFU/mL) in deionized water were aerosolized using a Collison three-jet nebulizer
- Sent through a diffusion dryer to remove excess moisture
- Additional nitrogen was introduced to the system
- Nitrogen-spore mixture passed through a mixing chamber



System Design: Inlet Biosampler

- An SKC BioSampler with ViaTrap mineral oil was used to sample the bioaerosol
- BioSampler design
- Cold Trap:
  - 50% dry ice, 50 % isopropyl alcohol
  - used to prevent any ViaTrap from reaching the mass flow meter



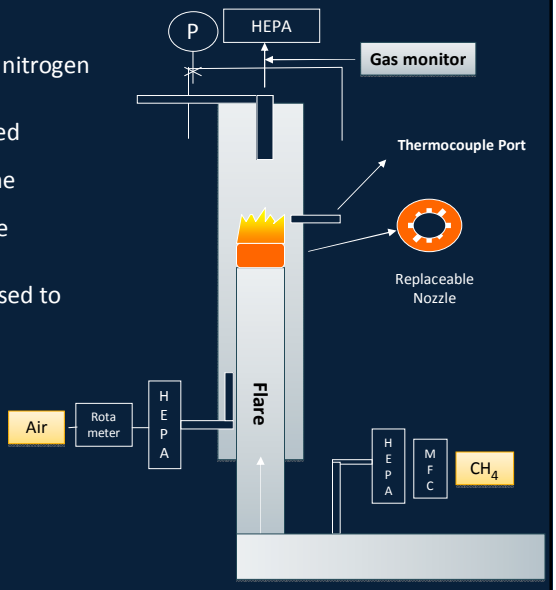


System Design: PID control

- A proportional-integral-derivative (PID) control was developed in DASYLab for the pre-flare nitrogen sources
- Ensured that the correct ratio of methane/nitrogen reached the flare
- Bypass system: allowed system to stabilize and assured proper flows

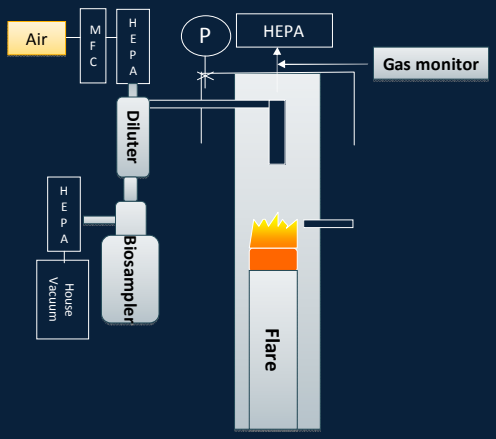
System Design: Flare

- Landfill gas mixture *used*: 52% nitrogen and 48% methane
- Dry filtered house air was added
- Mixture entered diffusion flame
- Thermocouple measured flame temperature
- A methane gas detector was used to assure safe levels



System Design: Outlet Biosampler and Exhaust System

- Post flare mixture entered a quartz diluter where it combined with filtered house air
- A second SKC BioSampler with ViaTrap mineral oil was used to collect spores



- Flare exhaust system cooled the exhaust, diluted any released methane with outside air, and collected any remaining spores

Analysis of Biosamplers

- A serial dilution spread-plate procedure was used
- Dilutions from 10^{-1} to 10^{-6}
  - plated in triplicate on Trypticase Soy Agar plates
- Controls
  - 3 blank plates
  - 3 plates with ViaTrap
  - 3 plates spread with beads
- Incubated at 55°C (± 2°C) for 24 hours

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Log Reduction of Spores

- CFU per extract:

*CFU per extract= (average CFU) * (1/DF) * (extract volume)*

where

*DF, decimal factor = volume plated (mL)*tube dilution*

- Log Reduction (LR) of spores:

$$LR = \log_{10}(c) - \log_{10}(t)$$

where c = concentration for the inlet BioSampler and

t = concentration for outlet BioSampler

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Quality Control

Measurement	Analysis Method	Accuracy	Check
Nebulizer, Additional N_2, Outlet Dilution Air	Sierra Smart Track C100L MFC	± 1%	Molbox flow Calibration and Gilibrator
Inlet BioSampler	Omega FMA 2811 MFM	± 1%	Molbox flow Calibration and Gilibrator
N_2 Flare	Hasting 200H MFM	± 1%	Molbox flow Calibration and Gilibrator
Methane	Dwyer 2107 MFC	± 1.5%	Molbox flow Calibration and Gilibrator
Combustion Air Flow	King 7520 Rotameter	± 6%	Gilibrator
Flare Temperature	Omega Temperature Monitor	± 1%	Thermocouple
Dilutions	Micropipettes	±1.5	In-house Biolab Calibration

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Preliminary Tests: Zero Tests

- *Purpose:* To ensure the bypass system worked correctly
- *Results:* No colony growth was observed on any of the plates from the inlet or outlet BioSamplers
  - -spores were successfully contained in the bypass system

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Preliminary Tests: Spike Tests

- *Purpose:* To quantify the effect of products of combustion on the outlet Biosampler
- *Results:*

Log Reduction	Average Log Reduction	t-test (p=0.05)
0.412 0.303 0.337	0.387	Significant

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Preliminary Tests: Isokinetic

- *Purpose:* To determine whether or not isokinetic sampling was necessary
- *Results:*

Log Reduction	Average Log Reduction	t-test (p=0.05)
0.024 0.055 0.072	0.050	Not Significant

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Preliminary Tests: Losses

- *Purpose:* To quantify the spores lost between the inlet and outlet Biosamplers due to impaction and settling
- *Results:*

Log Reduction	Average Log Reduction	t-test (p=0.05)
0.814 0.711 0.679	0.735	Significant

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Full Scale Tests

- The internal flare temperature: 820-900 °F (438-482 °C)
- No *G. stearothermophilus* spores were found in the outlet BioSamplers in any runs
- Bench scale landfill flare system successfully destroyed all spores

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Future Work

- Increase the concentration of spores
- Make additional temperature measurements
- Develop a procedure to measure spore fallout
- Test other surrogates
- Increase the size of the existing system

Conclusions

- Bench-scale landfill flare system was shown to work as intended
- Preliminary tests determined adjustments are needed for:
  - Losses through the system
  - Products of combustion in the outlet Biosampler
- Full-scale tests show a complete destruction of *G. stearothermophilus* spores

Development of an Aerosol Deposition Method for *Bacillus* Spores

Sang Don Lee, EPA/ORD/NHSRC

Development of an Aerosol Deposition Method for *Bacillus* Spores

Sang Don Lee, Shawn P. Ryan, Emily Gibb Snyder

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

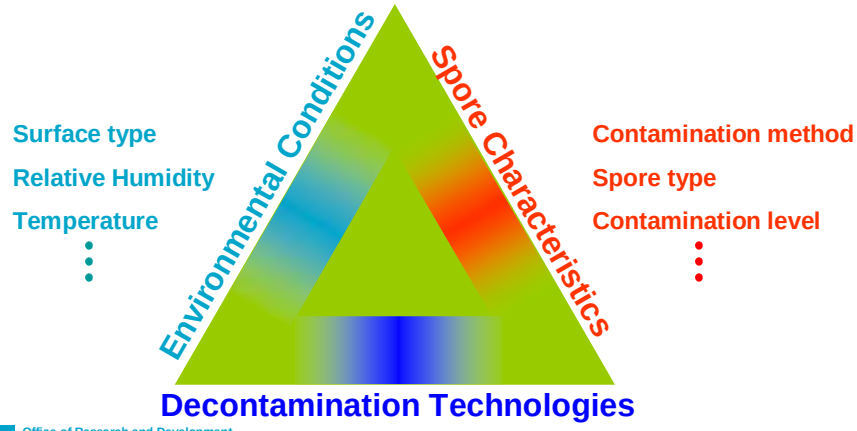
Presentation Outline

- **Aerosol Spore Deposition Method**
  - **Background**
  - **Method**
  - **Results**
  - **Summary**
- **Aerosol Deposition vs. Liquid Inoculation**
  - **SEM analysis results**
  - **Summary**

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

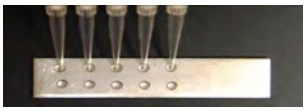
Why is an Aerosol Deposition Method for *Bacillus* Spores Needed?

Decontamination studies provide information on the potential successful application of technologies/methods under various contamination conditions (need scenarios).



Spore Deposition Methods

- **Typical sample preparation is by liquid inoculation**



- **Existing aerosol deposition method**
  - **Gravitational settling chamber**
- **Limitations of settling chamber method**
  - **Speed of sample preparation**
  - **Consistency**
  - **Surface spore concentration (<10^7 per coupon)**

Requirements for New Deposition Method

- Aerosol Deposition
- Applicable to various surfaces
- > 10^7 viable spores per coupon (d.a. 18 mm)
- < 50% of coefficient of variance (C.V.=Standard Deviation/Mean)
- Fast and controllable coupon preparation

Test Coupons

- Coupon size: 18 mm diameter disc 
- Surface types: carpet, metal, painted wallboard paper, wood



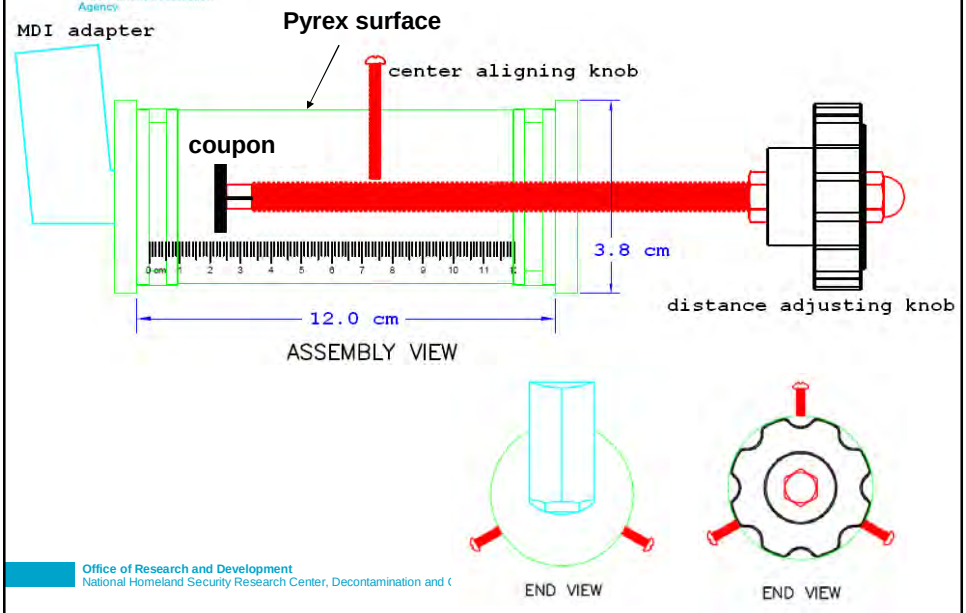

- Spore deposition source*: Metered Dose Inhaler (MDI) 0.5 wt% ***Bacillus Subtilis***

- Material sterilization

- Logistics to avoid cross contamination

*Metered dose inhalers (MDIs) were prepared by the aerosol science laboratory at Edgewood Chemical and Biological Center (ECBC).

Spore Deposition Chamber



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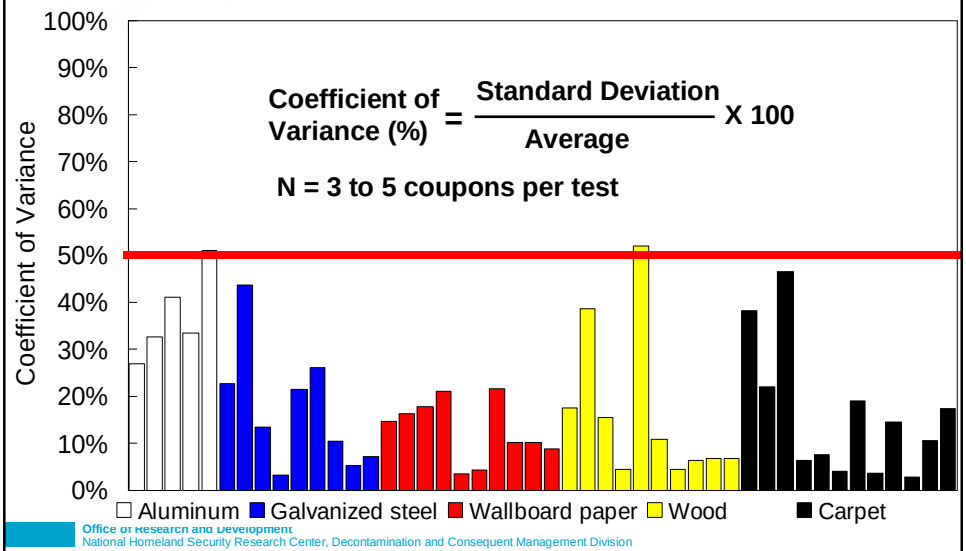
National Homeland Security Research Center, Decontamination and C

Test Results of Spore Deposition on Five Surfaces (1)



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Test Results of Spore Deposition on Five Surfaces (2)

Material	# of Coupons	Average Spores (per coupon)	CV (%)
Aluminum stub	25	4.47×10^7	47
Galvanized Steel	40	4.05×10^7	14
Painted Wallboard paper	43	1.52×10^7	14
Wood	38	6.92×10^7	14
Carpet	56	3.65×10^7	20

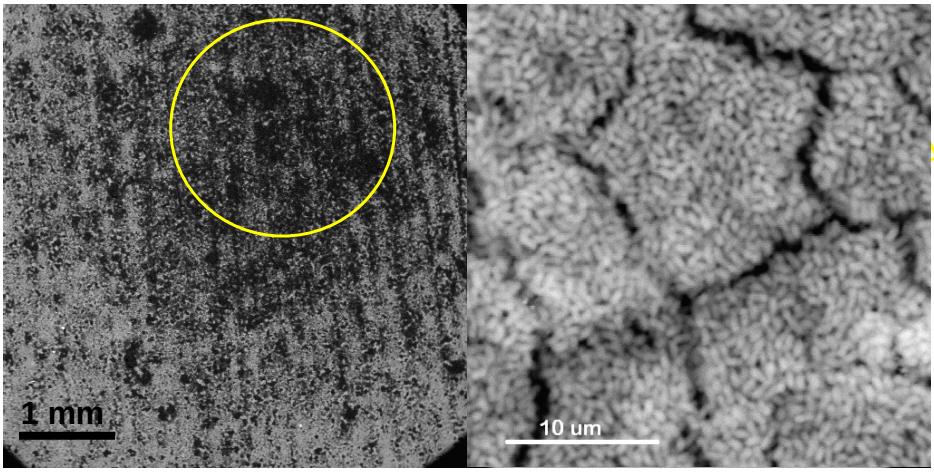
Summary of New Deposition Method

- Development of new spore deposition method
  - ✔ Aerosol Deposition
  - ✔ Applicable to various surfaces
  - ✔ >10^7 viable spores per coupon
  - ✔ Less than 50% of coefficient of variance (C.V.)
  - ✔ Fast and controllable sample preparation
- Aerosol Deposition vs. Liquid Inoculation

Aerosol Deposition vs. Liquid Inoculation

- **Physical profile of deposited *B. subtilis* spores on various surfaces**
- **Scanning Electron Microscope**
- **Galvanized steel, carpet, wood, painted wallboard paper**
- **Sample preparation by**
  - **Aerosol deposition (A): new method**
  - **Liquid inoculation (L): 100 L of spore suspended in distilled water**

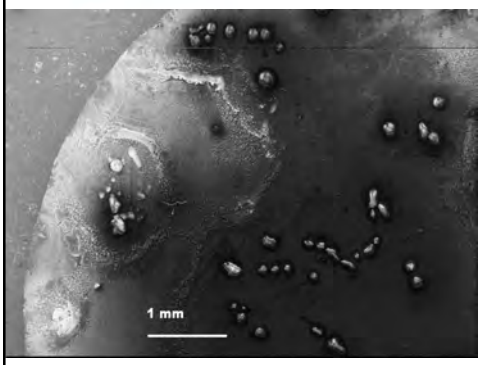
Aerosol Deposition (A) vs. Liquid Inoculation (L) Comparison (1)

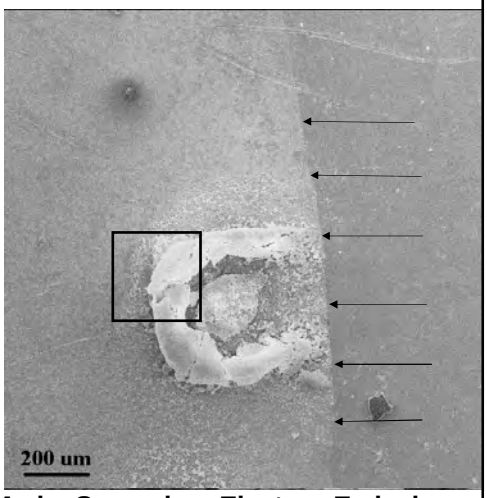


Painted Wallboard Paper (A) **Painted Wallboard Paper (L)**

ASPEX personal SEM, Mag: x 17, Mode: Backscattered Electron Emission

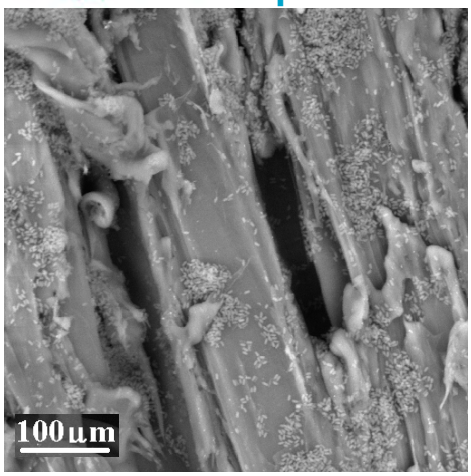
Galvanized Steel: Liquid Inoculation

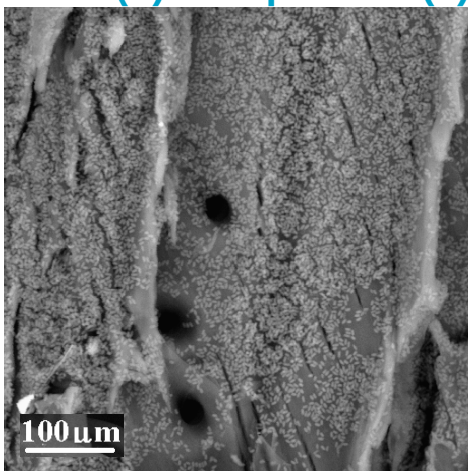




LEO S440, Mag: x 19, 50, and 300, Mode: Secondary Electron Emission

Aerosol Deposition (A) vs. Liquid Inoculation (L) Comparison (2)

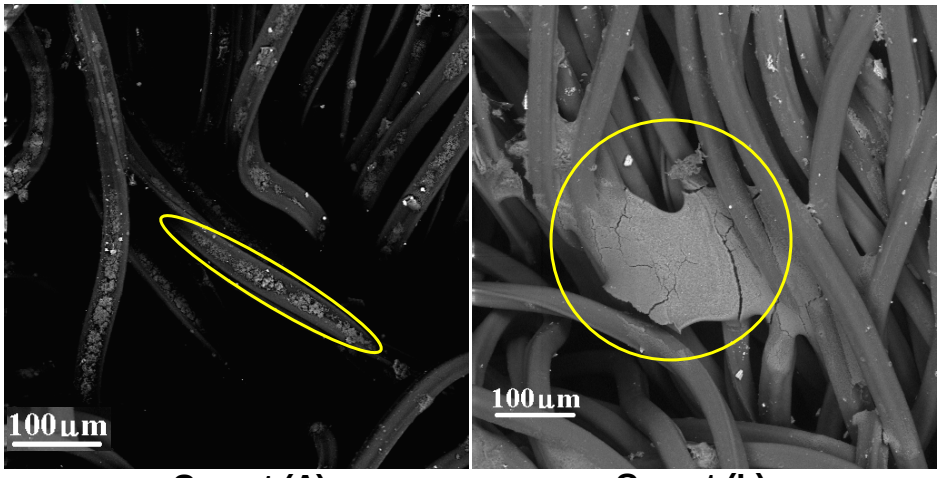




Wood (A) **Wood (L)**

ASPEX personal SEM, Mag: x 100, Mode: Secondary Electron Emission

Aerosol Deposition (A) vs. Liquid Inoculation (L) Comparison (3)



Carpet (A) Carpet (L)

ASPEX personal SEM, Mag: x 100, Mode: Secondary Electron Emission

Summary of Aerosol Deposition vs. Liquid Inoculation

- SEM image analysis
  - Liquid inoculation:
    - Densely populated spore areas depending on surface types
    - Potential impact of liquid droplet on surface deposition
  - Aerosol deposition:
    - Dispersed pattern of spore deposition
      - But densely populated spore areas are in the center of deposition.
    - Similar pattern for all surface types
- New method has been applied to the decontamination studies
  - Comparison of both deposition methods in fumigation studies (Dr. Shawn Ryan)

Impact of CT and Relative Humidity on Efficacy and Material Effects of Chlorine Dioxide

John Y. Mason, Sabre Technical Services, LLC

Presentation not available for distribution

Methodology for Quantitative Analysis of the Impact of Decontamination on Electronic Equipment

G. E. Derkits, Alcatel-Lucent

Alcatel·Lucent

Methodology for Quantitative Analysis of the Impact of Decontamination on Electronic Equipment

Gustav Derkits , M. L. Mandich, C. Xu, D. Fleming, W. D. Reents, J. P. Franey, R. Kopf, and T. Wiecek (Alcatel-Lucent)

Shawn Ryan(EPA) and Lance Brooks (DHS)

Alcatel-Lucent (LGS Innovations, Decon Study USMMM235W9)

Project sponsored by EPA and DHS through CBRTA

Project Overview and Justification

Aim of Work Presented

This presentation is concerned with the Methodology for obtaining quantitative analysis of the impact of decontamination on electronic equipment, not principally with the results of the experiments, which will be discussed by Dr. Mandich in the next talk.

Prior work on the effects of decontamination on electronic equipment was mainly qualitative and subjective, dealt with short time scales, and was often biased by commercial interests.

The Principle goals of the work at Alcatel-Lucent were to introduce **Objectivity**,

Reproducibility,

Quantitative methods, and

Traceability into the study of decontamination impact on electronic equipment for the purpose of providing objective information to the agencies of the U.S. Government responsible for decontamination oversight.

Methods

The methods used are adapted from best practices in the field of electronic and telecommunication system environmental testing.

Specific methods applied to this investigation include:

A. Standard Test vehicles – Personal Computers (PCs) were chosen as test vehicles because they are highly standardized(1).
B. Quantitative Correlative information – The use of pure metal coupon process monitors was adapted from ASTM standard test methods for calibrating mixed flowing gas test chambers for testing of electronic equipment.
C. Objective assessment of system failure was performed using industry standard PC Doctor® software which enables the point of failure to be identified by subsystem and sometimes by subunit.
D. Photographic Recording - Replacement of visual inspection by high resolution (sub-mm) photographs of a pre-specified set of test points.
E. Root cause analysis has been adapted from industry protocols. In our method a complete destructive physical analysis of failed subunits down to the materials level has been performed to establish the root cause of failure.
F. Quantitative Assessment of Damage Progression was created by performing the PC Doctor® tests, photometrology(2), and Destructive Physical analytical tests repeatedly over time.

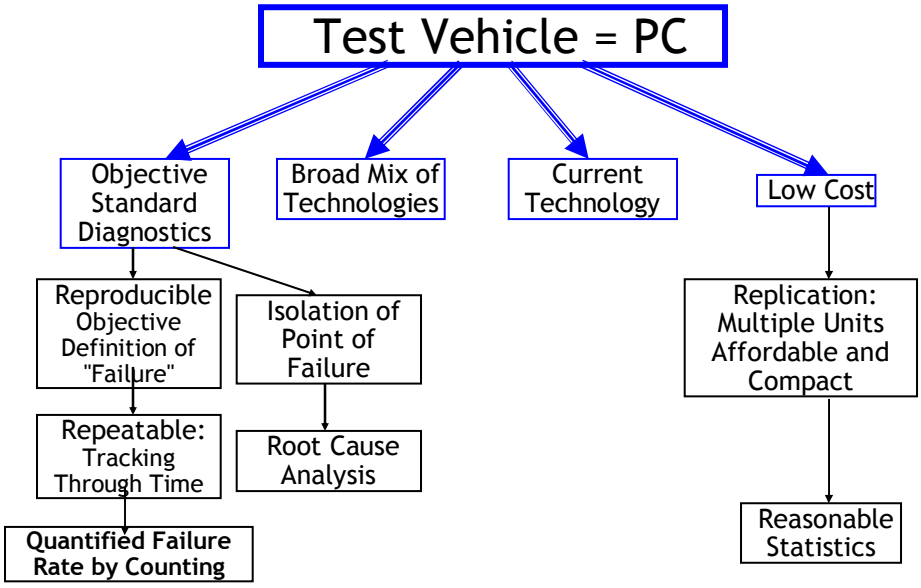
Foundation: Designed Experiment with 3X Replication

Test Condition	Power State	Treatment	ClO2 [ppmv]	RH %	Temp °F	Time [hrs]
1	Off	Sporicidal Fumigation	3000	75	75	3
2	On	Sporicidal Fumigation	3000	75	75	3
3	On	High RH Fumigation	3000	90	75	3
4	On	High RH only	0	90	75	3
5	On	Low ClO2 Fumigation	75	75	75	12
6	On	Low ClO2, Low RH Fumigation	75	40	75	12
7 (control)	On	Ambient (control)	0	40	75	--

One computer from each Test Condition was submitted blind to Alcatel-Lucent for destructive physical analysis.

A. Standardized Test Vehicles: Personal Computers

Using PCs as Experimental Test Vehicles has Immediate Positive Consequences



PCs are "Complete Systems", Highly Competitive, Large Volume, Low Cost

- Contain typical electrical, optical and mechanical components
- Wide range of possible corrosion-susceptible materials

Plastics used for cables, chip packages, connector bodies, printed circuit board laminates, CPU cooler housing, and optics

Aluminum fins on CPU and video chip heat sinks

Copper heat pipes and base of CPU Cooler

Copper metal in all connectors even when gold-plated

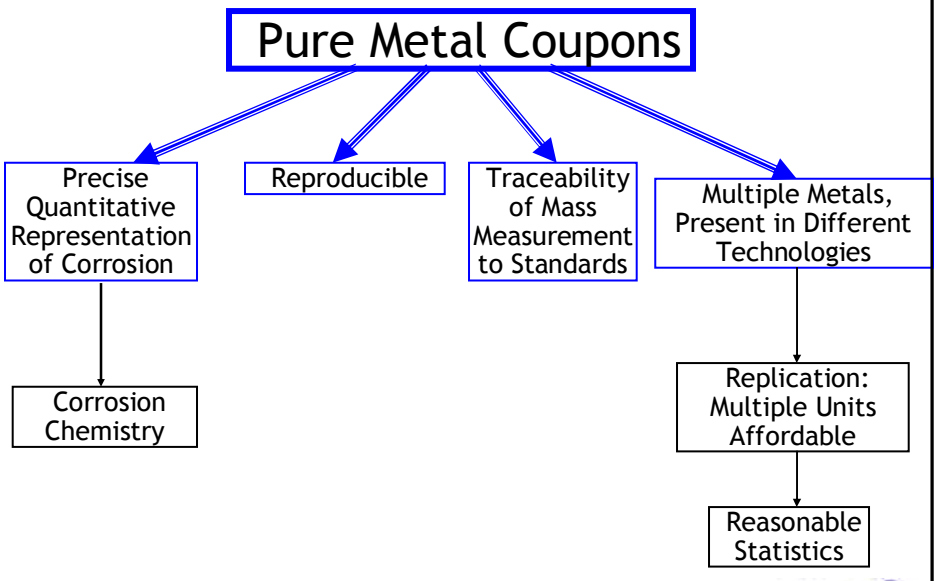
Copper Planes and Transmission Lines

Immersion **Silver** Board Finish

Ferrous metal chassis

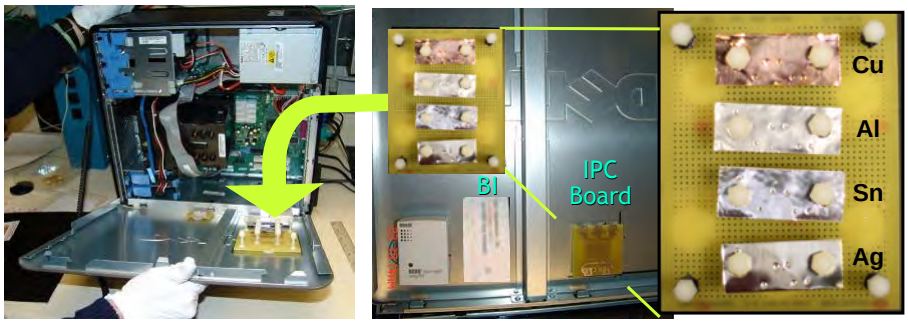
B. Quantitative Correlative Information - Pure Metal Coupons

Pure Metal Coupons as Monitors allow Precision Corrosion Metrology



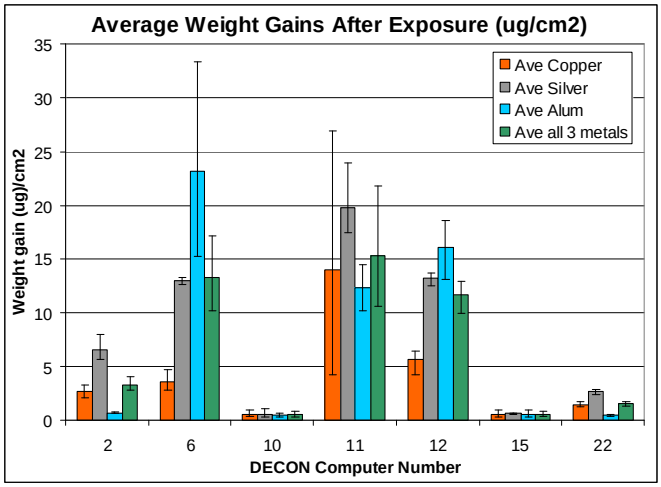
Pure Metal Coupons Provide Quantifiable Corrosion Monitor

Pure copper, silver, aluminum and tin metal coupons – "corrosion gas monitors"



Quantitative Correlative information – The use of pure metal coupon process monitors was adapted from ASTM standard(3) test methods for calibrating mixed flowing gas test chambers for environmental testing of electronic equipment. The material of the coupons is source-traceable. The effect of each exposure is measured by the weight gain of coupons of Al, Cu, Sn, and Ag using a precision microbalance calibrated using NIST-traceable standards.

Pure Metal Coupon Weight Gain in µg/cm². Error Bars Show Spread of Weight Gains over Three Computers for Each Exposure Condition



Comparison of Visual Inspection images of the blind test sample with the coupon weight gains enabled Alcatel-Lucent team to identify test conditions corresponding to each PC with 100% accuracy.

C. Objective Failure Determination - PC Dr®

PCDoctor[R] Provides a Full Kit of (>300) Software and Hardware Tests

Key Features

- More than 300 up-to-date diagnostics and features for all widely used PC components
- Comprehensive system information
- English and Japanese versions available
- Easy-to-use, intuitive graphical user interface
- Accurate Field Replaceable Unit (FRU) identification
- Fast, 10-second start-up with no installation requirements
- Test results can be saved and printed for a permanent record
- No installed operating system required to perform low-level offline tests
- Intuitive script editor to create custom scripts for specific systems and/or common problems
- Multiple boot options: run from CD, run from Multipurpose USB Device, or install on hard drive
- Support for Microsoft Windows Vista, XP, Server 2003, and 2000 (contact sales@pc-doctor.com for legacy support of Windows 98/ME or NT)
- NEW! Multipurpose USB Device based on patented technology provides test progress indicators and acts as a USB test device — great for use in testing multiple systems using a Keyboard, Video, Mouse (KVM) switch
- Includes hardware test devices: PCI POST card, power supply tester, network loopback device, and test devices for game, serial, audio, and parallel ports

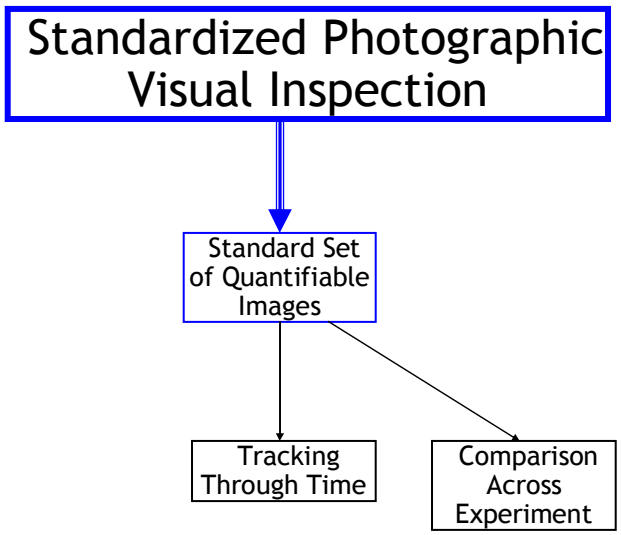
Objective Definition of "Failure": Section of PC-Doctor^{R} Record for Computer #11

	HL-DT-ST DVD+-RW GSA-H31N			
46	(DVD-RW Drive) Read Write Test	Y	PASS	
47	(CD-R Drive) Read Write Test	Y	FAIL	Warning Message: Test canceled by user. No media or wrong media type detected
48	(DVD Drive) Linear Seek Test	Y	PASS	
49	(DVD Drive) Random Seek Test	Y	PASS	
50	(DVD Drive) Funnel Seek Test	Y	PASS	
51	(DVD Drive) Linear Read Compare Test	Y	PASS	
52	(DVD+R Drive) Read Write Test	Y	PASS	
53	(CD-RW Drive) Read Write Test	Y	FAIL	Warning Message: Test canceled by user. No media or wrong media type detected
54	(CD-ROM Drive) Linear Seek Test	Y	FAIL	Warning Message: Test canceled by user. No media or wrong media type detected
55	(CD-ROM Drive) Random Seek Test	Y	FAIL	Warning Message: Test canceled by user. No media or wrong media type detected
56	(CD-ROM Drive) Funnel Seek Test	Y	FAIL	Warning Message: Test canceled by user. No media or wrong media type detected
57	(CD-ROM Drive) Linear Read Compare Test	Y	FAIL	Warning Message: Test canceled by user. No media or wrong media type detected
58	(CD-ROM Drive) CD Audio Test	Y	FAIL	Warning Message: Test canceled by user. No media or wrong media type detected

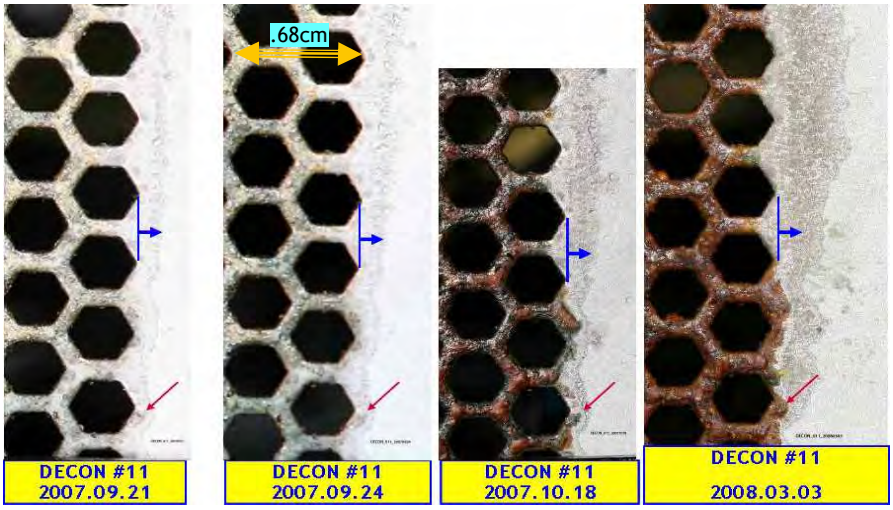
PC-Doctor^{R} enabled an objective and repeatable definition of "failure", free from most of the issues created by subjective or biased determinations in earlier reports. Tests were repeated on the sample at the EPA to allow a quantitative (counted) record to be created over time. Slide 24 shows the results of this method.

D. Specified Test Point Photographic Data Collection

Results of Using Precision Photographic Images as Visual Inspection Method



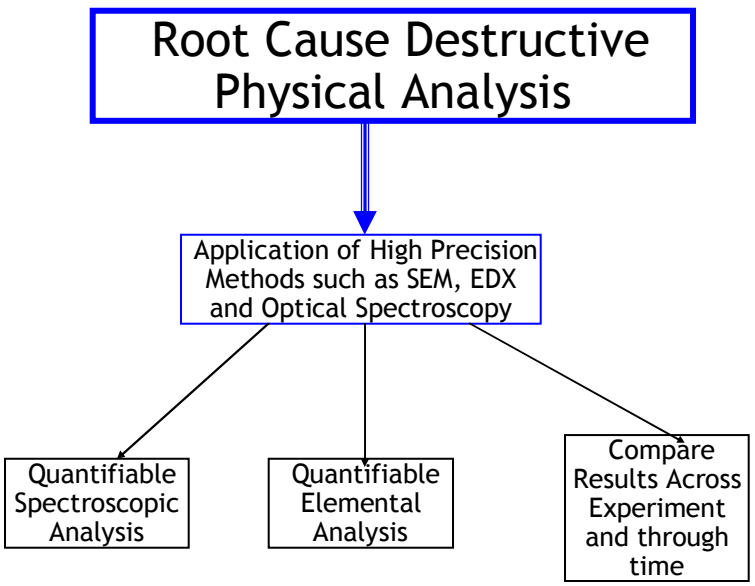
Progressive Cut-Edge Corrosion on Back Screen Measured over time



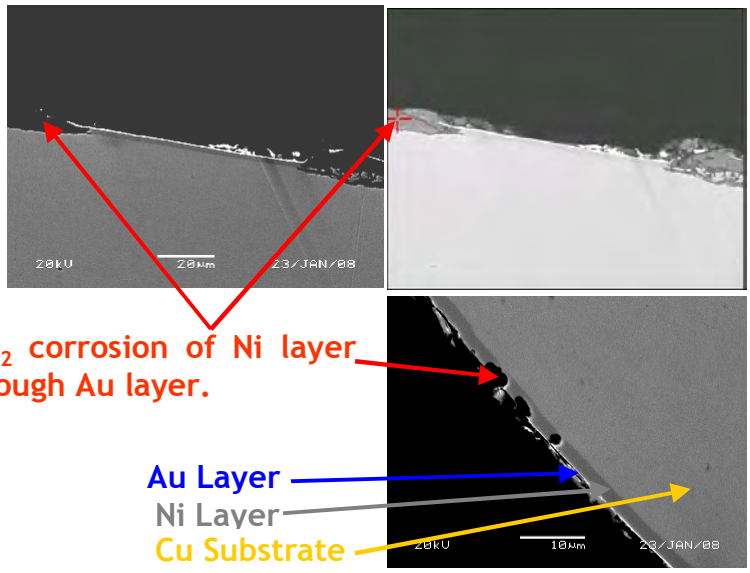
High resolution, large contrast dynamic range, and excellent color rendition of camera enable calibrated measurement and numerical analysis of corrosion front progression seen on slide 25.

E. Destructive Physical Analysis to Identify Root Cause of Failure

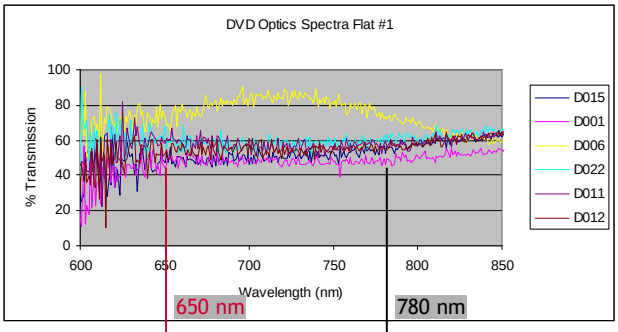
Root Cause Destructive Physical Analysis Uses Modern Precision Tools



Cross Section SEM View of DIMM Socket Connector on Motherboard from a Computer Exposed to 3000 ppmv ClO_2 (DECON #6)

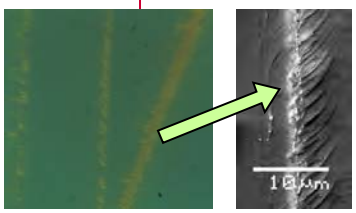


Comparison of Quarter-wave Plate Transmission Spectra for DECON DVD/CD Drives following Exposure.



% Transmission		
#	650nm	780nm
1	47	48
15	50	54
6	75	74
11	58	58
12	54	54
22	61	60

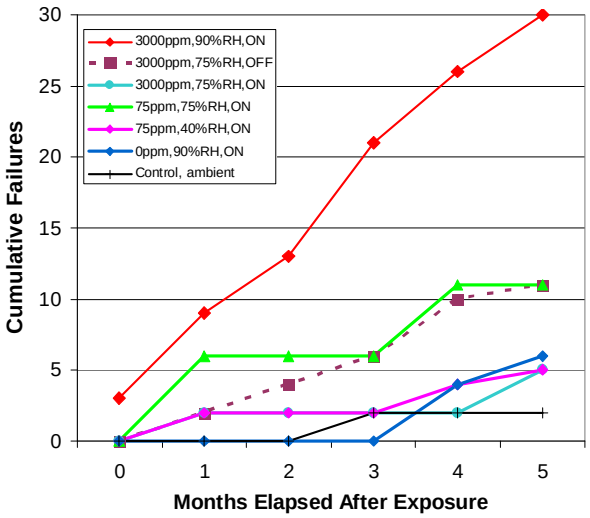
Red denotes computer with CD/DVD drive failures



Laser damage to plastic coating of quarter wave plate in Decon 6.

F. Quantitative Assessment of Damage Progression Through Time

PC Dr Repeated Measurements Demonstrate Progressive Damage



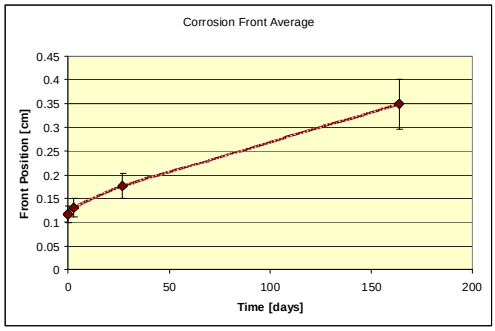
As noted on slide 15 repeated use of PC Dr was made over six months on samples retained at the EPA.

Damage to PCs continues to accumulate for months after exposure.

All PCs were tested immediately after decontamination. Immediate failures which occurred in high-exposure PCs are indicated by the "0" month data.

Cut-Edge Corrosion Progression
Measured on Repeated "Visual Inspection" Photographs

Cut-edge Corrosion Measurement										
G. Derkits										
Standard Distance = 0.68cm = Width of 2 internal Hexagons										
Hexagon Width pxl	Hexagon Width cm	cm/pxl	Dates	Date Differences [days]	Corrosion Front A [pxl]	Corrosion Front A [cm]	Corrosion Front B [pxl]	Corrosion Front B [cm]	Corrosion Front C [pxl]	Corrosion Front C [cm]
67	0.34	0.005075	9/21/2007	0	27	0.1370	19	0.0964	23	0.1167
64	0.34	0.005313	9/24/2007	3	29	0.1541	20	0.1063	25	0.1328
64	0.34	0.005313	10/18/2007	27	34	0.1806	36	0.1913	30	0.1594
64	0.34	0.005313	3/3/2008	164	55	0.2922	69	0.3666	73	0.3878



Corrosion Front Progression measured on photographs in slide 18 shows that damage continues for months after initial exposure.

Two thirds of damage occurs from weeks to months after the single day decontamination.

G. Summary, Conclusions, and Lessons Learned

Summary and Conclusions

A quantifiable objective assessment of the impact of biological decontamination on electronic equipment is enabled by using personal computers as test vehicles and analytical methodology adapted from standard environmental reliability studies of telecommunications equipment.

Until this study the results in this field were qualitative and subjective. We have advanced the state of art of biodecontamination studies and improved the quality of information used by U.S. Government agencies for the evaluation of decontamination technology.

The adoption of standard industrial practice for environmental reliability studies to assess the impact of decontamination by ClO2 and H2O2 has resulted in a set of data and conclusions which can be quantified and are demonstrably repeatable and objective.

The specific examples used in this presentation refer mainly to the initial study of ClO_2 decontamination, but the method described here has been adopted in going forward with other studies, as well.

Lessons Learned

1. Power=ON state is very difficult to define for intelligent systems programmed to conserve energy.
2. Determination of in-system Relative Humidity as a function of time throughout a run is difficult, especially near condensing conditions.
3. Corrosion Transfer among hardware test connectors can cause spurious results.
4. In highly competitive technologies driven by cost, modern manufacturing methods (e.g. "Just In Time") provides unexpected variation.
5. Human "common sense" sometimes defeats even well-documented procedures. Operators sometimes attempted to fix failures during testing, e.g. by disconnecting and reconnecting failed memory cards.

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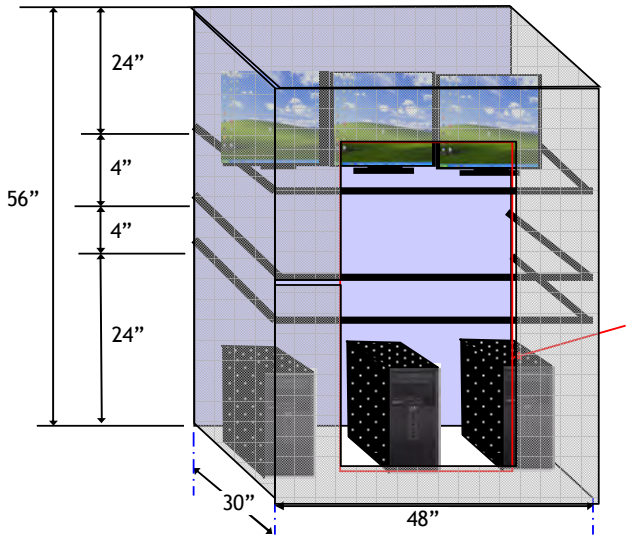
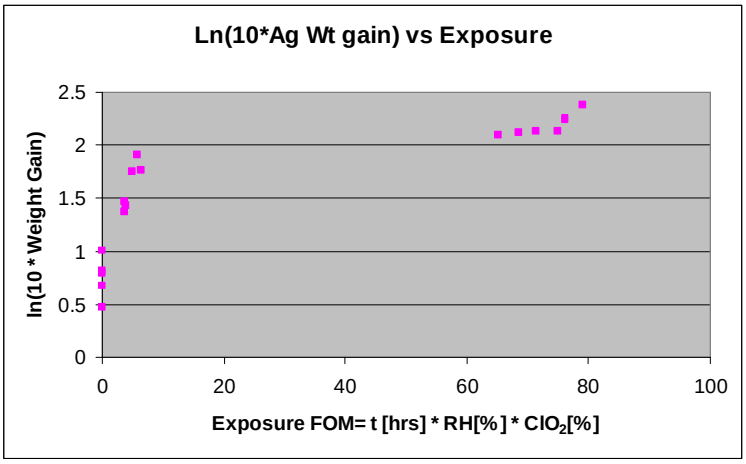
Personal Computers are compact enough to allow repetition in test chamber

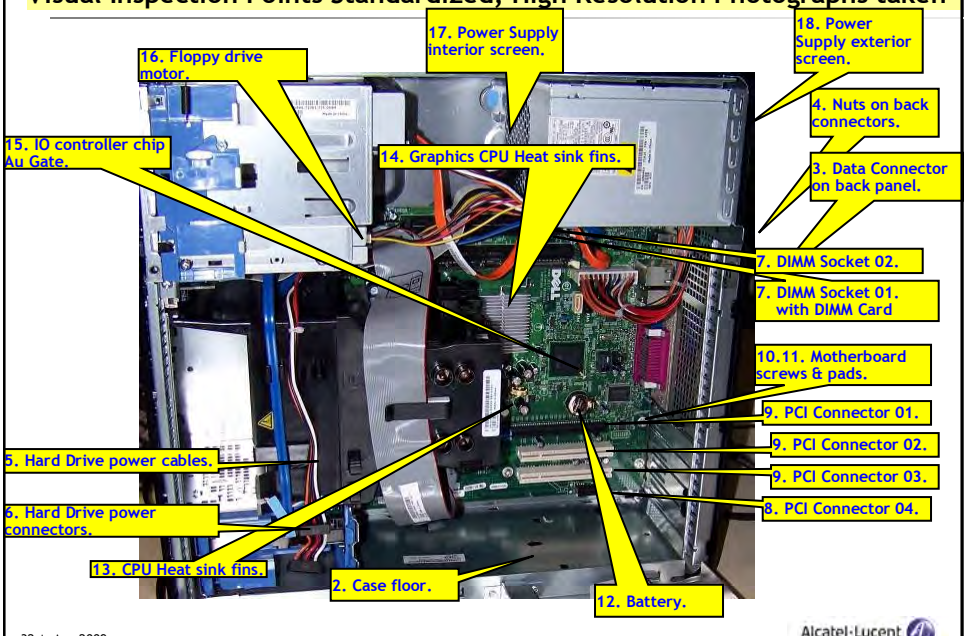


Weight Gain vs Exposure Suggests Surface Ion Transport Limited by RH

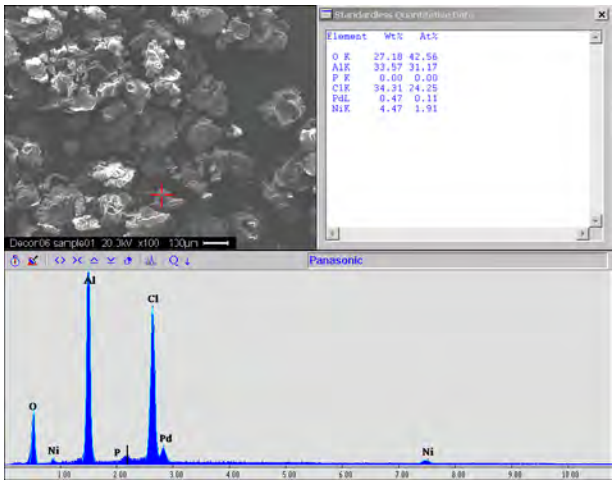


Quantitative data on Corrosion Mass Gain suggests that corrosion is strongly influenced by surface ion transport controlled by adsorption of water. The shape of the curve is similar to a BET Isotherm.

Visual Inspection Points Standardized, High Resolution Photographs taken



Precision Elemental Content Measurement: Cl Content of Al Corrosion Particle from DECON #6

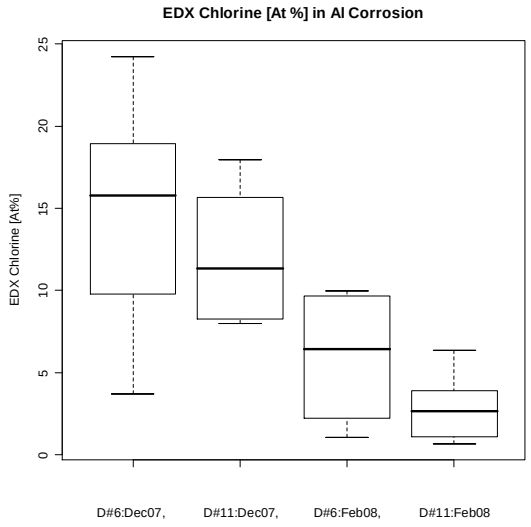


Cl content of corrosion particles emitted by the CPU heat sinks was repeatedly measured over time using Energy-Dispersive X-ray Analysis (EDX).

These measurements showed a decline in Cl consistent with the action of processes such as hydration and hydrolysis occurring long after the initial exposure.

See slide 34 for further information.

Progressive Change in Cl Content of Al Corrosion Comparison: Dec 2007 vs Feb 2008



Particles emitted by exposed Aluminum heat sinks change composition through time for months after initial exposure, measured by EDX, as noted on slide 33.

Chlorine concentration of particles indicates that hydration and hydrolysis processes continue on the surface.

NOTES designated in the slides by superscript in parentheses.

(1) *PC Standardization*: The descendants of the IBM PC, originally controlled by licensing of microchannel bus and other intellectual property from IBM, are now controlled by a variety of standards such as the PCI bus, controlled by the PCI special interest group, http://www.pcisig.com/home .

(2) *Photometrology* is a technical term used since at least the 1970's to describe the extraction of quantitative information from photographs. It is nearly synonymous with *photogrammetry*, but that term is more often used in the specialized sense of extracting three-dimensional information from aerial photographs.

(3) ASTM B 810-01A "Standard Test Method for Calibration of Atmospheric Corrosion Test Chambers by Change in Mass of Copper Coupons" and ASTM B 827-05 "Standard Practice for Conducting Mixed Flowing Gas (MFG) Environmental Tests" are examples of standards adapted for decontamination studies.

Assessment of the Impact of ClO_2 and H_2O_2 Decontamination on Electronic Equipment

M. L. Mandich, Alcatel-Lucent

Alcatel·Lucent

Assessment of the Impact of ClO_2 and H_2O_2 Decontamination on Electronic Equipment

Mary Mandich, C. Xu, D. Fleming, G. Derkits, J. Franey, R. Kopf, T. Wiecek, and W. Reents (Alcatel-Lucent)

Shawn Ryan (EPA) and Lance Brooks (DHS)

Alcatel-Lucent (LGS Innovations)

Project sponsored by EPA and DHS through CBRTA

Outline

1. Project overview and justification
2. Test matrix
3. Accomplishments in ClO_2 and H_2O_2 Decontamination Studies
4. Lessons learned including impact of COTS (commercial Off-The-Shelf) components
5. Conclusions and future studies

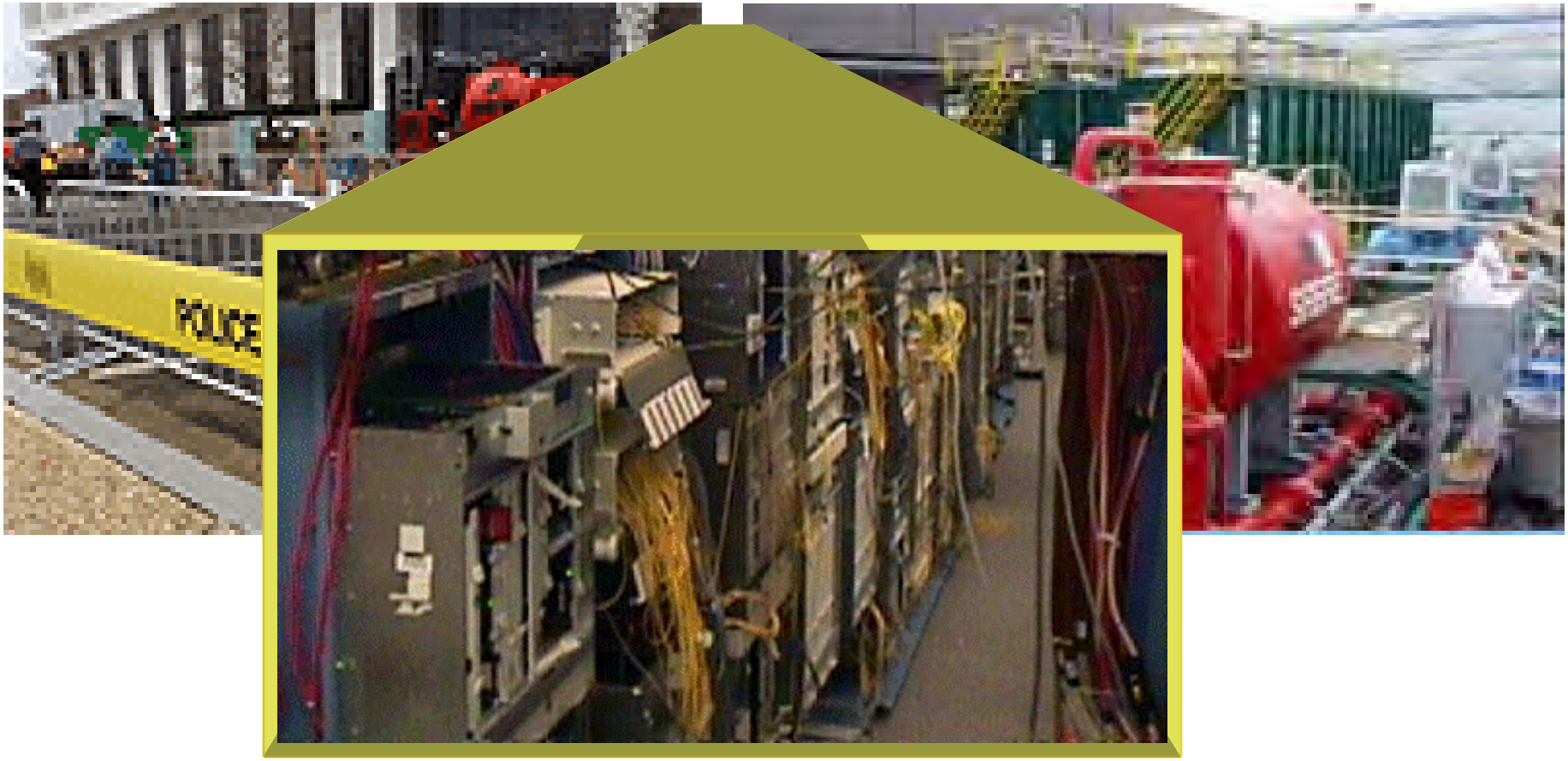
Project Overview and Justification

Fumigation technologies are being used to decontaminate buildings exposed to biological agents

Mandich

Hart Senate Office Bldg., Washington DC

Curseen Morris Postal Processing and Distribution Center, Hamilton, NJ



What happens to complex electronic equipment exposed to these fumigants?

Development of Strategies, Guidelines and Plans to Decontaminate Equipment following a Biological Weapons Attack

Mandich

- *Response to Homeland Security Presidential Directive 10: to develop comprehensive and coordinated responses to biological weapons attack*
- Goal: acquire specific data about impact of biodecontamination agents on electronic equipment
- Fumigants studied to date:
  - ClO_2 in 90%, 75% and 40% RH environments
  - H_2O_2 (both BIOQUELL and STERIS technologies)
- Test Vehicle: Dell desktop computers (prototypical electronic equipment)
- Objectives of testing are to determine:
  - impact of sporicidal ClO_2 and H_2O_2 fumigations
  - effect of humidity level during fumigation
  - impact of equipment power state (ON vs. OFF) during and after fumigation
  - assess impact of lower Concentration-Time exposures for remediating other biological threat agents and in-building mold

Test Matrix

Summary of Test Matrix Conditions (3 computers tested at each condition)

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Test	Equipment Power State During Fumigation	Treatment (all performed at EPA NHSRC)	Fumigant		Treatment Conditions		
			ClO_2 ppmv	H_2O_2	RH %	Temp ^0C	Time (hrs)
1	On	High humidity fumigation	3000		90	24	3
2	Off	Sporicidal fumigation conditions	3000		75	24	3
3	On	Sporicidal fumigation conditions	3000		75	24	3
4	On, busy	Sporicidal fumigation conditions	3000		75	24	3
5	On	Low ClO_2 concentration fumigation	75		75	24	12
6	On	Low ClO_2 concentration and low RH fumigation	75		40	24	12
7	On	BIOQUELL HPV		41g (30 vol-%)	>90	29	2
8	Off	BIOQUELL HPV		41g (30 vol-%)	>90	29	2
9	On	STERIS VPH		250 ppmv	32	29	4
10	Off	STERIS VPH		250 ppmv	32	29	4
11	On	High RH only (no ClO_2 exposure)			90	24	3
12	On	Ambient (control)			40	24	--

Accomplishments in ClO_2 and H_2O_2 Decontamination Studies

Assessment of Damage following ClO_2 or H_2O_2 Exposure

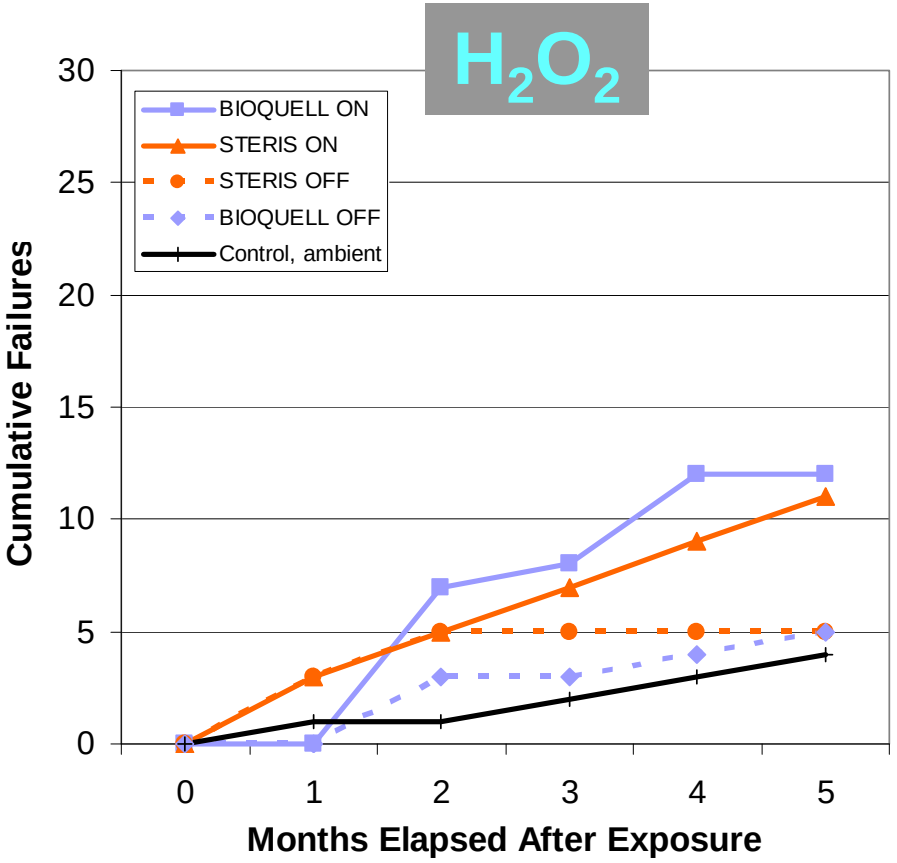
Mandich

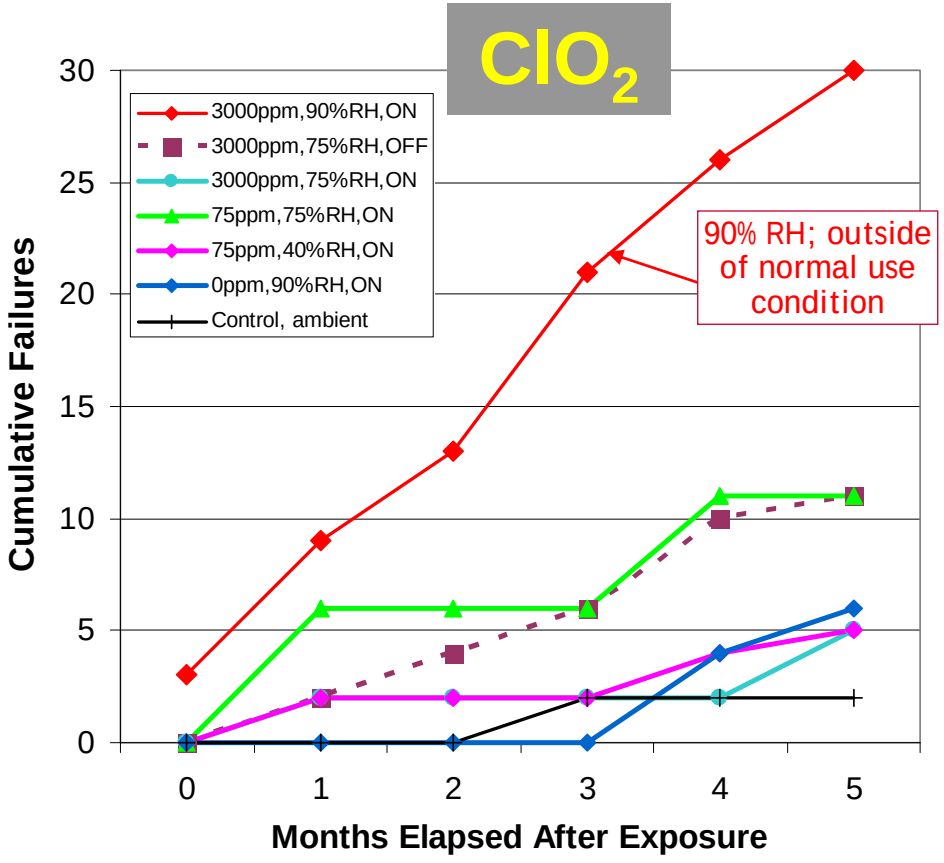
1) Computer diagnostics (using PC Doctor™)
2) Visual Inspection
3) Detailed assessment of failure modes resulting from exposures

Degradation of Computers: PC Doctor™ Failures During Post-Exposure Monitoring at EPA NHSRC

Meridich

- **Some failures intermittent. Overall, number of failures increases over time**
- **Comparable numbers of cumulative failures seen for H_2O_2-ON and ClO_2 (*both 3000 and 75 ppm*)**





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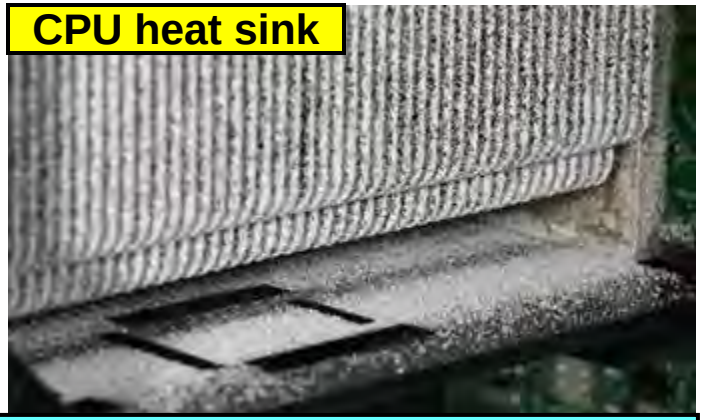
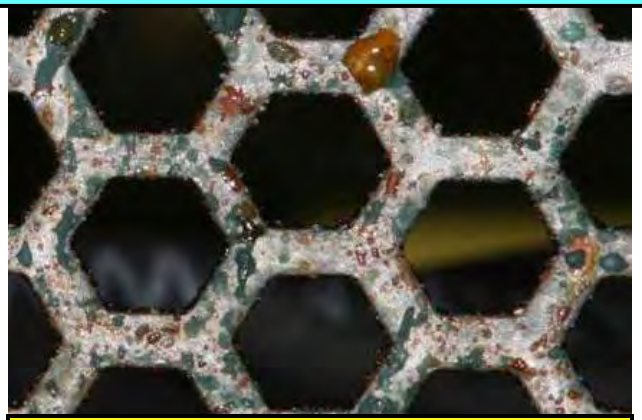
Assessment of Damage Using Visual Inspection

- Visual corrosion only occurred in computers exposed to ClO_2
- No *obvious* corrosion seen for H_2O_2 fumigated computers
- Corrosion from ClO_2 observed in multiple materials including aluminum, steel, silver, and plated copper
- Different types of corrosion observed
  - extensive particulate formation from CPU Al alloy heat sink fins
  - pore corrosion of plated copper
  - corrosion of plated steel parts
  - bleaching of cables
  - hygroscopic salt generation
- Static Intercept™ packaging observed to protect against further corrosion under ambient environmental conditions

CPU heat sink



Fumigation Conditions:
3000 ppmv ClO_2 – 75%RH - Off



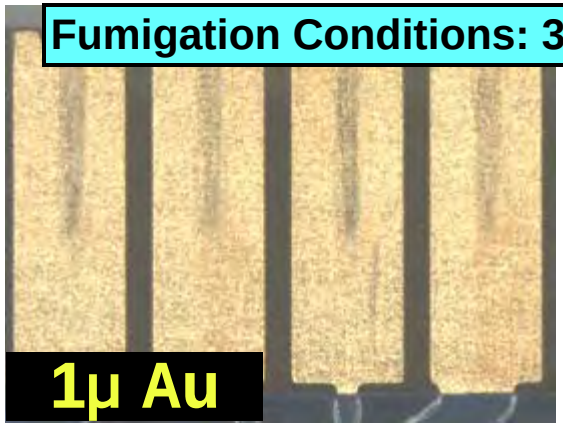
Fe-Cl, Zn-Cl from sheet metal

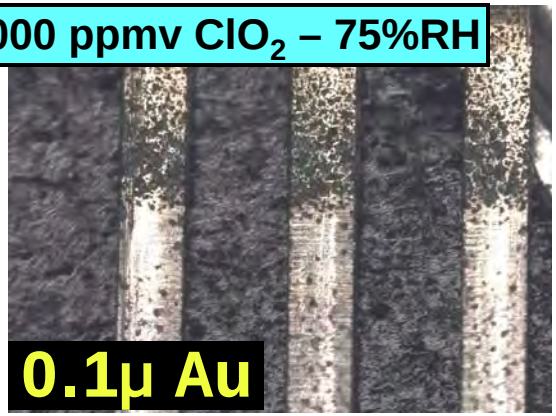
Susceptibility of Connectors to Corrosion from ClO_2 Exposure Determined by Gold Thickness

Mandich

Contact Plating Structure

Fumigation Conditions: 3000 ppmv ClO_2 – 75%RH





	DIMM Module		Hard Drive	
	Connector on DIMM	Connector on motherboard	Connector on drive	Connector on cable
Au Thickness	**1 µm**	**0.5 µm**	**0.5 µm**	**0.1 µm**
Ni Thickness	3 µm	2 µm	2 µm	4 µm
Au Coverage	complete	selective	complete	selective
Corrosion Thru Au Layer?	**NO**	**YES**	**YES**	**YES**

>0.5 µm thick Au plating over Ni is required for connector to survive the corrosive environment during ClO_2 decontamination.

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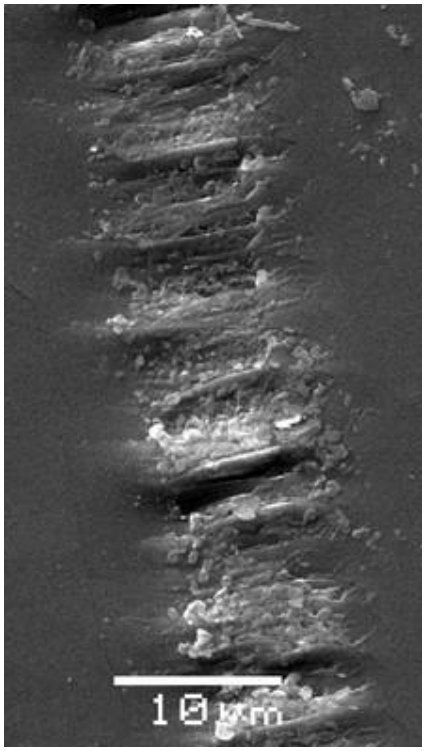
Many Dual DVD-CD Drive Failures Occurred in Exposed Computers
Location of Damage: Passive Optics in Optical Pickup Assembly

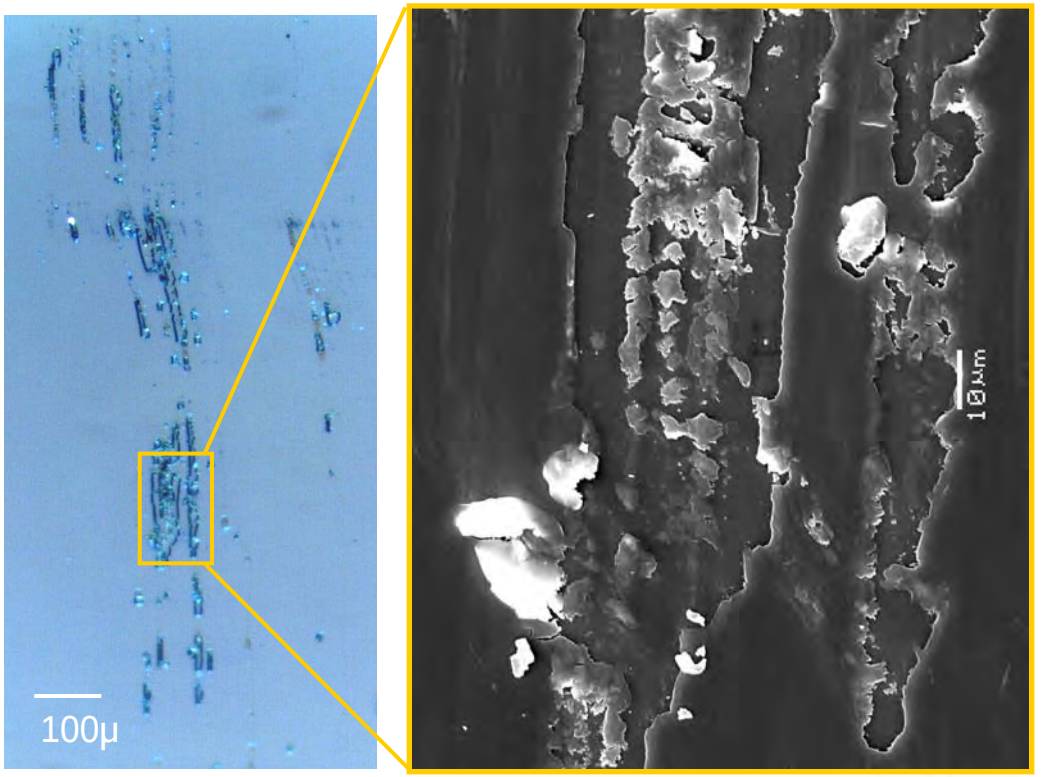
Mandion

- Both ClO_2 and H_2O_2 fumigation damages DVD-CD drives
- Most damage is laser-assisted; worst is seen for H_2O_2 exposures
- Optics with most damage fabricated with plastic optical materials.

ClO_2 Fumigated 1/4-Wave Plate



H_2O_2 Fumigated CD Laser Beamsplitter

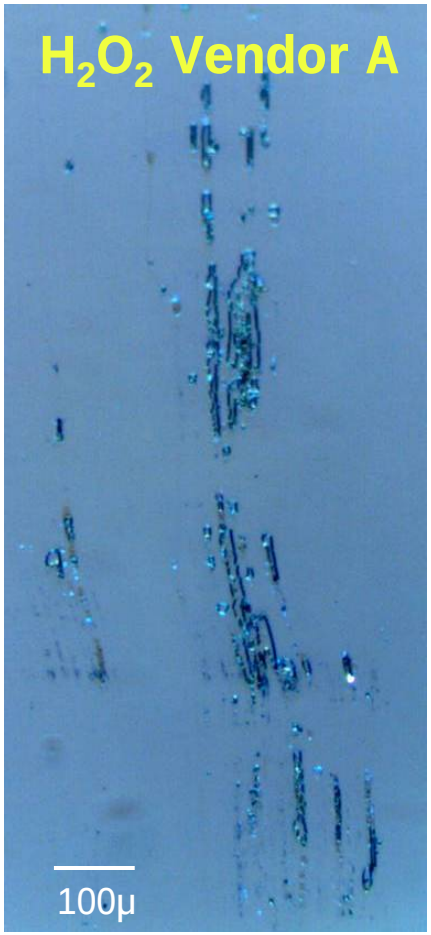


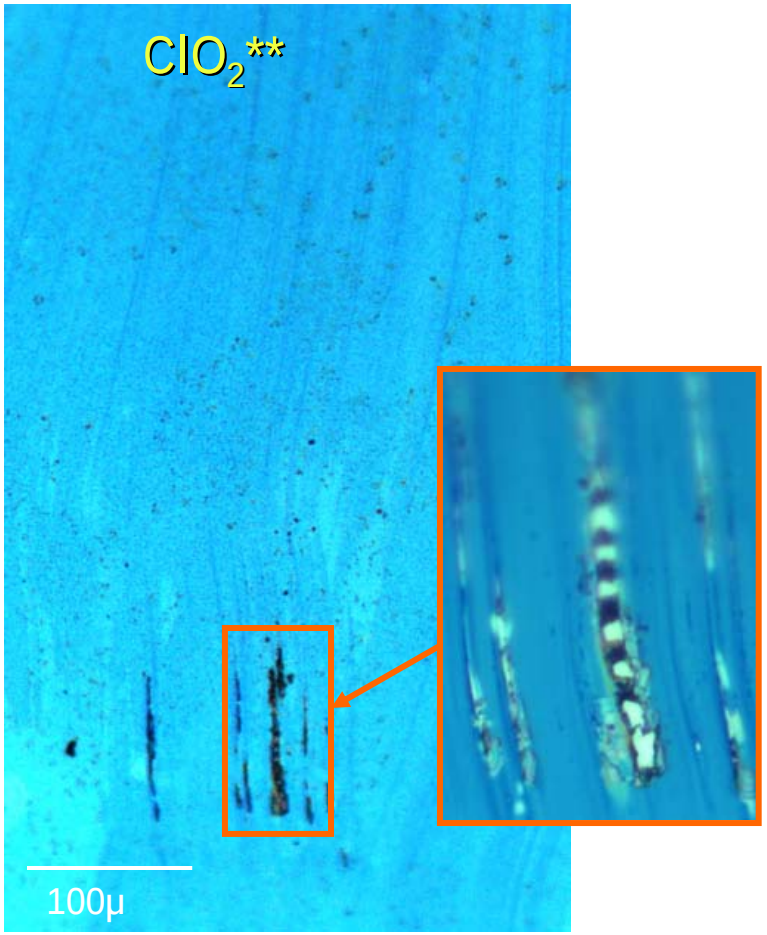
Alcatel·Lucent

Failure Analysis of Most Heavily Damaged Optical Element in the OPA in Phase2 Studies: CD Laser Beamsplitter

Mandich

Increasing amount of damage





** Note: small splotchy areas in this image are sputtered gold for SEM imaging purposes

Alcatel·Lucent

Lessons Learned

Summary of the Short and Long Term Impact of *ClO_2 and H_2O_2 on Materials and Components in Electronic Equipment

Mandich

Impact Observed	Reliability Problem				Impact on Equipment			
	Short Term		Long Term		Catastrophic		Aesthetic	
	ClO_2	H_2O_2	ClO_2	H_2O_2	ClO_2	H_2O_2	ClO_2	H_2O_2
CPU heat sink corrosion			●		●			
Connector corrosion	●		●		●			
Joint corrosion (e.g. solder, bond pads)	●		●		●			
Plated steel corrosion			●				●	
Optics damage (especially plastic optics)	●	●	●	●	●	●		
Dust formation	●		●		●			
Cable bleaching							●**	

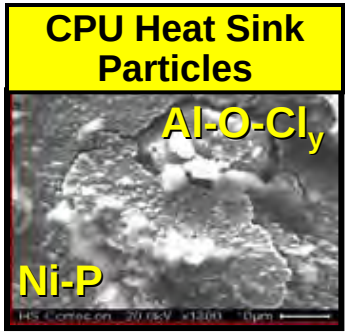
✱ Using sporicidal ClO_2 fumigation conditions

✱✱ Potentially catastrophic for larger systems and installations involving complex wiring

Subsystem Repair and Cleaning Are Not Effective Means to Mitigate Corrosion and Failure

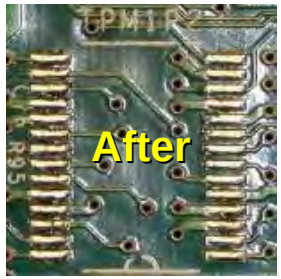
Mandich

1. Tried: monthly cleaning of hygroscopic dust particles
   - *Palliative only: new dust particles form in ambient room air*
   - Possible safety hazard: dust has particles with sizes in sub-μm range that disperse easily and contain Al, Ni, Cl, Fe, P, Cu



2. Tried: disconnection-reconnection to solve connector failures (especially DIMM memory)
   - Relief temporary: failure often repeated
   - Replacement DIMM cards only temporary solution: corroded motherboard connector transfers corrosion to new cards

3. Performed reflow to simulate circuit board repair
   - ICs on control motherboard survived
   - Observed IC detachment on exposed motherboard, *indicates hidden damage to solder*



Effective mitigation requires using more robust materials suitable for these harsh environments

Alcatel·Lucent

Conclusions and Future Studies

Impact of COTS Components on Equipment Survivability

Mandich

1. Use of optical plastics in COTS components
   - Optical plastics highly susceptible to both ClO_2 and H_2O_2 induced damage
   - Both H_2O_2 fumigation technologies cause much more damage than ClO_2
   - Expanding use of optical plastics in COTS components
     - Lower cost materials and manufacturing
     - Can be made as "one piece" with precision mounting components
   - Proliferation of optical plastics in many different technologies
     - Digital cameras
     - CD/DVD players, optical sensors, optical mice
     - LED optics for lighting
     - Optical scanners (fingerprint and retinal scanners) and sensors

2. Cost reduction in gold use in COTS components
   - ClO_2 fumigation damages connectors with <0.5 µm thick gold
   - Greatest ClO_2 damage to connectors using thin gold and selective plating
   - H_2O_2 causes no apparent damage even for thin gold
   - Commercial electronics market using thinner gold/selective plating to save costs
     - Gold plating on many connectors in Dell Optiplex computers less than 0.5 µm
     - Consumer electronic market often uses "flash Au" which is only 0.1-0.25 µm thick

Significant, In-depth Data Now Available on Impact of ClO_2 and H_2O_2 Fumigation on Electronic Equipment

Mandich

- Material choices used in test computers a significant reason for extent of damage
  - Examples used by COTS commercial market for cost saving:
    - thinner gold plating on connectors
    - plastic optical components
    - cut plated steel
- Have comparative damage summary for ClO_2 and H_2O_2
  - Corrosion of many different metals, e.g. Al, Ag, Ni, plated Cu, steel
  - Bleaching of plastic coating on cables
  - Variety of subsystems damaged, e.g. Au-plated connectors and CD/DVD drives
- Much of the damage progresses in time
- ClO_2 fumigation forms copious quantities of corrosive, submicron size dust
- ClO_2 fumigation causes extensive corrosion of many connectors in computers
- Most computers exposed to ClO_2 or H_2O_2 suffered DVD/CD disk drive failures

Current Work:

Study impact of Methyl Bromide decontamination on electronic equipment

Visible Corrosion of the Aluminum CPU Heat Sink as a Function of Fumigation Conditions

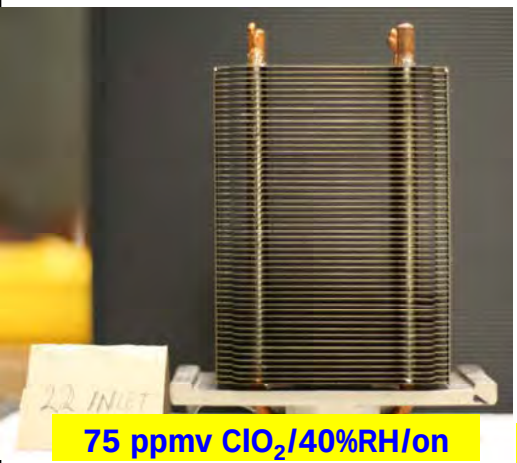
Mandich

3000 ppmv ClO_2/90%RH/on

3000 ppmv ClO_2/75%RH/off

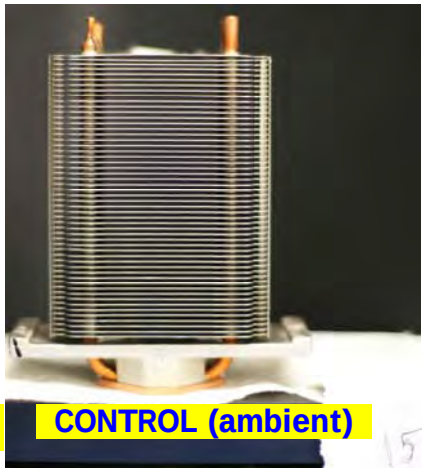
3000 ppmv ClO_2/75%RH/on

75 ppmv ClO_2/75%RH/on



75 ppmv ClO_2/40%RH/on

no ClO_2/90%RH/on

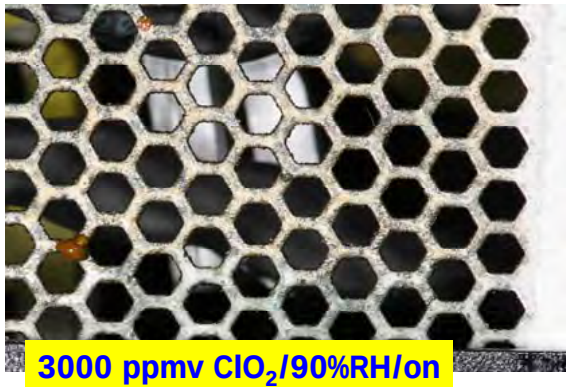


CONTROL (ambient)

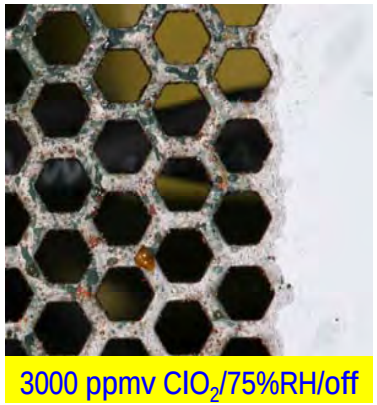
- All CPU heat sinks exposed to 75-3000 ppmv ClO_2 and ≥75% RH significantly corroded.
- The CPU heat sink exposed to 75 ppmv ClO_2/40% RH shows possible discoloration
- CPU heat sinks <u>not</u> exposed to ClO_2 exhibit no corrosion.

Visible Corrosion of the Rear Case Screen as a Function of Fumigation Conditions

Mandich



3000 ppmv ClO_2/90%RH/on



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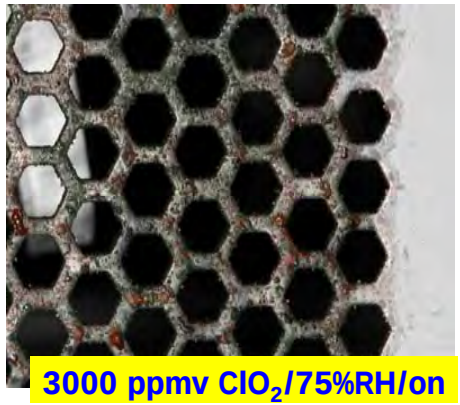
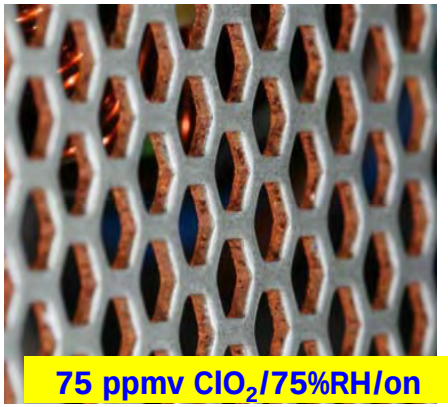
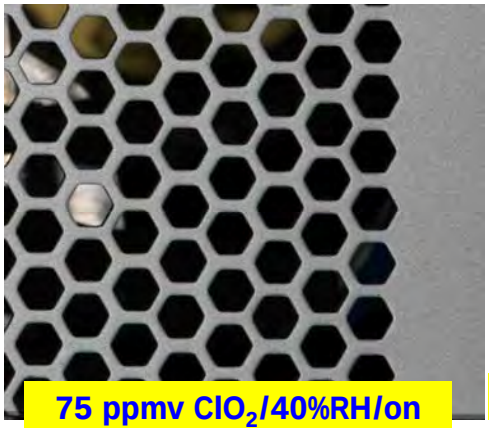


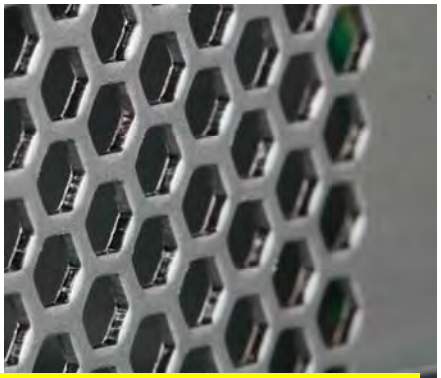
3000 ppmv ClO_2/75%RH/on



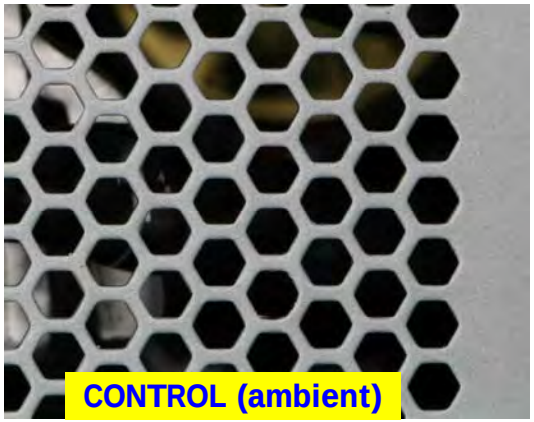
75 ppmv ClO_2/75%RH/on



75 ppmv ClO_2/40%RH/on



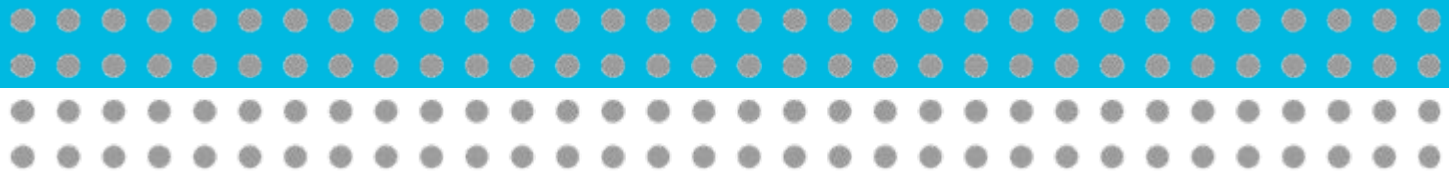
no ClO_2/90%RH/on



CONTROL (ambient)

- Screens exposed to 3000 ppmv ClO_2 and ≥75% RH exhibit obvious corrosion of both steel and Zn.
- Screens exposed to 75 ppmv ClO_2/75% RH have corrosion of steel along edge, no corrosion of Zn.
- Screens exposed to 75ppmv ClO_2/40%RH or <u>not</u> exposed to ClO_2 show no signs of corrosion of either steel or Zn.

www.alcatel-lucent.com



Evaluating Strategies for CWA Decontamination of Indoor Facilities

Adam H. Love, Consultant to Lawrence Livermore National Laboratory

Presentation not available for distribution

Test Methodology for the Assessment of Chemical Warfare Agent Decontaminant Performance on Porous or Complex Surfaces

Paul Brister, Clean Earth Technologies, LLC

Presentation not available for distribution

Basic Research Needs in Decontamination

Jennifer Becker, U.S. Army Research Office

U.S. Army Research, Development and Engineering Command

Basic Research Needs in Decontamination

April 2010

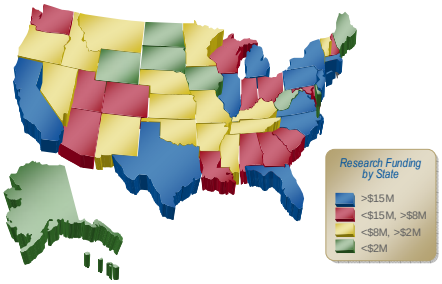
TECHNOLOGY DRIVEN. WARFIGHTER FOCUSED.

Dr. Jennifer Becker
Chemical Sciences Division
Organic and Inorganic Chemistry
Army Research Office
jennifer.j.becker@us.army.mil
919-549-4224

Army Research Office Overview

Mission: to serve as the Army's premier extramural basic research agency in the engineering, physical, information and life sciences; developing and exploiting innovative advances to ensure the Nation's technological superiority.

- ***Exploit Scientific Opportunities for Revolutionary New Army Capabilities***
- ***Drive Science to Develop Solutions to Existing Army Technology Needs***
- ***Accelerate Transition of Basic Research***
- ***Strengthen University, Industry, and Government Partnerships***
- ***Educate and Train the Future S&E Workforce for the Army***



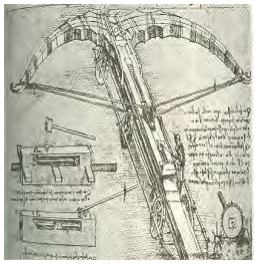
- 256 Institutes of Higher Learning
- 861 Individual Investigators
- 47 Research Centers

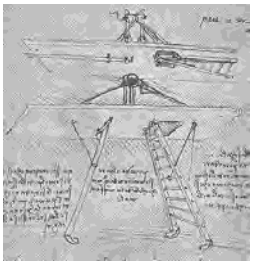
Research Thrusts

Chemistry	Materials Science
Computing & Info Science	Mathematics
Electronics	Mechanics
Environmental	Network Science
Life Sciences	Nanoscience
	Physics

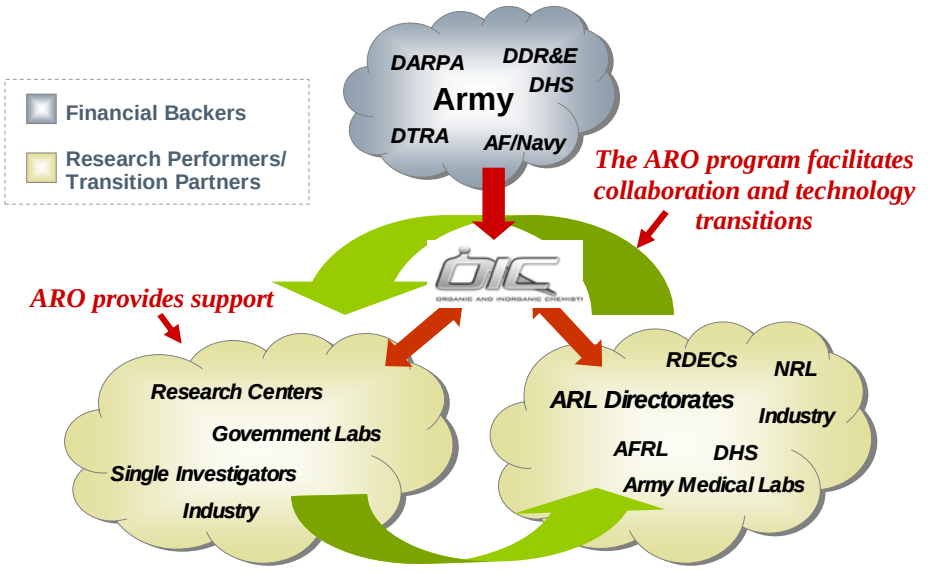
Funding Scientific Breakthroughs

- **Extrapolation of Existing Technologies (needs driven)**
  - Incremental, Continued Improvement in Existing Technologies
  - Often Driven or Enabled by **Commercial** Market
    - Disposable handheld sensors
    - First responder decon solutions
  - May be a "Disruptive Technology" (e.g. personal vs. mini computers)
- ***Revolutionary New Applications from Scientific Breakthroughs (opportunity driven)***
  - Utilizes Two Somewhat Distinct Mechanisms
    - Fundamentally new approaches to solving old problems
    - Fundamentally new capabilities
  - Examples from Past
    - Navigation - Satellites and atom clocks for GPS
    - Range Finders and Target Designators - Lasers
  - ***Potential Examples for Future***
    - ***Smart materials – sense and neutralize threats***
    - ***Integration of protection with living systems***
    - ***Nanotechnology based capabilities for protection, decon, or detection***





ARO Basic Research Role

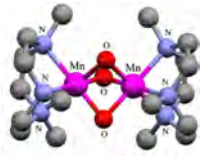


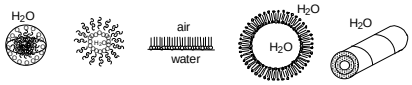
Vision

To develop a molecular level understanding of catalytic reactions, functionalized surfaces and organized assemblies that will provide the foundation for creating new materials and processes to protect the soldier from hazardous chemicals and materials.

Research Thrusts

1. Surfaces and Catalysis
2. Organized Assemblies





Organic and Inorganic Chemistry

Hazardous Materials Management

Decontamination

ORGANIC AND INORGANIC CHEMISTRY

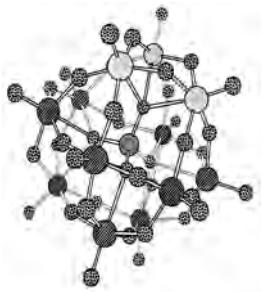
Protection

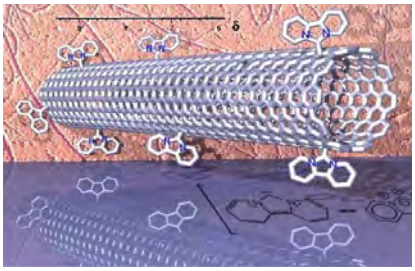
Detection

Surfaces and Catalysis Thrust Scientific Objectives

Scientific Objectives

- To design and synthesize nano-structured catalysts with known properties and well-defined morphologies
- To fully understand the kinetics and mechanisms of catalytic reactions
- To develop a mechanistic understanding of reactions on surfaces and at interfaces
- To understand and enhance mass transport on surfaces

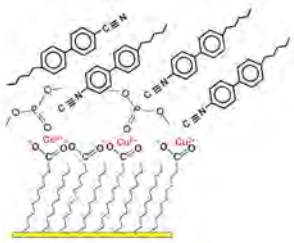


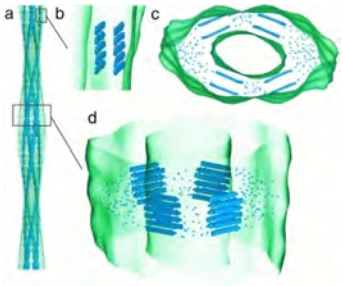


Organized Assemblies Scientific Objectives

Scientific Objectives

- To design new approaches to synthesize controlled self-assembled structures
- To incorporate functionality into self-assembled structures
- To design self-assembled systems with responsive behavior
- To understand how to control assembly under different conditions





Surface Chemistry
A Molecular Level Understanding

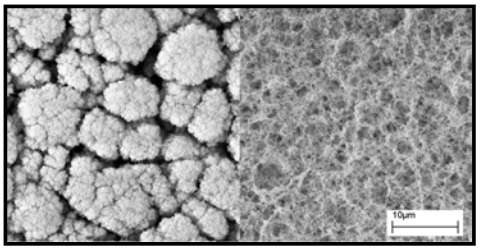
John Morris, Virginia Tech

Scientific Goal

To understand the molecular level mechanisms and kinetics of reactions on surfaces

Approach

- Synthesize metal oxide nanoparticle catalysts
- Design ultra-high vacuum time-resolved techniques
- Characterize surface bound and gas-phase reaction products



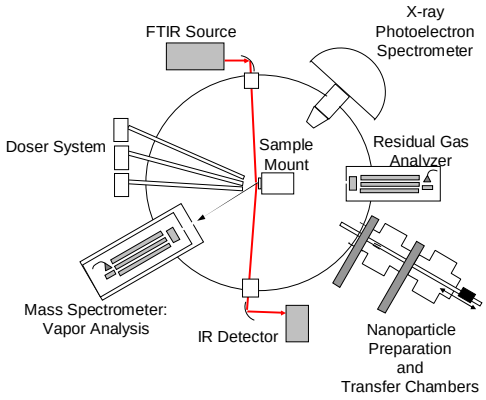
1 nm Y_2O_3 made in 1 Torr N_2

5 nm Y_2O_3 made in 10 Torr N_2

Surface Chemistry
A Molecular Level Understanding

John Morris, Virginia Tech

Experimental Set-Up



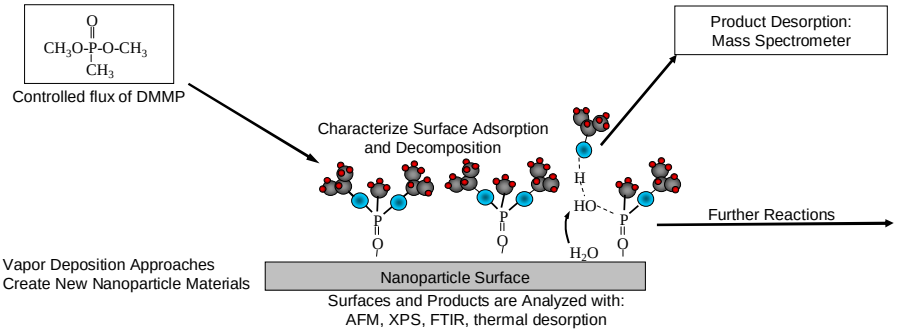
Actual System

Surface Chemistry
A Molecular Level Understanding

John Morris, Virginia Tech

Room temperature adsorption and decomposition of DMMP

Dissociated:molecular bound DMMP increases by factor of 2 with smaller particles (2nm vs 5nm)



15

Conjugated Polyelectrolytes
As Versatile Antimicrobials

David Whitten, University of New Mexico

Scientific Goal

To explore the biocidal activity of conjugated polyelectrolytes

Approach

- Materials synthesis
- Studies of biocidal activity of CPE and OPE in various formats
- Mechanistic studies of dark and light-activated biocidal activity
- Photochemical, photophysical and theory/modeling studies of OPE and CPE

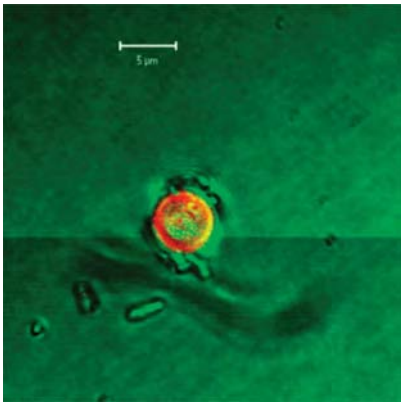
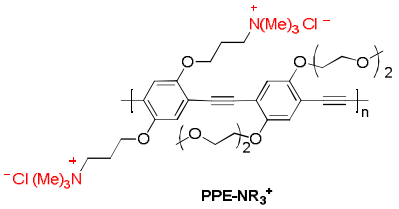
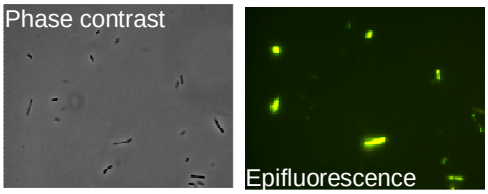


Image of single surface grafted conjugated polyelectrolyte SGCP-particle with captured bacteria

Conjugated Polyelectrolytes As Versatile Antimicrobials

David Whitten, University of New Mexico





E. coli with PPE-NMe_3^+

Lu., et al. ***Langmuir.*** 2005, 21, 10154.

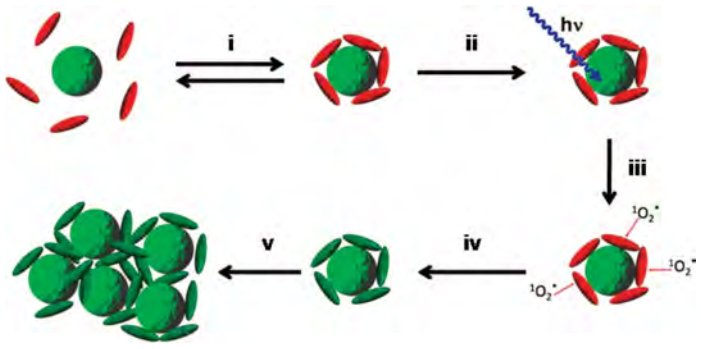
Initial Findings

- PPE-NR3+ shows biocidal activity vs both ***Escherichia coli*** vegetative cells and ***Bacillus anthracis*** spores
- Biocidal activity enhanced by illumination with visible light
- Solution phase PPE-NR3+ associates with bacteria
- >1 monolayer coverage on B. anthracis Sterne spores

Conjugated Polyelectrolytes As Versatile Antimicrobials

David Whitten, University of New Mexico

Mechanism of Biocidal Action of SGCP



i) Reversible bacteria adhesion to the particle.

ii) Photoexcitation of CPE.

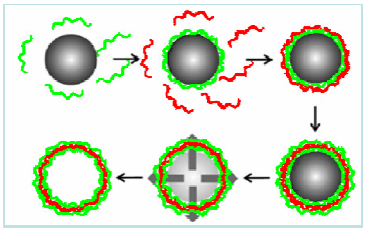
iii) Singlet oxygen generation.

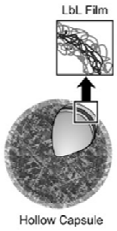
iv) Killing bacteria by singlet oxygen.

v) Aggregation of particles.

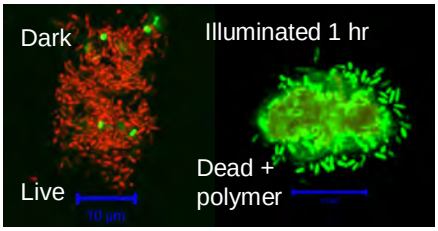
Conjugated Polyelectrolytes As Versatile Antimicrobials

David Whitten, University of New Mexico





Micro “Roach Motels” based on layer-by-layer assembly of oppositely charged CPEs



- Left: Confocal laser scanning micrograph of μRM cluster 10 minutes after introduction into a solution of ***Pseudomonas aeruginosa*** (10^7/mL) kept in the dark.
- Right: Central slice of 20 mm z-stack showing interior of mRM cluster with entrapped, killed bacteria after 1 hour exposure to white light.

Corbitt., et al. ***ACS Appl. Mat. Interf.*** 2009, 1, 48.

Molecular Machines as Abiotic Enzymes

Chad A Mirkin, Northwestern University

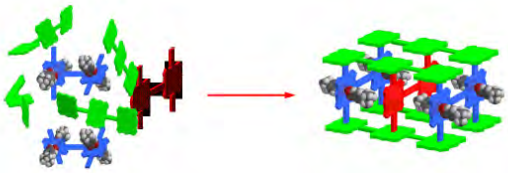
Scientific Goal

To explore the fundamental assembly and functional chemistry approaches to develop easily assembled abiotic catalysts (“artificial enzymes”)

Approach

- Synthesize and characterize new types of supramolecular allosteric catalysts
- Design and synthesize bio-inspired structures that facilitate directional energy transfer
- Explore novel signal transduction and amplification strategies within the supramolecular assemblies

A spontaneously-assembled “molecular machine” that displays highly selective, ***cavity-controlled*** catalytic chemical oxidation

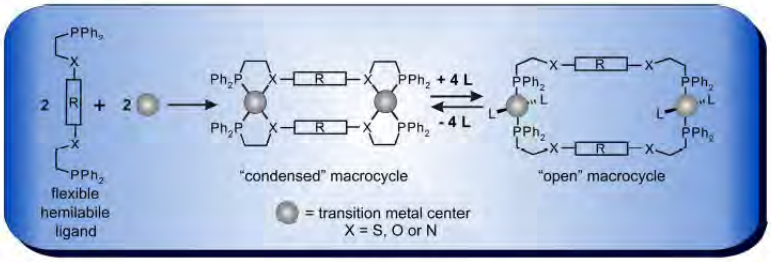


Active sites = coordinatively encapsulated, torsionally rigid, manganese porphyrins

Molecular Machines as Abiotic Enzymes

Chad A Mirkin, Northwestern University

Cataylst/Cavity Assembly Strategy: The Weak-Link Approach (WLA)



Key Points:

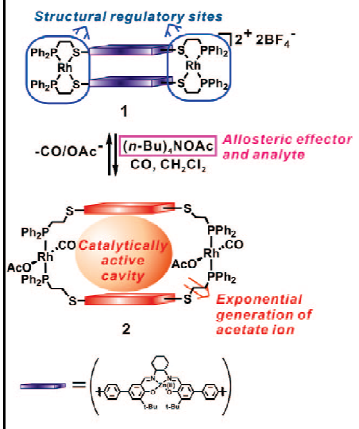
- General and high yield syntheses
- Flexible ligands
- Multiple levels of tailorability
- Coordinatively unsaturated metal centers
- Multiple geometries available *in situ*

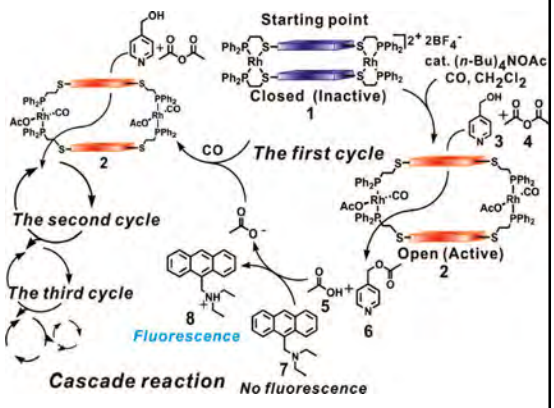
Holliday, *et al. Angew. Chem. Int. Ed.* **2001**, *40*, 2022.
Gianneschi, *et al. Acc. Chem. Res.* **2005**, *38*, 825.

Molecular Machines as Abiotic Enzymes

Chad A Mirkin, Northwestern University

Sense and Respond System Example





Dynamic Combinatorial Chemistry

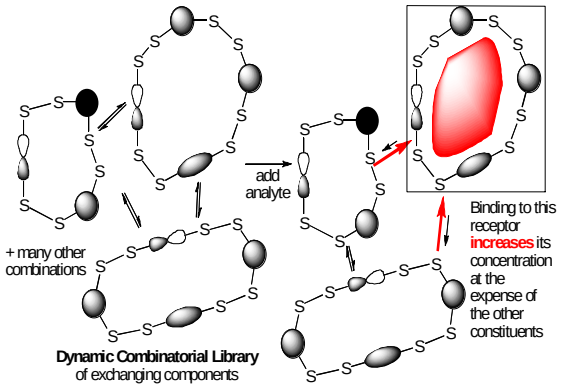
Michel Gagne, University of North Carolina-Chapel Hill

Scientific Goal

To develop Dynamic Combinatorial Chemistry as an effective and powerful tool for discovering new functional host-guest combinations with a focus on analyzing complex libraries

Approach

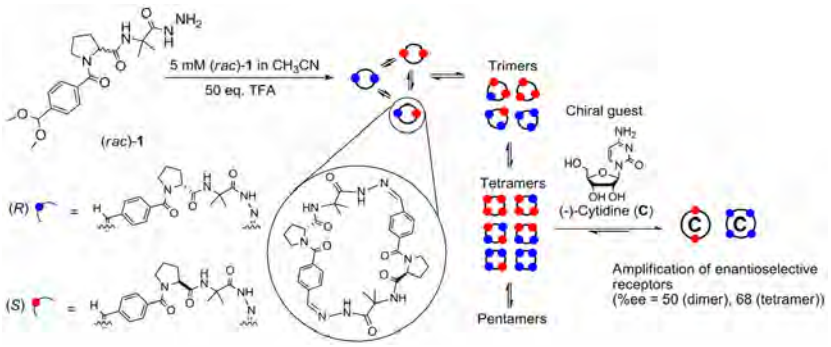
- Develop new ultrahigh resolution LC techniques (UPLC and 2-D LC)
- Develop new assays for detecting binding/response behavior of aqueous receptors
- Develop new libraries, reactions, and strategies for high-throughput analysis



Dynamic Combinatorial Chemistry

Michel Gagne, University of North Carolina-Chapel Hill

The initially racemic library can deracemize on binding to (-)-cytidine or (-)-2-thiocytidine (10 eq with respect to (***rac***)-**1**), resulting in the amplification of the homo-dimer ((***SS***)-dimer) and the homo-tetramer ((***RRRR***)-tetramer) at the expense of the trimers and hexamers



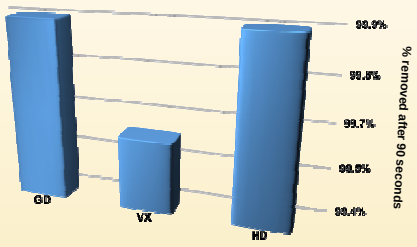
Basic Research Success: Activated Metal Oxides to Decontaminants

- **Mid-1980's – Fundamental investments in activated metal oxides; potential broad uses in filters, pre-concentrators, and decontaminants**
- Fundamental decontamination research effort funded with Professor Ken Klabunde at Kansas State University – "Activated Metal Oxide Surfaces as Highly Basic & Reducing Environments"
- **1995 – Research leads to breakthrough development of "nanostructured sorbents" which becomes one of the first nanotechnology products**

Very small 2 – 4 nm cubes/waffles can be seen that aggregate into polyhedral structures.

Basic Research Success: Activated Metal Oxides to Decontaminants

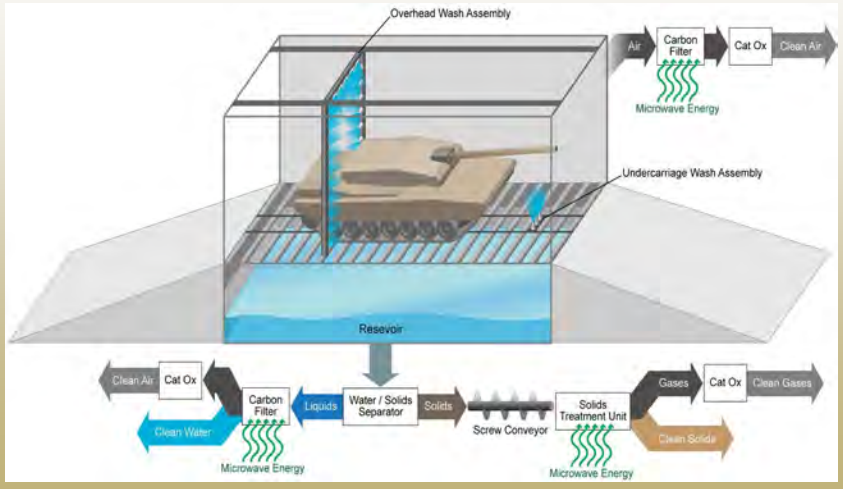
- 1990's Breakthrough leads to development of Nanoscale Fast-Act Decontaminant



Collaborative Research Programs in CBD between DTRA, ECBC, and ARO lead to the development of the commercially available decontaminant effective against nerve, blood, and blister agents.

Basic Research Success: Vehicle Wash System *

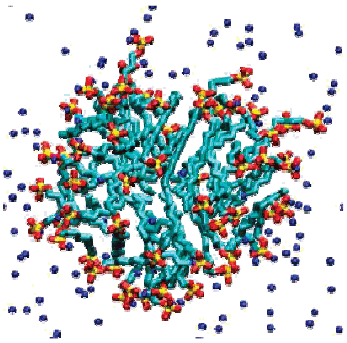
Octaflex and Cha Corporation



Vehicle Wash System at Ft. Leonard Wood Demonstration in 2009

Decontamination Challenges

- Mass transport
- Mechanistic and kinetic studies
- Structure-function relationships
- Control of responsive and dynamic systems
- Agent-simulant correlation
- Dissolution of agents



Structure of a sodium dodecyl sulfate micelle, a surfactant aggregate

Organic and Inorganic Chemistry Program Dynamics/Future Directions

- Nano-Structured Porous Functional and Reactive Materials by Design
  - Controllable pore sizes, shapes, and functionalized surfaces
  - Fundamental understanding of structure-function relationship
  - Understanding of principles that govern synthesis, functionalization, adsorption, and reactivity
- Bio-colloids combining colloid chemistry and biotechnology
  - Functional biological materials to create advanced materials in high yield and regularity
  - Targeted synthesis of self-organizing biocolloids

Suggestions for Applicants

ARO Single Investigator Program (no deadlines):

1. Discover ARO Interests - www.aro.army.mil, **talk to program managers**
2. Write Pre-proposal (several pages) - clear goals, some technical detail, level of support needed, special equipment
3. Email Pre-proposal - expedites review by Army scientists

ARO Opportunities

ARO Broad Agency Announcement
- **Proposals Due ~ October** **even though BAA is always open**
- **Conference / Symposium / Workshop Grants**
- **Short Term Innovative Research - STIR**
- **Young Investigator Program - YIP and PECASE**

Multidisciplinary University Research Initiative - MURI
- **Proposals Due ~ November**

Defense University Research Instrumentation Program - DURIP
- **Proposals Due ~ August**

Small Business Innovative Research - SBIR
- **Proposals Due ~ May**

Small Business Technology Transfer - STTR (university partners)
- **Proposals Due ~ April**

Other Opportunities
- **DARPA, DTRA, DoD Laboratories**

Knockdown and Neutralization of Aerosolized Chemical Agent Simulants Using Charged Decontaminant Sprays

Rita Betty, Sandia National Laboratories

Knockdown and Neutralization of Aerosolized Chemical Agent Simulants Using Charged Decontaminant Sprays

Presented at the 2010 US EPA Decontamination Research and Development Conference
April 15, 2010

Rita G. Betty, John Brockmann, Dan Lucero, Mark Tucker, Jonathan Leonard, Mollye Wilson, Brandon Servantes Andres Sanchez, Ashley Allen

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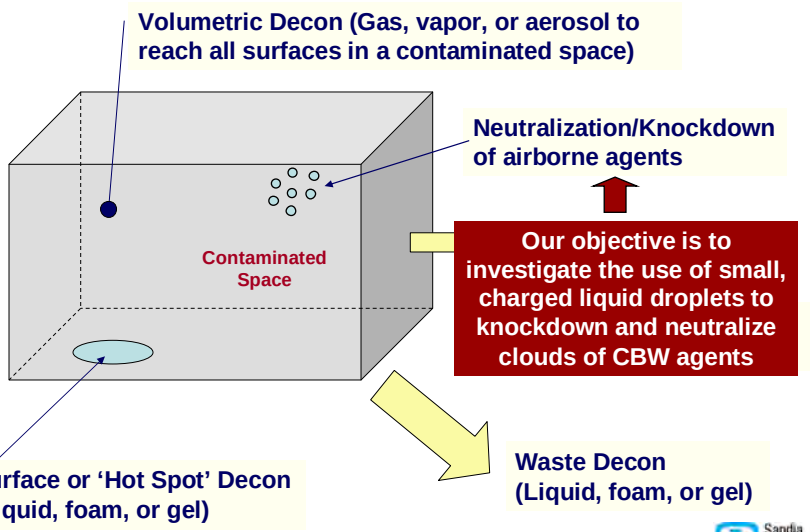
Neutralization or decontamination of toxic chemical or biological materials may require a set of technologies and approaches



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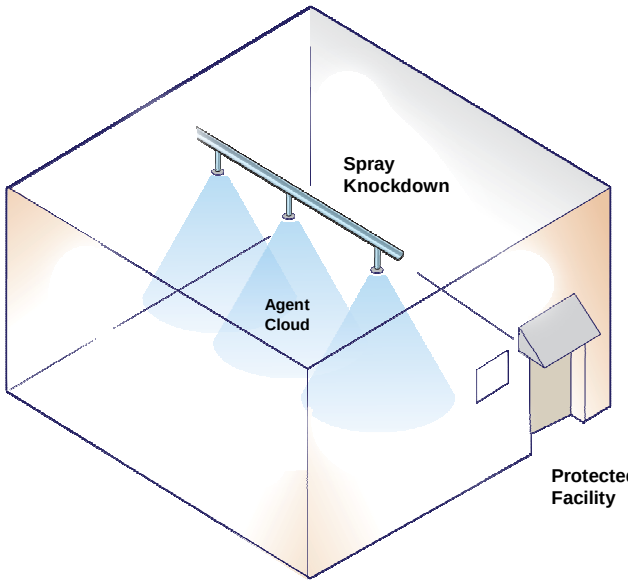
Airborne Agent Knockdown & Neutralization Concept

Interior Protection



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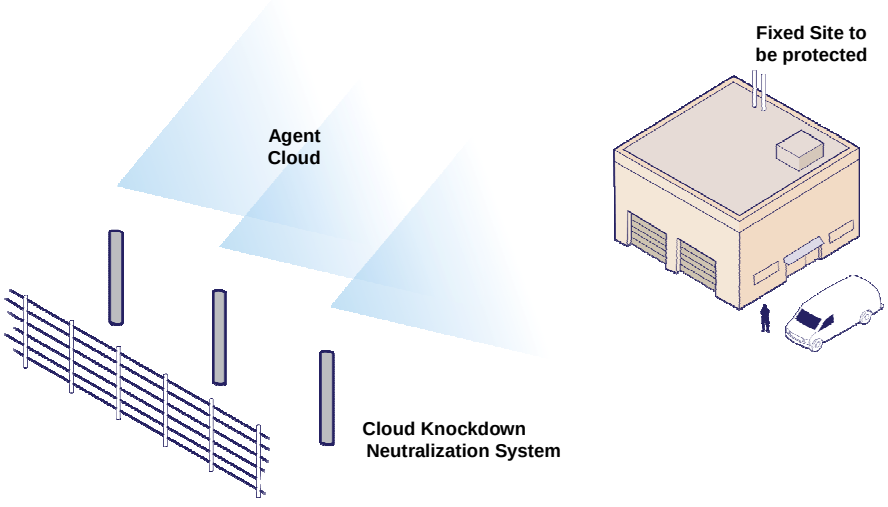
Agent Cloud Knockdown & Neutralization Concept

Fixed Site Protection



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Through a series of three projects, Sandia has developed and demonstrated a fundamental agent cloud knockdown process

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2001-2002	2004-2005	FY2009
DARPA Immune Building Project	Laboratory Directed Research and Development (LDRD)	Non-Stockpile Chemical Materials Agency (Chem Demil)
▪ Knockdown and neutralization of CBW agents in an interior facility ▪ Small (~30-90µm), uncharged droplets of modified DF-200 ▪ Prototype system developed for Anniston, AL test facility	▪ Knockdown and neutralization of CBW agents in an outdoor setting ▪ Small (~30-50µm), charged droplets of modified DF-200 ▪ Feasibility study	▪ Knockdown and neutralization of CW agents in an interior or temporary demil facility ▪ Small (~30-50µm), charged droplets of modified DF-200 ▪ Prototype system to be installed

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Fundamental Requirements for Airborne Agent Knockdown & Neutralization System

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Define the Threat

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

Detect the Agent Cloud

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

Knockdown and Neutralize the Agent Cloud

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

Knockdown efficacy requirements have been developed for each project

Our work has primarily focused on this part of the problem

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Example calculations for airborne agent knockdown efficacy requirements

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

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

Fundamental Requirements for Airborne Agent Knockdown & Neutralization System

Define the Threat

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

Detect the Agent Cloud

- Stand-off Detection
- Direct Detection
- Particle Detectors

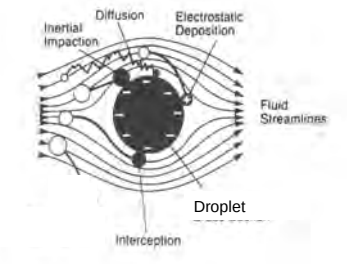
We have utilized fundamental physics and experimental work to determine the required physical properties

Knockdown and Neutralize the Agent Cloud

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

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

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



From Spurney, "Advances in Aerosol Filtration"

The optimal properties of the knockdown spray parameters are determined through modeling and experimental work

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Aerosol Test Chamber for Spray Knockdown Tests

- 8-ft wide by 16-ft long by 8-ft high chamber divided into two 8-foot cubes separated by an intervening wall (512 cu. ft.)
- The chamber was fitted with an array of nine electrostatic spray (ESS) nozzles (Maxcharge™ Spray Nozzle - Agricultural Manufacturing Company, Inc.) located at the top of the test chamber
- Spray droplet sizes from the nozzles are 30-80 microns in diameter
- Required air pressure for each nozzle is 20-90 psi
- Air consumption is 2.9–10 CFM
- The liquid flow rate is 50–200 ml/min for each nozzle

Aerosol Test Chamber

ESS nozzles in the chamber

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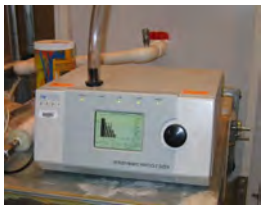
Instrumentation in the Sandia Aerosol Test Chamber

- ***BioSamplers*** (aerosol samplers, SKC Model No. 225-9595, Operated at ~10 liters per minute)
- ***Collison Nebulizer*** (BGI Incorporated Model No. CN-60, used to aerosolize chemical simulants)
- ***Aerodynamic Particle Sizer*** (TSI Inc., Model 3321, used to characterize the particle diameter of the simulants in the chamber and distinguish between vapor and particulate)
- ***Malvern Spraytec*** (Real-time Liquid Droplet Sizing system, Malvern Inc., Model RS500, used to measure liquid droplet size distributions from the spray nozzles)
- ***Fluidized Bed Generator*** (used to disperse bacterial spores into the test chamber)

Collison Nebulizer



Aerodynamic Particle Sizer (APS)

Control and Data Acquisition System

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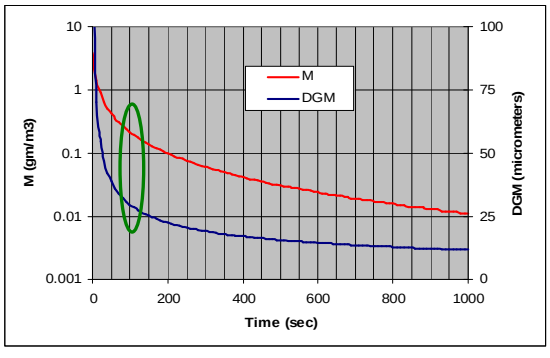
Threat Scenario Definition

Based on a theoretical accident at a typical EDS deployment



- **4.2” mortar shell, 3.0 Kg of HD**
- **Source term is a liquid drop dispersion**
- **Airborne mass concentration and drop size decrease from 3.9 to 0.22 gm/m3 and 150 to 30 micrometers in 100 seconds**
- **~ 0.9 gm/m3 additional vapor for a total airborne concentration of 4.8 to 1.12 gm/m3**

We design to mitigate this airborne source.

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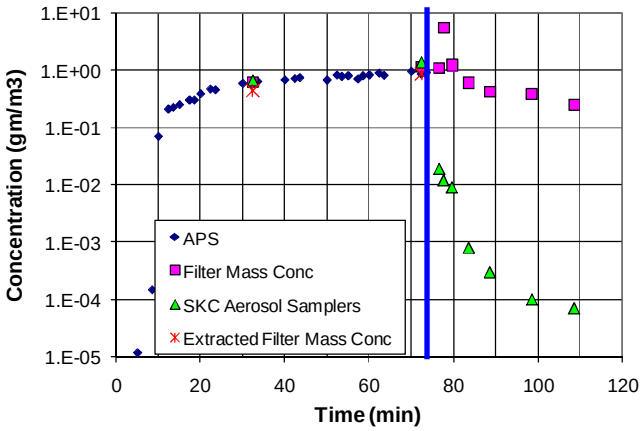
Rapid Knockdown and Neutralization of Aerosolized G-Agent Simulant

1-minute Charged DF200 Spray in an unmixed environment



Maximum efficacy of >4 orders of magnitude reduction at 30 minutes post-spray

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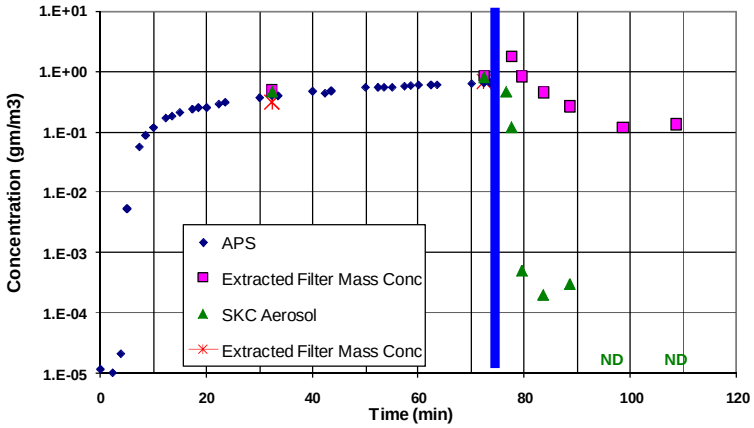
Rapid Knockdown and Neutralization of Aerosolized G-Agent Simulant

2-minute Charged DF200 Sprays, reduced air flow for Minute 2



Increased neutralization rate achieved using “Staged” spray strategy

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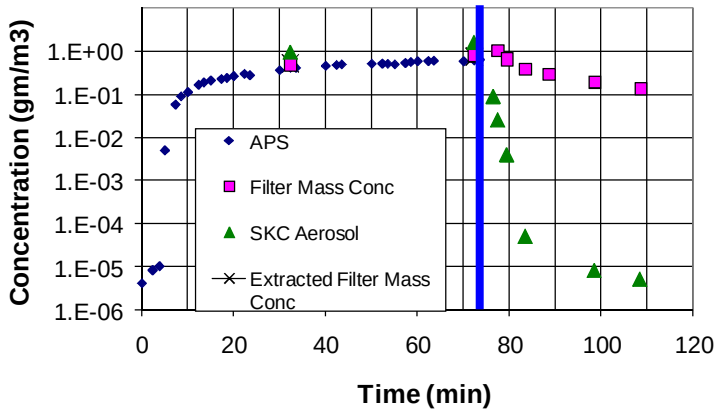
Rapid Knockdown and Neutralization of Aerosolized G-Agent Simulant

1-minute Charged & 1-minute neutral DF200 Sprays
Reduced air flow for Minute 2



Increased neutralization rate achieved using "Staged" spray strategy

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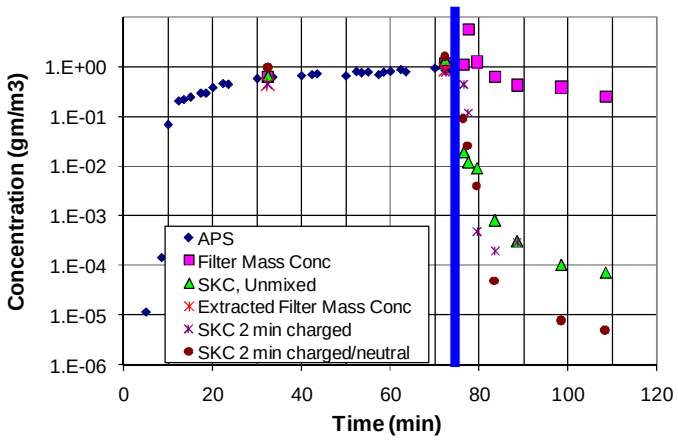
Rapid Knockdown & Neutralization of Aerosolized G- Agent Simulant



Improved knockdown & neutralization by change in spray parameters

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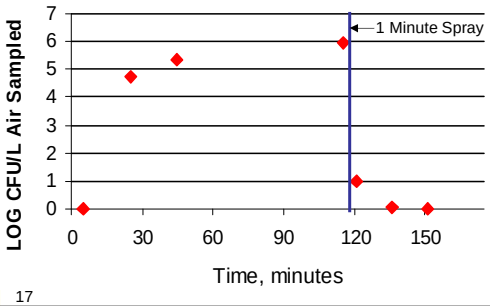
DF-200 Knockdown & Neutralization Spray
BW Agent Simulant Data

- Tests were conducted against 'weaponized-like' *Bacillus atrophaeus* spores
- Spores were introduced into the chamber at a concentration of 10^6 log CFU/l. After 120 minutes of mixing, DF-200 spray was deployed for one minute through the ESS nozzles.
- Total spray volume deployed was 2 L and the concentration of DF-200 was approximately 138 g/m^3 in the chamber.
- The simulant was collected by aerosol sampling and concentration in the chamber was determined by culturing at <5, 15, and 30 minutes after the end of the spray period.
- The results demonstrated a 5 log knockdown and kill of the simulant immediately after the spray was stopped. A 5 log knockdown and kill was also observed using a 92 g/m^3 spray density and a 4 log knockdown and kill was observed using a 46 g/m^3 spray density.



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

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Fundamental Requirements for Airborne Agent Knockdown & Neutralization System

Define the Threat	Detect the Agent Cloud	Knockdown and Neutralize the Agent Cloud
▪ Agents of Concern ▪ Airborne Concentrations and Exposures ▪ Knockdown & Neutralization Efficacy Required	▪ Stand-off Detection ▪ Direct Detection ▪ Particle Detectors	▪ Chemical Properties for Neutralization – Efficacy – Safety and Environment ▪ Physical Properties for Efficient Collection – Droplet Size – Charge ▪ Deployment – Disperse Knockdown Spray into Agent Cloud

We have developed a number of concepts and preliminary designs for deployment of the knockdown and neutralization spray formulation

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Potential Applications

- **Many applications for fundamental capability.**
- **Potential applications for military use**
  - **Force protection (battlefield)**
  - **Force protection (fixed sites)**
  - **Chemical demilitarization**
  - **Immune building**

- **Potential applications for civilian use**
  - **Chemical plants**
  - **Subways**
  - **Nuclear plants**
  - **High-profile buildings**
  - **Special events**

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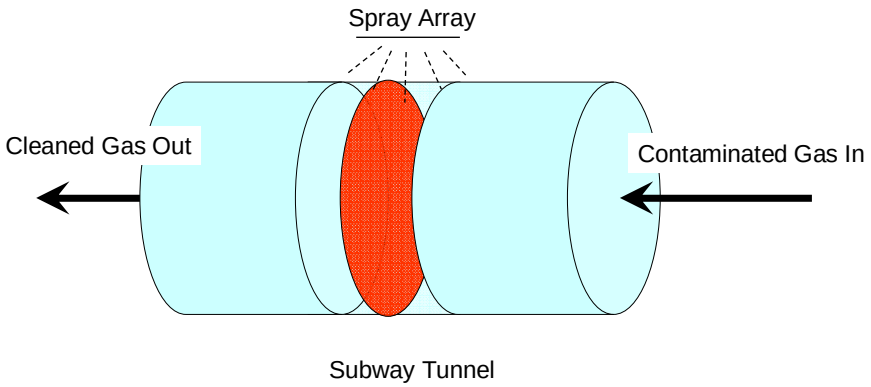
Airborne CBW Agent Knockdown & Neutralization
Subway Tunnel



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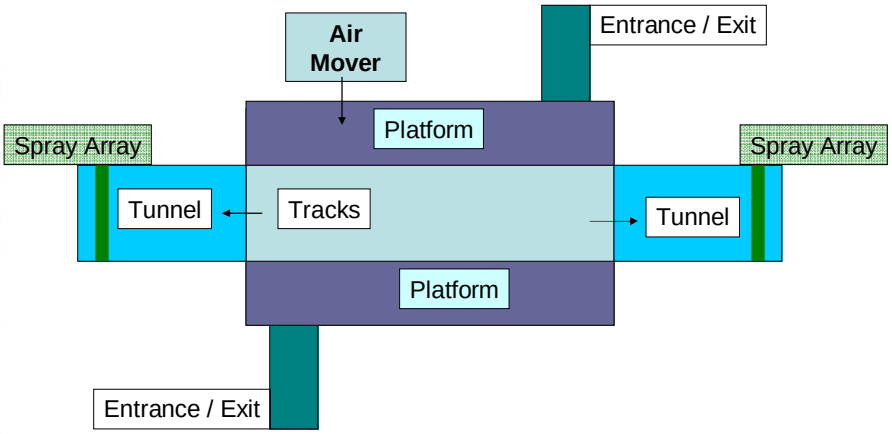
Airborne CBW Agent Knockdown & Neutralization

Subway Station



Strategic placement of Mitigation Sprays will limit spread of contamination

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Full-Scale Prototype Mitigation Spray Safety System at Sandia National Labs

- **Spray density capability of new structure based on experimental outcome provided by smaller aerosol chamber tests**
- **Ideas for full-scale optimization have been proposed**

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HOMELAND SECURITY & DEFENSE

Summary of Sandia Airborne Chemical and Biological Knockdown Effort

- Sandia has successfully demonstrated knockdown and neutralization of airborne CBW agent simulant releases
- Various deployment scenarios have also been developed
- A prototype system has been developed for installation at a Chem Demil Facility

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

A release mitigation spray safety system will remove airborne CBW contaminants to protect personnel, limit contamination spread, and minimize overall remediation timelines.

Backup Slides

HOMELAND SECURITY & DEFENSE
Sandia National Laboratories

Sandia Decon Formulation (DF-200)

Component

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

Mix

Formulation

Synergistic formulation (multiple reactive species)

Spray, Foam, Mist, or Gel

Multiple Uses

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

Final peroxide concentration is ~3.6%

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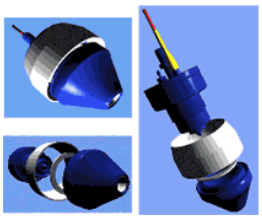
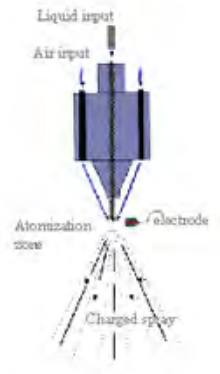
Sandia National Laboratories

ElectroStatic Spray (ESS) Nozzles

- Made by Agricultural Manufacturing Company, Inc.
- Two-fluid mixing nozzle
- Charges droplets by induction without using high voltages
- Recommended operating conditions are application dependent



The ESS MaxCharge™ Spray Nozzle



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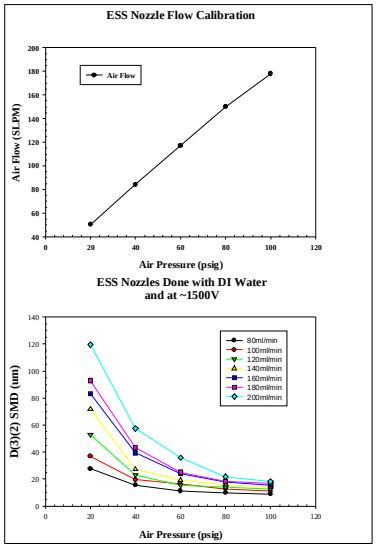
Sandia National Laboratories

ESS nozzle characterization

- **Near-linear response with respect to air flow (SLPM) and air pressure (psig).**
- **Volume mean particle size (µm) as a function of various liquid flow rates (80-200 ml/minute) and various air pressures (20-100 psig).**

We defined test spray parameters based on nozzle characterization and desired performance.



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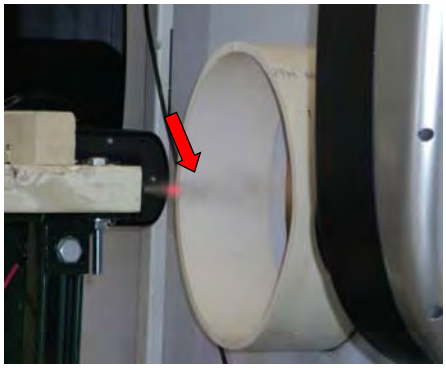
ESS nozzle characterization

- **Test and characterize new ESS nozzle design (Spring 2009)**
  - Vary air and liquid flows to produce varying droplet sizes and spray densities
  - Measure droplet sizes
    - Average droplet diameter <30µm (@ 100 psi dispersion air)
- **Other nozzles capable of generating smaller droplets may also be tested**



ESS nozzle characterization (side-view) – A close-up photo of the spray emitted from the ESS nozzle tip (red arrow).

Sandia National Laboratories

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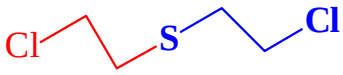
Chemistry Optimization

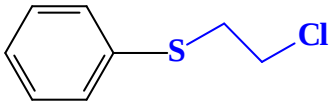
- **We have optimized the DF-200 chemistry to better mitigate for HD releases**
  - Increasing solubility of agent into formulation is key

Decontaminant	HD Simulant (solution tests)	
	5 Min.	60 Min.
DF-200	70.0	99.8
DF-200, modified	99.3	ND

Mustard (HD)



2-Chloroethyl phenyl sulfide



Efficacy of Sandia Formulations against CW Agents
ECBC Modified Stirred Reactor, 2010
(funded by NSCMA)

% Destruction Efficiency

Decon Reagent	CN		HD		HD in HM		GD		VX	
	No Metals	Metals	No Metals	Metals	No Metals	Metals	No Metals	Metals	No Metals	Metals
DF-200	99.5	94.5	99.9	99.9	99.9	99.9	99.9	99.9	100	100
SNL Modified # 1	98.9	99.1	99.9	99.9	99.9	99.9	99.9	99.9	100	100
SNL Modified # 2	99.8	99.2	100	100	100	100	99.9	99.9	100	100

Test Conditions:
- 50±2 °C for 6 hours, duplicate
- Two treatment variables - with and w/out added 320 mg Fe & 1.5 mg Cu
- Volumetric loading of 1:100, (agent:reagent), stirred
- Post-reaction extraction, analyses by GC/MS

Study of the Release of Pesticides From Building Materials

Geneviève Thouin, SAIC Canada

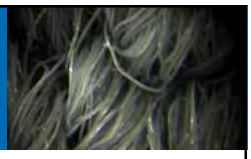
Study of the Release of Pesticides from Building Materials

Geneviève Thouin, Wenxing Kuang, and David Cooper
Science Applications International Corporation (SAIC Canada), Ottawa, Ontario

Ken Li and Konstantin Volchek
Environment Canada, Ottawa, Ontario

2010 US EPA Decontamination Research and Development Conference
April 13-15, 2010

Environment Canada Environnement Canada

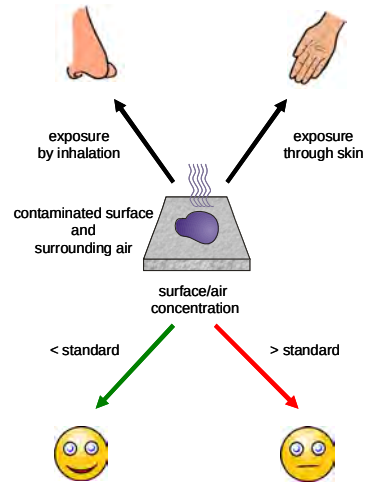


Project Overview and Objectives

Project Overview

- Project CRTI-04-0018RD “Development of Standards for Chemical and Biological Decontamination of Buildings and Structures Affected by Terrorism”
- Project team
  - Chemical: EC, SAIC Canada, U.S. EPA, DRDC Suffield, RIHTOP, University of Leeds
  - Biological: EC, SAIC Canada, PHAC, University of Ottawa, University of Leeds
- Objectives for chemical standards
  - Development of preliminary theoretical standards
    - For chemical agents on equipment, surfaces, and air
    - For inhalation and dermal exposure
  - Database of existing data
  - Toxicity testing of target chemicals
  - Study of the fate and behaviour of target agents on surfaces and inside buildings

Objectives of the Fate and Behaviour Study



Evaluation of transfers to skin

Toxicity studies

Desorption study

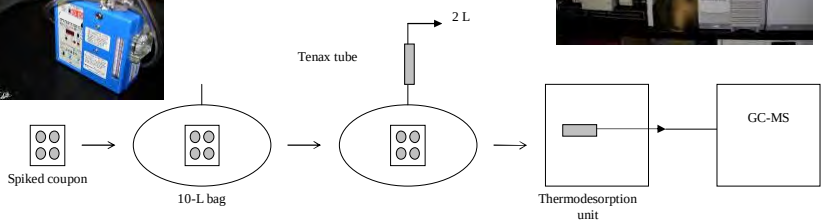
Penetration study

Development of standards

Test Methods for the Evaluation of the Desorption of Pesticides from Construction Materials

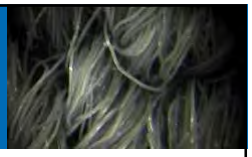
Experimental Method

- Coupons of surface materials (5 cm x 5 cm)
- Spiked with known amounts of target compound
- Coupons placed in 10-L Tedlar® bags
- Sample bags stored at target temperature
- 0.1-L to 2-L samples pumped through Tenax® tubes
- Tubes analyzed using a thermodesorption unit and GC-MS

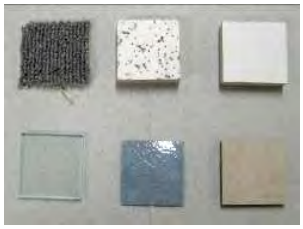


Tedlar is a registered trademark of E.I. Dupon de Nemours and Company in the United States and/or other countries.
Tenax is a registered trademark of Buchem BV Corporation in the United States and/or other countries.

Conditions



- Target compounds: pesticides
  - Lindane (97%)
  - Carbofuran (98%)
  - Diazinon (neat)
  - Malathion (95%)
- Concentrations on surfaces
  - 0.04 mg/cm^2 to 40 mg/cm^2 (0.4 g/m^2 to 400 g/m^2)
  - 25 cm^2 in 10 L (equivalent to 1 m^2 in a 125-m^2 room)
- Surface materials
  - Glass
  - Carpet
  - Ceramic tile
  - Vinyl tile
  - Painted drywall
  - Ceiling tile
- Temperatures
  - 20°C
  - 40°C
- Gases
  - Nitrogen
  - Air



Saturated Vapour Phases: Theoretical Saturation Concentrations

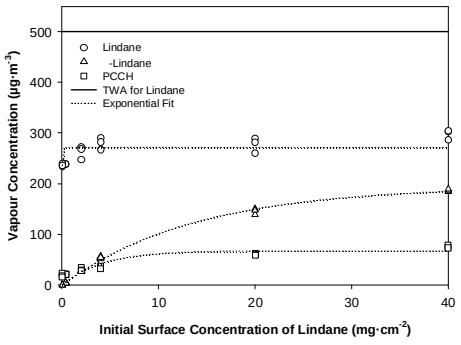
Pesticide	Temperature (°C)	Vapour Pressure (Pa)	Theoretical Saturation Concentration (µg/m^3)
Lindane	20	$3.75 \cdot 10^{-3}$	450
	40	$4.87 \cdot 10^{-2}$	5,500
Carbofuran	20	$5.8 \cdot 10^{-5}$	5
	40	$1.5 \cdot 10^{-3}$	130
Diazinon	20	$1.2 \cdot 10^{-2}$	1,500
	40	$1.47 \cdot 10^{-1}$	17,000
Malathion	20	$1.36 \cdot 10^{-4}$	20
	40	$8.17 \cdot 10^{-3}$	1,000

ATSDR, 2006; Boehnke et al., 1996; McGraw-Hill, 2007; WHO, 2003; and Zhang et al., 1987

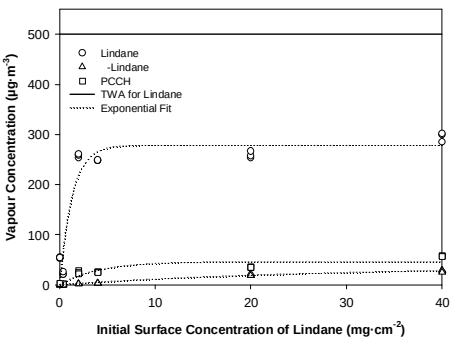
Desorption Experiments: Test Results

Vapour-Phase Concentration Depending on Surface Concentration

Lindane from Glass at 20°C

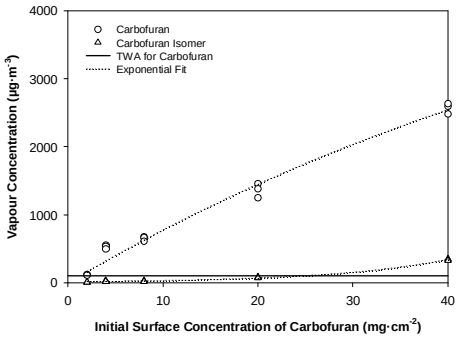


Lindane from Carpet at 20°C

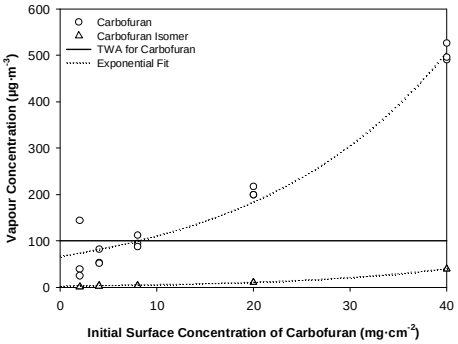


Vapour-Phase Concentration Depending on Surface Concentration

Carbofuran from Glass at 20°C



Carbofuran from Carpet at 20°C



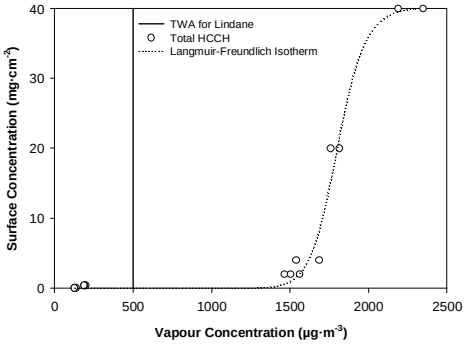
Langmuir-Freundlich Isoterms

$$C_s = C_{sm}\frac{(kC_g)^n}{1+(kC_g)^n}$$

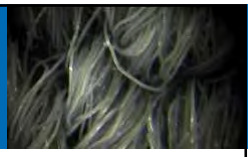
where:

- C_s is the concentration of pesticide on the surface, in mg·cm^{-2}
- C_{sm} is the maximum concentration that can be adsorbed on the surface, in mg·cm^{-2}
- k is the equilibrium constant, in m^{3}· µg^{-1}
- C_g is the concentration of pesticide in the vapour phase, in µg·m^{-3}
- n is a dimensionless empirical constant

Lindane from Carpet at 40°C



Vapour-Phase Concentrations and Health Concerns at 20°C



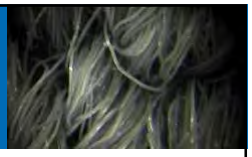
Pesticide	TWA (µg/m³)	Theoretical Saturation Concentration (µg/m³)	Vapour-Phase Concentration of Pesticide (µg/m³)	Total Vapour-Phase Concentration (µg/m³)
Lindane	500	450	300	560
Carbofuran	100	5	2,650	3,025
Diazinon	100	1,500	430	430
Malathion	1,000	20	30	30

ACGIH, 2004; NIOSH, 2006; Sanusi et al., 1999

Vapour-Phase Concentrations and Health Concerns at 40°C

Pesticide	TWA (µg/m³)	Theoretical Saturation Concentration (µg/m³)	Vapour-Phase Concentration of Pesticide (µg/m³)	Total Vapour-Phase Concentration (µg/m³)
Lindane	500	5,500	1,800	7,300
Carbofuran	100	130	870	920
Diazinon	100	17,000	1,650	1,650
Malathion	1,000	1,000	130	130

Surface Concentrations Corresponding to Vapour-Phase Concentrations Equal to TWAs



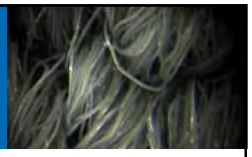
Pesticide	TWA (µg/m³)	Corresponding Surface Concentration at 20°C (mg/cm²)	Decon Efficiency for a Surface Contaminated with 40 mg/cm² at 20°C	Corresponding Surface Concentration at 40°C (mg/cm²)	Decon Efficiency for a Surface Contaminated with 40 mg/cm² at 40°C
Lindane	500	10	> 50%	0.001	> 99.99%
Carbofuran	100	1	> 90%	1	> 90%
Diazinon	100	0.1	> 99%	0.01	> 99.9%
Malathion	1,000	N/A	N/A	N/A	N/A

Vapour-Phase Concentration in a Ventilated Building

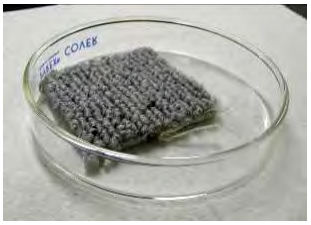
- Evaporation model developed by Nielsen et al. for workplace environments
- Scenario
  - 100 mg of pesticide spilled over 25 dm² (50 cm x 50 cm)
  - At the centre of a 10 m x 10 m x 3 m room (floor area: 100 m²; volume: 300 m³)
  - Ventilation rate: 15 air exchanges per day

Pesticide	TWA (µg/m³)	Temperature (°C)	Calculated from Experimental Data (µg/m³)	Calculated from Literature Data (µg/m³)
Lindane	500	20	560	160
		40	2,900	2,100
Carbofuran	100	20	3,000	2
		40	3,600	50
Diazinon	100	20	430	500
		40	1,600	6,300
Malathion	1,000	20	7	6
		40	130	380

Result Overview

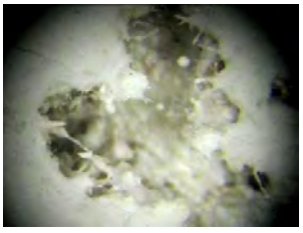


- Vapour-phase concentration
  - 3 to 10 times greater for glass than carpet
  - 5 to 10 times greater at 40°C than 20°C (except for carbofuran)
  - Similar profiles
- Importance of surface material
  - Release rate higher for glass and ceramic tile
  - Release rate lower for carpet and acoustic tile
  - Desorption component of the release higher for carpet than glass (Langmuir-Freundlich isoterm)
- Types and amounts of by-products varied depending on
  - Temperature
  - Surface material
- Quantity of pesticide in headspace
  - At most 0.001% of surface concentration
  - Release possible over a long period of time



Result Overview

- Maximum headspace concentrations
  - Measured concentrations and calculated concentrations were of the same order of magnitude for lindane, diazinon, and malathion
  - For carbofuran, measured concentrations were 500 times greater than theoretical concentrations
- Headspace concentrations
  - Exceeded the TWAs at 20°C and 40°C for lindane, carbofuran, and diazinon
  - Attained 15% of the TWA for malathion at 40°C
- Expected level of decontamination required
  - Low for malathion
  - High for carbofuran
  - Very high for diazinon
  - Medium to very high for lindane
- Model for ventilated office space
  - Based on Nielsen's evaporation model
  - Concentrations of the same order of magnitude than in experiments, except for carbofuran



Acknowledgments

- Financial support from the Chemical, Biological, Radiological/Nuclear, and Explosive Research and Technology Initiative, CRTI-04-0018RD

Assessment of Fumigants for Decontamination of Surfaces Contaminated With Chemical Warfare Agents

Emily Snyder, EPA/ORD/NHSRC

Assessment of Fumigants for Decontamination of Surfaces Contaminated with Chemical Warfare Agents

US EPA Decontamination Research and Development Conference
Research Triangle Park, NC

Emily Snyder[1], Joe Cappello[2], Meg Stapleton[2], Rich Fitzpatrick[2], Bob Ambrusko[2], Jacqueline Hill[2], Shannon Serre[1], and Roy Sieber[3]

[1] EPA/ORD/NHSRC
[2] CUBRC
[3] Eastern Research Group

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
  - –What is the optimum generation rate and exposure time for steam fumigation?
  - –What conditions (concentration, environmental conditions) are optimum for decontamination using Modified Vaporous Hydrogen Peroxide® (mVHP ®)?
- Where do we go next?

Significance and Impact of this Research

- Assessment of technologies performance at certain operational conditions
- How technologies can best be implemented in the field
- Who uses this information:
  - EPA Special Teams
  - EPA On-Scene Coordinators
  - DOD

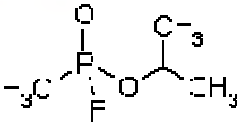
2

Overall Experimental Approach

- Technologies are investigated as a function of:
  - Technology operating conditions (concentration, time, temp, fumigant output rate or flow, RH)
  - Materials (building materials - IBMs): galvanized metal ductwork (GM), carpet (CA), ceiling tile (CT), and decorative laminate (DL)
  - Chemical agent
- Two-phased approach

3

Chemical Agents Tested in this Program



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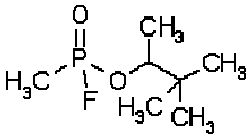

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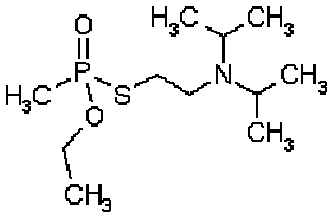
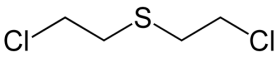


VX

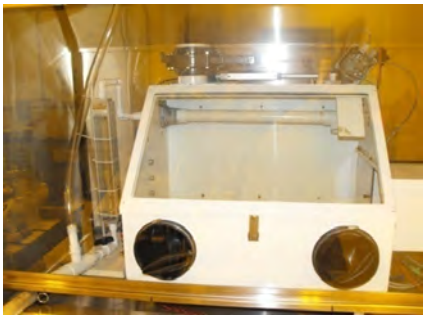


Sulfur Mustard

4

Experimental Approach

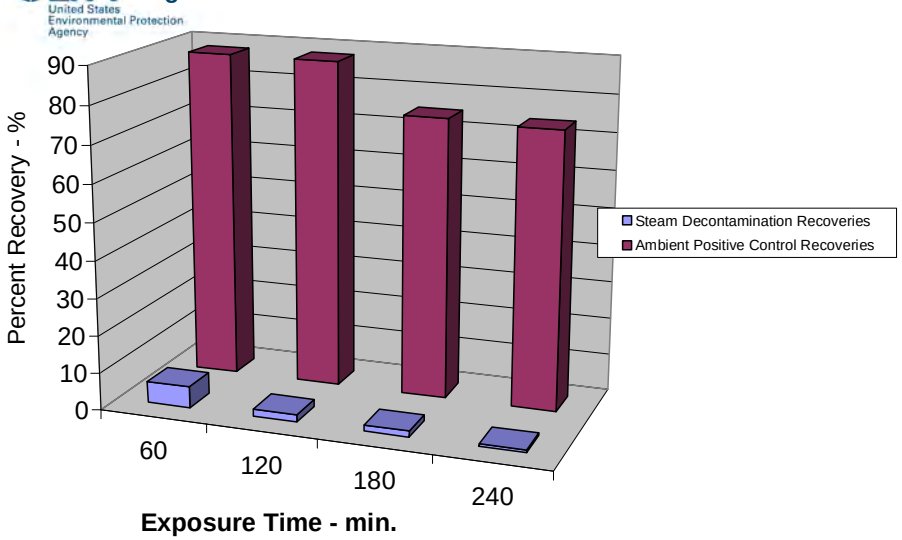
- ~ 2 mg of CWA on coupons
- Positive controls or test coupons and procedural blanks placed in test chamber
- Relative humidity, temperature, and air exchange rate controlled
- Fumigant technology applied
- Air monitoring is conducted
- Coupons extracts analyzed by GC/MS for CWA



Completed Testing at CUBRC, Buffalo ,NY

5

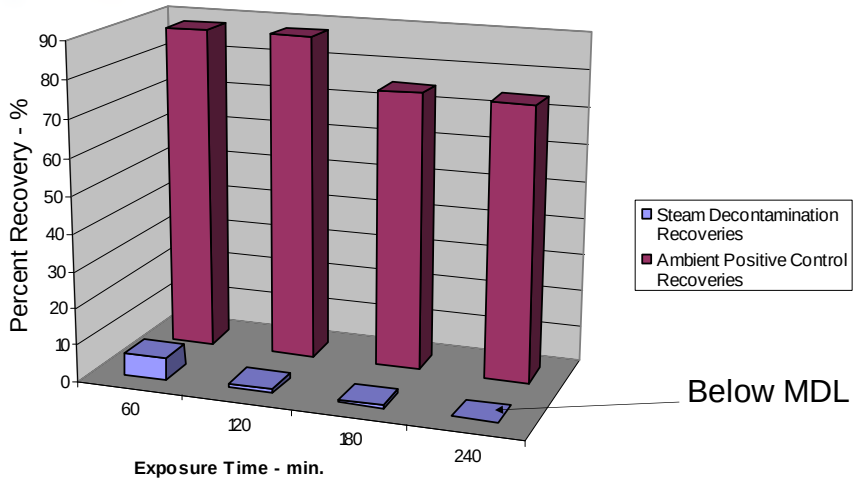
Decontamination of Carpet Contaminated with VX using 1.5 kg/hr Steam



99% Decontamination Efficacy at 240 minutes

6

Decontamination of Carpet Contaminated with VX using 3.0 kg/hr Steam



> 99% Decontamination Efficacy at 180 minutes

7

Summary of Other Steam Results

Agent	Materials	Steam Generation Rate	Time to get >99% Efficacy
VX	CT	1.5 and 3.0 kg/hr	60 min
VX	GM, DL	3.0 kg/hr	120 min
HD	GM, DL, CT, CA	1.5 and 3.0 kg/hr	120 min
GB	CT, CA	1.5 and 3.0 kg/hr	60 min
TGD	GM, DL, CT, CA	3.0 kg/hr	60 min

$$\text{Efficacy} = (C_0 - C_F)/C_0 \bullet 100\%$$

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Agent Remaining in Condensate

1 liter condensate collected during the test (collection began after coupons inserted into chamber)

Sample Description	Steam Rate kg/hr, time	HD, µg/mL
HD All Materials	1.5, 3.0 (60, 30 min)	<0.02
		GB, µg/mL
GB - CT, CA	1.5 (60 min)	5.4
GB- CT, CA	3 (30 min)	0.9

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Agent Remaining in Condensate

Sample Description	Steam Rate kg/hr, time	VX, µg/mL
VX – GM, DL	1.5 (60 min)	1.8
VX - CT, CA	1.5 (60 min)	0.4
VX – GM, DL	3 (30 min)	0.4
VX – CT, CA	3 (30 min)	0.4
		GD, µg/mL
GD – GM, DL	1.5 (60 min)	1.5
GD – CT, CA	1.5 (60 min)	2.4
GD – GM, DL	3 (30 min)	7.5
GD – CT, CA	3 (30 min)	2.8

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Material Effects and Other Considerations

- Ceiling tile dissolved (coupons could fall apart after removal from the chamber)
- Agent was not detected on any of the procedural blanks
- Agent residence time prior to decontamination would likely yield different efficacies
- Agent vapor/fumigant interactions differ from agent liquid droplet/fumigant interactions

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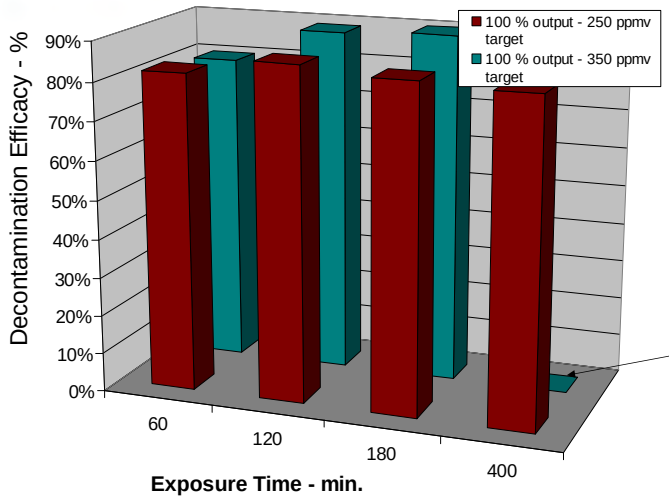
mVHP® Decontamination Efficacy for HD Contaminated Carpet

Calculated from ambient positive controls



Not determined for this exposure time

250 ppmv (158 ppmv actual) & 350 ppmv (219 ppmv actual)

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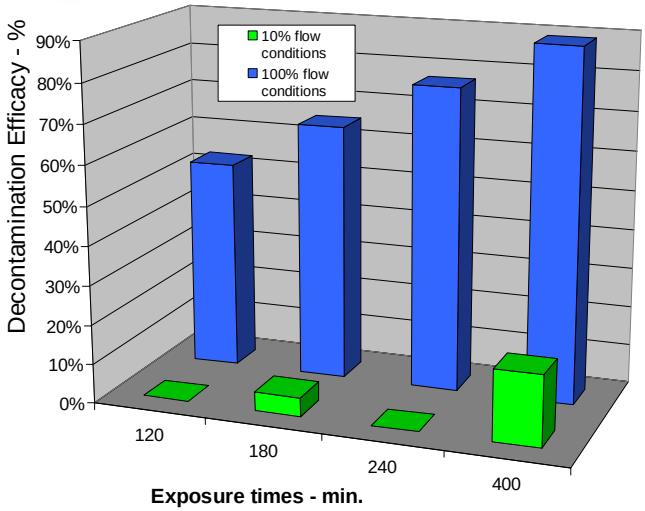
Decontamination Efficacy of mVHP® (250 ppmv target) for GM Contaminated with VX

Calculated from ambient positive controls



10 % flow = 272 ppmv actual & 100 % flow = 154 ppmv actual

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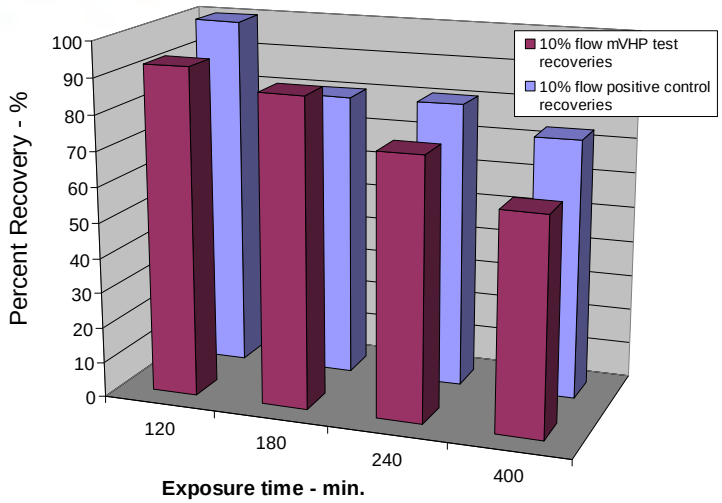
Decontamination of CT Contaminated with VX by mVHP®



100 % VHP concentration = 154 ppmv 10 % VHP concentration = 261 ppmv

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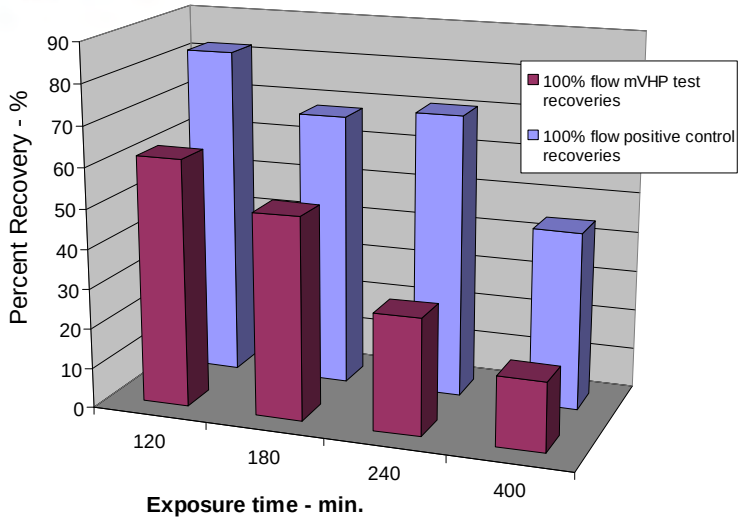
Decontamination of CT Contaminated with VX by mVHP®



100 % VHP concentration = 154 ppmv 10 % VHP concentration = 261 ppmv

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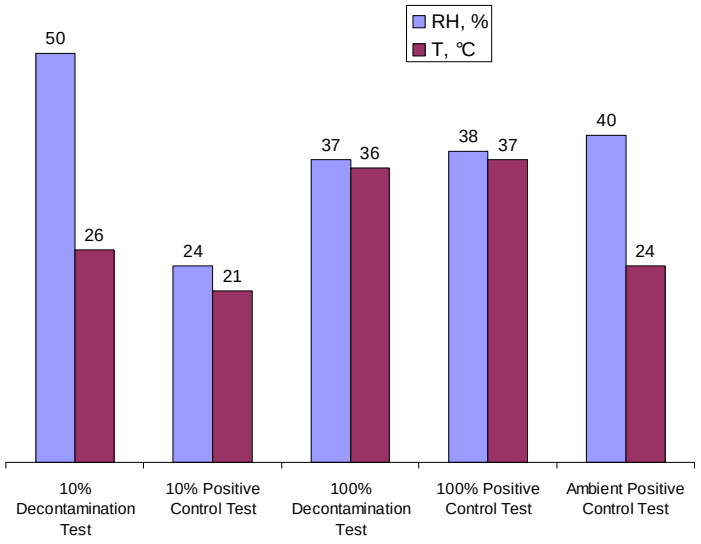
Environmental Conditions for CT-VX-mVHP® testing



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Concentration of HD in Gas-Phase (0-60 min) During mVHP® Testing and Positive Controls - Sampling with Tenax

IBMs	Target ppmv H_2O_2	Actual ppmv H_2O_2	STERIS Output	Mean Concentration and Standard Deviation (n=3), mg/m³
GM, DL, CA, CT	0	0	100%	5.4 ± 0.8
GM, DL	250	157	100%	2.4 ± ND
CA, CT	250	158	100%	2.5 ± 0.3
GM, DL	350	215	100%	3.6 ± 4.E-03
CA, CT	350	219	100%	2.4 ± 0.6

ND - not determined only one sample was taken

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Material Effects and Other Considerations

- No visual material effects – a white residue remained on the GM
- HD was detected in the sorbent tube samples
- HD was found on the CA and CT procedural blanks for the 10% flow tests

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Material Effects and Other Considerations

- At 100 % flow difficult to reach target VHP™ concentration due to sensor/temperature issue
- Agent residence time prior to decontamination would likely yield different efficacies
- Agent vapor/fumigant interactions differ from agent liquid droplet/fumigant interactions

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Conclusions and Future Work:

- Conclusions:
  - Steam is effective at removing surface contamination but agent was present in condensate (except HD)
  - mVHP® is efficacious against HD surface contamination but HD in vapor phase - longer exposure times needed against VX
- Future work:
  - Examination of steam cleaners
  - Longer exposure times for mVHP® testing

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