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2007 Workshop on Decontamination, Cleanup, and Associated Issues for Sites Contaminated with Chemical, Biological, or Radiological Materials

REPORT

Office of Research and Development
National Homeland Security Research Center

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Report on the 2007 Workshop on Decontamination, Cleanup, and Associated Issues for Sites Contaminated with Chemical, Biological, or Radiological Materials

Prepared by

Sarah Dun
Eastern Research Group, Inc.
Lexington, MA 02421

For

Joseph Wood
U.S. Environmental Protection Agency
Office of Research and Development
National Homeland Security and Research Center
Decontamination and Consequence Management Division
Research Triangle Park, NC

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Note

This report was prepared by Eastern Research Group, Inc. (ERG), a contractor for the U.S. Environmental Protection Agency (EPA), as a general record of discussions from the "2007 Workshop on Decontamination, Cleanup, and Associated Issues for Sites Contaminated with Chemical, Biological, or Radiological Materials." The report captures the main points of scheduled presentations and summarizes discussions among the workshop panelists but does not contain a verbatim transcript of all issues discussed. EPA will use the information presented during the workshop to address decontamination and cleanup challenges faced at sites contaminated with chemical, biological, or radiological materials.

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This document does not represent the official views of the EPA and, as such, no product or technology endorsement should be inferred.

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List of Abbreviations

ANSTO	Australian Nuclear Science & Technology Organisation
AOAC	Association of Analytical Chemists
ATP	adenosine triphosphate
BI	biological indicator
BROOM	Building Restoration Operations Optimization Model
BTEX	Bio-Terrorism Experts Group
°C	degrees Celsius
CBRN	chemical, biological, radiological, and nuclear
CBRNC	Chemical, Biological, Radiological, and Nuclear Countermeasures
CDC	Centers for Disease Control and Prevention
CFU	colony forming units
ClO2	chlorine dioxide
ClorDiSys	ClorDiSys Solutions, Inc.
CT	concentration x time
CWA	chemical warfare agent
DCMD	Decontamination and Consequence Management Division
DDMP	dimethyl methylphosphonate
DEFRA	UK Department for Environment, Food and Rural Affairs
DEM	diethyl malonate
DHS	U.S. Department of Homeland Security
DNA	deoxyribonucleic acid
DoD	U.S. Department of Defense
DoS	U.S. Department of State
DTRL	Decontamination Technologies Research Laboratory
ECBC	Edgewood Chemical Biological Center
EDS	electrostatic decontamination system
EPA	U.S. Environmental Protection Agency
°F	degrees Fahrenheit
FBI	Federal Bureau of Investigation
FIFRA	Federal Insecticide, Fungicide, and Rodenticide Act
ft^3	cubic feet
GAO	Government Accounting Office
GDS	UK Government Decontamination Service
H5N1 strain	highly pathogenic avian influenza H5N1 strain (A/Vietnam/1203/4)
H7N2 strain	low pathogenic avian influenza H7N2 strain (A/H7N2/chick/MinhMah/04)
HEPA	high-efficiency particulate air
HPS	Health Protection Scotland
HVAC	heating, ventilation, and air conditioning
ICT	Incident Control Team
INL	Idaho National Laboratory
L	liter
LAX	Los Angeles International Airport

List of Abbreviations (continued)

LIBS	laser-induced breakdown spectroscopy
LLNL	Lawrence Livermore National Laboratory
LOAEL	lowest observed adverse effect level
m^3	cubic meter
mg/kg/d	milligrams of agent per kilogram body weight per day
ml	milliliters
MS	mass spectrometer
NDT	National Decontamination Team
NHSRC	National Homeland Security Research Center
NIOSH	National Institute for Occupational Safety and Health
NIST	National Institute of Standards & Technology
NRMRL	National Risk Management Research Laboratory
NYC DHMH	New York City Department of Health and Mental Hygiene
NYES	New York Environmental Services
NYPD	New York Police Department
OPP	Office of Pesticide Programs
OSC	on-scene coordinator
OSHA	Occupational Safety and Health Administration
OTD	Operational Technology Demonstration
PCR	polymerase chain reaction
ppb	parts per billion
ppbv	parts per billion by volume
PPE	personal protective equipment
ppm	parts per million
ppmv	parts per million by volume
pptv	parts per trillion by volume
QAPP	Quality Assurance Project Plan
QSTR	quantitative structure toxicity relationship
RDD	radiological dispersal device
RNA	ribonucleic acid
RT-PCR	reverse transcriptase-polymerase chain reaction
Sabre	Sabre Technical Services
SFO	San Francisco International Airport
SNL	Sandia National Laboratory
SOP	standard operating procedure
SPI	single-photon ionization/time-of-flight mass spectrometry
STERIS	STERIS Corporation
STM	Single-Tube Method
TAGA	trace air gas analysis
TIC	toxic industrial chemical
TSM	Three-Step Method
TSWG	Technical Support Working Group
TTEP	Technology Testing and Verification Program
UK	United Kingdom
µl	microliters

List of Abbreviations (continued)

µm	microns
USDA	U.S. Department of Agriculture
UV	ultra violet
VHP	vaporized hydrogen peroxide
VOC	volatile organic compound
WIPD	Water Infrastructure Protection Division
WMD	weapon of mass destruction

Executive Summary

Opening Remarks

Opening and introductory remarks were provided by leaders within EPA's Office of Research and Development, and in particular, the National Homeland Security Research Center (NHSRC). These speakers discussed EPA efforts to collaborate with its international partners in decontamination research, provided some background on NHSRC and its research programs, and highlighted the advancement in decontamination technology since the 2001 anthrax attacks.

U.S. Perspectives

Brooks (DHS) provided an overview of his division's efforts to address large-scale biological and chemical agent response and recovery, such as the restoration of an airport following a chemical or biological attack and the restoration of an urban environment following an anthrax release.

McKinney (TSWG) provided an overview of the Chemical, Biological, Radiological, and Nuclear Countermeasures (CBRNC) subgroup and highlighted some of the subgroup's research and development activities. These projects included detection technologies for both threat agents and decontamination chemicals, decontamination chemical application systems, and disposal of contaminated agricultural materials.

Kempter (EPA) discussed a potentially new pesticide product category—sporicidal decontaminant—that would apply to products intended to inactivate *B. anthracis*. This new category would streamline the process of getting products registered for *B. anthracis* inactivation since currently none exist. Kempter also described some of the fumigant test requirements under consideration for registration under this category.

Wagner (FBI) discussed forensic sampling issues, while Martinez discussed various projects the Centers for Disease Control and Prevention (CDC) is involved with related to biological agent sampling. Many of the CDC projects have bio-aerosol implications. One lab study seeks to compare the efficiency of swab, wipe, and vacuum techniques for the sampling of bacterial spores, while in another study, investigators compare various air sampling filters.

International Perspectives

Hillesheim (DoS) provided an overview of the G8 Bio-Terrorism Experts Group (BTEX). The formation of the G8 BTEX group was initiated in 2004. G8 BTEX members have held workshops on forensic epidemiology, protecting food supplies, and decontamination. Hillesheim provided additional examples of bilateral collaborative efforts between the U.S. and other nations, including initiatives with Russia, India, and Australia.

Niederwöhrmeier discussed Wofasteril, a decontamination technology being developed by German researchers. Wofasteril is formulated with peracetic acid, hydrogen peroxide, acetic acid, and other proprietary ingredients. It can be employed as a thermal fog or liquid for direct application to surfaces. Niederwöhrmeier presented results of efficacy tests deactivating various spore species using formaldehyde; a peracetic acid-based product; and Wofasteril SC250 with alcapur, a foaming agent that raises the pH.

Volcheck, of Environment Canada, discussed the results for a series of field demonstrations of decontamination technologies for biological, chemical, and radiological threat agents. The objectives were to demonstrate building decontamination technologies; analyze agent concentrations before, during, and after decontamination; evaluate technology performance with various materials; calculate associated cost, material, and labor requirements; and develop manuals and guidelines based on findings.

Seto (Japan) presented the results of previous testing and evaluation for over a dozen detection devices currently available for chemical and biological agents. For each device, he presented agent detection capabilities, whether false positives or negatives occurred, response times, and detection limits. Seto also discussed ongoing research in Japan to improve and develop identification and detection capabilities. This research seeks to combine existing technologies such as the monitoring tape method, biosensors, chemical sensors, and counter-flow technologies.

Ramsey (UK) discussed a fatal case of inhalation anthrax that occurred in Scotland in 2006. His presentation provided a general overview of the entire event, including the lengthy legal, clinical, and environmental investigations that were involved. In the following presentation, Lloyd and Spencer (UK) provided more details on the response, focusing more on the sampling and decontamination processes. Investigations confirmed that the deceased participated in a drumming group and made his own drums using animal skins. In the drum storage area of a Belford home that was contaminated with *B. anthracis*, HEPA vacuuming served as the decontamination method. *B. anthracis* was also found in the village hall, where drumming-related activities occurred, and was decontaminated with chlorine dioxide gas. The drums themselves were decontaminated with a surface application of a formaldehyde solution with a contact time of 12 hours.

Biological Agent Decontamination

Ryan (EPA) presented and discussed the results from the extensive biological and chemical agent decontamination projects that he oversees. He presented results from tests to assess the impact of different building materials and operating conditions (temperature, relative humidity) on the log reduction of *B. anthracis* and surrogate spores decontaminated with various technologies. Ryan presented some results for the toxic industrial chemical (TIC) and chemical agent persistence and decontamination tests he has

conducted. He noted that preliminary findings indicate that chlorine dioxide may be effective for VX but not for sarin or soman. Ryan also briefly presented preliminary results from the persistence and decontamination tests with ricin toxin and vaccinia virus (a smallpox virus surrogate).

Tomasino (EPA) presented the results of test efforts conducted by the Office of Pesticide Programs (OPP) to determine appropriate modifications to the AOAC Method 966.04 Sporicidal Activity of Disinfectants Test, a qualitative procedure to determine a product's effectiveness in inactivating bacterial spores. Tomasino also discussed his research to evaluate quantitative test methods for determining decontamination efficacy. OPP focused the evaluation on two well-developed methods to generate a quantitative assessment of efficacy—ASTM E2111-05 and the three-step method (TSM).

John Mason (Sabre Technical Services) provided an overview of his company's chlorine dioxide decontamination technology and experience since the anthrax attacks in 2001. Along with other projects, Mason's company decontaminated the Brentwood US Postal Service building, has done extensive mold remediation work in New Orleans following Hurricane Katrina, and participated in the Scotland *B. anthracis* decontamination. Mason then discussed an upcoming project to decontaminate a 12 million cubic feet medical facility suspected of mold contamination.

Rastogi (ECBC) discussed the collaborative efforts with NHSRC to conduct systematic studies of the performance of three fumigant technologies for the decontamination of building materials contaminated with *B. anthracis*. The study objectives were to evaluate the kill kinetics and D-values (time required for a 1-log reduction) for chlorine dioxide against *B. anthracis*, assess the effect of bioburden on the recovery of spores and its effect on the efficacy of VHP and chlorine dioxide, and identify an appropriate surrogate for *B. anthracis*. For the surrogate work, the results indicate that the NNR1Δ1 strain may be an appropriate avirulent surrogate. ECBC also evaluated *B. subtilis* and *Geobacillus stearothermophilus* as potential surrogates.

Norrell (EPA) described the response events following an inhalation anthrax case occurring in New York City in February 2006. A drum maker and performer (who used animal hides from Africa) was confirmed with inhalation anthrax. Sampling confirmed the presence of *B. anthracis* in his home, workshop, and van. For the decontamination of his home and workshop, a combination of pH-amended bleach and HEPA vacuuming was used—depending on the type of material. The van and some materials from the home and workshop were fumigated with chlorine dioxide. Perimeter monitoring ensured no release of chlorine dioxide from the treatment enclosure. Arranging for disposal of materials was the most difficult component of the response. Materials were eventually autoclaved, but following this, no landfills would accept the treated waste. After additional coordination, a facility in Ohio accepted the decontaminated waste for incineration.

In a second presentation, Ryan discussed research being performed in NHSRC's Decontamination Technologies Research Laboratory (DTRL), which is used to investigate some of the engineering aspects of promising decontamination methods. Ryan discussed some of the current projects, such as ClO_2 measurement technology evaluation and adsorption of ClO_2 on activated carbon. Another focus of the DTRL research involves fumigation—material interactions, such as material demand of the fumigant, by-products, and materials compatibility. Ryan outlined upcoming tests (in collaboration with DHS) to determine the impacts of ClO_2 on computers and monitors.

Krauter (LLNL) discussed her research to investigate technologies designed to minimize spore (e.g., *B. anthracis*) reaerosolization. Several published reports discuss reaerosolization as a possible source of anthrax cross-contamination at the Brentwood postal facility. Krauter tested various polymer formulations in small and large chambers. The research confirmed that certain polymer sprays inhibit spore resuspension by adhering particles to a surface.

Martin (EPA) discussed advances in technologies and decontamination process streamlining to expedite the overall decontamination timeline and reduce cost. He gave examples of advances in ClO_2 fumigation technology, such as the use of tents (for containment of the gas during a building fumigation) and the size reduction in chlorine dioxide generation equipment. To expedite the decontamination process, pre-planning is essential; however, only a limited number of critical facilities (e.g., airports) may have the resources to prepare a comprehensive plan. Efforts to improve biological indicators (BIs), have more products obtain FIFRA registration, and optimize characterization and clearance sampling may further reduce the time and cost associated with restoring a facility contaminated with *B. anthracis*.

Chemical Agent Decontamination

Knowlton (SNL) discussed the Facility Restoration Operational Technology Demonstration (OTD) project, which addresses restoration of an airport following a chemical agent release. This project focuses on facility interior remediation, and the resulting restoration plan for Los Angeles International Airport will serve as a template for other airports. The project also includes an experimental phase to address data gaps identified when developing the LAX restoration plan. Knowlton listed four current research projects: investigation of surface sample collection efficiency; material and agent interactions; gas/vapor decontamination; and statistical sampling algorithm validation.

Moudgal (EPA) discussed quantitative structure toxicity relationships (QSTRs), which are mathematical equations that determine the correlations between a chemical's molecular structure and observed biological activity. QSTR is most useful in providing toxicity estimates when no agent-specific experimental toxicity data are available. The QSTR methodology initially involves gathering data on a toxicity endpoint and the mode of action of an agent, if available,

which then can be used to develop specific de novo QSTR models. Once validated, the model can be used to predict toxicity in other agents with similar structures. Moudgal provided an example using the QSTR methodology to estimate a reference dose for 1,4-thioxane (a TIC).

Love (LLNL) discussed his current research, which is being conducted as part of the Facility Restoration Operational Technology Demonstration (OTD) project, to address data gaps in CWA persistence and interactions on various surfaces. Love's study will use three CWAs and eight different materials found at airports. At high concentrations, the bulk properties of the agent dominate fate and transport (e.g., volatilization, dissolution, infiltration). As the concentration decreases, molecular properties dominate (e.g., hydrolysis, oxidation, others). Love presented concentration data on VX and its degradation products as a function of time.

Mueller (DTRA) began by stating that the civilian definition of decontamination does not exactly coincide with that of the military, i.e., the military does not necessarily require 100% decontamination for reuse. Historically, the military sought a decontamination solution that would apply to all agents in all circumstances. Currently, the military is rethinking this approach. Disposal may be the best option in a domestic event where equipment replacement is readily available, but decontamination might be required in a front-line situation with limited resources. Mueller provided examples of research completed in 2007, such as the development of a decontamination wipe and a new chlorine dioxide formulation with a broader capacity for decontaminating G-agents. Some ongoing projects include an aerosolized activated hydrogen peroxide technology for decontamination of aircraft interiors and an electrochemically generated decontamination solution.

Biological and Foreign Animal Disease Agent Decontamination

Wood (EPA) described two decontamination projects, the first of which is completed. With the first one, he provided the results for eleven spray-applied sporicidal decontamination technologies that were evaluated for their ability to decontaminate glass inoculated with *B. anthracis* Ames spores. Wood also provided results comparing the efficacy of pH-amended bleach, CASCAD SDF, Hi-Clean 605, KlearWater, and Peridox on three different test material coupons and three different bacterial spore strains. The results indicate that even the best liquid sporicides could not completely inactivate spores on porous materials. The second project is currently underway and is designed to assess the persistence of the highly pathogenic avian influenza H5N1 virus under various environmental conditions and materials. The project's second purpose is to investigate the efficacy of various generic chemicals to inactivate the virus.

Alphin (University of Delaware) is currently leading a project to assess avian influenza virus inactivation using various common chemicals. The ideal decontaminant would be effective against the virus on a variety of surfaces and would be widely available, biodegradable, and inexpensive. The test agent is a low pathogenic isolate of the avian influenza virus, H7N2. To assess viral inactivation, fluid from the decontaminated test coupons was injected into eggs, and then after a 5-day exposure period, fluid from each egg was examined for hemagglutination activity. Alphin provided detailed test results. The testing so far has identified several common chemicals that may be suitable for avian influenza virus inactivation. Further testing with additional disinfectants is underway.

Einfeld (SNL) began by noting that although guidelines exist, there are currently no U.S. standard methods to evaluate virucide efficacy against various organisms, which are needed for product registration. Researchers at Plum Island Animal Research Center are currently conducting studies with the foot-and-mouth disease virus, which infects cloven-hoofed animals and is highly infectious. The study objectives are to optimize coupon carrier inoculation and recovery for common agricultural materials and evaluate various virucide efficacies for the foot-and-mouth disease virus. Einfeld presented the results for the eight virucides tested, indicating that each virucide, except ethanol, performed well. In general, the porous material carriers negatively impacted virucide efficacy. Overall, carrier tests showed worse, but adequate, virucide efficacy compared to previous suspension tests.

Radiological Agent Decontamination

Bettley-Smith (UK GDS) described the 2006 polonium incident in the UK. On November 24, 2006, GDS was informed that a substance, confirmed as polonium-210, had been associated with the death of an individual. Polonium is an alpha emitter, a type of radiation easily contained by bagging. Detecting the short-lived alpha particles to identify the contaminated materials, however, is difficult. Alpha particles tend to adhere to materials, and detection is accomplished with instrumentation. Characterization surveys using a variety of sampling and analytical techniques occurred at each location prior to decontamination to determine the extent of contamination. Over time, a total of ten locations were identified for decontamination. Currently, decontamination is complete at nine of these ten locations. The materials that could not be remediated were packaged and transported to an appropriate disposal facility. Waste management was time consuming and complex.

Decontamination of common urban area materials contaminated with radiological agents can be influenced by grime layers and many other material and environmental factors. The further the agent migrates into a surface, such as concrete, the harder decontamination becomes. Fischer and Viani (LLNL) described several studies undertaken to further the understanding of factors that affect urban environmental contamination and restoration following detonation of a "dirty bomb." Their studies have focused on concrete surfaces and cesium contamination.

Parkinson (ANSTO) described a project to assess the effectiveness of commercially available, low-impact radiological decontamination technologies for a variety of

common building materials. Results from this project will assist organizations preparing response guidelines. Coupons of five common building materials were contaminated with cesium-137, americium-241, and strontium-90. Ten decontamination products were tested, including six strippable coatings and four wet chemical products (e.g., surfactants and/or chelating agents). Parkinson presented the results and noted that the liquid chemical technology approach provided better decontamination than the strippable coatings.

Lee (EPA) presented his research, in which the specific objectives were to characterize the physicochemical properties of cesium chloride particles generated during an outdoor detonation and to estimate the cesium chloride deposition and penetration on limestone. In conjunction with LLNL, two outdoor detonations were conducted. Particle concentrations were measured on limestone coupons and via air sampling and monitoring. Lee presented some of the aerosol data and electron microscope photographs of particles captured from one monitor. Analysis of the limestone coupons is ongoing. Laser-ablation inductively coupled plasma/mass spectrometry and other techniques will be used to determine the extent of cesium penetration into the limestone. Overall, experimental results indicate that most cesium particles were below 10 μm.

Drake (EPA) discussed a project to evaluate rapid decontamination technologies after a radiological dispersal device (RDD) event. The goal is to evaluate the performance of commercially available products that are quickly deployable and fast acting for building and outdoor area decontamination. The test approach consists of depositing cesium chloride on 2-foot by 5-foot concrete coupons, measuring contaminant levels, conducting decontamination, and measuring residual contamination. Sets of contaminated coupons will be held in controlled humidity and temperature conditions for both 14 and 28 days, and then tests will begin to evaluate both chemical and mechanical decontamination technologies. A short list of proposed decontamination technologies has been generated, of which two will be initially selected for testing and evaluation.

Research and Development for Decontamination-Related and Support Activities

Fox (EPA) oversees NHSRC's Water Infrastructure Protection Division (WIPD). This group's primary research focus is on detection and decontamination methods to be used following a threat agent attack on drinking water sources and systems. To a lesser degree, this group also researches technical issues related to wastewater collection, treatment, and disposal procedures. Fox noted that water supply system decontamination includes water treatment as well as decontamination of the system infrastructure.

In some cases, pipe abandonment in place may be the best response to a contaminated distribution system situation. Ongoing and future research, however, strives for removal of the contaminant. Within water systems, contaminants may be dissolved or suspended in the water or adhere to the pipe walls. Decontamination is also affected by agent attachment to biofilms, reaction with pipe walls or corrosion products, and permeation through pipe walls. Fox briefly described several decontamination research projects currently underway.

NHSRC's research and development program for disposal of potentially threat agent-contaminated materials focuses mostly on the effectiveness and environmental impacts of landfill options and thermal destruction technologies. Lemieux's presentation focused primarily on thermal destruction research efforts and noted that incinerator operators have many concerns about accepting threat agent-contaminated waste. Lemiuex (EPA) described experiments using a pilot-scale rotary kiln incinerator in which building material bundles embedded with BIs are fed into the kiln. Lemieux provided example test results from trials with carpet and ceiling tile bundles. He also discussed a model developed to predict whether an incinerator will completely destroy the threat agent of interest.

Snyder (EPA) provided an update on several detection-related research projects. The focus of his presentation was on detection technologies applied to support decontamination research. Research with Laser Induced Breakdown Spectroscopy (LIBS) includes determining detection limits for pure samples of *B. atrophaeus* (a surrogate for *B. anthracis*). Single-Photon Ionization/Time-of-Flight Mass Spectrometry (SPI) and Dual-Source Triple-Quadrupole Mass Spectrometry have been used by Snyder to detect fumigants and fumigant by-products. Snyder provided schematics of each device's principle of operation and presented data. He also briefly presented data from ongoing efforts to determine cesium penetration into building materials using LIBS and efforts to develop a rapid detection method for *F. tularensis* and *Y. pestis* (viable and nonviable) on building materials.

Throughout the workshop, speakers discussed numerous detection, containment, decontamination, and disposal issues. Much research has occurred, is ongoing, or is planned. All this information feeds into the actions and decisions of OSCs and other responders. Mickelsen (EPA) emphasized that responders are the ultimate end-users of the decontamination information being developed and that they need it in user-friendly formats. Few manuals or hands-on materials exist. Mickelsen outlined specific areas of interest and data needs, such as the need for faster and cheaper detection and decontamination methods, and guidance related to PPE selection, clearance, and disposal. In conclusion, Mickelsen noted that through coordination, cooperation, and communication, decontamination stakeholders are capable of producing products, based on the completed research, that impact decontamination, reduce restoration costs, and create effective responses.

I. Introduction

This report summarizes presentations and discussions from the "2007 Workshop on Decontamination, Cleanup, and Associated Issues for Sites Contaminated with Chemical, Biological, or Radiological Materials," which was held June 20–22, 2007, in Research Triangle Park, NC. The technical content of the report is based entirely on information and discussions from the workshop.

The workshop allowed participants from federal agencies and laboratories, international organizations, academia, and decontamination technology companies to share information and discuss issues associated with the decontamination of chemical, biological, and radiological threat agents.

During the workshop, speakers gave presentations on specific topics. Following each presentation, speakers held a brief question and answer period. The presentations and panel discussion covered a number of topics and were organized into seven sessions:

- *Some U.S. perspectives.* Representatives from the U.S. Department of Homeland Security (DHS), the Federal Bureau of Investigation (FBI), the Technical Support Working Group (TSWG), U.S. Environmental Protection Agency (EPA) Office of Pesticide Programs (OPP), and the Centers for Disease Control and Prevention (CDC) provided an overview of domestic decontamination research projects. Brooks (DHS) summarized DHS projects and programs addressing decontamination issues. Wagner (FBI) outlined the FBI's role as an enforcement authority during a threat event and discussed evidentiary concerns during decontamination. McKinney described research underway through multi-agency TSWG programs. Kempter provided an overview of OPP's process for permitting the use of decontamination agents. Martinez highlighted CDC decontamination concerns and current research projects.
- *International perspectives.* Hillesheim (U.S. Department of State) introduced the U.S. approach to combating bioterrorism and emphasized international collaboration goals. Representatives from Germany, Canada, and Japan each provided information about ongoing research in their respective nations. Topics included assessment of fumigation technologies, a field demonstration of building decontamination technologies, and development of on-site decontamination technologies. Representatives from the United Kingdom (UK) described a case study of a single, natural anthrax case and the resulting response actions.
- *Biological threat agent decontamination research and development.* Researchers and industry representatives gave eight presentations that provided information about decontamination technologies that are currently available or under development and are specific to biological threat agents. In addition to describing decontamination technologies, speakers discussed decontamination efficacy testing and validation. Norrell described a case of naturally occurring anthrax and the subsequent response actions. Martin reviewed the components of a decontamination and restoration event and highlighted research needs to reduce the time and cost of this process.
- *Chemical threat agent decontamination research and development.* The four presentations in this session described projects addressing chemical agent decontamination. Knowlton described a project to assess and preplan for a chemical warfare agent (CWA) release at an airport. Moudgal discussed a methodology for assessing risks associated with chemical agents and developing agent-specific screening levels for restoration. Love provided an overview of research to understand the fate of CWAs in the environment. Mueller highlighted chemical agent decontamination research related to military applications.
- *Biological and foreign animal disease agent decontamination.* Three speakers provided information about ongoing research to address foreign animal diseases. Wood summarized two projects underway at EPA's National Homeland Security Research Center (NHSRC). One evaluates sporicidal decontamination technologies; the other evaluates virus persistence and decontamination under varying conditions. Alphin described research assessing the disinfectant properties of several common cleaning products. Einfeld discussed ongoing research regarding inactivation of the foot-and-mouth disease virus.
- *Radiological agent decontamination.* Five presentations addressed concerns related to radiological agents. Bettley-Smith described a case of polonium contamination in multiple public facilities in London. He provided information about response actions and lessons learned during this event. Other speakers described ongoing research to understand surface interactions with radiological agents, to test the efficacy of various decontamination technologies, to evaluate agent dispersal during detonation, and to assess rapid decontamination technologies.
- *Research and development for decontamination-related and support activities.* The final four presentations highlighted additional areas of decontamination research. Fox discussed projects

to assess decontamination of drinking water supply and wastewater systems. Lemieux described NHSRC research to evaluate incinerators as a disposal option. Snyder highlighted several recently developed detection devices undergoing testing at NHSRC. Mickelsen closed by discussing how on-scene coordinators (OSCs) use research results and products during response actions.

II.
Presentations and Associated Question and Answer Periods

Opening Remarks

Lek Kadeli, Deputy Assistant Administrator, U.S. Environmental Protection Agency, Office of Research and Development
Nancy Adams, Director of the Decontamination and Consequence Management Division, U.S. Environmental Protection Agency, National Homeland Security Research Center
Blair Martin, U.S. Environmental Protection Agency, National Risk Management Research Laboratory

Kadeli welcomed participants and provided an overview of the workshop schedule. During the course of the workshop, attendees would hear presentations regarding U.S. and international decontamination perspectives and research. EPA currently has working relationships with the UK and Canada, and hopes to foster partnerships with the other G8 countries and additional nations such as Australia and Singapore. Kadeli mentioned a meeting the day before with EPA, the US Department of State, and G8 country representatives to discuss potential decontamination research collaborations.

EPA became involved in researching homeland security issues after the 2001 anthrax attacks and subsequent decontamination efforts. At that time, EPA served as the lead federal agency in decontaminating and restoring facilities contaminated with anthrax. To foster and facilitate improved decontamination approaches in potential future events, Congress provided funding, and Homeland Security Presidential Directive 10 named EPA as the lead agency, for addressing biological threat agent decontamination. In response to the Congressional directives, EPA's Office of Research and Development created NHSRC, bringing together scientists and engineers from many disciplines. The goal of NHSRC's research and development is to provide a scientifically sound basis for effective remediation of contamination of indoor and outdoor facilities and environments contaminated with a range of potential biological, chemical, and radiological agents. This research and development is intended to assist in effective remediation of these agents with the minimum time and cost.

NHSRC maintains its own research program, as well as collaborates with a number of other federal agencies and departments, academia, and industry. Kadeli emphasized that success has come from collaborations and working relationships developed across governmental departments and with other nations. He provided several examples of collaborative research projects, including the work with Edgewood Chemical Biological Center (ECBC) to study decontamination methods.

Adams continued with a brief overview of the four areas of research completed and underway in NHSRC's Decontamination and Consequence Management Division (DCMD): detection, containment, decontamination, and disposal. Much of DCMD's early research focused on decontamination and building protection related to anthrax events. DCMD's research has now expanded to consider chemical and radiological events as well. Adams's presentation in Appendix D provides more information about some of these projects.

Martin concluded by emphasizing that decontamination research continues to develop improved technologies. As research provides additional data, responders will be able to better apply these technologies during responses. Martin stressed the benefits of collaborating across disciplines and nations, such that groups can leverage each other's efforts and maximize resources. Each nation and organization is interested in restoring facilities and infrastructure to safe use as quickly as possible after an event. The current time and cost to restore a facility should an event occur will be greatly reduced compared to the 2001 anthrax attacks in the U.S., but technology improvements and early preparedness can further reduce time and cost needs.

Session 1: Some U.S. Perspectives

Overview of Select U.S. Department of Homeland Security (DHS) Science and Technology Programs

Lance Brooks, U.S. Department of Homeland Security

During the "2006 Workshop on Decontamination, Cleanup, and Associated Issues for Sites Contaminated with Chemical, Biological, or Radiological Materials," Brooks provided an overview of DHS research projects. Since the last meeting, DHS has undergone reorganization. Three directors—research, innovation, and transition—now head the Science and Technology Directorate and oversee six divisions. The directors are integrated across the divisions and align research within the divisions to meet DHS needs and minimize duplicate efforts. The research lead and transition lead in each division support and report to the directors. With this reorganization, the focus will shift from applied to more basic research.

DHS research seeks to develop technology and science solutions to assist others in addressing homeland security events. Agencies such as the Federal Emergency Management Association (FEMA), US Coast Guard, and Transportation Security Administration are a few of the primary recipients of DHS research. The Capstone Integrated Product Team, which includes members of various DHS

offices and operational groups, identifies research gaps and needs through Presidential Directives, Congressional guidance, national planning, risk studies, and private, local, and state stakeholder input. In the Chemical/Biological division, research falls under three thrust areas—biological (which includes the Biowatch program), agricultural (which includes the Plum Island Laboratory), and chemical—and focuses on developing new technologies or advancing existing systems.

Brooks discussed the systems approaches for addressing biological and chemical response and recovery efforts. He then briefly described a few of his division's programs:

- *Airport restoration guidance.* DHS, in conjunction with the San Francisco International Airport (SFO), developed a restoration guidance document and checklist to assist airports in responding to a bioattack. The report is due to be published soon. This guidance includes prereviewed protocols and plans to assist in preplanning efforts and speed restoration. DHS, in partnership with EPA and CDC, has held workshops to familiarize airports with this restoration plan and to assess possible response actions. DHS is developing additional guidance documents, which build from the airport restoration document, for transit systems.
- *Integrated biological restoration demonstration.* Under a collaborative effort with U.S. Department of Defense (DoD), DHS aims to provide a coordinated, systems approach to restoring wide urban areas after an anthrax release. This effort will evaluate social, economic, and operational interdependencies; establish a working relationship between DoD and DHS; identify restoration plans and technologies; and include restoration activity and technology solution exercises. Currently, the project focuses on the response and recovery to an outdoor, urban dispersal of anthrax. The first task, which is currently in process, involves conducting an analysis of existing capabilities and data gaps. Results from this analysis will feed into a second task to develop and enhance existing decision frameworks. The resulting frameworks will support the third task to identify and develop methods, procedures, and technologies to enhance restoration. As a final task, DHS and DoD will conduct a series of exercises and workshops to demonstrate the applicability of the plans and technologies. Brooks noted that planning efforts drive technology research efforts.
- *Biological sampling.* DHS is working with a number of federal partners to validate sampling plans, which discuss sampling strategy and sample collection, transportation, extraction, and analysis. The initial focus is anthrax, but research will extend to other agents in the future. DHS is also conducting demonstrations to verify sampling methods.

For chemical response and recovery, DHS aims to demonstrate a systems approach to critical facility restoration and to develop prototype fixed and mobile laboratories to support chemical restorations.

- *Mobile laboratory capability.* DHS is working to develop a mobile laboratory that is rapidly deployable and provides high-throughput analysis of environmental samples. DHS considers high-throughput as the analysis of at least 100 samples in a 24-hour period. The laboratory must also identify toxic industrial chemicals (TICs) and CWAs at or below their permissible exposure levels. Capabilities include identification of samples for reanalysis, automated sample tracking, sample processing, waste analysis, and data management. DHS is in the last stages of developing this mobile laboratory and aims to transfer ownership of the laboratory to EPA.
- *Facilities restoration demonstration.* DHS, along with interagency partners and committees, is conducting a project to promote rapid recovery and minimize the economic impact of a chemical release at an airport. The project also seeks to enhance public health decisions regarding the restoration of these facilities. Tasks under this project include preplanning restoration at a representative facility, developing planning tools, identifying and evaluating sampling and decontamination methods, and developing analysis tools. DHS plans a final demonstration and transfer of the systems approach to additional facilities in fiscal year 2009.

Question and Answer Period

Workshop participants posed no questions.

Evidence Awareness for Remediation Personnel at Weapon of Mass Destruction (WMD) Crime Scenes

Jarrod Wagner, Federal Bureau of Investigation

The FBI presented at the "2006 Workshop on Decontamination, Cleanup, and Associated Issues for Sites Contaminated with Chemical, Biological, or Radiological Materials" to communicate with OSCs and other remediation personnel. Communication and cooperation between law enforcement and remediation workers is critical to ensuring proper evidence collection. Wagner sought to continue these communication efforts.

The World Trade Center attack illustrates the complexity of a weapon of mass destruction (WMD) crime scene. In that situation, the FBI is unlikely to identify all relevant evidence before restoration begins. During the response to the anthrax release at Capitol Hill, the FBI was sorting through mail evidence as EPA was beginning remediation. These cases illustrate the need for remediation workers to be able to identify possibly relevant evidence and report that evidence to law enforcement.

In the U.S., a WMD crime scene includes any location where WMD have been prepared, used, or discovered. WMD include chemical, biological, radiological, nuclear, and explosive materials. Wagner noted that some nations use a military response when faced with WMD crime scenes. Civilian federal and local agencies respond to these events in the U.S.

A WMD incident response involves four phases: tactical phase, operational phase, crime scene phase, and remediation phase. These phases do not necessarily occur chronologically but can overlap. The tactical phase involves removing the hostile threat. For example, firefighters responding to calls during Los Angeles riots had to avoid gunfire. The operation phase includes the first responders who are working to protect public health. The FBI is typically not involved in this phase. The crime scene phase consists of evidence collection and packaging. In this phase, the FBI goes to the scene, collects evidence, and sends the evidence to laboratories for analysis. Contaminated materials do not get processed through the FBI laboratories but are sent to partner laboratories at Lawrence Livermore National Laboratory (LLNL) and ECBC in the case of chemical evidence. Biological and radiological materials are sent to partner labs in these program areas. Evidence collection may also be used to characterize the extent of contamination and to inform the remediation process.

Processing a WMD scene requires extensive time and effort. The FBI supports 27 teams consisting of over 300 people for these efforts. In addition, other personnel, such as local law enforcement with hazardous materials training, may become involved in evidence collection. Wagner outlined the FBI's 12-step approach to processing a WMD crime scene. More information about crime scene processing can be found in the FBI Handbook of Forensic Services posted on the Department of Justice Web site. Remediation begins after the FBI releases a scene. At release, the FBI will meet with EPA, or the local or state entity responsible for remediation, to provide information about the agents found, the location of these agents, possible protective equipment needed for site entry, and materials remaining at the scene.

During evidence collection, the FBI is concerned with personal and public safety, evidence integrity, evidence preservation, and accurate documentation of the evidence chain-of-custody. Forensic evidence includes anything that indicates a crime was committed, anything taken from the scene or left at the scene by suspects, and anything taken from the scene or left at the scene by victims. WMD evidence specifically includes any chemical, biological, or radiological materials or any items contaminated with these materials. Wagner noted that the FBI has a team specially trained to respond to biological, chemical, or radiological events.

Ideally, the FBI has collected all critical evidence prior to releasing the WMD scene for remediation. However, the FBI counts on remediation workers to be able to identify critical evidence and to contact the FBI or other law enforcement agencies when they encounter such evidence. Critical evidence may include device components, concentrated WMD materials, attack plans, or identification documents. If remediation workers discover these items, they should contact the OSC, who in turn notifies the FBI case agent or WMD coordinator. The FBI case agent or WMD coordinator then communicates with FBI headquarters to determine next steps in addressing the additional evidence. Wagner recommended that OSCs identify and meet WMD coordinators before an event occurs to build a working relationship.

To ensure that evidence can support litigation, trained personnel should properly document the chain of custody for the evidence/samples. At least one or two law enforcement agents must witness evidence collection and ensure proper chain-of-custody and transport to an appropriate laboratory for analysis. During the period when additional evidence is identified, remediation efforts cease. Remediation resumes once the evidence has been collected and removed from the site.

In summary, Wagner emphasized that remediation workers play a critical role in recovering from a WMD event. These workers, however, should be aware that critical evidence may still be present following release of the crime scene. Communication and coordination with the FBI and local law enforcement is necessary to ensure the safe collection of this evidence.

Question and Answer Period

- *When the FBI handles a scene contaminated with chemical, biological, radiological, or nuclear (CBRN) materials, what agency is responsible for the proper disposal of wastes?* The FBI is responsible for properly disposing wastes and contaminated materials. The FBI will coordinate disposal with EPA or local fire departments with hazardous materials units.

Technical Support Working Group (TSWG) Decontamination Research & Development Activities

John McKinney, Technical Support Working Group

TSWG is a multi-agency group that coordinates and researches counterterrorism technologies. McKinney provided an overview of the Chemical, Biological, Radiological, and Nuclear Countermeasures (CBRNC) subgroup and highlighted the subgroup's research and development activities.

The CBRNC subgroup's mission is to identify interagency user requirements related to terrorist-employed CBRN materials. The group provides rapid research, development, and prototyping of technologies. Projects typically require 24 months from conception to completion. The group objectives include providing an interagency forum to coordinate research, sponsoring research not addressed by individual agencies, promoting information sharing, and influencing basic and applied research. Research falls under four main areas: protection, detection, information resources, and decontamination. McKinney noted that his presentation covered decontamination research only. Some of the projects he discussed are highlighted below.

- *Personnel decontamination simulation kits.* These kits assist in first responder training exercises. The kits contain safe (as defined by the International Dictionary of Cosmetics and Fragrances) surrogates for threat agents. These surrogates mimic the physical properties of CWAs and radiologicals such that first responders can assess how these agents will act during a release.

- *Building disinfection by-products database.* This planning tool estimates fumigant consumption and chemical by-products that occur during building decontamination. The fumigants include ozone, chlorine dioxide, vaporized hydrogen peroxide (VHP), and methyl bromide. The tool is currently available to any government agency.
- *Wireless multisensor environmental monitors.* These monitors provided real-time detection of agents, primarily TICs and CWAs, to verify decontamination efforts. The unit is battery operated, lightweight, portable, and inexpensive. At any one time, the unit can monitor up to six different parameters through interchangeable sensors. The wireless units form their own network and transmit data through wireless or Internet/Ethernet communications.
- *Sensor web for fumigation applications.* The sensor web is a network of wireless sensors that provide real-time monitoring of various building fumigation parameters (e.g., temperature, humidity, fumigant concentration) in a building or location. For example, during fumigations conducted in New Orleans in 2006, this system replaced sampling tubes and ensured that environmental conditions remained favorable and fumigants were properly dispersed within a building to achieve decontamination.
- *Electrostatic decontamination system (EDS).* An EDS provides a means for applying liquids, which are activated with the use of ultraviolet light, to decontaminate biological and chemical agents. The systems require no scrubbing and, therefore, generate minimal waste or run-off. Clean Earth Technologies has demonstrated an EDS that is compact and easy to use by a single operator. One EDS used one sixth as much decontamination solution as foam but still achieved greater than a 6 log reduction of *Bacillus anthracis* and high chemical agent decontamination efficacy. Testing at ECBC found the solution comparable to bleach and DF-200 for decontamination efficacy. The decontamination solution itself has also shown high material compatibility. EDSs are currently undergoing EPA regulatory review but are available for procurement.
- *Expedient mitigation of a radiological release.* IsoFix and HeloTRON are two currently available formulations that minimize the spread and impact of radiological releases by fixing radioactive materials in place with a strippable coating.
- *Radiological decontamination technologies.* Argonne National Laboratory is developing a gel that uses chemical processes to remove cesium-137 from porous building materials. The gel draws the cesium-137 from the building material, sequesters the cesium-137 molecules, and then hardens into a material that can be vacuumed for removal.
- *Guidelines for disposal of contaminated plant and animal waste.* TSWG, in collaboration with the Texas Agricultural Experiment Station, is developing a clear, concise, and easy-to-use handbook for first responders disposing of contaminated plant and animal materials. This guidance will enable responders to quickly identify disposal methods that meet their specific needs. In conjunction with this guidance, TSWG has designed a portable gasifier that is capable of large-scale, environmentally safe, animal carcass removal. TSWG is working with EPA to conduct an emissions test of the gasifier.

McKinney briefly discussed decontamination projects planned for fiscal year 2008. One project seeks to develop personal protective equipment (PPE) decontamination procedures, such as decontamination of face masks without disposal or destruction of the masks.

Question and Answer Period

- *Has testing of the strippable coatings for radiological agents examined possible scatter or aerosolization of the radiological agent during application of the coating?* Efforts have examined, and have not found, scatter during application on a porous surface.

Regulating Bio-Decontamination Chemicals

Jeff Kempter, U.S. Environmental Protection Agency, Office of Pesticide Programs

Under the Federal Insecticide, Fungicide, and Rodenticide Act (FIFRA), EPA regulates any substance or device applied to or used on inanimate surfaces for the purpose of inactivating a pest, including microorganisms. Before a manufacturer can sell or distribute a pesticide for use in the U.S., the manufacturer must undergo the FIFRA registration or exemption process. To obtain registration, the manufacturer submits an application, including data and product labeling, to EPA. To obtain an exemption, a state or federal agency must submit a request, along with pertinent information, to EPA. Both registration and exemption require EPA to conclude that no adverse effects to humans or the environment will result from product use.

When applying for a FIFRA section 18 exemption, a state or federal agency may request a specific, public health, quarantine, or crisis exemption. During the anthrax attacks in 2001, no product had been approved specifically for use against *B. anthracis*. As such, EPA needed to issue crisis exemptions for each sporicide and each decontamination event. EPA received 63 requests, of which only 28 were approved. For fumigants, the application needed to include a remediation action plan, a sampling and analysis plan, and an ambient air monitoring plan.

To ensure that a product meets use claims, EPA requires efficacy testing. Testing requirements depend on its use as either a sanitizer, disinfectant, virucide, or sterilant/sporicide. Sterilants and sporicides must pass the AOAC Sporicidal Activity of Disinfectants Test (AOAC Official Method 966.04). For EPA acceptance, both porous and nonporous

carriers with *B. subtilis* and *Clostridium sporogenes* must show no growth on 720 treated carriers. For claims specifically related to the inactivation of *B. anthracis* spores, manufacturers must also conduct this test using *B. anthracis* and again report no growth on all 720 carriers.

In July 2007, however, EPA will propose a new product category at the FIFRA Scientific Advisory Panel. This category—sporicidal decontaminant—will apply to products intended to inactive *B. anthracis*, as supported by data from a well-developed, quantitative sporicidal test. The product would be tested on *B. anthracis* or a surrogate on porous and nonporous materials and report a 6 log reduction, based on recoverable spores. The purpose of having this new category is to facilitate or streamline the process of getting products registered for *B. anthracis*, since currently none exist. After receiving input from the panel, EPA intends to issue a Pesticide Assessment Guideline for anthrax-related products. Overall, EPA seeks to help biological agent incident responses by having anthrax-related products already registered.

Typically gas and vapor product registration has been limited to use in small indoor spaces, such as glove boxes used in hospitals. To apply to larger spaces, such as a hotel room, office, or building, the gaseous product must undergo the simulated use test. The purpose of this test is to ensure that key parameters for gas use can be met in all areas of the space and to establish product parameters for effective use. Prior to conducting a simulated use test, the manufacturer should submit the test protocol to EPA to ensure that the test is appropriate and represents real-world situations. Test rooms should be a similar size and contain relevant materials (e.g., beds in hotel rooms, desks and chairs in offices) to real-world conditions. During the test, the manufacturer must document the test conditions (e.g., gas/vapor concentration, temperature, humidity) and the number and location of monitoring devices. The manufacturer must also specify the maximum volume that can be treated and the minimum concentration and contact time required. Overall, the test must be conducted under Good Laboratory Practices per 40 Code of Federal Regulations (CFR) Part 160, or in a federal laboratory with an appropriate Quality Assurance Project Plan (QAPP). A successful simulated use test shows that the parameters necessary to achieve decontamination (i.e., no growth on all carriers) can be achieved and maintained for the required contact time.

Product registration includes specified terms and conditions for approved use. For anthrax-related products, EPA intends to limit sale and distribution to OSCs, authorized government workers, and properly trained and certified users, such that public access is restricted. EPA will also require manufacturers to train and register approved users and keep records of purchasers. These processes will by-pass certifications required in each of the 50 states. Kempter indicated that EPA wants to track the use of these products but does not want to prevent their use by the people who need them.

Kempter concluded with a review of EPA goals to improve, harmonize, and validate sporicidal efficacy tests, such as the current validation of the Three-Step Method (TSM).

Question and Answer Period

- *If the liability associated with product use falls on registrants, how do registrants make sure that OSC and remediation personnel training meets the registrants' requirements?* An OSC plays an advisory role and brings information to on-site remediation personnel. The OSC likely will not actively apply the product; the on-site remediation workers will use the product. Regardless, the OSCs and registrants must work together to ensure proper training.
- *Does EPA have a means to register antimicrobial coatings?* EPA has registered very few products with a residual self-sanitation claim. Kempter suggested that manufacturers speak directly with EPA to identify product-specific efficacy testing.

Environmental Sampling for Biothreat Agents: Current Research and Validation Efforts

Kenneth Martinez, Centers for Disease Control and Prevention

Martinez began his talk with a discussion of CDC's renewed interest in environmental microbiology as a priority research area. The topic of environmental microbiology was touched on at the meeting with G8 representatives the day before. In 2004, CDC convened an expert workgroup to analyze CDC's environmental microbiology research portfolio. Martinez presented CDC's framework for environmental microbiology research. This framework consists of three components: detection and investigation, control and containment, and recovery and remediation. Martinez then provided an overview of some CDC research projects related to biological agent sampling.

- *Bioaerosol sampler.* This device collects a sample in a tube and allows for direct analysis without extraction or preparation. The device has been used to sample and analyze molds and flu mists.
- *Letter reaerosolization study.* In collaboration with TSWG and Canadian partners, CDC conducted studies to address concerns about existing guidelines for handling suspicious letters and packages to minimize transmission of potential biological agents. Initial results identified problems with existing guidelines.
- *Resuspension of* B. anthracis *from contaminated mail.* During investigations of anthrax cases, CDC never identified a source for two cases—a nurse in New York City and an elderly Connecticut woman. Cross-contamination of their mail has been suspected. To standardize procedures for assessing exposure from cross-contaminated mail, CDC, in conjunction with ECBC, constructed a chamber to identify factors that affect *B. anthracis* resuspension.
- *Sampling strategy toolkit.* The Government Accounting Office (GAO) report on anthrax recommended further

development of probabilistic sampling methods. In response to this, the National Institute for Occupational Safety and Health (NIOSH) is developing a toolkit approach that combines targeted and probabilistic sampling strategies to define contamination boundaries. This approach would maximize resources and minimize the recovery timeline.

- *Sampling validation studies.* Martinez highlighted field and laboratory sampling validation studies. One lab study seeks to compare efficiency of swab, wipe, and vacuum surface sampling techniques. Another compares various air sampling methods, including various filters. CDC is working toward validating the various sampling protocols. Part of the project has included the development of an aerosol system for creating uniform samples of deposited bacteria.
- *Validated sampling plan.* A GAO review identified the need to validate sampling methodologies used by various government agencies. As such, a number of federal agencies, including CDC, came together to create a strategic plan for validating environmental sampling and analysis methodologies used during biological contamination. The group identified five process steps to a sampling strategy: sampling plan development, sample collection, sample integrity, sample extraction, and sample analysis. Initially, the group considered developing a generic sampling plan to disseminate to first responders. Sampling plans, however, must consider unique situations and conditions. CDC, in collaboration with other participants, is assessing various aspects of the five process steps, including collection methods for air; porous and nonporous surface sampling, sample integrity during transportation and storage, exercises for sampling and analysis plans, and external peer review.

Question and Answer Period

- *What is the time frame for the generation of plans and results for validated sampling plans?* CDC is targeting completion of a sampling plan by the end of 2007 and completion of the project by the end of 2008.
- *If a scenario occurs in which three major airports suffer anthrax attacks, and other airports fear attack, are existing sampling collection and analysis capabilities sufficient?* Collection efficiencies are about 50%, which is sufficient to understanding the risk to the public. From a decontamination perspective, collection efficiencies may impact the understanding of whether agents remain after remediation. Currently, the largest information gaps include understanding the exposure risk, infectious disease resuspension, and application of environmental sampling results to public health.
- *How do response plans address different types of air-handling systems, such as those found in airports (e.g.,* terminals versus aircrafts)? Some research has been conducted to understand different air flows in terminals versus aircrafts versus jetways. Buses are more complicated. The type of air-handling system, such as a shared system, impacts whether people are at risk from cross-contamination versus resuspension.
- *Is there any research to validate methods during natural disease outbreaks?* Martinez was unaware of validation research conducted during natural disease outbreaks.

Session 2: International Perspectives

G8 Bio-Terrorism Experts Group (BTEX)

Lindsey Hillesheim, U.S. Department of State

Hillesheim spoke about the U.S. approach to combating bioterrorism and the need for intersectoral and international collaboration in preparing for and responding to bioterrorism. The G8 Bio-Terrorism Experts Group (BTEX) is an example of such intersectoral and international collaboration.

Bioterrorism is different from other forms of terrorism for a number of reasons, including:

- It may occur silently. Officials may not recognize that an attack has occurred until symptoms become apparent several days or more after a release. At that point, the agent may have had widespread transmission.
- Bioterrorism attacks also lack geographical boundaries, with possible global movement as victims unwittingly spread the disease.
- Distinguishing between bioterrorism events and natural epidemics can be difficult.
- In bioterrorist events, health care workers (e.g., nurses, doctors, emergency room workers) are the first responders. Therefore, response agencies must engage with health care workers to identify events as quickly as possible.
- Biological agents, Hillesheim noted, could be the most cost-effective weapons for a terrorist. The cost for a single death has been estimated as $1,000,000 for a nuclear weapon, $1,000 for a chemical weapon, and $1 for a biological agent.

The U.S. strategy for handling bioterrorism events consists of four components. The first component is threat awareness, which includes threat assessment activities. Prevention and critical infrastructure protection comprise the second component. The third component—surveillance and detection—includes early identification of unusual disease patterns, epidemiological investigations, laboratory release confirmations, and information dissemination. Response and recovery, the fourth component, includes response planning, mass causality care, risk communication, medical countermeasure development, decontamination, and recovery.

The formation of the G8 BTEX group was initiated in 2004. G8 BTEX members have held workshops on forensic epidemiology, protecting food supplies, and decontamination.

In addition to BTEX, the U.S. currently works through a number of international partnerships, forums, and vehicles to foster intersectoral cooperation and collaboration. These include the Global Health Security Action Group and the

Asia Pacific Economic Cooperation. Hillesheim provided additional examples of bilateral collaborative efforts between the U.S. and other nations, including initiatives with Russia, India, and Australia.

In conclusion, identifying areas of intersecting interests, collaborating on concrete responses, and building relationships before an event are vital to addressing bioterrorism.

Question and Answer Period

- A participant noted that the U.S. has shown leadership on bioterrorism issues and stated that each nation gains from collaborative efforts. This participant thought that all could benefit from additional collaboration.

Biological Decontamination with Peracetic Acid and Hydrogen Peroxide

Bärbel Niederwöhrmeier, Armed Forces Scientific Institute for Protection Technologies, Germany

Ideal decontamination technologies are effective, rapid, and noncorrosive. They also must not inconvenience the public. Niederwöhrmeier listed six common decontamination agents but focused her presentation on technologies using formaldehyde, hydrogen peroxide, and/or peracetic acid formulations.

For interior space decontamination, Germany has most commonly used formaldehyde. Formaldehyde, however, has a number of disadvantages, such as its toxicity and resulting strong liquid precipitation. The high toxicity has led to numerous regulations overseeing formaldehyde use. Formaldehyde decontamination is also a wet process, which is often incompatible with sensitive equipment.

Sublimating paraformaldehyde to a gas is easy and treatment requires less contact time than liquid formaldehyde for effective decontamination. Niederwöhrmeier presented several parameters, such as contact time and temperature, for interior space fumigation with formaldehyde vapor. Maintaining the proper relative humidity and temperature is very important for proper decontamination. Niederwöhrmeier presented test results from fumigating two different sized chambers containing *B. cereus* and/or *B. atrophaeus*.

VHP is an alternative to formaldehyde decontamination. It is compatible with most materials; however, some material compatibility issues exist (e.g., copper), and some materials absorb VHP (e.g., textiles), so surfaces should be clean and dry. The mobile VHP unit used treats a maximum of 124 cubic meters (m^3). In Germany, laboratory testing of VHP efficacy has been conducted with *B. cereus* and *B. subtilis* on stainless steel carriers to meet European requirements. These spores were more resistant to hydrogen peroxide than *B. stearothermophilus*, which has been used elsewhere for validation. Additional testing using *B. anthracis* is planned.

Niederwöhrmeier described the decontamination of two army tanks contaminated with mold. VHP decontamination was recommended because of the low toxicity—personnel would spend many hours in the tanks after fumigation—and the compatibility with sensitive equipment. STERIS Corporation (STERIS) completed the decontamination and monitored bioindicators; German researchers conducted biological sampling. Niederwöhrmeier provided details regarding the decontamination parameters. Immediately after decontamination, yeast, but no fungus, was found during sampling. All five sampling points were negative for fungus contamination four weeks after decontamination.

German researchers have also developed a decontaminant called Wofasteril, which is formulated with peracetic acid, hydrogen peroxide, acetic acid, and other proprietary ingredients. It can be employed as a thermal fog (Wofasteril fog 300; to aerosolize the liquid) or liquid for direct application to surfaces (Wofasteril SC250). Niederwöhrmeier presented results of efficacy tests deactivating various spore species using formaldehyde, Peraclean (a peracetic acid-based product), and Wofasteril SC250 with alcapur, which is a foaming agent that raises the pH.

Question and Answer Period

- *Would you recommend any of the interior space decontaminants for complex spaces (e.g.*, airplanes)? One reason to select VHP over other decontaminants is its apparent compatibility with sensitive materials. Sensitive equipment in the two tanks treated with VHP appears unaffected.
- *What was the VHP concentration in the tanks one hour after aeration?* Continuous monitoring data recorded VHP concentrations. Personnel entering the tanks to remove the bioindicators wore personal protective equipment (PPE). Additional aeration beyond one hour was required to reach acceptable concentrations for reentry without PPE.
- *Was a visible structural change in the fungus in the tanks observed after treatment?* All the fungus samples were inactive after treatment and four weeks later. Niederwöhrmeier did not visually inspect the fungus under a microscope after treatment.

Field Demonstration of Advanced Chemical, Biological, Radiological, and Nuclear (CBRN) Decontamination Technologies

Konstantin Volchek, Environment Canada

Environment Canada, in collaboration with other Canadian federal and industrial partners and with participation from EPA, is conducting a series of field demonstrations of decontamination technologies for biological, chemical, and radiological threat agents. The objectives are to demonstrate building decontamination technologies; analyze agent concentrations before, during, and after decontamination; evaluate technology performance with various materials; calculate associated cost, material, and labor requirements; and develop manuals and guidelines based on findings.

For the chemical and the biological demonstrations, Environment Canada built custom structures that consisted of three open rooms, each constructed of different building materials. Room A contained brick walls and ceramic floor tiles. Room B contained drywall and linoleum flooring.

Room C contained wood pine panel walls and carpet flooring. Volchek provided a diagram and photograph of the structure.

For the chemical agent demonstration, Environment Canada conducted laboratory trials to identify appropriate surrogates. Diethyl malonate (DEM) served as a surrogate for the "G" series nerve agents. Malathion also served as a surrogate because it is a persistent agent with established sampling and analysis protocols. Both DEM and malathion also react with the decontaminants used to destroy CWAs. These agents were disseminated in the test rooms with hand-held sprayers. After agent dissemination and monitoring, Surface Decontamination Foam, a commercial product developed by Defense Research and Development Canada, and provided by Allen-Vanguard Corp., was applied for decontamination. After a 30-minute contact time, the decontamination team used a vacuum system to remove the foam. Volchek provided photographs of the agent application, foam decontamination, and foam removal.

During the demonstration, Environment Canada collected hundreds of surface, air, and water samples, and Volchek presented some detailed sampling results. Overall, the decontamination yielded satisfactory results. Higher concentrations of DEM and malathion remained in Room C because overspray during the initial application resulted in higher than expected concentrations in that room. Also detected was Malaoxon, which is toxic and results from incomplete degradation of malathion. Researchers concluded that two to three applications of the foam were needed for a more complete decontamination, especially when higher initial concentrations were present. Environment Canada was able to estimate a cost for chemical decontamination. The costs, as presented by Volchek, included labor, materials, and electricity but not waste disposal or site security costs.

For the biological demonstration, Environment Canada dry dispersed *B. atrophaeus*, a surrogate for *B. anthracis*, in a similar three-room structure. Dry dispersal consisted of puffing air into a test tube containing the spore powder. A total of 1 gram (1/3 gram per room) was released. After spore dispersal, decontamination was conducted using the STERIS VHP system. Researchers collected air and surface sampling predispersal, post-dispersal, and post-decontamination. Stainless steel biological indicators (BIs) were also placed in the facility. Volchek provided detailed sampling results, noting that the log reduction was in most cases between 3 and 5. Some post-decontamination samples, however, had spore levels up to 10^5. These higher levels following decontamination might be due to VHP concentrations not reaching the required level in some areas of the test structure. Another reason for this was likely cross-contamination with *B. atrophaeus*, which was present from previous testing on the same site.

For their radiological decontamination demonstration, Environment Canada has scheduled testing on the exterior of a test structure for fall of 2007. The demonstration will employ several decontamination techniques.

Reports summarizing the findings of the chemical and biological demonstrations should be available through Environment Canada in the fall of 2007.

Question and Answer Period

- *For radiological decontamination, how will run-off be contained and how much of an issue is run-off during building decontamination?* The volume of liquid waste is estimated at 300 gallons. The runoff will be collected in trenches and pumped to storage containers. It will remain there for about three weeks until the radiation is reduced to safe levels.
- *For the chemical trials, what solvent was used to spray the chemical agents?* DEM was used in a pure form, and malathion was mixed with an organic solvent.
- *What stoichiometric rates of decontamination reagents to surrogate agent were used in the chemical trial?* The stoichiometric excess rate ranged from 2 to 5. The rooms with an excess of 5 achieved more meaningful decontamination.

Japanese Research Project for Development of On-site Detection of Chemical and Biological Warfare Agents

Yasuo Seto, National Research Institute of Police Science, Japan

Rapid and sensitive on-site detection of chemical and biological agents leads to proper treatment and reduced casualties during an event. Seto listed a number of chemical and biological agents' lethal doses or concentrations and the associated levels of detection that must be achieved. He also provided examples of countermeasures used in the field during two events that occurred in Japan.

Seto presented the results of previous testing and evaluation for over a dozen detection devices currently available for chemical and biological agents. For each device, he presented agent detection capabilities, whether false positives or negatives occurred, response time, and detection limit. Seto's presentation in Appendix D provides details.

Seto also discussed ongoing research in Japan to improve and develop identification and detection capabilities. This research seeks to combine existing technologies such as the monitoring tape method, biosensors, chemical sensors, and counter-flow technologies.

Some of the technologies that were evaluated or are currently undergoing development for CWA or TICs detection include colorimetric gas detection tubes, ion mobility spectrometry, surface acoustic wave detection, photoionization (ultraviolet) detection, Fouier-transform infrared spectrometry, spectrophotometric tape method, and atmospheric pressure chemical ionization mass spectrometry. For biological agent detection, technologies Seto discussed included those based on bioluminescence (which measures adenosine triphosphate [ATP]), lateral flow immunoassay, and surface plasmon resonance. Results from these tests have been published or are in press.

Question and Answer Period

- *Were the data regarding various detector performances based on new research or a literature review?* The validation data represent information generated by Japanese research.

A Fatal Case of "Natural" Inhalational Anthrax in Scotland–Decontamination Issues

Colin Ramsay, Health Protection Scotland

Ramsey discussed a fatal case of inhalation anthrax that occurred in Scotland in 2006. This presentation provided a general overview of the entire event, whereas the following presentation by Lloyd and Spencer provided more details on the response.

In August 2006, Health Protection Scotland (HPS) learned of a confirmed case of anthrax infection based on blood taken from a patient who had died on July 8, 2006. The deceased was a 50-year old male who lived in rural Scotland. He reported three days of flu-like symptoms prior to death. A number of issues were immediately raised, including the time gap between death and confirmation of *B. anthracis*, uncertainties about continuing public risk, the lack of precedents and experience with these incidences in the UK, the potential for a deliberate release, and the need for a legal investigation. As an immediate response, an Incident Control Team (ICT) and Environmental Investigation Team were formed. These teams comprised numerous agencies and working groups.

Understanding the deceased's history, activities, and risk factors prior to the illness were the first steps in addressing the incident.

The deceased's home was sealed as a preventative measure, so investigators relied on friends and family for information about the home and the deceased's activities. Investigators were unable to determine whether the deceased had traveled abroad prior to reporting symptoms. Friends and family also provided conflicting information about a sore on the deceased's finger, which could have been an indication of cutaneous anthrax. Investigations confirmed that the deceased was a woodworker, participated in a drumming group, and made his own drums using unknown animal skins. He had recently fixed a drum-head with a new goat skin and had attended drumming events days before reporting symptoms. The deceased also had a previous history with leukemia, which was in remission, and had seen a clinician prior to his death. At that time, all blood work results were normal.

Based on information about the deceased and a case of anthrax in a drummer in New York City, HPS hypothesized that the anthrax exposure occurred during the remaking of a drumhead. Other hypotheses considered that the deceased may have contracted anthrax through exposure to some environmental source near the home or through contact with anthrax spores from other drums. Legal, clinical, and environmental investigations focused on these hypotheses.

Ramsey detailed the environmental investigations and sampling and resulting decontamination efforts. Two teams conducted exhaustive sampling at the deceased's home in Scotland (Black Lodge). Additional investigations occurred at other drumming-related locations, such as a village hall in Scotland (Smailholm), and two homes in England (Belford and Cumbria). Samples collected at Block Lodge and Cumbria were negative. Samples from Smailholm and Belford identified *B. anthracis* from cultures and polymerase chain reaction (PCR) analyses.

ICT created a clearance committee and also convened an expert advisory group, which included representatives from EPA and CDC, to assist in addressing sampling and decontamination issues. In establishing decontamination parameters, ICT not only needed a defensible rationale for decisions, but also needed to balance the political considerations of England versus Scotland and the possibility of setting a precedent in clearance requirements.

ICT selected a precautionary approach to decontamination. The Smailholm and Belford properties were deemed contaminated, and no detectable viable spores was selected as the clearance level. Based on literature reviews and consultation with experts, chlorine dioxide gas was selected for decontamination of the Smailholm village hall and garage. The decontamination was completed in March 2007. All BIs and verification sampling results were negative; a concentration x time (CT) dose of 9000 parts per million (ppm)-hours chlorine dioxide was achieved. Ramsey did not discuss the Belford decontamination effort.

This event raised many issues. The case investigation itself, as well as the number of agencies involved, added complexity to the situation. In addition, no benchmarks or guidelines existed for addressing natural anthrax cases in the UK, in terms of sampling, risk management, and other areas. The public response to the incident was generally calm, perhaps due to the area's agricultural background and history of anthrax in agriculture.

Ramsey recommended several actions to improve future responses. These included improving the published database regarding natural anthrax and responses; enhancing environmental investigation and decontamination capabilities in the UK; investigating and quantifying risks associated with goat hides and drums; and agreeing to a risk communication message for natural anthrax incidents.

Question and Answer Period

- *Has blood testing of other people also exposed to* B. anthracis *identified antibodies?* The two people who operated the drumming school were offered blood testing, which they both refused.
- *Was the strain found previously undetected?* The strain identified by the Porton Down laboratory was previously unidentified. A sample was sent to CDC for further identification.
- *What was the cost of decontamination?* As an order of magnitude estimate, the cost was in excess of $500,000 (US).

- *Did the victim's status as immuno-compromised due to leukemia treatment impact the case?* A clinician had reviewed the victim's blood work before his death. At the time all values were normal.
- *What methods were used for environmental sampling?* A variety of standard methods were used.
- Bettley-Smith from the Government Decontamination Service (GDS) in the UK acknowledged the rapid response and assistance provided by EPA in addressing this incident.

Case Study of Fatality Due to Anthrax Infection in the United Kingdom (UK)

Graham Lloyd, Health Protection Agency, United Kingdom
Robert Spencer, Health Protection Agency, United Kingdom

Lloyd and Spencer presented additional information regarding the fatal case of anthrax in Scotland in summer 2006, with a focus on the sampling and decontamination aspects.

In August 2006, a blood culture from a person who died in July 2006 was identified as containing *B. anthracis*. The case highlights a number of public health dilemmas that arise when an unexpected case occurs, such as clinical diagnostic concerns, laboratory diagnostic concerns, potential public health risks, and forensic needs. Lloyd noted that the clinical diagnosis was not anthrax and the laboratory finally reporting the case found *B. anthracis* in only one of four blood cultures. During the time between death and identification of anthrax, the drumming group associated with the deceased continued to visit schools and public areas, which posed a public health concern. The drums repaired by the deceased and used by the drumming group were the focus of investigations.

The Health Protection Agency maintains a laboratory in Porton Down. This laboratory plays an advisory and support role during incident response. In this incident, investigations expanded from the deceased and his home in Scotland (Black Lodge) to a village hall in Smailholm, Scotland, and residences in Belford and Cumbria in England. The multisite and multinational scope of the incident added many layers of complexity to the investigations. For example, simply coordinating the logistics of multiple responding agencies (e.g., ambulance services, fire services, law enforcement, press, public health agencies) was difficult.

Lloyd presented a summary of investigations undertaken at locations in Scotland and England. Before environmental and remediation sampling could began, investigators needed to consider and reach consensus regarding sampling methods, sample locations and numbers, and validation methodologies. They also needed to consider sampling location accessibility. Overall, sampling results needed to meet the requirements of multiple agencies with multiple end points (e.g., forensics versus public health). In addition to sampling the locations in Scotland and England, the drums themselves needed to be sampled to ensure safe use.

Lloyd described sampling at Black Lodge and presented a site map and photographs from the sampling event. Both targeted and probabilistic sampling strategies were employed. A grid system was used to document each sample location. Lloyd provided photographs to illustrate the complexity of sampling a residence. The bedroom also functioned as a workshop; collecting all materials for sampling was impossible. Lloyd noted that the personnel on-site wore high levels of PPE to ensure their protection in an unknown situation. After review of available sampling methods, high-efficiency particulate air (HEPA) vacuum sampling was chosen, as it allowed large surface area sample collection. None of the methods, however, completely remove spores from surfaces. Lloyd also briefly described sampling conducted at the Belford residence.

Results from Black Lodge indicated no environmental evidence of *B. anthracis*. A residence in England also contained no evidence of *B. anthracis*. As such, no decontamination was deemed necessary at these locations. At a residence in Belford, molecular and biological evidence of *B. anthracis* was found in drum storage areas of the home. A village hall and drum storage area in Smailholm, Scotland, also contained evidence of *B. anthracis* contamination. Decontamination was recommended in these locations.

For the buildings requiring decontamination, responding agencies grappled with questions about selecting appropriate decontamination methods, delineating the extent of decontamination, and determining acceptable clearance parameters. At the Belford home, vacuuming contaminated areas served as the decontamination method. At Smailholm, complete building fumigation with chlorine dioxide served as the decontamination method. After conducting laboratory studies with VHP and various concentrations of formaldehyde, the drums were decontaminated with a surface application of a formaldehyde solution for 12 hours.

This case illustrates how a response effort can expand beyond the original event and highlights questions and issues that can arise when an event occurs. Numerous questions regarding sampling remain, such as method validation, method peer review, error rates, and general method acceptance by the scientific community. In this event, responding agencies sought consensus but were unable to reach consensus regarding response protocols, strategies, standards, and spore detection methods. Key considerations in an effective response include understanding the chain of infection, infectious capabilities, and impact of conventional cleaning methods on transmission. Responding agencies must also consider environmental microbiology in the context of laboratory results. An agent found in a laboratory sample does not necessarily translate to public risk. Lloyd stressed that interagency coordination, cooperation, and consensus regarding sampling method selection and validation is paramount to future responses.

Question and Answer Period

- *Were samples collected after decontamination and what were the molecular results?* Post-decontamination sampling found no molecular positive results.

- *When was GDS formed?* The Department for Environment, Food and Rural Affairs (DEFRA) established GDS in October 2005. GDS supports all territories in the UK and abroad.
- *Does the UK have a unified command system similar to the U.S.* incident command system? The UK does have a similar system, which was not activated in this incident.
- *International standards exist for many agents.* Because an incident such as this can quickly cross international borders, is an international response standard needed? Each incident serves as another learning experience. Each incident is also unique, so responses must be flexible.
- *Who is responsible for site clearance?* In Scotland, a clearance committee reviewed the post-decontamination evidence and presented this evidence to the local health department, which then declared that no viable spores remained. No single individual decided whether the site could be cleared.

Session 3: Biological Threat Agent Decontamination Research and Development

National Homeland Security Research Center (NHSRC) Systematic Decontamination Studies

Shawn Ryan, U.S. Environmental Protection Agency, National Homeland Security Research Center

Ryan started his presentation with some background information about NHSRC and its decontamination research program. He then presented results from assessing the impact of different building materials on the log reduction of *B. anthracis* and surrogate spores decontaminated with various technologies. Based on tests with VHP, pH-amended bleach, and chlorine dioxide gas, the results highlight the importance of material effects on the log reduction. As an example, Ryan presented a spectrum of building materials in order of difficulty to decontaminate, based on the systematic decontaminations studies with chlorine dioxide gas. Carpet and painted concrete required the lowest CT, while ceiling tile and wood required the largest.

Ryan next discussed the use of BIs, noting how much easier they were to inactivate compared to the same population of spores on building materials. During decontamination studies of various building materials, BIs consistently resulted in no growth well before (i.e., a much lower CT) a 6 log reduction occurred on the building material coupons. BIs typically showed no growth at chlorine dioxide CT levels of 3,000 to 4,000 ppm-hours, whereas ceiling tile coupons required chlorine dioxide CTs as high as 15,000 ppm-hours for a 6 log reduction. With VHP testing, BIs were similarly inactivated at lower CTs compared to building materials.

NHSRC has also evaluated the impact of varying operating conditions on decontamination efficacy. Typically, chlorine dioxide fumigation requires a relative humidity of greater than 75% at 75 degrees Fahrenheit (°F). Decontamination testing of *B. anthracis* at varying relative humidities—ranging from 40% to 85%—suggested that the reduction in spore viability is a strong function of relative humidity. Ryan presented detailed results from chlorine dioxide decontamination of various building material coupons inoculated with *B. anthracis* Ames. At a relative humidity of greater than 90%, all materials reported decontamination after a 20-minute contact time. These results emphasize the need to document laboratory test conditions in order to properly translate results to field applications.

Quality assurance monitoring of decontamination conditions is essential to achieving successful decontamination. Measuring high concentrations of the reactive gases used in decontamination, however, is not trivial. No standard monitoring methods exist, and the gases themselves may interfere with monitoring other parameters (e.g., relative humidity). Ryan reported results from two different monitors measuring relative humidity. The sensor that had previously been exposed to chlorine dioxide reported a significant difference in relative humidity at the target range.

In addition to evaluating biological decontamination, NHSRC has begun evaluating the decontamination of five building material surfaces contaminated with TICs and CWAs. Ryan is investigating the use of chlorine dioxide (Sabre Technical Services [Sabre] system) for TIC decontamination and gaseous chlorine dioxide, aqueous chlorine dioxide, and diluted bleach for CWA decontamination. He followed a two-phase approach with initial studies assessing agent persistence and subsequent studies investigating decontamination technologies. Ryan presented some results for malathion persistence and decontamination tests. He also noted that analysis of data from CWA decontamination studies is ongoing; preliminary findings indicate that chlorine dioxide may be effective for VX but not for sarin or soman.

Ryan also briefly presented preliminary results from persistence and decontamination tests with ricin toxin and vaccinia virus (smallpox virus surrogate), and noted that a final report should be available later in 2007.

Ongoing research efforts include the systematic evaluation of methyl bromide and the STERIS VHP system to decontaminate various building materials contaminated with *B. anthracis* Ames. NHSRC is also working to develop BIs that better correlate to real-world building decontamination. Further studies will also evaluate various liquid decontaminants and kill kinetics data for decontamination of biological agents, as well as determine persistence and decontamination kinetics using fumigants against biological agents on porous and nonporous materials. In a joint effort with OPP, NHSRC is also conducting ongoing systematic decontamination studies to assess efficacy as determined by three different methods. This effort seeks to assess how the different methods vary in efficacy findings.

Question and Answer Period

- *What was the relative humidity during CWA decontamination experiments?* The relative humidity was 75–80% and no liquid water was observed.

- *BIs with liquid inoculation do not represent real-world scenarios compared to aerosol exposures. BIs have been successfully used during sterilization of both porous and nonporous medical devices. These industries likely have cumulative data regarding the role of relative humidity, temperature, and other parameters.* Efforts are underway to consider the differences between liquid and aerosol inoculation of BIs. Researchers acknowledge that the liquid-inoculated BIs provide conservative results when compared to aerosol deposition.
- *What were the sampling efficiencies of carpet versus pine?* Studies considered the varying positive control recovery efficiencies of different materials to determine the log reduction. Wood has one of the lowest positive recovery values, approximately 50–80%.
- *Hospital situations may provide useful information.* Hospitals conduct sensitive equipment sterilization, and researchers have looked to that industry for information. Their research focus has been on materials impacts versus sampling efficiencies. Adams (NHSRC) noted that evaluations and existing data gap prioritization drive research at NHSRC. Areas considered the highest priority have been the focus of initial research.
- *Is NHSRC considering low concentration and long exposure durations versus high concentration and short exposure durations for decontamination technologies?* NHSRC is considering changing decontamination agent concentrations and exposure times, especially for non-spore forming threat agents. Evaluations of lower relative humidities and materials compatibility will also be pursued.

Improvement and Validation of Lab-Scale Test Methods for Sporicidal Decontamination Agents

Steve Tomasino, U.S. Environmental Protection Agency, Office of Pesticide Programs (OPP)

Researchers must acknowledge the applicability of a test method before using the method. The OPP Microbiology Laboratory has historically performed post-registration efficacy testing of antimicrobial pesticides and emphasizes the need for developing methods that are easy to understand and reproduce. These methods are not only useful for regulatory purposes but also can be useful tools for research and development. To that end, OPP's research has looked at improving and modifying existing methods, as well as developing new quantitative methods to supplement or replace existing methods. Tomasino discussed several of these efforts.

AOAC Method 966.04 (Sporicidal Activity of Disinfectants Test) is a qualitative procedure for determining product efficacy against spore-forming bacteria. This method is more relevant to clinical settings than to building decontamination. For a complete test, method 966.04 requires inoculation and subsequent decontamination of 720 porcelain carriers and suture loops. For designation as a sterilant, product testing must result in no growth on all 720 carriers. Tomasino provided a schematic of the method process, which requires 21 days for completion.

Tomasino presented the results of OPP's efforts to determine appropriate modifications to AOAC Method 966.04. OPP recommended several modifications to the method: replacing the soil extract nutrient broth with a defined nutrient agar, adding a spore enumeration procedure (carrier counts), establishing a minimum and maximum spore titer per carrier, and adding a neutralization confirmation procedure. Four laboratories undertook a collaborative study to compare the current and modified methods to determine whether the methods were statistically equivalent; Tomasino presented the results of that work.

OPP has also conducted research to evaluate quantitative test methods for determining product decontamination efficacy. OPP focused the evaluation on two well-developed methods to generate a quantitative assessment of efficacy—ASTM E2111-05 and TSM. Three laboratories conducted three replicates of each method side-by-side using three commercially available liquid decontamination chemicals. OPP's primary goal was to examine method performance within and across laboratories. Tomasino presented detailed results, which indicated that both methods performed comparably within and across laboratories. No significant differences in control carrier counts occurred, no significant differences in the log reduction of spores arose, and the standard deviations stayed within acceptable limits.

The project comparing ASTM E2111-05 with TSM also assessed test method attributes, such as protocol clarity, test preparation, and results recording and interpretation to identify one method for further validation studies. Three laboratories identified TSM as the easier method to perform. As such, OPP advanced the TSM to validation testing with AOAC INTERNATIONAL, the standard-setting organization, to further determine method performance across many laboratories. The validation study was launched in fall 2006 and involved ten laboratories conducting three replications for three decontamination products treating glass carriers with *B. subtilis* spores. AOAC method 966.04 served as the reference method.

Tomasino provided detailed results for the TSM validation testing. No obvious data outliers or unexpected patterns occurred. The log reduction varied most for the tests that achieved intermediate log reductions. For each decontaminant, efficacy-response curves were repeatable. Overall, the data strongly support validation.

As a next step in the TSM validation process, OPP will submit the TSM validation report to AOAC for review. Additional OPP activities related to test method development include completing modifications to AOAC method 966.04 for application to suture loops and gaseous chemicals, evaluating other carrier materials, exploring efficacy testing for non-spore forming threat agents, and developing interactive methods.

Question and Answer Period

Workshop participants posed no questions.

Full-scale Experience in Decontaminations Using Chlorine Dioxide Gas

John Mason, Sabre Technical Services

The Sabre chloride dioxide system has evolved since its first use following the 2001 anthrax incidents. In 2001, Sabre built its chlorine dioxide generation system at the Brentwood US Postal Service site over the course of six months. During responses (mold remediation) in New Orleans after Hurricane Katrina, Sabre used generators loaded on truck trailers. These required 30 minutes for set up. Their technology advances have resulted from collaborations and ongoing field applications (e.g., mold and mildew decontamination, *B. anthracis* decontamination in Scotland).

Sabre is currently examining the effectiveness of low chlorine dioxide concentrations coupled with longer contact times. At concentration-times of less than 500 ppm-hours, with a 10-hour contact time, good spore inactivation has been achieved. As a caveat, Mason noted that field spore loading is very low compared to laboratory testing. Sabre has also found that *B. atrophaeus* is consistently harder to inactivate than other spores.

During decontamination efforts in New Orleans, Sabre qualitatively examined chlorine dioxide compatibility with many of the materials encountered. About 20% of the materials experienced a color reduction or bleaching effect from treatment. Sabre has been unable to identify in advance what materials will experience this effect. No short-term effects to sensitive electronics have been reported. For some of the New Orleans facilities that they have decontaminated, Sabre has over two years of post-decontamination information related to materials impacts.

In August 2007, Sabre will be decontaminating a medical facility suspected of mold contamination. The decontamination will occur at an operating hospital facility in southern California. The facility is 12 million cubic feet (ft3) and contains two patient wings, a critical care facility, emergency room, and administrative offices. The schedule calls for evacuation, decontamination, and reoccupancy within six days. Sabre will pre-stage the tenting materials and immediately begin installing sampling lines and dosimeters at the start of the demonstration. Decontamination will occur using 100 ppm of chlorine dioxide with a 12-hour exposure. A hydrogen peroxide system will be used to scrub the building after decontamination. The schedule is aggressive, however, resuming operations as quickly as possible is critical. Throughout the decontamination process, Sabre will collect hundreds of data points that track chlorine dioxide concentrations, relative humidity, and temperature. BIs will also be placed throughout the facility. Mason demonstrated Sabre's sample tracking software, which has been updated to be more user friendly. The program allows users to create sampling plans and indicate sampling locations while walking through a facility. The program tracks samples and results, and can be used for various building parameters (e.g., chlorine dioxide gas concentrations in various locations). Mason anticipated that Sabre would face similar challenges to those experienced before: interagency communication, scheduling, and materials compatibility—the facility contains over 2,800 materials, including sensitive equipment.

Question and Answer Period

- *Has Sabre examined the long-term impacts to sensitive electronics following decontamination with high concentrations of chlorine dioxide?* Sabre has not conducted any validated and controlled laboratory studies of sensitive electronic impacts. Sabre, however, has tracked facilities undergoing chlorine dioxide decontamination in New Orleans. These facilities included restaurants with computers, electronic telephone systems, and high-quality stereo systems. The early decontaminations occurred at high concentrations (e.g., CT values of 20,000 ppm-hours to 30,000 ppm-hours). Sabre has heard of only a single failure of an inexpensive scanner.
- *What is the mechanism of interaction for chlorine dioxide oxidation on a surface?* The oxidation mechanism needs to be verified through research. Chlorine dioxide is a true gas and will react with almost any material. On metals, this reaction likely creates a film that protects the material from further oxidation. Copper and aluminum, specifically, seem to create protective barriers. Regardless, decontamination should occur at the highest relative humidity possible and with the purest form of chlorine dioxide possible.
- *What PPE is required during decontamination?* The PPE level depends on a person's location and tasks. Typically operators and laboratory staff wear standard coverall and gloves. Chlorine dioxide is easy to smell, with most people detecting its presence at a concentration of 40 parts per billion (ppb), which is below harmful levels. Sabre does not conduct entries during fumigation, but full protective gear would be required if entries were needed.
- *Has a cost-benefit analysis been conducted to assess hard-wiring critical infrastructure for fumigation, similar to existing sprinklers for fire protection?* Sabre's ultimate goal would be hard-wiring critical facilities, but current technology advancements focus on reducing the response time. Commercial facilities must consider costs. For a hospital, the cost of decontamination is minimal versus the cost of lost income due to closure.
- *Can you compare fully loaded cost estimates per ft^3 to decontaminate the Brentwood facility versus the hospital scenario presented?* Much of the estimate depends on sampling and analysis activities, such as characterization sampling, post-decontamination sampling, BIs, and clearance needs. Assuming only post-decontamination environmental sampling and a reasonable number of BIs, decontamination of the Brentwood facility may require an estimated three weeks and $15 million. For the hospital scenario, an estimated total cost, including moving patients and ensuring site security, would be approximately $30 million. The cost of the chlorine dioxide itself is

insignificant compared to the lost revenue during closure.

- *Past fumigations with tenting have resulted in accidental mortality due to premature reoccupancy or unintended fumigant migration. How does Sabre prevent these accidents?* Sabre has been fortunate to avoid fatal accidents. Chlorine dioxide is strongly irritating to people before fatal concentrations are reached. So premature reoccupancy is unlikely. During fumigation, Sabre maintains negative pressure within tents, which has vastly reduced external leaks, and continuously monitors for leaks. Before reoccupancy, Sabre also conducts clearance sampling and involves a technical working group to review analytical clearance methods and health and safety measures. Sabre would like to use the trace air gas analysis (TAGA) van for ambient air monitoring to take advantage of the low detection limits that the TAGA instruments can achieve.
- *How well does chlorine dioxide penetrate through paper?* Under normal conditions, chlorine dioxide can penetrate through 15 sheets of paper.

Systematic Decontamination–Challenges and Successes

Vipin Rastogi, Edgewood Chemical Biological Center

Rastogi provided results from ongoing collaborative efforts with NHSRC to conduct systematic studies of fumigant performance for decontamination of building materials contaminated with *B. anthracis*. The specific study objectives were to evaluate the kill kinetics and D-values for chlorine dioxide against *B. anthracis*, assess the effect of bioburden on recovery and efficacy of VHP and chlorine dioxide, and identify an appropriate surrogate for the virulent Ames strain.

The experimental design consisted of testing six building materials with three fumigant technologies—chlorine dioxide by Sabre and ClorDiSys Solutions, Inc. (ClorDiSys) and VHP by STERIS—at various time points and fumigant concentrations. The overall experimental program resulted in a large number of samples to be analyzed each day. No methods, however, existed that could handle this sample load. As such, ECBC developed the Single-Tube Method (STM), which has been optimized and expanded to include surface sampling analysis. With various improvements made to previous techniques, such as the use of pour plating, STM was able to achieve low viable spore detection limits (1–5 spores), even with pulverized materials such as ceiling tile and wallboard.

Real-time and titration methods were used to monitor the chlorine dioxide concentrations during decontamination. Maintaining a constant relative humidity throughout the test improved the decontamination cycle. Rastogi provided photographs of the test equipment and materials.

Before beginning tests, ECBC considered the effect of coupon titer on decontamination efficacy. Using chlorine dioxide and a 6-log titer, nearly complete inactivation of spores on all building material coupons was achieved. With an 8-log titer, inactivation was much reduced. At this higher spore concentration and density, a higher chlorine dioxide concentration and/or contact time is required for complete inactivation. Based on these results, ECBC selected a 7-log inoculation.

Rastogi also investigated whether bioburden in the spore prep impacts spore recovery or decontamination efficacy. He presented results from decontamination of coupons with spore preparations containing various concentrations of a serum protein. Results indicated that a 5% serum protein content reduced spore recovery. The serum protein, however, did not affect decontamination efficacy for chlorine dioxide. Based on these findings, studies included 0.5% serum protein content in the spore preparations.

To optimize spore recovery, the spore preparations included 0.01% of Tween 80, which is a surfactant. Inoculations were also conducted as seven mini-droplets versus a single, larger drop. Rastogi presented results illustrating the different percent recoveries between spore preparation formulations.

A number of different terms are used in discussing decontamination. The D-value is defined as the time required for a decimal (1-log) reduction in the number of viable spores for a given set of conditions. The D1-value is the time required to achieve an initial 1-log reduction, and the D6-value is the time required to achieve 6-log reduction. Rastogi presented his analysis in which D1-values were used to extrapolate to a D6-value. The extrapolated D6-value tends to underestimate the measured D6-value. These results indicate that kill kinetics are nonlinear. Results also indicate that D-values vary across different building materials.

ECBC also investigated the suitability of using various species as surrogates for the virulent *B. anthracis* Ames strain. Rastogi presented results from chlorine dioxide decontamination of cinder block and steel coupons inoculated with the Ames strain and the NNR1Δ1 strain. These results indicate that the NNR1Δ1 strain may be an appropriate avirulent surrogate. ECBC also evaluated *B. subtilis* and *Geobacillus stearothermophilus* spores as surrogates for *B. anthracis* Ames. This evaluation consisted of inoculating wood coupons and conducting decontamination using chlorine dioxide for two different contact times. Results for each spore were comparable, and thus each may be an appropriate surrogate for *B. anthracis*.

Question and Answer Period

- *Do the data suggest that low concentration and long contact times achieve better inactivation?* Decontamination tests in December 2006 and January 2007 examined the efficacy using a concentration of 500 ppm chlorine dioxide with a 36-hour contact time. Follow-up tests consisted of higher concentrations with shorter contact times. ECBC would like to conduct further studies of lower concentrations coupled with longer contact time. Ryan (NHSRC) stated that investigations indicate that the total CT is the most important factor in successful decontamination.

New York City Anthrax Response

Neil Norrell, U.S. Environmental Protection Agency, Region 2

Norrell works as an OSC for EPA Region 2. He described the response events following a single inhalation anthrax case occurring in New York City in February 2006.

On February 16, 2006, an African drum maker and performer collapsed during a performance in Pennsylvania. The Pennsylvania Department of Health confirmed infection with inhalation anthrax on February 21, 2006. CDC confirmed the diagnosis the next day. The New York City Department of Health and Mental Hygiene (NYC DHMH), the New York Police Department (NYPD), FBI, and NIOSH began investigating the case for public health and possible criminal implications. Investigations focused on three locations: 31 Downing Street in New York City (the victim's home), 2 Prince Street in Brooklyn (the victim's workshop), and the victim's van. Sampling confirmed anthrax in each location.

To make the drums, the victim imported hides from overseas and used only hand tools (e.g., knives, razors, scrapers) to work the hides following traditional methods.

Coordination was a substantial consideration in conducting this response. Numerous agencies and organizations, as well as representatives of the victim's family, were involved. NYC DHMH served as the lead agency in addressing human health issues, determining sampling methods and analysis, locating samples, and clearing the affected locations for reoccupancy. OSCs provided support to NYC DHMH.

Overall, Norrell listed a number of issues considered when selecting decontamination technologies for each location. NYC DHMH considered sampling procedures, identified materials for decontamination versus disposal, arranged the logistics for decontamination (e.g., street closures, public meetings), and coordinated with family representatives to identify items of sentimental value. EPA, including the National Decontamination Team (NDT), supported NYC DHMH in decision making regarding materials to decontaminate versus those to be disposed of. Protecting public health and preventing reinfection of the victim were primary concerns. NYC DHMH selected a combination of pH-amended sodium hypochlorite (bleach) solution, HEPA vacuuming, and chlorine dioxide gas—depending on the type of material. All food, bedding, textiles, and other porous materials were disposed of.

From the victim's home, a total of 16 cubic yards of waste materials designated for disposal were bagged and rinsed with the amended bleach several times before removal from the apartment. Remediation workers used a modified sodium hypochlorite solution and HEPA vacuums to decontaminate remaining items and surfaces. After initial decontamination, clearance sampling reported several positive samples from the apartment floor (made of wood). The flooring material was more porous than initially anticipated. Complete decontamination of the floor occurred after reapplication and agitation of the decontamination solution (amended bleach). Several sensitive or sentimental porous materials (e.g., traditional costumes), however, were preserved and decontaminated with chlorine dioxide gas.

Arranging disposal was the most difficult component of the response. Facilities refused to accept anthrax-contaminated wastes, primarily because of the public perception of harm from anthrax, even naturally occurring anthrax. In addition, transport of the waste (considered a medical waste) across states would require a special permit for each state traversed. Several agencies collaborated to identify an acceptable disposal solution. New York Environmental Services (NYES), a medical waste autoclaving facility in New York, agreed to accept materials from the victim's apartment with some conditions. NYES personnel would not handle the waste, autoclaving would occur during off-hours, and sampling would ensure effectiveness. Autoclaving was completed in March 2006, and no growth was reported on BIs used to assess spore inactivation. Regardless, no landfills would accept the treated waste. After additional coordination, a facility in Ohio accepted the decontaminated waste for incineration.

The Prince Street warehouse, where the victim maintained a workshop, was a much larger facility with a much greater volume of material for disposal. The building owner hired its own contractor to conduct the decontamination, with oversight by NYC DHMH. The same decontamination methods used at the victim's home on Downing Street—modified sodium hypochlorite solution and HEPA vacuums for surfaces and chlorine dioxide gas for porous materials not disposed of—were applied here. Limited information regarding this decontamination is available because a private contractor conducted the work.

The victim's van and some materials from the victim's apartment and workshop were stored at an NYPD impound yard. NYC DHMH negotiated with NYPD to allow decontamination of the van and materials at the yard by fumigation with chlorine dioxide. Perimeter monitoring ensured no release of chlorine dioxide from the treatment enclosure. Norrell provide photographs and a schematic drawing of the decontamination. The van and materials have been released to the victim.

Question and Answer Period

- *What was the cost of the response to this event?* The response at Downing Street and the work at the impound yard (the van and other material decontamination) cost an estimated $750,000 (US).
- *Was the source of the animal skins investigated?* Information about the source of the skins is based on hearsay. Reportedly the victim would return home to Africa to obtain the skins. Customs officials provided no clear information regarding the legality of the skin import.
- *In conducting clearance sampling of the victim's apartment, only targeted areas were sampled. A targeted approach does not provide great confidence in the decontamination efficacy. A more comprehensive clearance sampling plan should be required.* Norrell

agreed that clearance was based on a target sampling approach and that this approach may not provide great confidence in decontamination efficacy. NYC DHMD, however, was responsible for declaring clearance and was comfortable in doing so with the available clearance sampling results. Norrell noted that clearance sampling included samples collected in the victim's apartment, as well as air monitoring results from adjacent apartments.

- *What type of incinerator was used for disposal of the autoclaved materials?* The Ohio facility is a medical waste incinerator.
- *During arrangements for disposal, where was the waste stored?* The waste was held at a transport yard in Albany, New York. Regulators approved holding time waivers to allow for the unplanned, extended storage time. The difficulties with disposal illustrate the importance of the disposal phase. Norrell thought that difficulties stemmed from perceptions regarding anthrax.
- *To what extent did the family accept fumigated materials?* The family reclaimed the heirlooms, costumes, and similar items. Mason (Sabre) indicated that approximately 20% of the items experienced bleaching or color change. The family also reclaimed the van.
- *When decontamination consistency was being considered, what criteria were used to decide which items were treated by gas versus liquid application?* At the time, NYC DHMH was unclear about chlorine dioxide gas fumigation and public pressure required a rapid response at the Downing Street location. Norrell thought that if a future event occurred, NYC DHMH would likely explore chlorine dioxide fumigation in homes.

Update on EPA Decontamination Technologies Research Laboratory (DTRL) Activities

Shawn Ryan, U.S. Environmental Protection Agency, National Homeland Security Research Center

Ryan's previous presentation focused on decontamination technology efficacy evaluations. This presentation discussed research being performed in NHSRC's Decontamination Technologies Research Laboratory (DTRL), which investigates some of the engineering aspects of promising decontamination methods. Current studies have primarily focused on chlorine dioxide gas applications because chlorine dioxide has been shown to be a highly effective decontaminant. However, research with other fumigant technologies will be conducted in DTRL as well.

DRTL is located in Research Triangle Park, North Carolina, and consists of complementary research facilities. Fumigation research and analytical support are the current research focuses. Studies address application issues to consider when selecting a fumigant and to improve technologies for better efficacy and reduced costs. Ryan discussed six research projects currently underway at DTRL.

- *Fumigant process parameter measurements.* No standard method exists for measuring high concentrations (i.e., >10 ppm) of chlorine dioxide in air. DTRL has extensively evaluated two methods—a modification to the AWWA SM-4500 (E) method and an instrumental technique using the ClorDiSys EMS—capable of measuring high concentrations. AWWA SM-4500 (E) is designed to analyze chlorine dioxide in water. The method has been modified to extend to gas sampling, however, the modifications eliminated the method's ability to speciate between chlorine gas and chlorine dioxide. The modified method has a detection limit of approximately 25 parts per million by volume (ppmv). The ClorDiSys EMS photometric method provides real-time measurement and has a detection limit of approximately 36 ppmv. As illustrated by the results presented, a good correlation exists between the measurements reported by both methods.

  For low concentration measurements, DTRL has evaluated the Dräger Polytron 7000 instrument method and the Occupational Safety and Health Administration (OSHA) Inorganic Method ID-202. The Dräger electrochemical method provides real-time measurements of chlorine dioxide with a detection limit of 50 parts per billion by volume (ppbv). The OSHA method is based on analysis of impinger liquid using an ion chromatograph and achieves a detection limit of 60 ppbv. A good correlation, as illustrated in a graph of the results, exists between the two measurement methods.

  DTRL is constructing a dual-source, triple-quadrupole mass spectrometer (MS) bench-top system (the same instrument used in the TAGA van) and also uses a single-photon ionization/time-of-flight mass spectrometer (SPI) for some of its studies. The triple-quadrupole MS provides real-time measurements for both chlorine dioxide and chlorine gas with a quantitation limit as low as 2.3 ppbv. SPI also provides real-time measurement for chlorine dioxide with a detection limit of 0.3 ppm but cannot measure chlorine gas.

  Ryan noted that technology efficacy may vary greatly depending on process parameters (e.g., relative humidity, temperature) and decontaminant concentrations. As such, accurate measurement and control of the temperature and relative humidity is critical to successful decontamination, especially when conducting research to examine impacts of these parameters. Ryan presented an example of divergent relative humidity readings from two separate monitoring devices. One of the devices had previously been exposed to chlorine dioxide.
- *Fumigant permeability.* Effective decontamination requires fumigant containment in a defined volume for a specified concentration and time. Leakages from this defined volume increase the fumigant generation

requirements and may present worker and public health concerns. DTRL devised a system to assess permeability of materials that may be used for fumigant containment. Ryan presented results of chlorine dioxide permeability testing of various potential tenting/containment materials.

- *Fumigant adsorption.* Solid sorbents (e.g., carbon beds) or catalysts are used to capture the chlorine dioxide gas during or after a fumigation event. The air is withdrawn to keep the structure under negative pressure and routed to a capture device. At some point, these materials reach the adsorption capacity and breakthrough occurs. DTRL is conducting studies to determine the chlorine dioxide adsorption capacity of different sorbent materials at various parametric conditions.
- *Material demand.* Materials undergoing fumigation can substantially affect the fumigant concentration within a defined volume, either through chemical reaction or adsorption onto the material. When determining how much fumigant will be required, decontamination planners must account for homogeneous decomposition and material interactions. Research conducted by ECBC concluded that some materials have a significant fumigant demand. For VHP, the inflow concentration had to be double the target concentration within a chamber containing various building materials (e.g., concrete, ceiling tile, wood). DTRL is expanding this area of research to develop a calculator tool that will determine how much fumigant is needed to decontaminate a building as a function of the decontamination conditions and building materials. This tool will assist in determining whether a fumigant generator has enough capacity to meet the required CT. DTRL's initial focus is chlorine dioxide because of its high efficacy in decontaminating porous and nonporous test materials.
- *Material and fumigant by-products.* Researchers are beginning to assess and monitor building material–fumigant by-products. During the aeration phase of material demand and compatibility studies, DTRL analyzed gaseous by-products from off-gassing and residuals from coupons.
- *Material and equipment compatibility.* DTRL, in collaboration with ECBC, recently began evaluating fumigant impacts to materials and equipment. Preliminary results for chlorine dioxide and VHP identified no aesthetic or structural strength impacts. Published results should be released soon. DTRL plans to continue examining fumigant impacts on material and equipment aesthetics and functionality, testing first with chorine dioxide and then expanding to VHP. Ryan requested that workshop participants provide input regarding materials to evaluate and outlined upcoming tests (in collaboration with DHS) with computers and monitors.

Question and Answer Period

Workshop participants posed no questions.

Localizing and Controlling Biothreat Agent (BTA) Transport with Polymer Sprays

Paula Krauter, Lawrence Livermore National Laboratory

Krauter discussed her research investigating technologies designed to minimize spore (e.g., *B. anthracis*) reaerosolization. Several published reports discuss reaerosolization as a possible source of anthrax cross-contamination at the Brentwood postal facility. Inhibition of anthrax resuspension may have provided decision makers with more time to evaluate decontamination options while limiting further contamination.

Krauter's research aimed to investigate ways to limit spore transport by increasing adhesion and inhibiting resuspension. Following this concept, Krauter sought to identify a polymer aerosol droplet (~50 microns [µm]) with a slight negative charge. (The polymer[s] tested had negatively charged functional groups.) Weapons-grade *B. anthracis* spores have a slight positive charge and would be attracted to such a polymer. (Although Krauter did not test *B. anthracis* for its charge, she assumed that a similar spore preparation will have an electrostatic charge close to *B. atrophaeus*, which she did measure.) As the polymer settled on a surface, it would agglomerate as the solvent evaporated and would adhere the spores to the surface. Krauter listed key polymer spray selection criteria (e.g., high adhesion strength, negative charge, low viscosity and surface tension, moderate evaporation rate, and low corrosivity and toxicity) and characteristics of a number of polymer formulations.

After identifying several promising polymers, Krauter conducted screening tests in a small chamber. Powdered spores were dispersed, the polymer solution was sprayed and allowed to dry, and resuspension was measured using an aerosol particle sizer and microbial plate counts. The process of spraying the polymer itself or a decontaminant liquid can resuspend the spores. As such, Krauter also used small-chamber tests to optimize polymer formulations and low-pressure spray applications. The terpolymer of butylaminoethyl methacrylate, octylacrylate, and acrylic acid (NS-2) performed the best in the small-chamber studies.

As the next step, Krauter conducted validation studies in a larger test chamber in September 2006. The larger test chamber was designed as an antistatic aerosol chamber to represent a worst-case release environment. Krauter provided a photograph and schematic diagram of this chamber and its components. The validation tests consisted of disseminating spores, allowing overnight settling, purging unsettled spores, resuspending and resettling spores, spraying the test or control solution, permitting solution drying, and applying a high-velocity mechanical airflow. An ethanol-water solution served as the control. (Spores resuspended overnight due to the temperature gradients caused by turning off the heat at night. This observation is unassociated with the application of the water control but shows how easily these spores were reaerosolized.) In applying the polymer, a thin or partial

coating was sought to allow for some measurement of resuspension after application.

Results from validation tests showed a 0.41% to 0.7% reaerosolization efficiency before the NS-2 application. After application, reaerosolization was 0.3% for the control solution and 0.03% and 0.0002% for the NS-2 applications. The difference in reaerosolization efficiency for the two NS-2 tests was due to the polymer spray application rate. Three tests were conducted. Test 1 was a process control that applied the water-ethanol spray at a rate of 0.12 liter (L)/m^3 to inhibit spore resuspension. Test 2 used the copolymer solution, NS-2, at a rate of 0.1 L/m^3. Test 3 applied NS-2 at a rate of 0.12 L/m^3. Using data generated from validation tests, Krauter calculated the resuspension factor, which is the ratio of the number of spores in the air versus the number of spores on the surface. According to comparisons of resuspension factors calculated during testing, the control solution inhibited resuspension by 0.5 orders of magnitude. NS-2 inhibited resuspension by 2 orders of magnitude. These results indicate that a very small amount of the polymer spray—only 300 milliliters (ml) of polymer were applied in a 3.5 m^3 antistatic chamber—could significantly reduce reaerosolization. Based on this success, LLNL is exploring polymer sprays that will contain and minimize contact with other hazardous materials, such as beryllium and uranium particles.

The research confirmed that certain polymer sprays will inhibit spore resuspension by adhering particles to a surface. As a secondary goal, Krauter sought and successfully identified a noncorrosive polymer. Additional testing indicates that this and other polymers can be formulated to target specific particles. Overall, use of a polymer spray can limit agent migration and provide a margin of safety for personnel during decontamination and recovery.

Question and Answer Period

- *What were the spore loadings on the surfaces tested?* The B. atrophaeus used in this study was a dry powder with a titer of 1.77 to 2.33 $\times$ 10^{11} spores/gram. The surface concentration during the deposition phase was about 5 $\times$ 10^9 spores/square meter. Initial spore release resulted in about 2.5 $\times$ 107 $\pm$ 6.4 $\times$ 10^6 colony forming units (CFU)/L air in the aerosol chamber.
- *In considering next-generation polymer sprays, can the polymer formulations be altered to bind and inactivate agents?* Studies have focused on simply binding the agents as the first phase of a two-phase decontamination process. Binding and resuspension inhibition provides decision makers with more time to research and select the most appropriate decontamination technology for the situation.
- *Is the polymer coating strippable?* In these tests, the polymer coating is too thin to strip, but it can be washed away. Applying another strippable coating on top of the polymer, however, may be possible. Research would be needed to assess this approach.

Can We Expedite Decontamination?

Blair Martin, U.S. Environmental Protection Agency, Air Pollution Prevention and Control Division

Decontamination efforts have a reputation for being time consuming and costly. The response to the anthrax contamination at Capitol Hill, however, spanned only two months. When considering critical infrastructure, the cost of decontamination is minimal compared to other costs, such as the economic impact of closing a large airport.

Martin reviewed several decontamination events to illustrate the range of situations encountered, the variety of decontamination technologies used, and the evolution and improvement of these technologies over time. He presented specific details regarding the Brentwood facility and the SA-32 Building decontamination events. The events highlight differences in site-specific conditions and the use of different fumigant technologies: chlorine dioxide and VHP. Since 2001, chlorine dioxide has also been used to treat *B. anthracis* at the American Media International Building, mold at a department store, and mold at numerous facilities in New Orleans. Advances in this technology include the use of tents and the size reduction in chlorine dioxide generation equipment.

At NHSRC, the systematic evaluation of fumigant efficacy and decontamination technologies has focused on chlorine dioxide, although studies have also considered VHP and methyl bromide. These evaluations consider impacts of fumigation parameters (e.g., concentration, time, relative humidity, temperature) and materials on efficacy. Martin presented data from several studies to illustrate material impact on decontamination efficacy. In tests with BIs, after treatment at 6,000 ppm-hours with chlorine dioxide, no growth occurred on any tested BIs; however decontamination of *B. anthracis* on wood or cinderblock required higher treatment levels to achieve complete decontamination.

NHSRC is also interested in streamlining the decontamination process. When a release occurs at critical infrastructure, decision makers must conduct decontamination with an approach that minimizes the impact to the general population, the area economy, and the restoration cost. Preplanning is essential; however, only a limited number of critical facilities (e.g., airports, urban transportation facilities) may have the resources to prepare a comprehensive plan. Preplanning can range from simply keeping current facility drawings to precontracting with decontamination vendors and arranging restoration insurance.

As a first step in selecting suitable decontamination technologies, decision makers must assess the contamination extent based on information from witnesses to the release, forensic and characterization sampling, threat agent properties, and indications of threat agent migration. This information feeds decisions regarding PPE level and additional sampling needs. Martin suggested that characterization sampling include heating, ventilation, and air conditioning (HVAC) system samples. If the threat agent is in the HVAC system, it has likely been dispersed throughout

the facility. Decision makers could proceed immediately to fumigation without further surface characterization sampling. Much debate exists regarding the best type of characterization sampling (e.g., biased versus random) and best decontamination technology. Each situation must be evaluated individually.

History has proven that existing technologies have the capacity to fumigate an entire building. Any fumigant, however, must comply with FIFRA requirements, either through registration or exemption. Martin outlined the steps of a decontamination process. These steps do not necessarily occur linearly; some activities can occur simultaneously. Critical components of the process include containing the threat agent to minimize migration and impact, preparing decontamination documentation, implementing the physical decontamination process, and confirming successful decontamination. The decontamination process involves sealing the facility to prevent fumigant leaks, installing equipment and monitoring devices, conducting the fumigation, and collecting BIs. Martin recommended minimizing BI use because it is costly and does not necessarily confirm successful achievement of decontamination process conditions.

The Brentwood decontamination spanned 18 months. With the state of the art now, Martin thought decontamination would currently require only 4 months for a Brentwood-like decontamination. Pre-planning and preparation are critical to reducing the timeline; the fumigation itself requires only a single day. Compared to ancillary requirements (e.g., sampling), the fumigant cost and single-day application is minimal. Martin suggested focusing efforts and resources on facility clearance to ensure safe reoccupancy.

Future efforts to improve BIs, obtain FIFRA registration, and optimize characterization and clearance sampling may further reduce the time and cost associated with restoring a facility contaminated with *B. anthracis*. Research and development in a number of other areas will also provide additional guidance and support future decontamination events. Martin listed a number of these research areas. NHSRC continues to interact with the user community to target key data gaps and dispense research findings. Overall, decontamination technologies are much improved; however, additional process improvements are still needed.

Question and Answer Period

The question and answer period was waived due to time constraints.

Session 4: Chemical Threat Agent Decontamination Research and Development

Airport Restoration Following a Chemical Warfare Agent (CWA) Attack

Bob Knowlton, Sandia National Laboratory

Knowlton discussed the Facility Restoration Operational Technology Demonstration (OTD) project, which addresses restoration of an airport following a chemical agent release. This project focuses on facility interior remediation, and the resulting restoration plan for Los Angeles International Airport (LAX) will serve as a template for other airports. This is a DHS-sponsored project being conducted by the U.S. Department of Energy (DOE) national laboratories, with representatives from EPA, DoD, and other agencies acting as advisors.

As an example of possible economic consequences, Knowlton stated that closing an airport such as San Francisco International Airport (SFO) would have an estimated $80 million per day impact on the regional economy. Unfortunately, transportation centers are highly vulnerable to chemical terrorism. They also contain a number of unique areas and materials that pose a wide range of decontamination and remediation challenges.

This project seeks to develop a systems approach to facility remediation that will decrease the time required for recovery following a CWA attack. Tasks focus on preplanning, recommending decontamination technologies, and filling technology data gaps through an experimental program. Knowlton noted that preplanning is critical and may consist of maintaining current building plans, understanding HVAC systems, and establishing remediation contracts before an event. The project builds upon the knowledge learned in conducting the Biological Restoration Domestic Demonstration and Application Program. Many of the fundamental concepts, technical developments, and key relationships developed for the biological response apply to a chemical response, with some exceptions, as explained in detail by Knowlton.

The primary project goal is to develop a remediation plan for LAX and a template remediation plan for use by other airports. Much of the historic delay in restoration was linked to the development and approval of remediation plans. Preparing this plan in advance will allow officials to address key issues, such as determining sampling zones and deciding what materials to decontaminate versus dispose of (e.g., carpets). Officials should also identify stakeholders and their needs in restoring a facility. Knowlton noted that a remediation plan must address multiple contamination scenarios.

The Facility Restoration OTD team consists of a number of working groups that address different aspects of the restoration process.

- *Partnerships.* This group conducts outreach to stakeholders and manages and facilitates relationships between stakeholders. Stakeholders include airport owners and operators, and federal, state, and local agencies.
- *Threat scenarios.* With input from DHS and other federal agencies, this working group has developed realistic threat scenarios for transportation facilities. The scenarios consider likely agents (e.g., CWAs, TICs), release types, release locations, and agent amounts. These scenarios will be considered when conducting a tabletop exercise to demonstrate preplanning capabilities and tools.

- *Cleanup guidelines.* Cleanup guidelines exist for air concentrations of some CWAs, but no standards exist for surfaces. This group is gathering data to develop a set of recommended cleanup standards specifically for airport workers and transit passengers. Knowlton noted that EPA is working on a similar task and is involved in reviewing guidance developed by this working group.
- *Sampling.* This group is developing recommendations for sampling and analysis during the characterization, remediation verification, clearance, and monitoring phases of restoration.
- *Decontamination.* Many potential decontamination technologies are available, but their effectiveness varies depending on the agent and other factors such as the surface material. This group, with support from decontamination experts, seeks to identify and recommend technologies to address specific agents listed in the LAX remediation plan.

The Building Restoration Operations Optimization Model (BROOM) is a decision support tool being adapted for use in CWA attack planning and post-event operations. BROOM is a system to collect, manage, visualize, and analyze large amounts of data. The sample management component relies on hand-held systems, barcodes, and wireless technology to track sample locations and results. The data analysis component maps contamination areas, highlights areas of contamination uncertainty, and identifies optimized sampling to reduce uncertainties.

The Facility Restoration OTD project also includes an experimental phase to address data gaps identified when developing the LAX restoration plan. Knowlton listed four current research projects: investigation of surface sample collection efficiency; material and agent interactions; gas/vapor decontamination; and statistical sampling algorithm validation. Knowlton provided details about two of these projects:

- *Surface sample collection efficiency.* No validated standard methods exist for surface sampling and analysis of trace CWAs. A need exists to demonstrate CWA detection at concentrations below guidelines (e.g., 300 nanograms per square centimeter). Studies will examine sampling efficiencies of three CWAs on airport material types. Knowlton presented preliminary results from initial tests. Extraction efficiencies are relatively high for nonreactive surfaces.
- *Gas/vapor decontamination method scale-up evaluation.* This task involves the evaluation of hot air and existing fire sprinklers for decontamination. For more volatile agents, natural attenuation and ventilation may be a viable decontamination technology. Researchers are evaluating heat to desorb agents from surfaces. This research seeks to understand the temperatures needed to desorb agents and identify technologies that can achieve these temperatures. Researchers are also evaluating whether existing fire sprinkler systems can be used to scrub a chemical agent "cloud." Knowlton presented information from an initial trial using a fire sprinkler to scrub a G-agent simultant (dimethyl methylphosphonate [DDMP]).

Question and Answer Period

- *In developing response plans, how do you communicate with stakeholders?* The Facility Restoration OTD team has worked extensively to identify and bring together stakeholders from multiple groups and agencies. Workshops are one way to bring stakeholders together.
- *What was the 10% bleach solution recommended as a decontamination technology?* The 10% bleach is simply household bleach with a 10-minute contact time.

Quantitative Structure Toxicity Relationships (QSTR) to Support Estimation of Cleanup Goals

Chandrika Moudgal, U.S. Environmental Protection Agency, National Homeland Security Research Center

The risk assessment paradigm developed by the National Academy of Science in 1983 serves as the foundation for EPA risk assessments. The four components are hazard identification, dose-response assessment, exposure assessment, and risk characterization. Hazard characterization involves determining whether an agent causes an adverse effect. Dose-response assessment quantitatively characterizes the relationship between dose and effect. Exposure assessment considers the magnitude, frequency, duration, and routes of exposure. Risk characterization estimates the likelihood of adverse health effects in an exposed population.

Moudgal presented a figure that highlights the relationship of risk assessment, risk management, and research. Research, such as animal toxicity studies, epidemiological studies, and computational methods, feed into hazard characterizations and dose-response assessments, which in turn feed risk characterization and risk management decisions.

Risk-based cleanup goals are agent concentrations in environmental media that serve as screening estimates to determine remediation needs and to support risk management decisions. These values are health-based and are derived using estimates of toxicity, exposure, and target (acceptable) risk or hazard levels. When appropriate, such as when evaluating possible decontamination alternatives, these values can serve as initial cleanup goals. Risk-based cleanup goals are not de facto cleanup standards. Cleanup standards for a site should also consider agent detection limits, economics, and technological feasibility of decontamination alternatives.

Risk-based cleanup goals can be calculated based on exposure over a lifetime. Typically, EPA selects a hazard index of 1 for noncarcinogens and a risk of 1 in 1,000,000 to 1 in 10,000 for carcinogens. Moudgal provided equations for calculating cleanup goals and provided Web links for more information. A number of EPA regional offices (Regions 3, 6, and 9) have generated cleanup goals for common pollutants using default assumptions. Risk-based cleanup goals may be applied to children, adults, or the overall population. Most values consider chronic exposures.

Quantitative structure toxicity relationships (QSTRs) are mathematical equations that determine the correlations between various features of a chemical's molecular structure and observed biological activity. For example, if a particular chemical structure or agent is associated with liver toxicity, another structurally similar chemical or agent could be correlated to liver toxicity using mathematical models. A number of currently available software programs can generate thousands of descriptors. Statistical packages, such SAS, can be used to determine the correlations between computer-generated descriptors and a biological end-point. QSTR is most useful in providing toxicity estimates when no agent-specific experimental toxicity data are available. This method provides rapid and reliable results and can permit quick screening and ranking of a number of untested chemical agents.

The QSTR methodology initially involves gathering data on a toxicity endpoint (e.g., lowest observed adverse effect level [LOAEL], lethal dose for 50% of a population [LD50]), and the mechanism or mode of action of an agent, if available. This information can then be used to develop specific de novo QSTR models. Traditionally, commercially available software or other resources are used to obtain chemical structure descriptors based on QSTR. From these data, statistical analysis and experimental validation are conducted to determine the model's applicability and performance. Once validated, the model can be used to predict toxicity in other agents with similar structures.

Existing or custom QSTR models can be applied to develop cleanup goals for agents. Moudgal provided an example using the QSTR methodology to estimate a reference dose for 1,4-thioxane (a TIC). Using a commercially available software package called TOPKAT®, Moudgal computed a LOAEL of 219.3 milligrams of agent per kilogram body weight per day (mg/kg/d). Assuming certain risk and exposure assessment factors, a cleanup goal of 4,000 milligrams of agent per kilogram of soil was determined.

Alternatively, the QSTR software can be used to find the most appropriate chemical analogs (surrogates) for which cleanup goals have already been established. This second approach is fast, inexpensive, and reliable when a validated model is used.

Moudgal ended her presentation with a summary of the advantages and disadvantages of using QSTR models and how they could be applied to decontamination.

Question and Answer Period

- *For chemical threat agents, are dose-response data already available?* To date, a number of CWAs have been studied extensively and substantial experimental and epidemiological health effects data exist. For TICs, available data are more scattered. QSTR could play a role in better understanding the toxicity of these agents, specifically acute versus chronic toxicity and qualitative versus quantitative toxicity.
- *One participant commented that QSTR use should expand into routine use, perhaps in combination with uncertainty factors.* This participant suggested that Moudgal communicate with EPA regulators and NIOSH researchers. Moudgal noted that QSTR has been used more extensively in the premanufacturing process to model possible exposures and support process decisions. QSTR uses a weight-of-evidence approach more than an uncertainty factor approach when deriving values. The European Union is more accepting of QSTR and has established guidelines and criteria for its use in regulatory decision making.

Determining Chemical Warfare Agent (CWA) Environmental Fate to Optimize Remediation for Indoor Facilities

Adam Love, Lawrence Livermore National Laboratory

Love discussed his current research, which is being conducted as part of the Facility Restoration OTD project, to address data gaps in CWA persistence and interactions on various surfaces. Most research to date has focused on vapor hazards to address DoD concerns; very little information is available on the behavior of CWAs on surfaces.

To address this data gap, Love's study will use three CWAs and eight different materials found at airports. At high concentrations, the bulk properties of the agent dominate fate and transport (e.g., volatilization, dissolution, infiltration). As the concentration decreases, molecular properties dominate (e.g., hydrolysis, oxidation, biodegradation, catalysis, sorption, complextion). Most restoration projects will likely have many surfaces with low levels of contamination.

Love indicated that data from studies of agent persistence and surface interactions could enable better decision making during the restoration process. First responders will be able to target areas with known affinities for an agent and mitigate cross-contamination. During the characterization phase, the sampling plan can focus on surfaces with the highest probability of retaining an agent. Agent fate data will also inform decisions about remediation approaches.

Agent fate and transport greatly depend on whether the agent is released in liquid, vapor, or gas form. A vapor or gas release will result in a greater spatial spread, but lower agent concentration. In addition, vapors may be adsorbed on materials, then volatilized off the material. In a liquid release, the agent does not disperse as much but will be higher in concentration.

From their experimental work, Love's research team seeks to gain a mechanistic understanding of persistence based on physical and chemical characteristics. With this knowledge, the persistence for thousands of agent and material combinations can be assessed without actually testing each combination individually.

Love's research seeks to understand a material's affinity for, and rate of accumulation of, CWA vapor. The loss (attenuation due to airflow) of CWA from different materials, as a function of either vapor or liquid deposition, will also be investigated. Detailed surface examination will also be included as part of the data-gathering activities.

Love presented affinity and accumulation data for HD on various surfaces. A mass balance approach is used to more completely understand the fate of the CWAs, in particular the potential chemical reaction products between the agents and materials. As an example, Love presented concentration data on VX and its degradation products as a function of time.

Love discussed the issue of using surrogates, noting that although a limited number of materials can be tested using actual CWAs, surrogates often poorly simulate chemical interactions. Nonetheless, surrogates can be used to categorize surfaces with similar physical accumulation and persistence dynamics. This process may enable limited CWA data to be extended to additional untested materials with similar characteristics.

Ultimately, research regarding agent persistence and surface interactions seeks to reduce the time and effort required for restoration. Surfaces that do not accumulate CWAs may not need to be decontaminated or sampled. Surfaces that accumulate CWAs, but have a short persistence time, may be used for characterization sampling. Surfaces that accumulate CWAs and have a long persistence time should be the primary focus of sampling and decontamination efforts.

Question and Answer Period

Workshop participants posed no questions.

Chemical & Biological Defense Program Physical Science & Technology Program Overview–Hazard Mitigation

Mark T. Mueller, U.S. Defense Threat Reduction Agency

Mueller began by stating that the civilian definition of decontamination does not accurately reflect military missions, capabilities, and objectives; military decontamination does not necessarily require 100% decontamination for reuse.

Historically, the military sought a decontamination solution that would apply to all agents in all circumstances. Currently, the military is rethinking this approach. The military must consider variations in personnel deployed in a domestic terror event versus a front-line warfare situation. Disposal may be the best option in a domestic event where equipment replacement is readily available, but decontamination might be required in a front-line situation with limited resources.

Mueller compared decontamination approaches to automobile detailing. No single product is available to fully detail all components of an automobile. Specialized products and process are required. Agent decontamination requires the same specialized products and processes to be effective.

Military decontamination also faces a number of scientific challenges. Additional research is needed to build a basic understanding of agent reactions, as well as reaction kinetics for the agents, material surfaces, and field grime on material surfaces. For sensitive equipment, materials compatibility and impacts to equipment service life are large concerns. A better understanding of the correlation between simulants and agents is needed, and application and dispersion of the decontamination liquid is critical.

Mueller listed several research highlights from 2007; some examples follow. Development of a decontamination wipe (comprised of activated carbon cloth) containing a freon substitute (hydroflouroether) to restore sensitive surfaces was completed. Contaminated human remains from front-line efforts or a mass casualty event present a unique decontamination problem. Research identified candidate technologies for addressing human remains and their transport. A new chlorine dioxide formulation (containing bromine) with a broader capacity for decontaminating G-agents was developed.

A number of additional research efforts are ongoing. Some highlights are as follows:

- *Effect of droplet size on efficacy of aerosolized peroxy decontamination.* This effort evaluates the impact of different droplet sizes on decontamination efficacy of DF-200. In 2008, testing will expand to additional agents and include the design and demonstration of an aerosol generation system.
- *Aerosolized activated hydrogen peroxide technology for decontamination of aircraft interiors.* In conjunction with Sandia National Laboratory, this research seeks to develop a technology based on Sandia DF-200 to decontaminate aircraft interiors and other hard-to-reach places. Live agent testing and field testing are scheduled for 2007.
- *Electrochemically generated decontamination solution.* Aqueous chlorine dioxide is generated electrically and tests will be conducted to optimize the application of the decontamination solution to surfaces.
- *Portable decontamination for vehicle interiors and cargo.* Solvent wipes provide a portable, lightweight system for decontaminating vehicle interiors and sensitive equipment. Goals for 2007 included demonstrating this technology in a realistic environment, evaluating packaging, and developing reactive wipes. This technology is currently ready for application.
- *Sprayable powders for surface decontamination of CWAs.* This effort seeks to develop a system to spray nontoxic reactive nanoparticles onto surfaces to achieve decontamination. The nanoparticles would penetrate further into a surface than a foam spray and provide improved decontamination. In 2007, efforts focused on developing a deployment system. In 2008, efforts will focus on improving this system for testing in relevant environments in 2009.

Question and Answer Period

- *Most military decontamination research has focused on warfare situations. How has the focus changed when considering civilian events and open-air or wide-area decontamination?* Assessing these variations is one objective of a rock drill exercise. Emphasis is on a theater of operations perspective. How that perspective will feed specific decontamination scenarios is not well delineated at this time.

Session 5: Biological and Foreign Animal Disease Agent Decontamination

(1) Results from the Evaluation of Spray-Applied Sporicidal Decontamination Technologies (2) Test Plans and Preliminary Results for Highly Pathogenic Avian Influenza Virus Persistence and Decontamination Tests

Joseph Wood, U.S. Environmental Protection Agency, National Homeland Security Research Center

Wood described two decontamination projects. The first project is completed and was conducted under the Technology Testing and Evaluation Program (TTEP). Eleven spray-applied sporicidal decontamination technologies were evaluated. Wood presented a table summarizing the technologies and the contact time used for testing.

Wood provided the quantitative efficacy results for all of the technologies; all of the technologies were evaluated for their ability to decontaminate glass inoculated with *B. anthracis* Ames spores. pH-amended bleach was prepared by mixing off-the-shelf bleach with water and 5% acetic acid. The amended bleach is less corrosive and is a more effective sporicide, due to the hypochlorous acid that is formed at the lower pH. Detailed results from testing the pH-amended bleach against *B. anthracis* Ames spores and three other spore-forming bacteria (*B. subtilis*, *B. anthracis* Sterne, and *G. stearothermophilus*) on various coupon materials indicate that porous surfaces are harder to decontaminate than nonporous surfaces (e.g., carpet versus glass). *G. stearothermophilus* also appears to be the most resistant to inactivation.

Wood provided a chart to compare the efficacy results for pH-amended bleach, CASCAD SDF, Hi-Clean 605, KlearWater, and Peridox on three different test material coupons and three different spore strains. Again, results indicate that porous materials are harder to decontaminate than nonporous materials, and efficacy is highly dependent on the test coupon material and the spore species.

The quality assurance test plan and the final report for the spray-applied sporicide tests are available on the NHSRC Web site.

The second project Wood discussed is currently underway. The primary purpose of this project is to assess the persistence of the highly pathogenic avian influenza H5N1 virus (strain A/Vietnam/1203/4) and the low pathogenic avian influenza H7N2 virus (strain A/H7N2/chick/MinhMah/04) under various environmental conditions. The project's second purpose is to investigate the efficacy of various generic decontamination liquids.

Persistence testing of the H5N1 virus will be conducted with four materials at four nonzero time points. The tests will be conducted at two different temperatures—with and without exposure to simulated sunlight. Based on test conditions producing the greatest persistence for the H5N1 virus, persistence tests for the H7N2 virus will include two materials, two nonzero contact times, and two environmental conditions. Decontamination studies will then follow the persistence studies.

Cytotoxicity tests will be conducted to ensure that the cells used to assay virus inactivation remain viable when exposed to the coupon material extracts and the neutralized decontamination liquid. For the quantification assay, results will be expressed as the tissue culture infectious dose of 50% (TCID50), based on cytopathic effects on cells using the Spearman Karber method. The assay for the H5N1 virus will use canine kidney cells, and the assay for H7N2 will use chicken embryo cells.

Preliminary results were presented for some of the cytotoxicity and virus recovery tests.

Question and Answer Period

Workshop participants posed no questions.

Inactivation of Avian Influenza Virus Using Common Soaps/Detergents, Chemicals, and Disinfectants

Robert Alphin, University of Delaware

Alphin is currently leading a project to assess avian influenza virus inactivation using various common chemicals. The project, which is funded by U.S. Department of Agriculture (USDA), will provide information to support efforts to restore poultry facilities after an avian influenza outbreak. Alphin noted at the beginning of his presentation that foam has been proven as an effective means to depopulate poultry populations infected with the virus. Adding decontamination agents to this foam may partially disinfect the facility at the same time.

The highly pathogenic avian influenza virus significantly threatens domestic and international poultry production. Humans who become infected have a high fatality rate (186 fatalities out of 307 cases.)

In case of another major avian influenza outbreak, or even worse a pandemic, USDA wanted to explore alternatives to the current EPA-approved disinfection agents because of their limited availability, expense, corrosive properties, and environmental impacts. The ideal product would be effective against the avian influenza virus on a variety of surfaces, widely available, biodegradable, inexpensive, and antimicrobial.

USDA and EPA selected several off-the-shelf chemicals for testing, including acetic acid, citric acid, sodium hypochlorite, and others. Alphin and his group developed a method to test foams, thermal fogs, and liquids that met EPA standards for temporary approval of disinfectants for hard, nonporous surfaces. Galvanized steel, plastic, and wood coupons were tested in the presence of hard water with 5% serum to account for organic matter. The test agent is a low pathogenic isolate of the avian influenza virus (H7N2) recovered from a 2004 outbreak of avian influenza virus on the Delmarva Peninsula.

To assess viral inactivation, fluid from the decontaminated test coupons was injected into eggs, and then after a 5-day exposure period, fluid from each egg was examined for hemagglutination activity. Positive and cytotoxic controls were also used. In addition to testing the egg fluid for hemagglutination activity, embryos were examined for

stunting and other lesions. To quantify results, Alphin compared the virus titer of the positive controls to the virus titer of the treated groups. Inactivation was deemed successful when the titer of the positive control was greater than 4 log and no recoverable virus was found on the test coupons (detection limit of <1.2 log).

Alphin provided detailed test results. The neutralization indices for the nonporous coupons (i.e., metal, plastic) were higher than the indices for the porous coupons (i.e., wood). All six disinfectants were effective for hard, nonporous surfaces; only two were effective for porous surfaces. Virus recovery from the wood coupons—both the positive controls and test coupons—proved to be difficult and affected conclusions regarding effectiveness on porous surfaces. The testing did identify several common chemicals that may be suitable for avian influenza virus inactivation. Further testing with additional disinfectants, including calcium hydroxide, calcium oxide, sodium carbonate, and sodium hydroxide, is underway. Preliminary results for calcium oxide indicate that this disinfectant is effective for nonporous materials.

Question and Answer Period

- *At the beginning of the presentation, the possibility of adding disinfectant chemicals to depopulation foams was mentioned. Examining the results, however, the disinfectants provide incomplete decontamination. How would these results impact use of these materials as foam additives?* Simply approving foams as an acceptable depopulation technique has required over a year of discussions with various stakeholders. Foam has been conditionally approved for avian influenza and other situations calling for rapid, humane depopulation. After depopulation, however, a large biomass can remain (e.g., a broiler house may hold up to 50,000 birds each weighing 5–6 pounds). The foam and any additive should not impede composting of this biomass or cause any animal welfare concerns. Many issues must be considered. As an additive, the disinfectant would serve as only a first step in the restoration process. Complete decontamination is not anticipated.
- *What were the contact times?* Coupons with the applied disinfectant were agitated for 10 minutes.
- *For the wood coupons, if the virus is not detected on the positive controls, how was efficacy measured?* Alphin agreed that a nondetect for a positive control would render the data inconclusive. The neutralization index needed to be greater than 2.8 (with a positive control of at least 4.0 and no detectable virus on any test coupons) to conclude that the disinfectant was effective. A neutralization index below 2.8 was considered inconclusive.

Inactivation of Foot-and-Mouth Disease Virus on Various Contact Surfaces

Wayne Einfeld, Sandia National Laboratory

Virucides are important in disrupting disease transmission cycles, which can be incredibly costly. The 2001 UK foot-and-mouth disease outbreak had an estimated economic impact of $13 billion (US). A single virucide, however, will not adequately treat all viruses; differences in virus resistance exist. In addition, environmental factors, such as presence of organic matter, temperature, humidity, and ultraviolet light, influence virucide efficacy.

Einfeld presented a table illustrating various virus types and their level of resistance to inactivation. Among all microorganisms, the nonenveloped viruses (e.g., foot-and-mouth disease virus) are relatively easy to treat, whereas bacterial spore formers (e.g., anthrax) are the most difficult to inactivate.

Currently no U.S. standard methods exist to evaluate virucide efficacy against various organisms. Standardized testing methods are needed for product registration and comparison. Einfeld listed several domestic and international agencies (e.g., EPA, American Society for Testing and Materials, Association Française de Normalisation, DEFRA) that have produced testing guidelines. In addition, many researchers conduct tests with surrogate viruses because testing highly pathogenic viruses is limited to specific laboratories. For example, the foot-and-mouth disease virus can be handled only at the Plum Island Animal Disease Center.

Einfeld reviewed the EPA guideline for virucide testing. This guideline outlines disinfectant application parameters, virus recovery requirements, and test protocol components. To be deemed effective, disinfectants must achieve inactivation of the target virus at all dilutions or show at least a 3-log reduction below the cytotoxic level. Einfeld listed a number of test parameter variables to consider when designing a virucide test. In addition to assessing efficacy, virucide tests may also evaluate the mechanism of inactivation. Different disinfectants may target the lipid envelope, capsid protein, structural protein, or nucleic acid. Einfeld listed various disinfectants and their target virus component. A flow chart provided by Einfeld illustrated the experimental approach to virucide efficacy and mechanism of inactivation testing. Past testing typically used viruses in suspension; current test approaches use a carrier configuration and nucleic acid evaluations, which help assess a disinfectant's target virus component.

Researchers at Plum Island Animal Research Center are currently conducting studies with the foot-and-mouth disease virus, which is a nonenveloped, single-stranded ribonucleic acid (RNA) virus. This virus infects only cloven-hoofed animals (e.g., bovine, porcine, ovine), but is highly infectious. No surrogates are currently available, so research is restricted to the Plum Island facility. The study objectives are two-fold: optimize coupon carrier inoculation and recovery for common agricultural materials and evaluate various virucide efficacies for the foot-and-mouth disease virus. Researchers selected eight virucides for testing.

Einfeld detailed the experimental method developed and used for efficacy testing. Concrete, rubber, and stainless steel coupons were inoculated with foot-and-mouth disease virus propagated at the Plum Island Animal Research Center. After inoculation with 100 microliters (μl) of virus, the carriers were dried in a biosafety hood for 30 minutes. Coupons were

then treated with 500 µl of the test virucides. After 5, 10, or 20 minutes, researchers added 5 ml of DMEM containing 4% fetal calf serum to the carriers and vortexed the samples vigorously. Dilutions of this solution were then used to inoculate baby hamster kidney cells (BHK-21). The Reed-Muench method and reverse transcriptase-polymerase chain reaction (RT-PCR) were used to quantify results.

Einfeld presented results for the 5-, 10-, and 20-minute exposures for each virucide, as quantified by both methods. Each virucide, except ethanol, performed well. Inactivation increased with increasing contact times; at 20 minutes, nearly complete inactivation was achieved. RT-PCR results provided no clear correlation between inactivation and RNA destruction. Further evaluation is needed to better understand the mechanism of inactivation.

In summary, the porous material carriers (i.e., concrete, rubber) negatively impacted virucide efficacy. Ethanol, which has a neutral pH, was consistently the least effective treatment. Results were affected by difficulties in virus recovery. Overall, carrier tests showed worse, but adequate, virucide efficacy compared to previous suspension tests. Carrier tests, as opposed to suspension tests, better mimic real-world conditions. Ongoing studies are needed to further evaluate efficacies; refine test methodologies; field validate inactivation, if feasible; further assess mechanism of action; and develop rapid on-site confirmation tests for decontamination effectiveness.

Question and Answer Period

Workshop participants posed no questions.

Session 6: Radiological Agent Decontamination

Decontamination of Polonium in the United Kingdom (UK)

Robert Bettley-Smith, Government Decontamination Service, United Kingdom

GDS, which began operations in October 2005, addresses decontamination issues associated with contaminated land, buildings, open spaces, infrastructure, and transport aspects. Human decontamination issues are excluded. GDS primarily provides advice and guidance to responsible authorities, maintains and builds a framework of specialized suppliers, and advises the central government regarding national response capabilities.

GDS has responded to a variety of contamination events, such as the 2006 anthrax event in England and Scotland, motorway accidents, and a 2006 polonium incident in London. Bettley-Smith described the 2006 polonium incident to illustrate a GDS response and highlight lessons learned from this incident.

On November 24, 2006, GDS was informed that a substance, confirmed as polonium-210, had been associated with the death of an individual on the previous day. GDS rapidly deployed a case officer, alerted GDS suppliers, and began meeting with involved parties to assess the situation. Bettley-Smith noted that polonium is an alpha emitter. As such, the radioactive materials are easily contained by bagging and removal from an affected location. Detecting the short-lived alpha particles to identify the contaminated materials, however, is difficult. Alpha particles tend to adhere to materials and detection is accomplished with instrumentation and not wipe sampling.

The Westminster City Council agreed to act as the lead agency overseeing the decontamination process. By the end of the day on November 24, 2006, responders had identified five contaminated locations. Over time, a total of ten locations were identified for decontamination. Currently, decontamination is complete at nine of these ten locations. Decontamination at the last venue will commence when funding issues are resolved. These venues comprise a mixture of facilities: restaurants, hotels, and historic sites. Characterization surveys using a variety of sampling and analytical techniques occurred at each location prior to decontamination to determine the extent of contamination.

Not all contaminated items could be remediated. These materials were packaged and transported to an appropriate disposal facility. Examples of items removed from a hotel room include upholstered furniture, large desks, and high-activity wastes. Decontamination activities at this hotel encompassed a bar area, a men's rest room, and guest rooms. Activities spanned 19 days and involved a supervisor, three health physicist monitors, and two decommissioning operatives. Bettley-Smith noted that doubling the number of decommissioning operatives would not necessarily halve the time required to conduct decontamination. More operatives would require more decontamination personnel and movement coordination within small spaces.

Bettley-Smith provided a photograph of a bathroom in a guest room as an example of conditions before and after decontamination. No matter the technology tried, the decontamination crews could not remove the polonium from the bathtub itself. The entire bathtub was extremely bulky and difficult to remove. As such the decontamination team simply removed the bathtub's enamel coating with a hammer and disposed of the enamel. This situation illustrates the complexity of decontamination events and the need for creative thinking during a response.

Several lessons can be learned from this response. Communication is critical to success. The event was classified as a hazardous material situation, not a CBRN incident. As such, insurance and payment responsibility became an issue. Bettley-Smith provided some order of magnitude cost estimates that ranged up to £130,000 for remediation. Sampling and monitoring of alpha particles, especially on soft surfaces such as upholstered furniture, presented challenges. Waste management was also time consuming and complex.

GDS also became involved in the post mortem. No facilities existed that could contain the alpha particles during a post mortem. Therefore, GDS proposed retrofitting an existing biological facility. GDS located a teaching hospital with a facility enclosed by air curtains designed to contain biologicals. In addition to sealing the facility and covering

the equipment with plastic, the air curtains drew the alpha particles into the HVAC system, which was retrofitted to capture these particles. Monitoring was conducted before, during, and after the post mortem. After the post mortem, the plastic, HVAC filters, and other materials were collected and disposed of. This waste, which contained both clinical and radiological wastes, presented unique disposal challenges.

Question and Answer Period

- *How was the body disposed of?* Burying the body in a sealed coffin was sufficient to prevent further release. Appropriate measures were taken to prevent ongoing alpha particle releases during transport from the hospital to the burial location.
- *Can you provide an order of magnitude estimate of the amount of polonium released?* Polonium is a very mobile material; only a small amount was released.
- *What was the physical form of the polonium released?* Polonium is also a weak gamma emitter. Did sampling seek gamma particles? Were swipe samples collected? Bettley-Smith was unable to disclose the polonium form. Once the material was identified as polonium, detection methods focused on alpha particles; gamma particles were not detectable. No swipe samples were collected. Contaminated surfaces, however, were rubbed to determine whether the polonium was fixed or mobile. In most cases, the polonium was fixed.
- *Some reports indicate that airports were involved in this incident.* How was decontamination handled in airports? Bettley-Smith could only confirm that seat material from an aircraft was involved. This material was removed and disposed of. The aircraft fell beyond the Westminster City Council jurisdiction. Decontamination was addressed by agencies within the aircraft jurisdiction.
- *What was the cleanup standard?* The cleanup standard was based on public health concerns. Bettley-Smith could not release the specific value. Some of the affected facility owners decontaminated to levels below this standard. Materials hosting mobile forms of polonium were removed completely to prevent contaminant migration. Bettley-Smith noted that determining a safe cleanup standard involves consideration of many issues.

Decontamination of Terrorist-Dispersed Radionuclides from Surfaces in Urban Environments

Robert Fischer, Lawrence Livermore National Laboratory
Brian Viani, Lawrence Livermore National Laboratory

Decontamination of common urban area materials contaminated with radiological agents can be influenced by grime layers, agent migration into pores and fissures, local pH effects, competing materials, surface carbonation, humidity, surface interactions, and surface weathering effects. For radiological agents, the further the agent migrates into a surface, such as concrete, the harder decontamination becomes. Fischer and Viani described several studies undertaken to further the understanding of factors that affect urban environmental contamination and restoration following detonation of a "dirty bomb." Their studies have focused on concrete surfaces and cesium contamination, which represent a worst-case decontamination scenario because these materials are the most difficult to address during restoration.

To characterize surfaces in mass transportation system facilities, various concrete samples were collected from mass transit systems such as the Bay Area Rapid Transit system. Core samples from two locations illustrate the differences in the grime layer and surface conditions. LLNL studies have shown that the grime layer did not affect the chemical behavior of cesium (i.e., the grime did not adsorb the cesium). Other radiological agents also had minimal interaction with this grime. The grime itself contains significant amounts of metals that could affect the efficacy of chelator technologies. Chelator technologies offer advantages over other decontamination technologies for radiological agents. Chelators can be applied to a variety of surfaces, offer minimal wastes, are rapidly deployed, and minimally impact the environment. Chelator technology tests, therefore, focus on identifying agent-specific materials that minimally interact with grime layers.

Fischer and Viani conducted a series of detonation experiments to simulate a realistic urban contamination situation. In one test, Fischer and Viani constructed and detonated a radiological dispersal device (RDD) indoors. Multiple concrete samples (e.g., wet, dry, clean, grime-covered) were placed within the detonation range to assess contamination levels. These coupons will be used later in decontamination studies. Fischer provided detailed study methodology and results. The results provided information about particle size morphology, particle density distribution, and particle penetration depth.

An outdoor detonation study followed the indoor test. This study sought to characterize near (<15 meter) and far (150–250 meter) field contamination after detonation. Again, Fischer and Viani constructed and detonated an RDD. The first detonation was suspended above ground; the second was entrained in soil. Fischer presented details and photographs illustrating the study methodology. The methodology and parameters used for the outdoor detonation built upon information gained from the indoor test. Study data regarding penetration are still undergoing analysis. Initial results, however, are similar to results from the indoor study. The depth of particle penetration appears to be a function of time and environmental conditions. The outdoor testing results will help researchers develop bench-scale methods to simulate cesium deposition.

Viani discussed some results related to particle penetration. Many surfaces in a transportation system are composed of porous materials, and penetration into these materials is a critical concern. Viani provided a schematic to illustrate the various factors that affect penetration (e.g., porosity, saturation, diffusion). Understanding the differences in

penetration for pristine coupons versus coupons produced from real-world cores may allow for penetration prediction, based on laboratory data, during an event.

Analysis of concrete coupons contaminated during the indoor detonation tests found cesium penetration varying from 0.5 to 2.5 centimeters after 28 days. These coupons were nominally dry; no data for saturated coupons are available. A literature search identified a study resulting in a similar level of penetration for saturated Portland cement. Viani presented the approach for additional laboratory testing of cesium penetration. These tests will consider the impact of water on penetration.

Viani also presented cesium deposition results from the outdoor detonation tests. All outdoor sample coupons were placed horizontally to measure deposition on horizontal surfaces. Samples collected after the second shot (soil detonation) contained higher off-plume background cesium concentrations but lower peak cesium concentrations than the air detonation. Viani speculated that the higher background concentrations resulted from resuspension of materials released during the first detonation test. Scanning electron microscopic analysis of the morphology and composition of the deposited materials showed that most were not cesium. Viani presented a series of photographs and graphs related to the cesium concentration of deposited materials. Preliminary data indicate a strong decrease in concentration with distance.

In summary, penetration of cesium in real-world materials significantly differs from standard laboratory coupons. Cesium penetration on dry materials can be significant and depends on contact time (e.g., days for millimeter penetrations, weeks for centimeter penetrations). Applicability of results is limited by the use of a stable cesium (Cs-133) in these studies. Fischer and Viani hope to employ cesium-137 in future testing. Additional testing will include continued analysis of the outdoor detonation results, laboratory bench-scale deposition and penetration studies, and chelator evaluations.

Question and Answer Period

The question and answer period was waived due to time constraints.

An Empirical Assessment of Post-Incident Radiological Decontamination Techniques

Andrew Parkinson, Australian Nuclear Science & Technology Organization

The Australian Nuclear Science & Technology Organisation (ANSTO) is Australia's national nuclear research and development organization and the nation's nuclear expertise center. ANSTO scientists collaborate with the forensic and counter-terrorism community to conduct strategic research on radiological and nuclear forensics and nuclear security issues. In addition to conducting research, ANSTO also provides advice, training, and operations support for all aspects related to radiological agent release events.

Parkinson's research efforts at ANSTO focus on two main project areas: effects of radiation exposure on critical forensic evidence and assessments of post-incident radiological decontamination techniques.

Decontamination and restoration strategies must remove radioactive contamination or reduce exposures to acceptable levels. Strategies can include denying access to a contaminated area, demolition and rebuilding of affected areas, or removal of the radiological agent. Low-impact and nondestructive decontamination methodologies are favored to minimize the social and economic impact of an event. Method efficacy, however, must be established.

Parkinson described a project to assess the effectiveness of commercially available, low-impact decontamination technologies for a variety of common building materials. Results from this project will assist organizations preparing response guidelines and enhance Australia's counter-terrorism capabilities. Currently accepted decontamination methods (e.g., natural decay, demolition) are not suitable in the event of a large area or urban event. This project seeks to fill the technology gap for addressing widespread urban releases.

Parkinson presented the study methodology. Coupons of five common building materials—concrete, sandstone paving, painted steel, mild steel, and road base asphalt—were contaminated with three radioisotopes. These isotopes—cesium-137, americium-241, and strontium-90—represent the range of commercially available isotopes that pose the greatest security risk. Contamination readings were collected after isotope application and after decontaminant agent application.

Ten decontamination products were tested, including six strippable coatings and four wet chemical products (e.g., surfactants and/or chelating agents). The strippable coatings consist of polymeric materials that capture the radiological agent and are then peeled from the surface after curing. For this test, researchers applied the strippable coating, allowed curing for 24 hours, and then removed the coating. The chemical-based products were applied to a contaminated surface, scrubbed, and removed with a wet vacuum or high-pressure cleaner. Parkinson listed the specific decontamination agents tested. Water served as a control for the liquid chemical decontamination technologies.

Parkinson provided detailed results for each of the test materials and decontamination products. Overall, the liquid chemical technology approach provided better decontamination than the strippable coatings and water alone. One of the chemicals, however, left a dark pink residue that would be unacceptable during an actual decontamination and restoration event. Wet vacuuming is recommended for removing liquids from hard, porous surfaces (e.g., paving, asphalt) and high-pressure washing is recommended for soft, porous materials (e.g., concrete). The liquid chemical decontamination technologies, however, generate a large volume of wastewater that could spread contamination. The porous materials were harder to decontaminate than the nonporous materials. The strippable coatings were particularly ineffective on the porous materials. Strippable coatings would best be used to decontaminate small areas

that are highly contaminated, where wastewater from the liquid chemical technologies would potentially spread the contamination. Application of the coatings would also fix the contamination in place while decision makers evaluated additional decontamination options.

Future research will expand efficacy testing to additional decontamination products and technologies, including dry ice blasting, high-pressure steam, gels and foams, and other novel technologies. ANSTO will also examine decontamination effects on forensic trace evidence, such as fibers, hairs, glass, fingerprints, and deoxyribonucleic acid (DNA). This future work will investigate whether decontamination methods are successful at removing radiological contamination without affecting the quality of the evidence and the forensic interpretation. Currently, Australia does not have a laboratory dedicated to radiological forensics.

Question and Answer Period

- *Many researchers are discussing chelation as a decontamination option.* In the U.S., no means of disposing of the mixed waste exists. How does Australia handle mixed wastes? Parkinson was unaware of regulatory limitations to disposing of mixed wastes in Australia. The waste management group at ANSTO handles these concerns.
- *How easy were the different isotopes to remove?* Yellowcake was the easiest to decontaminate, followed by cesium and strontium. Yellowcake was applied as a solid suspension and was very easy to remove once it had dried, whereas the cesium and strontium were applied as solutions, which enabled them to penetrate deeper into the surface.
- *Why was strontium the most difficult to remove?* The reason that strontium was the most difficult to remove is unclear and under investigation. Strontium may react with the material surface or penetrate deeper than the other radioisotopes.

Cesium Chloride Particle Characteristics from Radiological Dispersal Device (RDD) Outdoor Test

Sang Don Lee, U.S. Environmental Protection Agency, National Homeland Security Research Center

Lee presented data from his research with cesium chloride, the most common radioactive material used in medical facilities. Cesium chloride is a salt that transfers to an aqueous state above a relative humidity of 68%. In the aqueous phase, cesium chloride particles will easily migrate through channels in porous urban materials. The transition to the aqueous phase occurs in microseconds when relative humidity changes. Lee provided photographs of cesium chloride particles in different states at different relative humidities.

The specific objectives of the research that Lee discussed were to characterize the physicochemical properties of cesium chloride particles generated during an outdoor detonation and to estimate the cesium chloride deposition and penetration on limestone. In conjunction with LLNL, two outdoor detonations were conducted. Particle concentrations were measured on limestone coupons placed in the near field and via three polycarbonate air filter samplers and Sidepaks™ (real-time particle monitors that provide readings for PM2.5, PM10, and unfiltered particles) located far field—approximately 150 meters from the detonation site. Lee also evaluated the particle composition and size. For the first test, the RDD detonation occurred one meter above the ground surface. For the second test, the RDD was entrained in soil.

Lee presented particle concentration and size distribution data, and electron microscope photographs of particles captured from one far-field monitor. Lee noted that the black dots on the photographs are the 0.4-μm pores in the filter paper. Based on photographic analysis, most particles were less than 10 μm.

Lee presented particle size data for the second test as well. Although the far-field monitors captured very few cesium chloride particles, these results do not necessarily indicate a lack of a plume. They may be due to the monitors being positioned incorrectly to capture the plume. For the particles that were captured during the second test, they were generally larger (7–6 μm) than the particles formed from the first detonation. Particles also agglomerated with multiple components (e.g., carbon, silica).

Analysis of the limestone coupons placed in the near field is ongoing. Lee presented details regarding this component of the research. Both weathered and nonweathered limestone coupons were used. The coupons received post-conditioning at two different relative humidities before analysis. Laser ablation inductively coupled plasma/mass spectrometry and laser-induced breakdown spectroscopy (LIBS) will be used to determine the extent of cesium penetration into the limestone.

Overall, experimental results indicate that most cesium particles were below 10 μm. When detonated above ground, the cesium chloride particles were transported in a combined form with carbonaceous materials, whereas detonation in soil resulted in agglomeration with soil particles as well as carbonaceous materials. Materials surrounding the RDD at the time of detonation may affect particle characteristics and plume behavior. Ongoing research includes further analysis of the limestone coupons, and additional laboratory parametric investigations of cesium penetration into other building materials, as a function of environmental conditions.

Question and Answer Period

- *Have results been compared to RDD dispersion models?* Results have not been compared to existing dispersion models. Soil entrainment creates larger particles and more rapid fallout, which leads to a smaller impact area.

Radiological Dispersal Device (RDD) Rapid Decontamination

John Drake, U.S. Environmental Protection Agency, National Homeland Security Research Center

Drake discussed a project to evaluate rapid decontamination technologies after an RDD event. The goal is to evaluate the performance of currently available commercial products that could be used rapidly (quickly deployable and fast acting) for building and outdoor area decontamination. Based on the evaluation results, a technology selection guidance document for planners and operations personnel will be developed. The project also seeks to identify promising technologies for future development. A full-scale demonstration of effective technologies is planned within three to five years.

An RDD event is the deliberate dispersal of radiological material to cause harm. The current thinking is that the most likely RDD would consist of a conventional explosive containing radiological material; however, releases from crop sprayers or tanker trucks are also possible.

An RDD can be considered a weapon of mass disruption. Economic disruption is the dominant RDD event outcome. Acute health effects would be minimal; possible chronic health effects are the primary health concern. Rapid decontamination technology deployment is essential to address public concerns and pressures for restoration after an event. Drake noted that much could be learned from the UK experience with polonium contamination in multiple urban locations.

EPA would be the lead agency for restoration in the event of a nuclear or radiological incident. NHSRC provides scientific expertise and technical support to clean up operations, performed under the direction of OSCs and the NDT. NHSRC also provides expertise and guidance to other domestic and international agencies.

The RDD rapid decontamination project focuses on contaminated buildings, outdoor areas, and equipment. A number of challenges influence responses to RDD events, such as the pressure for re-occupancy, economic and political concerns, waste disposition, and available workforce. Drake listed the criteria used to prioritize decontamination technology selection for evaluation. The highest priority is placed on technologies that preserve building exteriors, treat large areas, and minimize cost. Prioritization also considers the volume of wastewater generated, effluent capture requirements, supporting infrastructure needs, and future land use. In general, the technology should minimize surface damage, cost, secondary waste, recontamination, personnel training, and deployment time. The technology should maximize speed, decontamination efficacy, availability, and applicability to the contaminant, affected substrate, and weather conditions.

The test approach consists of depositing cesium chloride on 2-foot by 5-foot concrete coupons, measuring contaminant levels, conducting decontamination, and measuring residual contamination. Cesium chloride and concrete were selected for testing because these materials are prevalent in urban environments and are among the most difficult to decontaminate. Sets of contaminated coupons will be held in controlled humidity and temperature conditions for both 14 and 28 days, and then tests will begin to evaluate both chemical and mechanical decontamination technologies. Contaminant measurements will be used to calculate a decontamination factor. Decontamination speed will also be measured. The project will use large coupons to mimic real-world situations as closely as possible. Using large coupons will enable evaluation of operational parameters (e.g., infrastructure needs, personnel training) and other factors (e.g., deployed costs, availability). Legacy decommissioning projects, which typically consisted of building demolition, provide most of the current knowledge regarding large-scale decontamination.

This project, which began six months ago, is being conducted under TTEP. The QAPP is complete and Idaho National Laboratory (INL) has been identified as the test facility. Tests at INL facilities will allow use of actual radioactive materials, instead of nonradioactive surrogates. A short list of proposed decontamination technologies has also been generated, from which two will be selected for testing and evaluation. Drake encouraged workshop participants to contact him with ideas for decontamination technologies to test, test parameters, or other information that would further support this project. He hopes to obtain initial results by December 2007.

Question and Answer Period

- *How will you deposit the cesium chloride on the coupons?* A deposition methodology has not been selected. The selected methodology must be easily verifiable and repeatable. Both dry and wet methods have been discussed. Wet deposition is repeatable, but will affect strippable coating efficacy.

Session 7: Research and Development for Decontamination-Related and Support Activities

Water Infrastructure Protection Division (WIPD) Decontamination Research Overview

Kim Fox, U.S. Environmental Protection Agency, National Homeland Security Research Center

Fox oversees NHSRC's Water Infrastructure Protection Division (WIPD). This group's primary research focus is on detection and decontamination methods to be used following a threat agent attack on drinking water sources and systems. To a lesser degree, this group also researches technical issues related to wastewater collection, treatment, and disposal procedures.

Several EPA offices collaborated to publish the Water Security Research and Technical Support Action Plan. This document outlines research needs and projects regarding water safety and security. Both drinking water and wastewater infrastructure concerns are included. The document serves as an action plan or guide to direct research regarding incident response, system decontamination, and water supply restoration. Fox noted that water supply system decontamination includes water treatment as

well as decontamination of the system infrastructure. Decontamination efforts must also consider public perception and political pressures surrounding drinking water safety. Fox listed some of the key collaborators involved in developing the action plan.

In some cases, pipe abandonment in place may be the best response to a contaminated distribution system situation. Ongoing and future research, however, strives for removal of the contaminant. Fox listed several water system research projects.

Within water systems, contaminants may be dissolved or suspended in the water, or adhere to the pipe walls. Health and economic impacts can vary widely depending on the release location, and those impacts may occur miles from the release location. Models are available to assess agent fate and transport.

Fox described the intentional release of chlordane into a water supply system to illustrate a response effort. Decontamination consisted of flushing the system and using surfactants to remove the chlordane. In some areas, affected pipes in the distribution system and in homes had to be replaced. The restoration process lasted more than nine months. As another example, in response to a mercury release, another water supplier quickly decided to remove and replace the impacted pipes.

Decontamination is affected by agent adherence to pipe walls, attachment to biofilms, reaction with pipe walls or corrosion products, and permeation through pipe walls. Different agents, such as petroleum products, CWAs, and pesticides, each react uniquely to affect decontamination techniques. Interactions between an agent and the pipe wall may prolong a release event. Surface roughness and corrosion may slow transport of the contaminating agent and diminish decontamination effectiveness. Biofilms may attract biological agents and result in continued agent releases. Additional information is needed to fully understand these interactions.

Fox listed several available decontamination methods. Typically, the first step in decontamination involves scouring the system with a high volume of water. Responders may then add detergents, which must also be removed from the system before service restoration. Fox briefly described several decontamination research projects currently underway.

- *Pipe loop studies.* EPA designed and built a pilot-scale water distribution system using clear pipes to allow evaluation of deposition and collection. The system includes ports to allow insertion of pipe coupons generated from actual water distribution system pipes. To date, WIPD has evaluated decontamination methods for B. subtilis, arsenic, and mercury. Historically, biological decontamination consisted of flushing followed by shock chlorination. Oxidation and scouring with bubbles from ozone are future decontamination research areas.
- *ECBC enzyme project.* WIPD is working with ECBC on bench- and pilot-scale research to investigate a catalytic enzyme-based product for treating water and water systems contaminated with nerve agents or pesticides. Fox provided photographs of the system and some initial bench-scale tests.
- *National Institute of Standards & Technology (NIST) project.* WIPD is partnering with NIST to conducts experiments to study the accumulation of agents and decontamination of building plumbing systems and appliances.
- *Radiological issues.* RDD events involving radionuclides such as cesium or strontium can have a huge impact on water supplies if the release is followed by rain or if restoration generates contaminated wastewater. Both rain water and wastewater will enter the wastewater system and impact this system even if the release did not directly target the wastewater system.

Question and Answer Period

- *The challenges faced by water suppliers are daunting.* Has EPA conducted exercises or communicated with other agencies and groups focused on biological or radiological release events? EPA has conducted exercises and communicated with other researchers to discuss how various release and restoration scenarios would impact water supplies.
- *After the 2001 anthrax incidents, did EPA consider the effects to the water supply from the event itself or from disposal of wastewater from the restoration?* EPA has considered the impacts of introducing anthrax to the wastewater system as a result of decontamination efforts. For naturally occurring anthrax, water suppliers can treat the spores as a biological contaminant and disinfect the system accordingly.
- *Is EPA concerned about the disposal of flushed water?* EPA is concerned about treatment of wastewater generated when flushing a system. In some instances, flushing dilutes the contaminant below health-based standards. Dilution, however, is not a universal solution. Consequence management is a substantial consideration for decontamination.

Incineration of Materials Contaminated with Bio-Warfare Agents

Paul Lemieux, U.S. Environmental Protection Agency, National Homeland Security Research Center

NHSRC's research and development program for disposal of potentially threat agent-contaminated materials focuses mostly on the effectiveness and environmental impacts of landfill options and thermal destruction technologies. Lemieux's presentation focused on thermal destruction research efforts.

Incinerator operators, who are often in the private-sector, have many concerns when accepting threat agent-

contaminated waste at their facilities. They must prevent contaminant migration, comply with existing permits, and manage residues. Operators are resistant to risk harming normal operations by accepting waste from a high-impact, infrequent event, even in the case of national security. If accepting a waste, operators have size constraints on the materials they process, which impacts potential size reduction efforts needed at the contaminated site.

Several types of incinerators exist, but not all may be applicable for every agent or have been used for destruction of a particular type of threat agent in the past. Therefore, thermal treatment may be technically feasible, but untested, for some types of incinerators and agents. Similarly, no guarantee exists that any given incinerator will achieve successful destruction of the agent. Operational variables can dramatically impact a given facility's ability to effectively destroy residual agents in the waste feed. Lemieux described an EPA study conducted in the early 1990s to assess the effectiveness of medical waste incinerators in destroying *G. stearothermophilus* spores (surrogate for pathogenic bacteria) doped on the waste. A few of the tested incinerators contained viable spores in the remaining ash and in the stack emissions.

NHSRC's approach to evaluating incineration as a disposal option includes conducting bench- and pilot-scale studies, as well as modeling efforts. Bench-scale studies employ small building material coupons containing *B. subtilis* and *G. stearothermophilus* to develop thermal destruction kinetic data.

For pilot-scale testing, NHSRC uses its rotary kiln incinerator located in Research Triangle Park, NC. This incinerator has a primary and a secondary combustion chamber. Building material bundles embedded with BIs enclosed in small pipes are fed into the kiln. After exposure to various times and incinerator temperatures, the BIs are then cultured to assess spore viability. Lemieux provided results from trials with carpet and ceiling tile bundles. In one test with wet ceiling tile, spores remained viable after 35 minutes in the incinerator. In general, complete spore inactivation occurs if the internal bundle temperature reaches approximately 400 degrees Celsius (°C).

Lemieux input data generated from the pilot-scale testing into a computational fluid dynamics model, which also uses chemical reaction kinetics, and mass and heat transfer calculations, to compare predicted versus measured results. For EPA's pilot-scale incinerator, the model under-predicted the drying time needed for the wet ceiling tile bundle, but overall, model predictions of bacterial spore inactivation agreed with measured results within an acceptable range. Once calibration of the model of the pilot-scale kiln is performed, the model can be run to predict behavior of similar materials in three types of full-scale commercial incinerators. Improvements to the model are being made.

Lemieux also briefly discussed the EPA disposal decision support tool, which is a Web-based tool designed to assist decision makers, planners, and responders. The tool includes a series of input threat scenarios and estimates potential waste volumes. The tool also lists contact and facility information for disposal facilities, including landfills, incinerators, wastewater treatment plants, and other facilities. Information regarding worker safety, waste packaging and storage, and waste transportation is also included. Modules exist for agricultural biomass disposal, water systems materials, and natural disaster debris. EPA is also developing a radiological debris module. Users must request access to the tool; Lemieux provided the information necessary to do so.

To conclude, Lemieux discussed a number of nontechnical issues and proposed solutions surrounding disposal of wastes from restoration efforts following a threat agent attack. One example is the reluctance of facilities to accept such waste due to the stigma associated with the threat agents. Lemieux recommended ongoing communication with facilities and communities to address their concerns about worker safety, business liabilities, and health concerns. Lemieux also discussed data and technology gaps, such as methods needed to confirm incinerator performance (i.e., agent destruction efficacy); methods to measure spores in stack gases and ash; guidance to best package materials at a site for optimized incinerator performance; information identifying the most appropriate facility for different waste materials; and disposal options for RDD waste.

Question and Answer Period

- *Is EPA considering plasma technologies for carcass decontamination?* EPA has explored plasma technologies. DOE and DoD have used plasma destruction on a small scale. Large-scale testing and application has not been conducted and is a possible area for future research.

Detection to Support Decontamination

Emily Snyder, U.S. Environmental Protection Agency, National Homeland Security Research Center

Snyder provided an update on several detection-related research projects. The detection technologies she discussed are primarily being used in support of decontamination research conducted by DCMD and elsewhere.

- *Laser Induced Breakdown Spectroscopy (LIBS).* The LIBS device uses a pulsed laser that passes through a lens to form a plasma on a sample surface. As the plasma forms and degrades, it emits a unique light spectra with characteristics specific to the sample material. LIBS may be used in the laboratory, and a backpack configuration of LIBS has also been developed for field use.

  Current research and development with LIBS focuses on determining detection limits with pure samples of *B. atrophaeus* (a surrogate for *B. anthracis*) and samples mixed with interference materials (i.e., mysterious white powders). Similar tests have also been done with ovalbumin, a surrogate material for ricin. Using LIBS, Snyder tested each sample to obtain its spectra, which can then be analyzed using either multiple least square

regression or neural network methodologies to predict sample concentrations. Both methods could be used to construct concentration plots (noted as log of CFU for *B. atrophaeus* spores). Snyder discussed more details about using the neural network software to construct sample identity classifications. The method uses a series of nonlinear equations to predict output variables from input variables. To train the model, information for half of the known spectra was included in the classification model, which used numerical designations for various contaminants. After training the model, Snyder tested it to quantify the rate at which false negatives and false positive readings occur. The rate of false negatives dropped as the agent concentration increased. False positives varied based on the interfering materials (e.g., humic acid, house dust) and the spectrum identification range. In testing mixtures, the number of false positives also increased with decreasing agent concentrations and increasing interference concentrations. Humic acid mixtures caused the highest false positive rate when mixed with *B. atrophaeus*.

Snyder also used soft independent modeling of class analogies to interpret LIBS results and identify sample components. More false negatives and false positives were reported using this model versus the neural network model.

Ongoing research with LIBS includes working to mitigate the interfering effects of the surface material (e.g., laminate, cement) on which the white power is found, increasing the available spectral library of potentially confounding materials, and developing a femtosecond LIBS system. In 2008, NHSRC hopes to establish an agreement with a commercial facility to develop a portable LIBS system for first responders.

- *Single-Photon Ionization/Time-of-Flight Mass Spectrometry (SPI).* This technology works by using a laser to ionize matter and time-of-flight mass spectrometry to analyze the ions. This method has been used by Snyder to detect fumigants and fumigant by-products. Snyder provided an example mass spectrum from a chlorine dioxide test and presented data comparing results with another chlorine dioxide measurement technique. Based on the data gathered, SPI reached a detection limit of 0.3 ppm for chlorine dioxide. Snyder thought that through future research a lower detection limit could be achieved.
- *Dual-Source Triple-Quadrupole Mass Spectrometry.* Snyder provided a schematic of this device's principle of operation and presented data for chlorine and chlorine dioxide. This method detects other fumigants and fumigant by-products, and future research may expand its application to TICs. Testing identified detection limits of 14.5 parts per trillion by volume (pptv) and 11.7 pptv for chlorine gas and chlorine dioxide, respectively. Using this instrument to analyze the purity of the chlorine dioxide gas produced from the ClorDiSys generator, it was determined that less than 0.017% of the chlorine dioxide was chlorine gas, which equals approximately 9 pptv or less (i.e., nondetect levels). No other chlorine compounds were detected in the generator gas.

Snyder also briefly presented data from ongoing efforts to determine cesium penetration into building materials using LIBS and efforts to develop a rapid viability PCR detection method for the detection of F. tularensis and Y. pestis (viable and nonviable) on building materials.

Question and Answer Period

- *For chlorine dioxide and chlorine gas generation, did the tests consider both Sabre and ClorDiSys generation technologies?* Tests were specific to the ClorDiSys system.
- *Is there information about vegetative cell survival on building materials?* Research regarding survival is ongoing.

EPA Responder Decontamination Needs

Leroy Mickelsen, U.S. Environmental Protection Agency, National Decontamination Team

Throughout the workshop, speakers discussed numerous detection, containment, decontamination, and disposal issues. Much research has occurred, is ongoing, or is planned. All this information feeds into the actions and decisions of OSCs and other responders. Mickelsen emphasized that responders are the ultimate end-users of the decontamination information being developed, and they need this information presented in user-friendly and up-to-date formats. Few manuals or hands-on materials exist. Mickelsen outlined specific areas of interest and data needs.

- *Personal protective equipment (PPE).* Responders need specific guidance regarding the types of PPE effective for specific threat agents and decontaminants. Guides also need to recommend which decontaminants should be used for different types of PPE. Guidance on whether responders can safely reuse some PPE is needed. When conducting decontamination, guidance is needed to reduce the spread of both the threat agent and the decontaminant.
- *Sampling and characterization.* Faster, cheaper, and better detectors and methods are needed. Responders need to understand how to sample in complex environments and how to validate their sampling programs. Research should develop methods to reduce the sample numbers required for characterization, validation, and clearance. Regulators should develop standard operating procedures (SOPs) for sample packaging and shipping to ensure sample integrity.
- *Decontamination methods.* Similar to sampling, faster, cheaper, and better decontamination methods are needed. Responders need information about technology efficacy for various matrices and agents. Research should evaluate in-place decontamination methods that would minimize waste disposal needs. SOPs are needed to outline parameters for specific decontamination

technologies to ensure efficacy and to handle high-value item decontamination.

- *Clearance guidelines.* Responders need guidelines that address cleanup needs and standards for specific agents, locations, and reuse activities. SOPs should outline clearances processes and documentation requirements.
- *Disposal guidelines.* Responders also need information about disposal options, including incineration, for specific threat agents, matrices, and decontamination wastes. SOPs should address waste transportation needs.

Responders may not have the products and guidelines necessary to inform decision making for several reasons. Responders may be unaware of available materials. Research may be complete, but the findings or resulting products are not available. Research may be ongoing or planned. Researchers may also be unaware of a responder need. Mickelsen noted that this workshop provides an excellent opportunity for information sharing between researchers and responders.

Regardless of research status, a need for guidance based on the best available data still exists. This guidance should be simple and direct and include the most current information possible, as well as outline data gaps. Collaboration and coordination between researchers, responders, and other stakeholders in decontamination efforts are required to produce such a guidance document. A guidance document would ensure that responders have the best and most current information available and that researchers have tangible evidence of the impact of their efforts. By identifying data gaps, the guidance document can direct, and possibly prioritize, data needs. Responders may identify incomplete information that is still sufficient to support decisions, allowing researchers to focus on addressing new data gaps rather than continuing to refine existing data.

In conclusion, Mickelsen noted that substantial research data are available for responders; however, these data need to be translated to field use. Through coordination, cooperation, and communication, decontamination stakeholders are capable of producing products, based on this vast research, that impact decontamination, reduce restoration costs, and create effective responses.

Question and Answer Period

- *Involving OSCs in research proposals will help ground projects.* Mickelsen agreed that communicating directly with OSCs will help researchers identify response needs. OSCs, however, should also contact researchers to provide feedback from actual responses. Communication must flow in both directions.

United States
Environmental Protection Agency
Decontamination and Consequence Management Division

2007 Workshop on Decontamination, Cleanup, and Associated Issues for Sites Contaminated with Chemical, Biological, or Radiological Materials

Sheraton Imperial Hotel
Research Triangle Park, North Carolina
June 20–22, 2007

Agenda

WEDNESDAY, JUNE 20, 2007

8:00 am **Registration/Check-in**

8:30 am **Welcome - Opening Remarks**
Lek Kadeli (Deputy AA, Office of Research and Development, US EPA)
Nancy Adams (Director, US EPA/NHSRC/DCMD)
Blair Martin (Deputy Director, APPCD)

Session 1: Some U.S. Perspectives
Session chair: Blair Martin, USEPA

9:00 am **Overview of Select U.S. Department of Homeland Security (DHS) Science and Technology Programs**
Lance Brooks (DHS)

9:30 am **Evidence Awareness for Remediation Personnel at Weapon of Mass Destruction (WMD) Crime Scenes**
Jarrod Wagner (FBI)

10:15 am **Technical Support Working Group (TSWG) Decontamination Research & Development Activities**
John McKinney (TSWG)

10:45 am **Regulating Bio-Decontamination Chemicals** *Jeff Kempter (US EPA/OPP)*

11:15 am **Environmental Sampling for Biothreat Agents: Current Research and Validation Efforts**
Kenneth Martinez (CDC/NIOSH)

Session 2: International Perspectives

Session chair: Lindsey Hillesheim, US Department of State

1:00 pm **G8 Bio-Terrorism Experts Group (BTEX)** *Lindsey Hillesheim (US Department of State)*

1:30 pm **Biological Decontamination with Peracetic Acid and Hydrogen Peroxide**
Bärbel Niederwöhrmeier (Armed Forces Scientific Institute for Protection Technologies, Germany)

2:00 pm **Field Demonstration of Advanced Chemical, Biological, Radiological, and Nuclear (CBRN) Decontamination Technologies**
Konstantin Volchek (Environment Canada)

2:30 pm **Japanese Research Project for Development of On-site Detection of Chemical and Biological Warfare Agents** *Yasuo Seto (National Research Institute of Police Science, Japan)*

3:15 pm **A Fatal Case of "Natural" Inhalational Anthrax in Scotland–Decontamination Issues**
Colin Ramsay (Health Protection Scotland)

3:45 pm **Case Study of Fatality Due to Anthrax Infection in the United Kingdom (UK)**
Graham Lloyd/Robert Spencer (Health Protection Agency, UK)

THURSDAY, JUNE 21, 2007

Session 3: Biological Threat Agent Decontamination Research and Development

Session chair: Nancy Adams, US EPA

8:00 am **National Homeland Security Research Center's (NHSRC) Systematic Decontamination Studies**
Shawn Ryan (US EPA/NHSRC/DCMD)

8:30 am **Improvement and Validation of Lab-Scale Test Methods for Sporicidal Decontamination Agents**
Steve Tomasino (US EPA/OPP)

9:00 am **Full-scale Experience in Decontaminations Using Chlorine Dioxide Gas**
John Mason (Sabre Technical Services)

9:30 am **Systematic Decontamination–Challenges and Successes** *Vipin Rastogi (ECBC)*

10:15 am **New York City Anthrax Response** *Neil Norrell (US EPA/R.2)*

10:45 am **Update on EPA Decontamination Technologies Research Laboratory (DTRL) Activities**
Shawn Ryan (US EPA/NHSRC/DCMD)

11:15 am **Localizing and Controlling Biothreat Agent (BTA) Transport with Polymer Sprays** *Paula Krauter (LLNL)*

11:45 am **Can We Expedite Decontamination?** *Blair Martin (US EPA/APPCD)*

Session 4: Chemical Threat Agent Decontamination R&D

Session Chair: Shawn Ryan, US EPA

1:15 pm **Airport Restoration Following a Chemical Warfare Agent (CWA) Attack** *Bob Knowlton (SNL)*

1:45 pm **Quantitative Structure Toxicity Relationships (QSTR) to Support Estimation of Cleanup Goals** *Chandrika Moudgal (US EPA/NHSRC)*

2:15 pm **Determining Chemical Warfare Agent (CWA) Environmental Fate to Optimize Remediation for Indoor Facilities** *Adam Love (LLNL)*

2:45 pm **Chemical & Biological Defense Program Physical Science & Technology Program Overview–Hazard Mitigation** *Mark T. Mueller (US Defense Threat Reduction Agency)*

Session 5: Biological and Foreign Animal Disease Agent Decontaminaiton

Session Chair: Shawn Ryan, US EPA

3:30 pm **(1) Results from the Evaluation of Spray-Applied Sporicidal Decontamination Technologies (2) Test Plans and Preliminary Results for Highly Pathogenic Avian Influenza Virus Persistence and Decontamination Tests** *Joseph Wood (US EPA/NHSRC/DCMD)*

4:00 pm **Inactivation of Avian Influenza Virus Using Common Soaps/Detergents, Chemicals, and Disinfectants** *Robert Alphin (University of Delaware)*

4:30 pm **Inactivation of Foot-and-Mouth Disease Virus on Various Contact Surfaces** *Wayne Einfeld (SNL)*

FRIDAY, JUNE 22, 2007

Session 6: Radiological Agent Decontamination

Session Chair: John MacKinney, US EPA

8:00 am **Decontamination of Polonium in the United Kingdom (UK)** *Robert Bettley-Smith (UK GDS)*

8:30 am **Decontamination of Terrorist-Dispersed Radionuclides from Surfaces in Urban Environments** *Robert Fischer/Brian Viani (LLNL)*

9:00 am **An Empirical Assessment of Post-Incident Radiological Decontamination Techniques** *Andrew Parkinson (Australian Nuclear Science & Technology Organization)*

9:30 am **Cesium Chloride Particle Characteristics from Radiological Dispersal Device (RDD) Outdoor Test** *Sang Don Lee (US EPA/NHSRC/DCMD)*

10:00 am **Radiological Dispersal Device (RDD) Rapid Decontamination** *John Drake (US EPA/NHSRC/DCMD)*

Session 7: Research and Development for Decontamination – Related and Support Activities

Session Chair: Joseph Wood, US EPA

10:45 am	**Water Infrastructure Protection Division (WIPD) Decontamination Research Overview**	*Kim Fox (US EPA/NHSRC/WIPD)*
11:15 am	**Incineration of Materials Contaminated with Bio-Warfare Agents**	*Paul Lemieux (US EPA/NHSRC/DCMD)*
1:00 pm	**Detection to Support Decontamination**	*Emily Snyder (US EPA/NHSRC)*
1:30 pm	**US EPA Responder Decontamination Needs**	*Leroy Mickelsen (US EPA/NDT)*
2:00 pm	**Closing Comments**	*Blair Martin (USEPA, APPCD)/Nancy Adams (US EPA/NHSRC/DCMD)*

Notes:
All speakers given 25 minutes for talk, plus 5 minutes for questions, unless noted.

Acronyms:

APPCD	Air Pollution Prevention and Control Division
BTA	Biothreat agent
BTEX	Bioterrorism Experts Group
CBRN	Chemical, biological, radiological, and nuclear
CDC	Centers for Disease Control and Prevention
CWA	Chemical warfare agent
DCMD	Decontamination and Consequence Management Division
DHS	U.S. Department of Homeland Security
DTRL	Decontamination Technologies Research Laboratory
ECBC	Edgewood Chemical and Biological Center
FBI	Federal Bureau of Investigation
GDS	Government Decontamination Service
LLNL	Lawrence Livermore National Laboratory
NDT	National Decontamination Team
NHSRC	National Homeland Security Research Center
NIOSH	National Institute for Occupational Safety and Health
OPP	Office of Pesticide Programs
QSTR	Quantitative structure toxicity relationship
R.2	US EPA Region 2
RDD	Radiological dispersal device
SNL	Sandia National Laboratory
TSWG	Technical Support Working Group
US EPA	U.S. Environmental Protection Agency
UK	United Kingdom
WIPD	Water Infrastructure Protection Division
WMD	Weapon of mass destruction

IV.
List of Participants

The following pages list workshop participants. This list does not include those who were invited to participate but could not attend the workshop. Asterisks denote presenters.

***Nancy Adams**
Decontamination and
Consequence Management Division
NHSRC U.S. Environmental Protection Agency
(E343-06)
Research Triangle Park, NC 27711
919-541-5510
Fax: 919-541-0496

Melissa Adkins
ORISE Postdoctoral Fellow
National Homeland Security
Research Center
ORISE – U.S. Environmental
Protection Agency
109 TW Alexander Drive (E305-03)
Durham, NC 27711
919-541-1140
Fax: 9195412157

Robert Alphin
Poultry Research Coordinator
Allen Laboratory
Department of Animal and Food Sciences
University of Delaware
107 Allen Lab - 601 Sincock Lane
Newark, DE 19716
302-831-0825
Fax: 302-831-8177

Ron Atlas
Dean
Graduate School
University of Louisville
105 Houchins Building
Louisville, KY 40292
502-852-3957
Fax: 502-852-2365

Donald Bansleben
Program Manager
Science & Technology
CBR&D
Department of Homeland Security
Washington, DC 20528
202-254-6146
Fax: 202-254-6166

James Barnes
Certified Health Physicist
Santa Susana Field Laboratory
Environment, Health and Safety
The Boeing Company
5800 Woolsey Canyon Road
(055-T487)
Canoga Park, CA 91304-1148
323-466-8766
Fax: 323-466-8746

Charles Bass
Capability Area Program Officer
Chemical and Biological Directorate
Physical Science and Technology
Defense Threat Reduction Agency
8725 John J Kingman Road (6201)
Fort Belvoir, VA 22060
703-767-3371
Fax: 703-767-1892

Doris Betancourt
Microbiologist
IEMB
Air Pollution Prevention & Control Division,
NRMRL
U.S. Environmental Protection Agency
109 TW Alexander Drive (E 305-03)
Durham, NC 27711
919-541-9446
Fax: 919-541-2157

***Robert Bettley-Smith**
Headquarters
Government Decontamination
Service
MoD Stafford
Beaconside
Stafford, Staffs ST18 0AQ
England
01785 216331
Fax: 01785 216363

Terry Brennan
Camroden Associates
7240 East Carter Road
Westmoreland, NY 13490
315-336-7955
Fax: 315-336-6180
Mark Brickhouse
Chemical Sciences Senior Team Leader
Edgewood Chemical and Biological Center
E3400 Ricketts Point Road
Aberdeen Proving Ground, MD 21010
410-436-8951
Fax: 410-436-7203

***Lance Brooks**
Program Manager
Chemical/Biological Research &
Development Section
Departyment of Homeland Security S&T
S&T/8-015
Washington, DC 20528
202-254-5768
Fax: 202-254-6167

Carl Brown
Acting Chief of the Emergencies
Science & Technology Division
Environment Canada
335 River Road
Ottawa, Ontario K1A 0H3
Canada
613-991-1118

Jay Burcik
Chemist
TSD
U.S. Secret Service
950 H Street, NW
Washington, DC 20223
202-395-9210
Fax: 202-395-9323

Joan Bursey
National Homeland Security
Research Center
Decontamination and Consequence
Management Division
U.S. Environmental Protection Agency
109 TW Alexander Drive (E343-06)
Research Triangle Park, NC 27711
919-541-2253
Fax: 919-541-0496

Anne Busher
Manager of Emergency Preparedness
Dynamac Corporation
3912 Idlewild Drive
Rocky River, OH 44116
440-578-0787
Fax: 440-333-4901

Philip Campagna
Chemist
Environmental Response Team
U.S. Environmetal Protection Agency
2890 Woodbridge Avenue (101)
Edison, NJ 08527
732-321-6689
Fax: 732-321-6724

Dorothy Canter
Senior Professional Biophysicist
National Security Technology Department
Johns Hopkins University
Applied Physics Laboratory
11, 100 Johns Hopkins Road (17-N664)
Laurel, MD 20723
240-228-2816
Fax: 240-228-1868

John Cardarelli II
Health Physicist
OSWER
National Decontamination Team
U.S. Environmental Protection Agency
26 West Martin Luther King (271)
Cincinnati, OH 45248
513 675-4745
Fax: 513 487-2537

Sandip Chattopadhyay
Senior Chemical Engineer
Energy-Transportation-Environment
Environmental Restoration
Battelle Memorial Institute
505 King Avenue
Columbus, OH 43201
614-424-3661
Fax: 614-424-3667

Adrian Clark
Dstl Porton
Detection
Defence Science &
Technology Lab
Building 06
Porton Down
Salisbury, Wiltshire SP4 0JQ
United Kingdom
+44 (0)1980 613203
Fax: +44 (0)1980 629806

Matt Clayton
Engineer
Arcadis
4915 Prospectus Drive - Suite F
Durham, NC 27713
919-541-5548
Fax: 919-541-5181

Gordon Cleveland
USDA Radiological POC
Veterinary Services
Animal Health Emergency Management
U.S. Department of Agriculture - APHIS
4700 River Road - Unit 41
Riverdale, MD 20737
301-734-8091
Fax: 301-734-7817

Carmen Costable
Applications Development Specialist
Genencor International
1700 Lexington Avenue
Rochester, NY 14606
585-277-4449
Fax: 585-277-4300

Katie Crockett
Senior analyst
The Tauri Group
675 North Washington Street - Suite 202
Alexandria, VA 22314
703-647-8078
Fax: 703-683-2866

***John Drake**
National Homeland
Security Research Center
Decontamination and Consequence
Management Division, NHSRC
U.S. Environmental Protection Agency
26 West Martin Luther King Drive
Cincinnati, OH 45268
513-235-4273
Fax: 513-487-2555

***Wayne Einfeld**
Project Manager
Sandia National Laboratories
P.O. Box 5800 - Mail Stop 0734
Albuquerque, NM 87185
505-845-8314
Fax: 505-844-7786

Victor Engleman
President
EAI
3129 Carnegie Place
San Diego, CA 92122
858-452-0835
Fax: 858-452-0835

***Robert Fischer**
Environmental Scientist
Lawrence Livermore National Laboratory
P.O. Box 808 (L-546)
7000 East Ave
Livermore, CA 94531
925-422-3004
Fax: 925-422-3879

***Kim Fox**
Director, Water Infrastructure Protection
Division, NHSRC
U.S. Environmental Protection Agency
26 West Martin Luther King Drive
Cincinnati, OH 45268
513-569-7820
Fax: 513-487-2555

Dianne Gates-Anderson
Lawrence Livermore National Laboratory
7000 East Avenue (L-786)
Livermore, CA 94550
925-423-0447
Fax: 925-422-3469

Jeffrey George
Captain
Canadian Forces Nuclear Biological Chemical
Defence School
Canadian Department of
National Defence
P.O. Box 1000 - Station Main
Canadian Forces Base Borden
Borden, Ontario L0M 1C2
Canada
705-424-1200 ex. 2571
Fax: 705-423-2344

Robert Goodfellow
IBRD SETA
Booze Allen Hamilton
8283 Greensboro Drive
McLean, VA 22102
607-341-2095

Diane Gordon
Research Assistant
National Microbiology Laboratories
Safety and Envrionmental Services
Public Health Agency of Canada
1015 Arlington Street
Winnipeg, MB R3E 3R2
Canada
204-784-7529
Fax: 204-789-5038

Nancy Hammond
Chief, Environmenal & Explosive Safety
Hazardous, Toxic, &
Radioactive Waste Branch
Engineering Division
U.S. Army Corps of Engineers
P.O. Box 1715
Baltimore, MD 21203
410-962-2714
Fax: 410-962-4266

Harold Heaton
Principal Staff Physicist
Special Applications
National Security Technology
Johns Hopkins University
Applied Physics Laboratory
11, 100 Johns Hopkins Road (17-N672)
Laurel, MD 20723-6099
240-228-5025
Fax: 240-228-1868

Marianne Heisz
Acting Director
Office of Lab Security
Public Health Agency of Canada
100 Colonnade Road
Ottawa, Ontario K18 0K9
Canada
613-957-1779

Jonathan Herrmann
Director
National Homeland
Security Research Center
U.S. Environmental Protection Agency
26 West Martin Luther King Drive
Room 163
Cincinnati, OH 45268
513-569-7839
Fax: 513-487-2555

Dudley Hewlett
Headquarters
Government Decontamination Service
MoD Stafford
Beaconside
Stafford, Staffs ST18 0AQ
England
01785 216331
Fax: 01785 216363

***Lindsey Hillesheim**
Policy Advisor
Office of International
Health & Biodefense
U.S. Department of State
2201 C Street, NW
Washington, DC 20520
202-647-6922
Fax: 202-736-7336

Nobutaka Hirooka
Major
OTSG
Japan Ground Self-Defense Force
5109 Leesburg Pike - Skyline 6
Room 693
Falls Church, VA 22041
703-681-0108
Fax: 703-681-3429

Pauline Ho
PMTS
Chemical and Biological Systems
Sandia National Laboratories
P.O. Box 5800 (MS 0734)
Albuquerque, NM 87185-0734
505-844-3759
Fax: 505-844-7786

Mario Ierardi
Homeland Security Team Leader
Hazardous Waste
Generator and Characterization
Hazardous Waste Identification
U.S. Environmental Protection Agency
1200 Pennsylvania Avenue, NW (5304P)
Washington, DC 20460
703-308-8894
Fax: 703-308-1561

Robert Jacobs
School of Public Health and
Information Sciences
Environmental and Occupational Sciences
University of Louisville
555 South Floyd Street - Suite 4026
Louisville, KY 40292
502-852-0196
Fax: 502-852-3304

Peter Jutro
Deputy Director
National Homeland
Security Research Center
U.S. Environmental Protection Agency
1200 Pennsylvania Avenue, NW (8801R)
Washington, DC 20460
202-564-3331
Fax: 202 564-1614

***Lek Kadeli**
Deputy Assistant Administrator
Office of Research and Development
U.S. Environmental Protection Agency
1200 Pennsylvania Avenue, NW (8101R)
Washington, DC
202-564-6620

Tetsuro Kagao
Major, Japan Ground Self-Defense Force
Bureau of Defense
Defense Policy Division
Ministry of Defense, Japan
5-1 Ichigayahonmuracho
Shinjyuku, Tokyo 162-8802
Japan
+81-3-5269-3245
Fax: +81-3-5229-2135

Melissa Kaps
Program Analyst
Generator and Characterization Branch
Hazardous Waste Identification Division
U.S. Environmental Protection Agency
1200 Pennsylvania Avenue, NW (5304P)
Washington, DC 20460
703-308-6787
Fax: 703-308-0514

***Carlton (Jeff) Kempter**
Senior Advisor
Antimicrobials Division, OPP
U.S. Environmental Protection Agency
1200 Pennsylvania Avenue, NW
Washington, DC 20460
703-305-5448
Fax: 703-308-6467

Aaron Kirtley
U.S. Department of State
OBO/PE/DE/MEB
Washington, DC 20520
703-875-7002
Fax: 703-516-1627

***Robert Knowlton**
Principal Member of the Technical Staff
Sandia National Laboratories
P.O. Box 5800 (MS 0734)
Albuquerque, NM 87185-0734
505-844-0080
Fax: 505-844-7786

***Paula Krauter**
Environmental Microbiologist
Chemical/Biological Division
Lawrence Livermore National Laboratory
7000 East Avenue (L-528)
Livermore, CA 94550
925-422-0429
Fax: 925-422-2095

David Langfitt
Mechanical Engineer
Mechanical Engineering Branch
U.S. Department of State
125 Henrico Road
Front Royal, VA 22630
703-875-4790
Fax: 703-875-1627

George Lawson
CBRN Integrator
Joint Requirements Office
for CBRN Defense
U.S. Department of Defense
Pentagon
Washington, DC 20318-8000
703-602-9032

***Sang Don Lee**
Physical Scientist
DCMD, NHSRC
U.S. Environmental Protection Agency
109 TW Alexander Drive (E343-06)
Research Triangle Park, NC 27711
919 541 4531
Fax: 919 5410496

***Paul Lemieux**
Disposal Area Lead
Decontamination and
Consequence Management Division
National Homeland Security
Research Center
U.S. Environmental Protection Agency
109 TW Alexander Drive (E343-06)
Research Triangle Park, NC 27711
919-541-0962
Fax: 919-541-0496

Alan Lindquist
Microbiologist
Water Infrastructure Protection Division,
NHSRC
U.S. Environmental Protection Agency
26 West Martin Luther King Drive
Cincinnati, OH 45268
513-569-7192
Fax: 513-487-2555

***Graham Lloyd**
Centre for Emergency
Preparedness and Response
Health Protection Agency
Porton Down
Salisbury, Wiltshire SP4 8BQ
United Kingdom
44 1980 612224
Fax: 44 1980 610848

***Adam Love**
Scientist
Forensic Science Center
Lawrence Livermore National Laboratory
P.O. Box 808 (L-091)
Livermore, CA 94550
925-422-4999
Fax: 925-423-9014

John MacKinney
Environmental Scientist
DCMD, National Homeland Security
Research Center
U.S. Environmental Protection Agency
1200 Pennsylvania Avenue, NW (8801R)
Ariel Rios Building
Washington, DC 20460
202-564-9522
Fax: 202-564-1614

***Blair Martin**
Associate Director, Air Pollution Prevention
and Control Division
NRMRL
U.S. Environmental Protection Agency
(E343-04)
Research Triangle Park, NC 27711
919-541-7504
Fax: 919-541-5227

***Kenneth Martinez**
Acting Associate Director
Emergency Preparedness and
Response Office
Centers for Disease Control/NIOSH
4676 Columbia Parkway (R11)
Cincinnati, OH 45226
513-841-4224
Fax: 513-458-7147

***John Mason**
Chief Executive Officer
Sabre
406 9th street
Watervliet, NY 12189
202-256-3449
Fax: 518-810-0126

Dino Mattorano
Industrial Hygienist
NDT, U.S. Environmental Protection Agency
26 West Martin Luther King Drive
Cincinnati, OH 45268
513-487-2424
Fax: 513-487-2102

***John McKinney**
Program Analyst
Battelle Memorial Institute
Technical Support Working Group
201 12th Street
Arlington, VA 22202
703-602-6230
Fax: 703-604-1729

Michael Metz
Manager, Environmental
Monitoring and Emergency Response
Office of System Safety
MTA/New York City Transit
2 Broadway
New York, NY 10004
646-252-5766
Fax: 646-252-5960

James Michael
Senior RCRA Advisor
Generator and Characterization
Office of Solid Waste
Hazardous Waste Identification
U.S. Environmental Protection Agency
1200 Pennsylvania Avenue, NW (5304P)
Washington, DC 20460
703-308-8610
Fax: 703-308-0514

***Leroy Mickelsen**
Engineer
National Decontamination Team
OSWER/OEM
U.S. Environmental Protection Agency
109 TW Alexander Drive (E-343-06)
Durham, NC 27711
919-541-1356
Fax: 919-541-4537

David Mickunas
Environmental Response Team
Office of Solid Waste and Emergency
Response, U.S. Environmental Protection
Agency
109 TW Alexander Drive (E343-04)
Research Triangle Park, NC 27516
919-541-4191
Fax: 919-541-0359

Ong Ming Kwei
Senior Executive
Pollution Control Department
National Environment Agency
40 Scotts Road
#12-00 Environment Building
Singapore, Singapore 228231
Singapore
+6567319701
Fax: +6568362294

Richard Morel
Lieutnant-Colonel
Defense
French Permanent Joint Headquarter
14 Rue Saint Dominique
Armees, 00456
France
+0033-176648706
Fax: +0033-176648713

Phil Morey
Director of Microbiology
Building Technology
Boelter Associates
2235 Baltimore Pike
Gettysburg, PA 17325-7015
717-337-2324
Fax: 717-337-0691

Hirohisa Mori
Principal Deputy Director
Bureau of Personnel and Education
Health and Medical Division
Ministry of Defense, Japan
5-1 Ichigayahonmuracho
Shinjyuku, Tokyo 162-8802
Japan
+81-3-5229-2131
Fax: +81-3-5229-2137

Deborah Motz
Logistics/Life Cycle Manager
JPM-Decontamination
Joint Program Executive Office
Chemical Biological Defense
50 Tech Parkway - Suite 301
Stafford, VA 22556
703-617-2466
Fax: 703-617-2452

***Chandrika Moudgal**
Toxicologist
National Homeland Security
Research Center, Office of Research and
Development
U.S. Environmental Protection Agency
901 North 5th Street (ENSV/IO)
Kansas City, KS 66101
913-551-7393
Fax: 913-551-8752

***Mark Mueller**
Decontamination Thrust Area Manager
Chemical and Biological
Technologies Directorate
Physical Sciences Division
Defense Threat Reduction Agency
8725 John J Kingman Road (6201)
Fort Belvoir, VA 22060-6201
703-767-2359
Fax: 703-767-1893

***Bärbel Niederwöhrmeier**
NBC - Protection
Head of Central Biological Laboratory
Armed Forces Scientific Institute for
Protection Technologies - NBC-Protection
P.O. Box 1142
Munster, 29623
Germany
0049-5192-136-375
Fax: 0049-5192-136-355

Sean Nolan
DTRA
9006 Stratford Lane
Alexandria, VA 22308
703-283-8493
Fax: 703-767-1892

Canice Nolan
First Counselor, Head of Section
European Commission Delegation
2300 M Street, NW
Washington, DC 20037
202-862-9533
Fax: 202-429-1766

***Neil Norrell**
On-Scene Coordinator
U.S. Environmental Protection Agency
2890 Woodbridge Avenue
Edison, NJ 08837
732-321-4357
Fax: 732-321-4425

James Oesterreich
Equipment Modernization Analyst
Headquarters Air Force Civil
Engineer Support Agency
Emergency Management
U.S. Air Force
139 Barnes Drive
Tyndall AFB, FL 32403
850 283-6021
Fax: 850 283-6868

Richard Orlusky
Environmental Specialist
U.S. Postal Service
21 Kilmer Road
Edison, NJ 08899
732-689-5674

Michael Ottlinger
Office of Emergency Management
National Decontamination Team
U.S. Environmental Protection Agency
26 West Martin Luther King Drive
Room 271
Cincinnati, OH 45268
513 487 2429
Fax: 513-487-2537

***Andrew Parkinson**
Institute of Materials and
Engineering Science
Forensic and Nuclear Security Group
Australian Nuclear Science and Technology
Organisation
PMB 1
Menai, NSW 2234
Australia
+612-9717-9237
Fax: +612-9543-7179

Cayce Parrish
Senior Advisor
Office of Homeland Security
Office of the Administrator
U.S. Environmental Protection Agency
1200 Pennsylvania Avenue, NW (1109A)
Washington, DC 20460
202-564-4648
Fax: 202-501-0026

Brooke Pearson
Threat Technologies Division
Cuibic Applications Inc.
5695 King Centre Drive - Suite 300
Alexandria, VA 22315
703-924-3050 x5156
Fax: 703-924-3070

Brian Platz
Lead Industrial Hygienist
Domestic Environmental and
Safety Division
U.S. State Department
2201 C Street, NW - Room B2A61
Washington, DC 20520
202-647-4845
Fax: 202-647-1873

Brandalyn Price
Biologist
U.S. Department of Agriculture - APHIS
1800 Dayton Avenue
Ames, IA 50010
515-663-7013
Fax: 515-663-7527

Vladimir Nikolayevich Prokhorov
Department of New
Challenges and Threats
Ministry of Foreign Affairs
Russia

***Colin Ramsay**
Health Protection Scotland
Clifton House
Clifton Place
Glasgow, Lanarkshire G3 7LN
United Kingdom
+44 (0)141 300 1127
Fax: +44 (0)141 300 1100

***Vipin Rastogi**
Research Biologist
Edgewood Chemical and Biological Center
R&T Directorate
U.S. Army
E-3150 Kinkscreek Street, N
Aberdeen Proving Ground, MD 21010
410-436-4856
Fax: 410-436-2081

Katie Reid
CBRN Analyst
J-8
Joint Requirements Office for CBRN Defense
Joint Chiefs of Staff
Pentagon
Washington, DC 20318-8000
703-602-9040
Fax: 703-602-0941

Brian Reinhardt
Homeland Defense Applied Technologies
Chemical/Biological Applied Technology
Defense Threat Reduction Agency
8725 John J Kingman Road
Fort Belvoir, VA 22060-6210
703-767-3350
Fax: 703-767-1893

Jacky Rosati
Environmental Scientist
Decontamination and Consequence
Management Division
U.S. Environmental Protection Agency
109 TW Alexander Drive
Research Triangle Park, NC 27278
919-541-9429
Fax: 919-541-0496

Richard Rupert
On-Scene Coordinator
Office of Solid Waste and Emergency
Response
U.S. Environmental Protection Agency
Region 3
701 Mapes Road
Ft. Meade, MD 20755-5350
410-305-2611
Fax: 410-305-3093

***Shawn Ryan**
Chemical Engineer
DCMD, National Homeland Security
Research Center
U.S. Environmental Protection Agency
109 TW Alexander Drive (E-343-06)
Research Triangle Park, NC 27712
919-541-0699
Fax: 919-541-0496

James Salkeld
Head of Operations
BIOQUELL, Inc.
101 Witmer Road - Suite 400
Horsham, PA 19044
215-682-0225
Fax: 215-682-0395

Gregory Sayles
Associate Director
National Homeland
Security Research Center
Office of Research and Development
U.S. Environmental Protection Agency
26 West Martin Luther King Drive
Room 163
Cincinnati, OH 45268
513-569-7607
Fax: 513-487-2555

Jim Seidel
Science Advisor
Homeland Security Division
U.S. Environmental Protection Agency
Building 25 - P.O. Box 26227
Denver Federal Center
Denver, CO 80225
303-462-9376
Fax: 303-462-9028

Yasuo Seto
Vice Director of Third
Department of Forensic Science
Third Department of Forensic Science
National Research Institute of Police Science
6-3-1
Kashiwanoha
Kashiwa, Chiba 277-0882
Japan
+81-4-7135-8001
Fax: +81-4-7133-9173

Bradly Setser
Senior Scientist
Cubic Applications Inc.
5695 King Centre Drive - Suite 300
Alexandria, VA 22315
703-924-3050 x5145
Fax: 703-924-3070

Gerry Shero
Scientist
Joint Program Executive Office Chemical
Biological Defense / Camber
5203 Leesburg Pike
Skyline 2 - Suite 800
Falls Church, VA 22041
703-931-9180 x230
Fax: 703-931-5153

Lisa Smith
Research Biologist
Edgewood Chemical and Biological Center
E-3150 Kingscreek Street, N
Aberdeen Proving Ground, MD 21010
410-436-3846
Fax: 410-436-2081

Kelly Smith
Senior Project Manager
Dynamac Corporation
2306 Riverfront Parkway
Cuyahoga Falls, OH 44221
330-388-3532
Fax: 330-926-0959

Curtis Snook
Medical Officer
OSWER
OEM/NDT
U.S. Environmental Protection Agency
26 West Martin Luther King Drive
Room 271
Cincinnati, OH 45268
513-498-2434
Fax: 513-487-2537

***Emily Snyder**
Research Chemist
National Homeland
Security Research Center
Decontamination and Consequence
Management Division
U.S. Environmental Protection Agency
109 TW Alexander Drive (E343-06)
Research Triangle Park, NC 27711
919-541-1006
Fax: 919-541-0496

***Robert Spencer**
Regional Microbiology Network
Health Protection Agency
Level 8 Queens Building
Bristol Royal Infirmary
Marlborough Street
Bristol, BS2 8HW
United Kingdom
0117 9 283242
Fax: 0117 9299162

Harry Stone
Battelle
10300 Alliance Road - Suite 155
Cincinnati, OH 45242
513-362-2600
Fax: 513-362-2610

Quee Hong Tan
Chief Engineer
Pollution Control Department
National Environment Agency
40 Scotts Road #12-00 Environment Building
Singapore, Singapore 228231
Singapore
65- 67319667
Fax: 65-67319651

Lee San Tay
Pollution Control Department
National Environment Agency
40 Scotts Road #12-00
Environment Building
228231 Singapore
(65) 67319103
Fax: (65) 62353379

Michael Taylor
Program Manager
Environmental Exposure and Assessment
Energy, Transportation and Environment
Battelle
10300 Alliance Road - Suite 155
Cincinnati, OH 45242
513-362-2600
Fax: 513-362-2610

David Tollerud
MD, MPH
School of Public Health and
Information Sciences
Environmental and Occupational
Health Sciences
University of Louisville
555 South Floyd Street - Suite 4026
Louisville, KY 40292
502-852-3290
Fax: 502-852-3304

***Stephen Tomasino**
Senior Scientist
Microbiology Laboratory Branch
Office of Pesticide Programs
U.S. Environmental Protection Agency
Environmental Science Center
701 Mapes Road
Ft. Meade, MD 20755-5350
410-305-2976
Fax: 410-305-3094

Ken Toomey
Captain
Support Training Group Headquarters
Canadian Forces
P.O. Box 1000 - Station Main
Canadian Forces Base Borden
Borden, Ontario L4N6N3
Canada
705-424-1200 Ext 2820
Fax: 705-432-2344

Dahman Touati
ARCADIS-US
4915 Prospectus Drive - Suite F
Durham, NC 27713
919-541-3662
Fax: 919-541-9717

Stephen Treado
Project Leader
NIST
226, B114
Gaithersburg, MD 20899
301-975-6444
Fax: 301-975-5433

***Brian Viani**
Energy and Environment Directorate
Lawrence Livermore National Laboratory
P.O. Box 505 (L221)
Livermore, CA 94550
925-423 -2001
Fax: 925-423-2001

***Konstantin Volchek**
Restoration Chemist
Environment Canada
335 River Road
Ottawa, Ontario K1A 0H3
Canada
613-990-4073

***Jarrad Wagner**
Chemist
Laboratory
FBI
2501 Investigation Parkway
(HMRU RM 3130)
Quantico, VA 22135
703-632-7925
Fax: 703-632-7898

Lanie Wallace
Research Biologist
BioDefense Team
Edgewood Biological and Chemical Center
E-3150 Kingscreek Street, N
Aberdeen Proving Ground, MD 21010
410-436-2725
Fax: 410-436-2081

Barb Walton
Assistant Laboratory Director
of Emerging Programs
Office of Research and Development
National Health and Environmental Effects
Research Laboratory
U.S. Environmental Protection Agency
109 TW Alexander Drive (B305-02)
Research Triangle Park, NC 27711
919-541-7776
Fax: 919-541-1440

Lucienne Wasserman
Assistant Technical Director
JPM-Decon/S&T
JRAD
50 Tech Parkway - Suite 209
Stafford, VA 22556
540-288-3132 x213
Fax: 540-288-3391

***Joseph Wood**
Engineer
Decontamination and Consequence
Management Divison
National Homeland Security
Research Center
U.S. Environmental Protection Agency
Research Triangle Park, NC 27713
919-541-5029
Fax: 919-541-0496

Yasuo Yanagida
Deputy Director
Bureau of Personnel and Education
Health and Medical Division
Ministry of Defense, Japan
5-1 Ichigayahonmuracho
Shinjyuku, Tokyo 162-8802
Japan
+81-3-5229-2131
Fax: +81-3-5229-2137

Norman Yanofsky
CRTI Portfolio Manager Chemistry
Defence R&D Canada
Centre for Security Science (5-35)
344 Wellington Street
Ottawa, Ontario K1A 0K2,
Canada
613-944-8161
Fax: 613-995-0002

Donn Zuroski
On-Scene Coordinator
U.S. Environmental Protection Agency
Region 9
75 Hawthorne Street (SFD9-2)
San Francisco, CA 94105
415-972-3035
Fax: 415-947-8111

* Speaker

V.
Presentation Slides

Decontamination Research at the U.S. Environmental Protection Agency

Nancy Adams, PhD, Director
Decontamination and Consequence Management Division
National Homeland Security Research Center

Current Programs

- Detection
- Containment
- Decontamination
- Disposal

Detection

Completed Products

- Enhanced OP-FTIR sensitivity
- OP-FTIR guide for building owners
- Expanded TAGA capabilities for monitoring chemical agents
- Guide of surface sampling methods for persistent chemical hazards

Current Research

- Portable systems for real-time detection
- Rapid spore assays
- Sampling strategies
- Improved surface sampling
- Improved biological indicators

Containment

Completed Products

- Evaluation of residential safe havens
- Guidance for sheltering in large buildings
- Evaluation of filters, air cleaners, and HVAC-UV systems
- Retrofit/HVAC guide for facility owners
- Training program on safe buildings

Current Research

- Deposition on outdoor surfaces
- Urban dispersion
- Infiltration studies
- Particle resuspension
- Inhalation/dose models

Decontamination

Completed Products

- Lessons learned from anthrax decontaminations and fumigant field studies
- Report on available biologial decon methods
- Technology evaluations
  - H_2O_2
  - ClO_2
  - HCHO
  - Methyl bromide
  - Liquids and foams
- Field evaluation of portable ClO_2 system

Decontamination

Current Research

- Persistence studies (indoor/outdoor)
- Standard efficacy test methods
- Lab evaluations (T, t, RH, surface types)
  - Biological agents
  - Chemical agents
  - Toxic industrial chemicals
- Fumigant containment
- Evaluations of sources and sinks
- Dirty bomb surface decontamination
- Materials effects
  - Structural
  - Sensitive electronics

Disposal

Completed Products

- Web-based disposal decision support tool
- Guidance for autoclaving spore-containing wastes
- Guidance on fate/transport/survivability of biological and chemical agents in landfills

Current Research

- Expansion of disposal decision support tool
- Agricultural waste disposal guide
- Prototype mobile gasifier
- Guidance for incineration of biological hazards
- Expanded guidance for land filling

Program Contacts

- Detection – Emily Snyder 919-541-1006
- Containment – Jacky Rosati 919-541-9429
- Decontamination – Shawn Ryan 919-541-0699
- Disposal – Paul Lemieux 919-541-0962

Overview of select DHS Science and Technology Programs

2007 Workshop on Decontamination, Cleanup, and Associated Issues for Sites Contaminated with Chemical, Biological, or Radiological Materials

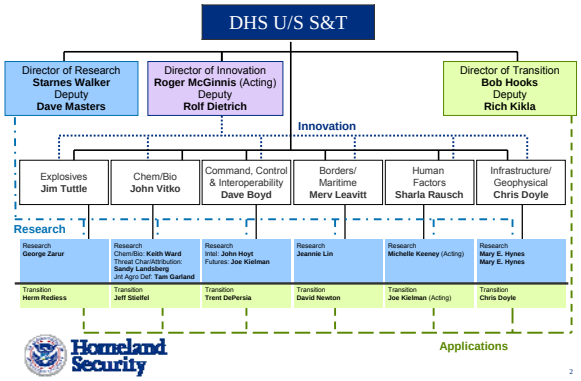
June 20, 2007

Lance Brooks
Program Manager
Chem-Bio Research & Development Section

Chemical and Biological Division
Science and Technology Directorate

Homeland Security

S&T Organization



Homeland Security

2

Major Customers

U.S. Citizenship and Immigration Services

Transportation Security Administration

FEMA

U.S. Customs and Border Protection
Securing America's Borders
CBP.gov

U.S. Immigration and Customs Enforcement

Ready Today Preparing For Tomorrow

Seven operational components receiving over 85% of DHS FY07 appropriated funds

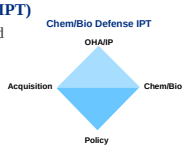
Homeland Security

3

DHS Chem/Bio Requirements

Directly from a Capstone Integrated Product Team (IPT)

- Co-chaired by DHS Office of Health Affairs (OHA) and DHS Infrastructure Protection (IP)
- Membership from other DHS operational arms
- Identified 50+ Capability Gaps



And they in-turn, base their requirements on

- Homeland Security Presidential Directives – 10, 7, 9, 18
- Congressional legislation & guidance
- National planning & implementation guidance – NIPP, NRP, NIMS, and the National Planning Scenarios
- Risk, vulnerability and mitigation studies
- Private, local, state inputs

Homeland Security

4

Chem/Bio Division Three Thrust Areas

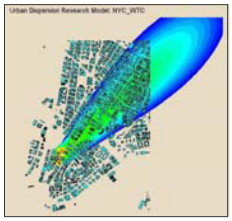
Overall structure reflects HSPD-9, 10, and 18 responsibilities

Thrust Area	Program	Major Products
Bio	Systems Studies	System tradeoffs e.g. Gen 3 BioWatch; policy net assessments
	Threat Awareness	Risk assessments; lab studies to close key gaps
	Surveillance and Detection Operations	Pilot, deploy and operate BioWatch, deployable systems
	Surveillance and Detection R&D	Detection systems for air, food; supporting assays
	Forensics	Enhance and operate the National Bioforensics Analysis Center (NBFAC)
	Response and Recovery	System approaches for recovering from a biological attack
Ag	Foreign Animal Diseases	Modeling, vaccines & diagnostics for FAD; JADO
Chem	Analysis	Chemical threat characterization and risk assessment; Develop and validate forensic analysis tools to enable attribution
	Detection	Chemical detection systems for facility monitoring and first responders
	Response and Recovery	Decontamination tools and systems approaches for recovering from a chemical attack

Homeland Security

5

Systems Approaches/Tools for Biological Response & Recovery



Goals

- Demonstrate systems approached to large scale urban decontamination & recovery
- Develop improved operational tools to support response & recovery

Roadmap

FY07: share results of Airport Restoration Demo thru workshops
FY07: initiate wide area restoration demo (joint effort with DTRA & Seattle)
FY08: guidelines & protocols for bio-agent sampling
FY09: 'demonstrate' wide area restoration
FY10: *validated* interagency sampling plan for anthrax

Homeland Security

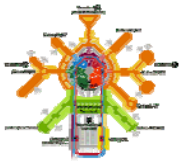
6

Restoration Guidance

– **Restoration Guidance & Checklist for Major Airports after a Bioterrorist Attack**
  - NAS Study: *Reopening Public Facilities after a Biological Attack: A Decision Making Framework*
  - "Pre-reviewed" Protocols & Plans

– **Airport Preparedness Workshop**
  - Co-sponsored with EPA/CDC
  - Eastern Airports (Port Authority of NY & NJ, Washington Metropolitan Authority, & Chicago Dept. of Aviation)

– **Restoration Guidance for Transit Systems**
  - Partners (WMATA, MTA)
  - Builds off of Restoration Guidance for Airports



Homeland Security

Integrated Biological Restoration Demo (I-BRD)

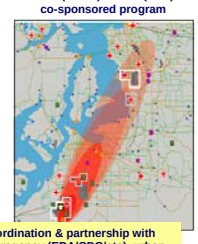
(Wide Area Restoration)

Goal/Objectives

- **Goal**: This program is focused on providing a coordinated, systems approach to the recovery and restoration of wide urban areas, to include DOD infrastructures and high traffic areas following the aerosol release of a biological agent.

- **Objectives:**
  - Study the social, econ, & ops interdependencies
  - Establish formal coordination between DOD & DHS
  - Develop strategic restoration plans for DOD & DHS
  - Id & demo technologies that support restoration
  - Exercise restoration activities & technology solutions

DOD (DTRA) & DHS (S&T) co-sponsored program



Coordination & partnership with Interagency (EPA/CDC/etc), urban area, and other identified partners

Homeland Security

IBRD Structure & Deliverables

- **Task 1: Conduct systems/front-end analysis**
  - **Systems engineering approach** (materiel & non-materiel focus)
  - Determine capabilities, gaps, & associated **choke-points**
  - Outputs feed into Tasks 2 & 3

- **Task 2: Establish & enhance existing frameworks**
  - Establish plans where needed; **decision frameworks**; refine existing policies, procedures, & operational approaches
  - Outputs evaluated in Final exercise planned for FY11

- **Task 3: Identify and develop methods, procedures and technologies to enhance recovery and restoration processes**
  - Id & demo **applied technology solutions;** enable recovery and restoration efforts
  - Outputs evaluated in Final exercise planned for FY11

- **Task 4: Conduct series of exercises & workshops to coordinate Civilian/Military interoperability, practical application of technology, and refined plans**
  - Stage and conduct **series of exercises and workshops** in Seattle Urban area to assess outputs from Tasks 2 & 3
  - Outcomes inform/recommend materiel & non-materiel solutions to program sponsors

Homeland Security

Biological Sampling

Strategy

– **Interagency Validated Sampling Plan**
  - MOU amongst DHS, EPA, HHS, FBI, NIST & DoD
  - Strategic plan including milestones, responsibilities, resources
  - Addresses sampling strategy, collection, transportation, extraction and analysis
  - Addresses anthrax first and then will extent to other agents

– **Strategy Verification Demonstration**
  - Chamber tests at JHU/APL for sampling methods,
  - Facility tests at INEEL for facility sampling strategies

Homeland Security

Systems Approaches/Tools for Chemical Response & Recovery

Field Trial of Prototype Mobile Labs

Goals
- Demonstrated systems approaches to restoration of critical facilities
- Prototype fixed and mobile laboratory capability to support the recovery

Roadmap
- ***FY07:*** demo mobile lab capability; prototype 3 fixed laboratories in high threat regions
- ***FY08:*** prototype and transition mobile lab to the EPA; prototype 2 additional fixed labs
- ***FY08:*** airport restoration table top exercise and restoration plan
- ***FY09:*** airport restoration demo

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Mobile Laboratory Capability

Goal: Develop and demonstrate a rapidly deployable capability for high-throughput analysis of environmental samples to assess contaminated area and facilitate restoration.

Objective:
-Ability to process, analyze and report on at least 100 samples/24 hr operation
- Ability to id contaminants (TICs & CWAs) to Permissible Exposure Levels (PEL)
- Automated sample tracking, processing, waste analyses, and data management/output
- Identification of samples requiring re-analysis

MOA to transition to EPA

Homeland Security

Facilities Restoration Demonstration

Goal: Promote rapid recovery from release of a chemical agent in a major transportation facility. Minimize the economic impact and facility closure. Enhance capability to make defensible public health decisions concerning the re-opening of major transportation facilities.

Objective:

-Pre-plan the restoration process at a representative critical transportation facility

-develop efficient planning tools

-identify sampling methods

-identify decontamination methods

-develop analysis tools

FY09: Conduct Final Demo; Transfer/conduct systems approach at other critical facilities

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TECHNICAL SUPPORT WORKING GROUP

TSWG Decontamination R&D Activities

John R McKinney
CBRN Countermeasures Subgroup
20 June 2007

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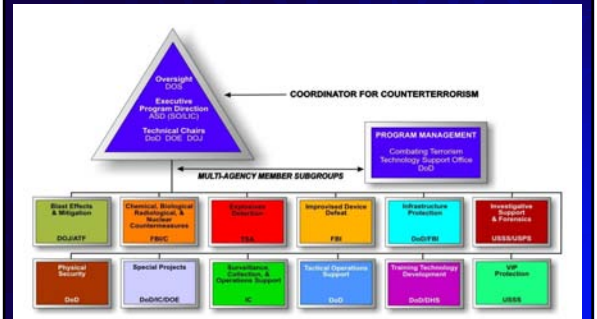
TSWG Organization



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CBRNC Subgroup Mission

- Identify interagency user requirements related to terrorist-employed chemical, biological, radiological, and nuclear (CBRN) materials
- Rapid research, development, and prototyping
- **Objectives:**
  - Provide interagency forum to coordinate R&D requirements for combating terrorism.
  - Sponsor R&D not addressed by individual agencies.
  - Promote information transfer.
  - Influence basic and applied research.

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CBRNC Focus Areas

Protection

Detection

Information Resources

Decontamination

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Subgroup Membership

- **DoD:** DATSD (CBD), DIA, DTRA, JCS, NSA, PFPA, USA (22ND CML BN(TE), 52nd ORD, CMLS, MANSCEN, NGIC, RDECOM-ECBC), USAF (ACC), USMC (CBIRF), USN (BUMED, NAVCENT, NAWC, NSWC)
- **DOS:** DS, OBO, S/CT
- **DHS:** FEMA, ICE (FPS), S&T (HSARPA), TSA, USCG, USSS
- **DOE**: SO
- **DHHS:** CDC, FDA, NIOSH
- **DOJ:** FBI, NIJ, USMS
- **USDA:** APHIS, ARS, FSIS
- **DOC:** NIST
- **OGA:** EPA, GSA, IAB, FDNY, NYPD, Seattle FD, Federal Reserve Board, Intelligence Community, NRC, U.S. Capitol Police, USPIS, U.S. Senate (SAA)

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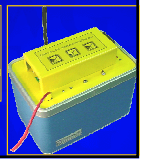
Overview of CBR Decontamination

Expedient Mitigation of a Radiological Release

Electrostatic Decontamination System (EDS)



Environmental Monitoring Unit

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Personnel Decontamination Agent Simulant Kit

Safe simulants (per International Dictionary of Cosmetics and Fragrances) imitating viscosity and solubility for CWAs (VX and HD), and radiological particulates marked with fluorescent dye to accurately reflect effectiveness of personnel decon actions in exercises.

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Building Disinfection By-Products Database

Planning tool to assist consequence managers in estimating chemical by-products that occur when decontaminating buildings.

- Measure decomposition products from common office furnishings exposed to ozone, chlorine dioxide, vaporized hydrogen peroxide, & methyl bromide
- Incorporate results into a planning database

- EPA and TSWG funding
- Database delivered and available

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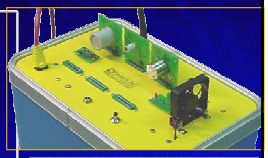
Wireless Multisensor Environmental Monitors

Real-time sensor systems that monitor chemical warfare agents and toxic industrial chemicals.

- Battery-operated or AC with 6 interchangeable, plug-and-play sensors
- Lightweight, portable, and inexpensive
- Wireless and Internet/Ethernet communication



- Esensors, Inc. is delivering Environmental Monitoring Unit (EMU) prototypes to end users for deployment

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List of Gas Sensors

HVAC/Environmental

- Carbon dioxide
- Humidity /Temperature
- Smoke

Decontamination/Industrial gases

- VOC/Methyl bromide
- Combustible gases
- Carbon monoxide
- Oxygen
- Ozone
- NOx (Nitric oxide, Nitrogen dioxide)

Toxic gas sensors

- Hydrogen sulfide
- Sulfur dioxide
- Chlorine (chlorine dioxide)
- Hydrogen peroxide
- Hydrogen cyanide
- Hydrogen chloride
- Arsine
- Phosphine
- Phosgene

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Gas Sensor Test Chamber

- Each sensor undergoes validation
- Known volumes of gas or solvent are injected into chamber in small increments
- Fan vaporizes and distributes
- Data (analog or digital) collected and plotted.

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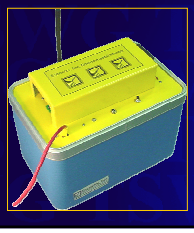
Redesign for End user

- Recent redesign to meet end-user needs
  - Improved scan time (decrease cycle time) to less than 12 seconds.
  - Easily removable batteries for when battery use is not expected.
  - Beta software to allow monitoring of several EMUs at different locations



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Sensor Web Combating Terrorism Applications

Develop a networked wireless sensor system to monitor temperature, humidity, and chlorine dioxide concentration or CO, H_2S, O_2 or LEL in real time.

- Deployed to New Orleans Jan. 2006 field tested during building mold remediation treatments
- USAR training/exercises at NASA Ames April 2006 and May 2007.
- Available from SensorWare Systems
- DHS Decon Test Bed support 2007

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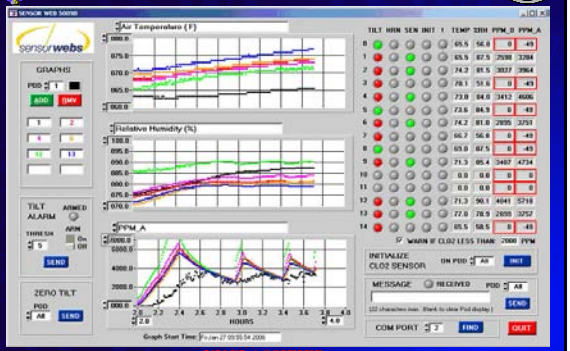
Building Fumigation



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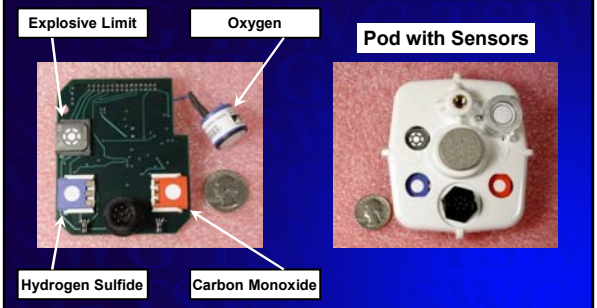
Sensor Web Urban Search & Rescue: Four-Gas Sensor Suite



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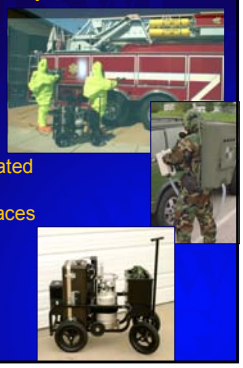
Electrostatic Decontamination System (EDS)

Effective, safe, and logistically efficient decontamination system to facilitate restoration of operations following contamination by chemical and/or biological weapons.



- Clean Earth Technologies demonstrated that EDS decontaminated "live" CB agents without damaging target surfaces
- Undergoing U.S. EPA regulatory processes
- Currently available for procurement

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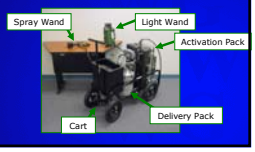
Electrostatic Decontamination System (EDS)

TECHNOLOGY OVERVIEW:

- Compact, modular design, one operator, simple to use
- Unique biological decontamination performance
- >6 logs *B. anthracis* spore kill in seconds
- High chemical agent decontamination efficacy without brushing, scrubbing, mopping, or scraping
- Requires 6-fold less solution for decontamination than foam
- Rugged
- Field-tested
- High material compatibility



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Expedient Mitigation of a Radiological Release

Minimize the impact of a radiological release by fixing radioactive particulates in place with a strippable polymer coating.

- Applied after rescue operations are completed while long term decon plan is being developed.
- Easily removed.

- IsoFIX and HeloTRON formulations available.
- Successful field tests by Army CoE; MARCORSYSCOM
- Demonstrated at JPEO Decontamination Conference

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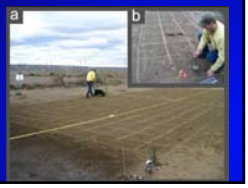
Isotron Field Tests

Lock-down testing for helicopter landings (dust palliative) and soil lock-down (retention over time).



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Isotron Follow-on Efforts

- Development of the IsoTrailer, a mobile response unit for lock-down
- Follow-on work funded by DTRA through TSWG is currently ongoing to develop coating resistance to CB agents
  - UV stability studies
  - Third-party testing will be conducted by AFRL

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Radiological Decontamination Technologies

Develop chemical processes to remove Cs-137 from porous building materials after an RDD event.

- Developer – Argonne National Laboratory
- Available for license

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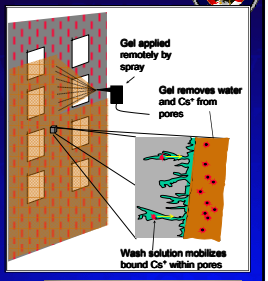
ANL Approach

- **3-Part Decontamination Process**
  - Ionic wash solution
    - *In situ* release of chemically bound radionuclides
  - Superabsorbent polymer gel
    - Extraction on radionuclide into super-absorbing polymer gel
    - Sequestration of radionuclide in the gel layer
  - Vacuum removal and consolidate gel waste
- Focusing on cesium and concrete
  - Solubilized cesium salt, little loose contamination
    - Worst-case scenario



Office of Science U.S. Department of Energy

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ANL Status

- Concrete chemistry
  - Radionuclides partition to components of concrete differently
- Wash solution development
  - Identified several ionic solution formulations suitable for exterior applications
  - Removal from cement material >97% in three applications
  - Removal from concrete >70% in single application
- Gel development
  - Identified coherent, robust, sprayable gel (20-40 g H_2O/g capacity)
- Scale-up
  - Several companies involved in application and removal testing, gel supplies.

Office of Science U.S. Department of Energy

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Guidelines for Disposal of Contaminated Plant and Animal Waste

Develop a clear, concise, and easy-to-use handbook on best practices and guidelines for the disposal of contaminated plant material and animal carcasses.

- Based on engineering, economic, & regulatory analysis of options
- Enables leaders to identify disposal methods that meet their needs

- Texas Agricultural Experiment Station
- Jointly funded and reviewed by EPA, USDA, and TSWG

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Rapid Contaminated Carcass and Plant Disposal

Destroy in an environmentally safe manner at least 100,000 pounds per day of contaminated animal and plant material from a biological or chemical terrorist attack on agriculture. System must be transportable on road and by air and operational within 24 hours after arrival on site .

- Mechanically reduce the contaminated material
- Incinerate using an oil-fired rotary kiln
- Treat exhaust gases in afterburner.

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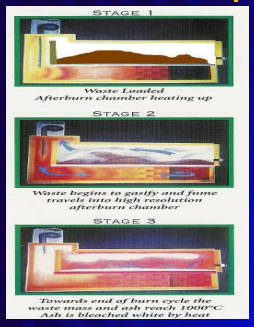
Rapid Contaminated Carcass and Plant Disposal



- Final design review held with USDA, FEMA, EPA.
- Initial equipment was redisigned to meet performance size, and cost goals.

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Current Decontamination Related Requirements Presented in the FY08 BAA

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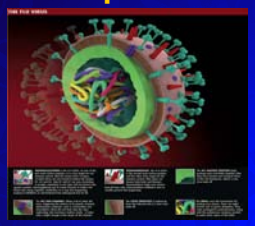
PPE Decon (Biodecon) Procedure and Biological Aerosol Test Method (BATM) Development



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Homemade Explosive Materials (HME) Clean-Up Kit

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Contact Information

cbrncsubgroup@tswg.gov

mckinneyj@tswg.gov

http://www.tswg.gov

FY08 TSWG BAA released in March 2007

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Regulating Bio-Decontamination Chemicals

Presented to

2007 Workshop on Decontamination, Cleanup, and Associated Issues for Sites Contaminated with Chemical, Biological, or Radiological Materials

Sponsored by
EPA National Homeland Security Research Center
Research Triangle Park, North Carolina

Carlton J. (Jeff) Kempter, Senior Advisor
Office of Pesticide Programs
Environmental Protection Agency
June 20, 2007

1

OVERVIEW

- Regulatory Background
- Efficacy Data Requirements
- Terms and Conditions of Registration
- EPA's Goals, Plans and Progress

2

REGULATORY BACKGROUND

- Substances used in or on living humans or animals:
  - Are Drugs or Medical Devices
  - Are regulated by the Food and Drug Administration under the Federal, Food, Drug and Cosmetic Act (FFDCA)
- Substances used in or on inanimate surfaces:
  - Are pesticide products or devices
  - Are regulated by EPA under the Federal Insecticide, Fungicide, and Rodenticide Act (FIFRA)

3

Antimicrobial Pesticides

- Under FIFRA, an antimicrobial pesticide is defined as a substance intended to disinfect, sanitize, reduce or mitigate microbiological organisms on inanimate surfaces (other than those on or in living humans or animals).

4

EPA Approvals Under FIFRA

- EPA approval for a pesticide product under FIFRA is either by registration (i.e., license) or by exemption (i.e., emergency approval).
- To obtain a registration, a registrant must submit an application to EPA along with required data and product labeling.
- To obtain an exemption, a state or federal agency must submit a request to EPA along with pertinent information.

5

FIFRA Registration

- Manufacturer must submit an application to EPA along with product labeling and the following data:
  - *New Active Ingredient product:*
    - product chemistry
    - environmental fate
    - fish and wildlife
    - acute/chronic toxicity data
  - *Old Active Ingredient product:*
    - chemistry
    - acute toxicity
    - efficacy data

6

FIFRA Exemption

- Section 18 exemptions: A state or federal agency may request to EPA to issue an exemption (four types):
  - Specific exemption
  - Public health exemption
  - Quarantine exemption
  - Crisis exemption

Crisis Exemptions

- When "anthrax attacks" occurred in October, 2001, no products were approved specifically for use against *Bacillus anthracis* spores
- Accordingly, crisis exemptions had to be issued for each sporicidal chemical at each contaminated site

Crisis Exemptions

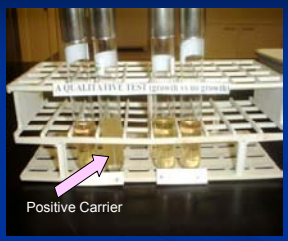
- Anthrax exemptions:
  - 63 requested
  - 28 approved
  - 35 denied
- Fumigation requests had to include
  - Remediation Action Plans
  - Sampling & Analysis Plans
  - Ambient Air Monitoring Plans

EFFICACY DATA REQUIREMENTS

- Current FIFRA efficacy test methods include:
  - Sanitizers (water, air, food contact surfaces)
  - Disinfectants
  - Virucides
  - Sterilants/sporicides
- Efficacy data are required to be submitted to support any public health related claim

Disinfectants

- Disinfectants must pass either the AOAC Use Dilution Test or Germicidal Spray Products Test (see http://www.epa.gov/oppad001/dis_tss_docs/dis-01.htm)
- Tests may include:
  1. *Salmonella choleraesuis* (Limited Disinfectant—1 or 2)
  2. *Staphylococcus aureus* (Broad-spectrum Disinfectant—1 and 2)
  3. *Pseudomonas aeruginosa* (Hospital Disinfectant—1, 2 and 3)



Adding Claims for Specific Microorganisms

- To claim inactivation of specific microorganisms (non-spore forming), a disinfectant must be successfully tested against those microorganisms using one of the above tests.
- For example, to add influenza A virus, need an AOAC disinfectant test with that virus.

Sterilants and Sporicides

- To be registered only as a "sterilant" or "sporicide," a liquid, gas or vapor product must pass the qualitative AOAC Sporicidal Activity of Disinfectants Test (AOAC Official Method 966.04)
  - on both nonporous and porous surfaces (i.e., porcelain penicylinders and silk suture loops),
  - using both *Bacillus subtilis* and *Clostridium sporogenes* spores, and
  - show NO GROWTH on all 720 carriers.

B. anthracis Inactivation Claims for Sterilants/Sporicides

- To claim inactivation of *B. anthracis* spores, a sterilant/sporicide should be tested:
  - On the virulent agent (*B. anthracis*) spores
  - On porous or nonporous surfaces, or both
  - Using AOAC 966.04, Method II, as a confirmatory test (i.e., 120 carriers per surface)
  - With NO GROWTH on any carrier

New Product Category— Sporicidal Decontaminant— for inactivating *B. anthracis* spores

- At a FIFRA Scientific Advisory Panel meeting in July, EPA will propose a new product category— Sporicidal Decontaminant
  - This product is intended to inactivate *B. anthracis* spores, but would be supported by data from a well developed, quantitative sporicidal test.
  - The product should be tested:
    - against virulent *B. anthracis* spores (or surrogate)
    - on porous or nonporous surfaces, or both,
    - and show at least a six (6) log reduction based on recoverable spores

Simulated Use Test for Gases/Vapors for Large Spaces

- Gases/vapors intended for use in large enclosed spaces must also pass a Simulated Use Test
- Purpose of the test is to:
  - Assure that key parameters for efficacy are met thoughout the space
  - Establish product generation rate (lbs/hr) and rate/volume (lbs/hr/ft^3)

Simulated Use Test for Gases/Vapors

- Test Procedure
  - Protocols for the simulated-use test should be submitted to the Agency for review and approval prior to conducting the test.
  - The testing should be conducted under conditions that are representative of the uses specified on the product's labeling, and in a setting that is representative of the label use site(s). For example, a product intended for use in a room or a large warehouse should be tested in an empty room or large chamber.

Simulated Use Test

- Should be set up in a sealed enclosure at least the size of a typical office and contain items that might normally be treated (e.g., dressers, upholstered furniture, carpet, etc,).
- Should specify the dimensions of the enclosure, and the number and location of monitoring devices for measuring gas or vapor concentration, total mass of gas or vapor injected, temperature, relative humidity, contact time, etc.

Simulated Use Test

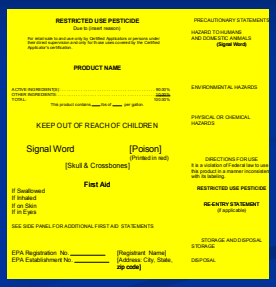
- All recorded test results pertaining to the test conditions/parameters should be submitted
- The maximum volume of space that can be treated and the minimum total mass of gas or vapor required to maintain the required concentration and contact time per cubic foot of space should be reported.
- This test must be conducted either in accordance with Good Laboratory Practices (GLP) per 40 CFR Part 160 or in a federal laboratory with an appropriate Quality Assurance Project Plan (QAPP)

Measure of Success for Simulated Use Test

- Evaluation of sporicidal success
  - Measurements should show that the same concentration, temperature, and relative humidity, can be maintained for the required contact time that were necessary to achieve NO GROWTH on any carrier in the AOAC 966.04, or a 6 log reduction in a well-developed quantitative test.
  - Measurements of the fumigant mass injection/generation rate (e.g., pounds/hour), divided by the volume of the simulated use test bed, that was used to calculate the required generation rate/volume (e.g., pounds per hour/cubic foot), should be included listed on the product label.

TERMS AND CONDITIONS OF REGISTRATION

- Who may purchase and use products with *B. anthracis* claims?
- What should the terms and conditions of registration be?
- On June 6, 2007, EPA issued a draft Pesticide Registration (PR) Notice, "Guidance for Antimicrobial Pesticide Products with Anthrax-Related Claims", which addresses these questions (see Federal Register, Vol. 72, No. 108, pp. 31325-6, June 6, 2007).


RESTRICTED USE PESTICIDE
Due to [insert reason]:
For retail sale to and use only by Certified Applicators or persons under their direct supervision and only for those uses covered by the Certified Applicator's certification.
PRODUCT NAME
ACTIVE INGREDIENT(S): 99.00%
OTHER INGREDIENTS: 1.00%
TOTAL: 100.00%
This product contains ____ lbs of ____ per gallon.
KEEP OUT OF REACH OF CHILDREN
Signal Word [Poison] (Printed in red)
[Skull & Crossbones]
First Aid
If Swallowed
If Inhaled
If on Skin
If in Eyes
SEE SIDE PANEL FOR ADDITIONAL FIRST AID STATEMENTS
EPA Registration No. _____
EPA Establishment No. _____
[Registrant Name]
[Address: City, State, zip code]
PRECAUTIONARY STATEMENTS
HAZARD TO HUMANS AND DOMESTIC ANIMALS
(Signal Word)
ENVIRONMENTAL HAZARDS
PHYSICAL OR CHEMICAL HAZARDS
DIRECTIONS FOR USE
It is a violation of Federal law to use this product in a manner inconsistent with its labeling.
RESTRICTED USE PESTICIDE
RE-ENTRY STATEMENT
(If applicable)
STORAGE AND DISPOSAL
STORAGE
DISPOSAL

Draft PR Notice for Anthrax-Related Products

- EPA intends to limit sale and distribution of bio-decontamination products for *B. anthracis* and other spore-formers to:
  - Federal On-Scene Coordinators
  - Other federal, state, tribal and local government workers authorized to perform bio-decontamination
  - Persons trained and certified competent by registrants
- The terms and conditions of registration will include registrant training and testing of applicators, and registrant record keeping as to who takes the training and who buys the product. EPA will review the training materials.

EPA's Goals, Plans and Progress

- Improve, validate and harmonize current sporicidal efficacy test methods through interagency collaborative research
  - AOAC International (AOACI) has published the AOAC 966.04, Method II. AOACI is currently validating the Three Step Method (TSM, a quantitative sporicidal test).
  - EPA will continue to collaborate on sporicidal research with other agencies through the Interagency Expert Panel on Efficacy Test Methods and Surrogates for *B. anthracis* Spores.

EPA's Goals, Plans and Progress

- Develop and issue Pesticide Assessment Guidelines on efficacy test methods that may be used to support the "*B. anthracis* claim"
  - On July 17-19, 2007 EPA will present draft guidance on efficacy tests involving *B. anthracis* spores to the FIFRA Scientific Advisory Panel (SAP).
  - After receiving the SAP's opinion, EPA intends to issue Pesticide Assessment Guidelines (810.2100) for anthrax-related products in 2007.

EPA's Goals, Plans and Progress

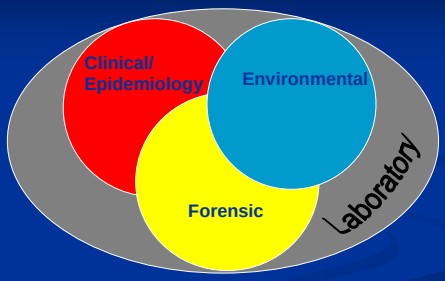
- Help the U.S. respond to biological incidents by making available registered anthrax-related products that are effective and cause no unreasonable adverse effects.
- Protect public health from the risks of *B. anthracis* spores by limiting the purchase of anthrax-related products to those who are properly trained in their use.
  - On June 6, 2007, EPA issued a draft PR Notice "Guidance for Antimicrobial Pesticide Products with Anthrax-Related Claims" (see Federal Register, Vol. 72, No. 108, pp. 31325-6, June 6, 2007).
  - EPA is seeking public comment on the draft PR Notice until August 28, 2007, and intends to issue the final PR Notice by the end of 2007.

Environmental Sampling for Biothreat Agents: Current Research and Validation Efforts

CAPT Kenneth F. Martinez, MSEE, CIH
Acting Associate Director, EPRO
National Institute for Occupational Safety and Health

NIOSH CDC

Disciplinary Partnership



CDC

Environmental Microbiology at CDC

Background

- Jan 2004 – CDC Director identifies environmental microbiology as a CDC preparedness and response priority.
- Mar-Jun 2004 – CDC convenes a workgroup of internal subject matter experts on environmental microbiology and completes an analysis of CDC's environmental microbiology research portfolio.
- Jul-Nov2004 – CDC collaborates with EPA to produce a joint report of recommendations to improve national laboratory preparedness through the National Laboratory Response Network (LRN).
- Nov 2004-Jan 2005 – CDC becomes a formal member of the Confederation.

CDC

Environmental Microbiology at CDC

Framework

Detection and Investigation → Control and Containment → Recovery and Remediation

Identifying Threat Agents	Determining Risk of Infection	Evaluating Techniques & Procedures for Risk Reduction
✓ Sampling and Recovery	✓ Virulence	✓ Protection
✓ Detection and Quantification	✓ Transmissibility	✓ Decontamination
✓ Identification	✓ Persistence	

CDC

Identifying Threat Agents

Bioaerosol Sampler
(B. T. Chen, G. Feather, J. Keswani)

Overview

- Sampler: cyclone-based micro-centrifuge tube (Din ~ 2 mm), personal/area, 4-L/min, D50 ~ 1.5 mm
- Analysis: PCR, immunoassay, or others
- Advantages: samples directly collected in the tube for preparation/analysis; no need for sample extraction from filters or other media used by current samplers
- In the case of PCR analysis:
  - Detection limit: spore count > 100, dust < 0.2 mg
  - Preparation: samples direct for bead-beating
  - Using crude extract without DNA purification

CDC

Determining Risk of Infection

Transmissibility
Letter Re-aerosolization Study
(S. Shadomy , R. McCleery , K. Martinez)

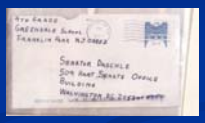
- **Purpose: To address concerns regarding existing guidelines for handling suspicious letters or packages.**
- **Main objective: To develop and test a revised model for assessing risk of exposure to anthrax simulant (BG spores) under an open office concept.**
- **Collaborators: Defense Research and Development Canada (Suffield) and Technical Science Working Group**

CDC

Determining Risk of Infection

Transmissibility
Letter Re-aerosolization Study

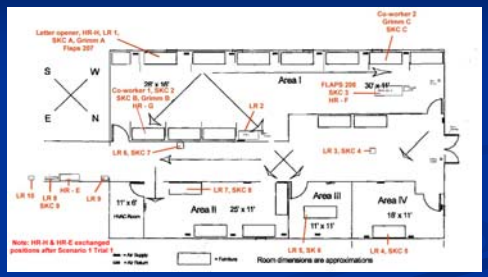
- Remote facility with open office concept, co-workers present.
- Controlled ventilation, positive pressure.
- Evaluation of various scenarios that may affect exposure risk.
- Use of modeling, computerized fluid dynamics, video exposure monitoring, and real-time exposure measurements.
- Develop objective evidence to refute or confirm adequacy of 2001 guidance.



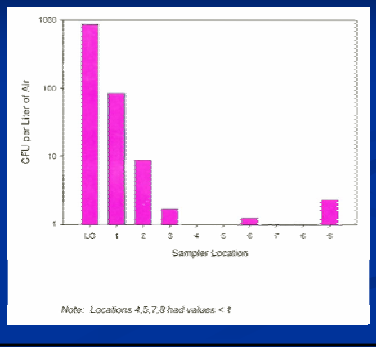
Technical Approach

- Slit to Agar aerosol samplers
  - High Resolution (4)
  - Standard (10)
- Grimm Aerosol spectrometers (3)
- Video cameras (3)
- Fluorescent Aerodynamic Particle sizers (2)
- SKC filter samplers (12)
- Swab samples (3 locations)

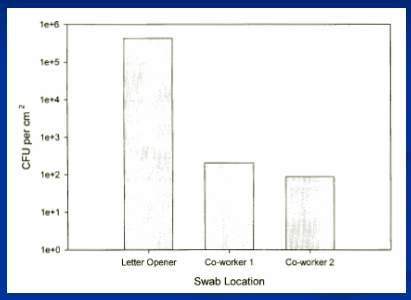
Experimental Room Setup



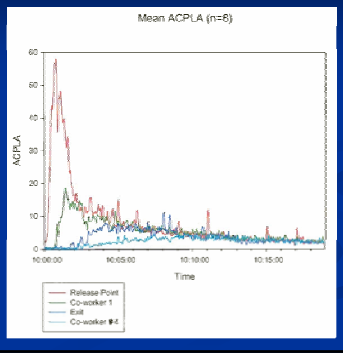
37-mm Filter Cassette



Surface Swabs



High Resolution Slit Sampler



Transmissibility Re-suspension of *Bacillus anthracis* Spores from Contaminated Mail

Mock-up chamber

- Purpose: ID factors affecting re-suspension of B. anthracis spores from contaminated envelopes
- Main objective: To develop standardized procedures for assessing exposure potential from cross-contaminated mail
- Collaborators: US Army Edgewood Chemical and Biological Center

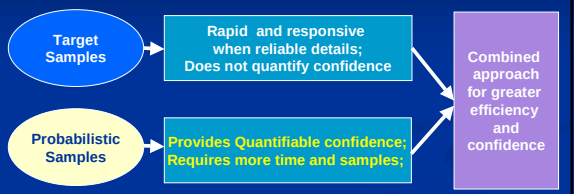
Government Accountability Office (GAO) Reports on Anthrax incidents

GAO review grew out of results related to Wallingford, Connecticut sampling

"…*strategies that include probability sampling need to be developed in order to provide statistical confidence in negative results*. Further, even if information on all the performance characteristics of methods is not yet available, a probability sampling strategy could be developed from assumptions about the efficiency of some of the *methods…This would enable agencies and the public to have greater confidence in negative test results* than was associated with the sampling strategy used in 2001.(p26)

Anthrax Detection: Agencies Need to Validate Sampling Activities In Order to Increase Confidence in Negative Results. GAO-05-251, March 31.2005

NIOSH developing Toolkit approach in response



Develop as suite of tools to assist investigator in the field

Overview of approach

Assess Incident details
Develop Judgmental sampling plan
Perform sampling

⬇

If results negative – have probabilistic option
Inputs include judgmental results, other inputs
Generate probabilistic sample plan options

⬇

Proceed with probabilistic sampling

Zones of Contamination

Validation Studies

- In the field
  - Sanderson, et al., Curseen/Morris (Brentwood) P&DC
  - McCleery, et al., Hamilton (Trenton) P&DC
- In the lab
  - Dugway Proving Grounds
    - CDC (NIOSH and NCID), EPA partnership
  - Sandia National Laboratory
    - CDC, EPA partnership

CDC

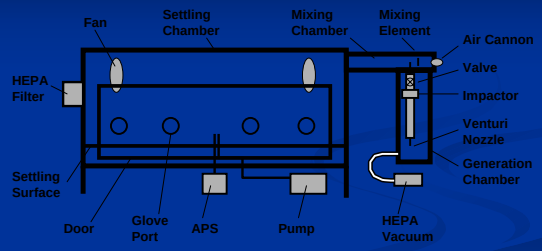
Development of an Aerosol System for Creating Uniform Samples of Deposited Bacteria

The objectives of the study was to determine the efficiency of sampling methods for *B. anthracis*.

1. Compare three surface sampling methods: swabs, wipes, and vacuum,
2. Compare analysis results from three laboratories,
3. Determine if additional sampling passes increase recovery
4. Determine recovery efficiency, precision, accuracy, and limit of detection for the three surface sampling methods,
5. Compare three air sampling methods: gel filters, PTFE filters, and Andersen single stage impactor.

CDC

Settling Chamber



CDC

Completed Manuscript

Baron PA, Estill CF, Beard JK, Hein MJ, Larsen L. [2007] Bacterial Endospore Inactivation Caused by Outgassing of Vaporous Hydrogen Peroxide from Polymethyl Methacrylate (Plexiglas®) Letter in Applied Microbiology (accepted).

Conclusions: H_2O_2 can be absorbed into plastic and be released after an extended period of time (weeks), allowing a sufficient concentration to accumulate in small volumes to inactivate spores. Out-gassing the plastic or coating the surface with an impermeable layer are potential solutions to reduce spore inactivation.

Significance and Impact of the Study: Many studies with bacilli and other organisms are carried out using small plastic containers that may have been sterilized using H_2O_2 or other agents. This study presents a cautionary note to ensure elimination of H_2O_2 or other sterilizing agents to prevent spurious results.

CDC

Chamber Description and Variability

Baron PA, Estill CF Deye GJ et. al. [2007] Development of an Aerosol System for Uniform Depositing *Bacillus anthracis* Sport Particles on Surfaces. (in NIOSH review)

Findings:

1. Three ways of analyzing the agar plates were used to evaluate spore coatings on viability and to differentiate between number of spore-containing particles and the number of spores.
2. The presence of spore agglomerates re-suspended by various sample handling activities in the chamber increased the variability of deposited particles.
3. A negative binomial regression model gave a relationship Mean CFU = 888 (APS Count) 0.947. The negative binomial model fit the data much better than the Poisson model because of the over-dispersion of the data. Predicted mean agar plate counts based on this model are 4.8 CFU (95% CI 3.5-6.4), 20 CFU (95% CI 17-23), and 160 CFU (95% CI 140-190) for future experiments at low, medium, and high concentrations, respectively.

CDC

B. anthracis Surface Sampling Study

- All experiments are completed, currently in data analysis phase.
- Results will:
  - Compare labs
  - Compare methods
  - Present recovery, precision, accuracy, and limit of detection for the three methods,
  - Evaluate multiple passes on each surface.
- Data are being collected now for the air sampling study.

CDC

Validated Sampling Plan

- The working group is comprised of technical experts from CDC, EPA, DoD, FBI, NIST, and DHS
  - DHS Science and Technology Directorate chairs the group
- Interagency strategic plan for validating environmental sampling and analytical steps occurring across all phases of response to an accidental or intentional incident involving biological contamination
- Occur under the auspices of the ICLN

CDC

Definitions

- ISO 17025 definition of validation
  - Validation is the confirmation by examination and the provision of objective evidence that the particular requirements for a specific intended use are fulfilled
- 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) that are combined to confidently answer specific hypotheses
- 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

CDC

Process Steps

- Sampling plan (scenario-specific approach as described above)
- Sample collection methods (from relevant matrices including, but not limited to air, drinking water, soil, and porous and nonporous surfaces)
- Sample integrity (maintaining sample integrity from site of potential contamination through transportation to and storage at the laboratory)
- Sample extraction (at the laboratory in preparation for analysis)
- Sample analysis (preliminary tests and confirmatory tests).

CDC

Major Categories of Activity

- Collection Methods for Air Sampling, Porous, and Non-Porous Surfaces
- Sample Integrity during Transportation/Storage
- Sample Processing and Analysis
- Sampling Strategy
- Sampling and Analysis Plan Exercise
- External Peer Review

CDC

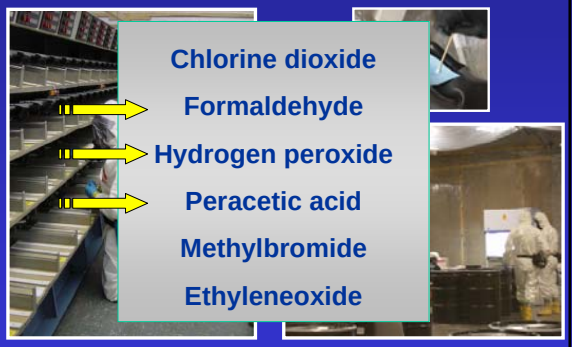
Armed Forces Scientific Institute
for Protection Technologies
- NBC-Protection -

Central Biological Laboratory

Biological Decontamination with Peracetic Acid and Hydrogen Peroxide

Bärbel Niederwöhrmeier

Disinfection of Interior spaces



- Chlorine dioxide
- Formaldehyde
- Hydrogen peroxide
- Peracetic acid
- Methylbromide
- Ethyleneoxide

Disinfection of Interior spaces

with formaldehyde

Disinfection of interior spaces using fumigation with formaldehyde-vapour

5 g FA / m³
rLf ≥ 70 %
reaction time 6 h
Effective range **AB**
16 h / **C**

TRGS 522 „Raumdesinfektion mit Formaldehyd“

Disinfection of Interior spaces

with formaldehyde

- **strong liquid precipitation**
- **neutralization leads to white precipitation**
- **long reaction time incl. time up to the safe entry of this area**

Disinfection of Interior spaces

with formaldehyde

Sublimating of Paraformaldehyde

4 g Paraformaldehyde pro m³

Disinfection of Interior spaces

Sublimating of Paraformaldehyde

RESULTS

2 m³-chamber **4 g ParaFA / m³ volume**
rLf > 70%
temperature > 23 °C
reaction time 3 h (without time for fumigation) for the inactivation of spores of Bacillus cereus and atrophaeus

120 m³-chamber **4 g ParaFA / m³ volume**
rLf > 70%
temperature > 23 °C
reaction time ≥ 7.5 h for the inactivation of spores of Bacillus atrophaeus

Disinfection of Interior spaces

Hydrogen peroxide

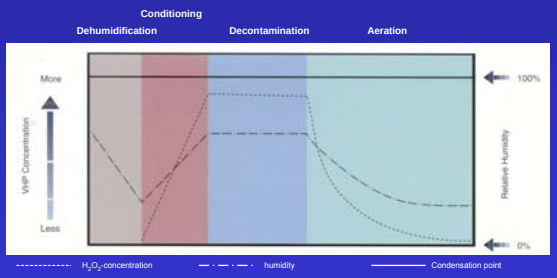
Fumigation

e.g. VHP-Generator
FA. STERIS AMSCO VHP

Disinfection of Interior spaces

Hydrogen peroxide-Fumigation

VHP-Decontamination Cycle



Disinfection of Interior spaces

Hydrogen peroxide - vapour

+

- no visible and toxic residues
- H_2O_2 is not stable, short removing time
- short D-values
- dry process
- good material compatibility
- process runs at room-temperature
- automatic process
- low operating costs
- USA – FDA licence

Disinfection of Interior spaces

Hydrogen peroxide - vapour

-

- mobile system up to max. 124 m³ volume
- H_2O_2 adsorbing materials e.g. textiles
- H_2O_2 split up materials e.g. copper
- surfaces have to be clean and dry
- validation of the disinfection-cycles

Disinfection of Interior spaces

Hydrogen peroxide

Current results of tests in a high level Laminar flow cabinet

Validation Bacillus stearothermophilus

WIS Bacillus cereus, Bacillus subtilis

Disinfection of Interior spaces

Hydrogen peroxide

Disinfection of Interior spaces

Hydrogen peroxide - vapour

actual examples for this procedure :
Disinfection of different tanks

- **disinfection procedure done by a company**
- **biological part done by WIS**

Disinfection of Interior spaces

Hydrogen peroxide - vapour

Disinfection Procedure

dehumidification:	air-volume of about 120 m³
humidity:	90 – 95 %
temperature:	18 – 24°C
using H_2O_2:	totally 2278 g 35%ige solution 0.8 – 1.0 mg / Liter
exposition:	330 min

Disinfection of Interior spaces

Hydrogen peroxide - vapour

Results

bioindicators - company:	**negative after 180 min**
bioindicators - WIS:	**all 13 positions negative after 6.5 h**
contamination with fungus:	**all 5 sampling-positions negative, but one yeast**
aeration overnight:	**0.4 ppm**

Disinfection of Interior spaces

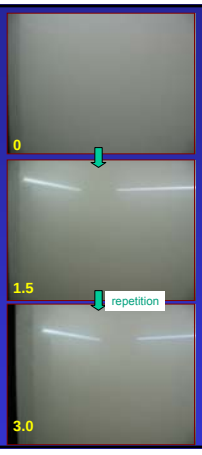
Thermal fog generator

Disinfectant **Wofasteril fog 300**
Wofasteril SC 250

(peracetic acid, hydrogen peroxide, acetic acid, de-sensitizing and stabilizing substance, special nebula materials)

Thermal fog generator

swingfog SN 50



Disinfection of Surfaces

Disinfection of Interior spaces

Thermal fog generator - Swingfog SN 50
- Wofasteril fog 300
- Wofasteril SC 250

Exposure-time of Wofasteril SC 250 8 h
23m³-Raum – 2 x 90 sec spraying
23-28°C – 90 –97% rLf

corrosion !?
time !?

Disinfection of Surfaces

Anthrax-spores
- tests in the context of the TEP -

10 % FA – 2 h

1 % PES – 2 h
Peracleart

with repetition of spraying after 1 h

800 - 1300 ml 10 % FA / m²

Ca. 1000 ml 1 % PES / m²

using 10^6 / carrier reduction of ca. 3 Log-steps

using 10^6 / carrier reduction of min. 5 Log-steps

Disinfection of Surfaces

Anthrax-spores
Tests with Wofasteril SC 250 + alcapur - foam

HDS 698 C ECO
+ Inno Foam Set

test-organism: Bacillus subtilis-Spores
10^6 / carrier

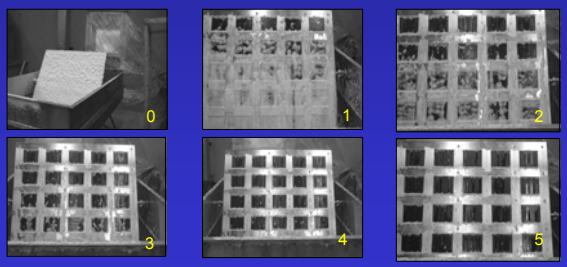
carrier: PUR-painted sheet metals
10 cm x 10 cm
inclination 110°

temperature: 17 – 22°C

Disinfection of Surfaces

tests with new formulations

Wofasteril SC 250 + alcapur



Disinfection of Surfaces

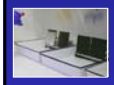
Wofasteril SC 250 + alcapur
2,3 % + 3,2 %

First results with the HDS 698 C ECO
+ Inno Foam Set (B.s./B.t.)

Exposition time was decreased

Problems with the inno foam set

Disinfection of Surfaces



Wofasteril SC 250 + alcapur
carriers: painted sheet metal, without organic load, RT

Reduction of the exposure-time
With different concentrations of the disinfectant

Exposure time was decreased up to
15 and 30 min
with reduction of 5-6 log-steps

Test organisms: *Bacillus subtilis*, *Bacillus cereus*
and Bacillus thuringiensis

Disinfection of surfaces and Interior spaces

Summary and further tests

Disinfection of interior spaces

Hydrogen peroxide vapour
Thermoaerolisation with Wofasteril

Disinfection of surfaces

Wofasteril with alcapur
Wofasteril SC 250 + alcapur - foam


Thank you for your attention!

Field Demonstration of Advanced CBRN Decontamination Technologies

Presented by Konstantin Volchek
Environment Canada

2007 Workshop on Decontamination, Cleanup, and Associated Issues for Sites Contaminated with Chemical, Biological, or Radiological Materials

Research Triangle Park, North Carolina
June 20–22, 2007

Participants

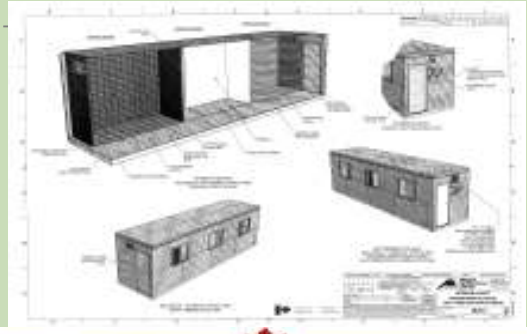
- **Project lead:** Environment Canada
- **Federal Partners:** DRDC Ottawa, Counter-Terrorism Technology Centre, DRDC Suffield, Public Health Agency of Canada
- **Industry Partners:** Allen-Vanguard Corporation, SAIC Canada
- **Other Participants:** US Environmental Protection Agency

Objectives

- Demonstrate building decontamination technologies for CBRN counter-terrorism
- Analyze concentrations of agent simulants or radioactivity levels on surfaces and in the air before, during, and after decontamination
- Evaluate technology performance on different surface materials
- Calculate associated costs and material and labor requirements
- Use trial results to develop manuals and guidelines for decontamination teams

Preparation: aerial view of trial site

Preparation: test structures for C and B trials



Preparation: complete setup

Interior surface materials

Chemical trial: agents and simulants

- Mixture of **diethyl malonate (DEM)** and **malathion** to be sprayed using a commercial air sprayer
- **DEM** was selected since it is a simulant for the "G" series nerve agents and the Chemical Agent Monitor (CAM) reacts to it and identifies it as a nerve agent.
- **Malathion** was selected since it is very persistent, techniques for sampling and analysis are well known and pervious laboratory studies were carried out (CRTI-02-0067RD).
- DEM and malathion react with decontaminants used to destroy chemical warfare agents. They are "reactive simulants" for CW agents.

Chemical trial: agent dissemination

Rooms A and B: 2.8 g/m^2

Room C: 12.5 g/m^2

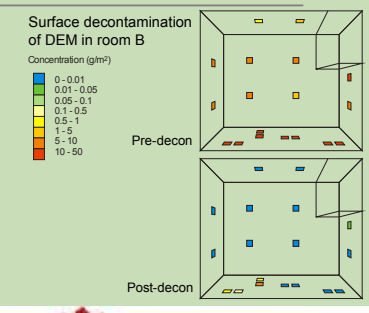
Chemical trial: sampling and analyses

- Several Hundred Surface and Air Samples (Solvent Extraction with GC-MS)
- Chemical Indicating Test Strips and Witness Cards
- Trace Agent Gas Analyzer (TAGA) (USEPA)
- Chemical Agent Monitor Stations (DRDC Suffield)
- Handheld CAMs (DRDC Suffield)
- Air Sampling Tubes
- VOC Meters

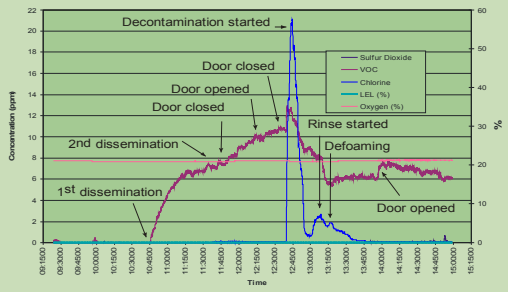
Chemical trial: decontamination

Chemical trial: surface coupon results

- Remaining DEM
  - *Room A: 1%*
  - *Room B: 1%*
  - *Room C: 58%*
- Remaining malathion
  - *Room A: 7%*
  - *Room B: 7%*
  - *Room C: 77%*
- Malaoxon generated
  - *Room A: 3%*
  - *Room B: 9%*
  - *Room C: 8%*



Chemical trial: air monitoring results



Chemical trial: problem areas

- The concentration of simulants in Room C was higher than that in Rooms A and B due to overspray. This resulted in lesser decontamination in Room C
- Inside CAMs were saturated with simulants and could not provide experimental data
- Decontamination was less effective on porous surfaces, due to hindered interactions between simulants and decon agents
- Formation of malaoxon, a toxic by-product, was observed as a result of incomplete oxidation

Cost Scenarios: chemical decon

	Scenario 1	Scenario 2	Scenario 3
Floor Area (m^2)	10	100	1,000
Wall Area (m^2)	60	600	6,000
Number of Responders	8	10	20
Duration (days)	5	5	5
Total Cost ($)	70,220	87,445	189,945
Cost per Wall Area ($/m^2$)	1,170	146	32
Cost per Floor Area ($/m^2$)	7,022	874	190

Biological trial: simulant agent

- *Bacillus atrophaeus*, a surrogate for *Bacillus anthracis*
  - Rationale: spores are hardest form to inactivate
  - Source: DRDC Suffield, formerly *Bacillus globigii* or 'BG'.
  - Concentration: ~1 x 10^{11} cfu/g

B. atrophaeus spore powder

Microscopic examination (dry mount)

B. atrophaeus colonies on filter

Biological trial: agent dissemination

- Puff of air (2.8 bar) in a test tube of spore powder (45 cm above floor) in each "room" simultaneously
- Total = one gram (1/3 g per room)

Spore powder in tubes

Dry powder dissemination apparatus, after dissemination of test agent.

Biological trial: decontamination with VHP

- STERIS Corp. VHP 1000-ARD-decontamination system using vaporous hydrogen peroxide (VHP)
- Continuous flow at three points in the structure, approx. 75 cm above floor, opposing each room
- Pedestal fan in corridor opposite each room
- Decontamination less than anticipated due to equipment malfunction (2.3 kg H_2O_2 instead of planned 3.0 kg)

VHP generator stationed outside the test structure

Dissemination & decon setup, room C

Biological trial: sampling

STA-100

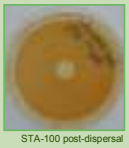
MAS-100

- **Air Samples**
  - H_2O_2 Sensors for VHP profile (one per room)
  - Two Anderson-style MAS-100 Eco air samplers
  - New Brunswick STA-204 slit-style air sampler
- **Surface Samples** (rayon-tipped swabs, pre-moistened sponge wipes, & HEPA vacuum socks)
- **Biological Indicators**
  - Surface samples spiked in-house with *Geobacillus stearothermophilus*
  - Steel disks with G. stearothermophilus (commercially available)

Biological trial: air results

- TSA plates at 35°C
  - Pre-dispersal: 2-24 colonies per 200-500 L air sampled
  - Post-dispersal: too numerous to count – no data
  - Post-decontamination:
    - MAS-100: both generated > 10^2 CFU in 200 L air
    - STA-100: one colony on one plate, two on the other.

MAS-100 pre-dispersal

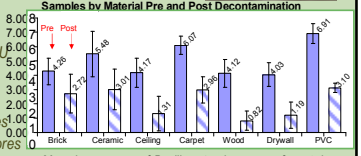


STA-100 post-dispersal

Biological trial: surface results

- Pre-dispersal:
  - Confounded by background flora (masking/inhibition)
  - Colonies on at least 7 of 62 plates, with up to 330 CFU
- Post-dispersal:
  - Swab: 1.89E+06 CFU
  - Sponge: 1.94E+07 CFU
  - Sock: 3.99E+09 CFU
- Post-decontamination:
  - Swab: 8.53E+03 spores
  - Sponge: 4.97E+05 spores
  - Sock: 1.71E+04 spores

Pre-dispersal surface sample, *B. atrophaeus* & background flora



Mean log recovery of *Bacillus atrophaeus* pre- & post-decon

Biological trial: problem areas

- Target agent present in site background
  - Surface sampling counts likely underestimated (masking etc.)
  - Background flora, including B. atrophaeus, reintroduced when doors opened post-decontamination, may falsely assume they are resistant to VHP
- Re-dispersion due to doors & personnel/equipment moving
- Failure of VHP generator to inject third bottle of H_2O_2
- No H_2O_2 neutralizer was used
- In-house biological indicators made from liquid suspension
  - may adhere more readily to surfaces (harder to inactivate?)

Radiological decontamination trial

- Late September - early October 2007
- Exterior surfaces of a two-storey building
- Na-24 as Na_2CO_3 and Tc-99
- Multi-stage decontamination to be used

Conclusions

- Commercial technologies chosen were effective in decontaminating affected buildings
- Surface material and agent to decontaminant ratios were major factors of
- One application of decon is not sufficient, especially for porous surfaces and higher agent concentrations
- Enough field data to assess decontamination costs
- Material collected for users' guides and manuals

Recommendations

- Build a more appropriate test structure
  - *better means of monitoring air circulation & filtration*
- Check background flora before selecting a site
- Use an H_2O_2 neutralizer
  - *prove that kill is caused by VHP in the specified time*
- Analyze run-off water quickly
- Use repeated applications of decon

Environment Canada
www.ec.gc.ca

Acknowledgements

- *Funding for this project was provided by the Chemical, Biological, Radiological, Nuclear, and Explosive Research and Technology Initiative (CRTI), project CRTI-04-0019TD*

Environment Canada
www.ec.gc.ca

Japanese Research Project for Development of On-site Detection of Chemical and Biological Warfare Agents

EPA 2007 Workshop on Decontamination, Cleanup, and Associated Issues for Sites Contaminated with Chemical, Biological, or Radiological Materials

Research Triangle Park, North Carolina, June 20-22, 2007

Yasuo Seto, Ph.D.
National Research Institute of Police Science, Japan

Detection and Identification in BC Terrorism Countermeasure

What are used for terrorism?

Crisis management → Consequence management → Incident management

Homeland Security — Forensics

Public Place
Territorial Border
Important Facility

Terrorism Incident

On-site Sampling → Transfer → Laboratory → Analysis → Court Trial

accurate
comprehensive

Prevention of Crime

Surveillance
Monitoring
Security Check

First Responder

rapid

continuous
sensitive

On-site Detection

rapid
simple

Disaster Minimization

Protection against Terrorism

Personal Protection

Medical Treatment
Criminal Investigation

Fatal Aerosol Concentrations and Required Detection sensitivity of Chemical and Biological Warfare Agents

On-site Aerosol 7 min collection (1,500 l/min) , Capture solution 5 ml

LC_{50}: Chemical agent, toxin - 1 min inhalation; Bacteria, Virus - 1 hr inhalation

	Required LOD
• Cyanide (volatility: 900,000 mg/m³) HNC – LCt_{50}: 4,500 mg · min/m³, acute (1 - 2 min)	5 mg/m³
• Phosgene (volatility: 6,000,000 mg/m³) $COCl_2$ – LCt_{50}: 3,200 mg · min/m³, subacute (several hr)	3 mg/m³
• Sarin (volatility: 23,000 mg/m³) – LCt_{50}: 150 mg · min/m³, acute (several min)	0.2 mg/m³
• Mustard gas (volatility: 600 mg/m³) $(ClCH_2CH_2)_2S$ – LCt_{50}: 1,500 mg · min/m³, subacute (several hr), blister	2 mg/m³
• Ricin – LD_{50}: 3 μg/kg, subacute (18 - 26 hr)	4 μg/ml
• Botulinum toxin A – LD_{50}: 1 ng/kg, subacute (1 - 5 days)	1 ng/ml
• Anthrax – 8,000 - 50,000 spores inhalation, delayed (3 - 5 days)	3 x 10^4 cfu/ml
• Plague – 100 - 1,000 bacteria inhalation, delayed (2 - 3 days)	400 cfu/ml
• Small Pox – 10 - 100 viruses inhalation, delayed (1 - 4 weeks)	40 pfu/ml

Importance of rapid and sensitive detection
Proper medical treatment really rescue lives of casualties

→ On-site detection

On-site Countermeasure by First Responders against Chemical, Biological Terrorism and White Powder Disturbance (Japan, 2002-)

- Personal Protection
  - Level A, C (Chemical)
  - HEPA filter (Biological)
- Preliminary Detection
  - Gas monitor, Detection paper, Gas detection tube
  - Ion mobility spectrometer, Flame photometric detector
  - Visual observation, pH, Water solubility
  - Ninhydrin reaction (protein assay)
- Sampling
  - Send to FSL, NRIPS (Chemical), local hygiene laboratories (Biological)
- Identification (Advanced teams)
  - GC-MS (Chemical)
  - Lateral flow immunoassay (Anthrax, Plague, Tularemia, Brucella, SEB, BTX, Ricin)
  - Real time PCR (Anthrax, Brucella, Plague, Tularemia, Small pox)
- Detection Achievement
  - Foul smell disturbance
  - HD detected at Samukawa (former Military abandoned chemical weapons)
  - White powder disturbance, FIFA World Cup Soccer 2002

Society for Countermeasure against Biological and Chemical Terrorism Disaster, "Biological and Chemical Terrorism Countermeasure Handbook" , Shindan To Chiryo Sha, Tokyo, 2003, p. 189.

R&D of On-site Detection Method for Chemical Warfare Agent

NRIPS, Fourth Chemistry Section

Gas detector using monitoring tape

Photoacoustic multi gas monitor

Criteria

- Sensitivity
  - less than 1/100 of lethal level
- Accuracy
  - specific, low false positive rate
- Response
  - short alarm time, real-time
- Performance
  - simple and easy operation, automated
- Resistibility
  - short recovery time

Chemical warfare agent vapor

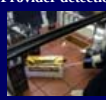
Ion mobility spectrometer

APCI mass spectrometer with counter-flow introduction

Hume hood

Drager Safety Gas Detection Tube

Detection of vapor agent, response several min
Provider detection limit sub mg/m³



HD

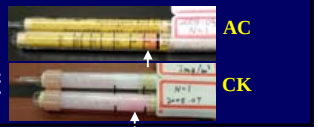
Mustard gas (for thioether)
If mustard gas passes into a silica gel tube impregnated with silver chloride and chloramine, the tube turns to Orange

Nerve gas (for phosphoric ester)
If a nerve gas passes into a tube, cholinesterase activity is inhibiting and substrate degradation is suppressed, turning to Red

Lewisite 1 (for organic arsenic compounds and Arsine)
If L1 passes into a Zn/HCl layer, forming AsH_3, then it reacts with gold/mercury complex, tuning to greyish-black

Hydrogen cyanide (for hydrocyanic acid)
If HCN passes into a $HgCl_2$ layer, forming HCl, indication layer of Methyl Red tunes to Red

Cyanogen chloride (for cyanogen chloride)
If ClCN passes into a pyridine reagent, forming dialdehyde, then it reacts with baribiturate reagent, tuning to Pink



Drager Safety Gas Detection Tube

GB	PE tube	LOD 0.002 mg/m^3	Response 5 - 6 min
GD	PE tube	LOD 0.02 mg/ m^3	Response 5 - 6 min
GA	PE tube	LOD 0.5 mg/ m^3	Response 5 - 6 min
VX	PE tube	LOD 2 mg/m^3	Response 5 - 6 min
HD	TE tube	LOD 2 mg/ m^3	Response 2 min
L1	OAA tube	LOD 40 mg/ m^3	Response 2 min
AC	HC tube	LOD 0.3 mg/ m^3	Response 1 min
CK	CC tube	LOD 0.8 mg/ m^3	Response 3 min

PE tube positive: DDVP, methomyl
TE tube positive: 2-CEES, 1,4-Tioxane;
PE tube false negative: GD in CO_2 gas

Tedious, Slow response

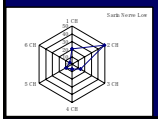
BUNSEKI KAGAKU 56 (2007) 355-362

Ion Mobility Spectrometer (Aspiration-type)

Response several sec
Sensitivity: 3 mode
Nerve gas: 0.02 mg/m^3
Blister agent: 0.05 mg/m^3
Blood agent: 1 mg/m^3

80 μCi Am-241
Ionization
Air flow
Ions collide with collector plates depending on charge and weight
Portable (PC size)
Field filtrate part of ions
Simultaneously detect of + ion and - ion

Environics OY (Finland)



Discrimination by 6 channel pattern recognition

Agent	Tabun	Sarin	Soman	VX	DMMP	*n*-hexane
Detection	Nerve	Nerve	Nerve	-	Nerve	-
	1 mg/m^3 hexane	1 mg/m^3 hexane	2 mg/m^3 hexane	vapor	vapor	vapor
					False positive	

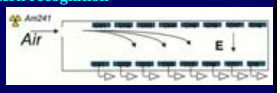
Agent	HD	HD	L1	HCN	CNCl	2-mercapto ethanol	acetone
Detection	Nerve Blister	Nerve	Blister	–	–	Blister	-
	vapor	20 mg/m^3	8 mg/m^3 hexane	1000 mg/m	1000 mg/m	vapor	vapor
	Wrong detection	Wrong detection		False negative	False negative	False positive	

Jap. J. Sci. Technol. Ident. 9 (2004) 39-47

Ion Mobility Spectrometer (Aspiration-type)

Detection of vapor agents and chemicals
ChemPro100 Environics OY (Finland)
16 channel pattern recognition

3 (Nerve, Blister, Blood) categorized



Sarin	Nerve	LOD 0.5 mg/m^3	Response 13 sec	Recovery 17 sec
Soman	Nerve	LOD 0.3 mg/m^3	Response 15 sec	Recovery 17 sec
Tabun	Nerve	LOD 0.5 mg/m^3	Response 17 sec	Recovery 18 sec
HD	Blister	LOD 10 mg/m^3	Response 18 sec	Recovery 13 sec
L1	Blister	LOD 40 mg/m^3	Response 22 sec	Recovery 23 sec
HCN	False Negative	7,000 mg/m^3	Low sensitivity	
ClCN	Unknown	LOD 1,000 mg/m^3	Response 38 sec	Recovery 23 sec
CCl_3NO_2	Unknown	LOD 332 mg/m^3	Response 26 sec	Recovery 3 sec

Nerve false positive (*partially)
Dimethylmethylphosphonate, Trimethylphosphate, Triethylphosphate*, Dimethylformamide*
Blister false positive (*partially)
2-Chloroethylethylsulfide, 1,4-Thioxane*, 1,4-Dithiane*, 2-Mercaptoethanol*, Ethanol*, Benzene*, Toluene*, Xylene*, Chloroform*
Blood false positive
None
False positive
Unknown chemical (100%)
Methanol , Acetone, Diethylether, Acetonitrile, Acetic acid, HCl, Ammonia, Formaldehyde, Diethylamine

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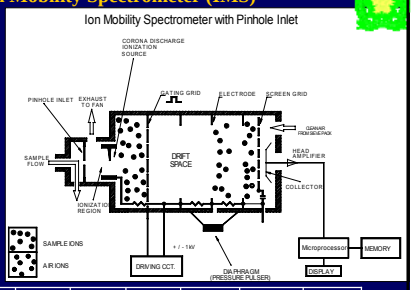
Ion Mobility Spectrometer (IMS)

Smiths Detection (UK)
LCD-3.2E
2 (Nerve G, the others H) categorized

Ionization:
Colona discharge



Agent	GB	GD	GA	HD	L1	AC	CK	PS
Alarm	G	G	G	H	H	H	H	H
LOD	0.2 mg/m^3	0.15 mg/m^3	0.3 mg/m^3	10 mg/m^3	5 mg/m^3	15 mg/m^3	500 mg/m^3	12 mg/m^3

Low sensitivity

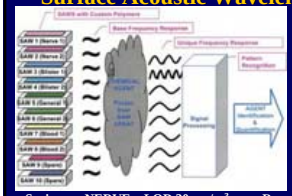
Response, Return Several sec

False positive G: TMPO, TEPO, n-propanol, diethylamine, triethylamine
H: 1,4-thioxane, 2-HSCH$_2$CH$_2$OH, diethylether, acetic acid

BUNSEKI KAGAKU 56 (2007) 117-124

False positive

Surface Acoustic Wavelength Detector (SAW)



ChemSentry
BAE Systems (USA)

Slow response

Sarin	NERVE	LOD 30 mg/m^3	Response 12 sec	Recovery 235 sec
Soman	NERVE	LOD 50 mg/ m^3	Response 12 sec	Recovery 234 sec
Tabun	NERVE	LOD 100 mg/ m^3	Response 13 sec	Recovery 230 sec
HD	BL	LOD 38 mg/ m^3	Response 8 sec	Recovery 236 sec
L1	NERVE	LOD 284 mg/ m^3	Response 109 sec	Recovery 272sec
	BL	56,700 mg/ m^3	Response 13 sec	Recovery 394 sec
HCN	BLOOD	LOD 28 mg/ m^3	Response 100 sec	Recovery 19 sec
ClCN	BLOOD	LOD 944 mg/ m^3	Response 133 sec	Recovery 27 sec

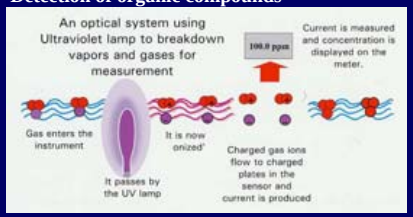
Low sensitivity
Residubility

NERVE False Positive
Methanol, Ethanol, *n*-Propanol, 2-Butanol, *t*-Butyl alcohol, Ethyl acetate, 1,4-Dioxane, Acetonitrile, acetaldehyde, *N,N*-Dimethylformamide, Pyridine
BL False Positive
Dichloromethane, 1,2-Dichloroethane, Chlorobenzene
BLOOD False Positive
Ammonia, Acetaldehyde
Confidential Check False Positive
False positive
t-Butyl alcohol, Acetone, Diethylether, Diethylamine, *N,N*-Dimethylformamide, Pyridine

BUNSEKI KAGAKU 54, 83 (2005)

Photoionization Detector

Detection of organic compounds



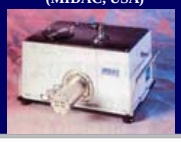
RAE Systems (USA)

Agent	BG	Sarin	Sarin	Soman	HD	CNCl
Value (ppb)	130	350 - 400	11,600	180 - 200	130 - 140	150
	Air	Vapor	4,000 mg/m^3	Vapor	Vapor	80 mg/m^3

Nonspecific

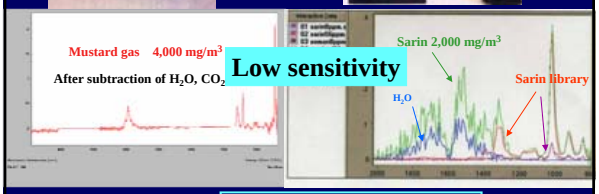
Fourier-Transform Infra-Red Spectrometer (FT-IR)

Industrial Gas monitor IGA-1700 (MIDAC, USA)



Movable

Multicomponent gas analyzer GASMET DX-4000 (Temet、Finland)



Constant response

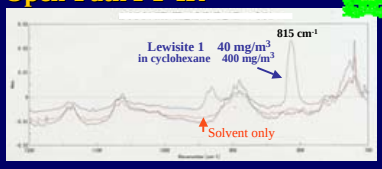
Detection limit: - 10 mg/m^3

Open-Path FT-IR

FTIR VIR-9500 (JASCO, Japan)

Light path 8 m gas cell

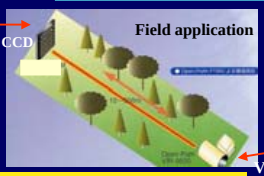
Movable



Sensitivity : - 2 mg/m^3

Array type CCD

Field application



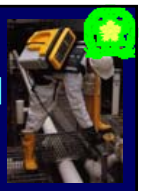
VIR-9500

Possibly improved sensitivity: 10 - 100 fold

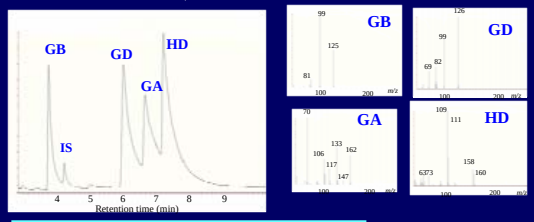
Gas Chromatography-Mass Spectrometry (GC-MS)

Hapsite (INFICON)

Slow response, Limited detection



- Air Sample: GB, GD 1 mg/m^3, GA 3 mg/m^3, HD 0.5 mg/m^3
- Microtrap: Tenax TA 15 mg, 1 min at r.t., raising to 280°C for 11 sec with 2.5 ml N_2/min
- GC:SPB-1 (0.32 mm X 30 m, thickness 1 μm), 3 ml N_2/min
  60°C (2 min) - 120°C (30°C/min) - 180°C (15°C/min, 2 min)
- MS: EI, 45-260 *m/z*, EI 70 eV, 300 μA, 0.84 sec/scan



LOD: GB 0.2 μg/m^3 (*m/z* 99), GD 0.5 μg/m^3 (*m/z* 126), GA 8 μg/m^3 (*m/z* 70), HD 0.3 μg/m^3 (*m/z* 109)

Forensic Toxicol. **24** (2006) 17-22

Detection Performance of On-site Equipment

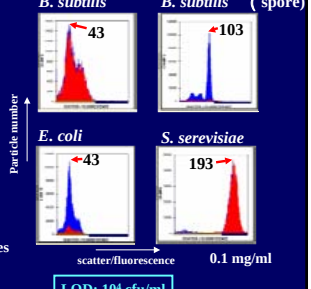
	Gaseous agent	Nerve agent	Blister agent	False Alarm	Response Time	Return Time	Operation
Gas Detection Tube	OK 0.5 mg/m^3	OK 0.05 mg/m^3	OK 5 mg/m^3	Δ	X 1 ~ 7 min	-	X
IMS	Δ 100 mg/m^3	OK 0.2 mg/m^3	Δ 5 mg/m^3	Δ	OK 3 ~ 20 sec	Δ Sec ~ min	OK Portable
FPD	X ND	OK 0.1 mg/m^3	Δ (nonAs) 1 mg/m^3	X	OK 2 ~ 5 sec	OK sec	OK Portable
PID	Δ 100 mg/m^3	X 100 mg/m^3	Δ 100 mg/m^3	X	Δ 5 ~ 10 sec	Δ sec	OK Portable
SAW	Δ 50 mg/m^3	X 50 mg/m^3	Δ 100 mg/m^3	X	Δ 15 ~ 30 sec	X 4 ~ 5 min	OK Portable
FT-IR	Δ 50 mg/m^3	X 50 mg/m^3	Δ 50 mg/m^3	Δ	Δ min	Δ -	Δ Movable
GC Tenax	X 0.001 mg/m^3	OK 0.001 mg/m^3	OK 0.001 mg/m^3	OK	X 5 ~ 10 min	-	Δ Fixed
GC-MS Tenax	X ND	OK 0.1 mg/m^3	Δ (nonAs) 0.1 mg/m^3	OK	X 10 ~ 15 min	Δ min	Δ Movable

BUNSEKI KAGAKU **54** (2005) 83-8; **55** (2006) 191-7; **56** (2007) 117-124 *Sens. Actuat. B* **108** (2005) 193-7

Flow Cytometer

MICROCYTE (BioDETECT, Norway)

Fluorescent → Red
Nonfluorescent → Blue



- Scattered light:
  Size (0.4 - 15 μm) and number of particles
- Fluorescence:
  Size and number of live and dead cells

Discrimination from white powder material

0.1 mg/ml

LOD: 10^4 cfu/ml

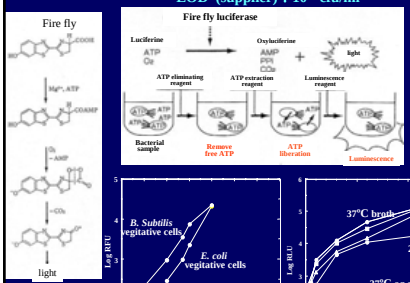
Jpn. J. Sci. Technol. Ident. **9** (2004) 9-18

Bioluminescence Technique

Measurement of ATP
Commercial kit for the hygiene test of bacterial contamination
LOD (supplier) : 10^4 cfu/ml

Kikkoman (Japan)

CheckLite™ 250 kit



LOD: 10^4 cfu/ml

J. Health Sci. **50** (2004) 126-32

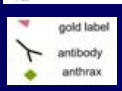
Lateral Flow Immunoassay

Detection of biological agents: antigen-antibody binding, Response: 15 min
Anthrax, Ricin, Botulinum toxin, Staphylococcal enterotoxin B, Small pox (anti-Vaccinia)

Portable

Guardian BTA
Tetracore (USA)

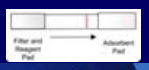
Just after sample application

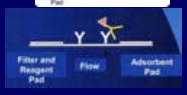


result

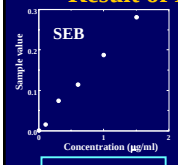
Positive

Negative

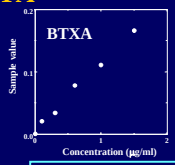




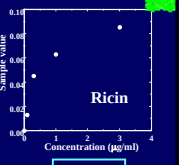
Result of BTA



LOD : 0.05 μg/ml



A 0.05 μg/ml, B 0.1 μg/ml



0.1 μg/ml

matrix	Control zone	Sample value	Remarks
Control (SEB 1 μg/ml)	Positive	0.221	
+ Wheat Flour 3%	Positive	0.181	
+ 0.1 M HCl	Positive	0.179	
+ 1 M HCl	Negative	ND	False negative
+ 0.1 M NaOH	Positive	0.106	Decreased value
+ 1 M NaOH	Negative	ND	False negative
+ 5% SDS	Positive	0.206	
+ 5% Na Cholate	Positive	0.183	
+ 3% NaCl	Positive	0.211	
Ethyl Red 1 mg/ml		0.0079	No false positive
Xylene cyanol FF 1 mg/ml		0.0092	No false positive

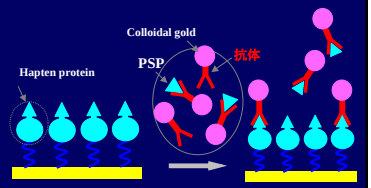
Jpn. J. Forensic Toxicol. **22** (2004) 13-6; **23** (2005) 18-20

On-site detection Kit for Saxitoxin
PSP Immunostrip MIST Alert™

Jellett Rapid Testing Ltd. (Canada)

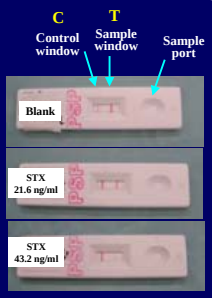
Saxitoxin: MW 299.3,
Paralytic shellfish poisoning,
LD_{50}: 10 mg/kg (mouse, i.p.)
Na channel blocker

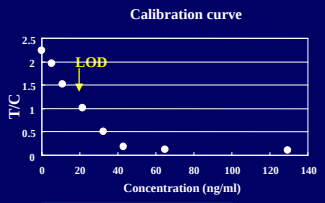
Indirect Competitive Method



PSP kit Result

Measurement of band intensity by TLC Scanner

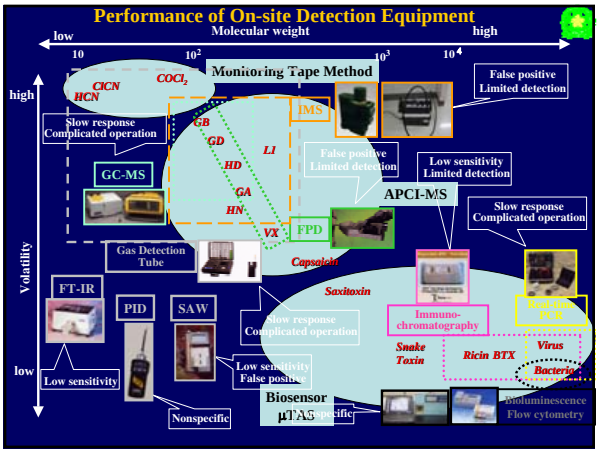




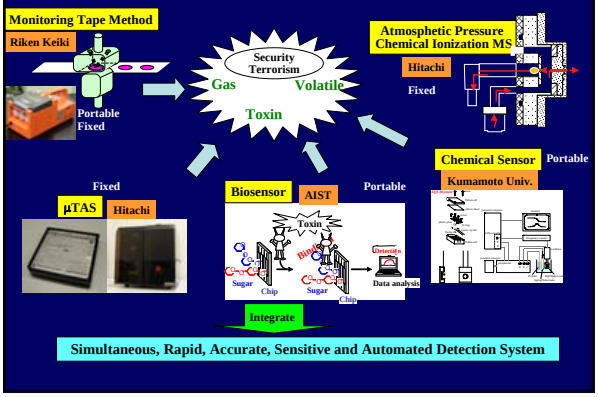
LOD : 20 ng/ml

Interference
White flour (10 mg/ml): no effect
1.0 M HCl: false positive
1.0 M NaOH: false negative
0.5% NaClO, 1.2 M HCHO: impossible
3.5% H_2O_2, 0.1 M $NaNO_2$: no effect

Performance of On-site Detection Equipment



Ongoing Development of On-site Detection System for Chemical and Biological Warfare Agents (MEXT 2005-8)



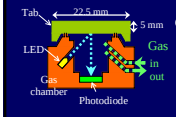
Simultaneous, Rapid, Accurate, Sensitive and Automated Detection System

Monitoring Tape Method (1)

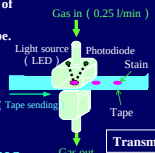
NRIPS with Riken Keiki, Ltd.

This method is based on the spectrophotometric measurement of the color product developing on the tape where the sample gas reacts with the specific reagents impregnated in the porous tape.

Diffusion



Coloration mechanism
Reduction by metal salt
Production of color compounds
Reaction with pH indicator

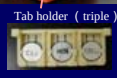


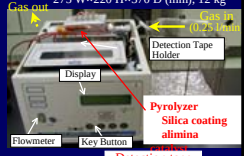
Transmission

FP260S
FP-260AGZ (Pyrolyzer)
275 W×220 H×370 D (mm), 12 kg

Portable multi-arrayed detector
FP-100


CNCl stain


Tab holder (triple)




Detection tape

Characteristics:
- ✓ Dry method
- ✓ Simple
- ✓ Small devise
- ✓ Continuous monitoring
- ✓ Specific
- ✓ Automatic

Characteristics of Detection Tape (or TAB) for Gases

Response Value (output, %)

$A = (V_0 - V_1) / V_0 \times 100$, $A = -\log (V_1 / V_0)$

V_0: Voltage before gas introduction
V_1: Voltage after gas introduction

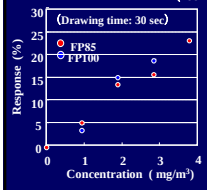
Detection Sensitivity:
Transmission type > Diffusion type

Mechanism	Reagent	Target	Concentration range	Time
Reduction by metal salt	Silver *p*-toluenesulfonate	PH_3	0.02 - 0.6 ppm	20 sec
		AsH_3	0.01 - 0.6 ppm	20 sec
		SiH_4	1 - 15 ppm	40 sec
	Palladium sulfite	CO	3 - 50 ppm	60 sec
Production of color compounds	Silver perchlorate	H_2S	2 - 50 ppb	5 min
	p-Butoxyaniline	Cl_2	0.05 - 1.5 ppm	40 sec
	Saltzman reagent	NO_2	0.01 - 0.5 ppm	10 min
	Potassium iodide	O_3	0.005 - 0.3 ppm	60 sec
	Copper acetate, 4,4'-Bis(dimethyl amino)diphenylmethane	HCN	0.2 - 15 ppm	60 sec
	4-*p*-Nitrobenzylpyridine	$COCl_2$	0.006 - 0.2 ppm	60 sec
	4-Benzylpyridine, Barbituric acid	ClCN	0.2 - 20 mg/m³	30 sec
Reaction with pH indicator	Rose Bengal	NH_3	0.1 - 1 ppm	60 sec
			0.5 - 2 mg/m³	10 hr
	Metanil Yellow	HCl	0.1 - 2 ppm	40 sec
	Hydroxylamine sulfate, Methyl Yellow	HCHO	0.15 - 4 ppm	5 min
			0.01 - 1 ppm	30 min

Detection of volatile CWA (Monitoring Tape Methods)

(1) Lewisite 1

$ClCH{=}CHAsCl_2 \xrightarrow[\text{(room temp.)}]{2H_2O} ClCH{=}CHAs(OH)_2 + 2\,HCl$



LOD: 0.04 mg/m³

Reaction with pH indicator

TAB017

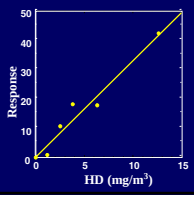

Stain

Conversion rate of L1 to HCl = 98 %
(Comparing to HCl standard gas)

(2) Mustard gas (Blister agent)

Pyrolysis

→ pH indicator (Methyl Orange) pink

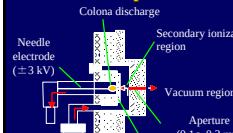


LOD: 0.008 mg/m³

Apparatus : FP-260AGZ (silica-coated alumina catalyst)
Tape : FV-017
Time : 30 sec

APCI Mass Spectrometer with Counter-Flow Introduction (2)

NRIPS with Hitachi, Ltd.




Ion-Trap MS

Positive ion mode:
$M + H_3O^+ \rightarrow (M+H)^+ + H_2O$

Negative ion mode:
$M + O_2^- \rightarrow M^- + O_2$

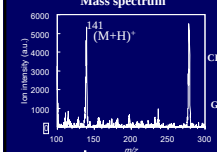
Corona discharge
→ primary ions and neutral molecules (or radicals)
Elimination of these neutrals
→ fewer unwanted reactions caused by neutral compounds
→ greater sensitivity & selectivity

	Agent	LOD μg/m³
Nerve	GB	1.8
	GD	
	GA	0.13
	VX	
Blister	HD	0.6
	L1	0.6 (-)
	HN-1	
	HN-2	
	HN-3	
Vomit	DA	3
	DC	0.03
Tear	CN	
	CS	
	OC	

LOD: 2 sec; (-): negative

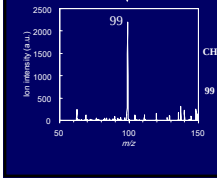
Detection of Sarin by APCI-MS

Mass spectrum

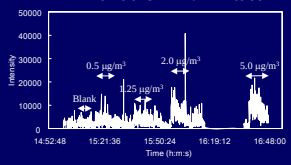


GB (MW: 140)

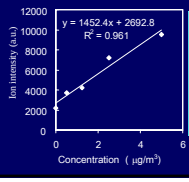
Collision



Profile of SRM *m/z* 141 to 99



Calibration curve

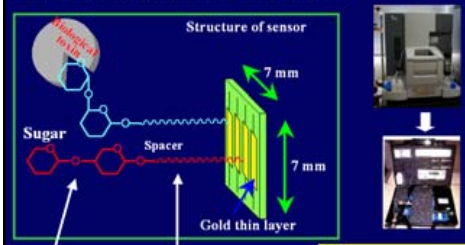


LOD
(2 sec, S/N=3)
1.8 μg/m³
(3 min, S/N=3)
0.16 μg/m³

Sugar Chain Biosensor (3)

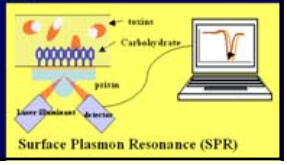
Portable Biological Toxin Detection Equipment

NRIPS with AIST



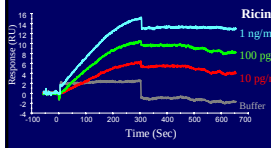
Biacore T-100 (Laboratory analysis)

Field portable SPR Detector



Detection of Biological Toxins by Sugar Biosensor Technology

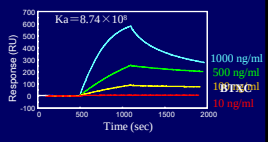
(1) Ricin



Biacore T-100

LOD: 10 pg/ml

(2) Botulinum toxin



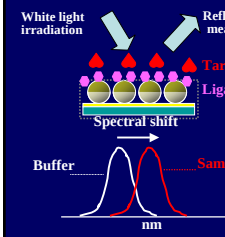
Biacore 2000

LOD: 10 ng/ml

10 mM HEPES, 0.15 M NaCl, pH 7.5
10 µl/min
50 µl injection

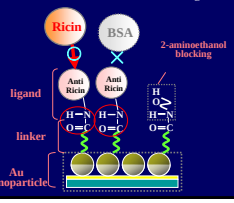
Localized Surface Plasmon Resonance (4)

Portable Biological Toxin Detection Equipment



Hitach, Ltd.

Nonlabeling constant detection



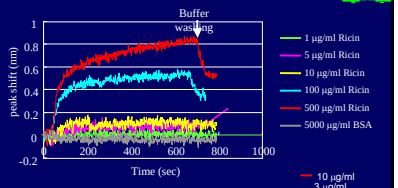
Detection of Ricin by LSPR

(1) Antibody

Rabbit anti-Ricin
fixing : 25 µg/ml, 10 min

Blockace (10 min)

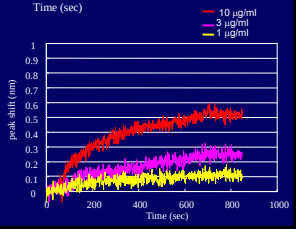
LOD: 5 µg/ml



(2) Sugar

fixing : 50 µg/ml in CH_3OH, 24 hr
solvent exchange CH_3OH to aq x 3
buffer equilibration

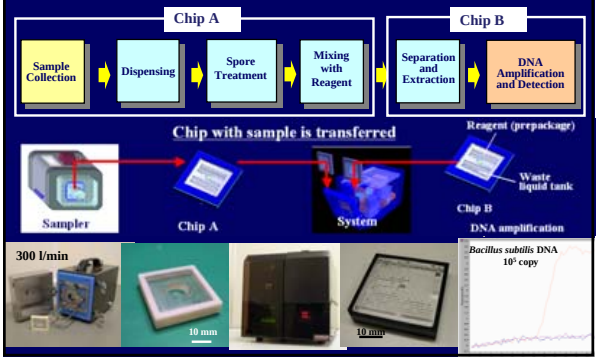
LOD: 1 µg/ml



Bacterial Identification System using Micro-Fluidic Chip (5)

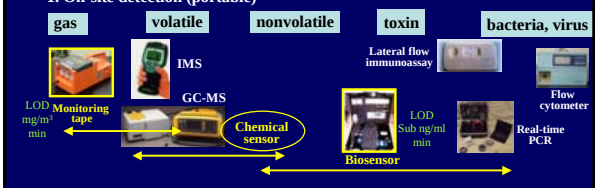
Assembled chip system consisting of bioaerosol sampling, spore treatment and DNA extraction and amplification

NRIPS with Hitachi, Ltd.

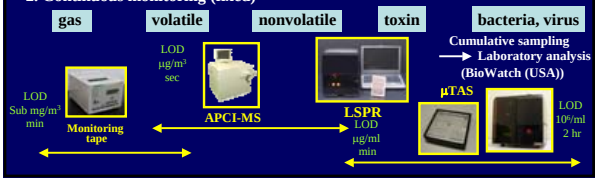


Detection Strategy by Combining Different Kinds of Equipment for Chemical and Biological Warfare Agents

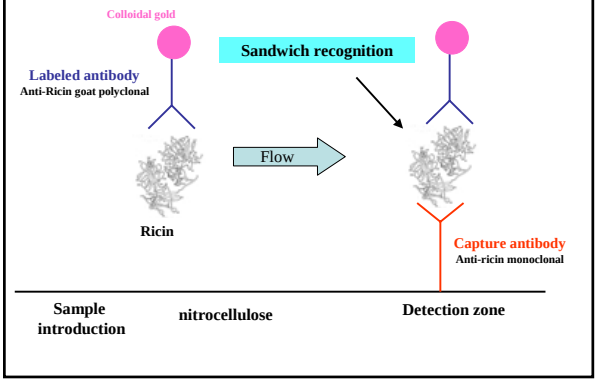
1. On-site detection (portable)



2. Continuous monitoring (fixed)



Lateral Flow ImmunoAssay



Effect of Interfering Substances(1)

BTA SEB Strip, Sample：SEB　1 μg/ml, control value：0.139 ～ 0.188

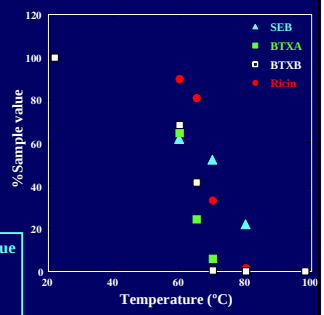
	Control window	%Sample value	Remark
Control（SEB）	Positive	100%	
White flour 10 mg/ml	Positive	ND	
SEB＋White flour 10 mg/ml	Positive	117.6%	
Starch 10 mg/ml	Positive	ND	
SEB＋ Starch 10 mg/ml	Positive	38.3%	Decrease
BSA 10 mg/ml	Positive	ND	
HSA 10 mg/ml	Positive	ND	
Human plasma 10 mg/ml	Positive	ND	
SEB＋0.1 M HCl	Positive	81.9%	
SEB＋1.0 M HCl	Negative	ND	FALSE
SEB＋0.1 M NaOH	Positive	37.8%	Decrease
SEB＋1.0 M NaOH	Negative	ND	FALSE
SEB＋SDS 50 mg/ml	Positive	66.5%	Decrease
SEB＋Na Cholate 50 mg/ml	Positive	97.3%	
SEB＋Na Deoxycholate 50 mg/ml	Positive	35.6%	Decrease
SEB＋NaCl 30 mg/ml	Positive	112.2%	
Methyl Red 1.0 mg/ml	Positive	ND	Red pigment
SEB＋Methyl Red 1.0 mg/ml	Positive	104.7%	
Xylene cyanol FF 1.0 mg/ml	Positive	ND	Blue pigment
SEB＋Xylene cyanol FF 1.0 mg/ml	Positive	99.6%	

ND: Sample value ＜ 0.01 （Threshold value）

Jap. J. Forensic Toxicol. 22 (2004) 13-6; 23 (2005) 18-20

Effect of Heating

Toxin solution（2.0 μg/ml）
10 min heating
↓
After cheating,
mixed with equal volume of buffer
↓
Applied on BTA



Temperature giving 50% Sample value
SEB：　70°C
BTXA：　62°C
BTXB：　63°C
Ricin：　68°C

Forensic Toxicol. 25 (2007) in press

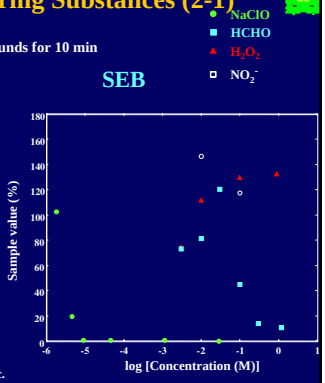
Effect of Interfering Substances (2-1)

Toxin solution（1.0 μg/ml）
Incubated with interfering compounds for 10 min
↓
mixed with equal volume of buffer
↓
Applied on BTA

Concentration giving
50% Sample value（mM）

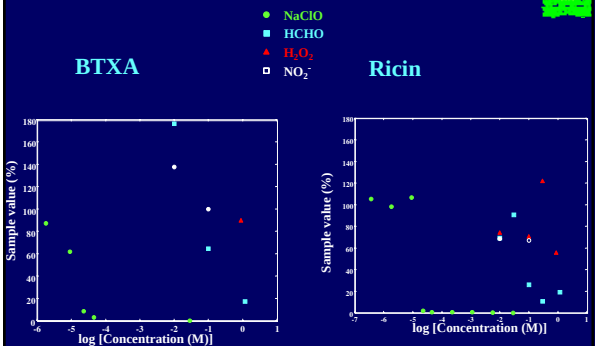
	SEB	BTXA	Ricin
NaClO	0.0031	0.011	0.015
HCHO	88	210	NE
H_2O_2	NE	NE	NE
NO_2^-	NE	NE	NE

NE: % Sample value > 50% at highest conc.
（H_2O_2: 8.8 M, NO_2^- 1.0 M）



Forensic Toxicol. 25 (2007) in press

Effect of Interfering substances (2-2)



Forensic Toxicol. 25 (2007) in press

Health Protection Scotland

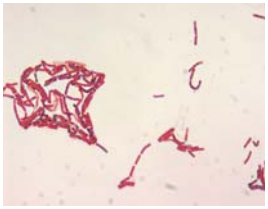
NHS National Services Scotland

A Fatal Case of "Natural" Inhalational Anthrax in Scotland - Decontamination Issues

US EPA Decontamination Workshop 2007

Dr Colin N. Ramsay
Consultant Epidemiologist
Health Protection Scotland

PRESENTATION AIMS



- **Describe**
  - **the investigation and incident management**
- **Describe**
  - **decontamination decision processes and rationale**
- **Describe**
  - **problems and lessons identified**

August 2006 - INCIDENT INITIATION

8 August 2006

HPA-NDPL advise NHS Borders/HPS
– confirmed culture of *Bacillus athracis* from blood culture taken from "PN"

Case History

- 50 yr old male, living in rural Scottish Borders
- 3 day history of flu-like symptoms, developed septicaemia and collapsed, comatose
- died 8 July 2006
- (Fiscal) Post Mortem confirmed septicaemia, aetiology unknown, little else of note

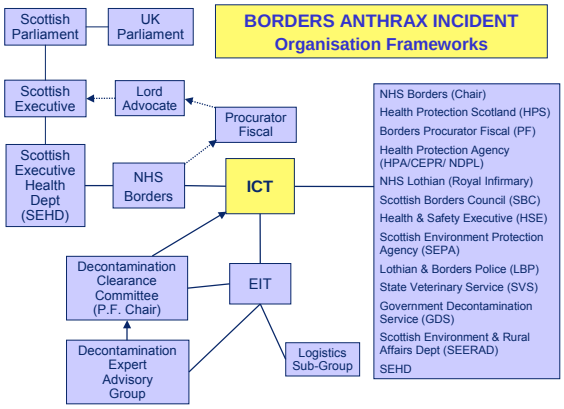
Immediate issues:

- time gap from death to confirmation
- potentially inhalational, therefore airborne anthrax – when/where/how
- uncertainties – continuing risks to public
- lack of precedents and local/UK experience
- background of US deliberate release cases
- "legal" investigation (Procurator Fiscal)

Immediate response:

- Incident Control Team (ICT) convened NHS Borders/HPS/HPA/GDS etc.
- Environmental Investigation Team (EIT)
  – subgroup to investigate possible sources of anthrax

BORDERS ANTHRAX INCIDENT Organisation Frameworks



INCIDENT RESPONSE Framework & Priorities

Incident Management Process

Investigation of Case
– history prior to illness
– risk factors/activities

Generate
exposure hypotheses

Identify
potential contamination sources for investigation

Risk Analysis Process

Risk Assessment
- identification of those "exposed"
- ongoing risks to"community" from airborne contamination?

Risk Management
- agree criteria and measures for minimising ongoing risks
- isolation of suspect site
- prophylaxis of "at risk" contacts

Risk Communication
- family/friends/contacts
- neighbours
- local rural community
- wider Borders/Scotland/UK
- politicians
- press/media
- international networks (WHO etc)

CASE INVESTIGATION

Case History

PH – AML in remission
5 July – fever, cough
6 July – slight improvement
7 July – breathless, headache product. cough, rash, collapse, septicaemia
8 July – death

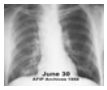
PM – haemorrhagic septicaemia, mediastinal haemorrhage

Blood culture
– *Bacillus species* – local labs. suspect skin contaminant
– review by HPA NDPL confirms *B.anthracis* – unknown strain

Uncertainties
– 1 month gap
– unable to access PN personal effects diary/ laptop
– 2nd hand information
– conflicting accounts and "evidence"

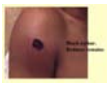
Route of infection unclear

Risk Factors & Activities
- Rural woodland home - ***Black Lodge*** - workshops and garden
- woodworker and musician
- made musical instruments
- recently taken up drumming, attended drumming courses etc.
- made his own *Djembe* drum using unknown animal skin - badger/deer?
- recently "remade" drum-head with new goat skin hide?
- 2 July attended a local drumming workshop
- 4 July attended regular local drumming class



Inhalational Anthrax

Cutaneous Anthrax



(CDC. www.bt.cdc.gov/agent/cutaneous.asp)

INVESTIGATION HYPOTHESES

Primary Hypothesis

Exposure to *B. anthracis* spores at Black Lodge, during remaking of Djembe drumhead - shaving animal hide

- Feb 2006 - New York drummer case
  - exposure associated with shaving a goat-skin for a new drumhead
- History of PN making a Djembe drum and recently making a new drumhead with (possibly) a goat-skin
- PN took advice from drumming coach on shaving a goat-skin hide
- Family suggested PN worked on hide in bedroom at Black Lodge


The New York Times

New York City Man Has Inhalation Anthrax, Officials Say

A 44-year-old New York City man contracted inhalation anthrax last week from working with untreated animal hides in the first naturally occurring case of the illness in the United States in 30 years, officials announced yesterday. The case led officials to give antibiotics to three other people as a protective measure and to search two buildings in Manhattan and Brooklyn last night....

Published: February 23, 2006

INVESTIGATION HYPOTHESES

Secondary Hypotheses

Exposure via environmental contamination

- gardening/composting
- animal contact/rescues
- contaminated private water supply at Black Lodge - PN recently dug new drinking-water well

Exposure via contact with other drums/hides used for drums

- contact with other drums at local drumming classes
- drums and spare goat hides brought to UK from Guinea, West Africa by drumming school owners

INVESTIGATION STRATEGY

Procurator Fiscal/Police Investigation

Clinical Investigation

Review of case history (CDC/Emory State Uni)

- Atypical inhalation "anthrax haemorrhagic pneumonia"

Review of histopathology CDC - Jan 2007

- imunohistochemistry finds bronchiolar macrophages +ve for *B.a.* antigens - supports inhaled exposure

Environmental Investigations

Black Lodge
Environmental sampling

Drumming Activities
Sampling of:

- drums
- hides
- properties (S/E)
- vehicles

ENVIRONMENTAL INVESTIGATIONS

Black Lodge

HPA – NDPL

- Forensic sampling

Sabre -VLA

- Characterisation

- Surfaces/dust/air
- House
- Wood workshop
- Garage/metalshop
- Garden
- Vehicles
- Bat corpse
- Water supply

ENVIRONMENTAL INVESTIGATIONS

Drumming Activities

Stage 1 - HPA

- ***Smailholm*** – garage/drums
- ***Belford*** house (England), drums removed to Porton
- ***Cumbria*** (England) - goat hide and drum

Stage 2 – Sabre/HPA

- ***Smailholm***
  - house/garage
  - Village Hall
- ***Belford***
  - house/vehicle/more drums
  - neighbouring houses (door mats)

ENVIRONMENTAL SAMPLING RESULTS

Cumbria (England)

- Drum + goat skin
  All negative

Black Lodge (Scotland)

- HPA – 51 samples
- Sabre – 113 samples
  All negative (including the bat)

Belford (England)

- *B. anthracis* cultured from from drums, one (goat)hide, bedroom floor/rug – PN strain (plus others)
- PCR +ve evidence wide-spread in house and vehicle

Smailholm (Scotland)

- Village Hall – cultures +ve from soft chairs, floor/brooms and more PCR +ve surfaces
- Garage floor - culture positive and PCR +ve surfaces
- Farmhouse - PCR +ve surfaces but all cultures –ve
- cultures indistinguishable from PN strain

RISK MANAGEMENT OF CONTAMINATED PROPERTIES - THE PLAN

Decontamination Decision Processes (Scotland)

Issues to resolve

- interpretation of culture and PCR results
- designation of "contaminated" and "uncontaminated" properties
- agree decontamination and final clearance criteria
- appraisal of decontamination methods
- obtain expert advice from range of sources
- select final decontamination process
- select contractor

"Clearance" Committee created to advise ICT

– "Lay" chair – Procurator Fiscal

Joint (S/E) "Expert Advisory Group" Created

Provided with findings and advice requested on decontamination options

- US EPA/CDC
- HPA – NDPL
- Deutsch Bundeswehr
- GDS

RISK MANAGEMENT OF CONTAMINATED PROPERTIES – THE REALITY

Problems

- Need for a defensible rationale and proportionate decision on decon.
- Lack of definitive published evidence and guidance for management of domestic "natural" anthrax contamination
- Range of opinions from "Expert Advisory Panel"
- Concerns over setting "precedents" for "clearance" criteria in UK
- Political dimension to decontamination decisions (Scotland v. England)

Solutions

Properties

- Smailholm Hall and garage, Belford house all designated as "contaminated"
- "Precautionary approach" to clearance standard – *"no detectable viable spores"* (by characterisation sampling)
- "Precautionary approach" to decontamination method based on "expert group"advice
- Reviewed "published" recommendations - NAS report, 2005 cited "Chlorine Dioxide" as "the standard"
- Consulted decontamination operators (via GDS) on practical options

Drums

- Contaminated drums decontaminated by HPA-NDPL using formaldehyde

DECONTAMINATION SOLUTION

Smailholm Hall and Garage

Porous and non-porous surface contamination, no airborne spores detected *but* potential site of fatal inhalation exposure by PN.

Options considered

- porous surfaces – remove for disposal/external decon.
- non- porous – liquid decontamination +/- HEPA vacuuming
- or gas/vapour fumigation to cover all surfaces plus air spaces

Final Decision

Precautionary approach in view of history, Hall being a public building and complications of disposal of furnishings (concern re: hall tapestry).

- Gas/vapour fumigation as method of choice chlorine dioxide as agent of choice – characteristics, penetration of porous surfaces, track record and NAS (2005) recommendation for public facility decontamination
- Contract awarded to Sabre Technologies.

March 2007
Decontamination of Smailholm Village Hall and Garage

Planning & Logistics
(Sabre/GDS/NHS Scotland)

- transport of specialist vehicles, equipment & personnel

Sabre Deployment in UK

- local logistics, practicalities
- community liaison
- media, politicians




March 2007
Decontamination of Smailholm Village Hall and Garage

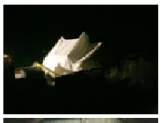
Complications

- the wind/weather
- bring your own clips!
- driving people "potty"
- placating the natives

Final Clearance

- process validation - 9000 ppm hours CT minimum achieved
- 10^6 *B.atrophaeus* spore strips all negative
- verification re-sampling - all samples negative for culture and PCR. (HPA-NDPL)




Summary

July 2006

- 50 year old man, living in rural Scottish Borders, died of septicaemia, aetiology unknown

August 2006

- *Bacillus anthracis* of previously unknown type isolated by HPA-NDPL from a blood culture taken pre-mortem, pre-antibiotic therapy

August – January 2007

- contaminated drums and 3 contaminated properties identified
- investigation concluded that the case was inhalational anthrax and that the most probable route of exposure was inhalation of anthrax spores associated with playing or contact with contaminated West African Djembe drums imported from Guinea, at Smailholm, Scottish Borders.

March 2007

- 2 properties in Scotland, contaminated with *B. anthracis* spores, successfully decontaminated using gaseous chlorine dioxide, courtesy of Sabre (US) (and GDS)
- drums decontaminated with formaldehyde by HPA.

Issues Raised and Lessons Learned

- New experience for many involved
  - level of uncertainties made decisions problematic and encouraged a generally "precautionary approach"
- Complex investigation of a deceased case – uncertain/inaccurate history – unclear role of police
- No UK benchmarks for investigation and management of a "natural" human inhalational anthrax incident
- Lack of published evidence base for environmental investigation of domestic property
- Debate over sampling strategy - forensic *vs* characterisation
- Lack of published decontamination criteria for decision making

Issues Raised and Lessons Learned

- Variations in US/UK microbiological protocols and PCR test result interpretation created complications
- Complex multi-agency incident management organisation - committee approach vs "executive role" (Incident Commander)
- Complex and challenging task to co-ordinate disparate agencies but in general worked well
- Investigation and management strategy was not seriously contested
- Public (and political) reaction was generally calm and proportionate

Reflections

- Did we investigate far enough or too far?
  - where else had the contaminated drums been?
  - how far should we have looked for spores?
- Was the risk management strategy proportionate and reasonable?
  - anthrax is "everywhere" naturally – isn't it?
- Was it all cost effective?
  - were the financial (tangible) costs reasonable
  - were the intangible costs justified - collateral damage to individuals livelihoods, communities, relationships and professional reputations

Recommendations

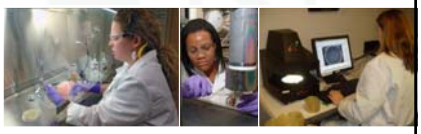
- Improve published evidence base for environmental investigation of "natural" anthrax
- Improve published evidence base and guidelines for incident management and decontamination
- Enhance environmental investigation and decontamination capacity in UK
- Improve understanding of background anthrax contamination and background exposure (sero-prevalence data) in UK
- Investigate and quantify risk associated with West African goat hides and drums
- Agree risk communication messages for "natural" (non-deliberate) release inhalational anthrax risk

Acknowledgements

- US EPA
- US CDC /Emory University School of Medicine
- HPA – NDPL (UK)
- GDS (UK)
- Sabre Technologies
- HSE (UK)
- SVS and VLA (UK)
- All other members of the Expert Advisory Group
- Members of the ICT, EIT, Clearance Committee and Logistics Groups
- The family of PN and community of Smailholm, Scottish Borders

NHSRC's Systematic Decontamination Studies

Shawn P. Ryan, Joe Wood, G. Blair Martin, Vipin K. Rastogi (ECBC), Harry Stone (Battelle)



August 17, 2007

Motivation

- EPA's National Homeland Security Research Center (NHSRC) was formed after the events of 9/11 and the anthrax letter incidents in the fall of 2001 to:
  - provide responsive expertise and products based on scientific research and evaluations of technology that can be used to prepare for, and recover from, public health and environmental emergencies.
- NHSRC's Decontamination Research Area mission is to provide expertise and guidance on the selection and implementation of effective decontamination technologies for indoor and outdoor CBRN event scenarios and to provide the scientific basis for a significant reduction in the time and cost of decontamination events.

Decon Program Area Overview

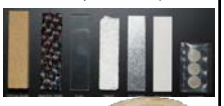
- Research Process:
  - Decontamination demonstrations (e.g., chamber and field studies)
  - Decontamination technology application studies (e.g., generation rates, material/equipment compatibility, containment)
  - Technology evaluations (e.g., TTEP, systematic decontamination studies)
  - Agent Fate (e.g., persistence, penetration)
  - Efficacy test methods
  - Decontamination method development

Presentation Overview

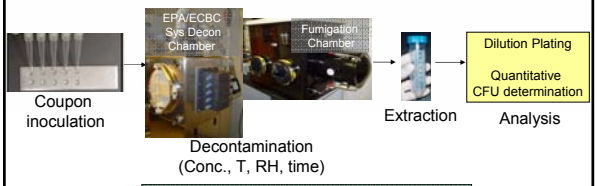
- Matrix effects on the inactivation of *B. anthracis* Ames, avirulent *B. anthracis* NNR1Δ1, *B. subtilis*, and *Geobacillus stearothermophilus*
- The lack of a correlation of biological indicators (BIs) results and inactivation of spores on building materials in fumigation studies
- Importance of controlling process parameters in efficacy studies
  - Effect of RH on fumigation results with chlorine dioxide
- Preliminary results for decon of chemical warfare agents and TICs with chlorine dioxide gas
- Ongoing efforts

Systematic Decontamination Studies

- Promising technologies are investigated to determine efficacy and decontamination kinetics as a function of:
  - Technology operating conditions (concentration, time, temperature, RH)
  - Materials (actual building materials)
  - Agents
    - Spore-formers (*B. anthracis* and surrogates)
    - Vegetative bacteria (*Y. pestis*, *F. tularensis*)
    - Viruses (smallpox, avian influenza)
    - Biotoxins (ricin, botullinum)
    - Chemical agents and TICs
- Two-phased approach:
  1. Environmental persistence (for non-spores)
  2. Decontamination Kinetics



Systematic Decontamination Studies: General Approach (Spores)

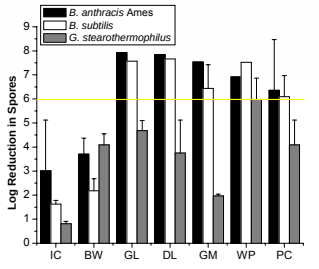


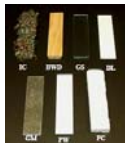
$$\text{Efficacy} = \log_{10} \frac{\text{Positive Control}}{\text{Test Coupons}}$$

Average number of viable organisms or amount of active toxin

Impact of Material Type on Log Reduction: Bioquell Hydrogen Peroxide Vapor (HPV)

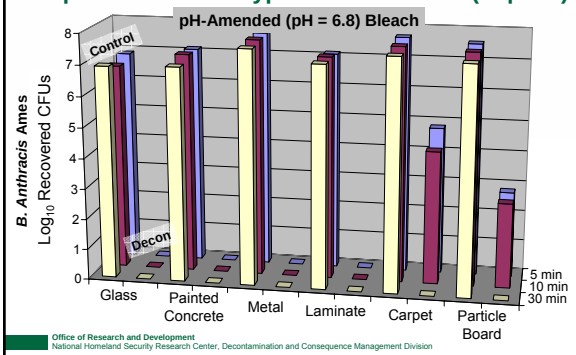
>1000 ppmv, 20 min, 40-91 % RH, 22-38 ºC





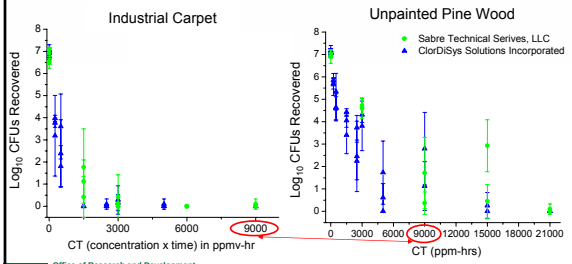
IC = Industrial Carpet
BW = Bare Wood
GL = Glass
DL = Decorative Laminate
GM = Galvanized Metal Ductwork
WP = Latex-painted Wallboard Paper
PC = Painted Concrete

Impact of Material Type on Kill Kinetics (Liquids)



Impact of Material Type on Kill Kinetics (Gas)

EPA/ECBC Studies: Decontamination of *B. anthracis* NNR1Δ1 spores with Chlorine Dioxide Gas (3000 ppmv, 75ºF, 75% RH)



Systematic Decon: Kill Kinetics (Gases/Vapors)

EPA/ECBC Studies: Decontamination of *B. anthracis* NNR1Δ1 spores with Chlorine Dioxide Gas (3000 ppmv, 75ºF, 75% RH)

- Time required for a six-log reduction (6-LR) in viable spores observed to be a strong function of material type
  - Observed times ranged from 40 – 250 min @ 3000 ppmv ClO_2 (75ºF, 75%RH)
- Order of increasing CT required to achieve a 6-LR observed to be independent of concentration:

Low CT → High CT

carpet << painted concrete < painted I-beam steel << painted wallboard < ceiling tile < wood

Building Material Decon and the Use of BIs

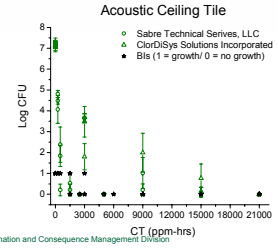
- Biological indicators (BIs) or spore strips:
  - A specific titer of a non-virulent *bacillus*-species spore type inoculated/dried onto standardized material (e.g., paper or stainless steel) and packaged in sterile envelopes (e.g., Tyvek® or glassine)
    - BIs: ~10^6 spores of *B. atrophaeus* or *Geobacillus stearothermophilus* on stainless steel disks in Tyvek® pouches
    - Spore strips: ~10^6 spores of *B. atrophaeus* on filters paper in glassine
  - Used extensively in past decontamination events to potentially provide an indication of efficacy of building decon post fumigation (prior to clearance sampling)
  - Designed to provide qualitative results within 7 days (growth/no growth)

Building Material Decon and the Use of BIs

- BIs consistently resulted in "no growth" well before a 6-LR or no growth was achieved on building materials
  - fumigation with chlorine dioxide (e.g., ceiling tile shown below) from EPA/ECBC systematic decontamination studies

BI: ~10^6 B. atrophaeus spores on stainless steel disk (APEX)

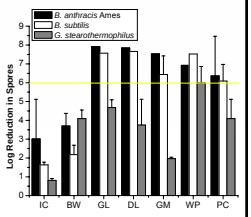
Material coupons



Building Material Decon and the Use of BIs

BIOQUELL HPV
>1000 ppmv, 20 min, 40-91 % RH, 22-38 ºC

	Indicator (organism)	Day 1 (S1, S2, S3)	Day 7 (S1, S2, S3)
Controls	*B. subtilis*	+, +, +	+, +, +
Controls	*G. stearothermophilus*	+, +, +	+, +, +
Controls	*B. atrophaeus*	+, +, +	+, +, +
Decon	*B. subtilis*	-, -, -	-, -, -
Decon	*G. stearothermophilus*	-, -, -	-, -, -
Decon	*B. atrophaeus*	-, -, -	-, -, -



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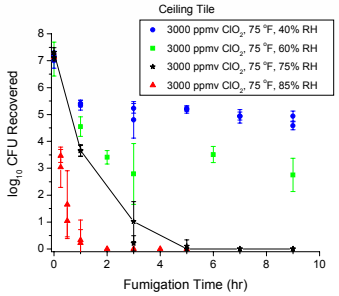
GL = Glass
DL = Decorative Laminate
GM = Galvanized Metal Ductwork
WP = Latex-painted Wallboard Paper
PC = Painted Concrete

Impact of Operating Conditions on Efficacy

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



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

Importance of Controlling Operating Conditions

- Effectiveness of chlorine dioxide for the inactivation of *B. anthracis* Ames on all matrices studied is very highly dependent on RH
- **Important to have tight control of process parameters in efficacy studies to ensure that studies are valid for actual technology application**

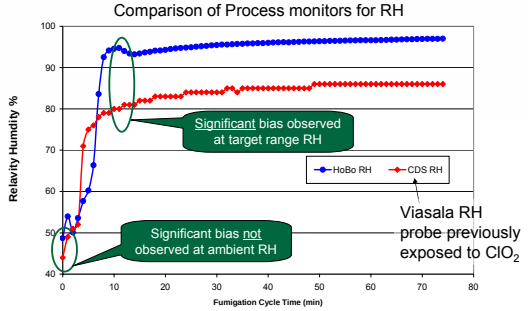
	Results for *B. anthraics* Ames with Sabre ClO_2 (3000 ppmv)					
	20 min (>90% RH, ~75 ºF) CT = 1000 ppm-hr		3 hr (>90% RH, ~75 ºF) CT = 9000 ppm-hr		4 hr (>90% RH, ~75 ºF) CT = 12000 ppm-hr	
	Control (%CV)	Decon (%CV)	Control (%CV)	Decon (%CV)	Control (%CV)	Decon (%CV)
Particle Board	4.55E+07 (49.9)	0.00E+00	3.53E+06 (18.9)	0.00E+00	na	na
Industrial Carpet	6.27E+07 (5.9)	0.00E+00	4.31E+07 (19.6)	0.00E+00	na	na
Glass	7.32E+07 (11.0)	0.00E+00	3.90E+07 (24.2)	0.00E+00	na	na
Painted Concrete	8.13E+07 (34.7)	0.00E+00	3.89E+07 (30.3)	3.30E+03 (1 rep)	na	na
Galvanized Metal Ductwork	2.35E+07 (81.7)	0.00E+00	4.68E+06 (42.7)	0.00E+00	na	na
Decorative Laminate	7.63E+07 (29.2)	0.00E+00	3.58E+07 (33.0)	0.00E+00	na	na
Blown Cellulose Insulation	na	na	4.83E+07 (44.1)	5.07E+02 (63.9%)	5.74E+07 (19.0%	0.00E+00

Environmental Conditions Measurement QA

- Quality assurance (QA) of process monitoring is essential
- Concentration measurement of many reactive gases is not trivial
  - $H_2O_{2(V)}$ undergoes rapid homogeneous and surface decomposition
  - No standard method for measuring (sampling) ClO_2 concentration in air at high ppmv concentrations exist
    - Difficult to speciate between ClO_2 and other relevant chlorine species
- Reactive gases may interfere with the monitoring of other process parameters (e.g., RH)

Environmental Conditions Measurement QA

Comparison of Process monitors for RH

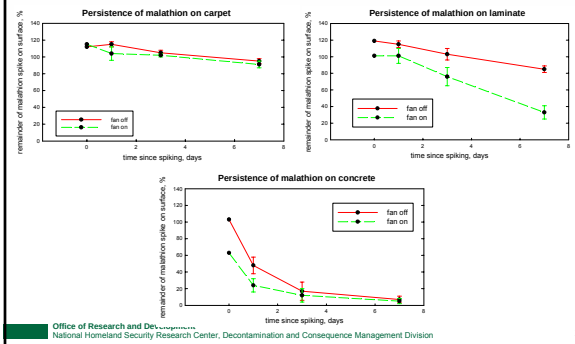


Decontamination of Materials for CWAs and TICs

- Investigation of persistence of toxic industrial chemicals (TICs) and chemical warfare agents (CWAs) on building material surfaces
  - TICs: malathion, dimethyl methylphosphonate (DMMP), TNT
  - CWAs: sarin (GB), thickened soman (TGD), VX
  - Materials: concrete, galvanized metal, decorative laminate, carpet, ceiling tile
- Decontamination of materials contaminated with TICs (malathion and DMMP) using Sabre ClO_2
- Decontamination of materials contaminated with CWAs using Sabre ClO_2, liquid ClO_2, or bleach

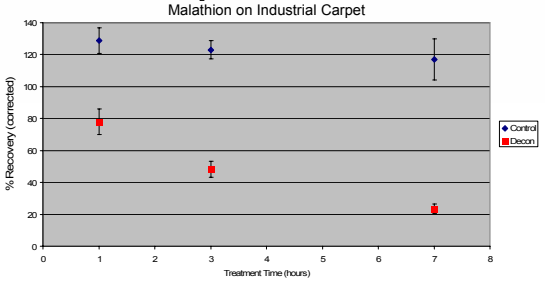

Testing at Battelle (BBRC, West Jeffersen, OH)

Persistence on Materials: TICs



Decontamination of Materials: TICs

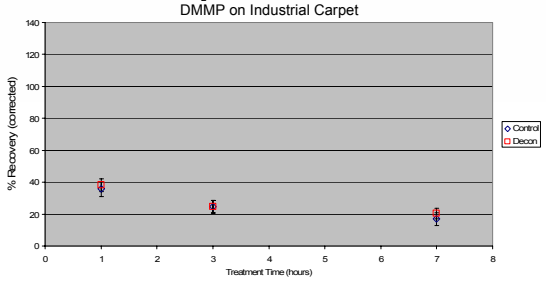
Sabre ClO_2 (~3000 ppmv, 75ºF, 79% RH)
Malathion on Industrial Carpet



Note: Observed conversion to malaoxon

Decontamination of Materials: TICs

Sabre ClO_2 (~3000 ppmv, 75ºC, 81% RH)
DMMP on Industrial Carpet



Decontamination of Materials: CWAs

- Decontamination studies with Sabre chlorine dioxide (3000 ppmv)
  - VX on galvanized steel, decorative laminate, industrial carpet
  - TGD on galvanized steel, decorative laminate, industrial carpet
  - GB on industrial carpet
- Data analyses are on-going
  - Preliminary results suggest:
    - VX decomposition complete within 1 hr; residual VX below DL on all surfaces
      - Similar results for malathion; perhaps higher decomposition of VX
      - EA-2192 not analyzed
    - TGD and GB results do not preliminarily appear too different from controls
      - For GB, similar results as those observed for DMMP

Other Recent (Preliminary) Research Results

- Ricin toxin and vaccinia virus (smallpox vaccine strain) can be highly persistent on painted concrete and galvanized metal ductwork; extent of study was 14 days
  - Matrix effect observed
  - Effect of RH
- Complete inactivation of ricin toxin and vaccinia virus (smallpox vaccine strain) using ClO_2 gas on all materials (porous and non porous) investigated was observed at ~150 ppmv-hr (200-300 ppmv for 30 minutes at 75ºF, 75% RH); lowest CT studied
- Chlorine dioxide liquid (Exterm-6, 1000 ppm) and pH-amended bleach inactivated vaccinia virus on all materials (porous and non porous) studied within a 10-minute contact time

Summary

- The overall efficacy and CT required for the inactivation of spores is highly dependent upon material type for all technologies investigated
  - Chlorine dioxide gas and liquid
  - pH-amended bleach
  - Formaldehyde vapor
  - Hydrogen peroxide vapor
- Biological indicators do not correlate with building material decontamination or required minimum CT for past building chlorine dioxide fumigations for *B. anthracis* spores
- Decontamination efficacy can be a very strong function of environmental conditions (e.g., effect of RH on decontamination using ClO_2)
  - Proper QA of operational parameter measurements is essential

Summary

- Chlorine dioxide will react with malathion (observed conversion to malaoxon); no observed reaction with DMMP on surfaces studied
- Analyses of chemical agent results are ongoing
  - Preliminary results suggest complete reaction with VX (1hr @ ~3000 ppmv)

Additional Ongoing Systematic Decontamination Efforts

- Systematic decontamination studies of methyl bromide (MeBr) fumigation for the inactivation of *B. anthracis* Ames on building materials
  - Effect of RH, concentration, contact time, material, spore type
- Systematic decontamination studies of Steris VHP® fumigation for the inactivation of *B. anthracis* Ames on building materials
  - Effect of concentration, contact time, material, and spore type
- Development of BIs that are better correlated to building material fumigation with chlorine dioxide (and other gases/vapors?)
  - Spore type, titer, and "standard" material

Additional Ongoing Systematic Decontamination Efforts

- Investigation of liquids for the decontamination of *B. anthracis*, ricin toxin, and vaccinia virus on materials
  - Generation of kill kinetics data
- Determination of persistence (ambient bldg.) and decontamination kinetics
  - Agents: *B. anthracis*, *Y. pestis*, *F. tularensis*, Botullinum toxin
  - Porous and non-porous materials
  - Fumigants: Chlorine dioxide and hydrogen peroxide

Additional Ongoing Systematic Decontamination Efforts

- Comparative efficacy study for *B. anthracis* Ames (NHSRC and OPP)
  - Joint effort between NHSRC and OPP
  - Efficacy of technologies determined by three methods:
    - AOAC sporicidal activity of disinfectants test (AOAC 966.04)
    - Three-step method, as modified by EPA/OPP
    - TTEP SOPs (Battelle) for the quantitative determination of efficacy on building materials
  - Technologies:
    - Fumigants: Sabre ClO_2, HP Technology, MeBr
    - Liquids: pH-amended bleach (std.), Exterm-6 ClO_2, 2 TBD
  - Parameters:
    - CT
    - Spore types and carriers

Improvement and Validation of Lab-Scale Test Methods for Sporicidal Decontamination Agents

Presented To:

2007 Workshop on Decontamination, Cleanup, and Associated Issues for Sites Contaminated with Chemical, Biological, or Radiological Materials

Stephen F. Tomasino, Ph.D., Senior Scientist
U.S. EPA, Office of Pesticide Programs
Biological and Economic Analysis Division
Microbiology Laboratory Branch
Fort Meade, Maryland

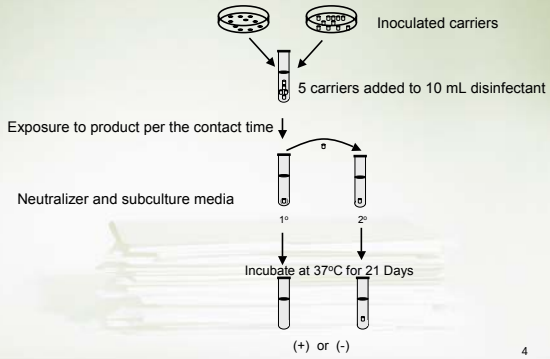
EPA Regulatory Method Activities

- **Test Method Research**
  - Modifications to AOAC Method 966.04 (Sporicidal Efficacy)
  - Quantitative method evaluation and development
  - Surrogate studies
  - **TSM validation**
  - Related initiatives involving bio-threat agents
- OMA Chapter 6: Editorial
  - Use-Dilution Methods
  - Tuberculocidal Activity
  - Germicidal Spray Products
- Chapter 6: Procedural
  - Use-dilution carrier count procedure
  - New recovery medium for *Mycobacterium*
- EPA/AOAC Contract Tasks
- Biofilm methods

Regulatory Standard for a Sporicidal Claim

- AOAC Method 966.04
- Qualitative assessment
- More relevant to clinical
- Technique sensitive
- Test challenge = *Bacillus subtilis* and *Clostridium sporogenes*
- Hard surface (Porcelain carriers and suture loops) - 60 carriers each
- Full study = 720 carriers
- Passing result = zero carriers positive
- Conservative method

Basic Schematic for Method 966.04



Modifying Method 966.04
Priorities and Process

- Priorities
  - *Bacillus*
  - **Liquids**
  - **Porcelain**
  - .....
  - *Clostridium*
  - Liquids
  - Porcelain
  - .....
  - Suture loops
  - Gases
- Official AOAC Method Modification Process
  - Pre-collaborative studies
  - AOAC Committee M
  - AOAC General Referee
  - Collaborative study
  - Collaborative study manuscript
  - First Action method

AOAC Method 966.04
Recommended Modifications

- Replace soil extract nutrient broth with a chemically defined medium (amended nutrient agar)
- Addition of a carrier count procedure for enumeration of spore inoculum
- Establishment of a minimum and maximum spore titer per carrier: 10^5 to approx. 10^6 spores/carrier
- Addition of a neutralization confirmation procedure
- Numerous editorial changes

Collaborative Study
Modifications to Method 966.04

- A collaborative study (4 labs) was undertaken to compare the current and modified methods and determine if the methods are statistically equivalent.
- Three medium/carrier combinations were compared:
  1) soil extract nutrient broth/porcelain carrier (current method)
  2) nutrient agar amended with 5 µg/mL manganese sulfate/porcelain carrier
  3) nutrient agar amended with 5 µg/mL manganese sulfate/stainless steel carrier
- Carrier counts, HCl resistance, efficacy, quantitative efficacy, and spore wash-off were the test variables.

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Collaborative Study
Conclusions

- The data strongly indicate that the modified methods, when used in place of the current method, provide a similar outcome for effective and less effective formulations.
- The amended NA procedure, the spore enumeration procedure, the target carrier count, and the neutralization confirmation procedure were adopted as official first action procedure modifications to method 966.04.
- Although the data support the use of stainless steel for *B. subtilis*, due to the current use of porcelain carriers for testing *Clostridium sporogenes*, the use of porcelain carriers was retained until stainless steel can be evaluated as a replacement carrier material for *Clostridium*.
- Collaborative study and new method have been published: Tomasino, S.F. and Hamilton, M.A. (2006) *J.AOAC* Int. **89**, 1373-1397

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Outcome: The Published AOAC Methods

- AOAC Method I
  - Original method
  - Available in 18th ed of AOACI OMA
  - Available on-line
  - Unedited
  - Contains the *Bacillus* and *Clostridium* components
  - Contains the porcelain and suture loop components
- AOAC Method II
  - Revised method
  - Available in 18th ed of AOACI OMA
  - Available on-line
  - Edited and modified
  - *Bacillus* and porcelain components only
  - *Useful for other spore formers, suture loops and testing gases*

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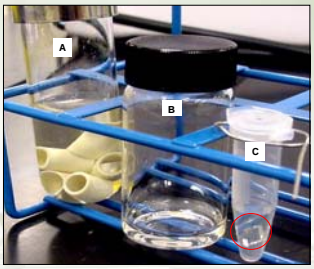
Research on Quantitative Test Methods



Carrier type and volume of sporicide tested for AOAC Method 966.04 (see A), ASTM E 2111-00 (see B), and TSM (see C). Circle in C indicates carrier.

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Quantitative Protocols for Sporicides
Selection of Methods

1. ASTM E 2111-05 (QCT-1): Standard Quantitative Carrier Test Method
2. ASTM E 2197-02 (QCT-2): Standard Quantitative Disk Carrier Test Method
3. Sagripanti, J. L., and Bonifacino, A. 1996. Comparative Sporicidal Effect of Liquid Chemical Germicides on Three Medical Devices Contaminated with Spores of *Bacillus subtilis*. Am. J. Infect. Control 24:364-371.

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Method Comparison Study
Test Design and Data Analysis

- Each lab (3) conducted each test procedure (3) on each chemical (3) three times.
- Log reduction of surviving spores following treatment was the primary response to be analyzed.
- Statistical analysis determined means and variances; ANOVA was conducted to estimate method reproducibility (within and between laboratory variation).

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Log Reduction Values for ASTM E 2111-05 and Three Step Method

Test Chemical	ASTM E 2111-00			Three Step Method			p^a
	LR	SD_r	SD_R	LR	SD_r	SD_R	
Sodium hypochlorite (3000 ppm with adjusted pH)	7.1	0.36	0.39	7.5	0.27	0.48	0.28
Sodium hypochlorite (3000 ppm with unadjusted pH)	3.6	0.66	1.12	1.2	0.26	0.26	0.053
Hydrogen peroxide & peracetic acid	6.7	0.45	0.52	7.3	0.25	0.75	0.25

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Method Comparison Study Conclusions

- Both quantitative methods performed in a similar fashion.
- No significant differences between control carrier counts for the quantitative methods.
- No significant differences between LR for strong or weak sporicides for the quantitative methods.
- Compared to the SD associated with other antimicrobial test methods, the ASTM and the TSM exhibited small and acceptable repeatability SD and reproducibility SD.
- Additional test method attributes were assessed.

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Additional Attributes

- Questionnaire Submitted to Analysts
  - The Protocols - use and clarity
  - Test Set-up - preparing for the test
  - Testing - performing the method, resources
  - Results - recording, compiling, and interpretation
- TSM selected for surrogate studies and validation testing
- For results of collaborative study see: Tomasino, S.F. and Hamilton, M.A. (2007) *J.AOAC* Int. vol. 90: 456-464

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Method Validation *Defined*

- "Validation of a microbiological method is the process by which it is experimentally established that the performance characteristics of the method meet the requirements for the intended application, in comparison to the traditional method." (*USP-NF, Validation of Alternative Microbiological methods, 3807-3810*)
- "Method validation is the process of proving that an analytical method is acceptable for its intended purpose." (*Green, M.J., 1996. A Practical Guide to Analytical Method Validation. Analytical Chemistry, 68: 305-309)*
- Conventional approach to method validation is desirable but not necessary. Official modifications to existing methods are also acceptable.

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Three Step Method Components

- Three fractions – A, B and C
  - Fraction A (loosely releases spores by washing)
  - Fraction B (sonication to dislodge spores)
  - Fraction C (agitation/germination of spores)
- The log reduction (LR) is the mean of control carrier $\log_{10}$ densities minus the mean of disinfected carrier log10 densities



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TSM Validation Study

- AOAC INTERNATIONAL-facilitated process
- OPP Microbiology Lab is the lead lab
- Collaborative Study Protocol
- 10 lab validation study (*8 reported*), mainly volunteers
- One microbe – *Bacillus subtilis*
- Three liquid chemicals
- Carrier type is glass
- Three replications per laboratory; nine total test days
- AOAC Method 966.04 (Method II) used as the reference method
- Launched in Fall 2006 – data analysis has been completed
- Potential outcome – a validated quantitative method for liquids on a hard surface!

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TSM Validation - Laboratory Participation
U.S. EPA OPP Microbiology Laboratory – lead lab
U.S. FDA Denver District Laboratory
U.S. FDA Winchester Engineering and Analytical Center (WEAC)
U.S. FDA Office of Science and Engineering Laboratory (OSEL) - White Oak
Advanced Sterilization Microbiology Laboratory
STERIS Corporation
MicroBioTest
ATS Labs
Bioscience Labs
Ohio Department of Agriculture

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Test Chemicals and Conditions

Test Chemical	Treatment Level and Test Parameters		
	High (LR ≥ 6)	Medium (LR 2-6)	Low (LR 0-2)
Sodium hypochlorite	▪6000 ppm ▪adjusted pH (7) ▪30 min	▪6000 ppm ▪unadjusted pH ▪10 min	▪3000 ppm ▪unadjusted pH ▪10 min
0.08% peracetic acid and 1.0% hydrogen peroxide	▪30 min	▪10 min	▪1 min
2.6% glutaraldehyde	▪180 min	▪60 min	▪10 min

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TSM Validation Test Design

Replication	Treatment and Levels	Test Method Performed	
Rep 1 (Day 1)	1. **Sodium Hypochlorite**	TSM	AOAC 966.04
	1. High 2. Medium 3. Low 4. Water Control	Yes Yes Yes Yes	Yes Yes Yes No
Rep 1 (Day 2)	2. **Peracetic acid and hydrogen peroxide**	TSM	AOAC 966.04
	1. High 2. Medium 3. Low 4. Water Control	Yes Yes Yes Yes	Yes Yes Yes No
Rep 1 (Day 3)	3. **Glutaraldehyde**	TSM	AOAC 966.04
	1. High 2. Medium 3. Low 4. Water Control	Yes Yes Yes Yes	Yes Yes Yes No

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TSM Validation Test Design
Randomization and Replication

Rep*	Random Order of Test Chemicals**									
	Lab 1	Lab 2	Lab 3	Lab 4	Lab 5	Lab 6	Lab 7	Lab 8	Lab 9	Lab 10
Rep 1	2, 3, 1	1, 3, 2	2, 3, 1	1, 2, 3	2, 3, 1	2, 1, 3	1, 2, 3	2, 3, 1	1, 2, 3	3, 2, 1
Rep 2	1, 3, 2	3, 1, 2	2, 3, 1	3, 2, 1	1, 2, 3	1, 3, 2	3, 2, 1	1, 2, 3	1, 3, 2	1, 2, 3
Rep 3	2, 3, 1	2, 3, 1	3, 2, 1	2, 3, 1	1, 3, 2	3, 2, 1	1, 2, 3	3, 2, 1	3, 2, 1	2, 3, 1

*Three total tests days per replication; one chemical class tested per day
**1 = sodium hypochlorite, 2 = hydrogen peroxide/peracetic acid, and 3 = glutaraldehyde; order within a test day will be High, Medium, Low, and Water Control.

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Measuring Method Performance
Is TSM a responsive, repeatable method?

- Method response - "efficacy-response" curves
- It is desirable for the repeatability (S_r) and reproducibility (S_R) standard deviations to be small.
- For disinfectant tests, the AOAC has issued no standards for how small is acceptably small.
- Some guidance is provided by a recent literature review showing that, for established suspension and dried surface disinfectant tests, S_r ranged from 0.2 to 1.2 with a median of 0.4 and S_R ranged from 0.3 to 1.5 with a median of 0.8 (Tilt and Hamilton 1999).
  - Tilt, N. and Hamilton, M.A. (1999) Repeatability & reproducibility of germicide tests: a literature review. *JAOAC Int.*, **82**, 384 – 389.
- It would be reasonable to claim that the S_r and S_R are acceptably small if they fall within these ranges.
- The TSM test achieved these criteria.

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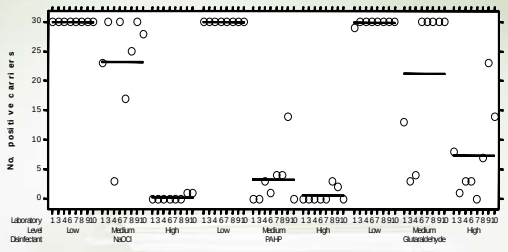
AOAC Method 966.04 – reference method
No. Positive Carriers



The horizontal line is the mean number of positive carriers for each treatment.

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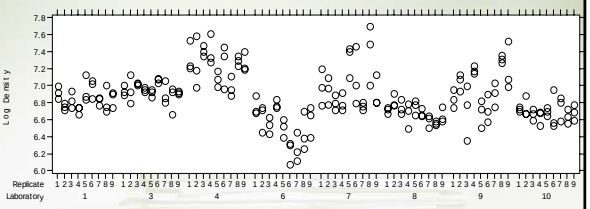
Statistical Summary
LR values for the AOAC 966.04 tests

Disinfectant	Level	Mean	SEM
Sodium Hypochlorite	Low	4.90	0.13
Sodium Hypochlorite	Medium	5.31	0.17
Sodium Hypochlorite	High	7.18	0.14
PA/HP	Low	4.90	0.13
PA/HP	Medium	6.69	0.25
PA/HP	High	7.11	0.17
Glutaraldehyde	Low	4.92	0.14
Glutaraldehyde	Medium	5.38	0.28
Glutaraldehyde	High	6.27	0.26

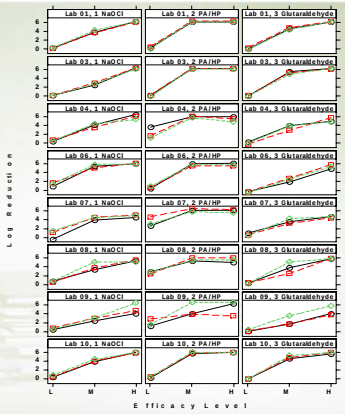
For the AOAC966.04 test, the LR values were calculated using the P/N formula (Tomasino and Hamilton, 2006 JAOAC).

TSM Validation
TSM Control Carriers

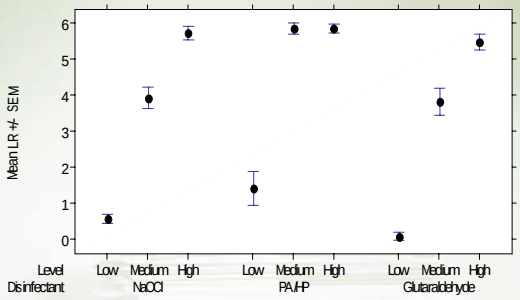


The overall mean (± SEM) was 6.86 (± 0.08). The total variance of the control carrier log density was 57% attributable to the variance among laboratories. For the mean of 3 control carriers per test, the repeatability standard deviation was 0.15 and the reproducibility standard deviation was 0.27.

TSM Efficacy Response Curves



TSM Validation LR Data - Summary of Results



Mean LR, with ± SEM error bars, for the 9 treatments, based on 24 TSM tests (3 tests in each of 8 laboratories). The SEM takes account of both inter-laboratory and intra-laboratory variation.

TSM Validation - Statistical Analysis

Disinfectant	Efficacy Level	Mean LR	SEM	Standard Deviation S_r	Standard Deviation S_R
Sodium Hypochlorite	Low	0.56	0.13	0.41	0.50
Sodium Hypochlorite	Medium	3.92	0.31	0.45	0.95
Sodium Hypochlorite	High	5.71	0.18	0.51	0.66
PA/HP	Low	1.41	0.46	0.70	1.43
PA/HP	Medium	5.85	0.16	0.58	0.65
PA/HP	High	5.85	0.13	0.64	0.64
Glutaraldehyde	Low	0.07	0.11	0.17	0.34
Glutaraldehyde	Medium	3.81	0.38	0.72	1.23
Glutaraldehyde	High	5.47	0.22	0.48	0.75

TSM Validation Study
Observations and Conclusions

- For AOAC control carriers, the overall mean (± SEM) was 5.52 (± 0.13).
- There were no obvious outliers or unexpected patterns.
- The greatest variability of LR values occurred for combinations of disinfectant x efficacy levels that had intermediate LR values.
- Analysis of the mean log density for 3 TSM control carriers per test showed that the overall mean (± SEM) was 6.86 (± 0.08) and the reproducibility SD was 0.27.
- For each test of each disinfectant, the LR was plotted against efficacy level. The resulting "efficacy-response" curves were repeatable and had the correct shape, indicating that the TSM is a responsive method.
- Other than the two PA/HP treatments, every TSM experiment produced LR values that properly ordered the efficacy levels. Not only did the LR consistently increase as the efficacy increased but the amount of increase was repeatable.

TSM Validation Study
Observations and Conclusions

- Across the 9 treatments, the TSM LR means ranged from 0.1 to 5.8. The repeatability SD ranged from 0.17 to 0.72 and the reproducibility SD ranged from 0.34 to 1.43.
- For the TSM LR, the repeatability SD values were 0.31 for treatments of low efficacy (overall LR = 0.3), 0.63 for treatments of partial efficacy (overall LR = 3.0), and 0.57 for treatments of higher efficacy (overall LR = 5.7). The reproducibility SD values were 0.43, 1.22, and 0.67 for the low, medium, and high efficacy treatments, respectively.
- *Overall, the method performance data strongly support validation.*

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Next Steps

- Submit the TSM validation report (JAOAC manuscript) to AOAC – conclusions will support validation of the method (i.e., for liquids on a hard non porous surface)
- Complete modifications to AOAC method 966.04 (applicable suture loops and gaseous chemicals)
- Evaluate other carrier materials for quantitative efficacy tests
- Explore quantitative efficacy tests for non spore-forming threat agents
- Development of interactive methods

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Acknowledgements

- NHSRC – Funding for Tiers 1, 2 and 3 (Sterilant Registration Protocol Development)
- Dr. Martin Hamilton – statistical support
- Rebecca Pines – Co-Study Director for TSM
- All collaborators including FDA and ECBC
- Interagency Expert Panel on Anthrax
- AOAC International

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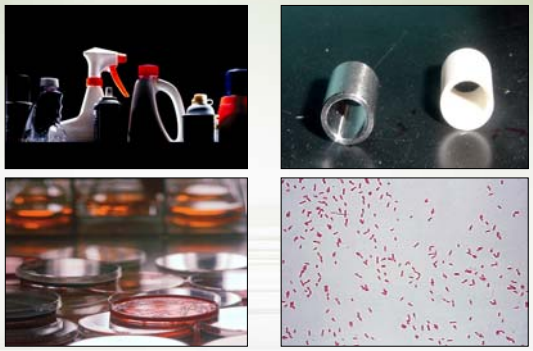
Questions/Comments?



Systematic Decon – Challenges and Successes

Vipin K. Rastogi[1], Lanie Wallace[1], Lisa Smith[1] and Shawn Ryan[2]
1. BioDefense Team, R&T Directorate, US Army – ECBC, APG, MD
2. EPA, ORD, NHSRC
vipin.rastogi@us.army.mil; 410-436-4856

Since 1917- A Tradition of Solutions.

Presented at the EPA Decon Workshop on June 21, 2007

Outline and Scope

- Overall Goal
- Experimental Matrix
  - Variables and Test Method for Efficacy of Fumigants
- Challenges
  - Sample Number and Complex Porous Building Materials
  - Quantitative test method?
- Key Strategies
  - Novel Sampling Port for Time-course Studies
  - High-throughput Processing and Semi-automation
- Fundamental Issues, Challenge Levels, Bioburden, Spore Recovery
- Kill Kinetics, D-values, Estimated D6 and Observed D6 and Material Effect
- Comparative Kill Efficacy of Virulent / Avirulent and Related Simulants

Goal and Objectives

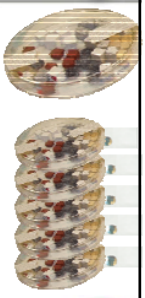
Goal - Conduct a Systematic Study on the Performance of Three Commercial Fumigant Technologies for their Efficacy in Decontamination of Building Interior Surfaces Contaminated with BW Agent or Selected Surrogates

Specific Objectives:

- Kill kinetics and D values for CD gas in its sporicidal action against *Bacillus anthracis* spores
- Effect of bioburden on recovery and kill efficacy of VHP and CD gas
- Appropriate surrogate for virulent Ames strain

Experimental Design

- Variables
  - Six building surfaces – carpet, painted wallboard, ceiling tile, painted I-beam, unpainted pine wood, and unpainted cinder block
  - Five replicates/material (TEST) and Five positive controls and Five negative controls
  - Five time points
  - Two CD gas technologies, Sabre and ClorDiSys and One VHP, Steris
  - Four CD concentrations, 500, 1000, 1500, and 3000 ppmv
  - Three plates/dilution (spread-plating) and 1/3rd sample volume pour-plated



Challenges

Per Time Point		Per 5 Time Points
6 Types of Test Coupons	30	
+ 6 +ve + 6 -ve Coupons	42	210 Coupons
50-mL Tubes (10-mL extractant) Sonicated 10-min + Vortexed 2-min	42	210 50-mL tubes (2.1 L extractant)
2 Dilutions/test sample & 1 Dilution each from controls	60 12	300 Dilutions tubes/test sample 60 Dilution tubes/controls
3 Plates/dilution	180+12 192	900 PLATES/Test samples + 180 PLATES/control samples

- Processing 210 coupons/experiment
- Spore enumeration in 'dirty' samples of ceiling tile and wallboard

Quantitative Test Method

- Which Method was Available for Processing 210 Coupons?
  - None! Most methods at the time processed 12-24 samples using liquid disinfectants!
  - 'Single Tube Method' (STM) conceived to meet the challenge (has been optimized and extended to include surface sampling with a DTRA funded program)
  - Spore extraction achieved in 10 mL BPW (0.5%) in a 50 mL sterile tube with 10 min sonication and 2 min vortexing
  - Percent recoveries improved with the inclusion of 0.01% Tween 80 and inoculation of 7-logs spores in a 50 µL volume as 7 mini droplets
  - Key attributes include spore enumeration even in the presence of pulverized material debris released from the ceiling tile and wallboard
  - Very low limit of detection of viable spores (1-5) because 1/3rd of the sample volume analyzed using pour plating
  - The CD gas concentration monitored by two independent methods, real-time (CDS, Inc.) and titration method (Thanks to Mr. John Mason)
  - The cycle improved by maintaining a constant RH throughout the run

Key Strategies

Fumigation Chamber

Sampling Port

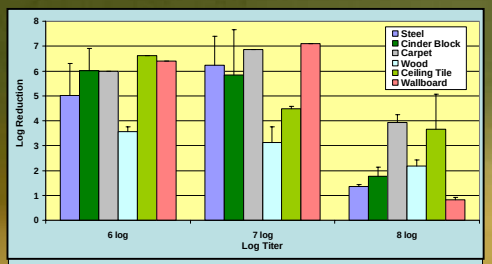
CDS GMP Generator

Automated Plate pourer

- Novel sampling port
- GMP quality chamber
- High capacity vortexer
- Multiple sonicators
- Automated plate pourer
- Plate counters
- Highly competent team of analysts
- Careful planning and many long shifts

Fundamental Issues – Titer Level & Efficacy

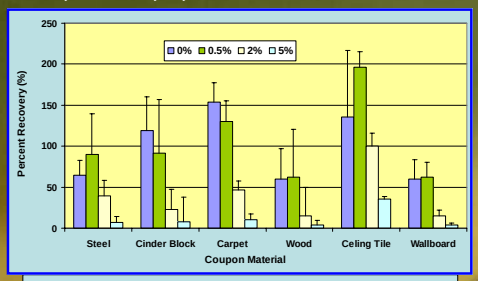
- What should be the initial titer challenge level for decon?
  - 8.4 mg/L (3000 ppmv) ClorDiSys CD gas for 3 hour with 75% RH
  - Past studies used a range between 5 and 8 logs applied as single spot or multiple spots



- Efficacy is a function of spore loading as a single spot!
- CD gas efficacy significantly reduced when 8 log spore tested

Fundamental Issues – Bioburden & Recovery

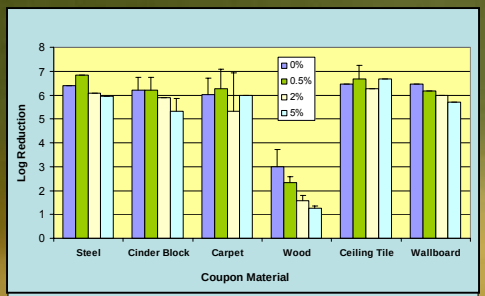
- Should any bioburden be used with spore prep for efficacy studies?
  - Serum protein has been used for liquid disinfectant testing (5%)
  - Recovery and/or efficacy may be affected



- Reduced spore recovery when 5% serum included!
- 0.5% serum was included in all later studies

Fundamental Issues – Bioburden & Efficacy

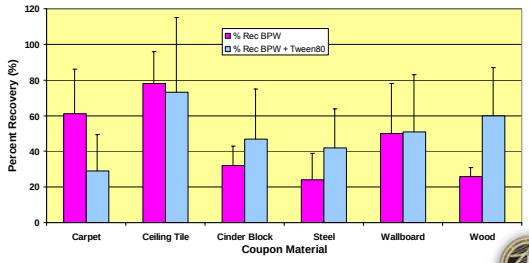
- Is efficacy affected by increasing levels of bioburden?
- 9000 ppmv.hr CD gas (ClorDiSys) with 75% RH



- No significant impact on efficacy by increasing bioburden!
- 0.5% serum included in all further studies

Fundamental Issues - Spore Recovery

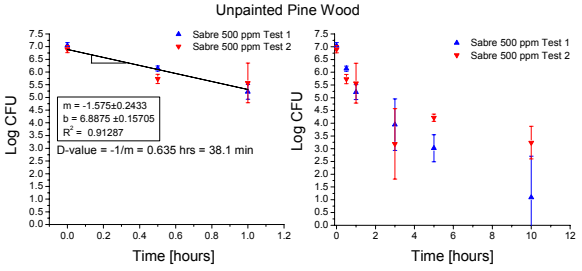
- When spore inoculated as one spot, recoveries variable and generally low
- Two changes significantly improved spore recovery, inoculation as seven mini-drops and inclusion of tween 80 (0.01%)



Microbial Kill & Efficacy criteria – Few Definitions

- Sterilization is removal or destruction of all viable organisms
- Disinfection is killing, removal or inhibition of pathogenic organisms
- Sanitization is reduction of microbial population to levels deemed safe, based on public health standards
- Microorganisms are not killed instantly
- D-value is defined as time it takes for a decimal reduction in the number of viable spores, i.e. if you have 10-million (7-logs) at time zero, Exposure Time required to reduce the number of viable spores to 1-million (6-logs) or 90% reduction
- CT, i.e. (concentration x time) required for achieving a 6-log-kill or ZERO positives of the post-decon sampling is another criteria for ascertaining effectiveness
- D1 value is the time it takes for the first log reduction - one measure of efficacy of a sporicidal agent. Can this D1 be used to extrapolate a D6 or time required for a 6-log reduction?
- For clearance, the ONLY accepted standard is "no growth" of environmental samples!

Spore Kill Kinetics – An Example



- Kill kinetics is non-linear and is strongly impacted by the material type
- D-values are computed from the initial linear part of the kill curve

Perspective on D values

D-values and Time Required for a 6-LR

D6 = Observed time required for a 6-LR

6xD1 = Time extrapolated from D1 for a 6-LR

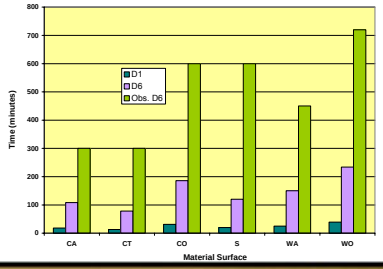
	D1	6 x D1	D6
Carpet	5.3	32.1	40
Ceiling Tile	11.7	69.9	240
Wallboard	11.6	69.6	230
I-beam Steel	9.4	56.5	130
Concrete	5.7	35.8	120
Wood	20.7	124.4	250

D1 (in minutes) for Sabre ClO_2 at 3000 ppmv

- Material type impacts the time required for initial 90% kill
- Because of the non-linearity of the kill curve, the observed time for a 6-log kill are significantly higher and is a function of material type

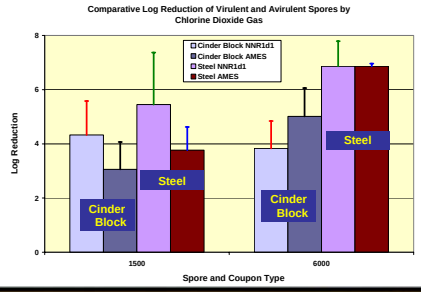
Estimated vs. Observed D6 Values

- ClorDiSys CD gas at 500 ppmv with 75% RH
- Since the kill curve is non-linear, observed CT required for 6 log kill is significantly high
- The required CT for a six log kill is a strong function of the test material type



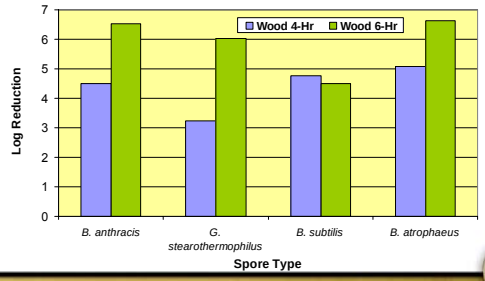
Avirulent vs. Virulent Ames Spores

- 3000 ppmv ClorDiSys CD gas for 30 and 120 min
- Avirulent NNR1Δ1 strain may be an appropriate surrogate of virulent Ames strain



Avirulent Anthrax vs. Simulant Spores

- 1500 ppmv ClorDiSys CD gas for 4 and 6 hour exposure with 75% RH
- *Bacillus subtilis* or *Geobacillus stearothermophilus* spores could serve as appropriate surrogates for *B. anthracis*



Conclusions

- With careful planning, semi-automation, high-throughput sample processing, and ingenuity in designing the sample port, an efficacy study of an unprecedented level was completed
- A quantitative test method for fumigant efficacy was conceived for processing over 200 coupons (this method has since been optimized with DTRA – DoD funding)
- Spore recoveries ranged between 30 and 100% (based on several hundred data points)
- High number of replicates and triplicate plates/dilution permitted statistical analyses and variability assessment
- Analysis of a large sample fraction (1/3rd) by pour-plating was a key to a very low detection limit (1-5)
- Spore kill kinetics is non-linear and is a function of material, concentration, and RH
- D values are just one measure of efficacy and can not be extrapolated to estimate the CT required for a six log kill
- Plasmid-free NNR1Δ1 spores may be an appropriate surrogate for virulent Ames Spores
- *Bacillus subtilis* and *Geobacillus stearothermophilus* spores may be appropriate BSL-1 surrogates for anthrax spores

ACKNOWLEDGEMENTS

- **Collaborative Partner and Funding**
  - EPA – NHSRC, Office of Research and Development
  - Blair Martin – Critical Guidance throughout the Program
  - Mark Brickhouse - Support as the original PM on this program

- **The Ace Team**

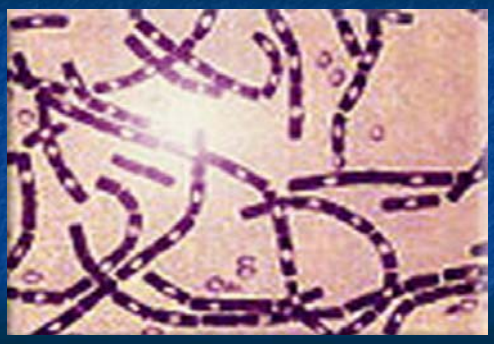
Lanie Wallace	Lisa Smith
Saumil Shah	Amber Prugh
Jonathan Sabol	Paul Clark

Thanks

Since 1917- A Tradition of Solutions.

Questions

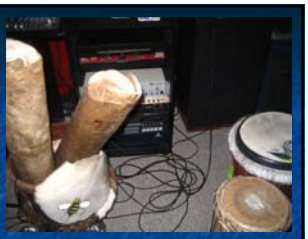
NYC ANTHRAX RESPONSE



USEPA REGION 02 ERRD-RPB

How it Started

- **February 16, 2006**
  - African drum maker and performer collapses during a performance in Pennsylvania
- **February 21, 2006**
  - Infection confirmed as Inhalational Anthrax by PA Department of Health
- **February 22, 2006**
  - Diagnosis as Inhalational Anthrax confirmed by CDC
  - Investigation initiated by NYC Department of Health and Mental Hygiene, NYPD, FBI and NIOSH
  - Investigation included 3 locations: 31 Downing Street, NYC (Apartment), 2 Prince Street, Brooklyn (Workshop/Studio), victims van

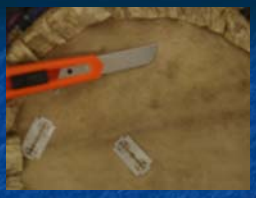


Contamination Confirmed

- Sampling performed by NIOSH Sampling Team
- Analysis by PCR and culture
- Positive results at all locations:
  - ✓ 31 Downey Street
  - ✓ 2 Prince Street
  - ✓ Van

The Exposure

- Victim was performer and drummer
- Made African drums using traditional methods
  - Imported natural hides from overseas
  - Used only hand tools to work hides (knives, razors, scrapers)
- Working the Hides
  - Hides soaked in water to soften
  - Hair scraped by hand tools
  - Hides smoothed by hand
  - Victim would be covered with hair and pieces of hide during the process
- Inhalation of spores during this procedure caused the infection



Coordination

- **Series of meetings to coordinate roles and responsibilities of all parties involved**
- **Players included:**
  - **NYC Dept of Health and Mental Hygiene (NYCDHMH)**
  - **NYPD Emergency Services Unit (NYPD-ESU)**
  - **Federal Bureau of Investigations (FBI)**
  - **NYC Dept of Environmental Protection (NYCDEP)**
  - **Occupational Safety and Health Administration (OSHA)**
  - **National Institute of Occupational Safety and Health (NIOSH)**
  - **NYC Mayors Office of Emergency Management (NYC MOEM)**
  - **Center for Disease Control (CDC)**
  - **NY State Dept of Health (NYSDOH)**
  - **Environmental Protection Agency (EPA)**
    - **Region 2**
    - **Environmental Response Team (ERT)**
    - **National Decontamination Team (NDT)**
  - **Representative of victims family**

Issues

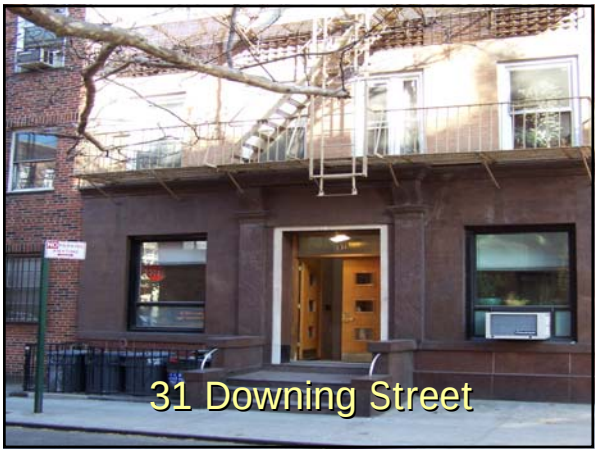
- **Who's in charge ?**
  - NYC DOHMH
    - Human health issue
    - Lab to perform sample analysis
    - Determine number of samples
    - Location of samples
    - Authority to declare re-occupancy

Issues

- **Decontamination**
  - EPA would support NYCDOHMH and perform the decontamination
  - More meetings (timeframe, street closure, public meetings)
  - NYCDHMH (sampling procedures, transport, lab time)
  - National Decon Team
  - What can be decontaminated ?
  - What will be disposed of ?
  - Negotiations with the family representative
  - Family heirlooms (items of sentimental value)
    - ✓ Books, costumes, photos
    - ✓ Bills, financial documents

Decontamination

- Decon Procedure
  - Sodium Hypochlorite solution (with Acetic Acid Buffer)
  - Vaporized Hydrogen Peroxide (Considered)
  - HEPA Vacuum
  - Chlorine Dioxide (Van, Saved Apartment Contents, Prince Street items)
- What to Decon
  - Non-porous surfaces (counters, tables, kitchen utensils, pots, pans)
- What to dispose of
  - Mattress, bedding, curtains, food, medications
  - All porous materials



The Response

- Decontamination of apartment 15 (approximately 500 sq ft) and common spaces of the building
- Used modified Sodium Hypochlorite Solution and HEPA vacuums
- Materials for disposal were bagged, rinsed, bagged, rinsed and bagged before removal from the apartment
- Materials to be decontaminated were
  - ✓ HEPA vacuum and bagged
  - ✓ Soaked in modified Sodium Hypochlorite
  - ✓ Boxed for additional treatment

Total of 16 cubic yards of material were removed from the apartment for disposal.

Disposal

- Problems almost immediately
  - ➢ Facilities who originally accepted all denied acceptance of the material
  - ➢ Private and public facilities
    - ✓ 4 states
    - ✓ 2 autoclave facilities
    - ✓ 3 incinerators
    - ✓ NYS landfills
    - ✓ 2 out of state landfills
      - ✓ "If it was generated in New York, tell New York to keep it."
  - ➢ Special transport permits for medical waste
    - ✓ For each state the material would be transported through

Disposal

- A Real Problem
  - ➢ Perception = The "A" Word
  - ➢ Facilities did not want to deal with the possible fallout of their permitting agencies or the public finding out they were accepting Anthrax

Autoclaving - NYES

- Coordinated Effort
  - NYS DOH, NYSDEC, EPA-ORD, NYES
  - NYSDEC and EPA ORD had performed testing on the effectiveness of autoclaving for the destruction of biological agents
  - Testing done at the NY Environmental Services (NYES) facility in Oneonta, NY
  - NYES agreed to accept the Downing Street material with some conditions
    - ✓ NYES personnel would not handle the material
    - ✓ Autoclaving would be done during facility off hours
    - ✓ Sampling would be done to insure effectiveness

Autoclaving - NYES

- Material from Downing Street Transported to NYES, Oneonta, NY
  - Autoclaving done on Saturday, March 18, 2006
  - Surrogate strips and temperature indicator strips wrapped in towels, bagged and places inside and outside the waste boxes
  - Boxes were perforated to insure maximum effectiveness
  - Material was treated for 3 hours at 295 degrees Fahrenheit
  - Surrogate strips were collected for analysis
  - Zero growth of surrogate
  - No acceptance at landfills anyway

Final Treatment - Incineration

- More Coordination
  - Autoclaved material still had no final resting place
  - EPA, NYES, NYSDEC, NYSDOH and the State of Ohio combined effort
  - April 13, 2006
    - Treated material from Downing Street was accepted and treated at the Stericycle Facility in Warren, Ohio

Summary – Downing Street

- Number of agencies involved
  - Sometimes its not "the more the merrier"
  - All in all they worked well together
- Private residence
  - 31 Downey Street was someone's home
  - The materials inside were all personal
    - ✓ Some had extreme sentimental value
    - ✓ Some were very private items
    - ✓ Sensitive Items (credit cards, check books, medical records)
  - Any item we decided to dispose of was part of the families life

Summary – Downing Street

- The "A" Word
  - Anthrax and the associated perception
- Logistics
  - Closure of entire street in Manhattan to setup work area and decon
  - Temporary displacement of all residents of the building
  - Restricted timeframe for work
- Disposal
  - Facility refusals
  - Double disposal
    - ✓ Autoclave
    - ✓ Incinerate
- Transport
  - Special Permits
  - Holding time required special waivers

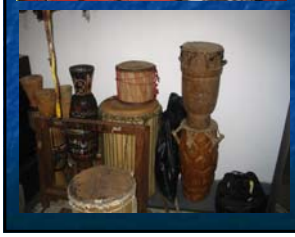
Prince Street Warehouse

Prince Street Issues

- Larger Building – Warehouse
- Larger area to decontaminate – Workshop, Studio, Storage Room, HVAC system and common areas
- Much higher volume of material for disposal
- Basically the same decon methods (HEPA vacs, bleach solution)
- Building owners hired their own contractor to perform the work
- NYCDHMH performed oversight of all operations
- More difficult to coordinate treatment and disposal
- Larger number of tenants to negotiate with

Prince Street Warehouse

Prince Street Warehouse



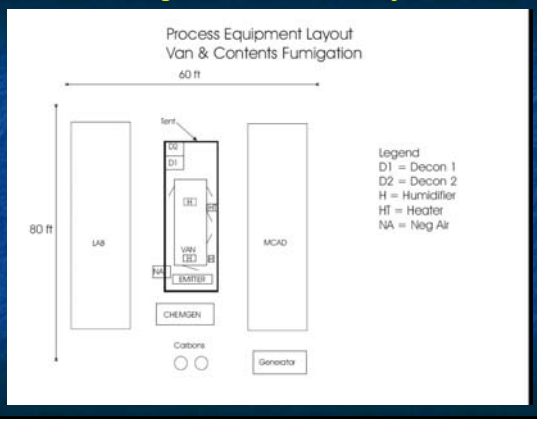
NYPD GOWANUS IMPOUND

Gowanus Impound Issues

- Negotiations with NYPD to allow treatment at the location
- Different treatment method – Fumigation with Chlorine Dioxide
- Specialized equipment
- NYCDHMH lead, EPA contractors performed work (Sabre Technologies)
- Fumigation of van plus materials from Downing Street and Prince Street
- Perimeter monitoring to verify no escape of Chlorine Dioxide from treatment enclosure
- Surrogate used to determine treatment effectiveness

Van Fumigation at NYPD Auto Impound

Van Fumigation at NYPD Auto Impound



Van Fumigation at NYPD Auto Impound

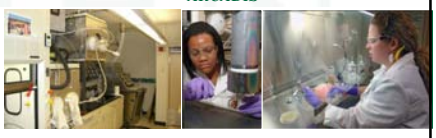
Van Fumigation at NYPD Auto Impound

Van Fumigation at NYPD Auto Impound

Update on U.S. EPA Decontamination Technologies Research Laboratory (DTRL) Activities

Shawn P. Ryan, Joe Wood, Emily Snyder and G. Blair Martin
National Homeland Security Research Center

Dahman Touati, Matt Clayton and Stella Payne
ARCADIS



August 17, 2007

Decon Program Research Area Overview

- Mission: To provide expertise and guidance on the selection and implementation of effective decontamination technologies for indoor and outdoor CBRN event scenarios and to provide the scientific basis for a significant reduction in the time and cost of decontamination events

- Research Process:
  - Decontamination demonstrations (e.g., chamber and field studies)
  - Decontamination technology application studies (e.g., generation rates, material/equipment compatibility, containment)
  - Technology evaluations (e.g., TTEP, systematic decontamination studies)
  - Agent Fate (e.g., persistence, penetration)
  - Efficacy test methods
  - Decontamination method development

DTRL Overview

- Decontamination Engineering
  - R&D on application related issues for efficacious technologies
    - What application issues must be considered in selection and implementation of a technology?
      - e.g., material demand and material/equipment compatibility, fumigant penetration
    - What are the best ways to improve effectiveness and decrease cost of application?
      - e.g., fumigant containment
  - DTRL is comprised of complementary research labs
    - Located in RTP; focus on fumigation research and analytical support

Research Overview

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

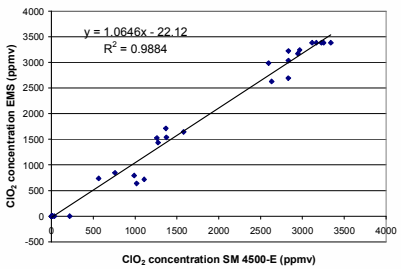
Process Parameter Measurement

- No standard method for measuring (sampling/analyzing) ClO_2 gas concentration in the high (e.g., >10 ppm) concentration range
  - AWWA SM-4500 (E)
    - Designed for analyzing ClO_2 in water samples
    - Extended to gas sampling by impinging into phosphate buffered KI-solution
    - pH-based titrations with sodium thiosulphate
      - Lose ability to speciate between Cl_2 and ClO_2 due to sampling method
      - Other impinging methods need verification
    - DL = 25 ppmv at 2 L gas sampled

  - ClorDiSys EMS™
    - Real-time measurement of ClO_2 via measurement of UV/VIS adsorption at 319 nm (DL = 36 ppmv)
    - Precautionary measures needed for high RH and pressure fluctuations (flow effects)

Process Parameter Measurement

ClO_2 Gas Concentration Measurements: EMS™ vs. SM-4500 (E)



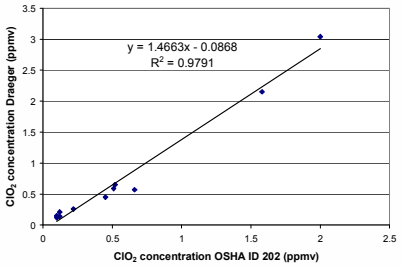
Process Parameter Measurement

– Dräger Polytron 7000
  - Real-time gas measurement of ClO_2 via electrochemical sensor (DL = 50 ppbv)
  - Combined response to Cl_2 and ClO_2
  - Observed hysteresis during continuous monitoring

– OSHA Inorganic Method ID-202
  - Sampling into carbonate buffered KI-solution
  - DL = 60 ppbv (7.5 L gas sampled)
  - Analysis via Ion Chromatograph (IC)
  - High ClO_2 peak interferes with quantification of Cl_2

Process Parameter Measurement

ClO_2 Gas Concentration Measurements: Dräger vs. ID-202



Process Parameter Measurement

- Other in-house capabilities:

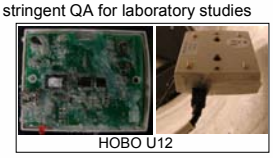
– Trace Atmospheric Gas Analyzer (TAGA)
  - Real-time gas measurement of ClO_2 and Cl_2 via dual source triple quadrupole mass spectrometer (Quantitation Limit = 2.3 pptv)
  - Linear dynamic range: 1 pptv – 100 ppbv; may be detuned to increase
  - Bench top system currently being constructed

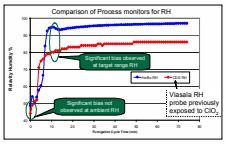
– Single-Photon Ionization/Time-of-Flight MS (SPI)
  - Real-time gas measurement of ClO_2 via laser ionization coupled with time-of-flight mass spectrometer (LOD = 0.3 ppm)
  - Large linear range (ionization mechanism does not limit range)
  - Unable to measure chlorine gas

Process Parameter Measurement

- Efficacy of technologies may be very dependent on process parameters (e.g., environmental conditions) in combination with the concentration of the decontaminant
  – e.g., the effectiveness of ClO_2 gas to inactivate spores is a very strong function of RH

- Measurement and control of process parameters is not trivial and requires stringent QA for laboratory studies

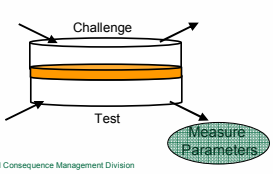




Fumigant Permeability

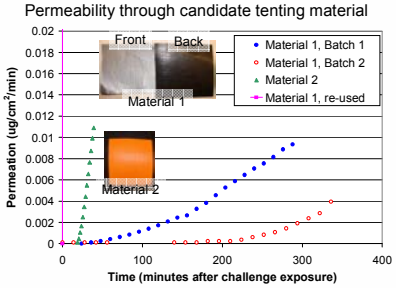
- Containment of a fumigant within a defined volume
  – Out-leakage increases generation capacity requirements to achieve target concentrations
  – Leakage may present a worker or public health risk

- Penetration of fumigants through porous materials
  – Correlation to efficacy?



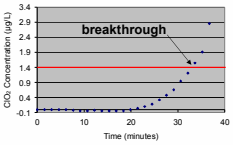
Fumigant Permeability

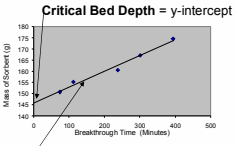
Permeability through candidate tenting material



Fumigant Containment: Adsorption

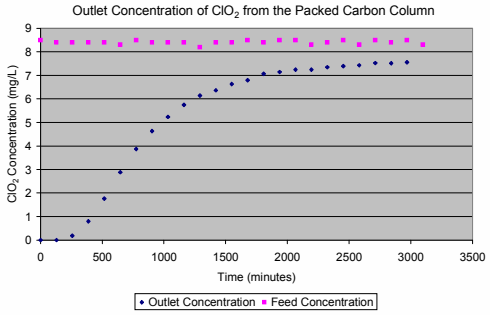
- Use of solid sorbents or catalysts to remove fumigants from process gas
- Initial testing to determine adsorption capacity of different sorbents for ClO_2
  - Use of ASTM D5160-95 for "Gas-Phase Adsorption Testing of Activated Carbon"
  - Development of adsorption isotherms for sorbents





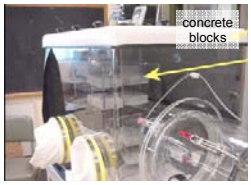
Sorbent Capacity = 1/slope x concentration x flow rate

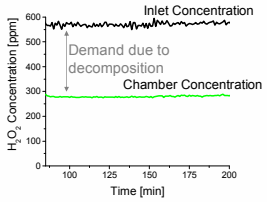
Fumigant Containment: Adsorption



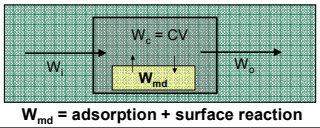
Material Demand

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

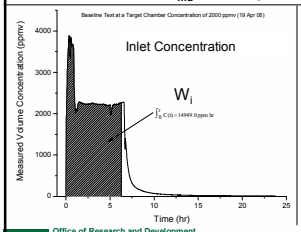


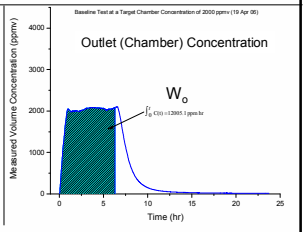


Material Demand



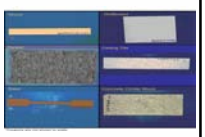
W_{md} = adsorption + surface reaction





Material Demand

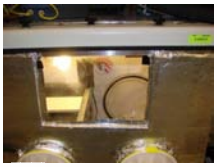
- Prior work with Edgewood Chemical and Biological Center (ECBC) on ClO_2 and VHP® concluded significant demand for some materials:
  - ClO_2: ceiling tile > wallboard
  - VHP®: concrete > ceiling tile, wallboard, wood
  - EPA/ECBC work done at limited conditions to determine potential importance of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

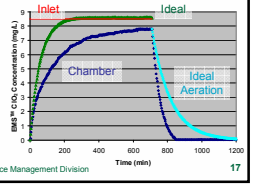


- Expanding on work in-house (DTRL) to support and develop a tool (material demand calculator) to determine material demand as a function of fumigation conditions and construction materials
  - Technology selection and implementation:
    - Does the generation system have enough capacity to overcome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

Material Demand

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



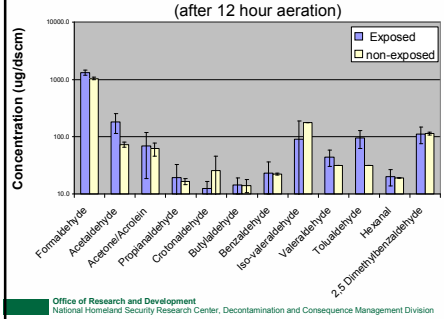


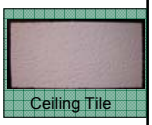
Fumigation By-products

- Screening for residual by-products from fumigation
  - Performed during the aeration phases of the material demand and compatibility studies
    - Gaseous residual by-products (off-gasing)
    - Residuals on materials
- Extraction of coupons for residuals
- Thermal desorption studies
- Analysis of chamber gas during/after aeration
  - DNPH tubes (EPA Method TO-11)
    - Full-scan aldehyde analysis
  - Varian 1200 MSMS (LPCI, APCI)

Fumigation By-products

Chamber Air Concentrations
(after 12 hour aeration)





Material/Equipment Compatibility

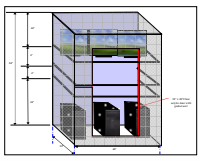
- Impact of fumigation on materials and equipment investigated as a function of fumigation conditions
- Initial work done as part of work with ECBC on ClO_2 and VHP® material demand
  - No aesthetic impacts on materials tested
  - No significant impacts determined during ASTM physical strength tests
    - Published report to be released soon

Material/Equipment Compatibility

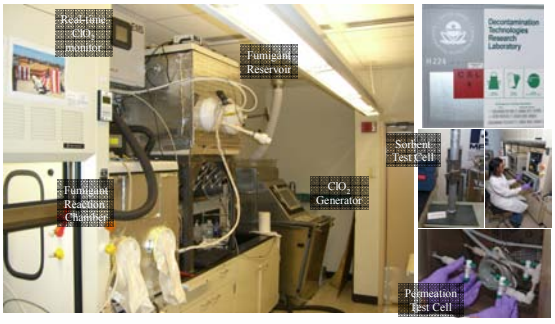
- Extension of material/equipment compatibility continuing in DTRL
- Initial work on ClO_2; plans to extend material demand and material/equipment compatibility studies to an HP technology in FY 08
- Includes aesthetic and functionality testing over time
  - Material/equipment down-select:
    - Aluminum,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

Material/Equipment Compatibility

- In-depth sensitive electronic compatibility study (EPA/DHS)
  - Treatment in the NHSRC fumigation lab to study the impact of the ClO_2 fumigation process on computers and LCD monitors:
    - *Standard* fumigation conditions for *B. anthracis*
      - 9000 ppmhv-hr (3000 ppmv for 3 hrs), 75ºF, 75% RH
    - Impact of high and low RH fumigation
      - 9000 ppmv-hr (3000ppmv for 3 hrs), 75ºF, low RH (40%) or high RH (90%)
    - Low CT fumigation
      - 900 ppmv-hr (75 ppmv for 12 hrs), 75ºF, 75% RH
    - Control (ambient T and RH; ambient T and high RH)
  - Detailed analysis, including effect over time, through the Chemical, Biological, Radiological Technology Alliance (CBRTA) Independent Assessment and Evaluation
    (LGS Innovations – Bell Labs)
    - Aesthetic and functionality evaluation (PC Doctor)
    - Visual inspection and more advanced diagnostics
    - Module-by-module investigation
    - Cross-section and failure mode analysis



Questions?



Localizing & Controlling BTA Transport with Polymer Sprays

June 21, 2007
EPA Decontamination Workshop

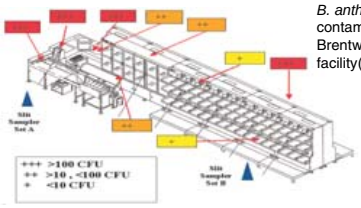
Paula Krauter

Chemical & Biological Nonproliferation Program
Lawrence Livermore National Laboratory
krauter2@llnl.gov

This work was performed under the auspices of the U.S. Department of Energy by University of California Lawrence Livermore National Laboratory under contract No. W-7405-Eng-48. UCRL-PRES-231759

Problem Statement

Biothreat agent (BTA) reaerosolization can spread the contaminate plume



B. anthracis cross-contamination occurred in the Brentwood mailroom facility(10/01)

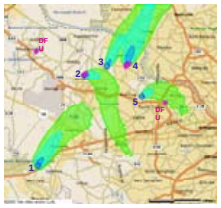
Dull et al (2002), *Emerg Inf Dis*, V 8, 356

Inhibition of BTA transport could provide decision-makers time to consider decontamination options while limiting further contamination

An Outdoor Release of Surrogate Spores Exhibited Resuspension

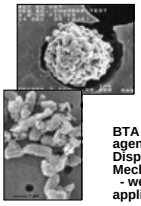
2006/2007 LANL & LLNL Gypsy Moth project

- ***Bacillus thuringiensis*** **subsp. kurstaki (Btk) is used to control Gypsy Moth populations and is a spore-forming surrogate**
- **A goal of this study was to designed and validated DNA signatures for Btk and screen aerosol and environmental samples**
- **More collectors had viable Btk spores 2 days after release, than during or 1 day after the release**
- **Viable spores collected up to 14 days post release (2007)**
- **Lessons learned: persistence and re-suspension of spore-forming organisms**



Thomas Bunt, LLNL
Biological Monitoring & Response
bunt1@llnl.gov

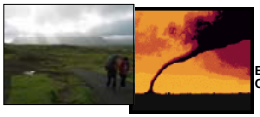
Multiple Influences Effect BTA Deposition



BTA Preparation

BTA *or* Decon agent Dispersal Mechanism - wet or dry applications

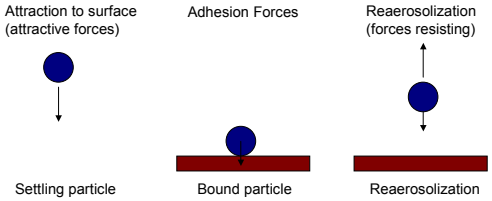
Secondary Dispersal Mechanisms



Environmental Conditions

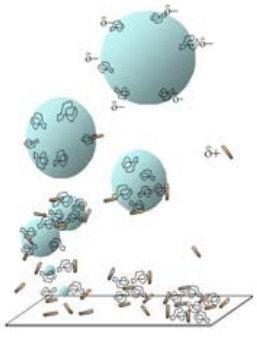
Influences from particle size to weather can alter particle drift and migration and extend the initial boundaries of contamination

Logic Behind Project Supported by the Physics of Adhesion and Reaerosolization



Goal of project was to consider a different response to a BTA incident by increasing adhesion force and inhibiting BTA resuspension

Original Concept: Polymer(s) Interact with the Coulombic Forces on the Particles



Aerosol droplet (~50 µm) containing negatively charged polymers (40 nm) attach to particles on surfaces and in the boundary layer

For example, an aerosol droplet containing polymer may attract positively charged spores (1-3 µm)

Non-charged ends of the polymer flocculate to form multi-spore aggregates

Polymer coagulate as solvent evaporates adhering particles to the surface

Polymer Spray Criteria

Formulas evaluated based on criteria:

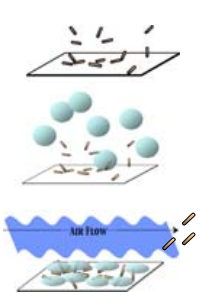
1) High adhesion strength
2) Negative electrostatic charge
3) Low viscosity and low surface tension (wetability)
4) Moderate evaporation rate
5) Low corresitivity
6) Low toxicity

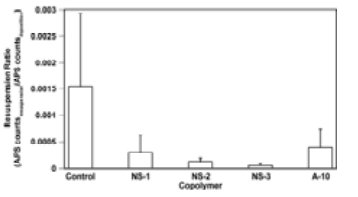
Polymer Formulation Characterization

Formula Identification	pH unit	Density g/mL	Viscosity cp	Surface tension mN/cm	Electrostatic charge nC/g
NS-1, urethane	9.07	0.957	20	31.49	0.60
NS-3, vinyl acetate	9.53	0.948	10	33.63	-1.8
NS-2, acrylate	7.07	0.953	8	32.18	-0.7
A-6, acrylamide, acid	7.96	0.997	N/A	71.81	-0.4
A-4, diallyldimethylammonium chloride	7.84	1.014	171	69.70	1.77
A-5, vinylpyrrolidone quaternized	6.91	1.009	74	68.21	1.81
A-8, vinyl pyrrolidone	6.72	1.010	90	67.98	1.17
A-9, vinyl pyrrolidone	Solubility problems				
A-10, styrenesulfonate	6.56	1.017	25	58.51	-0.5
A-7, ethylenimine	Too viscous, high molecular weight				

Cp- centipoise @ 50rpm, 23C

Resuspension Ratios for Top Performing Polymer Solutions and Control





Resuspension ratios for polymer or control solution application

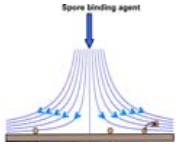
Screening tests in small chamber

1. Powdered spores disbursed with compressed air onto deactivated glass surface (very few spores settled)
2. Polymer solution sprayed (<10 psi) onto spore covered surface
3. Resuspension measured by APS with airflow ~1 m/min

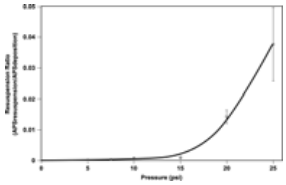
Application of Liquid Decon Agents can Displace or Resuspend Spores

Optimized polymer formula(s) for low pressure sprayer device

Evaluated the wetting agent, solvent blend, viscosity, elasticity, evaporation rate



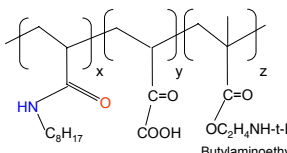
Application of a liquid decon agent has the potential to shear, lift or roll a spore



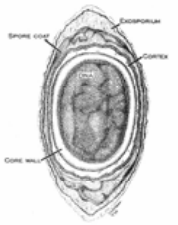
Determination of appropriate sprayer pressure

Top polymer was the terpolymer of butylaminoethyl methacrylate, octylacrylamide and acrylic acid

NS-2 is an amphoteric film-forming polymer solution



Octylacrylamid	Acrylic acid	Butylaminoethyl-methacrylate
$C_4H_6O_2$	$C_4H_6O_2$	$C_{12}H_{22}O_2$
MWt=86.09	MWt=86.09	MWt=198.3
C = 55.81%	C = 55.81%	C = 72.68%
H = 7.02%	H = 7.02%	H = 11.18%
O = 37.17%	O = 37.17%	O = 16.14%



We selected polymers known to adhere to keratin since keratin-like proteins are found in spore's outer coat

Validation Test at U.S. Army Dugway Proving Ground

A validation test was conducted in April & September 2006 in collaboration with biothreat experts

- **Success was measured by lower spore counts after the application of the copolymer formula in turbulent airflow**
- **Data provided the basis for calculation of deposition velocity, transport efficiency and reaerosolization rate with and without the application of the polymer solution**

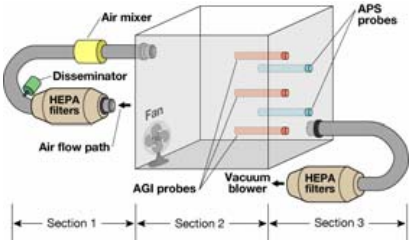
Dugway Proving Ground, Dugway, UT

Tested in a 'Worst Case' Environment- an Antistatic Aerosol Chamber with High Reentrainment Forces

Key issues in designing the chamber included isokenetic probes, antistatic materials, grounding, homogeneous concentration of enhanced spores, a large air volume, and multiple measurement systems.

Chamber constructed with poured Lexan sheets, antistatic EO™ coating and aluminum framing attached to BioDuct apparatus.

Anti-static Aerosol Test Chamber



Validation Test

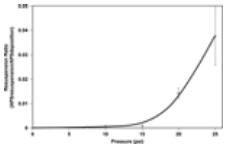
- Disseminated spores, settle over night
- Purge unsettled spores
- Spore resuspension
- Settle resuspended spores
- Copolymer solution application & allow to dry
- High-velocity mechanical airflow applied
- Repeat test with solvent only

- Air was drawn through an instrumented 3.5 m^3 chamber, spores were disseminated into turbulent airflow
- Four impinger probes located at 0.5, 0.75 and 1.4 m from the floor, 1 in effluent duct
- Three aerosol particle sizer probes, 2 in the chamber and 1 on the effluent duct

NS-2 Application

Ethanol-water control spray dripped

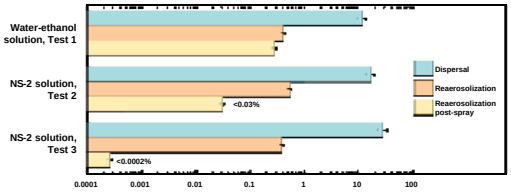
NS-2 polymer solution spray



Spray set to 10-15 psi so as not perturb spores

- Goal was to apply a light mist of the solution that provided a thin or partial coating (~20-22 nm) so as to not agglomerate all the spores
- Part of the selection criteria was low surface tension, low viscosity with strong adhesion

Results



- **We anticipated a total dissemination efficiency of about 10-15%. Aerosol chamber results were 11-27% (aqua)**
- **The reaerosolization efficiency without application was 0.7%, 0.41% and 0.45% (orange)**
- **The reaerosolization efficiency with application was 0.3% with water/EtOH and 0.03% and 0.0002% with NS-2 application (yellow)**

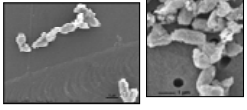
Resuspension Factor

Resuspension factor is the ratio of the air concentration of spores to the surface deposition concentration of spore contamination (spores serving as the source for the resuspension process)

The resuspension factor, R_f, is expressed as

$$R_f = [\text{Spores in air}]/[\text{Surface deposition of spores}]$$

Air concentration was measured by AGI samples, (CFU/cm^3)
Surface deposition of spores was measured by wet swab samples, (CFU/cm^2)



Results

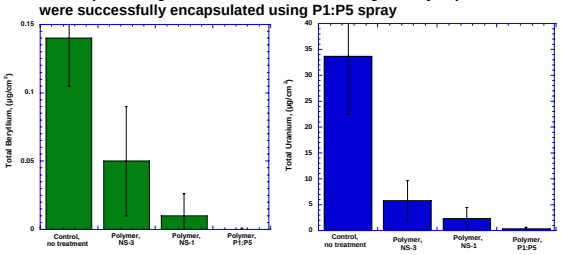
- **Resuspension factors for spores in these chamber tests without any inhibitor application ranged from 3.4 x 10^{-6} to 4.8 x 10^{-5} /cm, or 26% of the spores**
- **Resuspension factors show that NS-2 application (50 mL on 2.3 m^2) inhibited spore resuspension by 2-orders of magnitude**
  - **R_f, 3.4 x 10^{-7} to 5.5 x 10^{-8} /cm, respectively, or 0.7% and 0.4%**
- **Application of the water-ethanol control inhibited resuspension by a half-order of magnitude**
- **These results from a mechanical-type resuspension mechanism and are considerably greater, 1.5 to 2 orders of magnitude, than those reported for resuspension caused from natural, wind driven processes**

Reaerosolization Factors, R_f

Reaerosolization results (/cm)	Test 1 Control Water-ethanol spray	Test 2 NS-2 spray	Test 3 NS-2 spray
AGI- Before application	3.4×10^{-5}	4.8×10^{-5}	1.2×10^{-5}
AGI- After application	8.7×10^{-7}	3.4×10^{-7}	5.5×10^{-8}
AGI- Ratio	2.6×10^{-4}	7.0×10^{-3}	4.4×10^{-3}

Polymer formulations were designed specifically for other hazardous materials

Be & U particles generated in a Contained Firing Facility experiment were successfully encapsulated using P1:P5 spray



- Metal particulate were in the inhalable size range of 1 - 100 µm
- DOE wet-swipe collection method & modified NIOSH 7300 method used for metals analysis
- P1:P5 treated samples were significantly different (P <0.0001) from the control samples
- Error bars are the standard deviations, 7 samples/treatment

Summary

The goal of this project was to adhere airborne particulate biothreat agents in an air-volume by attracting and attaching biothreat particles to a surface thus containing the BTA.

A secondary goal was to provide a material that does not degrade surfaces with corrosive materials.

We evaluated an amphoteric acrylic copolymer solution (NS-2) in a worst-case environment; an antistatic chamber (3.5 m^3) and in high re-entrainment forces.

Potentially, the negatively charged groups of NS-2 bind a positively charged spore more efficiently. This material performed better than a solvent control in inhibiting spore resuspension.

Polymer solutions can be designed to adhere to specific particulate types.

An environment in which the spores are attached to a surface will allow those involved in the cleanup effort a margin of safety in which to decide how to best decon various materials and equipment.

Team & Publications

Art Biermann- Aerosol Physicist, LLNL

Mark Hoffman- Polymer Chemist, LLNL

Lloyd Larsen- Microbiologist, U.S. Army, DPG

Alex Vu- Biochemist, LLNL

Dave Zalk- Industrial Hygienist, LLNL

Todd Weisgraber- Fluid Dynamics, LLNL

Krauter PW, AH Biermann, DM Hoffman, LD Larsen. Inhibiting the Reaerosolization of Enhanced Spores. For submission to *J. Applied and Environmental Microbiology*. 2007.

Krauter PW, DM Hoffman, AK VU, GA Keating, DM Zalk. Inhibiting the transport of hazardous bio-particulates using polymer-based solutions. *J. Occupational and Environmental Hygiene*. *In publication, 11/07*.

Krauter Paula, Arthur Biermann. April 2007. Reaerosolization of fluidized spores in HVAC systems. *J. Applied and Environmental Microbiology*, V7.2165-2172.

Krauter PW, AH Biermann, LD Larsen. Transport Efficiency and Deposition Velocity of Fluidized Spores in Ventilation Ducts. 2005. *Aerobiologia* 21: 155-172.

Krauter PW, LD Larsen and AH Biermann, Novel Approach Towards Elimination of Inhalation Hazards Associated with Reaerosolization of Biothreat Particles. Presented to the American Society for Microbiology Biodefense and Emerging Diseases Research Meeting, February 27- March 2, 2007. Washington, D.C.

Questions?

Antelope at DPG

Contact information:
Paula Krauter
krauter2@llnl.gov
(925) 422-0429
7000 East Ave. L-528
Livermore, CA 94551

Can We Expedite Decon?

By: G. Blair Martin, Shawn Ryan, Emily Snyder, Joe Wood and Nancy Adams

U.S. EPA, Office of Research and Development
National Homeland Security Research Center

Presented at: Decon Workshop
Research Triangle Park, NC
June 20 – 22, 2007

INTRODUCTION

PURPOSE: Provide insight on past practice and ongoing R&D on decontamination of CB agents

GOAL: Minimize Time and Cost of Effective Decontamination

- Background
  - Field Experience
  - Research and Development
- Decontamination Process Improvements
- Summary

BACKGROUND

- In the fall of 2001 a number of buildings were contaminated with *B.anthracis* from letters mailed through the U.S. Postal Service
- All of the these buildings have been decontaminated using a variety of methods
  - ✓ Removal and disposal of contaminated materials
  - ✓ Surface cleaning with bleach, liquid chlorine dioxide or various hydrogen peroxide products
  - ✓ Fumigation with chlorine dioxide, hydrogen peroxide, or paraformaldehyde
  - ✓ The volumes fumigated at one time ranged from about 8,000 to over 14,000,000 cubic feet
  - ✓ FIFRA exemptions required as no products registered for *B.a.*
  - ✓ None registered now

BACKGROUND: Field Experience

PAST FUMIGATIONS FOR *B. anthracis:*
COMPARISON OF TWO FACILITIES

	BRENTWOOD	SA-32
● Location	Washington, DC	Sterling, VA
● Surroundings	Heavily Urban	Rural: Industrial Park, Subdivision
● Size		
- Volume	14,000,000 ft^3	1,400,000 ft^3
- Area	700,000 ft^2	70,000 ft^2
- Zone Size	Whole Building	40,000 t0 200,000 ft^3
● Approach		
- Area	Whole Building	Multiple Zones
- Fumigant	ClO_2	Vaporized Hydrogen Peroxide
- Concentration	750 ppm @ 12 hours	216 ppm @ 4 hours
- Mixing	Air Handlers & Fans	Inlet Flow & Fans
- Containment	NAU/Scrubber	NAM/Catalyst
- Waste	Liquids	None
- Fumigation Duration	One Day	Approximately 2 months

BACKGROUND: Field Experience

STORAGE TANKS & ClO_2 GENERATION EQUIPMENT

BACKGROUND: Field Experience

- Key technology evolution of ClO_2 fumigation
- American Media International (AMI) Building – *B.a.* contaminated
  - 700,000 cubic feet
  - Carbon cells in place of wet scrubbers
- Hudson Falls, NY Department Store – mold contaminated
  - 1,000,000 cubic feet
  - Single tarp
  - Small carbon cells
- Numerous mold contaminated buildings in Louisiana and Texas
  - 1500 to over 50,000 square feet
  - Termite tenting
  - Target 3000 ppm for 3 hours
  - Truck mounted generator and emitter
  - Small negative air unit and carbon cells

BACKGROUND: Field Experience

Restoring New Orleans –Bywater Station Post Office

BACKGROUND:Field Experience

Restoring New Orleans – Job Corps Center

BACKGROUND: Decontamination R&D

The National Homeland Security Research Center program

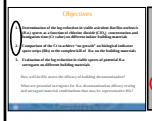
- Systematic evaluation of fumigant efficacy
  - Fumigants
    - Chlorine dioxide
    - Hydrogen peroxide
    - Methyl bromide
  - Parameters
    - Concentration
    - Time
    - Temperature
    - Relative humidity
  - Materials
    - Porous
    - Nonporous
  - Biological indicators

BACKGROUND: Decontamination R&D

Systematic evaluation of fumigant efficacy

- A few reminders – using logs can be deceptive
  - 5 log = 100,000 spores
  - 6 log = 1,000,000 spores
  - 7 log = 10,000,000 spores
- Therefore the number of spores in "a log reduction" is dependent on the staring contamination level
- We need a denominator – most reports are "per sample"
- Decon efficacy is dependent on spore loading
  - 10^6 (6 log) spores on 1 inch square sample equal:
    - 1.44 X 10^8 (8+ log) on a square foot
    - 1.296 X 10^9 (9+ log) on a square yard)
- Most environmental samples are at least a square foot
  - Results show <2 to >6 log per sample
- Guidance for fumigation conditions to type/extent of agent?

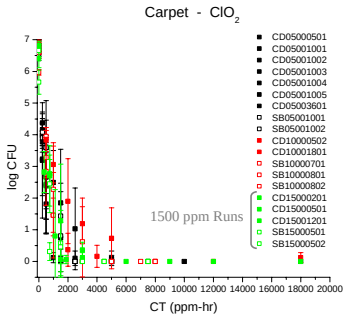
Systematic Decon Experimental Procedure



1. Determination of the log reduction in viable avirulent *Bacillus anthracis* (*B.a.*) spores as a function of chlorine dioxide (ClO_2) concentration and fumigation time (CT value) on different indoor building materials
2. Comparison of the CT to achieve "no growth" on biological indicator spore strips (BIs) to the no growth of *B.a.* on the building materials

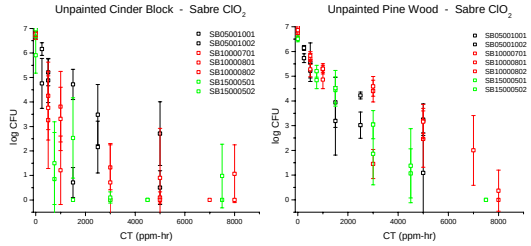
- 13 mm x 13 mm coupons (5 replicates per dish)
  - raw wood, unpainted cinder block, carpet, painted I-beam steel, ceiling tile, wallboard
- Inoculated with ~10^7 spores of avirulent *Bacillus anthracis* (NNR1Δ1) in 7 x 7.1 µL drops <10^9 per square foot
- Inclusion of 0.5 % BSA as bioburden
- Biological Indicator spores strips (BIs)
  - *Bacillus atrophaeus* (~1x10^6) on stainless steel backing in Tyvek pouches (APEX)

Decontamination of *B. anthracis* on Carpet



- Large variability in data at low CT
- Decay curve and variability not a function of ClO_2 generation method
- Optimal CT not affected by 2-fold increase in ClO_2 concentration
- No growth on any coupon after treatment at CT ≥ 6000 ppm-hr for all three concentrations tested

Effect of Material Type on Decontamination



- "No growth" criterion not achieved up to 8000 ppm-hr of treatment on unpainted cinder block or unpainted (structural) pine wood
- Log reduction is dependent on CT, no distinct difference in reduction due to fumigation at different ClO_2 concentrations (500, 1000, and 1500 ppm)
- Liquid inoculation of coupons may be a factor

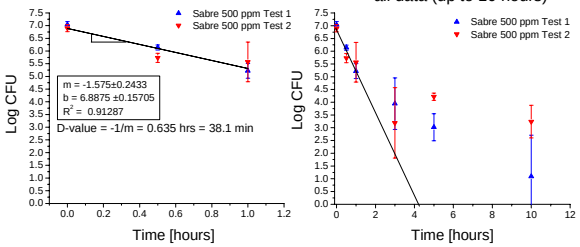
Some Definitions & D-Value Concept

- Microorganisms are not killed instantly and microbial population death usually occurs exponentially
- D-value is defined as the time it takes for a decimal reduction in the number of viable spores
  - For example, starting with 10-million (7-logs) spores at time zero, the D-value is the exposure time required for a disinfectant to reduce the number of viable spores to 1-million (6-logs)
- Another measure of efficacy is the CT (concentration x time) required to achieve a 6-log-kill reduction or "no growth" on culturing
- For building cleanup, the ONLY acceptable standard has been no growth of pathogenic spores from environmental samples!
- How does the D-value relate to the clean-up standard?

Non-linear D-Values

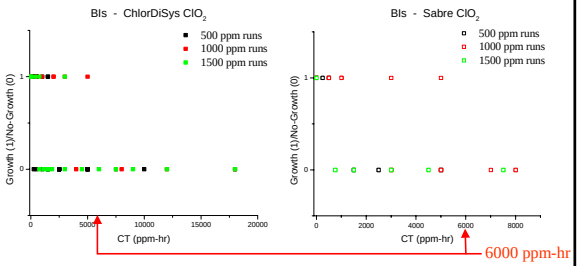
D-value from initial log reduction (1st 3 data points; up to 1 hour)

D-value from initial log reduction compared to all data (up to 10 hours)



- Kill curves are non-linear; linear D-value severely underestimate the time required for 6-log reduction and no growth

Effect of ClO_2 CT on BIs



- No growth on any of the BIs after 6000 ppm-hr of treatment
  - not consistent with results of *B. anthracis* (NNR1Δ1) on cinder block or wood
- May limit value of BIs as a fumigation indicator
- Alternative BIs may be required

STREAMLINED APPROACH

CRITICAL INFRASTRUCTURE CONTAMINATED

- Approach to minimize impact
  - Population
  - Economy – time
  - Cost of restoration
- Prior planning essential
  - Maintain current building CAD drawings
  - Generic response plans
  - Coordination with local authorities
  - Expedited decision making
  - Rapid contracting for services
  - Insurance instead of indemnification

STREAMLINED APPROACH

Decision process: Assess the extent of contamination

- Evaluation of information from others
  - Time between release and discovery
    - Movements of occupants
  - Results of confirmatory/forensic sampling
  - Nature of agent
    - Hazard category
    - Persistence
    - Amount
  - Indication of spread of contamination
    - Extended occupancy
    - Aerosolizable
    - Concentrated and/or contained
- Decision to proceed to characterization sampling
- Decision of PPE for characterization sampling

STREAMLINED APPROACH

CHARACTERIZATION SAMPLING

- Assess aerosol dispersion by sampling HVAC returns
  - Confirmed = consider proceeding to fumigation
  - Negative = proceed to characterization surface sampling
- Approach to characterization sampling (*approach in development*)
  - Biased/focused
  - Random stratified
  - Full probabilistic or hybrid
  - Software for selecting/locating/documenting sampling locations
- Assess surface samples and choose decon approach
  - Limited hard surfaces only = consider liquid/foam
  - Aerosolized spores and HVAC contaminated= proceed to fumigation
  - Widespread on porous and/or nonporous surfaces = proceed to fumigation

Any decontamination method chosen will require FIFRA compliance

- Registration
- Exemption

STREAMLINED APPROACH

DECON STRATEGY: FUMIGATION

Demonstrated capacity to fumigate entire building

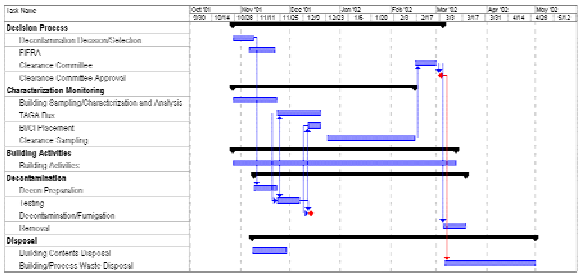
- Widespread contamination of porous and/or nonporous surfaces
- Aerosolized spores/persistent agent and HVAC contaminated
- Decontamination process steps
  - Containment of agent
    - Sealing and HEPA/negative air machine
    - Tenting and small HEPA/negative air system
  - Source reduction for general contamination = HEPA vacuum
  - Minimize materials removal
    - Paper goods
    - Any other contents that might have been moved
    - Building materials left in place
  - Decontamination documentation = RAP, SAP, AAMP

STREAMLINED APPROACH

DECON STRATEGY: FUMIGATION

- Decontamination process steps (continued)
  - Decontamination process implementation
    - Tenting building if not done for containment
    - Installation of equipment
    - Installation of monitoring equipment (concentration, T, RH)
    - Installation of BIs -minimize
    - Decontamination
    - Harvest of BIs
  - Decontamination confirmation
    - Process parameters are met (CT, T, RH)
    - Clearance sampling
    - Surface
    - Air and aggressive air sampling
  - Success = **No Growth** on all clearance samples

Condensed Conceptual Timeline Streamlined Approach



SUMMARY

DECON – YOU WANT IT WHEN?

- Sufficient basis is available for decontamination of B.a. in structures
  - Chlorine dioxide fumigation
    - Demonstrated efficacy
    - Experience provides basis for FIFRA exemption
    - Evolution of technology
    - Availability of decontamination infrastructure
    - Potential to improve response time
  - Minimize use of BIs
  - Improved sampling strategy
    - Use forensics to simplify characterization sampling
    - Clearance by Hybrid probabilistic method
  - Potential for further improvement
    - FIFRA registration
    - Accept compliance with label for clerance

SUMMARY

DECON -YOU WANT IT WHEN?

- R&D is providing additional guidance
  - Better information on liquids
  - Additional fumigants, e.g. hydrogen peroxide, methyl bromide
  - Additional biological agents, e.g. viruses, vegetative bacteria
  - Biological toxins, e.g. ricin
  - Chemical agents and Toxic Industrial Chemicals (TICs)
  - Effects of/on materials
    - Building construction and contents
    - Outdoor materials
    - Sensitive equipment
  - Improved methods of containment/scrubbing
  - Sampling and analysis methods/strategies
  - Controlled large scale indoor/outdoor decontamination (planned)
- Continuing interaction with the user community

SUMMARY

DECON – YOU WANT IT WHEN?

BOTTOM LINE: TECHNICALLY WE ARE MUCH BETTER OFF THAN WE WERE AND WE ARE GETTING BETTER PREPARED ALL THE TIME!

HOWEVER: CERTAIN PARTS OF THE OVERALL PROCESS STILL NEED TO BE IMPROVED

- **Streamlining decision process**
- **Access to demonstrated decon technology – critical systems**
- **Link to forensic sampling**
- **Characterization strategy**
- **Application of BIs**
- **Clearance procedures**

Airport Restoration Following a Chemical Warfare Agent (CWA) Attack

Robert G. Knowlton, Ph.D., P.E.
Sandia National Laboratories

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

Presentation Outline

- Background and Project Overview
- Project Activities
  - **Remediation Plan Development**
    - **Partnerships**
    - **Threat Scenarios**
    - **Clean-up Guidelines**
    - **Sampling Methodologies**
    - **Decontamination Technologies**
  - **Decision Support Tool Development**
  - **Experimental Studies to Fill Technology, Data, and Capability Gaps**
- Summary

A chemical agent release in a facility may result in…

- High Casualties
  - Office Buildings
  - Indoor Stadiums
  - Transportation Hubs
- Loss of National Prestige
  - National Monuments
  - Government Buildings
- Large Economic Impact
  - Transportation Hubs

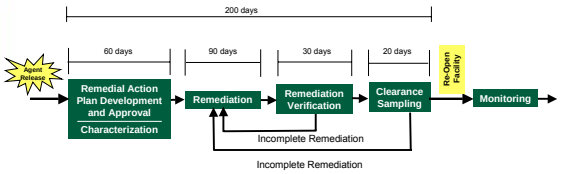
Economic impact is the most important factor in selecting a facility that needs to be restored quickly and efficiently

A chemical agent release in key transportation facilities could be devastating

- Severe economic impact if closed for even short periods
- Highly vulnerable to chemical terrorism
- Wide range of decon and remediation challenges
- The primary focus of the Facility Restoration OTD is on major airports
  - Project will focus on interior remediation only
  - Project will serve as a 'template' for other airports to follow

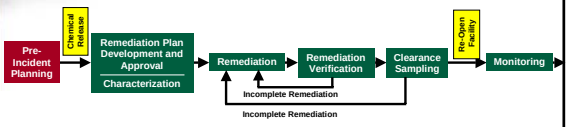
We are working in close collaboration with a partner airport (LAX) and regulatory agencies

Previous recovery activities were very lengthy



The time of the overall recovery operation is governed by the length of the combined activities

Implementing a systems approach will decrease the time required for recovery



Objectives:

- **Advance the state-of-the-art in facility recovery through the development and demonstration of efficient planning, decontamination, sampling and analysis tools**
- **Enhance rapid recovery from chemical attacks**
- **Minimize economic impact from chemical attack**
- **Provide the capability to make defensible public health decisions**

To achieve these objectives, we are focusing on

- **Pre-planning the recovery process**
- **Selecting the "best-available" methods and technologies for each activity**
- **Filling data and technology gaps critical to the recovery process**

Developing a systems approach to chemical remediation and recovery

The systems approach is following the structure developed by an interagency panel of experts

Response and Recovery Activities					
Crisis Management		**Consequence Management**			
Notification	**First Response**	**Remediation/Cleanup**			**Restoration (Recovery)**
		Characterization	**Decontamination**	**Clearance**	
Receive and assess information Identify suspect release sites Relay key information and potential risks to appropriate agencies	HAZMAT and emergency actions Forensic investigation Public health actions Screening sampling Determination of agent type, concentration, and viability Risk communication	Detailed characterization of biological agent Characterization of affected site Site containment Continue risk communication Characterization environmental sampling and analysis Initial risk assessment Clearance goals	Worker health and safety Source reduction Decontamination strategy Remediation Action Plan Site preparation Waste disposal Decontamination of sites, items, or both Verification of decontamination parameters	Clearance sampling and analysis Clearance decision	Renovation Reoccupation decision Long-term environmental and public health monitoring

This project focuses only on the consequence management phase

The Facility Restoration OTD builds off of the recently completed Biological Restoration DDAP

- Many of the concepts will be similar to the *Biological Restoration DDAP*, except..
  - Agent decay may occur
  - Surface interactions with chemical agents must be considered
  - More rapid sampling and analysis techniques are available
  - Decontamination approach may vary depending on the agent
  - Clean-up standards better defined
  - Long term air monitoring may be required

A primary consideration is to utilize many of the fundamental concepts, processes, technical developments, and key relationships established during the *Biological Restoration DDAP*

The Facility Restoration OTD utilizes experts from the National Laboratories and other federal agencies

Collaborators
Sandia National Laboratories - PI
Lawrence Livermore National Laboratory – PI
Los Alamos National Laboratory
Pacific Northwest National Laboratory
Oak Ridge National Laboratory

DHS Project Manager
Don Bansleben

External Advisory Panel
Nancy Adams, US EPA
Veronique Hauschild, US EPA
Dennis Reutter, US DHS
Joe Wood, US EPA

Partner Airport
Los Angeles International (LAX)

Presentation Outline

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    - **Decontamination Technologies**
  - **Decision Support Tool Development**
  - **Experimental Studies to Fill Technology, Data, and Capability Gaps**
- Summary

One of the major delays in remediation projects has been the development/approval of remediation action plans

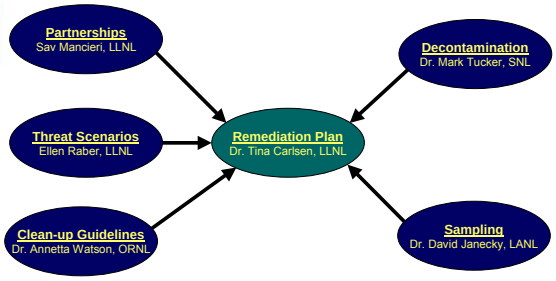
- The OTD is 'pre-planning' the recovery process by developing a comprehensive remediation plan
  - All phases of the operation are examined
  - Reduce the time before remediation can begin
- Key issues can be addressed before an incident occurs
- Planning templates can speed the process and help all stakeholders better understand the issues
  - Identify necessary resources (personnel, equipment, and consumables)
  - Make key decisions (e.g., decon versus replacement)
  - Determine sampling protocols and methods
  - Get "buy-in" from stakeholders

OTD

Development of a site-specific remediation plan for LAX and a generic remediation plan 'template' for use by other facilities

A Remediation Plan must to able to handle multiple contamination scenarios

The Facility Restoration OTD team has been divided into a series of Working Groups



Recovery operations will involve a wide range of stakeholders

Stakeholders include…

- Facility owners/operators
- Federal, state and local health agencies
  - NIOSH
  - US EPA
  - Department of Homeland Security (including TSA)
  - State EPA
  - Law enforcement (federal and local)
  - Department of Transportation
  - Local public health agencies

The Partnerships Working Group Establishes and Facilitates these Relationships

- MOU Signed
  - LAX, DHS, SNL, LLNL
- Meetings with Partner Airport
  - Briefings for LAX Management - Deputy Executive Director, Airport Law Enforcement and Protection Services supports project
  - Briefing to LAX Airport Safety Advisory Committee
  - Remediation Plan Team tour of LAX facility
- Response and Remediation Coordination Plan Development (Con Ops)
  - Notification and First Response Phases drafted and under review
  - Consequence Management Phase information under review
- Airport Remediation Plan (RP) Workshop
  - Objective: Familiarize Stakeholders with Remediation Plan Template
  - September 2007
- Tabletop Exercise
  - Objective: To demonstrate pre-planning capabilities and other tools
  - Spring 2008
- Final Demonstration
  - FY09

The Threat Scenarios Working Group has established a realistic threat space for the project

- Objective: To develop realistic threat space for critical transportation facilities
  - Agents and types of release to be addressed in the Remediation Plan
  - To support the Tabletop Exercise
- CW Agent List Defined
  - CW Agents
  - Toxic Industrial Chemicals
- Release Scenario Defined for Tabletop Exercise
  - Location – International Terminal at LAX
  - CONTAM modeling exercise in progress to support tabletop exercise

Threat scenarios developed with input from other DHS projects and other federal agencies

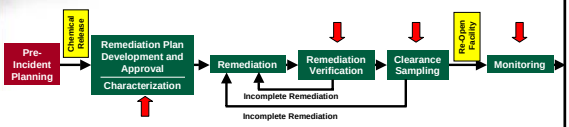
The Clean-up Guidelines Working Group is using historic data to develop a set of recommended clean-up standards

Table 2-3. Recommended civilian airborne (inhalation, ocular) exposure guidelines (mg/m³) for selected CWAs.

Type of Standard or Guideline	Exposure Scenario		Tabun (GA) (CAS 77-81-6)	Sarin (GB) (CAS 107-44-8)	Soman (GD) (96-64-0) and Cyclosarin (GF) (329-99-7)	VX (CAS 50782-69-9)	Sulfur Mustard (NH/D) (CAS 505-60-2)
Occupational							
STEL (Short-Term Exposure Limit)	Worker-acute-intermittent 15-min exposure (<4 x day)		1×10^{-4}	1×10^{-4}	5×10^{-5}	1×10^{-5}	3×10^{-3}
TLV© or WPL (Worker Population Limit)	Worker-chronic 8-hr, daily/30-yr time-weighted average		3×10^{-5}	3×10^{-5}	3×10^{-5}	1×10^{-6}	4×10^{-4}
Transit passengers			AEGL				
AEGLs (Acute Exposure Guideline Levels)	Level 1 mild-no effects	8 hr	0.0010	0.0010	0.00050	0.000071	0.008
Protective Estimate (calculated)			Derivation				
		≤ 8 hr	(See 8-hr AEGL-1)	(See 8-hr AEGL-1)	(See 8-hr AEGL-1)	(See 8-hr AEGL-1)	(See 8-hr AEGL-1)
		>8 ≤24 hr	0.0003	0.0003	0.0002	0.000024	0.003

Example of clean-up guidelines being developed by the Facility Restoration OTD for inclusion in the Remediation Plan

The Sampling Working Group is developing recommendations for sample collection and analysis



- The Sampling Working Group is focusing on four sampling phases:
  - Characterization
  - Remediation Verification
  - Clearance Sampling
  - Monitoring
- In addition, the sampling Working Group is also focusing on:
  - Statistical sampling methods to reduce number of required samples and to increase confidence in negative results
  - Utilization of the LRN and DHS mobile labs for analysis of chemical samples

Recommended sampling methods for each agent on the threat list will be included in the Remediation Plan

The Decontamination Working Group is identifying and recommending methods to decontaminate agents on the threat list

- Four types of technologies needed
  - Surface and 'hot spot' decon
    - Liquids, foams, gels
  - Large volumes (enclosed and semi-enclosed)
    - Gases, vapors, and aerosols
  - Sensitive equipment
    - Gases, vapors, aerosols, and solvent-based approaches
  - Waste
    - Liquids, foams, gels
- Decon technology may vary depending on agent released
- Have prepared a survey of existing and emerging decon technologies
- Engaging experts from outside of DHS
  - DOD, EPA

Decontamination technology recommendations are being developed for inclusion into Remediation Plan

Decontamination technology surveys were conducted for the Remediation Plan

Decon	HD		VX		G Agents		Corro-sive-ness	Toxi-city	Deploy-ment	Cost	Residue
	Contact Time	Efficacy	Contact Time	Efficacy	Contact Time	Efficacy					
DF-200[1]	30 min	>99.8%	30 min	>99.8%	30 min	>99.9%	L	L	M	M	Yes
L-Gel[2]	24 hr	100%	24 hr	65% on asphalt 99% on concrete	24 hr	98% on asphalt 99% on concrete	M	L	M	M	Yes
HTH[3]	5 min	✓	5 min	✓	5 min	✓	H	H	H	L	No
STB[3]	30 min	✓	30 min	✓	30 min	✓	H	H	M	L	No
Bleach[3,4]	5 min	✓	5 min	✓	5 min	✓	H	H	M	L	No
CASCAD[5]	5 min	>99.95%	5 min	✓	5 min	>99%	L	L	M	M	Yes
GDS 2000[6]	1 min 3 hrs	>99.8% 99.87%	1 min 3 hrs	>99.8% 99.97%	1 min 3 hrs	>99.8% 99.95%	—	—	M	—	Yes
Decon Green[7]	20 min 15 min	99.9% 99%	20 min 15 min	>99.9% 96%	20 min 15 min	>99.9% 90%	H	H	M	M	Yes
Liquid CO_2[8]	Minutes	Good	Hours	Poor	—	None	M-H	M-H	M	L	No
All-Clear[9]	—	—	—	✓	30 min	95%	L	L	M	—	—
BIT[10]	sec-min	98%	sec-min	99% >99.999%	sec-min	99%	L	L	M	M	No

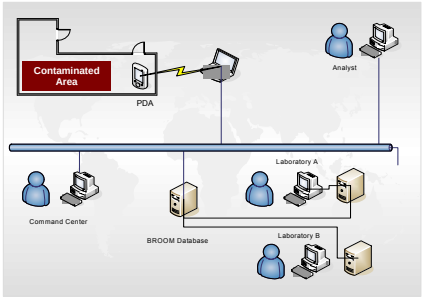
Result of survey of technologies for surface and hot spot decontamination

Recommendations for specific decontamination technologies are included in the Remediation Plan

- Surface and Hot Spot Decontamination
  - DF-200 (for surfaces where corrosion is an issue)
  - 10% Bleach (for surfaces where corrosion is not an issue)
- Volumetric Decontamination
  - mVHP (for persistent agents)
  - Ventilation and Enhanced Attenuation (for non-persistent agents)
- Sensitive Equipment Decontamination
  - mVHP (for large non-moveable items)
  - Solvent Bath (for small moveable items)
- Decontamination of Waste
  - 10% Bleach

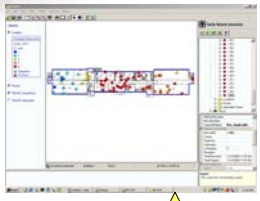
The Decision Support Tool Working Group is adapting the BROOM Decision Support Tool for chemical use

Building Restoration Operations Optimization Model (BROOM)



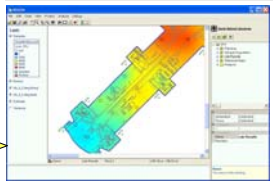
BROOM can be used for pre-event planning and post-event operations

BROOM can collect, manage, visualize, and analyze the large amounts of data associated with a chemical agent release



- **Data Collection, Management, and Visualization**
  - Sample locations
  - Sample results
- **Data Analysis**
  - Map Contamination
  - Map Uncertainty
  - Optimize subsequent sampling to reduce uncertainty in magnitude and extent

Data Management and Visualization



Data Analysis

The OTD is also integrating BROOM with PNNL's Visual Sampling Plan (VSP)

The Project is also addressing critical data and technology gaps

- Surface Sample Collection Efficiency and Detection Limits for CW Agents (Koester, LLNL and Hankins, SNL)
  - Objective: To determine the collection efficiency and detection limits of the surface sampling methods on porous and non-porous surfaces that would be typically found in the interior of a transportation facility. Experimental work will be conducted using relatively low concentrations relevant to civilian terrorist release scenarios.
- Interaction of Chemical Agents on Interior Surfaces and Natural Attenuation/Decay Rates (Love, LLNL and Ho, SNL)
  - Objective: To determine adsorption/desorption and decay rates for chemical agents on interior surfaces. Experimental work will be conducted using low concentrations relevant to civilian terrorist release scenarios since there is data available for very high concentrations.
- Gas/Vapor Decontamination Method Scale-up Evaluation (Tucker, SNL and Smith, LLNL)
  - Objective: To evaluate potential gas/vapor technologies at a larger scale by conducting a series of simulant, live agent and TIC tests. We will also assess barrier materials that could be used to seal facilities prior to a gas/vapor decontamination process.
- Statistical Sampling Algorithm Validation (Knowlton, SNL and MacQueen, LLNL)
  - Objective: To validate potential statistical sampling algorithms against data from actual release sites. In addition, we will integrate the validated methods into BROOM.

Task 1 - Surface Sample Collection Efficiency and Detection Limits for CW Agents

- No validated standard analytical methods available for trace level CWA sampling and analysis
  - Methods, such as those of EPA SW846, promulgated for regulated toxic industrial chemicals (TICs)
  - Proposed methods for other TICs & CWAs currently undergoing validation & other studies in progress (e.g. *A Literature Review of Wipe Sampling Methods for Chemical Warfare Agents and Toxic Industrial Chemicals*, US EPA, January 2007)
- Need to demonstrate detection of CWAs on relevant substrates at levels lower than guideline levels (~300 ng/cm2)

Task 1 - Continued

- Initial substrates selected are porous and non-porous materials typically found in building interiors
  - **304 stainless steel** (3 cm x 3cm)
  - **Vinyl tile** (Armstrong commercial flooring, Standard Excelon vinyl composition tiles, Pattern 51858, Imperial Texture, sandrift white, 1/8 inch thick)
  - **Concrete** (made in-house for uniform coupon & aggregate sizes)
  - **Painted, standard drywall** (painted with 1 coat Glidden commercial latex primer and 1 coat) interior eggshell paint, 1/4 inch thick
- CWAs selected for testing
  - GB (Sarin)
  - HD (Mustard)
  - VX

Task 1 - Continued

Initial experiments: solvent extractions of HD from glass control surface (100 ug/cm^2) with CH_2Cl_2

Conditions	Recovery (%)
Solvent control	100 ± 13
Glass treated with Sigmacote®	108 ± 2
Glass, 20-mL vial, nontreated	86 ± 23
Gold seal	103 ± 4
304 stainless steel (1 cm x 1 cm)	101 ± 2

Extraction method works well for non-reactive surfaces

Solvent extractions of HD from stainless steel surface (10 ug/cm^2) with CH_2Cl_2

Conditions	Recovery (%)
Solvent control	**100 ± 7**
Non-treated glass	**8 ± 5**
Sigmacote®-treated glass	**88 ± 14**
304 stainless steel	**ND**

Surface reactivity appears to be important at low concentrations (needs validation)

Swipe extractions of HD from substrates (10 ug/cm^2) with different liquids

Conditions	Recovery (%)
glass, direct extraction, 50/50 CH_2Cl_2/acetone	**82 ± 10**
glass, swipe extraction, 50/50 CH_2Cl_2/acetone	**29 ± 13**
glass, swipe extraction, ethyl acetate	**31 ± 17**

Swipe extraction not as efficient as direct solvent extraction under conditions used

The Project is also addressing critical data and technology gaps

- Surface Sample Collection Efficiency [illegible]gents (Koester, LLNL and Hankins, SNL)
  - Objective: To determine the collection efficie[illegible] sampling methods on porous and non-porous surface[illegible]terior of a transportation facility. Experimental work w[illegible]centrations relevant to civilian terrorist release scenarios.
- Interaction of Chemical Agents on Interior Surfaces and Natural Attenuation/Decay Rates (Love, LLNL and Ho, SNL)
  - Objective: To determine adsorption/desorption and decay rates for chemical agents on interior surfaces. Experimental work will be conducted using low concentrations relevant to civilian terrorist release scenarios since there is data available for very high concentrations.
- Gas/Vapor Decontamination Method Scale-up Evaluation (Tucker, SNL and Smith, LLNL)
  - Objective: To evaluate potential gas/vapor technologies at a larger scale by conducting a series of simulant, live agent and TIC tests. We will also assess barrier materials that could be used to seal facilities prior to a gas/vapor decontamination process.
- Statistical Sampling Algorithm Validation (Knowlton, SNL and MacQueen, LLNL)
  - Objective: To validate potential statistical sampling algorithms against data from actual release sites. In addition, we will integrate the validated methods into BROOM.

Task 2 regarding agent fate activities will be discussed in a subsequent talk in this session

Task 3 - Gas/Vapor Decontamination Method Scale-up Evaluation

- Decontamination Experimental Task
  - Hot Air Decon Evaluation
  - Fire Sprinkler Evaluation

Task 3 - Gas/Vapor Decontamination Method Scale-up Evaluation

Volumetric decontamination technologies may vary depending on the persistency of the agent

Ventilation
Natural Attenuation
Enhanced Ventilation

mVHP

G agents (Sarin, Soman, etc.) → Mustard → VX

Agent Persistency (Less Volatile)

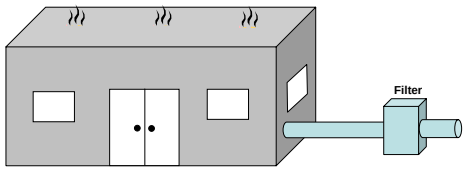
Gaps exist for volumetric decontamination technologies for low persistency agents

Considerable work has been conducted by the DoD to evaluate the mVHP technology

Objective: Reduce the time for decontamination and eliminate the need to use more time-consuming processes (i.e., mVHP)

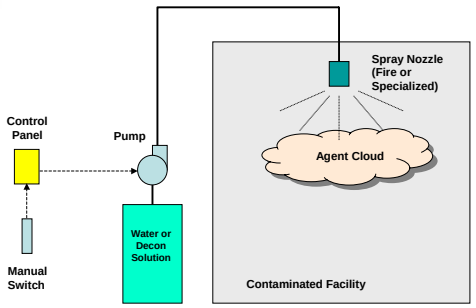
We are evaluating enhanced ventilation (heat assisted) as a rapid method to remediate facilities contaminated with non-persistent agents

1. Heat interior of entire facility to desorb agents from surfaces
2. Filter and remove agent from air



To evaluate enhanced ventilation as a decon method, we are addressing two issues: (1) What are the temperatures and time required to desorb chemical agents from materials of interest? and (2) What methods are required to heat a facility to the required temperature?

Can a fire sprinkler system (or a specialized spray system) be used to knockdown a chemical agent cloud in a facility?



Minimize casualties and minimize spread of contamination

Experiments were conducted to determine if fire sprinkler systems and other spray systems can knockdown a chemical agent cloud

Generate G agent simulant (DMMP) with Collison Nebulizers into 8'x8'x8' Test Chamber

Place porcine skin, non-sealed tile, and glass slides into test chamber

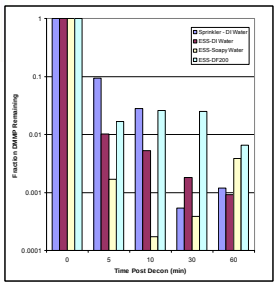
Run water at 10 gpm through sprinkler head (10 gpm is the NFPA requirement for a 64 ft² room).

Run DI water at 0.2 gpm, soapy water at 0.2 gpm, and DF-200 at 0.05 gpm through ESS nozzles

Measure concentration of DMMP simulant in chamber and on materials using gas chromatography

- **Air in chamber (using BioSampler™)**
- **Water on floor of chamber**
- **Porcine skin**
- **Non-sealed tile**
- **Glass slides**

Fraction DMMP Remaining in Chamber



- Sprinkler – DI Water (10 gpm)
  - 1 log knockdown within 5 min
  - 3 log knockdown within 30 min
- ESS Nozzles – DI Water (0.2 gpm)
  - 2 log knockdown within 5 min
  - 3 log knockdown within 60 min
- ESS Nozzles – Soapy DI Water (0.2 gpm)
  - 3 log knockdown within 5 min
  - 4 log knockdown within 10 min
- ESS Nozzles – DF-200 (0.05 gpm)
  - Almost 2 log knockdown in 5 min
  - 2 log knockdown within 60 min

Preliminary Knockdown Test Conclusions

- Fire sprinkler system may aid in mitigation of chemical attack for agents that are soluble in water
  - Reduce casualties
  - Reduce fraction of facility that is contaminated
- Under the test conditions with DMMP, the ESS nozzles did not perform as well as the fire sprinkler system. However, this may be attributed to the **smaller volume of liquid** that was released through these nozzles.
- IPA results (not shown) and other tests indicate that with a longer run time for the ESS nozzles, they work as well as the fire sprinkler system with smaller volumes of water.
- More tests should be performed.
  - Repeatability
  - Investigate chemical simulants that are not soluble in water
    - DMMP – 300% soluble in water and it's vapor pressure is lowered by the presence of water, which may give a higher success than may actually occur
    - Tests with ethyl mustard (HD simulant) showed almost no impact from turning the sprinklers on with water (ethyl mustard is not soluble in water)
- Need to identify in what cases this mitigation strategy should be taken – it may not be advisable in all cases.
- At the present time, **fire sprinklers systems cannot be turned on manually** – they are activated by the presence of heat.

Presentation Outline

- Background and Project Overview
- Project Activities
  - Remediation Plan Development
    - Partnerships
    - Threat Scenarios
    - Clean-up Guidelines
    - Sampling Methodologies
    - Decontamination Technologies
  - Decision Support Tool Development
  - Experimental Studies to Fill Technology, Data, and Capability Gaps
- Summary

We are developing a systems approach for chemical remediation and recovery

Response and Recovery Activities					
Crisis Management		**Consequence Management**			
Notification	**First Response**	**Remediation/Cleanup**			**Restoration (Recovery)**
		Characterization	**Decontamination**	**Clearance**	
Receive and assess information Identify suspect release sites Relay key information and potential risks to appropriate agencies	HAZMAT and emergency actions Forensic investigation Public health actions Screening sampling Determination of agent type, concentration, and viability Risk communication	Detailed characterization of biological agent Characterization of affected site Site containment Continue risk communication Characterization environmental sampling and analysis Initial risk assessment Clearance goals	Worker health and safety Source reduction Decontamination strategy Remediation Action Plan Site preparation Waste disposal Decontamination of sites, items, or both Verification of decontamination parameters	Clearance sampling and analysis Clearance decision	Renovation Reoccupation decision Long-term environmental and public health monitoring

QSTRs to Support Estimation of Cleanup Goals

Chandrika J. Moudgal
US EPA, ORD, NHSRC

Decontamination Workshop, RTP, June 20-22, 2007

Office of Research and Development
National Homeland Security Research Center, Threat and Consequence Assessment Division

Outline

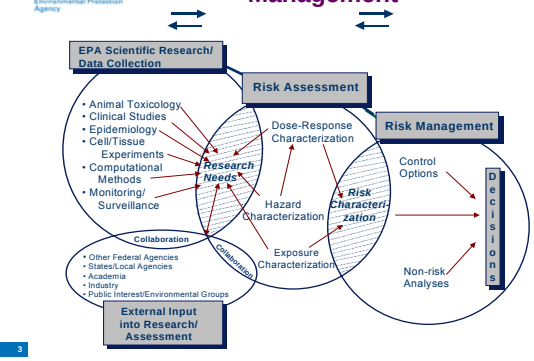
- Risk assessment paradigm
- Cleanup goals-an overview
- What is Quantitative Structure Toxicity Relationship (QSTR)?
- Applying QSTRs to determine screening level, risk-based clean-up goals
- Conclusions and recommendations for decontamination

Risk Assessment Paradigm-NAS 1983

- Hazard Identification[1]- process to determine whether exposure to an agent causes an adverse effect
- Dose Response Assessment- process to quantitatively characterize the relationship between a dose and the effect seen at that dose
- Exposure Assessment- process to determine the magnitude, frequency, duration, and route of exposures experienced or anticipated
- Risk Characterization- estimate the likelihood of adverse health effects in the exposed population

[1] Also referred to as Hazard Assessment-see EPA 2005 cancer guidelines

Linking Risk Assessment to Risk Management



Source: Courtesy, Dr. Hugh McKinnon, U.S. EPA, National Risk Management Research Laboratory

What are Risk-Based Cleanup goals?

- Concentrations of chemicals in a variety of environmental media based on estimates of toxicity, exposure and a target risk or hazard
- Used for site "screening" and as initial cleanup goals when applicable
- Can serve as target to use during the analysis of different remedial/decontamination alternatives
- Solely health-based
- They are **NOT** *de facto* cleanup standards

Risk Based Environmental Concentration

Risk = *f* (Exposure and Toxicity)

Lifetime incremental risks = Exposure factors and chemical concentration X Chemical specific effects

Cleanup Goals as Risk Based Concentration

Risk = Media Conc. X Exposure X Toxicity

$$\frac{\text{Target Risk}}{\text{Exposure X Toxicity}} = \text{Media Conc.}$$

Target risk for carcinogens is 1 E-6 to 1E-4
Target hazard index (HI) for non-carcinogens is 1

More information available at http://www.epa.gov/oswer/riskassessment

Risk Based Cleanup Goals

- Possible to generate media-specific screening values based on exposure factors, and toxicity value for chemical and a risk level
- Exposure assumptions may be default (i.e. Agency defaults) or site-specific
- Toxicity values may be carcinogenic or non-carcinogenic
- Most numbers are for chronic exposures
- Numbers can be for adults and/or children, population, etc.

Commonly Available Cleanup Goals[1]

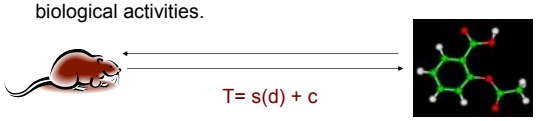
- US EPA Region 3 Risk-based Concentrations (RBCs)
- US EPA Region 6 Media-Specific Screening Levels (MSSLs)
- US EPA Region 9 Preliminary Remediation Goals (PRGs)
- Soil Screening levels (SSLs)
- Various state numbers

[1] Note: These are used for screening purposes only

Moving Onward to QSTR and it's application……..

What are QSTRs?

QSTRs are mathematical equations or models that describe the correlations between various features of a chemical's molecular structure and its observed biological activities.



T= s(d) + c

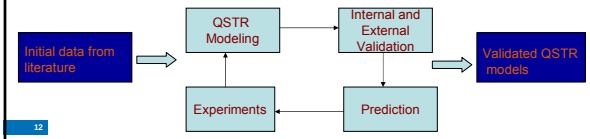
T= Toxicological endpoint
s= Statistical coefficient-generally linear
d= descriptor computed from the chemical structure-physical or chemical properties
c=constant

Why QSTR?

- QSTR can provide toxicity estimates to risk assessors and toxicologists for use in the risk estimation process when toxicity data are unavailable
- QSTR will provide rapid and reliable results
- QSTR will permit rapid screening and ranking of a number of chemical agents

QSTR Methodology

- Study phenomena/activity; e.g. lowest observed adverse effect level (LOAEL), carcinogenicity, etc.
- Get descriptors from chemical structure; several commercial descriptor generator pkgs available
- Perform statistical analyses
- Validate the QSTR model
- Predict activity for new set of compounds



Applying QSTRs to Cleanup Goals

- Utilize commercial or customized QSTR models to estimate toxicity of one or group of chemicals
- Use quantitative estimate (such as a LOAEL) to estimate a cleanup goal
- Could utilize the estimate directly using uncertainties (not recommended!) or utilize the QSTR estimate to determine an appropriate surrogate with an existing cleanup goal

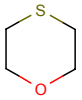
Applying QSTRs to Cleanup Goals

- Let's go through an example……..
- Using TOPKAT®, a commercial QSTR model
- Two scenarios:
  - Utilize the estimate directly to determine a cleanup goal-not recommended!
  - Utilize the estimate to determine an appropriate analog; analog can be determined using TOPKAT®'s unique "similarity search"[1] feature

[1] Moudgal et al., Environ Sci. Technol., 2003

QSTR Analysis of 1,4-Thioxane-TIC

- Using TOPKAT®'s chronic rat oral LOAEL model to obtain a useful quantitative estimate



1,4-Thioxane

Computed LOAEL Estimate

Submodel Utilized: Chronic LOAEL (Alicyclic) Model

Computed Chronic LOAEL = 219.3 mg/kg

95% Confidence Limits: 67.4 mg/kg and 713.0 mg/kg

Computed Chronic LOAEL, Log (1/Moles) = 2.677

DON'T TRY THIS AT HOME!

Hypothetical Cleanup Goal Using QSTR LOAEL Estimate

- Computed chronic LOAEL is 219.9 mg/kg-day
- Assuming usage of default uncertainty factors commonly used in the derivation of an RfD, we can estimate the computed RfD using the maximum allowed combined uncertainty factor of 3000 to be:

$$\text{Computed RfD} = \frac{219.9}{3000} = 0.07 \text{ mg/kg-day}$$

Hypothetical Cleanup Goal Using QSTR LOAEL Estimate

Calculation for non-carcinogenic effects in adults in residential soil[1]

$$C\ (mg/kg) = \frac{THQ \times BW_a \times AT_n}{EF_r \times ED_r \times [1/RfD_o \times IRS_a/10^6\ kg/mg]}$$

Parameters	Definitions	Default Value
C	chemical conc. in soil	
THQ	target hazard quotient (unitless)	1
BW_a	Body Weight-adult (kg)	70 kg
RfD_o	oral chronic reference dose (mg/kg-day)	chemical specific
AT_n	averaging time-noncarcinogens (yr)	30 yr x 365 days/yr
EF_r	exp. Frequency (days/yr)	350days/yr
ED_r	exp. Duration	30 yrs
IRS_a	Soil Ingestion-adult (mg/kg)	100

[1] See http://www.epa.gov/region09/waste/sfund/prg/files/04userguide.pdf Eq. 4-2

Hypothetical Cleanup Goal Using QSTR LOAEL Estimate

- Applying default factors to equation in slide 19 and the chemical specific computed RfD of 0.07mg/kg-day for 1,4-thioxane we arrive at:

$C_{1,4\text{-thioxane}}$ = ~4000mg/kg or 4.0E+03

Appropriate Analog Using TOPKAT®

- Using TOPKAT ®'s "similarity search" feature, the following analogs are recommended for 1,4-thioxane:

Suggested Analogs and Some Suggested Cleanup Goals

Name	PRG	SSL	MSL	RBC
1,4-Dioxane	A	NA	A	A
3-Sulfolene	NA	NA	NA	NA
Cyclohexylamine	A	NA	NA	NA
Dimethoxane	NA	NA	NA	NA
Gamma-butyrolactone	NA	NA	NA	NA
Pivalolactone	NA	NA	NA	NA

A-Available NA-Not Available

Advantages of QSTR

- Cheap and reliable
- Extremely fast
- Provides an understanding of the effect of structure on activity (mechanisms of reaction)
- Predictions may lead to the synthesis of novel chemicals

Disadvantages of QSTR

- False correlations
- Needs well qualified & quantified experimental values
- Co-correlation between descriptors
- Lack of acceptance

Advantages for Decon Methods

- Cleanup goals and QSTR methods could drive decon technology decisions
- QSTR methods may be used to assess the potential toxicity of chemicals that lack toxicity data
- QSTR methods may be used to assess the toxicity of the decon agent, if necessary
- QSTR methods may be used to assess the potential toxicity of decon by-products

Acknowledgements

Deborah McKean for providing assistance on cleanup goals

Questions?

Determining CWA Environmental Fate to Optimize Remediation for Indoor Facilities

Adam H. Love*, Carolyn J. Koester*, Armando Alcaraz*,
M. Leslie Hanna*, Pauline Ho+, John G. Reynolds*, Ellen Raber*

*Lawrence Livermore National Laboratory
+Sandia National Laboratory

NHI Nonproliferation, Homeland and International Security

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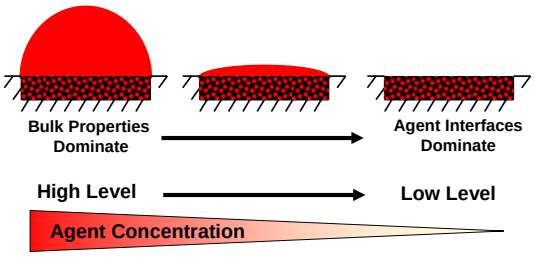
Lawrence Livermore National Laboratory, P.O. Box 808, Livermore, CA 94551

CWA Persistence on Indoor Surfaces

Dynamics, affinity, and reactivity control CWA persistence
- Current knowledge primarily on vapor hazards
- Limited information about surface contamination

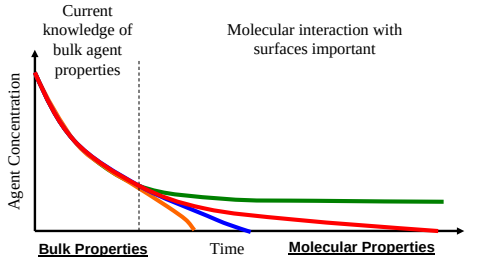
3 Agents: HD, GB, VX
8 Surfaces:
1. Glass
2. Stainless Steel
3. Vinyl Floor Tile
4. Latex Painted Wallboard
5. Concrete
6. Escalator Handrail
7. Polyester Flexible HVAC Duct
8. Galvanized Steel HVAC Duct

Concentration Matters for Persistence and Fate



Restoration will likely have many surfaces with low levels of contamination

Surface Properties Matter for Persistence and Fate



Bulk Properties		Molecular Properties	
Volatilization	Hydrolysis	Catalysis
Dissolution	Oxidation	Sorption
Infiltration	Biodegradation	Complexation

Enabling Better Decisions

First responders phase:
- mitigate any subsequent spread of contamination

Characterization phase:
- more quickly determine the extent of contamination

Decontamination phase:
- identifying materials that have no affinity for CWA or rapidly react with CWA to self-decontaminate
- determine if natural attenuation is adequate for decontamination
- identifying surfaces that require active decontamination or removal

Understanding Contamination Extent

2 Modes of Exposure:

Vapor Exposure
- Greater spatial spread
- Lower magnitude of contamination

Liquid Exposure
- Lower spatial spread
- Greater magnitude of contamination

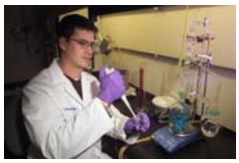
Understanding contamination distribution and magnitude focuses remediation efforts

CWA Fate Data

We would like to evaluate and use, where appropriate, Department of Defense and Environmental Protection Agency information

In addition, important new information is being generated through CWA persistence experiments to fill in missing technical information

- Affinity
- Accumulation rate
- Persistence

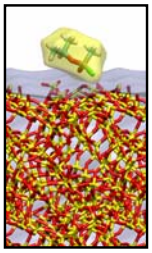


Ultimate goal is a mechanistic understanding of persistence

- Physical characteristics
- Chemical characteristics

Understand of CWA fate must be improved to address civilian exposure considerations

Realistic CWA Exposures



Experiments of CWA Fate must represent realistic contamination

- **Vapor Deposition**
  - Initial exposure to saturated CWA vapor to determine affinity
  - Rate of CWA accumulation from vapors determined
  - Rate of CWA attenuation from vapor contamination determined
- **Neat Liquid Deposition**
  - Rate of CWA attenuation determined
- **Detailed Surface Examination**
  - Understand deterministic properties

Avoiding solvent-diluted CWA since solvent can alter material interactions

Developing Analytical Methods for Mass Balance

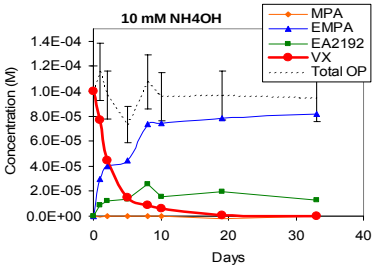
Mechanistic understand of CW fate require Mass Balance approach

- Usually different than analytical methods for characterization efforts
- Strive for 100% accountability

Volatile and non-volatile chemical analysis

- **Multiple techniques**
- **Individual extraction efficiencies**

Labor intensive, but necessary

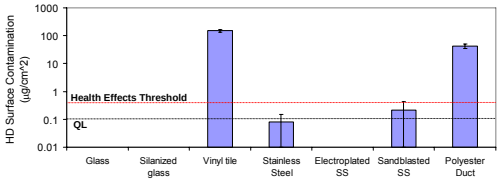


Evaluating CWA Affinity

1 Week Exposure Saturated Vapor

Rapid Screen for Vapor Accumulation

- **Achieves saturated vapor is < 8 hours**
- **Highly reproducible testing environment**
  - **Multiple coupons per jar**
  - **Multiple jars**
- **Worst-case vapor exposure**



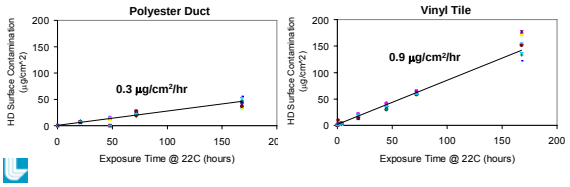
CWA Surface Accumulation

Dynamics of CWA accumulation has implications for restoration efforts

- Surfaces that act as collectors for characterization
- Impacts of delayed remediation on magnitude of contamination

Subsequent experiments will determine dynamics of persistence

- Natural attenuation
- Self-decontamination
- Persistent



Unique Approach to Surrogate Work

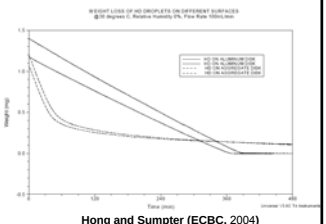
Limited number of materials can be tested using real CWA

Most CWA surrogates are poor at simulating chemical interactions

Instead, used to categorize surfaces that have similar physical accumulation and persistence dynamics

- Permits a larger number of materials to be evaluated
- Creates categories of materials with similar dynamics

May enable limited CWA results to be extended to materials not specifically tested



Hong and Sumpter (ECBC, 2004)

Enacting Better Decisions

Understanding CWA fate improves the efficiency of the time and effort spent on remediation

1. **Surfaces that do not accumulate CWA**
   - **Cannot be used for characterizing contamination extent**
   - **Nothing to decontaminate**
2. **Surfaces that do accumulate CWA but have short persistence**
   - **May be used for characterization**
   - **Self-decontamination requires little effort**
3. **Surfaces that do accumulate CWA and have long persistence**
   - **Ideal surface for characterizing contamination extent**
   - **Decontamination requires active efforts**

Resulting in more rapid and less expensive facility restoration

1. Results from the Evaluation of Spray-Applied Sporicidal Decontamination Technologies

2. Test Plans and Preliminary Results for Highly Pathogenic Avian Influenza Virus Persistence and Decontamination Tests

Joseph Wood

Presented at USEPA Decontamination Workshop

Research Triangle Park, NC

June 20-22, 2007

Results from the Evaluation of Spray-Applied Sporicidal Decontamination Technologies

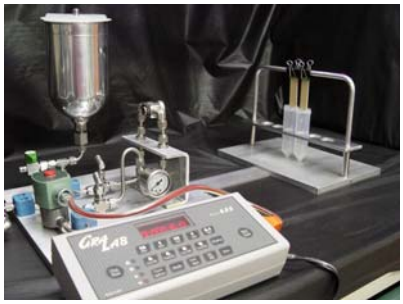
Joseph Wood, Shawn P. Ryan, et al., USEPA

Mike Taylor, James Roger, et al., Battelle Memorial Institute

Acknowledgements

- Battelle
- TTEP Stakeholders
- Peer reviewers
- Collaborators

General Overview of Method



Quantitative Determination of Effectiveness General Test Method

- Extraction
  - Coupons placed in 50 ml vials with 10 ml PBS + Triton X-100
  - Orbital shaker 15 minutes, 200 RPM
- Analysis
  - Dilution plating of extract
    - ➔ Quantitative determination of recoverable CFUs
  - Coupons placed in Tryptic Soy Broth (TSB)
    - ➔ Qualitative assessment of non-extracted viable spores

Calculation of Log Reduction

$$E = \frac{\sum_{i=1}^{n} E_i}{n}$$

n = number of replicate coupons in a particular decontamination trial

E = log reduction (LR) for a specific material (geometric mean of all replicates for a material)

$$E_i = \log_{10} \frac{\overline{N}}{X_i}$$

$\overline{N}$ = the mean number of viable organisms (CFUs) recovered from the positive control coupons

X_i = the number of viable organisms of a given type recovered from a replicate test coupon (*i*) after decontamination.

E_i = log reduction (LR) of 1 replicate coupon within a test

Liquid Sporicidal Technologies Evaluated

Product	Vendor	General Description/ Formula Type	Components	EPA Registration*	Contact Time (min)
Bleach	Clorox®	Sodium hypochlorite	Sodium hypochlorite 5-6% (pH-amended by Battelle by adding acetic acid 5% and water**)	5813-1	10
CASCAD SDF	Allen-Vanguard	Hypochlorite	Sodium myristyl sulfate 10-30%, sodium (C14-16) olefin sulphonate 10-30%; ethanol denatured 3-9%; alcohols (C10-16) 5-10%, sodium sulfate 3-7%; sodium xylene sulphonate 1-5%; proprietary mixture of sodium and ammonia salt along with co-solvent >9%; dichloroisocyanuric acid, sodium salt 48-85%; sodium tetraborate 3-7%; sodium carbonate 10-15%.	None	30
DeconGreen	Edgewood Chemical & Biological Center	Hydrogen peroxide	Potassium molybdate; potassium carbonate; propylene carbonate 25%; H_2O_2 35%, Triton X-100; polyethylene glycol 4-(tert-octyl)phenyl 25%	None	30
DioxiGuard	Frontier Pharmaceutical	Chlorine dioxide	Inerts	None	10

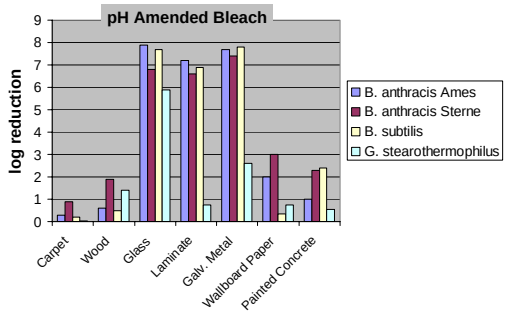
Liquid Sporicidal Technologies Evaluated

Product	Vendor	General Description/ Formula Type	Components	EPA Registration*	Contact Time (min)
EasyDecon 200	Envirofoam Technologies	Hydrogen peroxide	Hydrogen Peroxide <8%; quaternary ammonium compounds, benzyl-C12-C16 alkyl di-methyl chlorides 5.5-6.5%; diacetin 30-60%	74436-1 and 74436-2	60
Exterm-6	ClorDiSys Solutions	Chlorine dioxide	Inorganic acid 25-35%; sodium chlorite 15-30%; inorganic salt 35-45%; activator 5-10%	70060-19	60
HI-Clean 605	Howard Industries	Hypochlorous acid	Sodium dichlorisocyanurate 11%; trichloro-s-triazinetrione 3%	None	90
HM-4100	Biosafe	Quaternary ammonia	Octadecylaminodimethyltrimethoxysilylpropyl ammonium chloride 84%; chloropropyltrimethoxysilane 15%; dimethyl octadecylamine 1%	None	30
KlearWater	Disinfection Technology	Chlorine dioxide	<0.30% ClO_2 suspended in de-ionized water	None	30
Peridox	Clean Earth Technologies	Hydrogen peroxide	H_2O_2 23-25%; peroxyacetic acid 1-1.4%; acetic acid 1-1.4%; inert ingredients 1-2%	81073-1	10
Selectrocide	BioProcess Associates	Chlorine dioxide	Sodium chlorite 15-40%; activator 55-85%; inert ingredients <2%	74986-4	10

pH-Amended Bleach

- Using procedure recommended by stakeholders, water and 5% acetic acid was added to the household bleach to obtain a pH-amended bleach solution. The solution was prepared using 9.4 parts water, 1 part bleach, and 1 part 5% glacial acetic acid to yield a solution having a mean pH of 6.81 ± 0.15 and a mean total chlorine content of 6,215 ± 212 ppm. This "pH-amended bleach" was evaluated for sporicidal activity.
- Sporicidal activity enhanced at lower pH - due to shift in equilibrium from hypochlorite to hypochlorous acid (a more effective sporicide)
  - Dychdala, G.R. Chlorine and Chlorine Compounds, Chapter 7 of Disinfection, Sterilization, and Preservation, Fifth Edition. Seymour Block, editor.

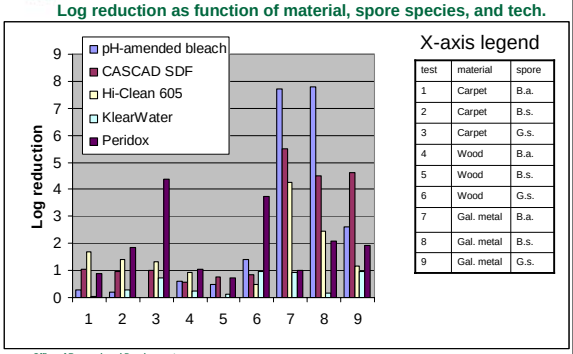
Evaluation Results: Efficacy of pH-Amended Bleach



Inactivation of *Bacillus anthracis* Ames Spores on Glass

Technology	Contact time (minutes)	Log Reduction
CASCAD SDF	30	6.4 ± 1.6
DeconGreen	30	3.4 ± 0.29
DioxiGuard	10	3.2 ± 0.13
EasyDecon 200	60	0.91 ± 0.10
Exterm-6	60	1.1 ± 0.20
HI-Clean 605	90	≥ 7.8
HM-4100	30	0.37 ± 0.22
KlearWater	30	≥ 7.8
Peridox	10	≥ 7.8
Selectrocide	10	2.3 ± 0.08

Log reduction as function of material, spore species, and tech.



X-axis legend

test	material	spore
1	Carpet	B.a.
2	Carpet	B.s.
3	Carpet	G.s.
4	Wood	B.a.
5	Wood	B.s.
6	Wood	G.s.
7	Gal. metal	B.a.
8	Gal. metal	B.s.
9	Gal. metal	G.s.

Available reports

See http://www.epa.gov/nhsrc/news/news072406.html

Test Plans and Preliminary Results for Highly Pathogenic Avian Influenza Virus Persistence and Decontamination Tests

Joseph Wood, Jonathan Kaye, Shawn Ryan
US EPA

James Rogers, Mike Taylor, Young Choi et al.
Battelle

July 17, 2007

Outline

- Acknowledgement
- Purpose
- Test matrix
- Experimental Methods
  - –Agents
  - –Cytotoxicity test
  - –Assay
- Preliminary Results

Acknowledgements

- Battelle
- TTEP Stakeholders
- Peer reviewers
- Collaborators
  - – USDA/APHIS and University of Delaware
  - – Interagency workgroup – led by Jeff Kempter

Purpose of Testing

- Assess persistence of highly pathogenic H5N1 virus and low path H7N2 virus under various environmental conditions and on various surfaces
- Assess efficacy of generic chemicals to inactivate both viruses
- Compare results of H5N1 and H7N2 to determine if H7N2 is suitable surrogate

Test Matrix Overview

- Persistence Tests - H5N1
  - – 2 ambient temperatures (4 and 26 degrees C) at 1 RH (~ 40%)
  - – With and without simulated sunlight
    - Target average UV-B level is ~ 70 microwatts/cm^2
    - UV-A levels ~ 100 microwatts/cm^2
    - UV-C level = zero
  - – 4 materials
  - – 4 non-zero contact times
- Persistence tests – H7N2
  - – 2 materials, 2 non-zero contact times, 2 environmental conditions
    - Selected based on highest persistence of H5N1
- Decontamination tests
  - – Matrix similar to above, except testing chemical inactivation in lieu of UV, Temperature, and time

Avian Influenza Test Agents

- H5N1 - A/Vietnam/1203/04
- H7N2 - A/H7N2/chick/MinhMah/04

Cytotoxicity tests and AI quantitation assay methods

- Cytotox test
  - –Purpose is to ensure that cells used to assay AI virus remain viable when exposed to coupon material extracts, neutralized decontamination liquids
  - –MTT assay (3-(4,5-dimethylthiazol-2-yl)-2, 5,-diphenyltetrazolium bromide)
- AI quantitation
  - –Expressed as $TCID_{50}$ (tissue culture infectious dose of 50%) , based on cytopathic effects on cells, using Spearman Karber method
  - –Use MDCK (Madin-Darby Canine Kidney) cells for H5N1
  - –Will use chicken embryo fibroblasts (CEF) assay for H7N2

Preliminary results

- Chamber set up, environmental conditions characterized
- Cytotoxicity (MDCK cells) of material extracts test results
  - – The required dilutions for material extracts have been determined so that cell viability for these extracts is above 90%.
- Propagation of virus
  - – H5N1 inoculum prepared ~ 10^7 $TCID_{50}$/ml
  - – H7N2 – ~10^4 $TCID_{50}$/ml – based on MDCK assay
    - May need to use CEF assay for low path virus
- Recovery of H5N1 off of materials (after 1 hour of drying)
  - – Recovery off of concrete and pine is zero, after trying different extraction methods
    - Will not be able to use these materials
  - – Mean recovery from glass ~ 9%
  - – Mean recovery from soil ~ 55%

Inactivation of Avian Influenza Virus Using Common Soaps/ Detergents, Chemicals, and Disinfectants

R.L. Alphin, E.R. Benson, M.E. Lombardi, K.J. Johnson and B.S. Ladman

UNIVERSITY OF DELAWARE

Introduction

- Avian influenza virus (AIV) is an ongoing global threat
- HPAIV significant threat to US and international poultry production
  - 186 human fatalities (307 cases; 5-07)
  - 140+ million poultry
  - Asian cost: $10 billion

Delmarva Broiler Industry

- Annual Broiler Production 2006 – 568 Million
- Total Pounds Of Chicken ~3.38 Billion
- Wholesale Value of Broilers~$1.62 Billion
- 13,900 Employed (1,956 Growers)
- Each Job In The Poultry Industry Creates 7.2 Jobs Elsewhere

Introduction

Current approved disinfecting agents in the United States have many limitations

- Limited availability
- Expensive
- Corrosive
- Harmful to the environment

Introduction

- Approval is needed for more economical and environmentally friendly disinfecting agents against AIV
  - Criteria for the ideal agent
    - Effective inactivation of AIV
    - Widely available
    - Biodegradable
    - Inexpensive
    - Antimicrobial

Introduction

- Agents selected by the USDA and EPA
  - Acetic Acid
  - Citric Acid
  - Sodium Hypochlorite
  - Calcium Hypochlorite
  - Powered Laundry Detergent with Bleach
  - Iodine/acid commercial disinfectant
  - Additional agents to be selected

Objective

- Evaluate widely available soaps/detergents, chemicals, and disinfectants (agents) for their efficacy in inactivating avian influenza virus.
- Develop test methods to meet the requirements for Section 18 EPA temporary approval for hard, non-porous surfaces.

Experimental Method

- 6-well plate test
  - Coupons (2.2 x 2.2 cm)
    - Galvanized steel
    - Plastic
    - Wood
  - Hard water (400 ppm $CaCO_3$)
- Viral agent:
  - A/H7N2/Chick/Minh Ma/04 LPAIV

Experimental Method

- Application of agents
  - Coupons with dried virus were placed into 6-well plates
    - 2 plates for each material (12 wells)
    - 1 plate for positive controls
      - 2 wells for each material
    - 1 plate for cytotoxic control (6 wells)
  - 2.0 mL of prepared disinfecting agent applied to each well
  - Plates agitated for 10 minutes
  - Fluid from each plate collected and pooled

Positive Control Plate with Coupons

Application of test solution to virus film on coupons in 6-well plate

Collection of test solution post exposure to virus film on coupon

Collected test solution to be diluted, post treatment of virus film on coupon

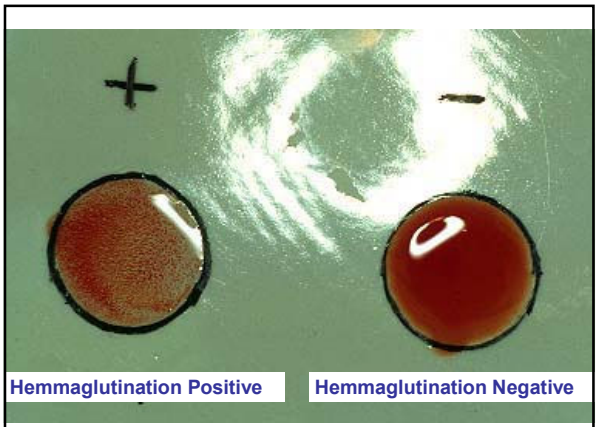
Inoculation of diluted test solution into embryonated eggs

Experimental Method

- Embryo Inoculation
  - Fluid from plates diluted using three 10-fold serial dilutions
    - Positive control materials diluted with six 10-fold serial dilutions
    - First dilution made with D/E Neutralizing Broth
  - Each dilution inoculated into five, 9-11 day old specific pathogen free (SPF) embryonated chicken eggs
  - Eggs candled daily for five days

Experimental Method

- Viral inactivation
  - Fluid collected from each egg
  - Examined for hemmaglutination activity (HA) to determine viral activity
- Cytotoxic control
  - 0.1 ml of PBS w/serum placed on plastic coupon
  - 2.0 ml disinfecting agent applied to plastic coupons
  - Fluid collected, diluted (1:10) & inoculated into eggs
  - Embryos examined for stunting and other lesions
  - Egg fluids tested for HA activity



Hemmaglutination Positive | Hemmaglutination Negative

Experimental Method

- Quantification of Results
  - Compared virus titer of positive control to virus titer of treated groups:
    - Agent successfully inactivated virus when the titer of the positive control group is ≥4 log, and there is no recoverable virus from any test coupon
    - Neutralizing Index ≥ 2.8
      - Titer of positive control virus recovered ≥ 4.0
      - Titer of virus recovery from tested coupon <1.2

Results

- Effective on hard, non-porous surfaces
  - Acetic Acid (5%)
  - Citric Acid (1 and 3%)
  - Sodium Hypochlorite (750 ppm)
  - Calcium Hypochlorite (750 ppm)
  - Powdered Laundry Detergent with Peroxygen (6 g/L)
  - Iodine/acid (300:1) commercial disinfectant

Results

- Effective on porous surface (basswood)
  - Citric Acid 1%
  - Iodine/acid (300:1) commercial disinfectant

Acetic Acid 5%			
	AIV		
	Positive Control Titer	Test Titer	Neutralization Index
Metal A	4.0	<1.2	>2.8
Metal B	4.0	<1.2	>2.8
Plastic A	4.5	<1.2	>3.3
Plastic B	4.5	<1.2	>3.3
Wood A	3.5	<1.2	>2.3
Wood B	3.5	<1.2	>2.3
Cytotoxic Control			
% Survival	Lesions	HA +	HA -
100.00%	None	0	4

Note: Exponential values of titers are calculated per 1.0 ml

Citric Acid 1%			
	AIV		
	Positive Control Titer	Test Titer	Neutralization Index
Metal A	6.9	<1.2	>5.7
Metal B	6.9	<1.2	>5.7
Plastic A	5.9	<1.2	>4.7
Plastic B	5.9	<1.2	>4.7
Wood A	4.1	<1.2	>2.9
Wood B	4.1	<1.2	>2.9
Cytotoxic Control			
% Survival	Lesions	HA +	HA -
75.00%	1	0	4

Note: Exponential values of titers are calculated per 1.0 ml

Citric Acid 3%			
	AIV		
	Positive Control Titer	Test Titer	Neutralization Index
Metal A	4.9	<1.2	>3.7
Metal B	4.9	<1.2	>3.7
Plastic A	4.2	<1.2	>3.0
Plastic B	4.2	<1.2	>3.0
Wood A	<1.2	<1.2	0
Wood B	<1.2	<1.2	0
Cytotoxic Control			
% Survival	Lesions	HA +	HA -
100.00%	None	0	5

Note: Exponential values of titers are calculated per 1.0 ml

Sodium Hypochlorite 750 ppm			
	AIV		
	Positive Control Titer	Test Titer	Neutralization Index
Metal A	4.3	<1.2	>3.1
Metal B	4.3	<1.2	>3.1
Plastic A	5.5	<1.2	>4.3
Plastic B	5.5	<1.2	>4.3
Wood A	<1.2	<1.2	0.0
Wood B	<1.2	<1.2	0.0
Cytotoxic Control			
% Survival	Lesions	HA +	HA -
100.00%	None	0	4

Note: Exponential values of titers are calculated per 1.0 ml

Calcium Hypochlorite 750 ppm			
	AIV		
	Positive Control Titer	Test Titer	Neutralization Index
Metal A	4.9	<1.2	>3.7
Metal B	4.9	<1.2	>3.7
Plastic A	5.1	<1.2	>3.9
Plastic B	5.1	<1.2	>3.9
Wood A	3.1	<1.2	>1.9
Wood B	3.1	<1.2	>1.9
Cytotoxic Control			
% Survival	Lesions	HA +	HA -
100.00%	None	0	4

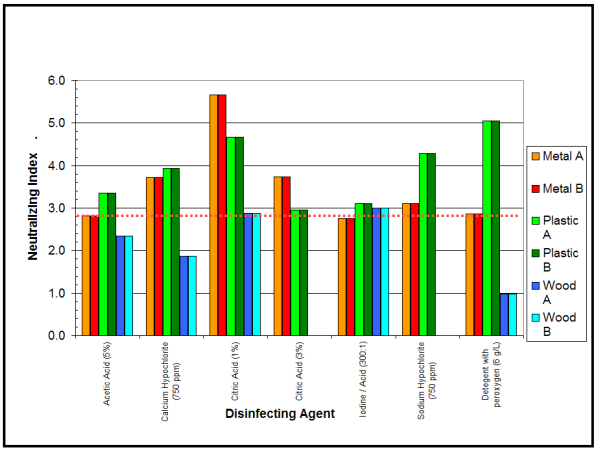
Note: Exponential values of titers are calculated per 1.0 ml

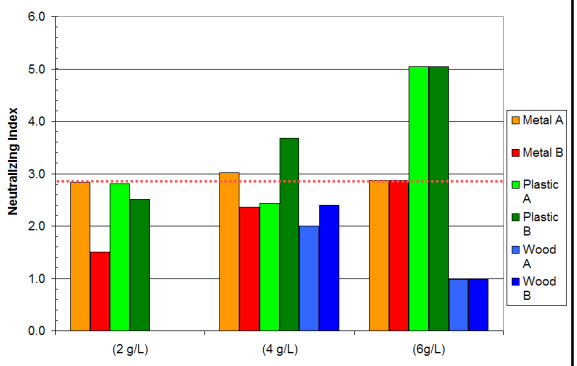
Detergent with Peroxygen 6g/l			
	AIV		
	Positive Control Titer	Test Titer	Neutralization Index
Metal A	4.1	<1.2	>2.9
Metal B	4.1	<1.2	>2.9
Plastic A	6.2	<1.2	>5.0
Plastic B	6.2	<1.2	>5.0
Wood A	2.2	<1.2	>1.0
Wood B	2.2	<1.2	>1.0
Cytotoxic Control			
% Survival	Lesions	HA +	HA -
80.0%	1	0	5

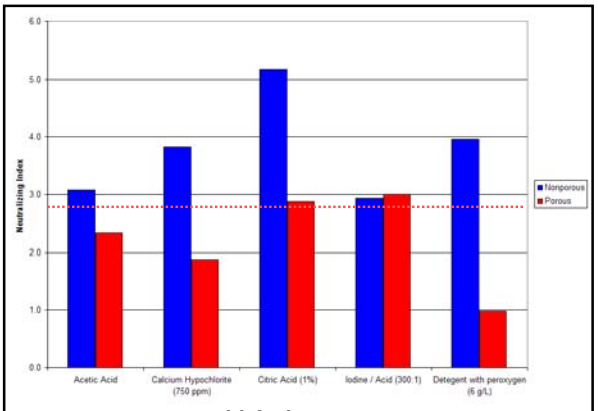
Note: Exponential values of titers are calculated per 1.0 ml

Iodine/Acid (300:1)			
	AIV		
	Positive Control Titer	Test Titer	Neutralization Index
Metal A	4.0	<1.2	>2.8
Metal B	4.0	<1.2	>2.8
Plastic A	4.3	<1.2	>3.1
Plastic B	4.3	<1.2	>3.1
Wood A	4.2	<1.2	>3.0
Wood B	4.2	<1.2	>3.0
Cytotoxic Control			
% Survival	Lesions	HA +	HA -
100.00%	None	0	5

Note: Exponential values of titers are calculated per 1.0 ml







Conclusions

- Several common chemicals may be suitable for post AIV outbreak cleanup.
- Lower NIs were recorded on porous surfaces than on hard, non-porous surfaces

Conclusions

- Acetic acid, citric acid, sodium hypochlorite, calcium hypochlorite, and the powdered laundry detergent with peroxygen were shown to be virucidal against LPAIV on non-porous surfaces.
- In addition, citric acid was shown to be virucidal against LPAIV on a porous surface (basswood).

Future testing

- Calcium hydroxide
- Calcium oxide
- Sodium carbonate
- Sodium hydroxide

Acknowledgements

- This research was supported by the USDA APHIS Veterinary Services

USDA

Inactivation of Foot-and-Mouth Disease Virus on Various Contact Surfaces

Wayne Einfeld[1]
Jill Bieker[2]
Brandalyn Price[3]
Tammy Beckham[2]

[1]Sandia National Laboratories, Albuquerque, NM
[2]USDA APHIS, Plum Island Animal Disease Center, Greenport, NY
[3]USDA APHIS, Ames, IA

USDA

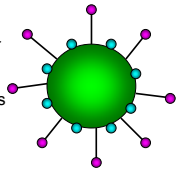
Sandia National Laboratories

Outline

- Virucide testing and validation
- Experimental methods
- Results
- Summary and conclusions
- Next Steps

Virucide Use and Validation

- Virus inactivation important to aid in disease containment
  - Disrupt transmission cycle
  - Dependent on mechanism of inactivation
- Preventive measure to help control reservoirs or vehicles involved in disease transmission
- Proper validation is necessary for efficacy claims
  - Differences in resistance exist among viruses
- Environmental factors influence efficacy
  - Organic matter, temperature, humidity, UV



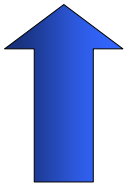
Estimated economic impact of 2001 UK FMD outbreak: $13 Billion

Virus Types and Resistance

Virus Type	Resistance	Features	Examples
Enveloped	Low	Lipid envelope, protein capsid, nucleic acid	Influenza, HIV, SARS
Large non-enveloped	Medium	Protein capsid, nucleic acid	Adenovirus, Rotavirus
Small non-enveloped	High	Protein capsid, nucleic acid	FMDV, Polio, Rhinovirus

Overall Organism Susceptibility

Most Resistant



Least Resistant

- Bacterial spore formers
- Protozoa (cysts/oocysts)
- Mycobacterium & Non-enveloped viruses
- Fungi
- Vegetative bacteria
- Enveloped viruses
- Non-Enveloped viruses (FMDV)

Virucide Test Methods

- No US standard methods currently exist for evaluating disinfectants against viruses
  - EPA guidelines, ASTM
  - International Standards: AFNOR, DEFRA
- Standardized tests are important for product registry and comparison
- Initial work often conducted using surrogate viruses
  - Member of same virus family but less pathogenic

EPA Guidelines for Virucide Testing

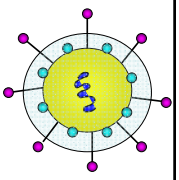
- Must follow use-directions (surface, liquid, or spray disinfection) at a specified exposure length
- Untreated control should recover a minimum of 10^4 infectious viral titer
- Protocol must include:
  - 4 replicates for virus recovery (endpoint)
  - Cytoxicity controls
  - Any special methods to increase virus recovery or reduce cytotoxicity
  - Activity of germicide for each test dilution
  - ID-50 values (tissue culture, embryonated egg, animal infection)
  - Data must show complete inactivation of virus at all dilutions, or at least 3-log reduction in titer beyond cytotoxic level

Key Parameters in Virucide Testing Methods

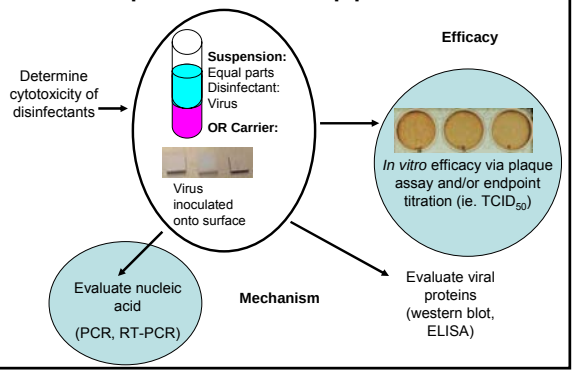
Parameter	Description
Test Configuration	Suspension vs. Carrier
Test Virus	Enveloped, Non-enveloped, Surrogate
Cytotoxicity	Washing, purification step
Organic Challenge	Addition of feces, serum, etc…
Exposure Interval	Contact time with virucide
Host Cell System	Virus specific, titer differences
Viral Enumeration	Endpoint dilution vs. plaque assay
Alternative Diagnostics	Nucleic acid, viral proteins, etc…

Evaluating Mechanism of Action

Virus target	Effective compounds
Lipid Envelope	QACs, Alcohols, Phenols, Chlorhexidine, Glutaraldehyde
Capsid Protein	Chlorine, Oxidizers, Peracetic acid, Alcohols, Glutaraldehyde
Structural Proteins	Chlorine, Oxidizers, Peracetic acid, Alcohols, Glutaraldehyde
Nucleic Acid	Oxidizers, Chlorine, Peracetic Acid

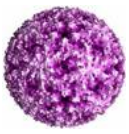


Experimental Approach



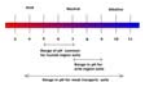
Target Virus: FMDV

- Non-enveloped, single-stranded RNA virus belonging to the family, *Picornaviridae*, genus Aphthovirus
- Only infects cloven-hoofed animals (bovine, porcine, ovine)
- Highly infectious and non-endemic in US
- Work with FMDV limited to Plum Island Animal Disease Center
- No surrogate virus presently available



Study Objectives

- Inoculate and optimize virus recovery from surfaces common in ag industry
  - Determine length of drying step
  - Determine optimum method for recovery
- Evaluate efficacy of disinfectant agents against FMDV
  - Systematic exposure and post-treatment enumeration with controls



Disinfectant Test Panel

- 5% acetic acid (pH 2.3)
- 10% bleach (pH 11.54)
- 70% ethanol (pH 6.68)
- 4% sodium carbonate (pH 11.71)
- 2% sodium hydroxide (pH 12.02)
- DF-200 (pH 9.95)
  - Surfactant, peracid, hydrogen peroxide
- 0.4% Oxy-Sept 333 (pH 2.44)
  - Peroxyacetic acid, hydrogen peroxide
- 1% Virkon S (pH 2.45)
  - Potassium peroxymonosulfate

Experimental Method

- Virus
  - FMDV O1 *Brugge* was propagated in Baby Hamster Kidney (BHK-21) cells and titer was expressed as $TCID_{50}$/ml
- Carrier Test Surfaces
  - Concrete, rubber, and stainless steel
    - Concrete was prepared in the base of a 50 ml tube
    - Rubber and stainless steel were cut into round 4.15 cm^2 pieces (about the size of a quarter)
    - Surfaces sterilized by autoclaving and/or UV exposure

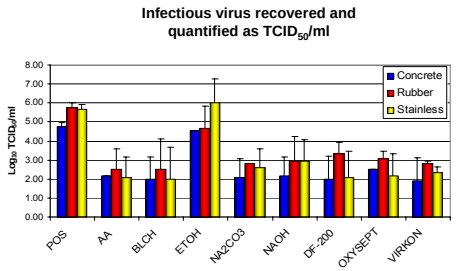
Experimental Method

- Sterile test surfaces inoculated with 100 µl FMDV; dry for 30 min in a biosafety hood
- Samples treated with 500 µl disinfectant (DMEM for positive control) to cover exposed area
- Following 5, 10, or 20 min, 5 ml DMEM containing 4% fetal calf serum added and samples vortexed rigorously

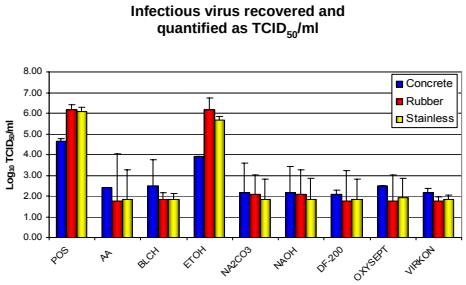
Experimental Method

- Serial ten-fold dilutions inoculated onto BHK-21 cells
- Endpoint titration calculated using Reed-Muench; infectivity expressed as $TCID_{50}$/ml
- Quantitative RT-PCR was performed on each undiluted sample using standard method (Callahan et al. 2002 JAVMA vol. 202)

Efficacy Results - 5 min

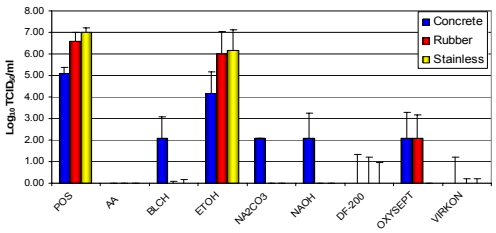


Efficacy Results -10 min



Efficacy Results - 20 min

Infectious virus recovered and quantified as $TCID_{50}$/ml



Quantitative RNA – 5 min

Quantitative RNA, reported as Log_{10} RNA units/ml

***Bold number indicates inhibition of PCR assay**

Treatment	Concrete	Rubber	Stainless steel
POS	3.61	6.03	6.05
AA	1.32	3.60	3.75
BLCH	**0.00**	5.15	1.34
ETOH	1.38	5.74	6.00
NA_2CO_3	1.12	2.68	2.85
NAOH	1.12	**0.00**	1.15
DF-200	0.00	2.55	1.26
OXYSEPT	1.65	4.14	3.09
VIRKON	1.12	3.05	2.60

Quantitative RNA – 10 min

Quantitative RNA, reported as Log_{10} RNA units/ml

*Bold number indicates inhibition of assay

Treatment	Concrete	Rubber	Stainless steel
POS	4.13	6.45	6.51
AA	2.90	5.70	5.60
BLCH	**0.00**	2.84	1.09
ETOH	4.62	6.19	6.08
NA_2CO_3	**0.00**	4.73	4.27
NAOH	1.66	1.11	2.24
DF-200	**0.00**	2.64	1.65
OXYSEPT	3.84	3.43	2.29
VIRKON	2.77	2.71	2.32

Quantitative RNA – 20 min

Quantitative RNA, reported as Log_{10} RNA units/ml

***Bold number indicates inhibition of assay**

Treatment	Concrete	Rubber	Stainless steel
POS	4.11	5.70	5.85
AA	1.16	4.82	4.53
BLCH	1.38	1.24	0.00
ETOH	1.41	6.10	5.19
NA_2CO_3	1.16	2.39	1.08
NAOH	**0.00**	0.00	0.00
DF-200	0.00	0.00	0.00
OXYSEPT	1.52	1.39	1.13
VIRKON	2.71	0.00	0.00

Summary

- Porous surfaces (concrete & rubber) negatively impacted virucide efficacy
  - Concrete showed the greatest effect
- Ethanol was consistently the least effective treatment (neutral pH)
- Results were affected by difficulty in recovering virus
  - Vortexing was used to recover virus
  - Concrete samples contained particulate debris which resulted in cell cytotoxicity at lowest dilution
- No clear correlation between virucide efficacy and RNA degradation
- Carrier tests show worse (but generally adequate) virucide efficacy compared to earlier suspension tests

Next Steps

- Continued evaluation for other viruses
  - H5N1, pox viruses, etc
- Refine test methodology for other viruses
  - Inoculum level, drying time, recovery process
- Field validation of inactivation
  - Dependent on virus (e.g. FMDV only at PIADC)
- Further study of virucide mechanism
- Development of rapid onsite post-decon tests for measurement of decon effectiveness

Acknowledgments

- DHS funding as part of the Agriculture Domestic Demonstration and Application Program (Ag DDAP)
- USDA/APHIS for in-kind assistance at Plum Island Animal Research Center

Questions?

Jill Bieker
USDA/APHIS
Plum Island Animal Disease Center
Jill.m.bieker@aphis.usda.org
631-323-3100

The Government Decontamination Service (GDS)

Robert Bettley-Smith FRICS
Chief Executive

Government Decontamination Service

- Operating since October 2005.
- Executive Agency of Defra.
- Remit for contaminated land, buildings, open environment, infrastructure and transport assets (CBRN and HazMat).
- Provides assistance to Responsible Authorities, and access to Specialist Supplier Framework

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.

…but does it work?

Polonium 210 (November, 2006)

24 November 2006 – Day one for the GDS.

- 06.15hrs – Defra contacts GDS Duty Liaison Officer.
- 08.38hrs - Substance confirmed as Polonium 210.
- 10.20hrs – GDS Case Officer deployed to London.
- 10.40hrs – GDS suppliers alerted.
- 13.00hrs – 19.00hrs – various meetings
- 23.15hrs – update on next round of meetings!

Polonium 210 (London, 2006): Timeline.

- **23.11.06** - Death of Alexander Litvinenko
- 24.11.06 - Confirmation that Polonium 210 was present
- **24.11.06** - GDS contacted @ 06.15 by Defra and agreed to deploy
- 24.11.06 - GDS Emergency Operations Centre opened, Director of Operations and Case Officer deploy to London
- 24.11.06 - First five contaminated venues identified.
- 25.11.06 - Responsible Authority identified as Westminster City Council who agreed to act by agreement as Agents for all venues
- 26.11.06 - GDS Contractor commenced monitoring at the restaurant
- 27.11.06 - GDS facilitated Post Mortem decontamination arrangements
- 10.06.07 - 9 venues (out of 10) have been monitored, decontaminated by GDS and returned to public use. Prohibition order served on 1 venue, awaiting decision over funding

Venues:

- GDS Suppliers decontaminated nine venues in London.
- Venues included:
  - restaurants,
  - Hotels, and
  - buildings with historic features.
- Interior of buildings (doors and communal areas) needed characterisation surveys.

Some Of The Equipment Used To Survey And Remediate

Some contaminated items could not be remediated…these were packaged ready for transportation

Polonium 210 (London, 2006): Decontaminating a hotel

- **When**
  - 6 to 24 March 2007 (19 day duration)
- **Where**
  - Bar area
  - Men's ground floor toilets
  - Guest rooms
- **Site Resource**
  - 1 Supervisor, 3 HP Monitors & 2 Decommissioning operatives

Polonium 210 (London, 2006): Decontaminating a hotel

Before

After

Issues One: Polonium 210 (London, 2006): Some of the key lessons

- Communication
- Payment/insurance – non CBRN incidents
- Sampling and monitoring
- Waste management
- Site logistics
- GDS resources

Issues Two: Alpha Post Mortem?

- Problems of finding a venue
- Making (a purpose built biological facility) venue fit for purpose
- Arrangements:
  - Pre post mortem monitoring (arrival of teams at 07:00)
  - Monitoring during post mortem
  - Assessment after post mortem
  - Decontamination of facility
  - Clearance (facility handed back 21:00 same day)
- Waste Issues (clinical and radiological)
- Lessons identified

Government Decontamination Service
MOD Stafford
Beaconside
Stafford
Staffordshire
ST18 0AQ
England

For Information
08458 501323

www.gds.gov.uk

UCRL-PRES-231780

Decontamination of Terrorist-Dispersed Radionuclides from Surfaces in Urban Environments

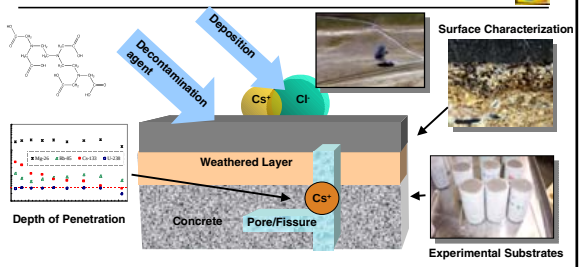
Presented to:
EPA Workshop on Decontamination, Cleanup, and Associated Issues for Sites Contaminated with Chemical, Biological, or Radiological Materials

June 22, 2007

Robert Fischer and Brian Viani
Lawrence Livermore National Laboratory

Work performed under the auspices of the U.S. Department of Energy by University of California Lawrence Livermore National Laboratory under Contract W-7405-ENG-48.

Understanding the science of urban surface decontamination



Urban surface decontamination can be influenced by several parameters including the presence of grime layers, migration into pores and fissures, local pH effects, competing metals, carbonation of surfaces, humidity, chemical interaction with the substrate and weathering effects.

Urban surface characterization

Caldecott Tunnel

Bore #1
20 samples collected from one location

Core

BART

Oakland Wye
52 samples collected from 6 locations

Vacuum

WMATA

15 samples collected from 2 locations

Wipe

Grime layer morphology differed substantially in the different systems being studied

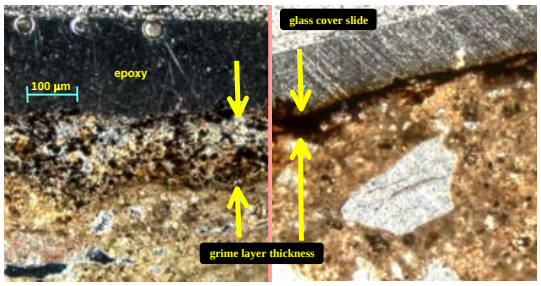
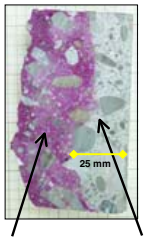


Image – AV-14 Halfway 3
Axiovert 100x VAR 1

Image – Bore 1 Wall 15
Axiovert 100x VAR 1

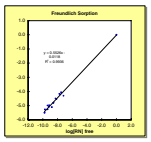
Urban surface characterization

Phenolphthalein treated x-section of concrete from BART tunnel wall

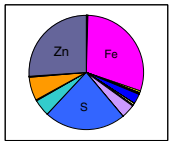


Interior zone: plus portlandite and/or CSH (pH >9.2)

Surface carbonated zone: minus portlandite and CSH (pH <9.2)



Our studies have shown that the presence of grime only affects the chemical behavior of americium (europium) at high pH



Analysis of grime layer indicates significant metal concentration

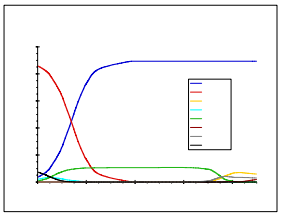
Studying the chemistry of surfaces and grime to design more efficient chelators

Of the many types of decontamination methods available, chelation offers advantages in regard to versatility on surfaces, waste minimization, rapid application and minimal environmental impact.

Additionally, chelation allows modification for selective binding of the radionuclide of interest.

We have investigated the chemical nature and surface interactions of cement and urban grime to identify potential interferences during chelation of radionuclides.

Candidate chelators are then chosen based on (i) affinity for target radionuclide and (ii) lack of interferences.

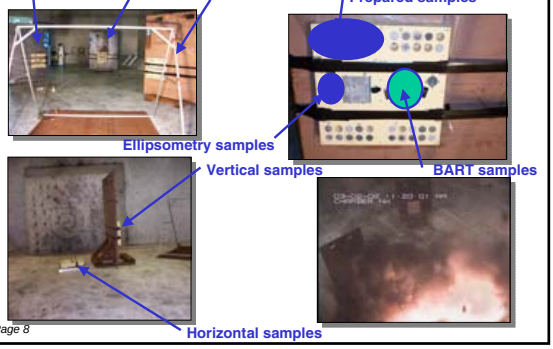


Indoor Explosive Deposition Experiment

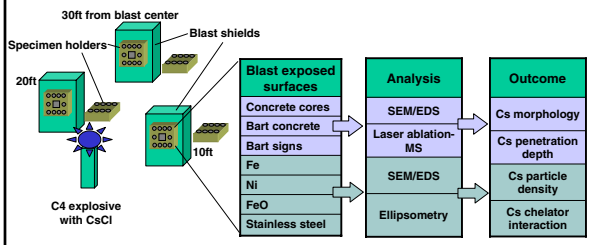
- Purpose was to realistically contaminate urban surfaces.
- A simulated Radiological Dispersal Device (RDD) was constructed (1.5 kg C-4, 1 kg stable CsCl. ^{137}Cs RDD = 56,663 Ci).

- Multiple forms of concrete placed into holders (wet, dry, grime covered, aged).
- Samples were analyzed to determine Cs fate under differing surface conditions.
- Contaminated samples will be used to test decontamination agents.

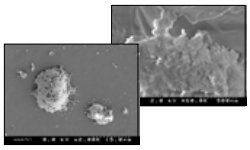
Indoor Explosive Deposition Experiment



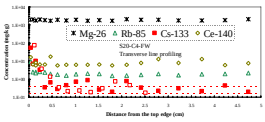
Indoor experimental details



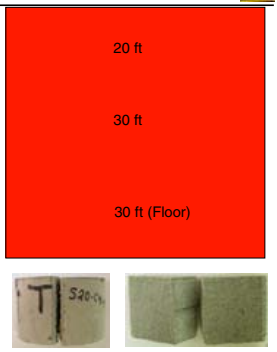
Experimental Results



Particle Morphology

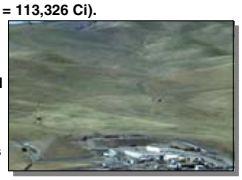


Depth of Penetration



Outdoor Explosive Deposition Experiments

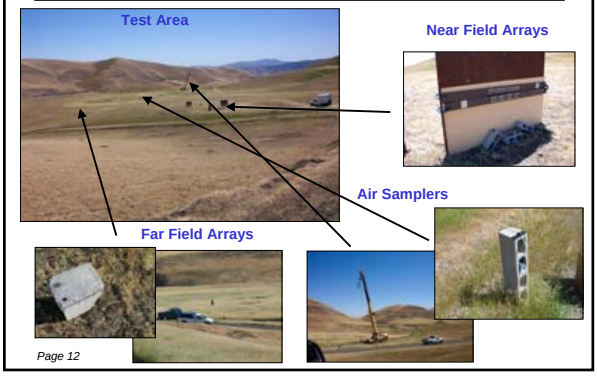
- Purpose was to realistically contaminate urban surfaces in both near (<15m) and far field (150m – 250m) collection areas.
- A simulated Radiological Dispersal Device (RDD) was constructed (2.0 kg C-4, 2 kg stable CsCl. ^{137}Cs RDD = 113,326 Ci).
- Experiment designed to build on lessons learned from indoor experiment
- Better controls on post shot storage and handling of samples.
- Techniques developed to freeze penetration at three specific time intervals (1, 7 and 28 days post shot)
- Multiple conditioning regimes used to study effects of wetting and drying on diffusion



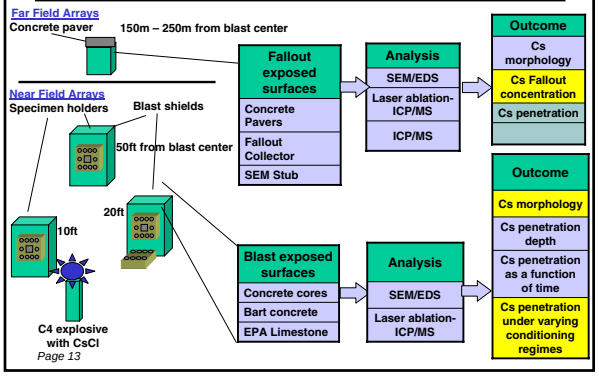
Shot #1 above ground

Shot #2 in ground

Outdoor Explosive Deposition Experiments

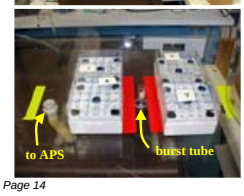


Outdoor Experimental Details

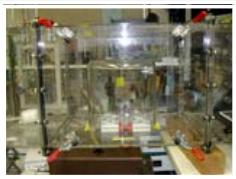


Bench Scale Testing

- Aerosolized 100 mg using 5 psi pressure burst
- Burst confined in bell jar
  - Jar supported on glass slides to provide air entry
- APS draw = 1 L/min



Bench Scale Testing



- Aerosolized 100 mg using 5 psi pressure burst
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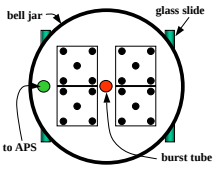
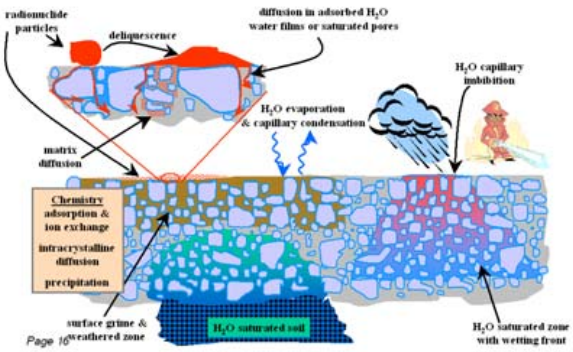
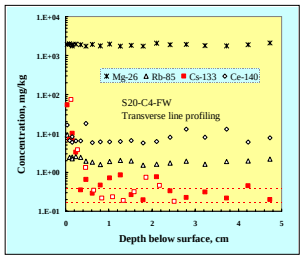


Physical and chemical processes control post-event radionuclide penetration into porous surfaces

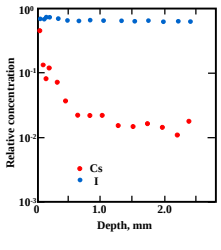


Post-deposition diffusion-driven penetration of soluble species into concrete

Laboratory prepared concrete
t=28 d, unsaturated, ambient RH



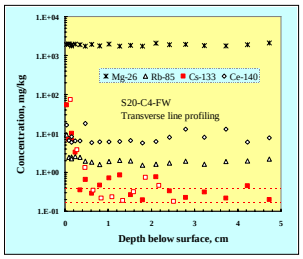
Portland cement
t=28 d, fully water saturated



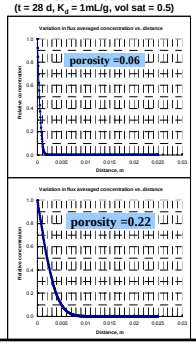
Atkinson and Nickerson (1987) *Rad Waste Manag.* 81:100

Post-deposition diffusion-driven penetration of soluble species into concrete

Laboratory prepared concrete
t=28 d, unsaturated, ambient RH



1-D Diffusion of Retarded Species Through Unsaturated Concrete
(t = 28 d, K_d = 1mL/g, vol sat = 0.5)

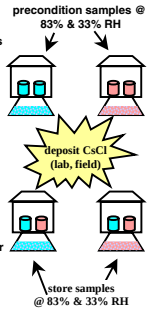


Approach

Characterization/preparation

- Microscopy
  - Optical, scanning electron
- Porous medium properties
  - Porosity
  - Permeability
  - Water retention
- Grime layer chemistry
  - Wet chemistry
  - GC
  - XPS
- Mineral identification
  - XRD
- Controlled composition for laboratory cements

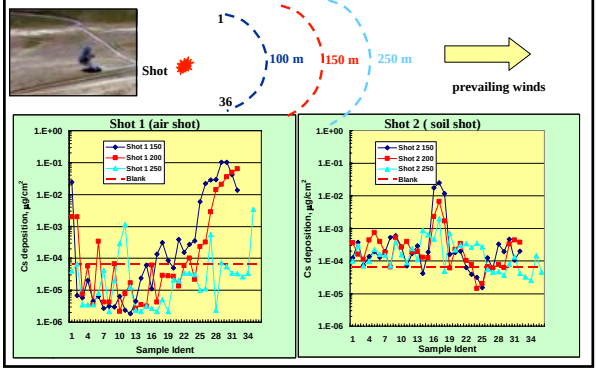
Deposition



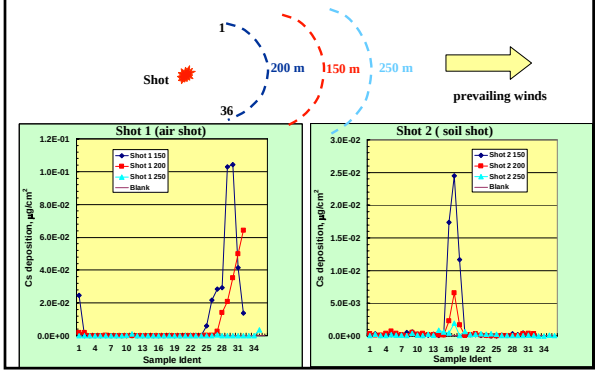
Measurements

- Deposition quantified using double stick tape collectors
- SEM analysis of particles captured on SEM stubs with double stick carbon tape
- Prescribed equilibration times of 1, 7 & 28 days
- Penetration stopped by freezing (-80 °C) followed by freeze drying
- Penetration followed using laser ablation mass spectrometry (LA-MS)
  - Surface profiling
  - Transverse profiling
    - Internal

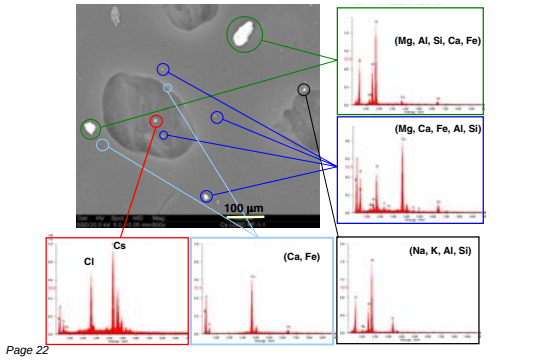
Outdoor test results: Cs Deposition on far-field collectors



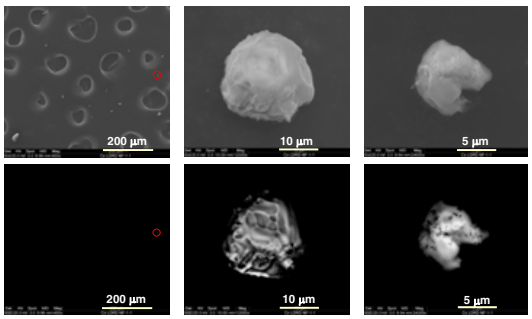
Outdoor test results: Cs Deposition on far-field collectors



Most particles were not CsCl Shot 1 (air shot); 50 ft

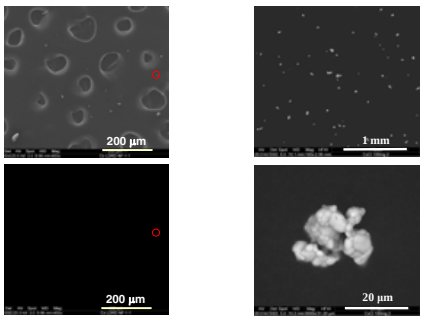


SEM images of carbon tape collector at 50 feet Shot 1 (air shot)



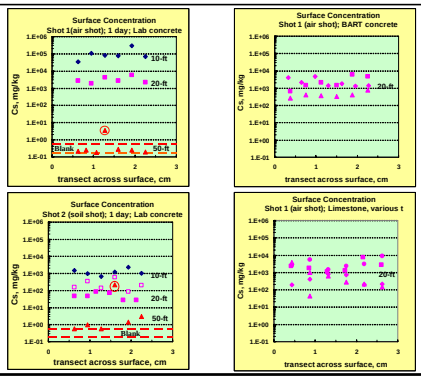
(0.07 µg Cs/cm^2; ~50 particles/cm^2)

SEM images of carbon tape collector at 50 feet Shot 1 (air shot)



(0.07 µg Cs/cm^2; ~50 particles/cm^2)

Outdoor test results: Surface concentrations (LA-MS) on near-field substrates



Summary

- **In-service materials (weathered and/or grime covered) differ significantly from standard test specimens, which may impact decontamination efficiency**
  - **Chelate efficiency in the presence of high concentrations of metals**
  - **Impact of pH differences on radionuclide solubility**
- **Three explosive deposition tests were conducted (indoor and outdoor)**
- **Penetration of dry deposited Cs into nominally dry porous media can be significant on time scales of days to weeks (mm to cm)**
- **Using ^{133}Cs and laser ablation mass spectrometry to measure penetration requires much higher Cs loadings than would be expected in a 'real' RDD because of relatively high ^{133}Cs backgrounds in the materials we studied**

Future work

- **Continued analysis of outdoor shot samples**
- **Laboratory bench scale deposition and penetration studies**
- **Comparison studies using ^{137}CS**
- **Testing sequestering capabilities of 4 chelates for Cs and Eu in the presence of various substrates**

Acknowledgements

LLNL Team

- **Mark Sutton** - Co-PI, complexing agent development
- **Max Hu** - Laser ablation
- **Jeremy Gray** - SEM/EDS, ellipsometry
- **Walt McNab** - Geochemical modeling
- **Dianne Gates-Anderson** - Decontamination/waste treatment
- **Defense and Nuclear Technologies Directorate** – For the use of explosive testing facilities

Collaborators

- **Bay Area Rapid Transit District**
- **California Department of Transportation**
- **Sandia National Laboratory –** Fred Harper
- **Environmental Protection Agency –** NHSRC (John Mackinney, John Drake, Sang Don Lee, Emily Snyder)

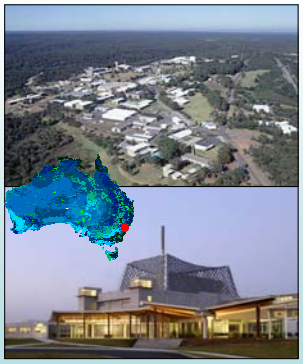
An Empirical Assessment of Post-Incident Radiological Decontamination Techniques

Andrew Parkinson, Tegan Evans,
David Hill, Michael Colella

Australian Nuclear Science & Technology Organisation
Counter-Terrorism Research Project

2007 CBR Decontamination Workshop
June 20-22 2007, Sheraton Imperial Hotel - North Carolina

About ANSTO



ANSTO is located 40km south of the Sydney CBD.

Australia's national nuclear research and development organisation and the centre of Australian nuclear expertise.

Strong collaboration with the forensic and counter-terrorism community on strategic research in radiological and nuclear forensics, and nuclear security research initiatives.

Counter - Terrorism Initiatives

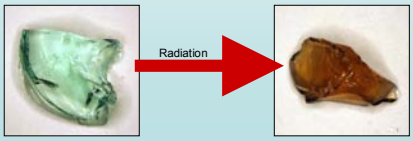
ANSTO provides scientific and technical advice to competently deal with all aspects of emergency management involving radioactive materials.

- scientific content to threat assessments
- on-going tactical forensics & CT research
- first responder and specialist training
- scientific advice & support
- consultancy
- operations support

Current Research

The Forensic and Nuclear Security group are involved in strategic research in the area of nuclear and radiological forensics and nuclear security initiatives.

- The effects of radiation exposure on critical trace evidence
- An empirical assessment of post-incident radiological decontamination techniques



Background

- Radiological materials are used extensively throughout industry, medicine and research.
- Illicit trafficking of radioactive materials occurs worldwide
  - between 1993 and 2006[1]
    - 1080 incidents
- A Radiological Dispersion Device (RDD) consists of radiological material coupled with a dispersion mechanism.
- The publics fear of radioactive exposure has the potential to cause negative psychological and economic consequences.
- The efficiency of the post incident clean up may be the best measure to counter a radiological terrorist incident.

1. IAEA Office of Nuclear Security - Illicit Trafficking Database, *Illicit trafficking in nuclear and radioactive materials*, 3rd Seminar on Trafficking of Nuclear and Radiological Materials, 13-14 March 2007, EUROPOL.

Background

Post-incident recovery (cleanup) strategies are designed to reduce radioactive contamination or exposure in the environment to ***acceptable levels.***

These strategies can include:

- Area denial
- Demolition and rebuilding
- Decontamination products and technologies
  - High impact (concrete shaving)
  - Low impact (chemical solutions)

To minimise the social and economic disruption low impact/ non destructive decontamination techniques are favourable. But, are they effective?

Project scope

This study aims to assess the effectiveness of commercially available low impact and innovative decontamination techniques on a variety of common surfaces found in a suburban/city setting.

The outcomes will:

- Assist organisations (HAZMAT, EPA, etc.) to prepare appropriate guidelines to react to such a radiological incident, and to minimize harmful social and economic consequences.
- Enhance Australia's counter-terrorism capabilities by being able to quickly and safely decontaminate wide spread urban environments.

Surface samples

Five different surface types were chosen to represent the most common range of outdoor surfaces in an Australian city environment.

Surface type	Uses	Sample description
Concrete	Buildings, pavement, roads, monuments	Pavement grade concrete (MPa 25)
Sandstone paving	Paving, monuments	High pedestrian-traffic grade pavers
Colorbond™ Steel	Roofing, guttering, buildings	Zn/Al coated stainless steel (Colorbond™)
Mild Steel	Buildings, structures, bridges	Mild steel, grade 350, surface oxidation
Road base asphalt	Roads, pavement	Asphalt bitumen AC-10 (Australian Standard)

Contaminants

Three radioactive isotopes were chosen to represent the range of commercially available isotopes that pose the greatest security risk.

Radioisotope of concern	Surrogate used in experimentation	Surrogate's properties
Cesium-137	Cesium-137	• Half life= 30.1 yrs; • Radiation Type = γ, β radiation; • Form = $CsNO_3$ in 500mL water • Activity ~ 250 cps/mL
Americium-241	Uranium-238 (Yellowcake)	• Half life= 4468 million yrs; • Radiation Type = γ, α radiation; • Form = U_3O_8 in 500mL water • Activity ~ 220 cps/mL
Strontium-90	Strontium-85	• Half life= 64.8 days; • Radiation Type = β radiation; • Form = $SrNO_3$ in 500mL water • Activity ~ 180 cps/mL

Contamination procedure

- 1mL of contaminant dispersed into a pre defined area (160x80mm).
- Contamination reading taken with a mixed alpha beta probe

Decontaminants

A total of ten decontamination products (6 strippable polymeric coatings and 4 wet detergent based products) were evaluated in this study.

Strip coat decontamination products: Decontaminating agents that form a polymeric coating that can be stripped off the surface once cured. This effectively peels off the contamination from the surface that has attached to the product.

Chemical decontamination products: Decontaminating products that are applied to the surface and scrubbed with water. These products react with the contamination which is removed with a wet vacuum cleaner or with high pressure water.

Decontaminants

Strip Coat Decontamination Products	Chemical Decontamination Products
Strip Coat TLC: water based, polymer matrix USA	Dez 1: complexing agent consisting of a mixture of surface-active and chelating agents Russia
VA: ethanol based, strippable polymeric coating Russia	Dez 4: oxidising agent consisting of a mixture of surface-active and chelating agents Russia
VL: water based, strippable polymeric coating Russia	Decon 90: anionic and non-anionic surface active agents concentrate England
Geopolymer composite: modified partially crystalline alumino-silicate polymer ANSTO, Australia	RBS: anionic and non-anionic surface active agents concentrate Belgium
Latex: natural polymer Australia	Water: no additives
NuCap: silicone based geopolymer USA	

Strip coat products

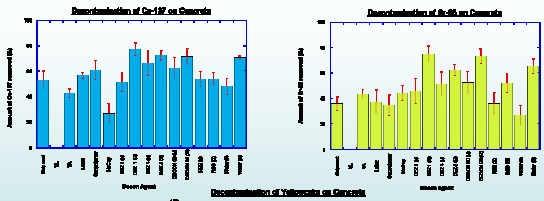
1. 2. 3.

4. 5. 6.

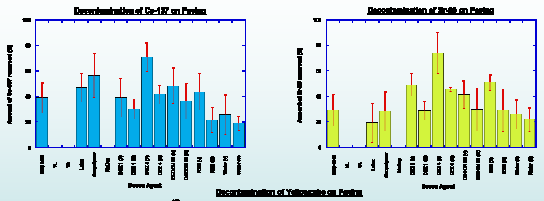
Chemical products

Decontamination solution scrubbed and then removed with wet vacuum or high pressure cleaner

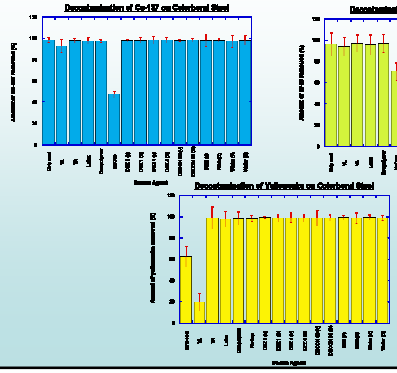
Concrete samples



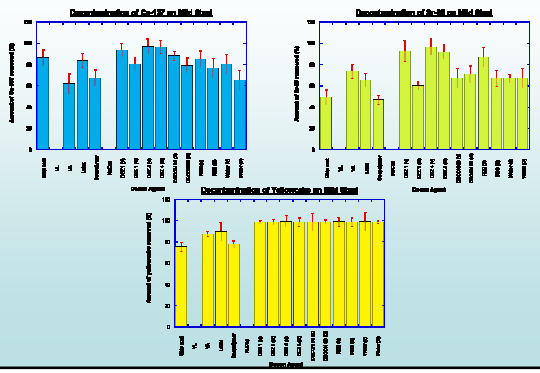
Paving samples



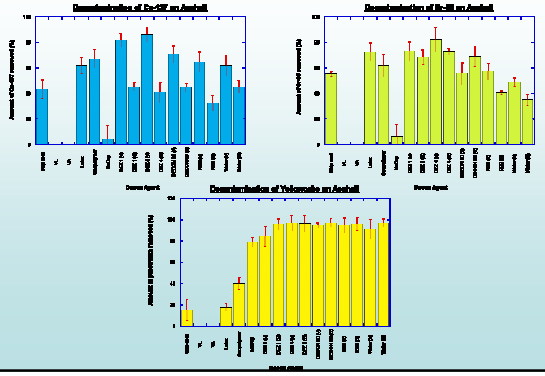
Colorbond™ samples



Mild Steel samples



Asphalt samples



Conclusions

	Concrete	Asphalt	Sandstone pavers	Mild steel	Colorbond Steel ™
Strip Coat TLC	partial	partial	partial	✓	✓
VA	partial	×	×	✓	✓
VL	×	×	×	×	✓
Latex	partial	✓	partial	✓	✓
ANSTO GeoPolymer	partial	✓	partial	✓	✓
Nucup Geopolymer	partial	×	×	×	✓
Dez 1	✓	✓	✓	✓	✓
Dez 4	✓	✓	✓	✓	✓
Decon 90	✓	✓	✓	✓	✓
RBS	✓	✓	✓	✓	✓
Water	✓	✓	partial	✓	✓

✓ (> 50% average) partial (30-50% average) × (< 30% average)

Conclusions

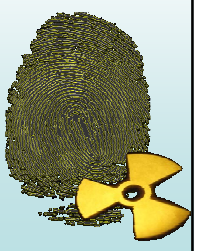
- Chemical Decontamination techniques are more successful when compared to the strip coat methods.
- The use of a chemical decontamination agents is more effective than using water on it's own.
- Wet vacuum recommended for hard porous surfaces (paving, asphalt). High pressure water cleaning recommended for soft porous surfaces (concrete).
- Wet decontamination methods could spread the contamination during a post blast clean up.

Conclusions

- Strip coat methods have the advantage of not spreading the contamination, however would have limited use on a large scale operation due to their tedious preparation, application and removal procedures.
- Ease of decontamination
  Yellowcake>Cesium>Strontium
- Chemical decontamination products and techniques can be used effectively to reduce the amount of contamination in public areas.
- However, effective decontamination of a public environment is dependant on a number of factors (surface and contamination type) and will require the use of a range of techniques/products.

Future work

- Expansion of decontamination products and technologies
  - dry ice blasting, high pressure steam, gels and foams, other novel products and techniques.
- Decontamination of forensic trace evidence:
  - Fibres, hairs, glass, documents, fingerprints, DNA, paint chips.
  - Is it possible?
  - Does the decontamination procedure effect the quality of the evidence and the forensic interpretation?
  - Is the decontamination procedure more beneficial (cost, time, & effort) than using dedicated "hot" instruments?



Australian Government
Department of the Prime Minister and Cabinet

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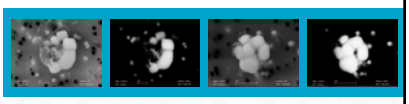
Andrew Parkinson
Forensic Chemist
Forensic & Nuclear Security Research
Australian Nuclear Science & Technology Organisation
PMB 1, Menai, NSW, 2234
T: + 612 9717 9237
F: + 612 9543 7179
E: andrew.parkinson@ansto.gov.au
www.ansto.gov.au

CsCl Particle Characteristics from Radiological Dispersal Device Outdoor Test

Sang Don Lee, Emily Snyder, John MacKinney, John Drake



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Acknowledgement

- Collaboration with Lawrence Livermore National Laboratory
  - Robert Fischer
  - Brian Viani
  - Dianne Gates-Anderson
  - Max Hu
  - Mark Sutton
  - 851 Crew

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National Homeland Security Research Center, Decontamination and Consequent Management Division

Radiological Dispersal Device (RDD)

- What is an RDD?
  - Explosive type - also called a 'dirty bomb'
  - combination of a conventional explosive device with radioactive materials
  - radioactive materials can be obtained from industrial, commercial, medical and research applications.
- What is the impact of an RDD?
  - casualties, disruption of the economy, and the potential desertion of the contaminated area
  - highly populated urban areas are the primary target

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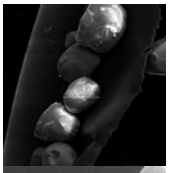
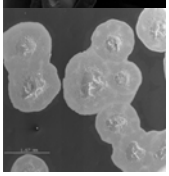
CsCl as RDD material

- Hygroscopicity-Deliquescence
  - CsCl is a salt like NaCl.
  - At relative humidity of 68%, CsCl particles become aqueous.
  - Aqueous form of CsCl can be transported through water channels on porous urban surfaces.

20 RH%



80 RH%



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Research Questions

- What are the characteristics of CsCl particles?
  - Particle size distribution
  - Particle composition
- How do urban surfaces become contaminated as a result of RDD exposure?
  - Cs penetration through the surface
    - Factors that control Cs penetration
  - Cs bonding to the surfaces

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Study Objectives

- To characterize the physicochemical properties of CsCl particles from outdoor explosion tests
- To estimate the CsCl particle deposition and its subsequent penetration into limestone at various relative humidity conditions.

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Description of Outdoor Test Shot I

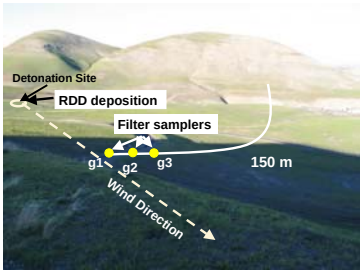
Test I: RDD was set 1 m high from the ground.

RDD: CsCl (2 kg), C4 (~2 kg)

Near Field: Limestone coupons

Far Field: Polycarbonate Filters and Sidepaks

Weather Condition	
WS (m/s)	7
WD	347
Temp (°C)	17
RH (%)	42

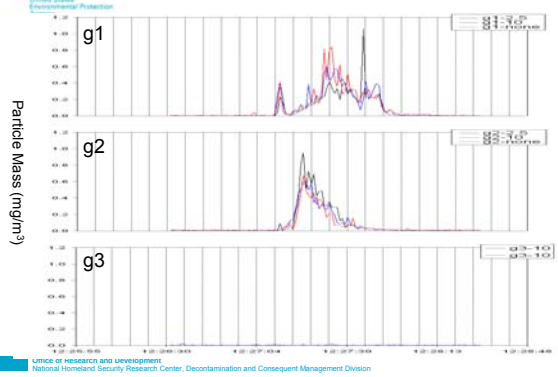


Summary of Test Shot I

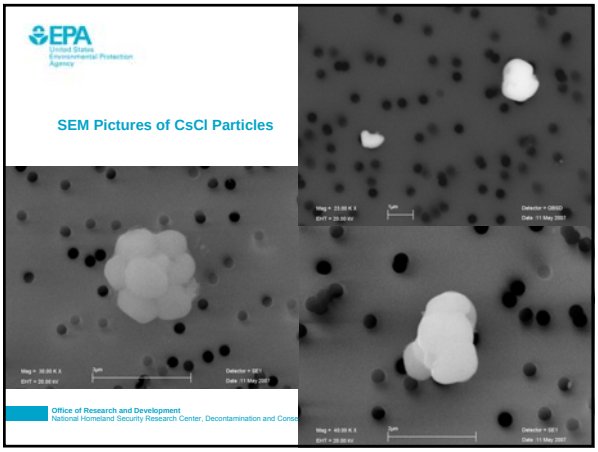
- **Sidepak data from Test I clearly show plume movement at location g1 and g2.**
- **SEM analysis also shows significant amount of CsCl particles on filters at g1.**

Location	CsCl particle concentration (#/cm²)	Other particle concentration (#/cm²)
g1	22107	2612
g2	6703	5776
g3	0	440

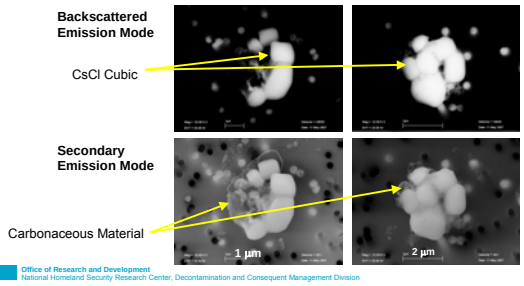
Results of Real Time Particle Monitors (Sidepak) from Test Shot I



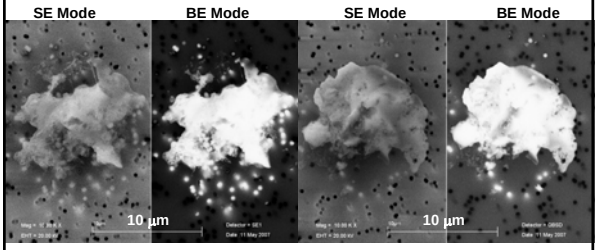
SEM Pictures of CsCl Particles



CsCl Particles Agglomerated with Carbonaceous Material



SEM Pictures of Large CsCl Particles

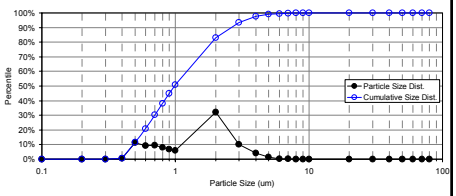


Particle Size Distribution from Test Shot I

Total number of particles analyzed: 6901

Particle mean diameter: 1.62 μm

Mass mean diameter: 4.36 μm



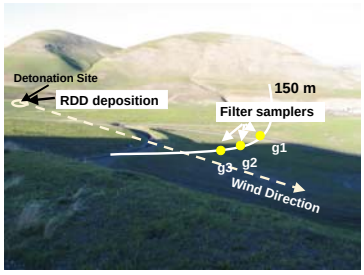
Description of Outdoor Test II

Test II: RDD was positioned in soil

RDD: CsCl (2 kg), C4 (~2 kg)

Far Field: Polycarbonate Filters and Sidepaks

Weather Condition	
WS (m/s)	2.4
WD	309
Temp (oC)	22
RH (%)	25



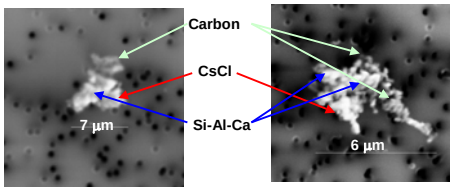
Summary of Test Shot II

- **Sidepak data from Test II does not show any plume movement.**
- **SEM analysis shows significantly low number of CsCl particles on filters.**

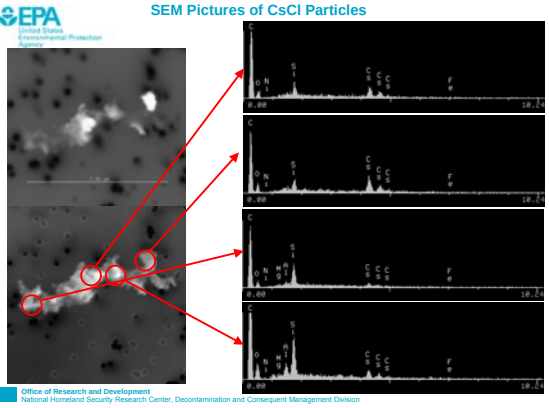
Location	CsCl particle concentration (#/cm^2)	Other particle concentration (#/cm^2)
g1	0	2155
g2	0	1839
g3	84	12608

SEM Pictures of CsCl Particles

- Most of CsCl contained particles are agglomerated with multiple components (carbonaceous, Si, Al, Ti, and Ca)



SEM Pictures of CsCl Particles

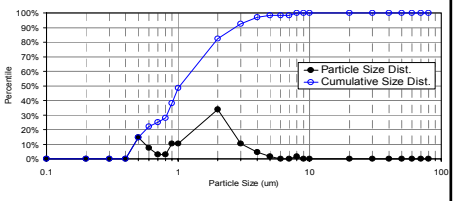


Particle Size Distribution from Test Shot II

Total number of particles analyzed: 68

Particle mean diameter: 1.71 μm

Mass mean diameter: 5.29 μm



CsCl Particle Deposition on Limestone Coupons

- ~1x1x1 in. limestone coupons near field (20 and 50 ft from ground zero).
- Weathered vs. non-weathered limestone surfaces.
- Horizontal vs. vertical
- Pre-conditioning at two relative humidities (30 and 80 RH%) before deposition.
- Post-conditioning at two different RH (30 and 80 RH%) before analysis.
- Laser-ablation ICP/MS and Laser Induced Breakdown Spectroscopy will be used to probe Cs penetration into limestone.

Summary of Results

- Most of Cs particles are smaller than 10 μm.
- From test shot I, CsCl particles are transported in pure form and also agglomeration with carbonaceous material (possibly C4 residue).
- Test shot II results show that CsCl particles are agglomerated with other minerals such as Si, Al, Ti, Ca (possibly from soil) as well as carbonaceous material.
- RDD surrounding materials affect particle characteristics and plume behavior (transportation and thermodynamic property).

Future Work

Limestone coupon analysis for Cs subsurface penetration from the test shot I
- Weathered surface vs. relatively clean surface
- Effects of relative humidity

Laboratory studies to investigate Cs penetration in limestone varying the following parameters
- CsCl initial loading including various particle size
- Exposed duration
- Rain
- Various substrates such as concrete, brick, granite, asphalt

RDD Rapid Decontamination

John Drake, John MacKinney Emily Snyder, Sang Don Lee

SCIENCE

RDD Rapid Decontamination

RDD - Radiological Dispersal Device

Rapid - Deploys quickly, cleans fast, available now

Decon - Removes contamination without damaging substrate

Project Goals

- Evaluate performance of commercially available cleanup technologies applicable to buildings and outdoor areas contaminated by an RDD
- Provide technology selection guidance for planners and operations personnel
- Identify promising cleanup technologies for future development
- Demonstrate a suite of effective technologies in a full-scale environment (future)

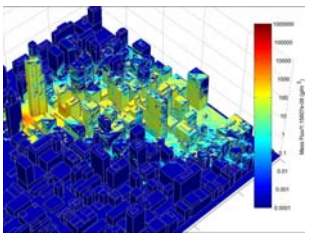
Radiological Dispersal Device (RDD)

- RDD: *"Deliberate dispersal of radiological material to cause harm"*
  - Typically made up of conventional explosive wrapped with dispersable radiological material
  - May be non-explosive (e.g. crop sprayer, tanker truck)
  - Rad material from commercial source or waste
- DHS planning scenario is 3000 lb truck bomb with CsCl (2300 Ci) from stolen commercial seed irradiators

Alfred P. Murrah Federal Building, Oklahoma City
After 5000 lb ANFO Truck Bomb

Effects of an RDD

- Weapon of Mass *Disruption*
  - Economic and terror weapon
- Economic effects
  - Denial of use of affected urban area
  - Cost to restore
  - Future use issues (residual levels, perceptions)
- Terror effects
  - Fear of anything nuclear or radioactive
  - Acute health effects minimal
  - Chronic health effects are the concern



Quick Urban & Industrial Complex (QUIC) image
Los Alamos National Laboratory

EPA is "Lead Agency" for clean-up*

- *On Scene Coordinators (OSC) and National Decon Team (NDT)*
- *Contamination control*
- *Clean-Up*
- *Certify for reoccupancy*

– **NHSRC** provides science expertise and technical support to OSC/NDT for decontamination

– Others: Fed, state, local, foreign

Trafalgar Square simulation, radiation notice © BBC/WGBH/NOVA

* National Response Plan (NRP), Nuclear/Radiological Annex

RDD Rapid Decon Project

- Focus is on
  - Buildings
  - Outdoor areas
  - Contaminated equipment
- Challenges
  - Intense pressure to reoccupy
  - Restoration vs. demolition
  - Driven by economics and politics
  - Emergency response climate
  - Private ownership and public access
  - Radionuclides postulated
  - Waste disposition unknown
  - Skilled and unskilled workforce

High pressure water spray

Priorities in selecting decon technologies to evaluate

- Preserve building exteriors (non-destructive)
- Large areas so speed & cost/ft² are crucial
- Water-intensive processes exacerbate contaminant migration into building materials (e.g. concrete)
- Effluent capture required to reduce spread of contamination (including water/wastewater utilities)
- Minimize the supporting infrastructure which must be brought in
- Future land/building use will drive decon strategy

Considerations for selecting decon technologies

Minimize

- Surface damage (texture, color)
- Cost
- Secondary waste
- Recontamination
- Operator skill requirement
- Time to deploy

Maximize

- Speed
- Decon factor
- Availability
- Applicability
  - Contaminant
  - Substrate
  - Weather conditions

Approach

- Deposit contaminant on “large” coupons
- Measure contamination levels before application of decontamination technology
- Apply decon technology is a realistic manner (e.g. using the same application techniques as would be used in the field)
- Measure the residual contamination levels
- Determine
  - Decon Factor (DF)
  - Speed (ft2/hr)
  - Operational parameters (difficulty, infrastructure, skill level, etc)
  - Other (deployed cost, availability, shelf life, etc)

Performance Test Design Decisions

- Radioactive CsCl chosen as initial contaminant
- Concrete chosen as initial building material
- Large” coupons to allow testing full scale decon equipment (2x5 ft array)
- Controlled humidity, temperature to reduce variables
- Two exposure scenarios: 14 days and 28 days
- Two decon technologies: (1) chemical method, (1) mechanical method

Execution

- Utilize existing EPA Technology Test and Evaluation Program (TTEP)
- Task Order #1127 SOW to Battelle
  - Develop test methodology
  - Develop test plan
  - Prepare facilities
  - Recommend list of proposed technologies for selection by EPA
    - EPA selects two technologies for FY07
  - Technology testing performed at radiological facility (INL)
  - Evaluate results and document

Current Status

- SOW completed, TTEP Technical and Cost Proposals accepted
- Task Order awarded
- Draft Quality Assurance Project Plan (QAPP) completed
- Test facilities identified (INL)
- "Short List" of proposed decon technologies completed

Please contact me if you have additional questions… know of projects, programs, products or technologies which could help meet these needs…

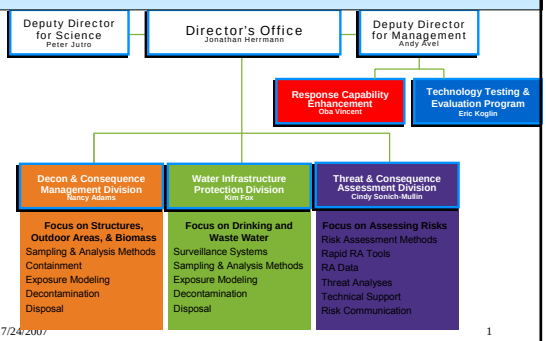
email: Drake.John@epa.gov
phone: 513/235-4273

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

Water Infrastructure Protection Division
WIPD
Decontamination Research Overview

Kim R. Fox
June 22, 2007

National Homeland Security Research Center
PROTECTING OUR COUNTRY THROUGH RESEARCH



NHSRC Primary Areas of Focus

- **Water Infrastructure Protection is charged with conducting research to detect and respond to terrorist attacks on the nation's drinking water sources and distribution systems and the wastewater collection, treatment, and disposal procedures**
- **Decontamination and Consequence Management** focuses on decontamination of buildings and outdoor environments, as well as the safe disposal of contaminated materials
- **Threat and Consequence Assessment** investigates human exposure to chemical, biological, and radiological contaminants to define dangerous levels of these contaminants and establish protective cleanup goals

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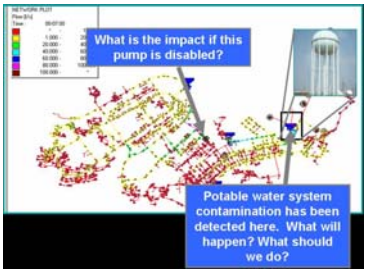
Impact of an intentional or un-intentional attack on a water system



- **Every system is different.**
- **How would a chem-bio contaminant propagate?**
- **What happens if a key system component is disabled?**
- **Where would an attack have the greatest impact?**

Homeland Security Presidential Directives

- **HSPD-7** Critical Infrastructure Identification, Prioritization and Protection: designates EPA as the sector-specific lead agency for critical water infrastructure safety and security
- **HSPD-9** Defense of US Agriculture and Food: directs EPA to develop a full-coordinated surveillance and monitoring program to provide early detection. Also requires EPA to develop nationwide lab network to support the routine monitoring and response requirements
- **HSPD-10** Biodefense in the 21st Century (classified): reaffirms EPA's role adding a clear directive for Agency's lead in decon efforts

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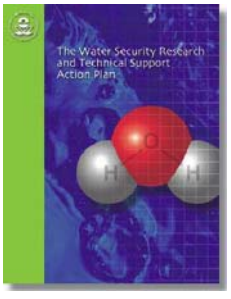
Water Security Research and Technical Support Action Plan



- Jointly developed by EPA's OW and ORD
- Based around issues, needs, and projects
- Addresses both drinking water and wastewater infrastructure
- Stresses physical, cyber, and contamination threats
- Extensive input from and review by stakeholders
- Reviewed by the National Academy of Science

Key Collaborators

- EPA's Office of Water
- EPA's Regional Offices, OPPTS, ORIA, OSWER
- U. S. Army's Edgewood Chemical Biological Center
- FDA's Forensic Chemistry Center
- U. S. Air Force's Air Force Research Laboratory
- Metropolitan Water District of Southern California
- DOI's U. S. Geological Survey
- DHHS's Centers for Disease Control and Prevention
- U. S. Army Corps of Engineers
- DOE's National Laboratories
- National Science Foundation

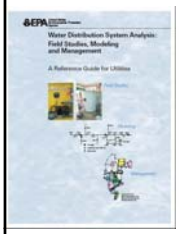
Decision Support Tool for Disposal of Contaminated Building and Water System Materials

NHSRC is developing a Web-based tool that will assist in this decision making.

A vital part of the contaminated site restoration process includes decisions related to:

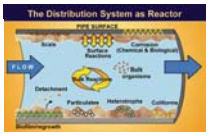
- Treatment or disposal options
- Selection of the appropriate disposal facility
- Packaging and storing residues
- Transporting materials to the disposal site
- Compliance with relevant permits
- Worker safety
- Protection of human health and the environment

Distribution Systems Research



Field Studies, Modeling and Management

Water Distribution System Analysis Symposium August 27-30, 2006

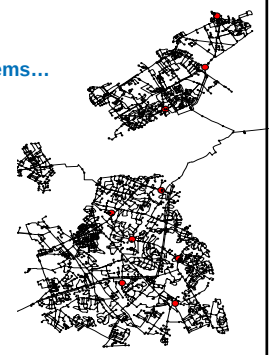


Water Quality and Management of Distribution Systems: A Utility Operator's Guide & Pocket Guides for Water Utility Managers

EPA United States Environmental Protection Agency

What we know about threats to drinking water distribution systems…

- We don't know where contaminant releases will occur
- Health and economic impacts can vary widely depending on the release location
- Significant impacts can occur miles from the release location

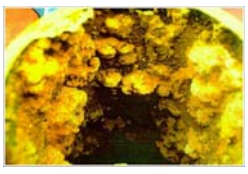


Need for Decon

- Adherence to pipe walls
- Attachment to biofilms
- Reaction with pipe walls or corrosion products
- Permeation through pipe walls
- Petroleum products, chemical warfare agents, pesticides, etc

Some Knowledge Gaps

- Any interaction between the contaminant and the pipe wall will prolong the the CB attack
- Surface roughness from scale or corrosion slows transport and inhibits decontamination.
- Biofilm - Biological contaminants may settle in the biofilm and continue to release contaminants



Potential Drinking Water Decontamination Methods

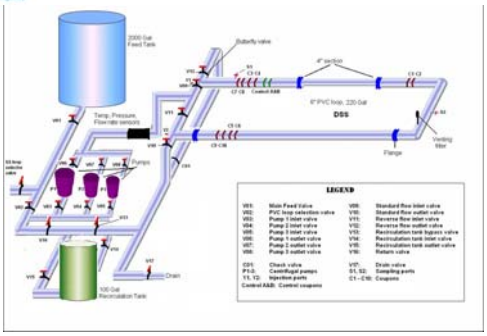
- Surfactants (detergents)
- Co-solvents (alcohols)
- Organic acids or chelating solutions
- Solutions designed to decontaminate CBW on surfaces
- Enzymes
- Other?

Decontamination Projects

- Standard Ops
- NIST IAG
- ECBC enzyme
- T&E pipe loop studies
- ECBC pipe loops
- Dahlgren IAG

EPA T&E Pipe Loops

- Clear pipe loop for evaluating areas of deposition and collection
- Use chemical simulants and biological surrogates
- Evaluate flushing and some chemical treatment



Experiments Conducted to Date: Decontamination Study

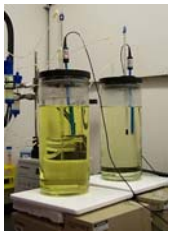
- **General Decontamination Study**
  - Simple flushing for arsenic, mercury, and *Bacillus Subtilis*
  - Low pH flushing for arsenic and mercury
- **Contaminant: Arsenic (sodium arsenite)**
  - Phosphate buffer flushing
  - Acidified potassium permanganate flushing
- **Contaminant: Mercury (mercuric chloride)**
  - Acidified potassium permanganate flushing
- **Contaminant: *Bacillus Subtilis***
  - Shock chlorination

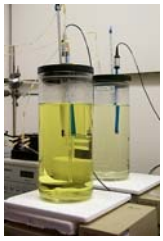
ECBC Enzyme Project

- **Evaluation and development of catalytic enzyme-based methods for treating contaminated water and/or decontaminating water distribution system equipment**
- **Enzymes with catalytic activity against most nerve agents and many related OP pesticides**
- **Development of an appropriate delivery method: liquid, filter, gel, foam, pipe lining**
- **Bench and field scale feasibility tests**

Containment Facility Test Loop

- Only research facility in the U. S. that allows experiments with live CB agents in an instrumented and computer-controlled environment
- Allows agent fate and transport behavior to be studied and modeled
- Allows validation of emerging sensors and countermeasure technologies
- Designed by ERDC and constructed at ECBC in FY03



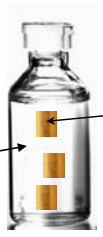


Tap water Paraoxon hydrolysis by OPAA-Agarose (left) and OPH-Agarose (Right) catalytic filter loops after 5 days. The 2 liter reservoirs in the foreground are for the Enzyme-agarose loops.

NIST Project Goals

- **Conduct experiments to study accumulation *and* decontamination of plumbing systems**
  - **–Chemical contaminants**
  - **–Biological contaminants**
- **Develop a predictive computer model to guide decontamination efforts**

Static (batch) Studies



Static (Batch) Studies
(Chemical contaminants)

- **Coupons w/ cultivated biofilm**

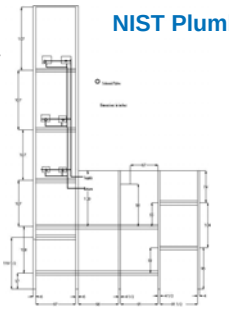
Bioreactor for cultivating biofilm (CDC)

Appliance Studies

- Hot water heaters
- Water softeners
- Water filters
- Ice makers/cold water dispensers

NIST Plumbing Tower

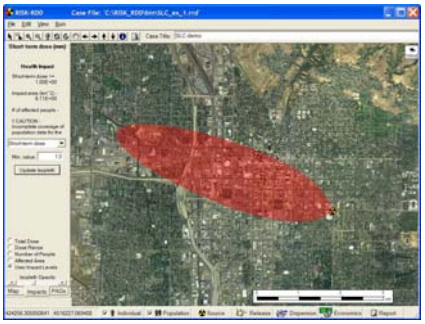
5th story



1st Story

NIST Plumbing Tower

Radiological Issues Follow an Event's Footprint



EPA's challenges in water security research

- Diversity and number of water and wastewater systems
- Rapid evolution of scientific information relevant to water security
- Interdisciplinary and Interagency coordination
- Stable leadership
- Pressure for rapid results versus long-term strategies
- Information sharing in the context of national security
- Multiple constituencies

Recommendations for future research directions

- Address data gaps in the following areas:
  - Decontamination
  - Surrogate identification
  - Contingencies for water emergencies
  - Distribution system models (field and laboratory testing for contaminant transport
  - Treatment of contaminants in water and wastewater

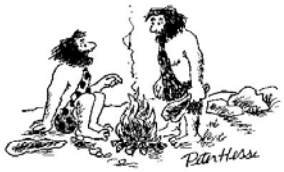
Incineration of Materials Contaminated with Bio-warfare Agents

P. Lemieux, J. Wood
US EPA National Homeland Security Research Center

Presentation for Decontamination Workshop
June 20-22, RTP, NC

Outline of Presentation

- Thermal destruction experimental and modeling work
- Online disposal decision support tool
- Incineration data gaps



It's called fire… It recycles wood.

Disposal R&D Program

- Guidance document development
- Thermal destruction of agents bound on matrices
  - Bench-scale
  - Pilot-scale
  - Modeling
  - Sampling/analytical methods for stacks and residues
- Permanency of landfilling
  - Survivability in leachate
  - Transport to landfill gas
- Destruction of Spores in Autoclaves
- Agricultural Residue Disposal (with USDA)

Issues for Incinerators

- Prevention of further contamination
- Compliance with permits
- Operational issues
- Sizing of material prior to shipment to disposal facility
- Residue management
- Selection of appropriate facilities
- Minimization of failure modes

Considerations of Thermal Treatment Technology Options

Technology	AGENTS BW	CW	TIC	Rad	Ag	REL. COST
Haz Waste Incinerator	↑	→	↑	↓	→	$$$$
Municipal Waste Combustor	↑	→	→	↓	↑	$$$
Medical Waste Incinerator	↑	→	→	↓	↑	$$$$
Industrial Boiler	→	→	→	↓	→	$$$
Cement Kiln	→	→	→	↓	→	$$$
Air Curtain Destructor	↓	↓	↓	↓	↑	$$
Gasification	?	?	?	↓	→	?
Plasma	?	?	→	↑	?	?
Mobile Incinerator	→	→	↑	?	→	$$$
Autoclave	↑	↓	↓	↓	→	$$

Used in past responses	↑
Technically feasible	→
Unknown	?
Not Recommended	↓

BW - biological warfare agents
CW - chemical warfare agents
TIC - Toxic Industrial Chemical
Rad - Radiological Agents
Ag - Agricultural Sector-Specific Agents

Medical Waste Incinerator Spore Survivability Tests

- Commercial hospital waste incinerators tested in early 1990s by EPA
- Doped with large quantities of *Geobacillus stearothermophilus* spores
- Spore survival measured in stack and ash
- > 6 Log reduction in most cases
- < 3 Log reduction in a few cases
- Primary chamber T and secondary chamber RT were most significant variables (see leverage plots from multiple least squares regression)

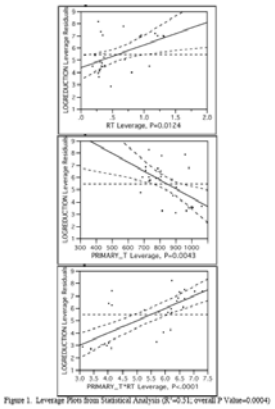
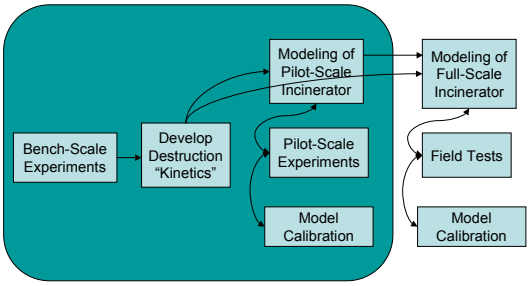


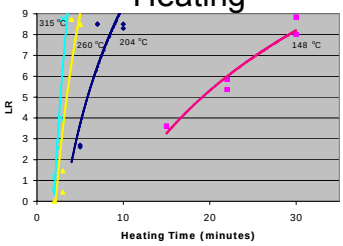
Figure 1. Leverage Plots from Statistical Analysis (R²=0.31, overall P Value=0.0004)

Source: Wood et al., 2004

Approach



Reduction of *Bacillus Subtilis* Spiked on Ceiling Tile after Heating



- Rapid reduction when heated at temperatures > 200 °C
- Reduction rate decreases with reducing heating temperature

Source: Lee et al., 2005

"Kinetic Fit" of Spore Destruction Data

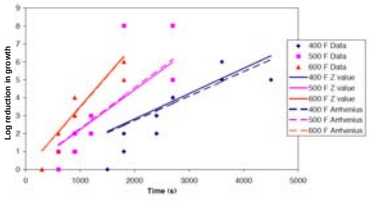
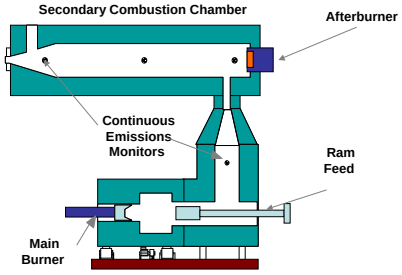


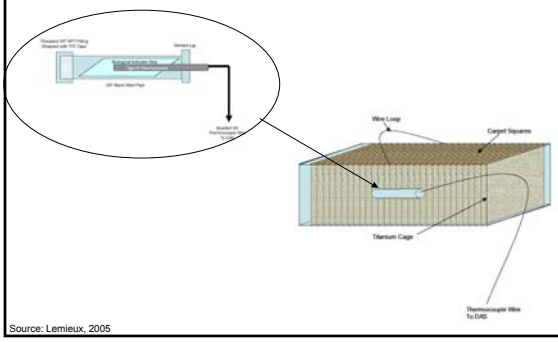
Figure 3. Log reduction versus time for B. subtilis on wallboard at various initial temperatures.

Source: Denison et al., 2005

Experimental Apparatus

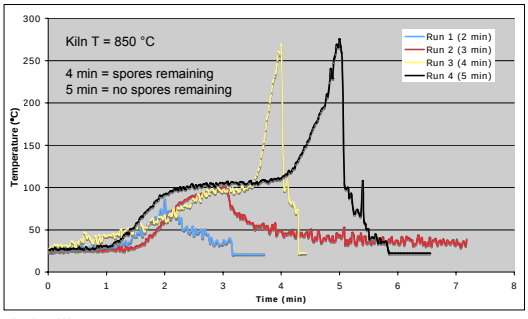


Spore Feed System



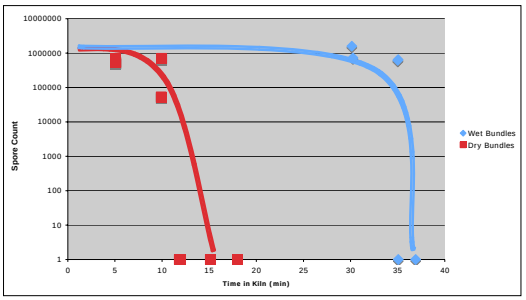
Source: Lemieux, 2005

Heatup/Quench of Carpet



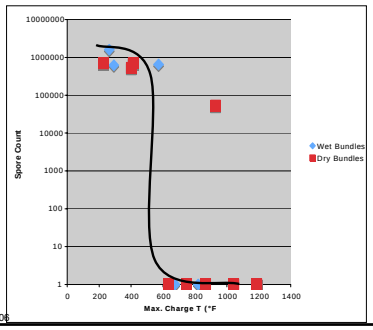
Source: Lemieux, 2005

Ceiling Tile: Time vs Spore Count



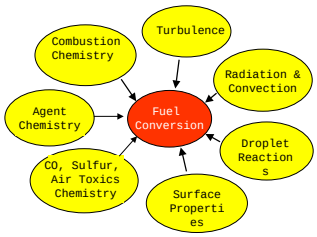
Source: Wood et al., 2006

Ceiling Tile: Spore Count vs Max T



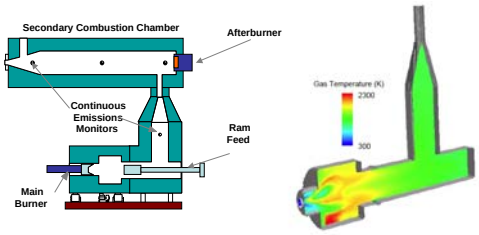
Source: Wood et al., 2006

Reacting CFD Model

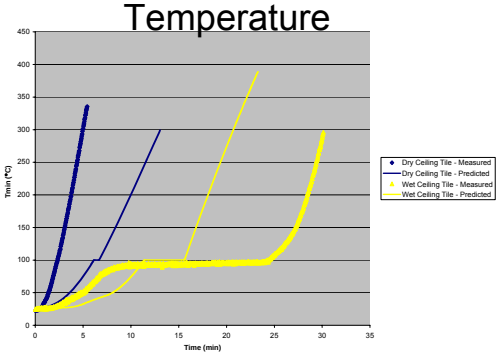


Source: REI

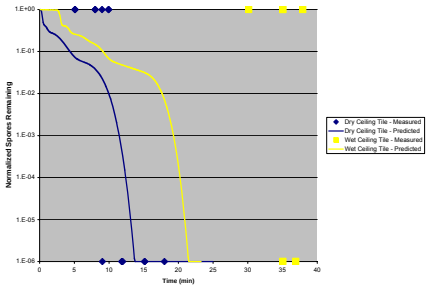
Simulation of EPA RKIS



Model vs. Experiment: Bundle Temperature



Model vs. Experiment: Spores on Ceiling Tile

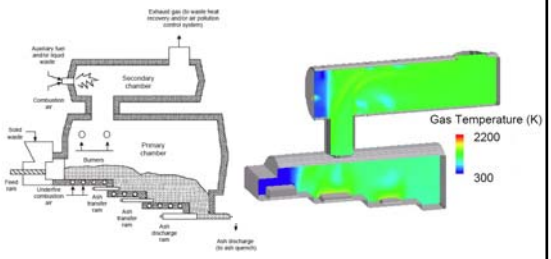


Model Input Conditions

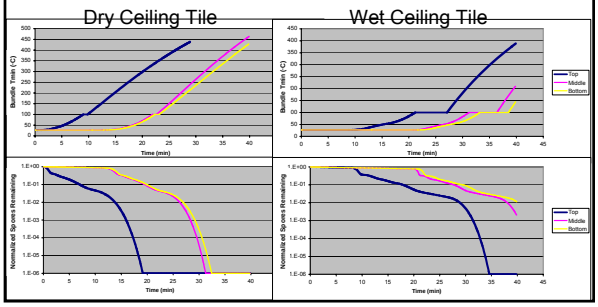
Ceiling Tile Composition, Dry Ash-Free Basis	
Carbon (%)	33.34
Hydrogen (%)	7.95
Oxygen (%)	57.79
Nitrogen (%)	0.00
Sulfur (%)	0.91
Chlorine (%)	3.3E-03
Heating Value (J/kg)	2.0E+06
K Value (W/m-K)	0.058
Heat Capacity (J/kg-K)	1340
Water Density (kg/m3)	1000

Bundle Composition	Small Dry Bundle	Small Wet Bundle	Medium Dry Bundle	Medium Wet Bundle	Large Dry Bundle	Large Wet Bundle
Bundle Length (m)	0.3	0.3	0.3	0.3	0.3	0.3
Bundle Width (m)	0.075	0.075	0.075	0.075	0.15	0.15
Bundle Depth (m)	0.075	0.075	0.15	0.15	0.15	0.15
Density (kg/m3)	296.3	592.6	296.3	592.6	296.3	592.6
Ash %	83.8	41.9	83.8	41.9	83.8	41.9
Water %	0.8	50.4	0.8	50.4	0.8	50.4
Fuel %	14.1	7.1	14.1	7.1	14.1	7.1

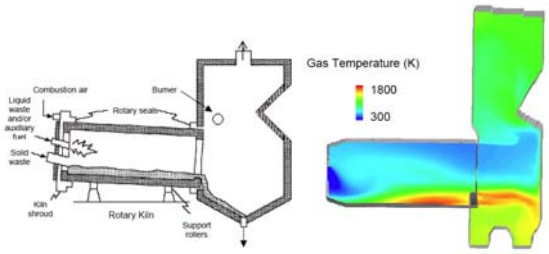
Simulation of Med-Path Incinerator



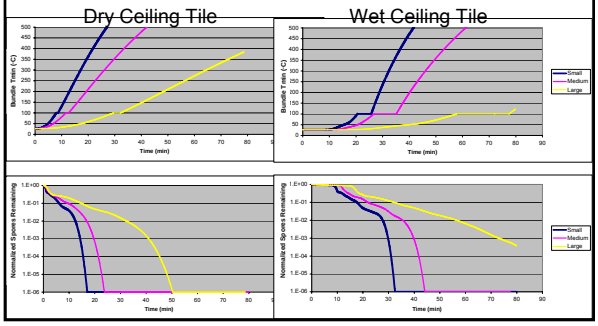
Model Predictions: Med-Path Incinerator (Comparison of Bundle Position in Bed)



Simulation of Commercial Rotary Kiln

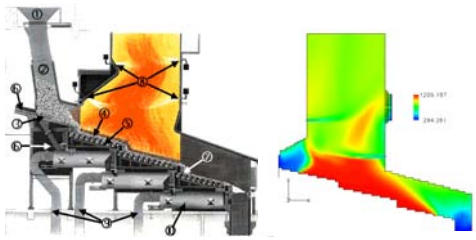


Model Predictions: Commercial Rotary Kiln (Comparison of Bundle Size)



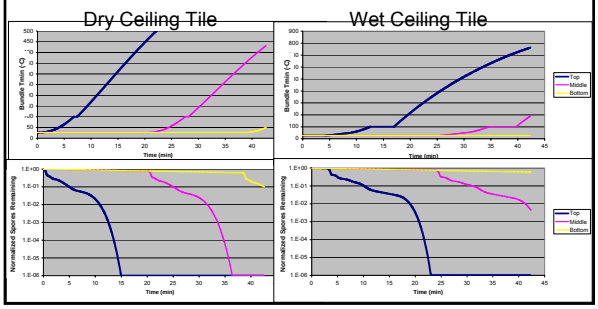
Simulation of WTE Stoker Combustor

1	Refuse Charging Hopper
2	Refuse Charging Throat
3	Charging Ram
4	Grates
5	Roller Bearings
6	Hydraulic Power Cylinders and Control Valves
7	Vertical Drop Off
8	Overfire Air
9	Combustion Air
10	Automatic Sifting Removal System



Source: http://www.detroitstoker.com/reciprograte.cfm

Model Predictions: WTE Stoker (Comparison of Bundle Position in Bed)



Conclusions: EPA RKIS Simulations

- Model reasonably predicts behavior of ceiling tile bundles in lab-scale rotary kiln
  - Somewhat underpredicts drying rates for wet ceiling tile
  - Spore kill times very well predicted for dry ceiling tile, slightly underpredicted for wet ceiling tile

Conclusions: Full-Scale Simulations

- Complete spore destruction is predicted for all 3 incinerator designs for small dry bundles
- It is suggested that for larger bundles, particularly if wet, incomplete spore destruction will occur prior to ash discharge
- If insufficient bed mixing occurs, incomplete spore destruction could result in all 3 incinerator designs, particularly for wet material

EPA Disposal Decision Support Tool

Current Features

- Web-based tool with restricted access
- Series of inputs defining scenario
- Estimates of residue mass & volume
- Database of disposal facilities (location, capacity, technical information, permits)
- Access to contaminant and decontaminant information
- Worker safety guidance
- Packaging and storage guidance
- Transportation guidance (links to DOE GIS tool)
- Agricultural Biomass Disposal Module
  - Includes “Lessons Learned” database on carcass disposal
  - Links to APHIS emergency response information
- Water Systems Material Disposal Module
- Natural Disaster Debris Disposal Module

DST Disposal Facilities

- Landfills
  - MSW
  - Construction & Demolition Debris
  - Hazardous Waste
- Combustion Facilities
  - Municipal Waste Combustors (Waste-to-Energy)
  - Hazardous Waste
  - Medical/biohazardous Waste
  - Industrial combustion facilities (e.g., boilers, smelters, etc)
- Decontamination Wastewater Disposal Facilities
  - Publicly-Owned Treatment Works (POTWs)
  - Federally-Owned Treatment Works (FOTWs)
  - Liquid Hazardous Waste Combustion Facilities
- Other Disposal Facilities
  - Centralized Waste Treatment (CWT) Facilities
  - Commercial medical waste autoclaves

Access to the Tool

- http://www2.ergweb.com/bdrtool/login.asp
- For first-time users will need to request a user ID and password – the link above has directions for making the on-line request.
- Your request will be approved and your login ID and initial password will be emailed to you.

Data Gaps and Other Issues

Disposal Non-Technical Issues

- Infrequent but potentially high-impact events
  - Not practical to stockpile large quantities of materiel resources that won't be used very often (i.e., Maytag repairman)
- Potential solutions
  - Need to utilize same infrastructure that is used for routine disposal, but must have surge capacity
  - Need to find "multiple-use" technologies that can supply ongoing needs (e.g., fumigation technology for mold remediation)

Disposal Non-Technical Issues (cont)

- Stigma associated with the waste
  - Disposal facilities have worked long and hard to develop good rapport with communities – these materials can cause PR problems
  - Some facilities (e.g., POTW, MWC) sell sludge, ash, or byproducts for reapplication (e.g., land application, construction)
- Potential Solutions
  - Include potential disposal facilities in planning activities for responses at major targets
  - Develop risk communications information in conjunction with facilities prior to event
  - Blanket purchase arrangements prior to an event
  - May potentially require "overkill" disposal activities (e.g., incineration of aqueous wastes)

Disposal Non-Technical Issues(cont)

- Industry concerns
  - Worker health and safety
    - Need to develop 'comfort level' at dealing with these materials
    - Union concerns
  - Protection of business assets
    - Long term impact of processing these wastes
    - Contamination of facilities
  - Indemnification
    - Disposal technologies not covered in Safety Act
- Potential Solutions
  - Bring facility in as stakeholder early in the planning process
  - Develop training for disposal workers
  - Perform research to understand relevant long-term effects
  - Discussions with DHS about indemnification

Incineration Data Gaps

- Need for "indicator" to assure effective performance
- Sampling methods for spores in stacks and combustor ash
- How best to package materials at the site to maximize effective combustion and contain agent
- Which types of facilities are most appropriate for which types of waste materials
- What to do with RDD debris (MAJOR DATA GAP)

Detection to Support Decontamination

3rd Annual Decontamination Workshop

Emily Snyder

Outline of Presentation and Collaborators (Co-PIs)

- Man-Portable LIBS for characterization of biological agent contamination – *Chase Munson, Andrzej Miziolek ARL*
- Single Photon Time of Flight Mass Spectrometry and Dual SourceTriple Quadrupole Mass Spectrometry for detection of TICs, fumigants, and fumigant-TIC byproducts *Dave Mickunas US EPA ERT*
- Bench-top LIBS for characterization of cesium penetration into outdoor building materials (limestone) *Sang Don Lee*
- Rapid viability PCR for quantitation of viable *F. tularensis* and *Y. pestis* on decontaminated building material coupons. *Staci Kane LLNL*

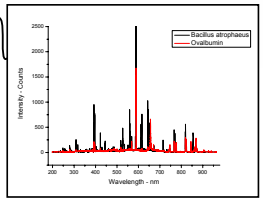
Laser Induced Breakdown Spectroscopy (LIBS) – Principle of Operation

Pulsed
Nd:YAG
1064 nm

A^+
A° A^*

Laser Induced Breakdown Spectroscopy (LIBS) – Principle of Operation

Pulsed
Nd:YAG
1064 nm



A^+
A° A^*

Generation of Pure Samples and Mixtures

- Pure *B. atrophaeus* (or ovalbumin) and interferent mixed
- Solutions were mixed to achieve desired binary mixtures of *B. atrophaeus* (or ovalbumin)and interferent (i.e. Pure, 71% w/w B. atrophaeus, 50%, 25%, 20%, 10%, and 5%)
- 10-15 µL of solution added to 1/8" screw sized region in Al dish
- Samples were allowed to dry overnight
- Only 1 LIBS spectra could be measured from each sample

Pulsed
Nd:YAG
1064 nm

A^+
A° A^*

Area of sample region = 0.079 cm^2

Data Preprocessing

13,604 Intensity Channels/MP-LIBS spectrum

⇩

15 elemental and molecular normalized peak areas from *B. atrophaeus* and ovalbumin

⇩

Summed peak areas for 9 elements

(Na, K, Mg, Mn, Si, C, P, Ca, Fe)

⇩

Place into data analysis models

Construction of Quantitative Models

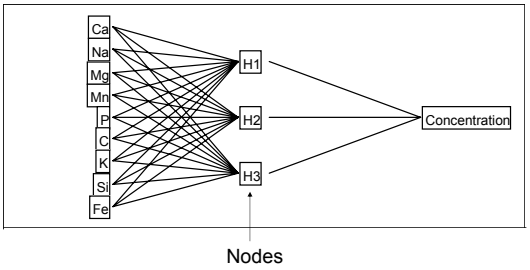
- Multiple Least Square Regression Analysis: the strength and direction of a relationship between several independent variables (in this case summed normalized peak areas) and a continuous dependent variable (in the case concentration) is described.

$$Y = \beta_0 + \beta_1 X_1 + \beta_2 X_2 + \ldots + \beta_k X_k$$

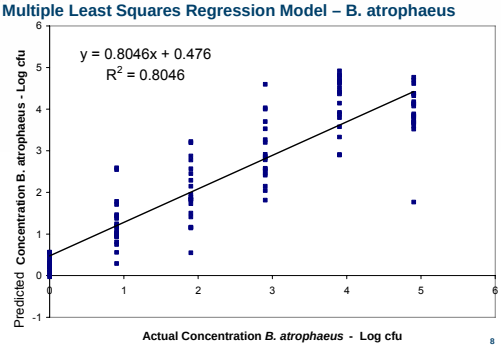
β = regression coefficients, X = peak areas

- Neural network is a series of non-linear equations used to predict output variables from input variables. This particular neural network model is based upon a single layer feed forward network

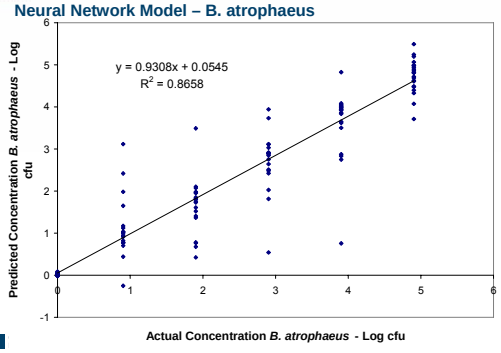
Construction of Neural Network Quantitative Models



Multiple Least Squares Regression Model – B. atrophaeus



Neural Network Model – B. atrophaeus

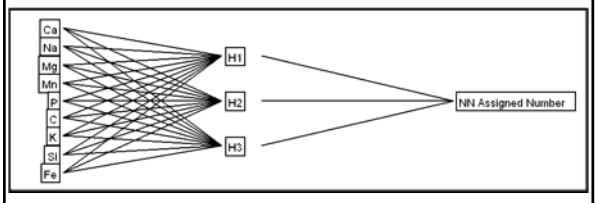


Construction of Neutral Network Model for Classification

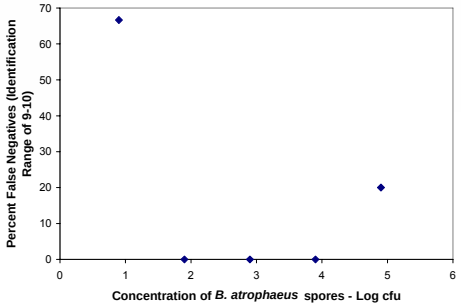
Identity of Sample	Assigned Number for Neural Network
b.a. – *B. atrophaeus*	10
ovalbumin	7
skim milk	5
mold	6
soot	1
Arizona dust	5
house dust	5
humic acid	6
blank aluminum	0

Construction of Neural Network Classification Model

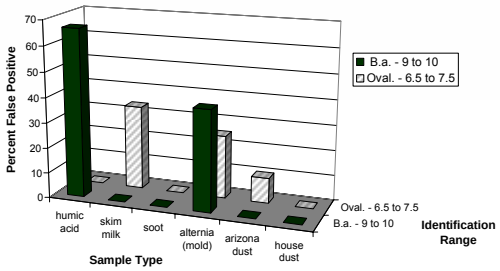
- Neural network is a series of non-linear equations used to predict output variables from input variables. This particular neural network model is based upon a single layer feed forward network. Half of known spectra were excluded to train the neural network.



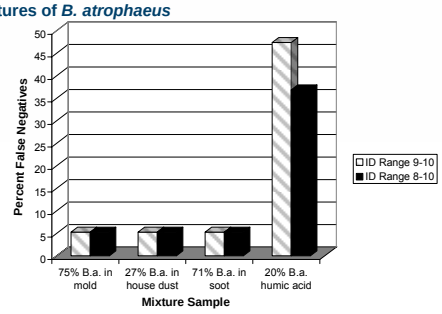
False Negative Rate as a Function of Pure *B. atrophaeus* Concentration – Neural Network Model



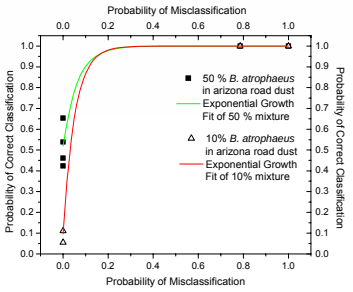
False Positives – Neural Network Classification Model



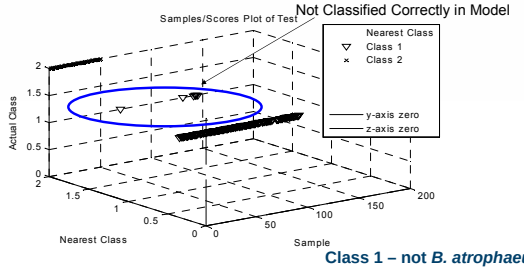
Mixtures of *B. atrophaeus*



Receiver Operating Characteristic Curves – *B. atrophaeus* Mixtures

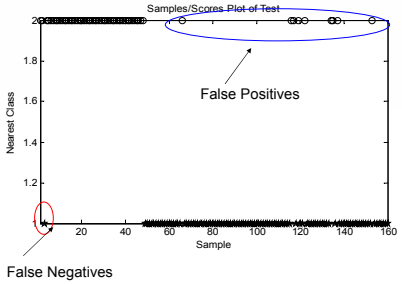


Soft Independent Modeling of Class Analogies – Training Set (identity known)



Class 1 – not *B. atrophaeus*
Class 2 – *B. atrophaeus*

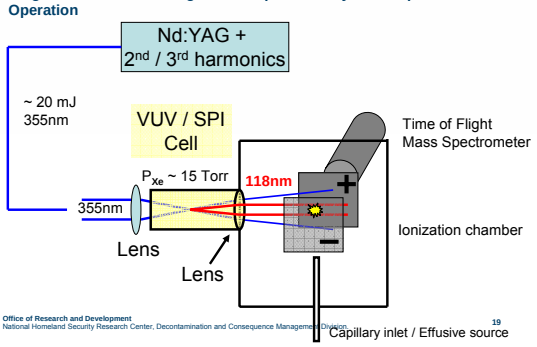
Soft Independent Modeling of Class Analogies – Test Set (identity unknown)



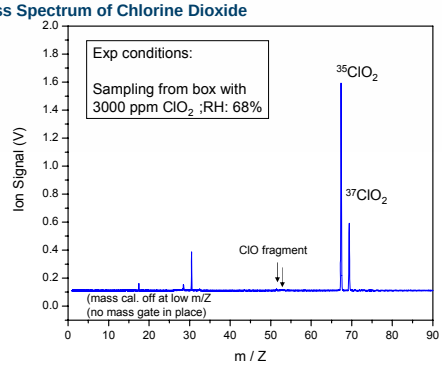
MP-LIBS Conclusions and Future Work

- Determined realistic limits of detection using classification model
- Evaluated two classification models and determined powders that may yield false positives
- Currently working to mitigate effects seen from analyzing powders on surfaces such as laminate and cement
- Currently increasing spectral library – looking for potential false positives
- Currently investigating femtosecond LIBS for increased spectra classification potential
- We would like to establish an agreement with a commercial entity to develop a Man-Portable System for the First Responder (FY08)

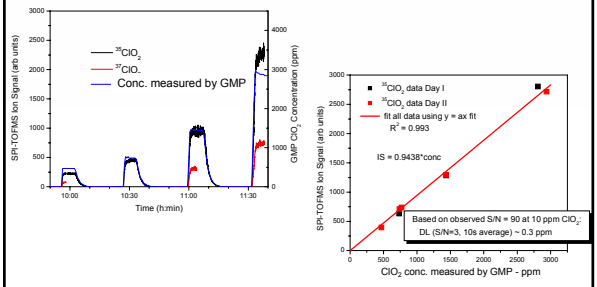
Single Photon Time of Flight Mass Spectrometry – Principle of Operation



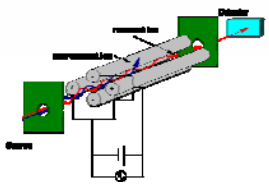
Mass Spectrum of Chlorine Dioxide



Chlorine Dioxide Calibration Curves

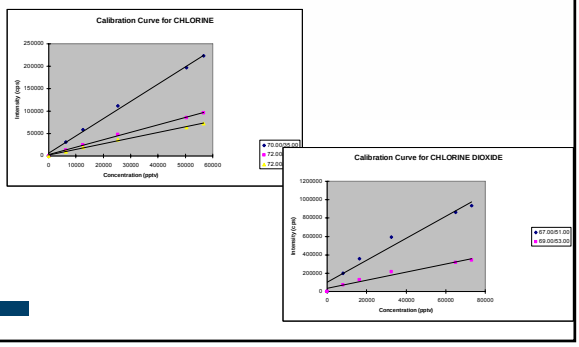


Dual Source Triple Quadrupole Mass Spectrometry – Principles of Operation



http://www.chm.bris.ac.uk/ms/theory/quad-massspec.html

Calibration Curves for Chlorine and Chlorine Dioxide



Limits of Detection for Chlorine and Chlorine Dioxide

Compound	Chlorine	Chlorine Dioxide
Limit of Detection	14.5 pptv*	11.7 pptv*

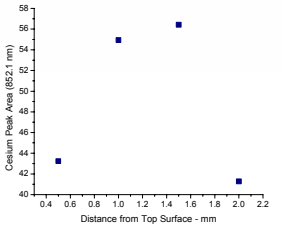
*Ion pairs for chlorine and chlorine dioxide were equally optimized

Determined <0.017% (of ClO_2 concentration) of Cl_2 broke through during the generation of ClO_2 (corresponded to 9 pptv Cl_2) – we were not able to definitively see any other products from the generation.

Conclusions and Future Work

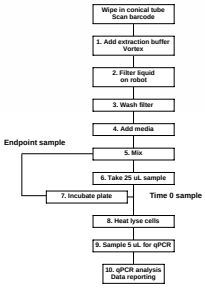
- Our facility has instruments that are able to measure chlorine dioxide, and chlorine in addition to other fumigants, TICs, and decontamination by-products
- In the future we will determine by-products from building materials and fumigants (chlorine dioxide and other fumigants)
- By-products of TICs and decontaminants will also be determined. Further experiments will be done in parallel with in-house TIC systematic decontamination experiments.

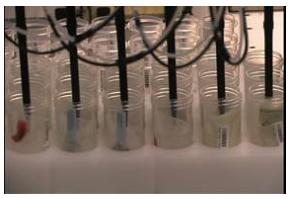
Determination of the Penetration of Cesium into Building Materials (limestone) via LIBS



Limestone coupon
20 ft from explosive

Rapid Viability PCR for Quantitation of Viable F. Tularensis and Y. pestis





EPA Responder Decontamination Needs

Leroy Mickelsen
EPA National Decontamination Team
June 20-22, 2007 Decon Workshop

Overview of Responder Needs

- User-Friendly and Updated.... Products
  - Personal Protection and Containment
  - Sampling and Characterization
  - Decontamination Methods
  - Clearance
  - Disposal

Personal Protection and Containment

- Guides for PPE
  - Effectiveness for threat agents
  - Effectiveness for decontamination agents
  - How to decontaminate
  - Effectiveness of decontamination
  - Reuse guide
- Guide for containing and reducing the spread of both agents and decontaminates

Sampling and Characterization

- Faster, cheaper, better and easy to use detectors and sampling methods
- How to sample in complex environments
- Validated sampling methods (easy to use)
- Guide to reduce amount of sampling
- SOP for packing and shipping samples

Decontamination Methods

- Faster, cheaper, better and easy to use decontamination methods
- Decontaminant effectiveness/agent/matrix
- SOPs for decontamination (t, C, T, R.H.)
- In-place decon to reduce disposal
- SOPs for handling high-value items

Clearance Guidelines

- How clean do we need to go?
  - By agent
  - By location/use of area
- SOP for clearance process and documentation for clearance

Disposal Guidelines

- Where to dispose
  - By agent, matrix and decontaminant
- SOP for transportation
- Incineration options

Current State of Affairs

- Why EPA Responders (OSC) do not have products for each category?
  - Products are there but OSCs are unaware
  - Research complete but usable product is not
  - Research in progress, incomplete, imperfect
  - Research is on the drawing board
  - Researchers unaware of needs

Most Research is In Progress, Incomplete, or Imperfect

- However, there is still need for guidance based on the best available data.
- Guidance should be as simple and direct as possible and include current research status (what data are lacking).
- Who will undertake the task to develop guidance based on best available data? Including constant updating?
- **Collaboration! & Coordination!**

Result of Guidance Development

- Responder will have best current guidance
- Research will have tangible impact
- Guidance documents will I.D. gaps for future research
- Guidance based on incomplete data may actually be good enough in some areas allowing research to be focused elsewhere
- Guidance documents may be useful in setting impact-based research priorities.

Conclusions

- Much data are available for guidance development.
- If properly coordinated we can connect-the-dots from research to field use, produce products that impact decontamination, reduce restoration cost and effectively recover from terrorism.
- We need to use the current data, though not complete, to develop user-friendly products.
- We need to collaborate, coordinate and produce up-to-date useful decontamination guidance.

Thank You

United States
Environmental Protection
Agency

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