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REPORT ON

2006 Workshop on Decontamination, Cleanup and Associated Issues for Sites Contaminated With Chemical, Biological, or Radiological Materials

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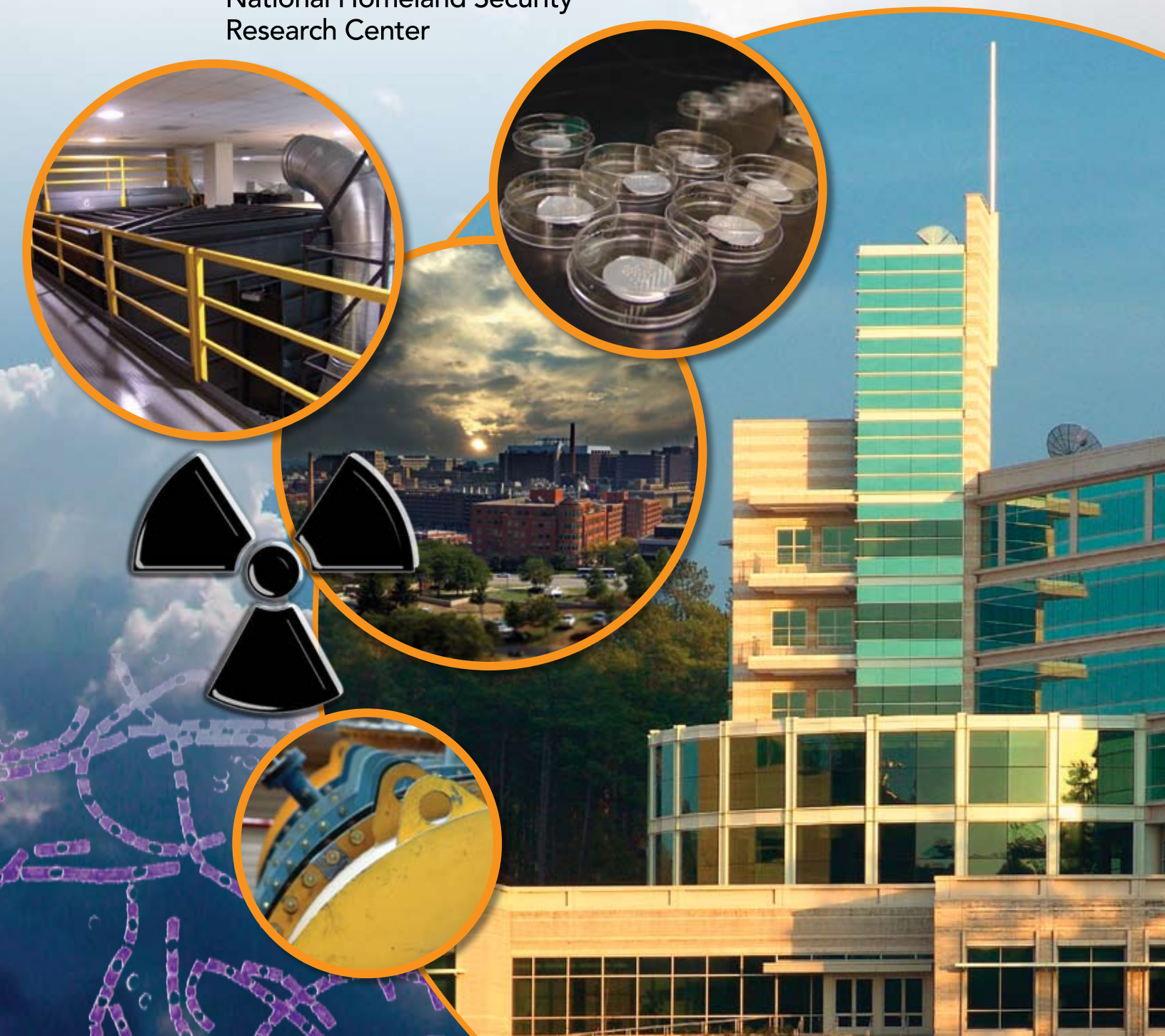

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Report on the 2006 Workshop on Decontamination, Cleanup, and Associated Issues for Sites Contaminated with Chemical, Biological, or Radiological Materials

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Notice

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 for the "2006 Workshop on Decontamination, Cleanup, and Associated Issues for Sites Contaminated with Chemical, Biological, or Radiological Materials." This report captures the main points of scheduled presentations and summarizes discussions among the workshop panelists, but it 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.

Disclaimer

The information in this document has been funded wholly or in part by the U.S. Environmental Protection Agency under contract no. EP-C-04-056 with Eastern Research Group, Inc. Information on which this report is based was technically reviewed and approved prior to presentation at the workshop. Approval does not signify that the contents reflect the views of the Agency, nor does mention of trade names or commercial products constitute endorsement or recommendation for use.

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List of Abbreviations

AEGL	Acute Exposure Guideline Level
AMI	American Media International
ANL	Argonne National Laboratory
AOAC	Association of Analytical Chemists
BI	biological indicator
BROOM	Building Restoration Operations Optimization Model
BSL	biosafety level
CBRNC	Chemical, Biological, Radiological, and Nuclear Countermeasures
CDC	Centers for Disease Control and Prevention
ClorDiSys	ClorDiSys Solutions, Inc.
CT	concentration and time values
CWA	chemical warfare agents
DARPA	Defense Advanced Research Projects Agency
DCMD	Decontamination and Consequence Management Division
DDAP	Domestic Demonstration and Application Program
DHS	U.S. Department of Homeland Security
DOD	U.S. Department of Defense
DOE	U.S. Department of Energy
DOJ	U.S. Department of Justice
DSTL	Defense Science and Technology Laboratory
ECBC	Edgewood Chemical Biological Center
eLRN	environmental laboratory response network
EPA	U.S. Environmental Protection Agency
ESF	Emergency Support Function
ETV	Environmental Technology Verification
^{o}F	degrees Fahrenheit
FBI	Federal Bureau of Investigation
FDA	U.S. Food and Drug Administration
FEMA	Federal Emergency Management Agency
FIFRA	Federal Insecticide, Fungicide, and Rodenticide Act
ft^2	square feet
ft^3	cubic feet
GDS	UK Government Decontamination Service
gpm	gallons per minute
GPS	Global Positioning System
HSPD	Homeland Security Presidential Directive
HVAC	heating, ventilation, and air conditioning
IND	improvised nuclear device

List of Abbreviations

LAX	Los Angeles International Airport
LIBS	laser-induced breakdown spectroscopy
LLNL	Lawrence Livermore National Laboratory
LRN	laboratory response network
mg/L	milligrams/liter
mm	millimeter
mVHP	modified vapor hydrogen peroxide
NAS	National Academy of Sciences
NDT	National Decontamination Team
NEPA	National Environmental Policy Act
NHSRC	National Homeland Security Research Center
NIOSH	National Institute for Occupational Safety and Health
NIST	National Institute of Science and Technology
OP-FTIR	open-path Fourier transform infrared
OPP	Office of Pesticide Programs
ORD	Office of Research and Development
OSC	on-scene coordinator
OTD	Chemical Restoration Operational Technology Demonstration
PCR	polymerase chain reaction
PHILIS	Portable High-Throughput Integrated Laboratory Identification System
PNNL	Pacific Northwest National Laboratory
ppb	parts per billion
PPE	personal protective equipment
ppm	parts per million
PVC	polyvinyl chloride
RCE	Response Capability Enhancement
RDD	radiological dispersion device
Sabre	Sabre Technology Services
SARS	severe acute respiratory syndrome
SFO	San Francisco International Airport
SNL	Sandia National Laboratory
STERIS	STERIS Corporation
TOC	total organic carbon
TSM	Three Step Method
TSWG	Technical Support Working Group
TTEP	Technology Testing and Verification Program
UK	United Kingdom
USCG	U.S. Coast Guard
USDA	U.S. Department of Agriculture

List of Abbreviations

USPS	U.S. Postal Service
VHP	vapor hydrogen peroxide
WMD	weapon of mass destruction
WWI	World War I

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Executive Summary

General Decontamination Topics

Martin (EPA) opened the workshop with a discussion of the six elements of the restoration process for a building contaminated with *B. anthracis*. He described developments that will greatly reduce the overall restoration time (compared to past experience) should another biological agent attack occur. These are primarily related to improvements in decontamination technology (e.g., chlorine dioxide [ClO_2]) and the sample clearance process. For further reducing building restoration time, Martin provided a number of recommendations, such as: having ClO_2 registered with EPA as an approved sporicide, having a full-time workgroup available on-site for document review, insuring the owner or vendor in lieu of indemnification, optimizing the characterization and clearance phases, and revising the criteria for and placement of biological indicators (BIs).

Bettley-Smith discussed the UK's Government Decontamination Service (GDS), which he heads and was established in October 2005. GDS provides advice and guidance on decontamination issues, and identifies and assesses available technologies. Local government agencies would provide the personnel and obtain the equipment necessary to conduct decontamination. The heart of the GDS is a framework of contractors that are available to provide local agencies with decontamination equipment, supplies, and experience.

Fingas (Environment Canada) discussed three overarching decontamination-related research and development projects underway at Environment Canada: the Multi-Agency Restoration Project, the Demonstration Project, and the Standards Project. The Multi-Agency Restoration Project was a 3-year study of radiation, chemical, and biological decontamination and waste management techniques, with testing performed at the laboratory scale. The Demonstration Project, planned for the summer of 2006, will involve full-scale tests of decontamination technologies. Separate facilities will address chemical, biological, and radiological contamination scenarios. The Standards Project is a 5-year study to develop standards for chemical and biological decontamination endpoints.

Kempter (EPA) gave an overview of EPA's regulation of biological agent decontaminants. Pesticides are approved by EPA under the Federal Insecticide, Fungicide, and Rodenticide Act (FIFRA), either by registration or by exemption (i.e., emergency, quarantine or crisis use). For the *B. anthracis* decontaminations, EPA issued 28 crisis exemptions. To be registered as a sterilant or sporicide, a liquid, gas or vapor product must pass the qualitative Association of Analytical Chemists (AOAC) Sporicidal Activity Test. EPA has developed a significantly improved AOAC SAT (pending approval), and is also working collaboratively to validate a quantitative sporicidal test method (Three Step Method). Gas or vapor products intended for use in enclosed spaces larger than a glove box must also pass a simulated use test with BIs. EPA is exploring a new product claim called "Decontaminant". Registration of "Decontaminant" products (intended to inactivate spore-forming bacteria such as *B. anthracis*) will require agent-specific efficacy data and will have label limitations.

Adams (EPA) gave an overview of EPA's National Homeland Security Research Center. NHSRC's mission is to provide state-of-the-art scientific knowledge and technologies to enable incident responders to effectively respond and safely restore affected areas following the release of biological, chemical, or radiological threat agents. She described the three divisions in the Center, and provided more specifics on the Decontamination and Consequence Management Division (DCMD), which she leads. DCMD has four main research areas: detection, containment, decontamination, and disposal. Dr. Adams provided a brief overview of the research in each of these areas.

Ottlinger (EPA) described the functions of EPA's National Decontamination Team. The objectives of the group include providing technical support to OSC's and first responders, effectively delivering information about decontamination options; enhancing preparedness, planning, and partnerships; serving as a liaison between stakeholders; and identifying operational shortfalls. The NDT develops standard operating procedures for handling various threat agents and compiles technical information about decontamination science, methods, validation, and resources, as well as disposal options.

Edwards (EPA) gave an overview of EPA's homeland security responsibilities and described in particular EPA's Office of Homeland Security (OHS) duties. OHS implements the EPA homeland security agenda and policy, and also serves as a liaison with the White House (via the Homeland Security Council), DHS, and other federal departments involved in homeland security concerns. Edwards reviewed EPA's involvement with six of the Homeland Security Presidential Directives (HSPD), and described EPA's program office HS responsibilities, such as emergency response, water quality, decontaminant use, hazardous materials remediation, ambient air monitoring (e.g., Biowatch), and research and development. Edwards noted several events of national significance where EPA was involved in the recovery, such as the World Trade Center attack, the 2001 anthrax attacks, the ricin event at Capitol Hill, and Hurricane Katrina.

Blackmon provided an overview of the Technical Support Working Group (TSWG) decontamination research and development activities. Blackmon is part of the Chemical, Biological, Radiological, and Nuclear Countermeasures (CBRNC) Subgroup, which is actively managing about 90 projects. Blackmon presented an overview of some of their decontamination projects. One involves the development of a low-cost, easy-to-use personal decontamination kit for victims exposed to chemical agents. In another project, a strippable polymer coating is being developed that is sprayed on a surface and fixes radioactive particles in place. TSWG is also working with Argonne National Laboratory to develop chemically-based removal of cesium-137 from porous building materials after an RDD event. TSWG is also developing software that will design a statistical surface sampling approach for determining the extent of building contamination following a CB terrorist attack.

Brooks (DHS) began by noting that DHS is not the primary lead in decontamination efforts, but rather serves an overall coordinating role and provides emergency services in support of other responding agencies (*e.g.*, EPA). However, under Presidential Directive #10, DHS is responsible for restoration of critical infrastructure facilities. Brooks provided an overview of some of the projects he is managing. These include development of restoration plans for airports, mass transit facilities, and large, outdoor, urban areas following a chemical or biological attack. Brooks is also managing projects to address laboratory issues, such as coordinating the Integrated Consortium of Laboratory Networks, the All Hazards Receipt Facilities to handle unknown samples, and a mobile laboratory prototype called the Portable High-Throughput Integrated Laboratory Identification System (PHILIS).

<u>Biological Warfare Agent (BWA) Persistence and Decontamination</u>

Rastogi (ECBC) and Ryan (EPA) presented the results of their systematic decontamination studies to determine the log reduction of *B. anthracis* viability as a function of ClO_2 dose (concentration times time, or CT) on six different building materials, and to compare the CT needed to achieve no growth on BIs and the six different building material coupons. Ryan noted that the BIs and coupons had high spore loadings (6 to 7 logs, i.e., 10^6 or 10^7 spores per BI or coupon). The researchers noted that the CT required to achieve no growth on coupons was not affected by a 2-fold increase in chlorine dioxide concentration. Unpainted cinder blocks and painted I-beams required a minimum CT of 9,000 ppm hours to obtain no growth, while for the BIs, no growth occurred on all samples after 5,000 ppm hours. (During the question and answer period that followed, a discussion ensued regarding issues with using BIs in building decontamination.)

In a separate presentation, Ryan presented the results of three other projects he is leading. He discussed a project which investigated how environmental conditions such as temperature and relative humidity may impact biological agent persistence. Vaccinia virus levels decreased over time on painted concrete and galvanized metal, with the decrease occurring more rapidly on the galvanized metal ductwork. Ricin toxin was very persistent on the painted concrete, but less persistent on the galvanized metal ductwork. Ryan then presented results of another project to investigate VHP and ClO_2 chemical interactions with building materials. Ryan discussed another project to evaluate four different techniques for measuring ClO_2 gas levels. Two of these techniques provided data in real-time, and were based on electrochemical or spectroscopic principles.

Wood (EPA) described the evaluation of several bio-agent decontamination technologies. The Sabre ClO_2 fumigant technology was evaluated for bio-efficacy against spores of *B. anthracis*, *B. subtilis*, and *G. stearothermophilus* on various types of material coupons. The Sabre technology achieved at least a 6-log reduction in spores on all materials at a concentration of 3000 ppm and contact time of 3 hours. Wood also described the current evaluation of several liquid sporicidal decontamination technologies (e.g., aqueous ClO_2, hypochlorous acid, hydrogen peroxide) for inactivating the same spores on 3 different types of materials. Lastly, Wood described a project with DoD to demonstrate a mobile decontamination trailer designed to produce ClO_2 at a rate of about 75 pounds per hour. The trailer also includes a scrubber to remove ClO_2 from the gas that would be withdrawn from the building to maintain negative pressure.

Mason described his ClO_2 technology company's (Sabre) decontamination experience, their lessons learned, enhancements made to their technology, and their efforts to lower building restoration times. Most of the reductions to the overall building restoration time and cost would be non-technical in nature, such as having available (or already assembled) equipment, enabling agreements, site agreements for content handling, pre-engineered insurance policies, first response community communication and education, draft planning documents, and established clearance criteria. Mason described Sabre's work to address the extensive mold contamination resulting from Hurricane Katrina. A mobile laboratory is used during decontamination for sampling and monitoring. Mason discussed the 3 to 4 million ft^3 facility that they decontaminated. With the advances Sabre has made, the total event time lasted only 3 days. Mason noted that mold fumigation used 3,000 ppm ClO_2 for 3 hours.

Czarneski (Clordisys) described their company's experience decontaminating a 180,000 ft^3 animal research facility using ClO_2. Much of the facility equipment was decontaminated in place. The decontamination system consisted of five chlorine dioxide generators and 20 gas sensing points. Fans distributed the ClO_2 gas because the facility was fairly complex with many small rooms and long hallways. ClO_2 concentrations of 0.5 to 0.8 mg/L were maintained for 6 hours. They fell short of the 1 mg/l target concentration, possibly due to leakage, although air monitoring outside the facility did not identify measurable concentrations of ClO_2.

Leighton (IVD/CHORI) discussed studies using ClO_2 to decontaminate vegetative bacterial cells (surrogates for plague, tularemia, glanders, etc.). He found that a dose of 20 to 50 ppm-hours completely inactivated most of the surrogates, although *S. aureus* required a 230 ppm-hours dose. His tests confirmed that shorter exposure times require higher ClO_2 concentrations. Leighton also reported that the ClO_2 did not oxidize cell DNA, thus forensic evidence remains after decontamination. In the next phase of his research, Leighton examined biotoxin (e.g., botulinum, ricin) inactivation with ClO_2 using various enzymes as surrogates. The study included evaluation of various assays for detecting inactivation, and development of assay methods continues. A ClO_2 dose of 2,400 ppm-hours resulted in a 6-log reduction in saporin (surrogate for ricin) activity, as measured by the assay.

McVey (Steris) and DiVarco (ECBC) discussed the use of VHP, with and with out the addition of ammonia, to decontaminate biological and chemical warfare agents. (Chemical agent decontamination presentations are discussed further below.) McVey presented D-values for inactivation of *G. stearothermophilus*, and discussed work they have done to determine compatibility of VHP with many different materials, including sensitive aircraft equipment. Steris has made changes to their technology to make their VHP delivery systems more portable, yet able to decontaminate larger objects such as aircraft.

Carlsen (LLNL) presented research showing that the level of the decontaminant vaporous hydrogen peroxide is greatly reduced over the length of galvanized steel ventilation duct, whereas VHP levels in ductwork made from PVC-lined steel remain essentially unchanged over the length of the duct. They found that the rate of decrease in the VHP concentration in the galvanized duct decreases with decreasing temperature and increasing velocity.

Lemieux (EPA) noted that the decontamination method directly affects disposal options. Wastes may include materials that have been removed from a contaminated building before decontamination, as well as materials that underwent decontamination but where complete decontamination cannot be confirmed. Lemieux noted that insurance and indemnification are large concerns for facilities in the disposal industry. Lemieux described some of his research, such as the development of an online waste disposal decision support tool, which can estimate the decontamination residue and disposal volume based on a series of user inputs. The tool also provides disposal options and facility locations. Lemieux also discussed incinerator and autoclave studies to determine materials impacts on the efficacy of thermally inactivating *B. anthracis* surrogates.

Chemical Warfare Agent (CWA) Persistence and Decontamination

Savage, of the Defense Threat Reduction Agency's Agent Fate Program, discussed his research initiated to understand the interaction between CWA and substrates, assess evaporation of CWA, and develop predictive models to determine hazard levels on a battlefield. Experiments in wind tunnels and in the field examine agent fate as a function of substrate, wind speed, drop size, temperature and humidity. Savage presented results from several substrate interaction investigations. In one test with mustard agent, it completely evaporated/dispersed after 4 to 4.5 hours. In other experiments with GD in soil and on concrete, a simulated rain event caused a resurgence of GD vapor. Experiments found degradation rates for mustard were increased with the presence of water. Mustard is of particular concern because the primary decomposition product H-2TG is toxic.

Divarco and McVey presented ECBC studies to evaluate modified VHP (mVHP) decontamination of agents. In experiments with VX, they confirmed that decontamination occurs more rapidly if the agent is spread thin vs. in a droplet form, and that required contact times are longer for CWA than for BWA. In general, from chamber tests conducted on numerous CWA, they found that levels on the material surface and in vapor form were reduced to safe levels within 8-24 hours using mVHP. ECBC has also worked to reduce the VHP generation equipment size and to improve mVHP distribution within a building, using computational fluid dynamics models.

Govan, of the UK's Defense Science and Technology Laboratory, discussed his work in developing decontaminants for CWAs. Their primary concerns are the agents' hydrophobicity (such as HD itself, or due to the addition of thickening agents) and entrapment into materials. Thus research seeks to identify decontaminants that have rapid solubility, maintain reactivity, and adherence to surfaces. One approach is the use of microemulsions, which are very small droplets of oils and water that enhance the solubility of hydrophobic CWAs. Govan presented results of chamber tests with various microemulsions. Govan also discussed research with colloidal mixtures (using oil, alcohols, and brine) that create surface turbulence that forces CWAs from capillary spaces and allows decontamination reactions. Lastly, current DSTL research includes investigation of surface coatings that will readily absorb liquid agents and prevent

contamination ingress. Coatings work focuses on improving contaminant absorption, and the addition of reactive materials to neutralize the agent. Govan presented data from chamber tests using a reactive, removable coating.

Tucker, of Sandia National Lab (SNL), discussed the development of a restoration plan for an airport following a CWA release. SNL is partnering with Los Angeles airport (LAX), to develop a plan specifically for LAX, but a generic CWA restoration template for other airports will also be developed. The plan will focus on interior restoration, and will address threat scenarios, clean up guidelines, decontamination technologies, and sampling related issues. The plan will follow most of the concepts from the biological agent restoration plan for airports (already developed), but must also address issues such as agent degradation, interaction with surface materials, and long-term air monitoring. In support of the restoration plan development, an experimental program is underway to investigate surface sampling issues; interaction of CWA on interior surfaces and natural attenuation/decay rates; gas/vapor decontamination methods; and statistical sampling algorithm validation.

Raber (LLNL) discussed her work with a stakeholder group to develop CWA clean up levels for transit facilities such as airports and subways. The study also includes select toxic industrial compounds (e.g., hydrogen cyanide, cyanogen chloride, phosgene), and critical degradation products from these agents and TICs. Raber presented a table of preliminary recommended clean-up levels for several agents, based on inhalation and ocular exposure. The project team selected the Acute Exposure Guideline Level (AEGL) as the basis for recommended guidelines for transit passengers. For workers, the occupational exposure guidelines developed by the military and Federal civilian agencies (*e.g.,* CDC, EPA, NIOSH) were used. The clean-up levels for workers are much lower than the clean-up levels for transit passengers, and thus the former may drive the overall restoration plan and the final recommended clean-up levels.

Water System Decontamination

The presentations given in this session primarily focused on adherence and decontamination of agents and pollutants on different types of pipe materials and other network components. Chattopadhyay (Battelle) focused on pipe materials used in drinking water systems, and chemical-based decontamination options for both chemical and biological agents. Randall (EPA) discussed adherence and decontamination of arsenic, mercury, and *B. subtilis* on different pipe materials, and the impact of pipe flow rate and biofilm. He discussed decontaminations techniques such as flushing (including at low pH), and the use of various chemical reagents. Treado's (NIST) research has been on the measurement and analysis of building water system decontamination. Building systems have their own particular challenges, such as smaller pipes, with a wide range of different materials, shorter runs, appliances, drainage, etc. Treado presented their lab-scale and full-scale research on adherence and decontaminations studies, which explored variables such as contaminant concentration, pipe material, exposure time, flow velocity, and water chemistry.

Welter (O'Brien and Gere) presented some water system contamination case studies, one of which was an incident where chlordane was intentionally introduced into a water system. Decontamination was completed via flushing of the system for 8 months, but monitoring continued for 2 more years. In their adherence studies, Welter found that attachment is mostly dependent on pipe type, and not significantly sensitive to water characteristics. Pipes with a biofilm or tuberculation reported the greatest adherence, and polyethylene and coated cement reported little adherence. Adherence increased over time, indicating that rapid decontamination is desirable. Decontamination studies found that surfactants can be effective for organic agents and chlorine can be effective for microbials if CTs can be maintained. The decontaminants tested for inorganics were only moderately and inconsistently effective.

Hall (EPA) discussed their research to assess the feasibility of using of common water quality parameters to indicate contamination by a chemical agent or surrogate. This assessment included evaluating commercially available real time sensors. Free and total chlorine, and total organic carbon were the most

useful parameters. Hall noted that one drawback to this approach is that these sensors cannot detect contamination on the pipe wall or in the biofilm. Flushing and superchlorination are decontamination techniques for water systems, although some contaminants may remain on the pipe surface, and then slowly be released over time.

Radioactive material surface decontamination

Mackinney (EPA) provided an overview of the NHSRC's radiological research agenda. The primary focus is on decontamination following a radioactive dispersal devices (RDD) event, but they will also begin to investigate issues relative to improvised nuclear devices. He noted that remediation of Department of Energy nuclear facilities has consisted primarily of demolition and disposal, and not decontamination. But this approach may not be feasible after in RDD event in an urban area, and hence NHSRC research is guided by the presumption that structures must remain in place for reuse. Mackinney noted many issues that need to be addressed, such as cross contamination, recontamination due to precipitation, vertical decontamination requirements, waste disposal, the speed of available technologies, surface chemistry interactions, decontamination of cracks/inaccessible areas, and subsurface effects.

Harper (SNL) discussed his research on the aerosolization of RDDs, noting that smaller particles tend to migrate farther and pose a greater inhalation risk; whereas larger particles do not migrate as far and pose a greater groundshine risk and dermal contamination risk. Materials reaching the liquid or vapor phase after detonation will result in respirable sized particles, and the remainder will result in large fragments. Detonating salts forms both respirable and powder-size particles (*e.g.*, 400 microns), whereas for ceramics, materials tend to shatter and most particles are greater than 50 microns; achieving greater than 5% aerosolization with ceramics is extremely difficult. His experiments lead him to believe that RDD modeling may overestimate the impact area.

Drake (EPA) began by noting that for an RDD event, decontamination implies removal of the RDD material from the substrate, thus making waste disposal a primary concern. In addition, the volume of secondary waste generated during decontamination may be much greater than the volume of the primary contamination. Demolition of a contaminated structure is an option, but may not be desirable (*e.g.*, historic landmarks). During demolition, dust and debris must be managed. Most decontamination methods are either mechanical (e.g., water wash down, vacuuming, grinding) or chemical (e.g., chelation, foams, strippable coatings) based, but novel methods currently under development include the use of microwaves, lasers and bacteria. Drake noted that decontaminating radiological agents becomes more difficult as time passes, since they become absorbed into substrates, but also the contamination footprint spreads via the weather.

Foreign Animal Disease (FAD) Decontamination

Grohs (EPA) discussed threats from FADs, which are diseases endemic in other areas of the world and may be intentionally or inadvertently introduced to livestock in the U.S. Herds are susceptible to FADs because animals have lost immunity to these diseases and because of concentrated animal feeding operations. Challenges facing FAD outbreaks include decontamination and maintaining biosecurity during depopulation and disposal of animal carcasses. FADs such as avian influenza, foot and mouth disease, and exotic Newcastle disease are of great concern. Grohs briefly discussed issues regarding avian influenza.

Bieker (SNL) began by noting that spores are the most resistant bio-agent, while enveloped viruses (*e.g.*, influenza) are the least resistant. Currently EPA has only guidelines (no standards) for evaluating decontaminants for viruses. Understanding the virucide mechanism of action dictates the appropriate analysis methods. For example, if a virucide disrupts the lipid envelope, then DNA analyses may not be a useful technique. Bieker discussed the analytical methods used and results from several studies to assess the efficacy of several decontaminants to inactivate viruses, including avian influenza. After exposure,

the samples were prepared for efficacy testing by *in vitro* culture or real-time PCR. Western blot tests were also conducted for the influenza samples. Tests results found that the organic challenge reduced decontaminant efficacy, real-time PCR was appropriate for determining viral inactivation caused by RNA degradation, and some surrogates used may not be appropriate for decontamination studies.

Agent Sampling, Analysis, and Transport

Wagner (FBI) discussed the need for evidence awareness during the recovery phase after an agent attack. Critical evidence may still be present after the crime scene phase and must be preserved. Discovery of any potential evidentiary materials during remediation would prompt FBI notification. Remediation personnel play an important role, but should not take samples with the intent of giving them to the FBI as evidence. If the FBI determines that critical evidence was found, remediation activities would stop until the evidence is removed. Wagner highlighted the importance of working together and communicating during the recovery phase.

Carleson discussed LLNL's development of a technology called Rapid Viability – Polymerase Chain Reaction (RV-PCR), that would reduce BWA analytical time from up to 7 days using conventional culturing techniques, down to less than 24 hours. In about 40 minutes, traditional PCR can identify the presence of a particular organism based on DNA analysis, but cannot determine whether that organism is viable. RV-PCR detects increases in DNA over time, indicating growth. Although RV-PCR assays can start detecting growth in a few hours, a period of about 14 hours for an organism such as *B. atrophaeus* is required to definitively assess for DNA replication. The technique was demonstrated with different matrices such as BIs, wipes, swabs, HEPA socks, air filters, and post-fumigation environmental samples. Various quality assurance-related checks were made of the method, such as comparing accuracy with culture methods, and assessing cross-contamination, biases, interferences, and detection limits.

Gibb (EPA) presented the use of laser induced breakdown spectroscopy (LIBS) for the detection of *B. anthracis* spores. LIBS is based on the principle that spores have divalent and monovalent cations in higher concentrations than the surrounding media. A majority of the research with LIBS has been determining how well (using statistical analysis) it differentiates spores from potential confounding materials such as ambient aerosols (e.g., pollen) household products (e.g., flour), building materials (e.g., plastics), dust mixtures, and surface sampling materials. Other work includes making the LIBS portable in a backpack.

Krauter (LLNL) presented her research on various aerosol properties of bacterial spores. In one project, the research investigated how spores deposit on different types of ventilation duct materials. Deposition was highest on the plastic, which may be due to its high negative charge. Krauter presented results of other projects to examine recovery of spores disseminated in HVAC duct (4-13 % recovery, depending on the material) and in a mock office (30-35% recovery). Recovery may be diminished due to sampling and culturing techniques, nonviable spores, reaerosolization, and overcoming spore-surface adhesion forces. In projects to address spore resuspension, test results show that more spores resuspend from plastic material than from galvanized steel, probably because more deposits on the plastic. Current work is underway to examine copolymer solutions that may inhibit spore resuspension.

Martinez (CDC) discussed the validation of sampling methods for *B. anthracis* spores. At Dugway Proving Grounds, three surface sampling techniques (wipes, swabs, and a vacuum sock) and three air sampling methods will be evaluated by three different laboratories. Most of the effort to date for this project has been in developing and characterizing the chamber/aerosol system. In a separate but related project with SNL, the efficiency of surface sampling collection and extraction methods for *B. atrophaeus* spores on porous and non-porous surfaces was evaluated. Total recovery efficiencies ranged from just under 20% to slightly over 30%. Martinez also presented the sampling detection limits based on these

results. Lastly, Martinez discussed projects investigating the reaerosolization of spores during the processing and opening of contaminated mail.

Rothman (EPA) gave an overview of the EPA/NHSRC Response Capability Enhancement projects. One project involves providing support to develop the Environmental Reference Laboratory Network. RCE has modeled the eLRN after the human health laboratory response network (LRN), and has established a chemical agent reference laboratory, the National Exposure Measurement Center, as part of the eLRN. Another project is to produce the Standardized Analytical Methods document to provide protocols for the analysis of chemical, biological, and radiological agents; so far140 agents are included in the document. Other involvement includes working with DHS and other partners on the PHILIS and All Hazards Receipt Facility projects.

Tomasino (EPA) described tests needed to update EPA's Sterilant Registration Protocol requirements. He first discussed recommendations for an alternative method to the AOAC Method 966.04, which is the current test required. The alternative method would differ by requiring nutrient agar, target carrier counts of 10^5 to 10^6 spores per carrier, and neutralization confirmation procedures. In a second project, Tomasino presented results that compared two efficacy test methods that provide quantitative results: the ASTM E2111-00 and the Three Step Method (TSM). No significant differences in results were found between the two methods. In the next phase, EPA will validate the TSM against the AOAC Sporicidal Activity Test Method with eight to ten laboratories. The study will involve one microbe (*B. subtilis*) on a glass carrier. In the last project discussed, the TSM was used to determine that *B. subtilis* and the Δ Sterne strain of *B. anthracis* appear to be suitable candidates for a surrogate for *B. anthracis* - Ames.

I. Introduction

This report summarizes presentations and discussions from the "Workshop on Decontamination, Cleanup, and Associated Issues for Sites Contaminated with Chemical, Biological, or Radiological Materials," which was held April 26–28, 2006, in Washington, D.C. The technical content of this 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 data, 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. Participants also engaged in a panel discussion to discuss decontamination issues. The presentations and panel discussion covered a number of topics and were organized into eight sessions:

- *Plenary session*. Representatives from the U.S. Environmental Protection Agency (EPA) National Homeland Security Research Center (NHSRC), the U.S. Department of Homeland Security (DHS), and the Federal Bureau of Investigation (FBI) presented during the plenary session. Martin (National Risk Management Research Laboratory) discussed a generic decontamination timeline and highlighted potential changes in the decontamination process that could shorten this timeline. Brooks (DHS) provided an overview of 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.

- *General decontamination issues*. Over the course of 11 presentations, speakers from federal and international agencies and organizations presented information about programs supporting decontamination research and international decontamination perspectives. Specific topics included sampling method development and validation programs, EPA research programs, EPA's regulation of biological decontaminants, EPA's laboratory response network (LRN), and the United Kingdom (UK) and Canadian decontamination approaches.

- *Decontamination technologies*. Researchers and industry representatives gave 11 presentations that provided specific information about available decontamination technologies and additional technologies under development. These presentations included technical information regarding chlorine dioxide and vapor hydrogen peroxide (VHP) decontamination, decontamination technology validation and efficacy testing, and facility restoration plans.

- *Decontamination research and development*. The four presentations in this session described ongoing efforts to systematically test decontamination technologies; to decrease fumigation time frames through developing tools to rapidly evaluate fumigant efficacy and reduce sample analytical time; to understand the fate of chemical warfare agents (CWA) in the environment; and to develop cleanup levels for restoration.

- *Radiological dispersion device (RDD) decontamination*. Three speakers provided information about ongoing research and available decontamination technologies for addressing an RDD event. MacKinney provided an overview of the NHSRC radiological research program. Drake described the RDD decontamination issues. Harper described ongoing research to understand particle formation and transport during and immediately following an RDD detonation.

- *Water decontamination.* Five speakers presented information about ongoing research projects addressing water system concerns associated with a contamination event. These projects primarily focus on understanding contaminant adherence to water distribution system materials and decontamination efficacy within distribution systems. In addition, one project sought to develop and validate a water quality sensing system that would indicate potential threat agent contamination based on changes to typical water quality parameters.

- *Foreign animal disease/avian influenza decontamination*. Two presentations addressed concerns associated with foreign animal diseases. Bieker discussed virucidal efficacy testing and highlighted the numerous factors that influence efficacy. Grohs provided an overview of the possible impacts of foreign animal disease outbreaks (such as avian influenza), emphasized the need for preparedness, and described the current structure for a multi-agency response to an outbreak.

- *Panel discussion: lessons learned, research and development needs, technology gaps*. Seven representatives from several federal agencies, including the Centers for Disease Control and Prevention (CDC), DHS, NHSRC, and other EPA offices, participated in the panel discussion. Participants briefly summarized issues and research needs that they believed were of greatest importance. They then discussed several questions posed by workshop participants. Overall, the panel members agreed that communication and collaboration between the various agencies and organizations completing decontamination and conducting research was critical. Panel members identified some specific research needs, including (but not limited to) sampling method validation, restoration time frame reduction, real-time sampling technology development, and, decontaminant-surface interactions. Several panel members also noted the need to address decontamination issues that stretch beyond science and technology, such as logistical, political, and public perception issues associated with conducting restoration.

II. Presentations and Associated Question and Answer Periods

Opening Remarks and Plenary Session

Opening Remarks; Conceptual Timelines for Decontamination Events

Blair Martin, U.S. Environmental Protection Agency, National Homeland Security Research Center

During the 2005 Workshop on Decontamination, Cleanup, and Associated Issues for Sites Contaminated with Chemical, Biological, or Radiological Materials, Martin discussed the phases of the decontamination process, including factors that influence each step of the process. This presentation served as a follow-up to the 2005 presentation and focused on how the projected decontamination timeline has changed. A review of the decontamination timeline highlighted steps in the process that could be controlled and condensed with additional research.

In the past, decontamination required many months for completion for a variety of reasons. In Fall 2001, letters sent through the U.S. Postal Service (USPS) contaminated a number of buildings with *B. anthracis*. Decontamination of these buildings employed a variety of methods: removal and disposal of contaminated material; surface cleaning with bleach, chlorine dioxide, or hydrogen peroxide liquids; and/or fumigation with chlorine dioxide, hydrogen peroxide, or paraformaldehyde. Most decontamination/fumigation experience is with chlorine dioxide, which served as the fumigant at the *B. anthracis*–contaminated Brentwood facility, Hamilton facility, and American Media International (AMI) Building. A home and a department store in New York State were also fumigated with chlorine dioxide to address mold contamination. Martin noted that chlorine dioxide containment with tenting (similar to termite fumigation), and the use of small carbon cells for its removal, were interesting innovations used during the mold decontaminations.

Based on his experiences, Martin identified six elements in the decontamination process:

- *Decision-making* regarding the selection of decontamination methods and identification of clearance parameters.
- *Characterization and monitoring* to determine the extent of contamination and track fumigation.
- *Building-related activities,* which include preparing the building, installing security, and ensuring the safety of the surrounding community.
- *Decontamination,* including the selection, design, and performance of the system.
- *Disposal* of waste materials from the decontamination processes.
- *Communication* with affected people and the community.

Past experience helped identify areas for improvement to reduce the time and cost of a decontamination event. Factors that allowed these improvements included additional fumigation experience, technology advances, equipment availability, streamlined approval processes, reduced material removal prior to fumigation, and reduce materials for disposal. For example, simply limiting removal activities and minimizing the time required for workers to wear high-level personal protective equipment (PPE) reduces the time and cost of a decontamination event.

Martin presented three conceptual timelines illustrating past, current, and possible future decontamination events. These timelines did not represent actual events. Each was a conceptual model based on engineering and professional judgment. Timelines can vary based on the duration of individual steps in the process. For each timeline, Martin presented a Gantt chart illustrating the relative time allotted for

each step in the decontamination process. Involvement of working groups and event management occurred throughout the event in each example.

The first timeline illustrated a hypothetical decontamination event based on the state of decontamination technology in 2001. This example involved a large-volume building contaminated with *B. anthracis*. Martin assumed that the fumigant was not registered, formal plans were required, a working group was formed, indemnification or insurance was obtained, extensive sampling was required, equipment was obtained or fabricated, some materials were removed before fumigation, and building clearance was contingent on approval of appropriate authorities (*e.g.,* state and local agencies). Early stages of the decontamination event included selecting a decontamination technology, contracting with a vendor, and obtaining or fabricating equipment. In parallel, formal plans (*e.g.*, sampling plans, restoration plans, crisis exemption applications) were generated and submitted for approval. Familiarity and experience with a technology strongly influences the permitting process. For example, an unfamiliar fumigant requires extensive testing before a crisis exemption may be issued. A period of forensic and characterization sampling occurred to gather evidence for possible legal actions and to determine the nature and extent of contamination. Part of the characterization phase included assessing the facility's heating, ventilation, and air conditioning (HVAC) system; identifying the extent of materials to remove prior to fumigation; determining if and how a building must be modified for fumigation; and integrating the fumigation system with existing building systems. A building assessment may require internal modifications to allow for complete fumigation. Fumigation required biological indicator (BI) placement, fumigant monitoring, BI removal, clearance sampling, and clearance report review. Martin noted that the actual fumigation was only a 24- to 36-hour event. Finally, disposal and restoration occurred; the time required to complete these final actions was the most variable component of the decontamination process.

The second timeline illustrated a decontamination event as it would occur today. For this example, the fumigation technology (*e.g.,* chlorine dioxide) was established, past experience expedited plan and document preparation, the technology itself was improved, and equipment was more readily available. Facilities themselves were better prepared by having generic sampling and restoration plans in place and keeping information about the building systems (*e.g.,* HVAC system) readily available. Technology improvements included use of negative air units to contain spores, tenting to reduce sealing requirements, and use of carbon units instead of wet scrubbers. Key in reducing the timeline was the availability of equipment such as chlorine dioxide generators, which historically required long lead times to procure or fabricate. A reduction was also seen in the time required to obtain public health exemptions because the technology was established. The availability of building information sped characterization sampling and increased confidence in clearance sampling, substantially reducing the time required for the building assessment. Overall, the timeline was shortened primarily because of the availability of equipment and confidence in the clearance process.

The third timeline illustrated a possible future decontamination event. In this event, Martin assumed that chlorine dioxide was a registered fumigant, a full-time working group was available for onsite document review, insurance by the owner or vendor was available in lieu of indemnification, contents were fumigated in place, and activities in high-level PPE were minimal. The registration and insurance components of the decontamination event were very quick. The fumigation, characterization sampling, BI placement and removal, and clearance sampling did not change much in this timeline as in the second timeline.

In conclusion, Martin reiterated that the timelines do not represent actual events and were based on engineering judgment and experience with *B. anthracis*. The timelines, however, illustrated the potential for large reductions in the time required to complete a fumigation event. Additional areas for time reduction may include linking forensic and characterization sampling, optimizing the characterization and clearance phases, and revising the criteria and placement of BIs. For a large building, the time and

expense associated with BIs can be quite large. For example, San Francisco International Airport (SFO) decontamination could require as many as 18,000 BIs, which represents a significant cost, if the whole airport was involved in a contamination event. In the past, BIs were used as a means to determine that the fumigant reached the proper concentration and time value (CT) required for decontamination. Recent research, which was the topic of other presentations during this workshop, indicates that BIs may not be appropriate for this use. Research into this issue, as well as improving BIs, is ongoing. Martin said he thought that ongoing research of additional agents of interest, other fumigants, and improved containment technologies also has expanded capability.

Question and Answer Period

- *What is the total time estimated to complete each of the three timelines?* Excluding the restoration phase, which can vary widely, the base event (the first timeline) required approximately 18 months for completion, the second timeline required 14 months, and the fully reduced timeline (the third timeline) required 8 to 9 months.

Department of Homeland Security (DHS), Science and Technology Chemical/Biological Restoration Programs

Lance Brooks, Department of Homeland Security

This presentation provided an overview of some of the decontamination programs and research underway at DHS. Additional presentations at this workshop provided details about specific projects.

DHS is not the primary lead in decontamination efforts: in incidences of national significance, DHS serves an overall coordinating role and provides emergency services in support of other responding agencies (*e.g.*, EPA, the U.S. Coast Guard [USCG]). Under Presidential Directive #10, however, DHS is responsible for detection and restoration of critical infrastructure facilities. As such, many of the DHS projects have focused on high-traffic facilities.

Projects underway at DHS include:

- *Biological—restoration of airport facilities.* DHS partnered with SFO to evaluate ways to reduce the overall time required to restore operation of a critical transportation facility (the airport) after a biological attack and to create generic decontamination and restoration plans. In looking at decontamination event timelines, the project team targeted agent contamination characterization and clearance sampling. They found that preparing characterization plans, selecting predetermined decontamination technologies, and improving clearance sampling could decrease the timeline. To improve clearance sampling, the team researched tools that improved monitoring and sample tracking. As part of this project, SFO will have a final restoration plan that will also serve as template for other airports.

- *National Academy of Sciences (NAS) study.* This study addresses concerns about re-opening public facilities after a contamination event and attempts to answer the question "What levels of residual agent are acceptable after decontamination?" Instead of providing specific numerical values and action levels, the project created a decision-making framework that considers issues and problems that influence decontamination decisions. The framework includes questions that facility operators need to ask and answer as part of the decontamination process. Considerations include issues surrounding infectious dose, natural background, quantitative risk assessments, past cleanup efforts, and residual contamination.

- *Restoration plan for airports.* Every day that a facility is closed has a huge economic impact on an area. DHS believes that having plans in place and having these plans pre-reviewed and approved can substantially reduce downtime. An airport restoration plan (for a bio-agent attack) is currently in final draft form and undergoing review by DHS and EPA. The main chapters consider characterization, remediation, clearance, and recommendations for pre-planning. DHS will use this document as a basis for transit system restoration plans tailored to system-specific needs. Transit systems must consider issues and circumstances that vary from airport concerns and even other transit system concerns. DHS has partnered with transit systems in Washington, D.C., and New York City. DHS hopes to generate a baseline restoration plan for transit systems.

- *Biological—wide area restoration.* This project is new in 2006. It shifts the focus from facilities to large outdoor releases in urban areas. DHS currently operates the BioWatch system, conducts active bioaerosol monitoring, and works to develop consequence management plans for facilities. Developing a restoration plan for open areas, which will outline restoration procedures for these areas, requires considerably more effort. Consequence management plans currently address only characterization activities; no restoration plans are available and ready to use. DHS is identifying a research venue and project partners (local government agencies) to work toward creating a restoration plan. Results from other research projects will be incorporated into this plan. DHS aims to develop a comprehensive, and easy-to-use, decision-making framework addressing radiological, chemical, and biological threats for use at a local level.

- *Chemical—facilities restoration demonstration.* DHS has partnered with Los Angeles International Airport (LAX) in a project that, though similar to efforts at SFO, focuses on decontamination technologies available to address a chemical agent contamination event. Under this project, DHS has examined various threat scenarios and possible contaminants, including action levels and cleanup levels. This information will feed into a restoration plan specific for LAX, but will also serve as a basis for developing a generic template for other airport chemical agent restoration plans, and possibly for other types of transit facilities.

- *Integrated consortium of laboratory networks.* DHS is also involved in evaluating laboratory surge capacity in the event of a large-scale chemical or biological attack. If an attack occurs, characterization and clearance activities will generate a significant number of samples. For example, an outdoor attack with anthrax could generate tens of thousands of samples. Currently, the consortium involves incorporating existing networks and does not include building new facilities or networks. The environmental laboratory response network (eLRN) is new, however, and is designed specifically to address the lack of capability for CWA. The lead project agencies include EPA, the U.S. Department of Defense (DOD), CDC, the FBI, and DHS. However, many other agencies are also involved.

- *All hazards receipt facilities.* In conjunction with the laboratory consortium, DHS is also researching sample receipt facilities that will protect laboratory staff and laboratory infrastructure during the handling of unknown samples. These facilities, which may be stand-alone structures placed outside laboratories, are designed to assess a large volume of potentially highly toxic, radiological, or explosive material. They would use a consistent protocol for analyzing and handling samples to maintain evidentiary credibility. A prototype is near completion and will be placed at a public health laboratory for a 1-year evaluation period.

- *Mobile laboratory (Portable High-Throughput Integrated Laboratory Identification System [PHILIS]) prototype.* PHILIS is a portable laboratory system that can place high-throughput analysis capabilities on site after an event. The mobile laboratory would be brought on site after a

large-scale event to allow analysis of thousands of characterization and other samples in a single day. Brooks noted that the lack of rapid analysis techniques is a shortcoming in current technologies.

Question and Answer Period

- *The first two presentations discussed the time required to receive regulatory approvals, such as crisis exemptions, but neither mentioned the National Environmental Policy Act (NEPA) process. How does NEPA, specifically environmental impact statements, apply to decontamination events?* Jeff Kempter of the EPA Office of Pesticide Programs (OPP) responded that NEPA and environmental impact statements have not been a component of the regulatory process associated with decontamination events. The Federal Insecticide, Fungicide, and Rodenticide Act (FIFRA) and other response authorities primarily oversee decontamination.

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

Jarrad Wagner, Federal Bureau of Investigation

A contamination event can be broken down into many different phases. The FBI focuses on crime scene and evidence collection aspects of an event. This presentation provided information about the FBI's role during an event and how the FBI processes a crime scene.

A weapon of mass destruction (WMD) crime scene is incredibly complex, as illustrated by the World Trade Center destruction. Due to the large amount of debris, remediation may have begun even though the debris itself may be evidence. A WMD crime scene includes not only the location of a WMD incident, but also any location where WMD have been prepared or discovered. For example, a laboratory where WMD material was manufactured or a location where a WMD was hidden presents a public health hazard because some material may be present and released. A legislative definition of WMD exists; Wagner defined WMD as any chemical, biological, radiological, nuclear, or explosive material.

Wagner outlined four phases in a WMD incidence response: tactical phase, operational phase, crime scene phase, and remediation phase. The tactical phase includes removal of a hostile threat by responders trained to ensure that an area is safe from physical threats, such as a sniper. The operational phase addresses public safety with responders (*e.g.*, National Guard, state and local police) focusing on identifying and mitigating hazards. The FBI becomes involved in the crime scene phase, which includes evidence collection and packaging. Remediation, the final phase, includes mitigation of hazards after an incident.

During crime scene processing of a terror event, the FBI serves as the lead federal investigation agency and conducts investigation activities for the U.S. Department of Justice (DOJ). Wagner works in the FBI unit involved in the safe collection and transport of hazardous materials evidence. The team responding to these incidents is specially trained to work in high-level PPE, but local or state personnel may be integrated with the FBI teams if necessary, trained, and available. The FBI team is on call and can rapidly respond to incidents.

The FBI processes a crime scene following a 12-step approach. The first nine steps of the process consist of activities to prepare, secure, and document the crime scene. Evidence collection occurs at step 10. Releasing the scene for remediation, step 12, is critical. Once the FBI releases a site, EPA remediation can begin. As part of this step, FBI and EPA personnel walk through the site and the FBI agent describes what materials were taken and what materials were left. The FBI does not gather all the hazardous materials, only enough to serve as evidence. For example, if two 55-gallon drums are present, the FBI

will collect only a small sample from the drums and leave the majority of the material for EPA remediation.

In collecting evidence from a WMD crime scene, personal and public safety are the primary concerns. The FBI, however, must also maintain sample integrity and preservation. Evidence is collected and then placed in an over-pack container; the over-pack container is decontaminated, not the evidence itself. The FBI must also maintain an accurate chain-of-custody for evidence in a criminal case. The chain-of-custody documentation tracks the movement and location of physical evidence from the time of collection to presentation in court. Maintaining this chain-of-custody is critical.

Due to the complex nature of WMD sites, the FBI understands that evidence at a WMD crime scene may remain after the FBI has released the site. Collecting all relevant evidence is not always possible. Wagner presented a description of FBI needs and evidence characteristics such that decontamination personnel can identify relevant evidence (*e.g.,* false outlet in the wall) and notify the FBI if additional evidence is found during remediation.

Forensic evidence at a crime scene includes information that indicates that a crime was committed, as well as materials taken from the scene or left at a scene by a suspect or a victim. WMD evidence includes the WMD material and anything contaminated with WMD. WMD evidence must be analyzed at an appropriate, accredited laboratory equipped to handle chemical, biological, or radiological materials. The FBI characterizes the WMD to identify sources or unique information (*e.g.*, signature analysis, attribution for anthrax). Often with pending litigation, the FBI cannot release detailed information about a WMD. Critical evidence, which includes anything that proves guilt or helps identify the perpetrator, consists of any improvised chemical, biological, or radiological device components, concentrated WMD, paperwork detailing attack plans, or identification documents. Discovery of any of these materials during remediation would prompt FBI notification; the FBI should collect this evidence to maintain integrity for use in a criminal trial.

Wagner has developed a protocol for notifying the FBI if additional critical evidence is found during remediation. Personnel should contact the EPA on-scene coordinator (OSC) or liaison, who will then contact the FBI WMD coordinator. The FBI WMD coordinators are special agents responsible for interacting with and training people who may come into contact with WMD (*e.g.*, local fire or police personnel, EPA OSCs). Wagner urged EPA OSCs to contact their WMD coordinators before an incident occurs. The FBI WMD coordinator will then contact the FBI case agent and other FBI groups, as necessary, to discuss the evidence and determine the appropriate action. If the FBI determines that critical evidence has been found, remediation activities will stop. Wagner noted that remediation is a process of destroying evidence. An FBI team, or other certified team, will return to the crime scene to collect the evidence. Remediation resumes once the evidence is removed.

Wagner highlighted the importance of working together and communicating during WMD events to ensure an incident response that not only protects on-scene personnel and the public, but also maximizes the ability of the FBI and other legal authorities to identify perpetrators. Wagner encouraged workshop participants to pass this information to other OSCs and remediation personnel.

Question and Answer Period

- *If evidence were decontaminated, would the breakdown products serve as evidence in a criminal case?* Using breakdown products to obtain a conviction is untested in case law. Signature analysis and breakdown products/metabolites analyses can be completed. The totality of this evidence may indicate that a crime occurred and could be valuable. Ideally, remediation personnel would contact the FBI before decontamination such that the neat agent could be collected. The FBI must

also consider how decontamination agents affect traditional evidence (*e.g.*, fingerprints, DNA) and agents used to collect traditional evidence (*e.g.*, superglue).

- *Has the FBI conducted research on sampling techniques and how these techniques affect evidence credibility?* The FBI has considered sampling technique (*e.g.*, swabs, swab materials, containment materials) impacts on traditional evidence. Wagner was not aware of any FBI research regarding decontamination materials (*e.g.*, hydrogen peroxide, chorine dioxide) impacts on traditional evidence.

- *How is superglue used?* Superglue acts as a fixative to cement together residues that make up a fingerprint so that the fingerprint remains intact during collection.

General Decontamination Issues

Validation of Environmental Sampling Methods: Current Research and Related Projects

Ken Martinez, Centers for Disease Control and Prevention

Martinez' presentation provided an overview of CDC efforts to update and validate surface and air sampling.

One project involves developing an aerosol system that creates uniform samples of deposited bacteria. CDC is conducting this research at Dugway Proving Ground in conjunction with multiple partners. The project goals are to aerosolize *B. anthracis* (Sterne strain) in a chamber, achieve low-level concentrations to assess detection limits, compare three surface sampling methods (vacuum, wipe, and wet swab on stainless steel and carpet), compare three air sampling methods (cascade impactor, PTFE membrane filters, and gel filters), compare three laboratories, and compare single-pass to multiple-pass analysis. For this project, Dugway Proving Ground designed and built a sampling chamber that can produce multiple identical samples of settled bacteria and uniform air concentrations. The chamber is constructed of stainless steel and Plexiglas and uses fans to stir the air to achieve a homogenous concentration.

To test surface sampling methods, CDC allows the particles to settle on the sampling surfaces within the chamber. Initially, CDC used agar plates for reference sampling; however, compared to stainless steel coupons, the agar plates dramatically underestimated the amount of spores present. Work to optimize the reference sampling is continuing; in addition to the agar plates and stainless steel coupons, CDC also settled particles on carpet coupons. Martinez provided a schematic diagram of the chamber and briefly reviewed the steps in chamber operation.

Preliminary results with bacteria found a predictable aerosol decay curve; initial rapid decay was potentially due to electrostatic losses. Results from 4 runs and 26 agar plates indicated low inter-sample variability. In conducting tests, researchers found that the act of collecting the samples re-aerosolized the spores. Lightly covering the non-sampling surfaces with oil addressed this problem.

Martinez described a collaborative second project to evaluate the efficiency of surface sampling collection methods for *Bacillus atrophaeus* spores on porous and non-porous surfaces. The project provides a robust scientific and statistical evaluation of current swab, wipe, and vacuum surface sample collection methods. Results should answer questions about how well spores can be pulled from a sampling surface and how well analysis methods extract spores from a swab or collection material.

A wipe sample may only collect 50% of spores on a contaminated surface. The extraction method (by sonification) then only pulls 50% of the spores from the wipe sample, achieving only a 25% total spore

recovery. CDC used a homogenous sampling chamber, similar to the chamber developed at Dugway Proving Ground, to create uniform samples. An aerosol generator feeds into a mixing chamber to reach the desired spore concentration in air. The spores then settle on a series of sample coupons (stainless steel [reference material], painted wallboard, carpet, or bare concrete). Non-sample areas between coupons were coated with an adhesive to prevent spores from re-aerosolizing.

Martinez presented results from testing swab, wipe, and vacuum sock collection methods. Swab efficiency for stainless steel and painted wallboard was 50% and the extraction efficiency was 80%, resulting in a total collection efficiency of 40%. Wipe efficiency for stainless steel and painted wallboard ranged from 55% to 68%, but the extraction efficiency was only 50%, resulting in a total collection efficiency of 25% to 30%. CDC did not test swabs or wipes on porous materials (carpet and bare concrete) because the inefficiency of swabs and wipes on these materials is well established. The vacuum sock was tested on both non-porous and porous materials with the understanding that the vacuum sock is the preferred method for sampling porous materials. The collection efficiencies were relatively low for all materials (less than 30% to 50%) and the extraction efficiencies were consistently almost 70%. Ultimately, the total collection efficiencies ranged from just under 20% to slightly over 30%. This information, however, was not consistent with observations from actually sampling events. Based on Martinez' field experience, the vacuum sock samples contained the highest concentrations of anthrax spores and were most consistent in finding positive detections. In evaluating the study results, CDC found small microscopic holes (10 to 15 microns) in the filters. These holes were too small to see, but large enough to allow a spore to pass through. In the field, the large sample volume collected clogs these holes and prevents pass-through; the small sample volume in a laboratory does not clog the holes.

During this project, CDC also attempted to quantify detection limits for each of the sampling methods. Martinez presented two tables: one listed detection limits for characterization sampling, which requires quantitative results, and the other listed detection limits for clearance sampling, which requires qualitative results (*e.g.*, presence or absence of spores). This information illustrates that the detections limits are higher (*e.g.*, hundreds of spores) than ideally desired (*e.g.*, tens of spores) for quantitative sampling. The detections limits drop significantly for qualitative sampling.

In related research, CDC has partnered with several groups in the United States and Canada to assess re-aerosolization of anthrax in letters. This project examines if following CDC guidelines truly minimizes anthrax re-aerosolization. Initial evaluations found problems with the guidelines. As a next step, CDC is examining additional scenarios to evaluate possible changes to the guidelines. CDC will evaluate an open office with co-workers present—previous studies evaluated a closed office. An actual person, fully clad in PPE, will open a letter. A number of sampling methods and BIs will assess spore movement and allow for modeling to assess spore movement. Results will allow agencies to evaluate protocols for responding to and containing spores during an anthrax event.

Martinez is also involved in a study of spore re-suspension from contaminated envelopes during mail processing. CDC aims to develop standardized procedures for assessing possible cross-contamination in the mail. Cross-contamination found in New York and Connecticut motivated this project. In responding to anthrax events, CDC successfully collected samples, identified spores, and tracked spore movement, with two exceptions—a nurse in New York City and a woman in Connecticut. CDC was unable to find an anthrax source although both victims died of inhalation anthrax. These incidents prompted projects to find lower concentrations of spores in the environment and assess the transfer of spores between letters. Preliminary studies produced uniform envelope coating with spores and indicated that predictable concentrations can be achieved. CDC plans to use actual letters from the anthrax event to further study cross-contamination in an effort to better understand risks to individuals manipulating cross-contaminated letters (*e.g.*, opening by tearing or with a knife) and to develop better protocols for controlling the spread of spores through cross-contamination.

The National Institute for Occupational Safety and Health (NIOSH) is working to create a new sampling technique for collecting bioaerosols. Martinez briefly described a sampler that correlates with other standard methods. This cyclone-based, micro-centrifuge tube directly collects samples onto the tube, which simplifies the analysis process because no extraction step is required. Polymerase chain reaction (PCR), immunoassay, and other standard methods can be used to analyze the sample. With PCR analysis, detection limits for fungal spore counts are greater than 100 and detection limits for dust are less than 0.2 mg.

Question and Answer Period

- *Has CDC worked with the LRN to illustrate the importance of using HEPA-sock techniques?* Martinez recognized that some LRN locations are not comfortable with HEPA-sock techniques because of personnel safety. Using appropriate analytical techniques and safety measures can minimize these risks. CDC successfully collected many HEPA-sock samples without incident during the anthrax events. CDC is developing protocols for analyzing HEPA-sock samples. CDC is also evaluating alternative sampling methods.

- *For the open office study, what is the volume of the office and what is the study time frame?* Martinez did not have the specific measurements for the open office area. For general perspective, the area is the width of a double-wide trailer and twice as long. A central corridor with office areas on either side runs the length of the area. The study is scheduled for completion by September 30, 2006.

- *Has CDC evaluated other spore collection methods?* CDC has researched alternatives to swabs and found a manuscript that reports good recoveries using macrofoams, which pull spores from non-porous surfaces. Research into other materials, such as electrostatic cloths like the commercial Swiffer product, has not been completed. Martinez expressed concern about extracting spores from these materials and interferences with chemicals used on the cloth or during the extraction. CDC is focused on establishing a baseline for methods already in use.

- *Is there concern about changes in viability of spores that undergo extraction processes? Would these changes affect efficiency calculations?* Because spores are so viable, persistence has not been a primary concern. Martinez found that sampling areas a year or more after contamination still detected high numbers of spores. No effort to compare the number of spores found initially and in later samples has been conducted.

- *Given that 50% of the spores remain after collection, has CDC attempted to collect additional samples from the exact same sample location after decontamination?* The NIOSH and CDC philosophy has been to resample locations using a targeted approach. Using a grid sample design is important, but should be combined with a targeted approach to identify areas of greatest concern for contamination. At the Brentwood facility, CDC specifically recommended that clearance samples be collected in the same location as characterization samples.

Decontamination Research at the U.S. Environmental Protection Agency (EPA) National Homeland Security Research Center (NHSRC)

Nancy Adams, U.S. Environmental Protection Agency, National Homeland Security Research Center

Decontamination efforts and research related to threat agents began in EPA 4 years ago with a core group of about 15 people. Since that time, research efforts have greatly expanded. Adams applauded the

establishment of multi-disciplinary, multi-agency, and multi-country collaboration about decontamination concerns, topics, and problems.

EPA organized a temporary NHSRC in 2002 in response to the anthrax letter events, which highlighted the need to better understand effective decontamination of buildings. NHSRC became a permanent group in 2004 and currently addresses decontamination of buildings and water systems. NHSRC supports the EPA's National Decontamination Team (NDT), OSCs, and other EPA responders. NHSRC personnel typically are not on site, but advise those involved with onsite activities and look to onsite personnel to identify data gaps and advise NHSRC on research needs.

NHSRC has three divisions—Water Infrastructure Protection, Threat and Consequence Assessment, and Decontamination and Consequence Management. NHSRC headquarters are located in Cincinnati, Ohio, with staff also located in Washington, D.C.; Research Triangle Park, North Carolina; and Las Vegas, Nevada. NHSRC staff also work with a number of collaborators, including the U.S. Department of Energy (DOE) National Laboratories, the Department of Defense, the National Institute of Standards and Technology, and other organizations in the EPA Office of Research and Development (ORD).

NHSRC's mission is to provide state-of-the-art scientific knowledge and technologies to enable incident responders to effectively respond and safely restore affected areas. NHSRC research focuses on biological, chemical, and radiological threat agents as released in buildings and water systems (*e.g.*, water distribution and wastewater systems). Initially, building releases were the primary concern; however, research has expanded to include outdoor urban areas. Technical areas of focus include enhancing response capabilities, improving sampling and analysis methods, containing releases, evaluating decontamination and treatment methods, and providing guidance for safe waste disposal.

Adams provided a partial list of the agencies and organizations with which NHSRC has collaborated to illustrate the many and various disciplines and organization involved in decontamination research. She also provided pictures of some of the specialized facilities available to NHSRC to illustrate the variety of research capabilities. These facilities include indoor air chambers, a drinking water pilot plant, a test house, a drinking water pipe-loop test facility, a combustion research facility, extensive aerosol testing facilities, wind tunnels, and a biosafety level 3 (BSL-3) laboratory.

NHSRC's Decontamination and Consequence Management Division (DCMD) has four main research areas: detection, containment, decontamination, and disposal. Adams provided a brief overview of ongoing research in each of these areas.

- *Detection*. Research in the detection area includes examination of microbe and chemical persistence on common indoor materials. NHSRC is also continuing a real-time spore identification project and beginning a project to develop prion surrogates that could be safely handled in BSL-2 laboratories. NHSRC adapted open-path Fourier transform infrared (OP-FTIR) technology for field applications, including miniaturized in-duct (HVAC) chemical detectors and applications with robotic sampling devices. NHSRC is also developing methods for sampling emissions during incineration to ensure that agents are not re-released; assessing the sampling efficiencies for *B. anthracis* on surfaces; and developing improved BI strips for monitoring decontamination efficacy. In 2005, NHSRC hosted a workshop to identify and discuss issues and concerns about characterization and clearance sampling.

- *Containment*. Research in the containment area examines resuspension of agents from common indoor and outdoor surfaces, infiltration of agents into buildings during outdoor releases, and evaluation of the Federal Emergency Management Agency (FEMA) sheltering-in place guidance.

NHSRC published an evaluation of shelter-in-place for residential structures and found that shelter-in-place can be very effective if done properly. An evaluation of sheltering-in-place for larger buildings will be released soon. NHSRC is working with CDC and other organizations to assess how human activities (*e.g.,* letter opening, walking on carpeting), environmental conditions (*e.g.,* temperature, wind direction, relative humidity), and indoor sinks/re-emitters (*e.g.,* materials that absorb and then slowly re-emit an agent) affect indoor exposure. Additional research examines retrofitting options (*e.g.,* filters, HVAC system modifications) for older buildings to make these buildings safer. NHSRC has just initiated a program to guide building managers in compiling information (*e.g.,* floor plans, maps of HVAC systems) and making this information readily available to speed responses and improve safety. A graduate program in building protection has also been initiated at North Carolina Agricultural and Technical State University.

- *Decontamination*. A number of research projects are underway in the decontamination area. NHSRC has compiled information on available decontamination methods and is conducting several studies to optimize the efficiency of methods. NHSRC has assessed and reported on the remediation of anthrax-contaminated buildings, preparing "lessons learned" from prior decontamination efforts. Studies are being conducted to assess tenting methods (*e.g.,* efficiency in containing fumigants) and scrubbing methods (*e.g.,* prevention of release of fumigants to the atmosphere). One planned research project will prepare test coupons through aerosol deposition, assessing decontamination efficiency on real-world materials. The Water Infrastructure Protection Division has collaborated with DCMD to conduct research on RDDs commonly known as dirty bombs, and their impacts on water systems. Future projects will also examine surface decontamination after an RDD event. DCMD has compiled available technologies and methods for addressing RDD contamination. Another new DCMD project will develop and test bacteriophages, viruses that infect specific bacterial species; bacteriophages may prove to be safe, efficient, and effective decontamination methods for bacterial pathogens. An ongoing field program is evaluating a portable chlorine dioxide fumigation system. Another laboratory study getting underway will assess fumigant reaction kinetics (*e.g.,* rate of decomposition, reactions with material surfaces, byproducts) on indoor and outdoor surfaces.

- *Disposal*. In this area, there are research projects examining bench-scale, pilot-scale, and full-scale thermal destruction, using surrogate threat agents on ceiling tiles, carpet, other indoor/outdoor materials, and agricultural wastes. Additional research includes developing a portable gasifier for diseased animal carcass disposal, modeling agent destruction to predict incinerator performance, and evaluating waste sterilization through autoclaving. NHSRC is also developing test methods for sampling and analysis of incinerator gases and ash to ensure that dangerous materials are not released. A decision support tool for decontamination of wastes, developed by DCMD, is a Web-based program that provides information for decontamination crews on packing, transport, thermal treatment locations, and disposal sites to support decisions about waste disposal. This tool has been employed during several incidents and is continually updated with new information.

Adams briefly discussed NHSRC's Technology Testing and Verification Program (TTEP). TTEP tests commercial or near-commercial technologies that could be used for detection, containment, decontamination, or disposal of a threat agent. Through TTEP, NHSRC has tested a number of air cleaners, filters, detection systems, and decontamination systems. Tests are conducted based on vendor specified conditions, yet NHSRC tries to be as realistic as possible when testing. Results are published on the EPA/NHSRC Web site.

Question and Answer Period

- *Collaboration with the U.S. Department of Agriculture (USDA) was mentioned. Has NHSRC considered working with the avian influenza virus, specifically assessing transmission in poultry houses or transfer to humans?* A number of NHSRC personnel are involved in workgroups assessing these issues, but NHSRC is not the lead agency addressing avian influenza. NHSRC is examining issues surrounding the disposal and landfilling of contaminated materials, as well as decontamination of the virus on surfaces.

U.S. Environmental Protection Agency (EPA) Regulation of Biological Decontamination

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

Any substance or device applied to or put into a human is regulated by the U.S. Food and Drug Administration (FDA). These include any type of drug or medical device. Thus, FDA regulates decontaminants used on people. Under FIFRA, EPA regulates any substance or device applied to or used on inanimate surfaces for the purpose of inactivating a pest, including microorganisms; under FIFRA such decontaminants are considered to be pesticides or pesticide devices.

EPA approves a substance for use as a pesticide either through registration or through exemption. Registration is the process, as described in Section 3 of FIFRA, of obtaining a license for use. A product manufacturer submits information regarding the chemical properties and product labeling to EPA for review and approval. Once the product is approved, EPA considers it registered and the manufacturer can distribute or sell it commercially with the approved label, which outlines its uses and precautions. Section 24(c) of FIFRA is a lesser-known registration process by which a state may register a product for additional uses that are not covered by the federal registration. Under this process, EPA is allowed a 90-day review period to accept, reject, or modify the state registration. State registration allows use only in the registered state and only for approved purposes. For example, three states recently approved a chlorine dioxide generating product for remediation of structures contaminated with mold and mildew.

Exemptions, as outlined in Section 18 of FIFRA, allow for a specific use of a product (*e.g.*, crop or pest control, public health concerns, quarantine). Ordinarily, EPA issues exemptions for agricultural products and rarely provides exemptions for antimicrobial products. Quarantine exemptions, which are effective for 1 to 3 years, typically apply to situations at ports or points of entry into the United States. USDA or another agency may need to treat import materials with a product normally not used or registered in the United States because of specificity to the foreign pest. A crisis exemption may be issued when insufficient time is available for a state or agency to apply to EPA for a full exemption. A state or federal agency—with oversight by EPA—can issue a crisis exemption. A crisis exemption is effective for 15 days and allows for use and application for a full exemption, if needed. During the anthrax events, EPA issued 28 crisis exemptions and rejected 35 applications.

EPA is currently considering regulatory issues surrounding the move from crisis exemptions to registration of products for decontamination of threat agents. In registering a product, EPA must consider two basic questions: what efficacy data should EPA require and what labels requirements are needed? For anthrax decontaminants, EPA must consider the efficacy of the product for inactivating spores on a surface and determine to what degree inactivation is acceptable.

Currently, antimicrobial products with public health claims fall into three categories, presented in order of efficacy: sanitizers, disinfectants, and sterilants/sporicides. Sanitizers provide limited antimicrobial action. Disinfectants are effective at inactivating most non-spore forming microorganisms. A disinfectant must pass either the Association of Analytical Chemists (AOAC) Use Dilution Test or the Germicidal Spray Product Test for registration. Kempter provided a Web site link for more information regarding

these specific tests. These tests look for inactivation of 59 of 60 treated carriers in three repetitions. The level of disinfection approval (disinfectant, broad spectrum, or hospital grade) depends on tests showing inactivation of one, two, or three different organisms. If a manufacture wants to add a microorganism (*e.g.*, severe acute respiratory syndrome [SARS]) to a product registration, the manufacturer must show inactivation of the microorganism or an acceptable surrogate. Kempter noted that testing a surrogate can be time-consuming because acceptability of the surrogate must be proven. Testing the target microorganism directly is recommended. The manufacturer can add a specific organism to the label upon EPA review and approval of test results.

Sterilant and sporicides are liquid, gas, or vapor products that address spore forming microorganisms. EPA and FDA require that a product pass the AOAC Sporicidal Activity Test (SAT). This test is conducted on porous and non-porous surfaces with representative anaerobic and aerobic spore-forming bacteria. To pass, EPA and FDA require no growth on 720 carriers. Similar to disinfectants, to add a claim for a specific microorganism to a registered sterilant, the manufacture must use the AOAC Sporicidal Activity Test to evaluate the product against the microorganism or an approved surrogate. EPA approval allows the manufacturer to add the specific microorganism to the product label.

In addition to the carrier tests, gases and vapors intended to be used in large spaces (*i.e.*, greater than 40 cubic feet [ft^3]) must pass a simulated use test in a representative test room. These tests include use of BIs to assess efficacy.

EPA is also considering establishing a new product claim for decontaminants. People involved in decontamination efforts are concerned that decontamination agents will fail the AOAC SAT, which was originally designed to assess sterilization in a hospital setting. Decontamination agents have been proven in other uses. EPA is considering policy issues associated with decontamination claims based on inactivation of a specific spore forming microorganism based on either the AOAC SAT or other quantitative sporicidal test methods and using porous and/or non-porous surfaces.

EPA is also working to improve the AOAC SAT. These improvements have been tested and validated, so approval is pending. EPA is also evaluating the AOAC SAT with other equivalent quantitative methods (*e.g.*, Three Step Method [TSM]) to determine the performance standards required for decontaminant registration. EPA is also considering issues associated with labeling decontaminants. EPA will limit the sale and distribution of these products to OSCs, authorized decontamination personnel, or registrant-certified personnel. In 2006, EPA will issue guidance on the terms and conditions of decontaminant registration and will seek public comment before finalizing the guidance.

EPA ORD has initiated a number of decontamination-related research projects. Kempter highlighted four issues associated with this research. A number of agencies and organizations are conducting research and need to communicate and coordinate efforts. A number of different test protocols are available; preferably researchers will use validated, well-developed, and/or widely accepted methods. Researchers and/or manufacturers should coordinate to identify product testing parameters. By clearly understanding objectives and leveraging existing research, researchers can minimize test variables and maximize the number of products tested without compromising the testing quality.

To review how prepared the United States is to react to another event, Kempter outlined a number of available and draft guidance documents. These documents address a variety of issues and topics ranging from anthrax information, sampling methods, response plans, decision-making tools for biological events, and restoration approaches. These documents tend to be sector-specific (*e.g.*, to address buildings, transportation, or water systems). Kempter noted that information sharing and coordination between agencies is critical. Kempter highlighted two reports of interest. NHSRC assessed the overall preparedness of the United States in responding to a bioterrorism event and is preparing a report for

submission to Congress. NAS released a report in June 2005 addressing the issue "how clean is safe?" Key conclusions of this report were that standard infectious doses cannot be determined with confidence, a contaminated facility cannot be guaranteed to be agent-free, and insufficient information is available to quantify safe amounts of a residual bacterial agent. These conclusions reinforce the need for site-specific sampling plans and goals to ensure that a facility is clean enough to return to use.

Question and Answer Period

Workshop participants posed no questions.

Test Method Update (Office of Pesticide Programs [OPP] Sterilant Registration Protocol Development)

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

Tomasino's core research has focused on development of sporicidal test methods and selection of surrogates for testing sporicides. The program under which Tomasino works began several years ago. When the program first started, efforts focused on understanding what testing technologies were available and what efficacy testing was needed. Now, the program goals are to advance the science of efficacy testing, develop alternative testing methods, standardize and validate testing methods, design comparative efficacy testing studies to aid regulatory guidance, identify a surrogate to *B. anthracis,* and prepare for testing with additional agents.

In 2003, program personnel adopted a three-tiered research approach. In Tier 1, researchers evaluated and improved existing methods. In Tier 2, surrogates for *B. anthracis* were evaluated. Tier 3 involved collaborative validation of test method and surrogate combinations at 10 to 12 different laboratories. As part of this research, EPA sought to identify a quantifiable analytical method for spore survival that reported more than a simple present/absent result without completely abandoning existing test methods. EPA contracted with a number of collaborators for these research efforts. Tomasino presented a timeline of start-up activities and ongoing actions to highlight research milestones.

Tomasino highlighted key components of five studies recently completed or underway through this EPA program.

- *Modifications to the AOAC Sporicidal Activity Test Method 966.04: Collaboration Study.* A decontaminant passes this AOAC Sporicidal Activity Test only with complete inactivation of representative anaerobic and aerobic spores on 720 porous and non-porous carriers. This test requires 21 days for completion and lacks standardization in several key steps. In 2005, Tomasino proposed modifications to the test. These included replacing the soil extract nutrient broth with a defined nutrient agar, replacing the porcelain carriers with stainless steel carriers, adding a carrier count process, establishing a mean minimum spore titer per carrier, and adding a neutralization confirmation process. These modifications have been evaluated at five independent laboratories. Testing has been completed and a manuscript outlining recommendations and summarizing conclusions was presented in March 2006.

  To compare the existing methods with the modifications, EPA compared various combinations of modifications side by side. These comparisons should report similar results, indicating that the modifications did not change the test or test results. EPA applied three different decontaminants at two concentrations to carriers and then used both the standard AOAC Sporicidal Activity Test Method and the modified AOAC Sporicidal Activity Test Method to test the treated carriers. Tomasino presented detailed results on decontaminants efficacy. Analysis of the test results found no significant changes based on modifications. Tomasino's manuscript recommends use of the

proposed modifications: use of nutrient agar, target carrier counts of 10^5 to 10^6 spores per carrier, and neutralization confirmation procedures. Use of stainless steel carriers was not recommended, however, because research with stainless steel carriers has not been completed.

- *Comparative Evaluation of Two Quantitative Test Methods for Determining the Efficacy of Liquid Sporicides and Sterilants on a Hard Surface*. EPA compared and researched two methods—ASTM E2111-00 and the TSM—used to quantify spore counts. Each method reports a log reduction in spores from a starting concentration to a final concentration after application of a decontaminant. Tomasino presented the log reductions found by each method after application of three decontaminants. No significant differences in results were found. Because no differences in results were found, EPA submitted questionnaires to analysts to evaluate the ease of completing each test (*e.g.*, clarity of protocols, simplicity for test preparation, ease of testing itself, interpretation of results). Analysts selected TSM as the preferred method for further investigation. As such, EPA has established a protocol for validating TSM against the AOAC Sporicidal Activity Test Method. Tomasino noted that focus on TSM does not indicate EPA approval or future preference for this method.

- *Comparative Study with* B. anthracis*—Ames Strain and Two Potential Surrogates (*B. subtilis *and* B. anthracis *[Δ Sterne])*. Because of health and safety concerns, only a small number of laboratories are equipped to study virulent *B. anthracis*. Finding a less-virulent surrogate would allow research in a wider array of laboratories. To be appropriate, the surrogate must be as resistant or more resistant to sporicides as virulent *B. anthracis*. As in other studies, inoculated coupons were treated with one of three different disinfectants. EPA then used TSM to assess the log reduction achieved for *B. anthracis* and BSL-1 and BSL-2 surrogates. EPA completed three replications for each sporicide and microorganism combination. Tomasino presented results from control tests that indicated that mean spore counts on the carriers were similar, and results from treated carriers that indicated similar log reductions for each microorganism and disinfectant, except sodium hypochlorite with *B. subtilis*. As expected, the lowest reduction was seen with unaltered bleach treatment. Understanding inter- and intra-laboratory variability in results is necessary. For this study, EPA only assessed intra-laboratory variability, as indicated by the relative standard deviation provided. This study found that *B. subtilis* and *B. anthracis* (Δ Sterne) appear to be appropriate surrogates for virulent *B. anthracis*. *B. subtilis* will be used as a test microbe for validation of TSM. Tomasino noted that study conditions were highly controlled and the identified surrogates only apply to liquid sporicides on hard surfaces. Future research likely will look beyond liquids on non-porous surfaces.

- *Validation Protocol for the Quantitative Three Step Method*. TSM validation, based on a study protocol reviewed in March 2006, is scheduled for summer 2006. The OPP laboratory will be the lead in this project. In addition, eight to ten federal, contract, and industry laboratories have volunteered to participate in the validation studies. As a requirement, half of these laboratories have no prior experience with TSM. The study will involve one microbe (*B. subtilis*) on a glass carrier. Three decontaminants at three different concentrations will be tested with three replicates. The AOAC Sporicidal Activity Test Method will serve as the reference method. The objective of the study is to validate a method for quantifying spore counts after liquid decontamination of a hard surface.

- *Determining the Efficacy of Sporicidal Chemicals Using AOAC Method 966.04 and the Quantitative Three Step Method*. As research moves toward quantitative testing methods, there is a need to correlate frequency of positive results with quantitative log reductions. A series of commercially available decontaminants were tested using the AOAC Sporicidal Activity Test

Method and TSM. *B. subtilis* on porcelain penicylinders served as the test microorganism and carrier.

Future research will address several areas of concern. EPA will assess the application of current analysis modifications to gaseous disinfectants and porous materials. Research regarding *Clostridium,* a key component of the AOAC Sporicidal Activity Test Method, is also needed. Additional surrogate studies are underway with *Yersinia pestis* and *Francisella tularensis*. EPA plans to investigate different coupon materials for efficacy evaluations and to compare quantitative test methods for fumigants.

Question and Answer Period

- B. anthracis *(Δ Sterne) lacks the one plasmid, but it is not a completely avirulent strain. Is this correct?* The strain of *B. anthracis* (Δ Sterne) studied is considered a BSL-2 organism. A workshop participant noted that *B. anthracis* (Δ Sterne) is fully avirulent; the microorganism lacks both plasmids. EPA included this strain in the test as an additional possible surrogate if *B. subtilis* was unacceptable. Unfortunately, the number of possible treatments limited the study, so EPA decided to select a single microorganism representative of BSL-1, -2, and -3.

- *Because* B. subtilis *and* B. anthracis *generate different kinds of spores, European laboratories conduct research on different strains. Did EPA consider other strains for this research?* EPA selected *B. subtilis* based on the current association with U.S. regulatory standards. The study results needed to create a bridge between current AOAC Sporicidal Activity Test Method requirements and quantitative methods.

U.S. Environmental Protection Agency (EPA): Partner in Protecting the Homeland

Jon Edwards, U.S. Environmental Protection Agency, Office of Homeland Security

The EPA Office of Homeland Security is a small office formed in February 2003. The Director of this office reports directly to the EPA Administrator to allow coordination of homeland security activities across EPA. Internally, the office implements the EPA homeland security agenda, supports EPA policy, and provides a single voice for communicating that policy to other agencies. The office also operates the Homeland Security Collaborative Network to bring together various EPA program managers with homeland security responsibilities, receives and disseminates information, and supports program offices and regions with homeland security responsibilities. The office is also involved in budget development for various EPA homeland security projects, such as decontamination research and increased water security. Edwards provided a list of homeland security programs underway at nine different EPA offices, such as building and outdoor decontamination research, emergency preparedness, and radiological responses. The EPA Office of Homeland Security works to coordinate these activities and collect the information generated through these programs. Externally, the office serves as a liaison between EPA, the White House, DHS, and other federal agencies and organization involved in homeland security concerns; represents EPA in committees and workgroups; informs the EPA Administrator about external issues and progress; and serves as a point of contact to ensure appropriate participation in Presidential Directives. Edwards noted that the OHS works closely with the White House Homeland Security Council, which is key in developing and driving national homeland security policy.

Edwards reviewed six Homeland Security Presidential Directives (HSPD) that the EPA Office of Homeland Security follows. HSPD 5 includes management of domestic incidents. The National Incident Management System and National Response Plan were developed based on this directive. HSPD 7 includes critical infrastructure protection with specific direction for EPA to consider water vulnerability (*e.g.*, drinking water, wastewater) and best security practices for water utilities. HSPD 8 includes national

preparedness for training and response to national incidents. HSPD 9 includes defense of agriculture and food. EPA is involved with this HSPD due to the national water quality monitoring and surveillance components. HSPD 10 considers biodefense research and decontamination issues. HSPD 12 includes policies for identification standards (*e.g.*, smart cards) for federal employees.

The EPA Office of Homeland Security leverages EPA's many years of experience in protecting human health and safeguarding the environment and applies this knowledge to homeland security issues. Most of EPA's program offices have homeland security–related responsibilities. These include, but are not limited to, programs that address emergency response, water quality, pesticide use, hazardous materials remediation, radiation and ambient (Biowatch) monitoring, and research and development. Edwards provided several examples of events (*e.g.*, the September 11 terror events, anthrax attacks, the *Columbia* Space Shuttle disaster, the ricin event at Capitol Hill, Hurricane Katrina) in which EPA applied existing knowledge to address a concern. EPA also used these incidents to expand its experience and capabilities. For example, during the Columbia Space Shuttle Disaster, EPA assisted in collecting debris and conducting a human health risk assessment associated with contact with this debris.

Edwards briefly reviewed EPA projects that fall under White House–defined homeland security program areas.

- *Threat response and incident management*. EPA operates an emergency response program to support local responders if they become overwhelmed during an incident. Recent information indicates that EPA employs approximately 250 OSCs and responds to about 300 events per year. Response teams can react quickly and decisively in the event of a hazardous substance or oil release. These teams also provide scientific, engineering, and technical research and support during response efforts. Edwards listed specific resources (*e.g.*, the Radiological Emergency Response Team) available to OSCs. In addition, EPA can provide law enforcement and forensic support through criminal investigation, national enforcement investigation, and national counter-terrorism evidence response team capabilities. The EPA laboratory network includes 37 stationary and 8 mobile laboratories, as well as additional contract laboratories, available for sample analysis. EPA is also involved in efforts with a number of other agencies to build the national environmental laboratory capacity to address possible surge capacity during a large-scale event. EPA provides broad-area monitoring capabilities with existing air monitoring networks and mobile monitoring technologies, such as the Airborne Spectral Photometric Environmental Collection Technology—a small aircraft that can detect and map a number of chemicals and radionuclides. EPA is also developing additional mobile monitoring technologies and a national monitoring system to provide real-time ambient air monitoring data for radiation.

- *Biodefense*. A number of EPA programs address biodefense concerns. The NDT is a highly specialized unit with expertise in WMD. The team collaborates with NHSRC and others to advance agent detection and decontamination technologies. EPA technology research and development efforts, through NHSRC, advance EPA biodefense efforts. Edwards listed a number of relevant NHSRC projects, such as threat assessment and simulation exercises, sampling and analysis method validation and development, and building and water system decontamination method evaluations. EPA also provides antimicrobial analysis and certification activities, such as antimicrobial agent certification and ongoing anthrax testing. Finally, EPA operates two BSL-2 laboratories that primarily handle agents that are persistent in the environment.

- *Critical infrastructure protection*. EPA is the lead federal agency responsible for water supply and wastewater security and protection. EPA ensures that drinking water systems prepare vulnerability assessments and emergency response plans, provides technical assistance and

training to water suppliers, distributes critical response tools, and develops best security practices. Edwards highlighted a critical project to develop a drinking water contaminant warning system. EPA is working on this effort in collaboration with other key federal and water sector partners. Ongoing technology research and development activities include, but are not limited to, threat assessments, rapid health risk assessment, and sampling and analysis method development and verification. Although DHS leads chemical industry concerns, EPA supports DHS efforts through several programs (*e.g.*, risk management program).

- *Food and agriculture security*. EPA plays a key role in pesticide licensing and safe use. EPA also supports animal carcass disposal programs and coordinates with other agencies in developing carcass disposal guidance and emergency response plans.

Question and Answer Period

Workshop participants asked no questions.

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

Rebecca Blackmon, Technical Support Working Group

Blackmon is part of the Chemical, Biological, Radiological, and Nuclear Countermeasures (CBRNC) Subgroup of the Technical Support Working Group (TSWG). TSWG has 11 different subgroups plus additional programs that focus on rapid research and prototype development. Usually, TSWG and collaborators sign a contract to start a project only 10 months after a research need has been defined. Typically, projects last about 18 months.

The CBRNC Subgroup identifies interagency user requirements related to terrorist-employed chemical, biological, radiological, and nuclear materials. Research focus areas include detection, protection, information resources, and consequence management, which includes decontamination research. The CBRNC Subgroup collaborates with many different federal organizations (*e.g.*, DOD, DOE, DHS, EPA). These collaborators may provide funding, technical oversight, and/or expert review. Overall the CBRNC Subgroup is actively managing about 90 projects. Blackmon presented an overview of some of the decontamination projects.

- *Low-cost chemical personal decontamination system*. There is a need for low-cost, easy-to-use individual decontamination kits for victims exposed to chemical agents. The kits are intended for use by ambulatory, untrained civilians as an emergency first step in personal decontamination. Lawrence Livermore National Laboratory (LLNL) is working to improve available kits to reduce or eliminated the need for scrubbing with wipes so that the kit can be used on sensitive areas, such as mucous membranes, eyes, or open wounds. LLNL is focusing on developing contact decontaminants for toxic industrial chemicals on skin, with a long-term goal of developing a system for contact decontamination of sensitive areas.

- *Personnel decontamination agent simulant kit*. During training exercises, participants need a means of assessing decontamination effectiveness. The simulant kits include safe (as defined by the International Dictionary of Cosmetics and Fragrances) surrogates for threat agents. These surrogates mimic the physical properties of CWA and radiologicals and are mixed with a fluorescent dye to help responders evaluate decontamination effectiveness. A prototype is currently available.

- *Wireless Multisensor Environmental Monitors*. Blackmon presented information about this project at the 2005 Decontamination Workshop. Esensors, Inc., developed portable sensor pods that monitor up to six different parameters simultaneously. The pods are battery-operated and transmit data through either Internet/ethernet or wireless communication using standard wireless protocol. The pods are meant to be low-cost and portable and have many applications. In decontamination, the sensor pods can track CWA or chemical/fumigant concentrations, as well as environmental conditions such as temperature or humidity. Sensor testing is complete and field testing of a sensor array is planned. A pod with six basic sensors costs about $2,500; additional sensors cost from $50 to $700. Blackmon listed 18 gas sensors that are available.

- *Expedient mitigation of a radiological release*. The CBRNC Subgroup, along with collaborators, has developed a strippable polymer coating that is sprayed on a surface and fixes radioactive particles in place. The coating forms a flexible sheet that can be easily pulled off a substrate, along with the transfixed radioactive particles. Blackmon introduced this project during the 2005 EPA Decontamination Workshop. Efforts in the past year have focused on polymer reformulations. In decontamination, responders could use the coating to contain radioactive materials while decontamination planning occurs. The military has also tested the coating as a dust suppressor (*e.g.*, to create a helicopter landing pad). Various field trials were completed in 2005. Currently available mechanisms and spray applicators can be used to apply the coating. In addition to smaller, personal applicators, the manufacturer has designed a mobile response unit that could serve as a command post and a distribution area for the coating.

- *Radiological decontamination technologies.* Argonne National Laboratory (ANL) is working to develop chemical processes to remove cesium-137 from porous building materials (*e.g.*, concrete) after an RDD event. ANL developed a three-part process that includes spraying an ionic wash to release the cesium-137 particles, spraying an absorbent gel to capture the particles, and vacuuming the gel to consolidate the waste. Initial testing achieved greater than 70% and 97% removal from concrete after a single and three repetitions, respectively, of the process. Additional testing is planned.

- *Statistical design tool for sampling contaminated buildings.* The CBRNC Subgroup, in conjunction with Pacific Northwest National Laboratory (PNNL), completed and deployed this software tool in July 2005. Based on existing technologies, PNNL built a software tool that helps design statistically valid surface sampling regimes for determining the extent of building contamination following a terrorist event. The program includes a number of decision criteria and rules and allows import of facility-specific information. The program identifies sample locations to identify potential hot spots, ensure statistically relevant results, and guide sampling decisions. One must decide on key considerations (*e.g.*, statistical rules, acceptable cleanup levels) before running the program.

- *Large-scale restorations of biologically contaminated urban areas*. The CBRNC Subgroup is developing a handbook that includes easy-to-use protocols for decontamination of bio-contaminated areas. Ultimately the handbook will guide decontamination events to reoccupation. The project began in December 2004 based on input from a round table workshop. A draft report is currently under review. Protocols should be compiled and available in summer 2006.

- *Guidelines for disposal of contaminated plant and animal waste*. Disposal of contaminated biomass is of great interest to TSWG, due to concerns about avian influenza and other foreign animal diseases. The guidance document is a clear, concise handbook describing the best methods for disposal of plant and animal materials. Methods are based on an evaluation of engineering,

economic, and regulatory factors. The guidance document will enable decision-makers to identify the disposal methods that meet their specific conditions, resources, and needs. A first draft is under review.

Blackmon briefly described several projects that address worker protection during decontamination. The Chemical Risk Assessment Tool recognizes that PPE use is a burden during decontamination. This tool provides incident commanders, through software on a handheld device, with information about chemical exposure guidelines, suitable PPE, breakthrough times, and stay times in PPE and contaminated areas. Beta testing is ongoing, and the tool should be widely available in July 2006. The Improved Chemical Protective Ensemble is a non-encapsulating suit that provides vapor, aerosol, and splash protection. The goal is to provide Level A protection with a Level B design. Tests to assess compliance with regulatory standards are ongoing. The suit should be commercially available in June 2006, with some regulatory testing pending. The Mass Decontamination Protocols provide useful information about decontamination in the handbook "Best Practices and Guidelines for Mass Personnel Decontamination." The handbook is available in hard copy or on CD and can be ordered through http://www.cbiac.apgea.army.mil. The project R-2161 Estimate Waste Quantities and Cleanup of RRD Events is under consideration and would include a software tool that estimates the quantity of waste and/or debris generated during an RDD event.

Question and Answer Period

- *Does the three step decontamination method for cesium-137 apply to alpha, beta, and gamma radionuclides or is there a difference in response?* ANL only assessed cesium-137.

- One workshop participant commented that statistical tools to design sampling events should be used with caution. During the 2001 anthrax events, CDC found that targeted sampling was the most efficient use of resources and provided the best means of assessing contamination. A software tool should not replace input from a qualified person. There is a fear that first responders will use the tool to replace collaboration with experts. Blackmon noted that hot spots and targeted sampling approaches can be input to the software. The software simply assists in identifying a statistically relevant sampling plan.

- *Could the sampling program provide a statistically valid sampling plan for a seven-zone area if contaminants are known to be in just one zone?* Users can input incident-specific information and the software tool will adjust the sampling design accordingly.

- *When will the CBRNC Subgroup release the draft documents addressing restoration of large urban areas and disposal of animal waste? Will there be an opportunity for peer review by other federal agencies?* Blackmon indicated that she could share the draft documents with other federal agencies, but the documents are not ready for wide distribution.-

A Decontamination Concept of Operations

Michael Ottlinger, U.S. Environmental Protection Agency, National Decontamination Team

The NDT has prepared a first draft of a document titled "A Decontamination Concept of Operations." The process of preparing the document helped clarify the NDT mission and role in decontamination of threat agents. The NDT does not serve as a response team; most regions already have response teams. As a group of 15 staff with various technical expertise, the NDT has chosen a role as an information resource center in support of OSCs, first responders, and other decontamination personnel. Ottlinger outlined the NDT's mission elements: scientific and technical, operational employment, and policy and management.

Ottlinger noted that the policy and management element is more appropriately a coordination and training mission.

The strategic objectives of the group include providing technical support to regions, effectively delivering information about decontamination options, enhancing preparedness and planning, enhancing partnerships, serving as a liaison between resources, and identifying operational shortfalls. The NDT becomes involved at a scene based on a regional request. NDT members can provide technical and scientific assistance from the start to the completion of decontamination. Currently, the NDT focuses on concerns associated with large-scale events. In the future, the team hopes to address small scale events as well.

On a daily basis, NDT members travel extensively to attend meetings and workshops, participate in technical working groups, meet regional response teams, and identify response team needs. Team members interface with federal, state, and local partners, as well as commercial manufacturers. The NDT develops standard operating procedures for handling various threat agents and compiles technical information about decontamination science, methods, validation, and resources, as well as disposal options. For example, the NDT will gather information from vendors about a specific decontamination technology and forward this information in an easy-to-use format to OSCs during an event.

The NDT consists of individuals with technical training, who then must become acclimated to specific EPA policies and regulations associated with decontamination events, regional response plans, and risk assessment and risk communication. Team members may also need health and safety training (*e.g.*, HAZWOPER, first responder training). In the case of an event, NDT members can safely work at a scene and support the incident command structure as needed. Members who are not deployed at a scene serve as support staff in providing technical information. They may also assist in obtaining specialized materials and equipment or serve a liaison between agencies to coordinate efforts. The NDT is available to respond to many emergency situations, not just attacks using warfare agents. Recently team members responded to the aftereffects of Hurricane Katrina.

Ottlinger briefly presented an example threat scenario to illustrate the concerns and milestones in a decontamination effort. This scenario assumes a release of anthrax to a number of mixed-use buildings and structures in New York City. This scenario illustrates the complexity and range of concerns that may be encountered. The NDT becomes involved at the scene during consequence management—after the initial casualties and actions to close transit systems, evacuate citizens, and secure the contaminated area. Ottlinger listed a number of concerns and questions regarding public safety issues and decontamination planning. For example, is sampling needed in three dimensions to account for vertical as well as aerial contamination; how is the contaminant contained; how is spread monitored; what are the needs for teams entering a hot zone? The execution of a decontamination plan follows the same process as most management plans: define goals, organize tasks, select and obtain resources, plan and execute the mission, chart progress, document quality assurance, and communicate/manage expectations. Within this framework, planners must establish agent avoidance and containment priorities and plan specific decontamination elements (*e.g.*, staging areas, hot zone exit routes, exterior versus interior decontamination). In addition, quality assurance and clearance sampling is critical in monitoring decontamination and preventing recontamination.

Ottlinger presented the FEMA phases of recovery and related these phases to a decontamination event. The response phase includes evacuation of people from contaminated areas. The initial recovery phase allows for safe repopulation once agent concentrations reach levels deemed safe for chronic exposure. Transitional recovery occurs during the re-establishment of local communities and long-term recovery is achieved with permanent rebuilding.

Question and Answer Period

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

Decontamination and Consequence Management Division (DCMD) Disposal Research

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

Disposal occurs when decontamination is deemed completed. EPA is usually left with the waste and must determine how to handle it. Lemieux has been working on coordinating decontamination and disposal because the two are linked—decisions made during decontamination directly affect disposal actions. The total cost of a restoration operation includes the costs for both decontamination and disposal.

Wastes may include materials that have been removed from a contaminated building before decontamination, as well as materials that underwent decontamination but for which complete decontamination cannot be confirmed. Wastes include building materials and furnishings (*e.g.*, wallboard), office equipment (*e.g.*, computers, desks, paper), indirect residue (*e.g.*, PPE, rags), filters from HVAC systems, aqueous residues, outdoor materials, and agricultural residues. These materials may be dry or wet, and involvement with agencies beyond EPA may be needed for proper disposal.

The DCMD goals for the disposal program are to:

- Assure the public that the selected disposal processes and procedures will be safe.
- Give guidance to accelerate disposal permitting activities and to select appropriate facilities and technologies.
- Give facilities guidance on ensuring permit compliance, worker safety, and protection of assets.
- Give responders guidance on incorporating disposal plans, waste minimization, and balancing of disposal/decontamination costs into the entire decision-making process.

Lemieux noted that insurance and indemnification are large concerns for facilities in the disposal industry.

To achieve these goals, DCMD has several disposal research and development programs. Lemieux provided an overview of some of the guidance document, thermal destruction, and autoclave spore destruction projects. Lemieux did not present results from projects researching permanency of landfilling and collaborative efforts with USDA and TSWG to assess agricultural residue disposal.

- *Guidance documents*. DCMD is developing a guidance document—the online Decision Support Tool—to outline available information about material disposal. OSCs, regulatory and public agencies, and facilities themselves are the target audience for this tool. The Decision Support Tool is a restricted-access, Web-based software program that can estimate the decontamination residue and disposal volume and mass based on a series of inputs defining the disposal scenario (*e.g.*, building type). The tool assumes that a decision has been made to dispose of the materials and does not attempt to influence the choice of decontamination method. The tool includes databases listing information about disposal facilities (*e.g.*, landfills, combustion facilities, wastewater facilities, autoclaves), worker safety guidance, packaging and storage guidance, and transportation guidance. DCMD is working to added latitude and longitude data to assess in locating disposal facilities geographically. Lemieux presented several screen captures illustrating

the disposal volume estimator, agent characterization, and facility query information. The tool was used during Hurricane Katrina cleanup and has been updated based on lessons learned during that use.

- *Thermal destruction*. DCMD has also been investigating the ability of thermal incineration to destroy spores. EPA testing of hospital incinerators in the 1990s found a greater than 6 log reduction of *Geobacillius stearothermophilus* spores in some instances, and less than 3 log reduction in other instances, as measured in stack gas and ash. These findings prompted bench-scale incinerator testing. DCMD conducted these tests to develop a kinetic expression for the destruction of *G. stearothermophilus* on different materials and at different temperatures. Based on calibration and modeling at the bench scale, DCMD aims to conduct larger, pilot testing to further refine and calibrate a model of a full-scale incinerator. Lemieux presented data from bench-scale tests of wall board. DCMD also conducted a pilot-scale test of 1-pound waste bundles in a rotary kiln incinerator with an afterburner. DCMD designed test parameters to maximize the potential for dioxin creation, because many decontaminants are chlorine-based. Results with carpet and chlorinated bleach as the decontamination agent found increased dioxin emissions. To evaluate destruction of spores bound to building materials, DCMD embedded BIs in carpet and ceiling tile and incinerated the materials at about 800 degrees Fahrenheit (ºF). The BIs were then tested for spore viability. Lemieux presented the results from several test runs at various time intervals: destruction did not occur for up to 30 minutes (wet ceiling tiles), which indicates that spores may survive a commercial incinerator if care is not taken. Additional modeling is underway to assess CWA and other types of incinerators.

- *Autoclave spore destruction*. Autoclaves are regularly used to sterilize hospital wastes, and commercial autoclaves can sterilize hundreds of tons of material a day. DCMD assessed whether autoclaves could also be used to sterilize materials contaminated with a threat agent. A series of paired BIs (one to test for viability and one to quantify survival) were placed in the center of densely packed wallboard and the wallboard was cycled through a commercial autoclave. A sensor tracked temperatures throughout the wallboard. (Lemieux presented several photographs depicting the study conditions.) The first run of the autoclave failed to achieve temperatures necessary to inactivate the spores. However, a second cycle raised the temperature throughout the wallboard high enough to achieve sterilization. Lemieux speculated that the steam injected during the first cycle condensed in the pores of the material and hindered heat transfer. In the second cycle, the excess water was removed during the vacuum cycle and the material was sufficiently heated to prevent condensation during steam injection. He showed graphs illustrating the temperature readings for both cycles. DCMD found that achieving 250 ºF for 15 minutes resulted in no viable spores. The best results were achieved with loosely packed, dry materials undergoing multiple sequential cycles at a higher autoclave temperature and pressure. Recently, these findings were applied to sterilize approximately 130 bags of material resulting from a small anthrax incident in New York City.

Question and Answer Period

- *How would you dispose of polymer materials used for radiological contamination containment?* DOE is addressing concerns about radiological disposal. Disposing of wastes from an RDD event is a huge issue. Wastes will likely be sent to a secured government landfill.

- *Will DCMD add radiologicals to the Decision Support Tool?* DCMD would like to add radiological to the tool. The current focus, however, is creating a solid product for chemical and biological agents. The radiological agents can be integrated later.

- *Why did the New York municipal landfills refuse the waste from the anthrax events?* Lemieux speculated that waste disposal facilities are extremely concerned about the impact of biological wastes on their business assets. The small quantity of waste—only 130 bags—was probably not worth the risk. Perhaps a landfill would have accepted a larger amount because the income would have been worth the risk. Waste disposal facilities also may have wanted to press EPA to address indemnification issues. A workshop participant noted that waste facilities may have insurance clauses that do not cover biological wastes; if so, they may not accept such waste. A hospital waste incinerator would only have a permit for medical waste. Anthrax waste would be outside of the permit limitations.

- *Have you had any contact with the Fort Detrick incinerator operators? They routinely burn biological wastes and burned much of the waste from the Capitol Hill decontamination.* The Capitol Hill incident was unique because the waste could easily be shipped to Fort Detrick. DCMD has focused on commercial incinerators because private sector operations likely will not have access to military incinerators.

A Sampling of Some of Canada's Decontamination Work

Merv Fingas, Environment Canada

Many programs are underway in Canada. For example, $178 million have been slated to fund research with chemical, biological, radiological, and nuclear research. Fingas briefly described a sample of three of these projects (Multi-Agency Restoration Project, Demonstration Project, and Standards Project). His presentation slides provided detailed project information. Fingas also noted that Canadian troops were heavily exposed to mustard gas during World War I (WWI), so decontamination projects were already in place in Canada at the time of the September 11, 2001, attacks.

The Multi-Agency Restoration Project was a 3-year study of radiation, chemical, and biological decontamination and waste management. The project focused on testing promising decontamination methods that had not been tested already and completing an overview of available technologies. A number of agencies from both Canada and the United States were involved in this project. For this project, restoration includes decontamination and disposal activities. As a result of efforts under this project, Environment Canada has completed extensive laboratory research, conducted an extensive literature review, and produced a basic manual. Additional papers and laboratory reports have been published.

Many factors affect decontamination; Fingas highlighted the problems associated with oleophilic and hydrophilic agents. CWA are generally hydrophilic and water-bearing decontaminants are appropriate. Pesticides are oleophilic, so water-borne decontaminants are ineffective.

Many generic decontaminants are available, and Environment Canada had conducted some testing with these materials. Environment Canada has also evaluated methods and materials specific to radiological, chemical, and biological agents. Nuclear and radiological decontamination presents unique concerns. Historical practice has been to remove the radioactive material from a surface by blasting with water, concentrate the wastewater, and store the waste at a facility forever. Alternatives under consideration include methods to use blast water containing acids and chelating agents and then concentrate the water with zeolites or lignins. Fingas presented results from some of these studies. Another radiological decontamination study examined membrane rejection as a treatment for the blast wastewater. Chemical restoration topics were also examined during the Multi-Agency Restoration Project. Environment Canada did not include CWA in these evaluations because military organizations have conducted extensive research with CWA. Research efforts focused on testing decontaminants for pesticides. Fingas listed nine

decontaminants that underwent testing and provided results for diazinon and malathion on carpet and ceiling tile. Biological restoration has drawn a great deal of attention in the United States because of the anthrax attacks, and has also been studied for hospital applications. Two sets of studies—one using a liquid decontaminant and one using a gas decontaminant—are underway. Fingas presented results from VHP testing.

Environment Canada also conducted disposal studies as part of the Multi-Agency Restoration Project. About 20 different building materials were tested. These projects addressed legal concerns, pre-processing needs, neutralization, landfilling, incineration, and alternate technologies.

The Demonstration Project, which is planned for summer 2006, is a full-scale test of well-known decontamination technologies. Separate facilities will address chemical, biological, and radiological contamination scenarios. The objectives are to test larger-scale decontamination in comparison to small-scale coupon research and gather as much data as possible about full-scale decontamination (including time, cost, and treatment repetition). Fingas detailed the decontamination agents and study parameters in his presentation slides. Reports from these studies will likely be available in spring 2007.

The Standards Project is a 5-year study to develop standards for decontamination endpoints, excluding radioactive agents. Project goals include generating information to answer the question "What are the acceptable cleanup levels?" for priority agents and developing procedures and guidelines for setting standards for biological and chemical agents. Many international agencies and organization are involved in this project. Standards must balance the conservative views about applying safety factors and practical considerations about the technical ability to achieve a standard. Fingas briefly described an example of decontamination of a large building versus a small building. This example illustrates the impact of the standard on cost and time requirements to achieve successful decontamination. Often, building a new facility is faster and cheaper than decontaminating the existing facility. The example scenarios found that if a standard is more than one or two orders of magnitude less than the average maximum contamination detected on a surface, decontamination is infeasible and uneconomical. The difference between 85% to 95% decontamination efficiencies creates a tremendous increase in time and cost because of the need for repeat applications. Fingas presented diagrams that illustrate concepts in setting chemical and biological standards.

In closing, Fingas noted that the three projects presented are examples of the more than 20 chemical-specific projects and over 100 chemical, biological, radiological, and nuclear projects underway in Canada.

Question and Answer Period

- *For RRD decontamination, is there any concern with aerosolization due to power washing or pressure washing?* Aerosolization is very much a concern. During the Multi-Agency Restoration Project, researchers added materials, such as zeolite, to absorb the radionuclides and minimize aerosolization.

The Government Decontamination Service (GDS): The United Kingdom (UK) Perspective on Decontamination Approaches

Robert Bettley-Smith, UK Government Decontamination Service

The UK's strategy for decontamination is to ensure that the government is capable of responding quickly and effectively to address and recover from the consequences of chemical, biological, radiological, and nuclear incidents, particularly those caused by terrorism. With that aim, the government created the Government Decontamination Service (GDS) to address uncertainty in global security, to form a cross-

government effort to address readiness in the UK, and to work with the chemical, biological, radiological, and nuclear program led by the Home Security Office. After 2 years of planning, the UK launched GDS on October 1, 2005.

In creating GDS, the UK evaluated a number of options ranging from creating GDS as an emergency service that only convened in times of emergency to a comprehensive agency that completed all aspects of a response and waited in a state of readiness. The final format of GDS falls between these two extremes. GDS operates with a core approach with staff that provides advice and guidance, identifies and assesses available technologies, and advises the central government on national decontamination issues. Responsible authorities, similar to local municipalities in the United States, provide the personnel and obtain the equipment necessary to conduct decontamination. The heart of GDS is a framework of contractors that are available to provide responsible authorities with decontamination materials and experience.

Responsible authorities, not GDS, assume responsibility for decontamination events. GDS does not fund decontamination events; nor does it deal with humans, animals, or their remains; define cleanup standards; or validate that decontamination standards are achieved. Bettley-Smith noted that conflicts of interest might arise if a single authority is responsible for setting standards, conducting decontamination, and monitoring decontamination. (Contractors on the framework have the ability to identify what is present and that the material has been removed to the required specification.)

Bettley-Smith provided an organization chart illustrating the structure of GDS, which is similar to but not based on a military brigade. Science, corporate strategy, and resources support three liaison teams made up of senior personnel. With this structure, GDS is capable of handling an emergency—senior personnel from the liaison teams are capable of arriving at a scene and directing operations if needed. They also conduct day-to-day tasks (*i.e.*, providing information, advising the government).

The framework of contractors able to conduct and advise on decontamination activities is critical to GDS. The first component of this framework was activated in October 2005. GDS is building relationships, through exercises and meetings, with a first group of contractors to ensure that the contractors are available and accessible in the event of a decontamination situation. GDS will reopen the framework for additional contractors in 2007. GDS has established fee schedules with these contractors, which allows for predictable costs and faster responses during an event. Through GDS, any government department, public sector organization, responsible authority, or private sector organization responsible for building or infrastructure safety can access the framework. Inclusion in the framework does not indicate accreditation or guarantee a technology, nor does it indemnify the contractor. Bettley-Smith indicated that a possible development is that GDS might offer an accreditation program or indemnification in, say, 5 to 6 years.

For emergencies, GDS has established a five-tier response plan:

- *Tier 0: planning advice and guidance*. These activities occur before an event or emergency situation. Bettley-Smith highlighted key guidance document available or in production. The Radiation Remediation Handbook was first published in 1986 and was revised in summer 2005. The Chemical and Biological Remediation Handbook, which is in production, mirrors the Radiation Remediation Handbook.

- *Tier 1: provision of information*. This tier consists of providing advice and guidance.

- *Tier 2: provision of advice and facilitation at an incident (local response).* Although GDS's role remains primarily providing advice and guidance at this tier, GDS may also serve as a liaison between stakeholders.

- *Tier 3: provision of advice and facilitation at an incident (regional response).* In this situation, an incident affects more than one local, responsible authority. GDS serves as a liaison between responsible authorities and contractors and GDS may begin to manage the situation.

- *Tier 4: provision of advice and facilitation at an incident (national response).* At this level, GDS provides project management in addition to providing advice and guidance and serving as a liaison.

When researching decontamination, Bettley-Smith felt, given the "relative maturity" of the area of work, the more we know the more we realize we do not know. For example, GDS staff has found that there is a shortage of trained people able to wear PPE. During a response, people may be needed to enter a building to turn values and shut down HVAC systems. Wearing full PPE and completing a task is not easy. The question becomes, "Is it easier to train an architect to wear PPE or train a responder how to shut down building systems?" The answer is not simple.

Future tasks for GDS include reviewing data gaps in the contractor framework, identifying additional decontamination needs, collaborating with international partners, assessing and validating technologies, evaluating new technologies, and researching material interactions. Bettley-Smith noted the need to balance the desire for solutions that are good enough for now with the desire to perfect solutions in the future.

Question and Answer Period

- *Will the Chemical and Biological Remediation Handbook include actual scenarios and responses to these scenarios or will it provide general guidance? When will the handbook be available?* The Chemical and Biological Remediation Handbook will follow the same pattern as the Radiation Remediation Handbook, which provides decision trees and guidance for responses. The release date is uncertain. The document is currently a good working draft that could be used during an event, but is not ready for wide distribution.

- *With respect to suppliers, does GDS purchase equipment?* GDS does not purchase or stockpile equipment. Other agencies, such as the Maritime and Coastguard Agency, responsible authorities, and other first responders, procure materials and stockpile equipment.

- *Was GDS involved in the July 2005 event?* GDS has been involved in two incidents. GDS worked with the Health Protection Agency in the remediation of the Underground during the July 2005 event. GDS was also involved in a (currently) classified incident in which a known substance was found in an unusual location.

Environmental Lab Response Network (eLRN) Support and Standard Analytical Methods

Rob Rothman, U.S. Environmental Protection Agency, National Homeland Security Research Center

Rothman works at NHSRC in the Response Capability Enhancement (RCE) group. RCE is responsible for supporting the eLRN and standardizing analytical methods, among other functions. Rothman provided an overview of RCE activities and projects.

- *eLRN*. RCE is assisting in the establishment of the eLRN. RCE established a chemical agent reference laboratory—the National Exposure Measurement Center—in Las Vegas, Nevada. This laboratory has been charged with method development, method validation, surge capacity, quality assurance, training, and PT samples. These are standard tasks for a reference laboratory in larger laboratory network. RCE has modeled the eLRN after the CDC human health response network (LRN). RCE will also establish radiological and biological reference laboratories.

- *All hazards receipt facility*. RCE, with sponsorship from DHS, participated in a workgroup that designed and developed a modular triage facility to handle unknown, potentially hazardous (initially working with CWA, but the goal is to be able to screen for all CBR agents) samples. The workgroup established a relatively low-cost and low-technology screening protocol for addressing unknown materials. The facility is in the testing phase. DOD is currently designing and constructing two mobile unit prototypes for field testing in 2006. The facility was originally designed as a mobile unit, but could also be implemented in a fixed laboratory.

- *PHILIS*. (Portable High-Throughput Integrated Laboratory Identification System) DHS and RCE collaborated to develop a mobile laboratory designed to identify toxic industrial chemicals and CWA and analyze 1,000 samples in a 24-hour period. In July 2005, they completed field testing of three prototypes and found that the mobile laboratories could analyze only 200 to 300 samples in a 24-hour period. Although the laboratories did not achieve the goal throughput, they provide necessary surge capacity. EPA proposes to use one unit to support the Las Vegas laboratory. RCE is working to configure the units to analyze samples following EPA methods and meet EPA data quality requirements.

- *Standardized Analytical Methods document*. RDE produced the Standardized Analytical Methods document to provide common protocols for analysis of chemical, biological, and radiological agents; 140 agents are included in the document. The intent is to have standard methods available so that multiple laboratories responding to a large event use the same analytical methods. Many of the methods, however, have not been validated. As such, RCE is working to validate methods. As a companion to the Standardized Analytical Methods document, RCE is also preparing Standard Analytical Protocols, which provide direction for conducting all phases of sampling, from collection to sample preparation, extraction, and analysis. RCE has drafted five protocols to date and an additional six protocols are scheduled for release in September 2006.

- *Analysis of CWA*. Access to CWA for research is limited and restricts research opportunities. RCE is currently working with DOD to gain access to ultradilute solutions of CWA. RCE will be able to conduct instrument calibration and initial research with these solutions. In the future, RCE hopes to gain access to dilute solutions for further research. DHS is also working to establish two CWA prototype laboratories to analyze environmental samples containing ultradilute concentrations of CWA. An EPA laboratory and a public health laboratory will likely serve as the prototypes.

- *Red team*. RCE also supports an emergency response advisory team of about 25 EPA specialists who are available at all times to assist in the case of an event. The team serves as a support mechanism for first responders.

- *Response tools*. The Homeland Security Experts database contains approximately 1,000 experts in various fields. These experts are available to provide information and advice to EPA as needed. The Chemical Biological Helpline is an expansion of a DOD document and is available for first

responders. The Edgewood Chemical Biological Center (ECBC) Reachback is a mechanism in place to allow access to ECBC experts during an event.

Future RCE activities will focus on supporting the All Hazards Receipt Facility installation and testing, completing additional Standard Analytical Protocols, validating existing Standard Analytical Protocols, completing laboratory screening activities, and supporting PHILIS.

Question and Answer Period

- *One workshop participant, who had been involved in reviewing the Standard Analytical Method and some of the Standard Analytical Protocols, felt that these documents focused more on method collection versus analytical methods. This participant also noted that none of them had been validated, and they should not be presented as standard methods. Additional input from other federal agencies should be sought. In regard to the All Hazards Receipt Facility, these laboratories could be useful for field applications, however, input from CDC seems absent.* RCE agrees that the Standard Analytical Protocols are sample collection documents versus analytical methods. These documents are rough drafts and will undergo significant revisions. RCE is going to release some Standard Analytical Protocols that focus on analytical methods and RCE will seek input from other agencies. RCE is attempting to focus on environmental media (soil, air, water). A workshop participant noted that CDC includes environmental media sampling for biological agents in their programs. Rothman agreed that EPA and CDC should collaborate in these efforts.

Decontamination Technologies

Bacillus anthracis Spore Detection Using Laser-Induced Breakdown Spectroscopy (LIBS)

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

Laser-induced breakdown spectroscopy (LIBS) is the process of passing a focused pulsed laser through a lens to form a plasma on a sample surface. As the plasma forms, it vaporizes the sample, atomizing it. As the plasma degrades, it emits a light that is characteristic of the sample. For spores, LIBS is based on the principle that spores have divalent and monovalent cations in higher concentrations than the surrounding media. Gibb presented a table of spore components and a LIBS spectra of *B. subtilis*, which serves as a surrogate for *B. anthracis*. Advantages of LIBS include little to no sample preparation, real-time *in situ* measurements, reagent free/low maintenance (*e.g.*, replace flash lamp, change laser water), relatively low cost ($30,000 to $50,000), and easy operation.

To investigate the applicability of LIBS to ambient air sampling, Gibb collected particulate matter from a variety of common ambient aerosols (diesel exhaust, pollen, protein, etc.) mixed with aerosolized anthrax spores. She then created a spectra library of the individual components of these mixtures and compared these to the spectra generated when analyzing the mixture. As illustrated by the results presented, the principal components of the spectra for the individual components overlapped with the principal components of the mixture. These results indicated that LIBS could apply to the measurement of *B. anthracis* spores found in ambient air samples.

As a next phase, the LIBS equipment was configured as a portable device that could be carried in a backpack. In the first configuration, the backpack housed the power supply, computer, and spectrometer. Gibb provided photographs of the backpack in use and the system components outside of the backpack. Requirements for the portable device included no external cooling system, battery operation, commercially available computer, weight of less than 20 pounds, and ability to operate in extreme

temperatures. The development of hermetic sealing for the device, which will allow for its easy decontamination after its exposure to the biological agents, is in progress.

Gibb presented the spectra from several biological threat agents and some common confounding white powders. LIBS must be able to distinguish these materials for successful use in real-world situations. As shown, each material has a unique fingerprint. Gibb started with a simple correlation of the entire spectrum and provided results of this correlation for *B. atrophaeus*. These simple calculations found close correlations (implying a potential for false positives) with house dust, but distinct differences with other materials. Gibb emphasized that these findings represent simple calculations; new software programs now in place will provide better preprocessing and statistical analysis.

Research also considered the impact of building materials and found that LIBS performed well with simple surfaces such as aluminum, stainless steel, and plastic, but poorly on complex surfaces. Although LIBS is meant to be a direct sampling method, Gibb evaluated powders on wipe materials to evaluate LIBS application to wipe sample analysis. Results provided were from a simple deposition of powder on the wipe material and do not reflect sampling efficiency.

The Army Research Laboratory conducted statistical analysis of these findings. They preprocessed the data to create 136 elemental/molecular intensity ratios. The laboratory then conducted principal component analysis of the original spectra data that Gibb had used for the simple correlation analyses. Analyses found that results from spores on a floppy disc and spores on cement occupy a different principal component space than the spore alone or the floppy disc and cement alone. These results are unacceptable. The spore spectra should overlap regardless of the substrate material. Partial least squares discriminant analysis of the same data was able to identify the spores on the floppy disc and some other office material surfaces.

From these studies, Gibb concluded that LIBS is effective in classifying powders on many building surfaces, Technicloth® is the most suitable wipe material for LIBS, and partial least squares discriminant analysis works to classify sample spectra. Because sampling problems arose from different sampling surfaces, use of sampling pumps or filters to provide an optimal background is being investigated.

Current research assesses mixture sampling and detection limits. Principal component analysis of Arizona dust, which is similar to house dust, and various concentrations of *B. subtilis* showed that these materials occupy similar component spaces. Partial least squares discriminant analysis of these spectra was unable to accurately distinguish the samples with low *B. subtilis* concentrations. These findings indicate that spectral discrimination in mixtures is possible, but the potential for false positives increases as the concentration of the biological threat agent decreases. Additional mixture studies are in progress.

Gibb has also been involved in research on developing a single photon time of flight mass spectrometry. The technology works by ionizing materials, as shown in a presentation diagram. Initially, research focused on using the technology to monitor ambient air for toxic industrial chemicals and CWA. Tests, however, found that one sample could not provide confirmatory results. As such, the focus shifted to using the technology to determine and quantify fumigant byproducts. Gibb noted that the technology is valuable because it can achieve extremely low detection limits (*i.e.*, parts per trillion). Currently, the instrument is available and has been evaluated using a small gas-tripling cell. Additional sensitivity will be achieved when a larger gas-tripling cell is implemented. Gibb is also planning to evaluate permeation tubes as a means to calibrate the system. Additional sampling in a fumigation chamber to assess fumigation byproducts during fumigation and aeration is also planned.

Question and Answer Period

- *Is LIBS applicable to small concentrations, such as clearance sampling?* LIBS is a bulk white powder sampling method. The detection limit is currently 1,000 to 4,000 spores. This detection limit may be decreased with development of more sensitive instrumentation.

- *Have you evaluated spores prepared on different matrices?* Gibb answered that she has completed some research on different spore matrices. She evaluated liquid preparations; however, LIBS ablates the liquid so testing is difficult. Gibbs is hoping to obtain additional powder formations for testing and receive additional funding for this research.

- *Can LIBS differentiate between spores of closely related bacteria?* Testing of closely related spores has not been completed because the laboratory has been unable to obtain powders of closely related spores.

Chlorine Dioxide Fumigation Developments

John Mason, Sabre Technology Services

Sabre Technology Services (Sabre) has been striving to lower response times by commencing decontamination more quickly, reducing the actual fumigation time, and speeding the restoration process. Sabre is also trying to reduce costs of decontamination. A reduction in time and cost to restore a facility would lower the overall impact of an event.

Mason listed a series of events and locations in which Sabre participated in fumigation and decontamination. In the course of these events, the actual time for fumigation was reduced from about 70 hours to only 3 hours. This reduction, however, only minimally affects the overall time frame for planning, sample characterization, clearance, and other restoration activities. Other factors that influence the time frame for decontamination include funding authorization, insurance needs, content assessment, and public perception. Mason provided a table that listed several events—from the U.S. Capitol Hill incident in 2001 through the Hurricane Katrina responses in 2006—that illustrated the lessons learned from completing a decontamination event.

Since the first biological threat agent events in 2001, changes accelerating their restoration approach have included equipment availability, event response software, enabling agreements, site agreements for content handling, pre-engineered insurance policies, first response community communication and education, draft planning documents, and established clearance criteria. Mason listed critical regulatory/procedural assets (*e.g.*, template planning documents, pre-authorized insurance, contract vehicles) and personnel assets (*e.g.*, event coordinator, science and technology teams, public relations staff) currently available for an event response. Mason listed the various mobile technologies available to Sabre as an example of equipment availability as a critical asset in decontamination.

A rapid fumigation sequence currently consists of activating enabling agreements (*e.g.*, contracts), planning documents, and clearance plans; sealing or tenting the facility; installing and preparing the fumigation and monitoring equipment; performing low-level chlorine dioxide tests; installing BIs; completing the fumigation; and conducting clearance sampling. Historically, the Brentwood fumigation event required approximately 440 days and $180 to $200 million for completion. One year ago, Mason estimated, a similar fumigation would have required 30 to 60 days and $10 to $15 million for completion. Excluding the pre-characterization phase, Mason believes, fumigation of a facility similar to Brentwood would now require only 5 days from start to finish.

Most recently, Sabre has been involved in a number of responses to address mold, mildew, and other biological contamination resulting from Hurricane Katrina. Mold and mildew are a tremendous problem. From the outside, a home may seem untouched, but inside the home and all its contents are covered with thick layers of mold and mildew. Mason provided a number of photographs of contaminated facilities. Approximately 90,000 square miles of affected area exists and the most common treatment is gutting a facility, which results in a huge waste disposal problem. Sabre evaluated how chlorine dioxide fumigation would apply to this situation. During the question and answer period, Mason noted that demolition of a typical residence (3,000 square feet [ft^2]) requires 6 to 9 months and $130,000 with a substantial amount of waste produced. Fumigation of the same residence costs about $35,000, requires a much reduced time frame and produces a much reduced waste stream.

Before beginning fumigations, Sabre scaled down the chlorine dioxide technology for transport through city streets. They created self-contained units, including the emitters, and tented buildings with ductwork that feeds to the unit for quick setup. Their system still uses "spider" sampling. The setup period has been reduced to only a few hours. A mobile laboratory is used for sampling and monitoring. Mason provided a photograph of a self-contained unit that can treat up to 50,000 ft^2. Sabre collected full data sets and filmed the inside of the facility during fumigation during initial tests. The chlorine dioxide treats the biologicals by oxidizing them. "Before" and "after" photographs of fumigated facilities illustrate the complete oxidation of molds. Earlier speakers mentioned the low cost of ceiling tiles and the cost benefit of removing and replacing the tiles versus decontaminating the tiles. For larger facilities, reusing tiles can significantly reduce waste volume and cost, and for threat agent decontamination, use of PPE could be reduced by fumigation before removal.

Mason provided an example of a larger facility that they decontaminated, approximately 3 to 4 million ft^3. With advances in the Sabre technology, the total event time was only 3 days. Mason noted that fumigation used 3,000 parts per million (ppm) of chlorine dioxide for 3 hours versus 750 ppm and a much longer dwell time. They drew off about 200 cubic feet per minute of gas and routed it to a carbon cell. During this fumigation, Sabre placed sampling tubes and spore strips in sealed sheetrock walls to ensure chlorine dioxide penetrations. Testing found that the only materials chlorine dioxide will not penetrate are glass or metal-based wallpaper. Tenting, however, allows penetration from the outside and the inside of the building; the chorine dioxide concentration is the same in the tent as it is in the building.

Decontaminating a commercial restaurant revealed that the chlorine dioxide pulls the oil out of stainless steel. The oil should be removed shortly after fumigation. Overall, a tremendous amount of decontamination and research remains to be done in areas affected by Hurricane Katrina. Sabre has completed fumigation in over 100 buildings in the past 6 months. Mason encouraged others to participate in this research.

Question and Answer Period

- *Do you need to conduct ambient air monitoring during the Hurricane Katrina fumigations?* Some ambient air monitoring occurs, but not to the extent that was required in the past. During trials in New York, Sabre found that tenting with negative pressure provides containment.

- *Is there any reason to believe that people sensitive to mold are less sensitive to oxidized mold?* Research has shown that oxidized, dead mold does not induce an allergic response. Clorox bleach research shows that bleach, even in low concentrations, eliminates allergenicity. The chlorine dioxide concentration is very high and oxidizes most everything. One workshop participant noted a planned research project to examine the residue that results from oxidizing mold.

- *Would the Sabre technology apply to highrises?* Sabre was scheduled to tent and fumigate a 14-story building in May 2006. Most buildings, even the Superdome, can be tented. Paints or polymer coatings are potential containment options for facilities that cannot be tented, such as an airport. In addition, Sabre has advanced the chlorine dioxide scrubber technology over the last 4 years so that the equipment can pull the fumigant from a building.

- *Do you use fungal spore stripes?* Sabre uses *B. globigii* spore strips because these are an accepted surrogate. In addition, people are concerned about biological contaminants other than mold. Sabre places 6 log BI strips in walls to confirm fumigation efficacy.

- *How do you preposition equipment and resources?* Prepositioning is an issue. Travel time to a response may require more time than the response itself. Currently, there is no need for a large chlorine dioxide generator. Constructing a large generator, if needed, would be time-consuming.

- *For a porous structure, like wall board and ceiling tile, have you sampled through the material to identify viable spores?* Sabre has tried to culture spores. They have found that when the bleaching effect occurs, no viable spores are found. Ceiling tiles that were black all the way through before treatment were completely bleached after treatment. Sabre has submitted these data to EPA.

Decontamination Technology Testing and Evaluation

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

EPA NHSRC's Technology Testing and Evaluation Program (TTEP) is an outgrowth from EPA's Environmental Technology Verification (ETV) program, with a focus on homeland security technologies. The initial focus (while still under ETV) was on the evaluation of fumigants to decontaminate *B. anthracis*. EPA has expanded TTEP to include projects addressing water decontamination and detection technology verification. TTEP evaluation and testing is typically conducted with the technology vendor, but vendor involvement is not necessarily a prerequisite. Because TTEP is not bound by vendor participations, the testing can be more encompassing and more flexible than testing conducted as part of ETV program. Wood listed a number of people and organizations that are stakeholders in TTEP.

The Sabre chlorine dioxide fumigant technology has undergone TTEP evaluation and testing. The tests, conducted under controlled laboratory conditions, evaluated the log reduction of *B. anthracis*, *B. subtilis*, and *G. stearothermophilus* on seven common building materials. Wood listed the specific experimental parameters during his presentation. Measuring chlorine dioxide concentrations was a key element of this evaluation. Wood presented the log reductions found for each spore species–building material combination. These results indicate that, for the most part, *B. anthracis* is most susceptible to chlorine dioxide and *G. stearothermophilus* is least susceptible. As such, one could argue that *G. stearothermophilus* would be a better surrogate for *B. anthracis* than *B. subtilis* because reductions in *G. stearothermophilus* are harder to achieve. Testing and evaluation is complete; results are undergoing quality assurance review and should be available soon.

Another project under TTEP involves screening 10 liquid decontamination technologies, along with the use of amended liquid bleach, to determine their efficiency in decontaminating *B. anthracis* (Ames strain). The amended bleach consists of commercially available bleach diluted with water and amended with acetic acid to lower the pH. Based on the screening results, four technologies will be selected to undergo more in-depth testing with two additional microorganisms and three additional coupon materials. Wood presented a diagram of the liquid spray decontamination system. The liquid is gravity-fed, with pressurized air added to atomize the liquid to a spray. The spray hits a coupon and runs into a catch vial. The coupon remains in contact with the liquid for the recommended contact time before a neutralizing

agent (primarily sodium thiosulfate) is added to stop the decontamination process. Wood discussed some of the preliminary testing that was conducted in order to do the decontamination tests. These included the spray/weigh tests and the neutralization tests. Wood noted that using the correct mass of neutralizing agent was critical because decontamination needed to cease but excess neutralizing agent could be toxic to the spores and affect efficacy findings. Wood presented the 10 technologies under review. Most are chlorine-based and some use more than one active ingredient.

Wood discussed another project dealing with a full-scale portable chlorine dioxide generation system. Although not a part of TTEP, the project can be considered a technology evaluation. Various organizations are collaborating in the project. An initial test of the system, in October 2004, identified leaks and other problems in the system. As a result, the system was redesigned/rebuilt, and a pressurized flow test with nitrogen and argon (for the generation system) and scrubber leak check was completed in May 2005. The test found only minor leaks. The next step includes testing the system with chlorine gas directed to the generation system to form chlorine dioxide, which will then go directly the scrubber; the test will assess the chlorine dioxide generation process, the emergency shutdown systems, and the scrubber removal efficiency. Depending on the outcome, a building test may then be conducted. Wood presented detailed information regarding the system design goals and a schematic of the system.

Question and Answer Period

- *Is TTEP considered a more robust evaluation of a technology than the ETV program validation or would TTEP be considered a method validation program?* TTEP and the ETV program are similar. TTEP, however, does not require vendor agreement or collaboration. As such, TTEP can provide technology validation and evaluation faster than the ETV program.

- *In an earlier presentation, Martin indicated that there was a move from scrubbers to carbon beds for removing chlorine dioxide from the air. Why does the mobile unit propose a scrubber technology*? Sabre has been successful with carbon bed technologies. Research to quantify and better understand carbon bed technologies will likely occur. A liquid scrubber was selected because of concerns about explosive hazards associated with chorine dioxide in the carbon bed. In addition, a workshop participant noted that the high operating levels of chlorine dioxide used in this system would quickly overwhelm a carbon bed.

- *Have you considered testing materials beyond painted concrete for evaluating fumigants*? Shawn Ryan is conducting more systematic studies of chlorine dioxide fumigation using additional materials. Currently TTEP has no plans to further evaluate chlorine dioxide technologies.

- *How is the portable chlorine dioxide system unique compared to other available technologies?* The portable system primarily provides an additional decontamination system event response. The project to design and build the portable system began about 4 years ago as a Defense Advanced Research Projects Agency (DARPA) project. At that time, portable systems were not available. TTEP became involved in January 2004 with the goal of completing evaluations by October 2004. Problems with the system required redesign and delayed the project. At this time, TTEP plans to move forward to testing the system with chlorine dioxide, although the building testing may not occur. Martin responded that other technologies, such as the Sabre technologies, are currently available.

Vapor Hydrogen Peroxide (VHP) Fumigation Technology Update

Ian McVey, STERIS Corporation

McVey began his presentation with an overview of his company, STERIS Corporation (STERIS). For decontamination applications, McVey noted the need to understand formulation chemistry in order to identify successful decontaminants, and process engineering in order to successfully deliver the decontaminants.

As a result of the anthrax incidents, STERIS identified the need to scale up existing technologies (for the healthcare industry) so that they would apply to larger decontamination events. STERIS is partnering with ECBC to develop and test decontamination technologies, focusing on military decontamination applications.

An ideal decontaminant would act rapidly (*i.e.*, over less than several days), apply to a broad range of chemical and biological agents, have high material compatibility, and leave no post-fumigation residues. Based on these criteria, STERIS has focused on VHP. McVey quickly reviewed the VHP generation process, noting that VHP acts as a sporicide at low concentrations (less than 0.01 milligrams/liter [mg/L]) and degrades to oxygen and water. (A catalyst is used in their scrubbing systems to more rapidly decompose the VHP.) Removing the humidity from the target air is key to reducing condensation. Increasing the ambient temperature and VHP concentration reduces the contact time needed for efficient decontamination. Research in conjunction with ECBC found that the addition of ammonia to VHP (referred to a modified vapor hydrogen peroxide, or mVHP) improves its ability to decontaminate CWA. Ongoing research seeks to optimize the ammonia and VHP ratios. McVey's presentation included process diagrams illustrating VHP and mVHP production.

ECBC conducted studies to evaluate the effect of the surface area to volume (of CW agent) ratio on the time required for decontamination. In one application, VX was spread as a thin layer; in another, the same mass of VX was applied as two droplets. The results indicate that decontamination occurs more rapidly with a greater surface area to volume ratio. Regardless of that ratio, improved decontamination can be achieved with increased contact times. McVey noted that chemical inactivation times are longer than biological inactivation times to allow for chemical degradation reactions to occur.

In working with the military, materials compatibility is a significant concern. Equipment must be decontaminated and reused rapidly. STERIS conducted compatibility studies with materials typically found in a C-17 aircraft—a critical military resource. Initial studies have focused on critical components with testing of additional materials planned. To date, only the nylon webbing was affected negatively (suffering a 10% to 15% loss in tensile strength). The structural materials have been unaffected over a year after testing.

STERIS designed a VHP delivery system that is modular and portable. With a modular unit, the user can string together two or more units, depending on the size of the decontamination, and disassemble the system for easy transport. The military required that the units be small enough for four men to carry. The military also wanted a system that could decontaminate sensitive equipment for reuse. The initial STERIS prototype resembled a dishwasher with shelves. Contaminated equipment was placed inside, the decontamination process ran, and cleaned equipment was removed. Military users found this design too small, but also too heavy. STERIS redesigned the unit to be smaller and easier to use. Peripherals, such as the generator, are housed within the unit when not in use or during transport. For larger decontamination needs, STERIS designed a tent system, which is small enough for transport on a Humvee but large enough to decontaminate the Humvee when assembled. STERIS has also investigated creating a shelving system for placement in the tent to allow decontamination of a large quantity of small equipment. McVey noted that the tenting system also has application in the healthcare industry for decontaminating

ambulances. Ambulances are hard to disinfect because of their large size and the complexity of their interiors.

STERIS also conducted testing on F-16 and C-141 aircraft. The F-16 aircraft will fit in the tent system, but the aircraft construction poses some challenges. The internal wiring and equipment is tightly constructed, so STERIS is investigating ways to integrate the VHP system with aircraft's air conditioning systems to ensure decontamination of small spaces. STERIS also completed testing with a C-141 aircraft. Since presenting information about this research at the 2005 Decontamination Workshop, STERIS has developed smaller, self-contained VHP units. STERIS completed testing several months ago; a draft report summarizing findings is in process.

STERIS and their collaborators have completed initial testing associated with several other projects; results are pending. Sensitive equipment testing involved decontaminating various instruments and devices and then operating the instrument to evaluate performance. Materials compatibility testing examines the effect of VHP on various materials. STERIS is also working to optimize and validate the cycle times for decontamination and writing the permits and protocols needed for VHP operation during a threat event. Research with F-16 aircraft is also ongoing. McVey noted that the space program has been examining VHP as a means to sterilize sensitive equipment before space flight to prevent introduction of biological contaminants during research.

Ongoing and future research includes room decontamination in a hospital setting, cycle time optimization (*e.g.*, minimizing the off-gassing phase), field generation of VHP, high-temperature mVHP delivery systems, large-scale mVHP systems for building decontamination, and wide-area decontamination systems.

Question and Answer Period

- *Do the kinetics for spore inactivation justify the use of a linear D-value calculation?* Data obtained to date indicate a straight line D-value calculation for the range of concentrations tested. A 6 log reduction is the target. The inactivation curve is not completely linear through the whole reduction. STERIS generates the D-value as the inverse of the first order rate constant for the death curve. The results shown are a compilation of many internal STERIS studies.

- *In terms of materials compatibility, are the ambulances back in service and have the aircraft been flown?* Aircraft testing was completed with aircraft waiting to be scrapped. The military will not allow any of the test aircraft to be flown or allow reuse of any of the equipment in other aircraft. STERIS is beginning to gather the materials compatibility data necessary for obtaining an air-worthiness certificate after decontamination. Pharmaceutical companies regularly decontaminate equipment with VHP and that equipment returns to use without deleterious effects. McVey believes that the decontaminated ambulances are back in use.

- *One participant suggested that STERIS and other technology vendors consider the economics, time frame, and logistics of conducting a wide-area decontamination of one city block contaminated with a threat agent. This scenario should include mixed-use buildings (e.g., residential home, restaurant, dry cleaner operation).* McVey agreed that no one has fully addressed a large-scale, wide-area decontamination scenario. A protocol for addressing different building uses should be developed.

- *Looking at the kinetic curve for VX, approximately 2 hours are needed to decontaminate equipment. The military, however, would often need decontamination completed in as little as 10*

minutes. Liquid technologies can currently decontaminate a vehicle in a matter of minutes. Can STERIS modify the VHP technology to compare with current methods? McVey agreed that liquid decontaminants are appropriate for decontaminating the exterior of a vehicle. A liquid, however, cannot reach all surfaces of the internal systems (*e.g.*, electronics, sensitive computers). The VHP technology may be most applicable for decontamination at the end of operations.

- *Is STERIS focusing on mVHP for military use or hospital use?* The addition of ammonia is not necessary for hospital uses because hospital decontamination focuses on microbes only.

- *Has STERIS conducted side-by-side efficacy testing of mVHP and VHP?* The focus of mVHP testing has been chemical efficacy. Early studies found no differences in biological efficacy.

- *How does mVHP or VHP perform when decontaminating porous materials (e.g., carpets)? Are there permeability data?* ECBC has examined nylon webbing and a few other porous materials, but most studies have focused on military materials (*e.g.*, painted metals).

Decontamination of a 65 Room Animal Facility Using Chlorine Dioxide Gas

Mark Czarneski, ClorDiSys Solutions, Inc.

Czarneski described a recent 65 room, 180,000 ft^3 facility decontamination completed by ClorDiSys Solutions, Inc. (ClorDiSys).

Czarneski briefly reviewed chlorine dioxide's properties and history of use. The yellow-green color enables real-time monitoring with a photometric device and allows for treatment adjustments, as necessary, during the course of decontamination. Chlorine dioxide also penetrates water, which allows for treatment of standing water in sinks or traps, and is a true gas at room temperature. The gas was first prepared in 1811, but commercial use did not occur until the 1920s. EPA first registered chlorine dioxide as a sterilant in 1988 and ClorDiSys registered their chlorine dioxide cartridge with EPA in 2004. Widespread current use means that chlorine dioxide is readily available and many people have already been exposed to chlorine dioxide (*e.g.*, during fruit and poultry washing and water treatment).

Many chlorine dioxide generation processes are available. Czarneski presented the process employed by ClorDiSys. This system produces a 4% chlorine dioxide gas using self-contained cartridges and 2% chlorine gas cylinders. Gas generation occurs on demand at the decontamination site. The individual generator units are small with a 1 to 60,000 ft^3 capacity. The system is scalable: multiple units can be combined to decontaminate larger areas. The decontamination process includes pre-conditioning to a relative humidity of 65% to 75%, conditioning at the target relative humidity, charging with the chlorine dioxide (approximately 360 ppm), dwelling at the target chlorine dioxide concentrations (typically 2 hours), and aerating the facility to remove the chlorine dioxide (usually 12 to 15 air exchanges).

Recently, ClorDiSys decontaminated a new animal research facility. Czarneski provided a blueprint and photographs of this facility. Decontamination before stocking the facility with animals was necessary to prevent contamination and cross-contamination from used equipment and other sources. Much of the facility equipment was decontaminated in place.

The facility owners required a 3-log reduction and evaluated four separate technologies for conducting decontamination: formaldehyde gas, VHP, chlorine dioxide gas, and manual wiping with a high-level disinfectant. Formaldehyde gas is inexpensive and effective, but leaves a residue that must be manually cleaned. EPA also considers formaldehyde a carcinogen. VHP is also effective, but condensation can be difficult to control and even distribution can be difficult to achieve. The facility would need to be divided

into smaller sections for VHP decontamination. Manual wiping was impractical because of the need to decontaminate many surfaces and types of equipment. The facility owners selected chlorine dioxide because of the effective penetration of the gas, even distributions, and lack of residues to clean.

ClorDiSys prepared for this decontamination effort similar to any building decontamination event. They sealed the facility, filled drains with water, deactivated the air supply, placed circulation fans, installed gas generators and sensing equipment, placed BIs, and began decontamination. ClorDiSys installed only a minimal number of BIs because the facility owners sought only a 3-log reduction for disinfection, not a 6-log reduction for complete decontamination. The decontamination system consisted of five chlorine dioxide generators and 20 gas sensing points. Fans distributed the chlorine dioxide gas because the facility was fairly complex with many small rooms and long hallways. Czarneski provide a facility blueprint showing the locations of chlorine dioxide injection, sensors, and BIs. Sensors were placed a locations farthest from the injection points. Czarneski noted that the sensors and BIs were placed in unique locations because a sensor reaching the target concentration indicates that decontamination has occurred.

During the decontamination, ClorDiSys targeted a concentration of 1 mg/L, but only achieved concentrations of 0.5 to 0.8 mg/L (approximately 200 ppm). As such, the contact time was increased from 2 to 6 hours. The rock roof and roof ventilation system, which could not be completely sealed, caused the reduced target concentration. Ambient air monitoring outside the facility did not identify measurable concentrations of chlorine dioxide. Chlorine dioxide monitoring data reported one area with low chlorine dioxide concentrations. This area drove the increased contact time. After the decontamination, the facility owner indicated that a chiller had broken through the interstitial space and the repair had been of poor quality. Chlorine dioxide had been lost to the interstitial space in this area.

Czarneski reviewed the advantages of using chlorine dioxide in this situation and provided specific conclusions from the animal facility decontamination. This project further supports chlorine dioxide as a practical and effective decontaminant. Decontamination achieved complete BI inactivation. No physical or measurable residues were observed. No visible indication of material degradation on any of the laboratory equipment was identified. Czarneski noted that the facility contained minimal paper and wood materials.

Question and Answer Period

- *Has the laboratory equipment been used since decontamination with chlorine dioxide?* The laboratory is operational and no problems have been reported. Czarneski mentioned a pharmaceutical customer that regularly exposes a $1 million piece of equipment to chlorine dioxide with no noticeable decrease in function.

- *Has ClorDiSys conducted controlled material compatibility studies?* Studies of computers, metals, stainless steel, gaskets, rubbers, and plastics have found no compatibility issues except with materials prone to corrosion by water (*e.g.*, carbon steel). Chlorine dioxide is an oxidizer, so materials that oxidize should be handled with care.

- *Have you examined copper (e.g., roofs, wiring, circuit boards) reactions with chlorine dioxide?* Copper testing has found no change in function. A thin, green oxidation layer does form. No change in the function of electrical wiring or outlets has been reported. Circuit boards have a much lower copper content than electrical wiring, but these are usually coated with a sealant of some kind. Nonetheless, Czarneski noted that users should always take precautions when exposing materials that oxidize to and oxidizer.

- *Has chlorine dioxide use in animal production facilities (e.g., poultry houses) been evaluated?* Animal production houses typically are not sealed very well, so gas technologies are probably not appropriate. Liquid decontamination is likely a better option. ClorDiSys decontaminated an equine hospital, which was one of the more challenging facilities to treat because of the concrete floors and wood stalls. They found that if they could seal the building they could reach concentrations necessary for decontamination. Tenting is an option for these facilities.

Decontamination Research—A New Approach

Norman Govan, Defense Science and Technology Laboratory, UK

The Defense Science and Technology Laboratory (DSTL) is a science and technology research branch of the UK Ministry of Defense. DSTL focuses on military research, although the technologies can overlap with commercial uses. Govan noted the importance of strong communication between government agencies and commercial vendors to share research data and lessons-learned experiences. DSTL is currently conducting research on a number of technologies; this presentation focused on work with reactive liquids and coatings to enhance the decontamination process.

Battlefield hazard management aims to maintain operations and prevent the spread of hazardous materials to reduce casualties and minimize the need for PPE. Hazard management is completed through a combination of detection, avoidance, weathering, chemical hardening, and decontamination. Govan noted that decontamination for clearance is a new term implying thorough or complete decontamination.

Current DSTL decontamination research aims to develop technologies that can decontaminate to required levels, maximize ease of use, apply to personnel and sensitive equipment, and indicate if required decontamination has been achieved. The military needs verification within hours versus days or weeks and currently uses chemical agent sniffers to verify decontamination. Thorough decontamination, as defined by DSTL, is orders of magnitude lower than decontamination levels achieved for clearance. No single technology is applicable to all situations and all materials. As such, a combination of technologies is needed to achieve desired decontamination levels.

CWA are water-soluble with exceptions (*e.g.*, sulfur mustard) and are often excellent penetrants that move into materials and capillary spaces easily. In addition, many weaponized CWA are thickened with polymers that are water insoluble and render the CWA highly persistent and viscous. As such, understanding solubility is critical in effective decontamination.

DSTL research includes bench-scale testing and large chamber testing. In one of the large chamber tests, DSTL applies a liquid decontaminant to large metal plates to assess contact times and total residuals remaining after decontamination. The residuals include materials on the surface of the metal plates, in capillary spaces, and on the chamber floor. Govan presented results from entrapment studies with various liquid decontaminants. None of the tested decontaminants achieved thorough decontamination on a flat metal surface. Efficacy with complex surfaces (*e.g.*, vehicles) was even lower.

Research on new reactive liquids seeks to identify decontaminant materials that have rapid solubility, maintain reactivity, and adhere to a surface long enough to work. An ideal decontaminant would combine all three of these characteristics. DSTL has focused recent research on microemulsions, which are very small droplets of oils and water that enhance the solubility of hydrophobic CWA materials. DSTL specifically investigated the microemulsion peracetic acid formed from tetraacetyl ethylenediamine, but this material requires specific conditions for activation and would be difficult to use in a battlefield. Acetylated perborate has potential battlefield applications, but is not readily available. DSTL developed F54, which is a microemulsion formulation based on currently available technologies. F54 is a complex mixture of solvents, surfactants, and co-surfactants. This formulation is effective at dissolving thickened

chemical agents, industrially viable, and meets current environmental regulations. Chamber tests with F54 have found thorough decontamination of flat surfaces, but not complex surfaces.

DSTL is also researching novel colloids that are generated by mixing oil, alcohol, and brine to form a three-layer surfactant with the middle layer consisting of a material with unique detergency properties. At the tricritical point of the formulation, the colloid creates surface turbulence that forces CWA from capillary spaces and allows decontamination reactions. Without the surface turbulence, a liquid decontaminant will sit on the CWA without accomplishing decontamination. This research is just beginning, and development of these colloids for battlefield application is still far in the future.

DSTL research also includes investigation of coatings, both active and passive. Coatings are materials that can be applied to a surface, readily absorb liquid agents, reduce contact hazard, and prevent contamination ingress of treated surfaces. In chamber tests, application of F54 with a removable coating achieved thorough decontamination on complex surfaces. The combination of liquid decontaminants and removable coatings is a rapidly maturing decontamination technology. DSTL has conducted extensive laboratory and field trials with prototype coatings. Plans currently exist to replace camouflage paint on vehicles with a durable, removable coating. DSTL is also considering uses of this technology on equipment beyond vehicles.

Ongoing DSTL research with coatings examines different passive and active coating options. Passive coating research aims to improve absorption without loss of mechanical or signature properties. Improved absorption is achieved through increased porosity and results in increased capacity and speed of CWA uptake. Traditional CWA decontamination must occur within approximately 4 hours, when weathering has removed most gross contamination and remaining CWA has sunk into capillary spaces. Passive coatings reduce vapor hazards and extend the effective decontamination period by trapping the CWA in the coating. DSTL is currently evaluating simultaneous use of coatings and other decontamination technologies, recognizing that coating are only effective for portions of a vehicle. Active coatings incorporate reactive materials in a coating. These materials actively reduce or eliminate off-gassing by degrading or otherwise changing CWA. DSTL is considering a wide range of materials, including materials that physically change (*e.g.*, change color) to indicate the presence of and reaction with CWA.

Question and Answer Period

- *Has DSTL evaluated facility decontamination?* The bulk of DSTL work has been directed at military applications.

- *Have you examined biological decontamination?* DSTL has examined biological agent decontamination, but did not present these data. The liquid systems have reported 6-log reduction in biological viability. The coatings are intended to remove materials from a surface, but some research evaluates trapping biological agents between layers of coating and then removing both layers.

- *Does F54 detoxify CWA?* Yes, F54 uses a combination of nucleophilic and oxidative pathways to neutralize the CWA. The coating compliments the decon process by preventing ingress of the contamination into capillary traps. Current versions of the coating are inactive; however, work on active coatings that actively neutralize absorbed agent has been initiated.

Decontamination of Toxins and Vegetative Cells Using Chlorine Dioxide

Terrence Leighton, IVD/CHORI

Leighton discussed studies funded by DARPA and the FBI. These studies examined the range and scope of chlorine dioxide decontamination methods for vegetative cells and toxins.

Chlorine dioxide is effective for spore decontamination, as indicated by numerous research studies and field applications. Chlorine dioxide data, however, are limited to bacterial spores and do not consider non-spore forming infectious agents or toxins. Leighton's research sought to fill this data gap by generating chorine dioxide efficacy data for a suite of vegetative cell and toxin surrogates.

Leighton selected five vegetative bacterial surrogates for testing. These surrogates represented a range of possible threat agents and included bacteria that are multi-drug-resistant, resistant to desiccation, and/or easily aerosolized. Leighton presented detailed information about each of the surrogates and the experimental procedures, which followed a standard coupon methodology. Data found that chlorine dioxide concentrations of 20 to 50 ppm completely inactivated most of the surrogates. *S. aureus* was most resistant and established the upper boundary for effective chlorine dioxide decontamination (230 ppm hours). Similar to spore decontamination, contact times are extremely important—shorter exposure times require higher chlorine dioxide concentrations. The concentrations used by commercial vendors to decontaminate spores would effectively address vegetative cells as well. The FBI sponsored research examining the effect of chlorine dioxide on cell DNA. DNA oxidation has not been found in vegetative cells or spores. As such, forensic evidence remains after decontamination.

As a next step, Leighton examined biotoxin inactivation by chlorine dioxide. Chlorine dioxide can inactivate a toxin through several modes (*e.g.,* breaking disulfide bonds, attacking functional sites). As such, research evaluated the effects of chlorine dioxide on enzyme toxin surrogates. Leighton noted that a 6-log reduction is considered the standard for decontamination. Current methods, however, cannot measure to this sensitivity, so the study included evaluation of various assays for detecting inactivation. Leighton provided information about the chemical reactions used to measure inactivation, the experimental parameters, and the results. The assays used to detect inactivation were extremely sensitive and able to confirm 6-log reductions in viability for *E. coli* β-galactosidase and calf alkaline phosphatase exposed to chlorine dioxide. Inactivation of saporin, which served as a ricin surrogate, is more difficult to measure because assays indirectly measure inactivitation. As such, Leighton created a coupled transcription/translation RIP assay using β-galactosidase as a reporter enzyme for bioeffects. This assay directly measures saporin inactivation and can have a greater than 8-log reduction sensitivity. Development of this method continues. Chorine dioxide concentrations of 4,300 ppm hours resulted in a 6-log reduction in saporin viability, as measured by the RIP assay.

Overall, results indicated that chlorine dioxide can be an effective decontaminant for vegetative cells and toxins. More research, however, is needed to further understand and develop chlorine dioxide technologies for application with these types of threat agents.

Question and Answer Period

- *When drying the vegetative cells, how long are the desiccated cells viable?* The *Streptococcus* and *Staphylococcus* cells are viable for months. The other surrogates were viable for days and possibly much longer. Some research has shown that *E. coli* can be viable for months under the proper circumstances.

- *Is the β-galactosidase a monomer? E. coli* β-galactosidase is active as a tetramer. Ongoing research on the RIP assay will consider other plant RIP assays. The intent of these studies, however, was not to examine receptor binding, but to determine if the basic biochemistry can be inactivated with chlorine dioxide.

- *What coupon recoveries were achieved for the vegetative cells?* Approximately 80% to 90% of the population can be recovered from dried glass or plastic coupons.

- *Were the coupon materials toxic?* The toxin tests were conducted on glass coupons designed for high recovery rates.

- *How did you generate chlorine dioxide?* Standard chemistry was used to generate a pure form of chlorine dioxide; no chlorine resulted from the reaction.

Restoration of Major Transportation Facilities Following a Chemical Agent Release

Mark Tucker, Sandia National Laboratory

The economic damage to the entire United States from an attack on an office building is relatively small, because office functions easily transfer to other office buildings. The economic damage resulting from an attack on a unique facility (*e.g.*, airports, transportation centers) can be enormous, because their functions cannot be transferred. For example, SFO has estimated an $85 million impact per day closed. Closing LAX for 15 minutes disrupts worldwide air traffic. Unfortunately, these facilities are also highly vulnerable to attack because they are open facilities.

The Chemical Restoration Operational Technology Demonstration (OTD) project, funded by DHS, addresses the need to enhance rapid recovery and minimize health and economic impacts from a chemical attack. The OTD project primarily focuses on interior restoration of airports, although Tucker acknowledged that exterior contamination would also be of concern. Sandia National Laboratory (SNL) is the lead laboratory for the OTD project, and has partnered with LAX for this effort; other DOE National Laboratories are involved as well. The information generated and documents produced during this project will serve as templates for other airports.

Tucker provided a diagram illustrating the sequence of activities after an event. The OTD project focuses on activities occurring after the initial release and first response. To meet the project objectives of advancing technologies, enhancing rapid recovery, and minimizing impact, research under the OTD project focuses on pre-planning activities, reducing total restoration time by reducing the time to complete individual restoration components, and identifying best-available methods for different situations.

A complete restoration plan for LAX is a primary deliverable of the project, but a generic chemical agent restoration template for other airports will also be developed. The chemical restoration plan will be based (i.e., issues addressed) on the Biological Restoration Domestic Demonstration and Application Program (DDAP). The chemical restoration plan, however, must consider agent degradation and interaction with surface materials. The plan also recognizes that rapid sampling and analysis techniques are available for chemical agents, decontaminants must be agent-specific, cleanup standards are better defined, and long-term monitoring may be required.

Tucker listed the various collaborators and partners in the OTD project who are conducting research that feeds into various aspects of the restoration plan. Project partners are organized into six working groups:

- *Partnership*. This workgroup brings stakeholders together to establish and facilitate relationships between organizations. The workgroup is developing a table of roles and responsibilities for these stakeholders.

- *Threat scenarios*. This group develops realistic threat scenarios that will be used to direct the restoration plan and support tabletop exercises.

- *Cleanup guidelines*. DHS does not have the regulatory authority to define cleanup standards. This workgroup will recommend realistic cleanup standards and then coordinate with EPA and other regulatory agencies to further define standards and guidelines.

- *Decontamination*. Different decontamination technologies are needed to address different threat agents. The workgroup identified four different decontamination technology needs: surface and hot spot, large volume, sensitive equipment, and waste. Any chemical agent event can produce a large volume of waste and handling of this waste is critical. The workgroup is preparing a survey of available and emerging technologies.

- *Sampling*. Often the sampling phase is the most time-consuming task in a restoration. The sampling workgroup focuses on four sampling phases: characterization, remediation verification, clearance, and long-term monitoring. The workgroup is also examining approaches for validating statistical sampling methods and communicating with other agencies to ensure use of the most up-to-date methods and protocols.

- *Decision Support Tool Development*. The Building Restoration Operations Optimization Model (BROOM) is a software tool prepared for the Biological Restoration DDAP. This tool facilitates sample collection, management, visualization, optimization, and analysis during an event. Sampling teams collect data using handheld devices (*e.g.,* PDAs) and then download information to a central database. This workgroup is adapting BROOM for use with chemical agents.

The workgroup efforts all feed into the final restoration plan. Tucker provided the table of contents for the restoration plan to illustrate the plan components. The body of the document provides general information and the appendices provide technical and facility-specific information.

During the OTD project, the workgroups and others have identified critical technology and data gaps. Tucker listed four specific projects underway to address some of these needs. These efforts address surface sample collection efficiencies and detection limits for chemical agents, interactions of chemical agents and substrates, gas and vapor decontamination methods, and statistical sampling algorithm validation. Tucker emphasized the need and desire of the OTD project to cooperate with others to maximize resources and prevent duplication.

Ongoing activities under the OTD project include completing a restoration plan template and facility-specific plan for LAX, conducing tabletop exercises, and addressing data and technology gaps. The tabletop exercises are meant to engage users of the restoration plan and begin the process of developing facility-specific plans for other airports.

Unrelated to the OTD project, SNL is also conducted decontamination development activities. Tucker briefly described these activities. Evaluation of surface sampling collection methods for anthrax spores is ongoing. Current activities focus on collection methods for dirty surfaces; previous work evaluated collection from clean surfaces. SNL also developed a decontamination product called DF-200 or Sandia Foam. SNL recently received a report from a Canadian study of various decontaminants investigating bio-

efficacy, chem-efficacy, material compatibility, and biodegradability. Only the two commercial versions of DF-200 passed all four criteria and qualified for phase 2 studies to develop a full decontamination system. Use of DF-200 is more prominent in military applications because of ease of use. However, DF-200 is approximately 80% water. SNL is also working to create a dry version of DF-200 that can be hydrated to the proper composition in the field. SNL expects a prototype for testing in June 2006.

Question and Answer Period

- *Will the final demonstration of the chemical restoration plan involve an elaborate tabletop exercise?* SNL is still planning the final demonstration, which will likely include a live demonstration similar to the Biological Restoration DDAP. SNL is seeking the necessary funding for final demonstration in spring 2008.

- *What percent solution is the hydrogen peroxide is created by dissolving the dry DF-200?* Dissolving the DF-200 creates a 4.5% hydrogen peroxide solution by weight.

The Development of Modified Vaporous Hydrogen Peroxide (mVHP) for Chemical- and Biological-Weapons Decontamination

Stephan Divarco, Edgewood Chemical Biological Center

In a previous presentation, McVey had discussed VHP and mVHP production by STERIS. STERIS has been using VHP technology for pharmaceutical applications for decades. In 2001, STERIS adapted VHP technology for decontamination of anthrax during the Capitol Hill event. STERIS and ECBC created mVHP with the addition of ammonia. VHP degrades to oxygen and water and mVHP degrades to oxygen, water, and ammonia, which is removed with scrubbers during aeration. The VHP and mVHP treatment cycles consist of dehumidification, conditioning, decontamination, and aeration.

In 2002, ECBC began chamber studies of mVHP decontamination of biological agents and CWA (*e.g.*, mustard gas, VX). These studies found that mVHP (250 ppm hydrogen peroxide and 15 ppm ammonia) effectively inactivates *B. anthracis* and *G. stearothermophilus*. Similar chamber tests found that mVHP also decontaminated CWA. Most recently tests were conducted with 500 ppm hydrogen peroxide and 30 ppm ammonia. Contact times were approximately 8 to 24 hours for the CWA tests. Additional chamber tests focused on optimizing cycle time and concentrations; results from these tests are pending.

Based on successful chamber tests with live agents, ECBC moved to field testing with surrogates in 2003. Initial field tests with C-141 aircraft considered interior decontamination of the cargo bay only. Divarco provide diagrams of the test system configurations for C-141 aircraft tests and building tests. The field tests proved that the technology could produce and maintain mVHP at concentrations necessary for effective decontamination. These tests only peripherally considered sensitive equipment—a personal computer was fumigated during one test. ECBC has since conduced more detailed testing of sensitive military equipment.

A photograph showed the actual mVHP equipment used for field testing and Divarco noted that the early generation equipment was bulky and awkward. As such, ECBC has also worked to reduce the equipment size and improve mVHP distribution. Current systems are much smaller than the first-generation system. Computational fluid dynamics models optimize fan placement to maximize mVHP distribution.

In summer 2005, ECBC participated in a program to assess sensitive equipment decontamination. The program served to showcase available decontamination equipment and to demonstrate use of this equipment. The program involved soldiers in mock gear and carrying typical sensitive equipment (*e.g.*,

night-vision goggles, Global Positioning System [GPS] tools) completing decontamination. Divarco provided pictures of the SAMS box, which has been used in military operations for biological decontamination. ECBC created a similar technology that addresses biological and chemical contamination simultaneously using mVHP. The report summarizing this program concluded that mVHP has potential applicability for decontamination of sensitive equipment in rear echelon applications. ECBC is currently evaluating a prototype system with mVHP to optimize equipment spacing, reduce contact times, assess the effect of pre-wiping, and identify the highest mVHP concentrations allowable without affecting sensitive equipment performance.

In concert with field tests of the sensitive equipment decontamination system, ECBC has been conducting chamber tests with live agents. The chamber mimics the field units and tests have yielded similar results. ECBC has tested a variety of coupon substrates. Soldiers suggested that pre-wiping gross contamination from equipment before decontamination could reduce the turnaround time between decontamination and reuse. ECBC conducted tests with pre-wiping and confirmed that this approach reduced turnaround time.

ECBC continues to conduct large-venue studies to improve these capabilities. Divarco provided a photograph of a large tent system that can house as many as four F-16 aircraft. The tent system allows simultaneous decontamination of interior and exterior spaces. VHP concentrations within the tenting system reached 250 ppm in the F-16 aircraft avionics bay, cockpit, and exterior space. Complete kill on 20 of 25 BIs was accomplished during the 4-hour test. Surviving BIs were located in areas of low VHP concentrations. Additional testing is ongoing. A second, smaller tenting system that can be carried on a Humvee has also been developed.

Future VHP and mVHP programs will evaluate these decontaminants for compliance with military decontamination requirements. The goal is to develop a single technology that meets both chemical and biological requirements and minimizes equipment needs for soldiers.

Question and Answer Period

- *For the flow dynamics and fan placement, do oscillating fans better distribute the mVHP?* ECBC began distribution with oscillating fans in rooms, but the fans generated competing flows. The optimized fan placement combines the kinetic energy of the fans. Indicator strips and coupons throughout the C-141 aircraft indicated that distribution and inactivation was achieved throughout the cargo space. In the most recent field test, ECBC opened the door to the cockpit of the C-141 aircraft and was able to achieve inactivation. Divarco noted that ECBC tested the cockpit radios before and after the testing and found no reduction in function after 2 weeks of testing.

- *Has ECBC examined fumigants other than VHP and mVHP (e.g., chlorine dioxide)?* ECBC considered a number of technologies but focused on testing VHP and mVHP based a review of the technology capabilities and user requirements. VHP and mVHP seemed to best meet the user needs as a flexible and effective technology for biological and chemical agents. Divarco noted that technology limits exist and VHP and mVHP should not be considered the only necessary decontamination tool.

- *How do you assess chemical decontamination effectiveness? What are the specifications for assessing acceptable decontamination levels? The standards mentioned apply to military applications and not civilian commercial use.* ECBC conducted a variety of analyses (*e.g.*, off-gassing, contact testing, material compatibility) during more recent field testing. However, the concept of acceptable cleanup levels is not defined. One workshop participant described the source of the target numbers used for one of the military cleanup standards. These standards are

based on a risk assessment for specific toxicity end points based on a 12-hour exposure in a confined area, such as the cargo bay of an aircraft. A number of people are working to establishing methodologies to generate acceptable cleanup levels. Standards for civilian populations will likely be generated and will be more stringent than military applications. Another workshop participant noted that EPA has been responsible for fumigant labeling to indicate product limitations. For public health, the biological standards have been no growth on BIs because BIs have been the best available technology. Established guidelines on acceptable levels, however, are available for many chemical agents.

Spore Contamination: What Concentration Deposits, What Resuspends, and Can We Inhibit Its Transport?

Paula Krauter, Lawrence Livermore National; Laboratory

Krauter provided a progress update for a project, begun 4 years ago, to assess the transport of biological threat agents. LLNL targeted four research areas—deposition velocity, transport efficiency, reaerosolization, and aerosol transport inhibition—based on discussions with many scientists and organizations. Some of the key questions considered were: What is the biological threat agent? How much settles? How much resuspends? How can we detect the agent? Can we inhibit resuspension? Krauter provided a list of investigators and publications regarding aerosol transport studies.

Before providing specific study results, Krauter noted that the LLNL studies were conducted with fluidized spores. Preparation is critical for transport studies. Krauter ensures that the spore samples are uniform in size and fluidized.

Initial transport efficiency and deposition velocity studies occurred in a ventilation duct system, as illustrated with a system diagram. A Dixon disseminator introduces the spores into an active air stream and air mixers create turbulent flow to distribute the spores. The test chamber consists of real-world materials to assess differences in transport and deposition based on material characteristics. NIOSH questions the use of air sampling after a ventilation system has been inactive and Krauter agrees that the initial spore plume moves through the duct system within seconds. This research, however, examined the effect of deposition and resuspension.

Krauter presented results from deposition velocity testing with flexible plastic, galvanized steel, and fiberglass. The deposition on galvanized steel and fiberglass was not statistically significant; however, deposition on the plastic was statistically significant. Krauter conducted a series of evaluations to understand these findings. Static charge measurements indicated that the galvanized steel and fiberglass are neutral, whereas plastic has a negative charge and the spores have a positive charge. When in contact with plastic, the charge on the spores diminishes, but remains. The spore charge encourages spore mobility and is important in understanding spore transport behavior.

Krauter compared the experimental deposition results to results from three particle models. The models considered size, density, velocity, duct dimensions, and surface roughness. Krauter presented results from these models. Comparing the experimental result to these modeled results showed that the experimental results fell within the modeled parameters and that the macro-scale roughness drove the deposition velocities. Krauter presented the deposition velocities for each material and noted that the fiberglass value was very low. She believes that the fiberglass coating contained copper sulfate, which inactivated the spores' charge.

Krauter also evaluated the adhesion strength of spores on glass versus plastic to determine the influence of adhesion on spore recovery. Spores adhered to plastic much more strongly than to glass.

Krauter also presented results from assessing spore transport efficiency in the ventilation duct system. The total dissemination efficiency equals the percent of the total spores in the powder that aerosolized and deposited in the system. Although these values seem low (*i.e.,* 4% for plastic, 12% for galvanized steel, 13% for fiberglass), these findings are typical. The geometry of the ventilation duct systems influences these results. The bends and rise remove the larger spore particles. For comparison, Dugway completed a study of spore deposition in an office. Researchers introduced 4 grams of spores using a Dixon disseminator and allowed the spores to settle for several days. Rough calculations of spore recovery indicated that only 30% to 35% of the initial powder was recovered through sampling.

LLNL research also included assessment of spore reaerosolization potential in ventilation systems. Krauter completed short-term (*i.e.,* five air exchanges), long-term (*i.e.,* 30,000 air exchanges), and on/off (*i.e.,* the system is turned on and off to simulate real-world HVAC systems) resuspension tests. Krauter provided a picture of the test system and indicated that the system is designed to allow resuspension of only spores that deposit in the test area. Recent results from on/off resuspension tests show that more spores resuspend from the plastic than from the galvanized steel because more deposits on the plastic.

As another area of interest, LLNL assessed spore transport inhibition by preventing spores from resuspending. As a concept, research would develop or identify charged solvents that would attract and bind spores as they settle. In 2005, LLNL tested many materials with powdered, weaponized spores. These tests found many issues with deploying powders and using mists or droplets to adhere to the spores. Based on their size (*e.g.,* 100 microns), these droplets will have their own influence on air flow. This air flow may simply move the spores instead of allowing the spore to adhere to the droplet. As such, there is a focus on surface force and adhesion force attractions, as well as sheer lift or roll of a spore. Using a new testing chamber, Krauter disseminated 2 grams of powder, confirmed a homogenous mix, and then allowed the particles to settle. After 12 to 18 hours, a fraction of the spores remained suspended. Krauter theorized that thermal convection was responsible. After clearing the chamber of the suspended spores, Krauter applied a copolymer formulation to cling to deposited spores and prevent resuspension. Measurements after introducing turbulent air flow found minimal resuspension. Krauter noted that altitude greatly influences the spray droplet size, which in turns influences results.

Based on these LLNL studies, Krauter posed several research questions: Will refined spores ever deposit? What airflow and environmental conditions will reaerosolize spores? Can we develop more useful predictive models based on experimental data?

In summary, LLNL's research found that spore enhancement greatly influences deposition velocity and transport efficiency. Research also found that particle and surface characteristics influence deposition and adhesion. Research results that increase the understanding of spore-surface interactions and processes can be used to enhance predictive models. Overall, resuspension was greater than predicted. A copolymer-based, film-forming solution, however, may be used to inhibit spore resuspension.

Question and Answer Period

Workshop participants posed no questions.

Studies of the Efficacy of Chlorine Dioxide Gas in Decontamination of Building Materials Contaminated with *Bacillus anthracis* Spores

Vipin Rastogi, Edgewood Chemical Biological Center
Shawn Ryan, U.S. Environmental Protection Agency, National Homeland Security Research Center

Ryan and Rastogi presented the results from studying the efficacy of chlorine dioxide in decontaminating *B. anthracis* spores on building materials. Ryan provided a brief overview of the events that motivated

this project. The 2001 *B. anthracis* contamination events involved three buildings decontaminated by fumigation with chlorine dioxide. For clearance, regulators required no growth on any samples. To date, BIs have been used to indicate that target fumigant concentrations have been reached. However, there is an ongoing debate about the use of BIs in sampling, building clearance, and building clearance criteria.

The objectives of this project were (1) to determine the log reduction of *B. anthracis* viability as a function of chlorine dioxide dose (concentration × time, or CT) on six different building materials and (2) to compare the CT needed to achieve no growth on BIs versus no growth on six different building material coupons. Ryan noted that the BIs and coupons had high spore loadings (6 to 7 logs, *i.e.,* 10^6 or 10^7 spores per BI or coupon).

Ryan provided the specific experimental design components. Building material coupons were 13 millimeter (mm) squares of raw wood, unpainted cinder block, carpet, painted I-beam steel, ceiling tile, and wallboard. Each coupon was inoculated with *B. anthracis* and 0.5% horse serum. A single fumigation included five plates. Each plated contained 30 inoculated building material coupons (five of each material), six uninoculated coupons (one of each material), and a BI with *B. atrophaeus*. Fumigations occurred in closed chambers with no airflow. The Sabre or ClorDiSys technologies generated the chlorine dioxide. The chamber was held at a constant fumigant concentrations, temperature, and relative humidity. During the study, one plate was removed at different time periods. Ryan provided a matrix illustrating the number of data points generated during the study.

Results for carpet coupons, as presented by Ryan, showed that data are variable at low CTs. The kill curve and the variability were not related to the chlorine dioxide generation method and the optimal CT was not affected by a 2-fold increase in chlorine dioxide. No growth occurred for all carpet samples at a minimum CT of 6,000 ppm hours. The optimal CT was dependent on the building materials. Unpainted cinder blocks and painted I-beams required a minimum CT of 9,000 ppm hours for no growth. For the BIs, no growth occurred on all samples after 5,000 ppm hours. Because these materials were so hard to decontaminate, this testing indicates that the minimum required chlorine dioxide dose that should be considered is 9,000 ppm hours. Furthermore, since the BIs used in the tests described herein did not indicate any viability beyond 5,000 ppm hours, they do not serve as an accurate indicator that the recommended 9,000 ppm hours CT has been achieved.

Rastogi continued the presentation and noted the lack of correlation between the doses required to achieve consistent no growth and different building materials. Rastogi discussed findings regarding the D-value concept. The D-value is the time required for a decimal reduction in the number of viable spores (*i.e.,* the time required to reduce a 7 log viable spore population to a 6 log viable spore population). The D-value is one quantitative measure of efficacy. The CT or dose required to achieve a “no growth” finding is another quantitative measure. Rastogi noted that EPA accepts only no growth results for building decontamination.

If the D1-value is the time require for a one log reduction, then the D6-value is the time required for a six log reduction. Rastogi investigated how different factors affected the D-value and how a D1-value could be used to predict the D6-value. He presented two examples of D-value derivations for unpainted pine wood and carpet. The D1-value required very little time, although it did change based on the building material. The D-value also decreased with an increase in chlorine dioxide concentration. Rastogi also compared the ClorDiSys and Sabre chlorine dioxide generation systems. Some differences were observed for the D-values for these two systems; however, the CT required for a 6 log reduction was similar. Rastogi presented data from an example of the D-value for unpainted pine wood. When a D1-value was extrapolated to a D6-value, the observed D6-value was significantly higher than the predicted value.

Rastogi highlighted unique features of the study design. Ceiling tile and wallboard coupons produced a particulate debris that required the use of three replicate plates, instead of one or two, per dilution assay. To better assess variability at sub-optimal CTs, five replicate coupons were tested instead of three. To enssure low detection limits, one third of recovered samples were pour-plated for each sample with a low number of viable spores.

Future research may include further testing and use of more realistic BIs, identifying chlorine dioxide efficacy against 8 log or 9 log coupons, comparing decontamination of chlorine dioxide using aerosolized versus liquid spore deposition, evaluating chlorine dioxide decontamination efficacy at sub-optimal conditions, and optimizing process parameters for chlorine dioxide to mitigate materials damage.

Question and Answer Period

- One workshop participant disagreed with the statement that the 9,000 ppm hours finding did not equate with the BIs. Early research indicated at Brentwood that all the BIs had been killed at 6,000 ppm hours. Because of the concern about environmental variability, however, a target of 9,000 ppm hours was selected for decontamination. Decontamination of large buildings has found that the criteria of 9,000 ppm hours equates well with achieving no growth on all BIs. Ryan commented that the BIs themselves do not indicate that a level of 9,000 ppm hours was achieved. Both agreed that multiple measures are necessary to assess decontamination and account for variability throughout a facility.

- Another workshop participant commented that a BI is a qualitative device and is not intended as a quantitative measure of spore reduction. A BI simply indicates whether no growth was achieved or not.

- A workshop participant noted that a fumigation event must meet the process variables established before fumigation (*e.g.*, fumigant CT, relative humidity, temperature) and all BIs must report no growth to be deemed successful. In fumigations at Brentwood and Trenton, areas of the buildings did not meet the 9,000 ppm hour criteria. These buildings were very hot and reaching the relative humidity in all areas was difficult. Areas that did not meet the 9,000 ppm hour criteria had the largest number of positive BIs found. Ryan indicated that studies of relative humidity are planned. A primary finding of this research, according to Rastogi, is that complete kill on BIs may occur at a concentration of 5,000 to 6,000 ppm hours; however, some building materials require much higher CTs to achieve complete kill.

- These findings, according to one workshop participant, illustrate that BIs should be viewed at face value and may not be the best indicators of successful decontamination. The exercise for SFO estimated a need for approximately 18,000 BIs at a cost of millions of dollars. These findings highlight the need to optimize BI placement to minimize cost while ensuring decontamination. Real-time monitoring becomes more important. Another workshop participant agreed that the limitations of each of the measurement methods should be recognized. When evaluating building clearance, clearance committees consider multiple factors. They do not base a final decision about clearance on a single piece of information.

- *Have you examined the spore populations to identify possible differences in sub-populations that would indicate variations in susceptibility?* To date, Rastogi and Ryan have only examined spore viability. However, they have discussed looking more closely at spore structure during future research.

Decontamination Research and Development

U.S. Environmental Protection Agency (EPA) National Homeland Security Research Center (NHSRC) Ongoing Research Efforts in Understanding the Efficacy and Application of Decontamination Technologies

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

The purpose of the systematic decontamination work under TTEP is to conduct parametric studies of technologies for decontaminating biological and chemical agents in both indoor and outdoor release scenarios. These studies go beyond typical TTEP testing and evaluation activities. They evaluate decontamination efficacy in non-optimal conditions for *B. anthracis* but also other chemical and biological agents. Studies also evaluate interactions between coupon materials, the agents, environmental conditions, and decontaminants.

The viability of biological microorganisms and chemical agent mass on substrates decreases as a function of time and can be influenced by a number of parameters (*e.g.,* agent characteristics, substrate materials, decontaminant concentration, ambient temperature, relative humidity). Ryan presented results from two efforts to assess optimal CTs (concentration × time, *i.e.,* dose) for combinations of threat agents and substrate materials, and to evaluate the effect of non-optimal conditions on the CT required for effective decontamination.

Persistence studies assessed the natural decrease in bioactivity of biological agents applied to building surfaces as a function of time during normal building HVAC system parameters. The studies sought to address questions about the fate of an agent that remains on a substrate material over time, the ability of test methods to assess the effect of decontamination technologies or natural attenuation, the need for decontamination if natural attenuation occurs, and the effect of manipulating environmental conditions to alter persistence. EPA tested vaccinia virus (smallpox vaccine strain), ricin toxin, and *Coxiella burnetii* on painted concrete and galvanized metal ductwork. EPA excluded bacterial spores because spore persistence has been well documented. Tests were conducted under ambient conditions, high temperature and low relative humidity, and high temperature and high relative humidity. Ryan provided graphs illustrating the persistence over time of vaccinia virus and ricin toxin on both substrates. Vaccinia virus (in plaque-forming units [PFU]) decreased over time on both materials with decay occurring more rapidly on the galvanized metal ductwork. Ricin toxin was very persistent on the painted concrete, but less persistent on the galvanized metal ductwork.

In addition, Ryan discussed systematic decontamination studies being conducted in collaboration with ECBC. Ryan mentioned the material compatibility and material demand tests of the STERIS VHP technology, and decontamination studies with the CDG chlorine dioxide technology. Material demand testing is complete for VHP and material compatibility work is in progress. VHP material demand testing found that, in the presence of concrete and wallboard, a higher VHP input is required to maintain the VHP concentration in a closed chamber. Material demand and material compatibility tests with chlorine dioxide are in progress.

Ryan then discussed decontamination research at EPA's laboratories in Research Triangle Park, North Carolina. For chlorine dioxide, EPA will focus on decomposition kinetics, residual reaction products, material compatibility, and fumigant containment (*i.e.,* permeability and adsorption studies). Ryan presented a diagram of the lab setup used to generate and manipulate the chlorine dioxide concentration and environmental conditions, as well as a diagram of the specific testing and sampling chambers. Ryan provided detailed information regarding a current study to evaluate four chlorine dioxide sampling methods. He also described the tests to evaluate permeation of chlorine dioxide through tenting materials,

and chlorine dioxide adsorption and breakthrough (0.05 ppm chlorine dioxide) on potential sorbents under different temperature and relative humidity conditions.

Question and Answer Period

- *Could you please provide additional information about the test conditions for the persistence studies? Specifically, was degradation by ultraviolet rays considered?* The persistence tests occurred in a translucent plastic container that blocked ultraviolet rays.

- *What test method was used for ricin analysis?* Ricin was analyzed using an MTT cytotoxicity assay.

- *What endpoints were used to assess persistence?* For biological agents, a growth or no-growth endpoint on the test materials was used. For chemical agents, residual concentrations on the test material and sampling for the agent in the air serve as the endpoints. A solid-liquid extraction was used to sample the test material. For both biological and chemical endpoints, results were reported as a function of time.

- *How does the rapid decontamination rate on galvanized metal ductwork affect efficacy testing?* Tomasino commented that these tests go beyond the standard stainless steel coupons used for efficacy testing. Results from these tests are relevant to real-world decontamination scenarios where multiple and varied surfaces must be addressed. One workshop participant commented that research with molds found similar reductions on galvanized metal ductwork.

- *Have you evaluated glass versus stainless steel?* Ryan's research group has undertaken no projects to compare these two materials.

- *Initial testing included only a few threat agents and substrate materials. Is EPA considering expanding this research to more substrate materials, particularly those found in real-world decontamination events?* Additional research with other threat agents and substrate materials is planned. EPA is also considering adding ultraviolet exposures to simulate outdoor conditions.

- *How will EPA select the liquid decontamination technologies?* EPA is currently soliciting information about liquid technologies. Ryan requested that workshop participants share relevant information with him.

Rapid Methods to Plan, Verify and Evaluate the Effectiveness of the Decontamination Process

Tina Carlsen, Lawrence Livermore National Laboratory

As previous presenters discussed, there is a great need to reduce the time required to resume facility operations after a biological event. Carlsen described two LLNL projects with the potential to reduce the fumigation process time frame. The first project focuses on methods to plan and evaluate the fumigation process and the second focuses on methods to reduce sample analytical time for fumigation verification and clearance.

During the 2005 Decontamination Workshop, Carlsen presented information from studies of VHP decontamination of duct systems and the use of duct systems to introduce VHP into a room. With results from these studies, LLNL aims to develop a simple tool to help evaluate the effectiveness of a fumigant in a specific setting. Ongoing chambers studies by others have examined the effects and interactions of fumigants and building materials. The LLNL study of VHP and a study of mVHP by Edgewood

Chemical and Biological Center use room-scale test systems and models with the goal of creating computational fluid dynamic models to describe fumigant transport. Results of the fluid dynamic models would then be used to modify and inform easy-to-use zonal models that could estimate CTs, consider build materials effects, and provide information about how a fumigant will react in different situations.

Carlsen described the fumigation trailer used in the room-scale testing. The trailer consists of a test room and a control room. The test room contains approximately 90 feet of duct work with numerous bends and turns. The STERIS technology is used to introduce VHP into the duct work and various sampling ports along the duct work allow for VHP concentration monitoring during testing. LLNL has tested both galvanized steel and polyvinyl chloride (PVC)–lined steel materials. Carlsen presented the results from testing three different VHP concentrations in both of these materials. The galvanized steel catalyzes the VHP as it flows through the system so that VHP concentrations drop substantially along the length of the pipe. The rate of VHP catalysis in the galvanized steel decreased markedly with a decrease in temperature. Increasing the flow rate also reduced the catalysis of VHP. PVC-lined pipes were essentially inert to the VHP and injected concentrations were similar to exit concentrations. Modeling of VHP flow through the systems found lower velocities and lower VHP concentrations at bends in the pipes. Ongoing studies aim to assess VHP concentrations at the surface of the pipe, where spore deposition occurs, versus VHP concentrations flowing through the pipe. Additional room studies are underway to validate the computational fluid dynamic models, enhance existing zonal models, and create simpler zonal models.

LLNL is also researching a state-of-the-art sample processing and analysis method for *B. anthracis* that will reduce sampling time. Currently, *B. anthracis* sampling and analysis methods are labor- and time-intensive, with a throughput of about 30 samples per day for most laboratories. LLNL developed a rapid, high-throughput viability method that reduced the analytical time for verification and clearance sampling. This method is applicable for surface samples and BIs.

The rapid-viability PCR is based on measuring DNA replication over time. In a matter of hours, *B. anthracis* and *Y. pestis* will show measurable increases in DNA copies, which occur during growth. The rapid-viability PCR leverages information from specific and sensitive real-time PCR assays for *B. anthracis* and *B. atrophaeus*. The real-time PCR assays can provide results in about 40 minutes. Although the analysis itself requires only 40 minutes, a period of about 14 hours for *B. atrophaeus* is required to allow for DNA replication when assessing decontamination verification samples, providing a detection limit of about five live cells. The rapid-viability PCR provides simple growth or no-growth results and does not provide quantitative results. LLNL has confirmed the rapid-viability PCR results with culture-based methods.

LLNL has developed rapid-viability PCR protocols for different sample types (*e.g.*, wipes, swabs, filters). LLNL is targeting daily throughputs ranging from hundreds to thousands of samples per day, depending on the sample type. For BIs, LLNL has been able to reach a throughput of 1,000 samples in a day. Most of the validation has been completed with BIs. Carlsen reported results for 100 samples with 6 log of dead spores spiked with 10 live spores and 100 samples spiked with 100 live spores. The rapid-viability PCR method consistently reported growth on all samples, whereas the standard culture method only reported growth on a portion of the samples. These results illustrate that the rapid-viability PCR can detect low levels of live spores in large background of dead spores, which is important when assessing clearance.

LLNL conducted a chlorine dioxide test with BIs to demonstrate accuracy and high throughput capacity. Hundreds of BIs were exposed to non-lethal concentrations of chlorine dioxide in carefully controlled conditions (*e.g.*, temperature, relative humidity). The samples were then analyzed for growth or no growth by a standard culture method and the rapid-viability PCR. Analysis included a number of blind positive samples. No significant difference in culture and rapid-viability PCR was found. The rapid-viability PCR reported no false negatives based on visual growth after 7 days, no cross-contamination,

and no residual chlorine dioxide impacts. Carlsen noted that the rapid-viability PCR was able to identify that several of the false positives reported in the culture analysis were attributable to cross-contamination with other organisms.

The data presented provides results from testing BIs. Carlsen indicated that LLNL would be interested in working with alternative BIs as they are developed. Ongoing testing also extends to environmental samples. Field tests have successfully demonstrated the use of rapid-viability PCR with wipe protocols. A detection limit of about 10 spores has been reported consistently.

Overall, rapid-viability PCR has performed well for fumigation efficacy testing and clearance sampling. LLNL is preparing a report summarizing findings and is developing method protocols for release. Future studies will assess use of rapid-viability PCR with vegetative cells, however, maintaining vegetative cell viability during sample collection and sample preparation is a concern. LLNL is also planning to validate sampling and analysis protocols for environmental samples (*e.g.*, filters, swabs). Future research may also include developing a quantitative rapid-viability PCR and integrating protocols with BioWatch and LRN detection protocols.

Question and Answer Period

- *How does chlorine dioxide affect DNA?* LLNL has not completed studies of DNA impacts from chlorine dioxide, but existing literature indicates that DNA is unaffected by chlorine dioxide. Analysis by rapid-viability PCR requires sampling at two time points (*e.g.*, 0 and 14 hours) to establish the background DNA levels and then to identify the change in DNA levels.

- *Are you speaking with contacts at the LRN program for method validation?* LLNL is speaking with these contacts.

- *What is the cycle threshold? With vegetative cells, there may be DNA breakdown so the DNA levels at the start time may be negative.* The threshold is 35 to 45. LLNL has a fairly sophisticated algorithm to ensure detectable growth above background. LLNL has not begun research with vegetative cells, and Carlsen agreed that DNA breakdown is a concern.

Agent Fate Program

James Savage, Defense Threat Reduction Agency

The Agent Fate Program began 5 years ago. It is an effort to understand the interaction of CWA and substrates, assess evaporation of CWA, and develop predictive models to determine hazard levels on a battlefield. Existing field guidance provides a range of conflicting information based on limited and/or questionable data sets. The research conducted under the Agent Fate Program directly benefits agent detection, protection, and decontamination efforts; augments existing military tools; and feeds into the Low Level Toxicology defense technology objective.

The program has three major thrust areas: predictive modeling, laboratory and wind tunnel research, and methodology development. These areas feed information to one another to support the objective of developing a science-based predictive capability for agent persistence. Research projects examine agent fate via wind tunnel evaporation and open air studies, and studies of surface and substrate interactions.

The overall research program covers three CWA, four operationally relevant substrates, three wind speeds, and three drop sizes at three different relative humidity levels and three temperatures. Testing each combination of these variables would require over 10,000 experiments. As such, Savage sought

experimental designs that would maximize the information provided. Using a central composite design, approximately 1,500 experiments will be conducted on 24 material/agent combinations. Savage noted that the variables selected will address approximately 95% of expected battlefield conditions.

In the wind tunnel studies, experiments are conducted at three different wind speeds. Experiments involve a range of different wind tunnel sizes. An outdoor test facility to validate the model created from the wind tunnel findings is also used. Scaling between the wind tunnels is not necessary because the wind tunnels possess the same velocity profiles. Savage provided photographs of some of the wind tunnels used for testing. Tests in these tunnels are intended to mimic real-world atmospheric conditions.

Savage provided data generated from testing mustard agent on glass, sand, and concrete in a lab-scale wind tunnel, and compared these to model predictions and field guidance. He noted that substrate influences the drop shape and, in turn, evaporation rates. For example, a drop remains intact on glass, but will spread and penetrate on concrete or asphalt. Savage presented results from several substrate interaction investigations.

- *Soil/sand substrate and GD*. For these experiments, a manufactured soil and sand matrix was constructed. Savage provided a graph of the GD concentration vs. time required for decay to non-detect levels. After non-detect levels were achieved, a rain event was simulated. The rain events caused a resurgence of GD vapor. Similar resurgence was seen with concrete.

- *Concrete substrate, temperature, and VX*. Results from these studies illustrate the complexity of reactions, which are based on factors such as moisture, temperature, and location within the concrete. Decomposition within the mortar fraction occurred at a different rate than decomposition in other concrete components.

- *Various substrates and mustard*. Experiments found degradation rates for mustard on various substrates (*e.g.*, asphalt, sand, limestone). The degradation rates varied with the presence of water. Mustard is of particular concern because the decomposition product—H-2TG—is toxic.

Future testing will focus on quantifying agents on various substrates to support risk estimates. Additional open air testing to validate predictive models is planned. Savage provided photographs of the open air testing area. Open air testing involves dispersing 40 to 50 grams of agent following appropriate regulatory requirements. Results from the open air testing and laboratory experiments will be used to further refine predictive models. The Agent Fate Program transitions information from experiments and models to others to improve safety recommendations.

Question and Answer Period

- *Have you analyzed substrates for residues or were analyses for gas alone?* Both the substrate and the gas were analyzed. Savage indicated that they used traditional extraction methods to remove as much agent as possible from a substrate and then analyzed the substrate itself. The substrate could contain as much as 20% of the agent. This remaining agent may be available for release from a substrate by rain or other factors.

Stakeholder Issues Surrounding Chemical Agent Restoration

Ellen Raber, Lawrence Livermore National Laboratory

Raber provided information about issues important to key stakeholders during chemical agent restoration. She briefly reviewed general cleanup issues and decision frameworks, outlined stakeholder concerns, and

provided greater detail regarding regulatory requirements and cleanup levels with a focus on semi-enclosed environments (*e.g.,* transit scenarios). Fully outdoor and indoor scenarios were excluded, although most of the discussion was relevant to those scenarios as well. The cleanup levels will be included in a restoration plan scheduled for future release.

Understanding cleanup levels is key to guiding a risk-informed decision-making process and allows decision-makers to determine if an actual or potential risk exists. Cleanup levels can guide restoration actions and decontamination needs. They can also improve understanding of potential secondary contamination and waste generation concerns. Cleanup levels impact long-term regulatory needs (*e.g.,* decontamination approaches and longer-term monitoring) and stakeholder concerns.

Threat agent reentry and decontamination issues have been previously studied and evaluated although some key technology and science gaps still exist. This objective of this project is to gather the relevant information and apply this information to the transit semi-enclosed scenario. The lessons learned from planning and executing military-related projects have applications to the public sector. For example, environmental impact statements for the chemical stockpile disposal program, emergency response planning, and agent-specific reference doses are available.

LLNL first published "Decontamination Issues for Chemical and Biological Warfare Agents: How Clean is Clean Enough?" in 2001 and updated the article in the February 2004 volume of *International Journal for Environmental Health Research*. Additional regulatory guidance and information has been released since 2004 and should also be applied to transit system threat scenarios. This information was discussed and reviewed as part of this presentation.

The overall project objectives have addressed five main areas: implementing an effective framework with recommendations addressing key stakeholder issues, summarizing existing regulatory guidance and applying these values to airports, surveying existing regulations for disposal requirements, recommending facility restoration and clearance guidelines, and applying standard assumptions and procedures to develop cleanup levels. The focus of this project has been on the consequence management phase, not the crisis management phase, of the restoration process. Cleanup levels drive decisions in the consequence management phase, such as characterization needs, risk communication needs, decontamination technologies, and clearance goals.

To date, the project has focused on a number of compounds of concern, including nerve and blister agents, selected toxic industrial chemicals, and critical degradation products. LLNL also considered additional compounds with key toxicological characteristics (*e.g.,* effects from short-term exposure, range of potency, multiple effects, rapid and severe effects). Chronic exposure has not been the primary concern.

Raber listed the key exposure guidelines that the LLNL and ORNL team members considered: ambient vapor concentrations, skin vapor exposure, surface contact, and ingestion. Data provided in Raber's presentation focused on ambient vapor concentrations for occupational, general public, and transit passenger receptors. The final guidance to be recommended by the team will also recommend waste disposal guidelines, identify critical degradation products, and provide long-term monitoring approaches as appropriate.

Determining responsible cleanup levels hinges on the existence of well-characterized exposure limits. The LLNL and ORNL team reviewed available guidelines developed by a number of different agencies. Occupation exposure guidelines are available through the military and general public exposures guidelines are available through several agencies (*e.g.*, CDC, EPA, NIOSH). Most values are based on varying models (*e.g.,* risk-based concentration model) and are typically at very low concentrations. The

models used to develop these guidelines have been used to develop cleanup levels for Superfund sites. The LLNL and ORNL team also considered site-specific cleanup levels developed for a recent site remediation effort near Washington, D.C. Raber noted that, unlike biological threat agents, chemical agents have sampling methods and detection limits in place, although improvements can still be made that would be very beneficial.

Most of the existing guidance values assume chronic exposures to a chemical for many years. Exposures in a threat scenario are not true chronic exposures. For example, transit passenger studies at LAX show that the average individuals have a stay period in the terminal for typically less than several hours. As such, the project team selected the 8-hour Acute Exposure Guideline Level (AEGL) as the basis for recommended guidelines for transit passengers. The team also conducted a straight-line extrapolation of the AEGL value to develop guidelines for transit passengers in a terminal for more than 8 hours and less than 24 hours. Raber provided a table of recommended guidelines for several agents and noted that all of these values were preliminary will be reviewed by appropriate agencies. The table also illustrated the format that is planned for documentation in the final restoration plan, which is part of the overall project's deliverable. Raber also noted that the cleanup levels for workers are much lower than the cleanup levels for transit passengers. The former may drive the overall restoration plan and the final cleanup levels recommended.

Raber highlighted several of the degradation products that LLNL and ORNL have reviewed. EA-2192, which is a degradation product of VX, is the most problematic because it is highly toxic and persistent. The best method for addressing EA-2192 is to prevent formation through use of highly acidic or caustic decontamination methods. Additional research to understand environmental degradation as a function of substrate is ongoing as part of the overall project.

Long-term monitoring was also discussed as a key concern for restoration and reuse confidence. Monitoring should focus on persistent and/or volatile compounds and degradation products. Long-term persistence is not expected because threat scenario events typically consist of single, short-term releases. Existing monitoring guidance can be used to design long-term monitoring programs based on facility-, agent-, and stakeholder-specific needs. Recommendations for long-term monitoring span from days to possibly months and would be very incident and facility specific.

Overall, restoration requirements for civilian sector decontamination are very demanding and conflicting. Economic drivers to achieve restoration quickly at critical transportation infrastructure must be balanced with stakeholder drivers to achieve restoration that ensures safety for reoccupancy.

Question and Answer Period

- *Could you please discuss the difference between the transit passenger and the worker cleanup levels?* Raber noted that almost an order of magnitude of difference exists between the preliminary project-recommended transit passenger and the worker cleanup levels. Regulators may determine that the worker cleanup levels should drive consequence management and overall clearance decisions. Raber noted that the existing general population cleanup levels are even lower than the worker cleanup levels. Information generated by this project would support use of the worker cleanup levels as protective of members of the general population using a transit facility. LLNL and ORNL selected the AEGL as the basis of the cleanup levels not only because of the short duration for which transit passengers are at a facility but also because the agents disperse and degrade quickly. Typically, agents are present for only short durations. Cleanup levels must balance the desire to select cleanup values that are conservative enough but with the need to consider analytical and laboratory constraints. LLNL and ORNL attempted to gather information about the cleanup levels used by the Japanese government to assess sarin levels after

the subway incident. No specific information was provided, but data indicate that the subway station was reopened based simply on non-detect levels found with field instrumentation.

Radiological Dispersion Device Decontamination

Strategy for National Homeland Security Research Center (NHSRC) Radiological Decontamination Research and Development Program

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

Potential radiological threat events can be divided into three general types:

- RDDs, which include dirty bombs that spread low-level radioactive materials over a wide area. Recent intelligence information indicates that a radiological event, if one occurs, would most likely involve RDD.

- Improvised nuclear devices (INDs), which are nuclear weapons that have been either purchased illegally or constructed.

- Attacks on nuclear facilities (*e.g.,* airplanes intentionally crashed at nuclear power plants).

The NHSRC radiological decontamination program research focuses on rapid RDD event decontamination and will include research involving INDs in the future. Attacks on nuclear facilities are currently not being considered. NHSRC research also excludes responses other than decontamination (*e.g.,* sampling, PPE); food, agriculture, and non-urban scenarios; groundwater remediation; indoor decontamination; risk analysis; and work health and safety.

MacKinney provided an illustration of the possible impact area of a dirty bomb detonated in Washington, D.C. Based on the model predictions, the affected area requiring decontamination could be very large (but MacKinney noted that models tend to overestimate the impacted area).

Radiological decontamination technologies currently available are based on experiences at DOE facilities (*e.g.,* Savannah River Site, Rocky Flats, Hanford), and the commercial nuclear industry. Typically, remediation consists of demolition and disposal, not decontamination. Decontamination for reuse is not typically cost-effective. Some decontamination may occur for waste minimization. For example, decontamination may remove a hot spot so that a building can be demolished as non-radioactive waste.

NHSRC presumes that structures must remain in place for reuse after an RDD event. As such, decontamination options beyond demolition are needed. MacKinney noted that regardless of new technologies, some demolition would likely be necessary. Decontamination technologies must consider occupied spaces and logistical needs, as well as cost, time, political, and economic pressures. The size of the radioactive particles, chemistry of materials on substrates, and a large impacted area drive decontamination needs. Smaller particles are harder to decontaminate but can affect a larger area, and the surface area requiring decontamination may encompass millions of square meters. The challenge is to find faster, better, and cheaper decontamination technologies.

In 2005, NHSRC began a literature search to identify decontamination technologies. This task is ongoing, and findings will be included in the OSWER/NDT technology portfolio. The literature search includes library and database reviews, vendor information, and information from other agencies.

NHSRC also held an RDD cleanup workshop in 2005. The goal of the workshop was to identify promising RDD decontamination technologies and tools that would meet real-world needs following a major RDD incident. The workshop brought together federal and private sector experts to discuss decontamination technology options while considering an RDD scenario. MacKinney also presented a model illustrating the impact area of the RDD scenario considered during the workshop. In this scenario, cesium chloride was released in Chicago. They focused on procedural and technology transfer to identify relevant technologies and technology gaps. MacKinney listed a number of workshop topics considered, such as cost estimation, worker health and safety, decontamination technologies, and waste management. Participants in the 2005 workshop identified many practical and technological concerns related to RDD decontamination. Practical concerns, for example, include project management needs, site characterization methods, cross-contamination prevention, recontamination due to precipitation, vertical decontamination requirements, and waste disposal needs. Cross-contamination and recontamination are inevitable at large, complex decontamination sites. This highlights the urgent need for faster and more effective decontamination methods. Technological concerns include, for example, the speed of available technologies for large urban situations, surface chemistry interactions, difficulties with vertical surfaces and reaching high heights with a decontamination equipment, decontamination of tiny cracks and seemingly inaccessible areas, subsurface effects, and waste generation. MacKinney noted that strippable coatings, which are under development, have limited applications. Urban area RDD event decontamination will require multiple technologies. Overall, the 2005 workshop helped NHSRC define how decontamination technologies can meet remediation and restoration needs. A technology must specifically address the urban RDD event, consider site-specific conditions, meet regulatory and cleanup requirements, minimize waste, and reduce time and cost of the decontamination process.

MacKinney listed ongoing NHSRC initiatives to address the concerns raised during the 2005 workshop. The RDD Rapid Decon initiative seeks to identify and test promising technologies for urban decontamination. In the future, research will be aimed at modifying existing non-radiological technologies to address radioactive contamination (*e.g.*, street sweepers). These initiatives will also examine water and wastewater impacts, particle-surface chemical interactions, and indoor particle infiltration.. NHSRC is also considering developing an RDD waste estimator to understand the waste disposal concerns resulting from an RDD event. As a long-term goal, MacKinney would like to conduct full-scale testing of an RDD event. Translating decontamination technologies from a coupon in a laboratory to real-world situations is a concern. Full-scale testing would enable the testing, evaluation, and validation of decontamination technologies.

MacKinney concluded his presentation with a brief review of IND event concerns. NHSRC has not begun addressing INDs yet. Historically, other agencies addressed IND issues. In 2005, EPA held a 1-day workshop to introduce IND concerns to EPA and begin discussions about EPA responses to an IND event. MacKinney presented a model of the potential impact area from a 50-kiloton IND detonated in Washington, D.C. The impact area spans hundreds of miles and includes millions of people. Basic research and development needs include understanding the effects of an IND event on an urban environment, evaluating the nature of fallout from an urban detonation (*e.g.*, physical and chemical characteristics, particle partitioning, urban deposition), and developing decontamination, mitigation, control, and remediation technologies.

Question and Answer Period

- *Is monitoring for protection (e.g., evacuating people downwind of a plume) versus monitoring for detection and treatment possible*? In order to monitor for protection, many real-time monitors would be required. A number of real-time monitors currently exist in the United States, and organizations are working toward expanding and improving these systems, including DHS. Unfortunately, the many existing monitoring systems are not interconnected. MacKinney noted

that monitoring systems in Sweden provided the first indication of the Chernobyl event to the outside world. Monitoring for protection, however, is critical, especially when considering nuclear fallout.

- *Although not a current focus, will future research consider detection and sampling concerns?* The NHSRC radiation decontamination program is not currently focusing on detection and sampling concerns. MacKinney suggested that organizations communicate to identify and address specific research needs.

- One workshop participant emphasized the need for early detection and faster detection methods. This workshop participant noted several specific monitoring networks and deployable monitoring systems that are available. Ongoing research focuses on finding better detection methods MacKinney noted that a successful monitoring system is a function of monitor density. Enough monitors must be in place to capture and track radioactive material plume movement. Cost is a restricting factor. In reality, if an IND event occurs, chaos will be likely and processes outlined on paper may not be appropriate.

- *If decontamination technologies are inadequate and the NHSRC budget for radiological decontamination is small, what tools are available for responding to an RDD event that could occur in the near future*? The current budget for the radiological decontamination group is about $600,000. MacKinney is hoping to increase this budget. A playbook for responding to an RDD event is available. Decontamination, however, is based on historical decontamination technologies, which are inadequate for an urban area event.

Decontamination Technologies for Urban Radiological Dispersion Device (RDD) Recovery

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

Drake presented information about decontamination technologies currently available to address RRD threat events in an urban environment. Radiological agents are different from biological or chemical agents because radiological agents must be removed. These agents remain radioactive after processing through an incinerator or via chemical reactions. Thus decontamination implies removal of the RDD material from the substrate.

For loose contamination, removal techniques could include wiping, vacuuming, scrubbing, or washing contaminated areas. For fixed contamination, decontamination (removal) could include chemical extraction or mechanical removal (*e.g.*, scabbling, blasting). Decontamination, however, can be costly and time-consuming. A single site may require the use of multiple decontamination technologies. Waste disposal is also a tremendous concern. Often the volume of secondary waste generated during decontamination is much greater than the volume of the primary contamination. Transport of this waste to approved disposal sites must also be considered. Demolition, however, is not always feasible (*e.g.*, for historic landmarks), and decisions about whether to conduct demolition are often based on economic and political reasons. During demolition, dust and debris must be managed. Disposal and waste transport issues also apply to demolition.

Drake noted that decontaminating radiological agents becomes more difficult as time passes. Radiological agents become absorbed into substrates and the contamination footprint increases as wind, weather, and other activities spread contamination. A restoration plan must consider a wide range of complex surfaces and geometries. For example, concrete compositions vary, weathering affects materials differently, and ornate architecture may be present. In addition, cleanup levels and public desire to restore an area to undetectable concentrations must be balanced with cost considerations.

Drake divided available decontamination methods into three categories: mechanical, chemical, and high-tech. Mechanical methods involve some degree of substrate destruction and typically produce secondary wastes. Dry methods produce dusts as secondary wastes. Often vacuum assistance is required. Mechanical methods tend to use simple technologies that are slow and cannot be automated. They are most effective on smooth surfaces decontaminated quickly after an event. Water washdown is cheap and easy to implement, but increases contaminant mobility and impact area, produces a large volume of secondary waste, and exacerbates fixed contamination problems. Drake also briefly described several other mechanical decontamination methods: grinding, scarifying, scabbing, blasting, and vacuuming.

Chemical decontamination methods typically involve substances that are applied to a surface and generate a secondary waste that must be disposed. Chemical methods can address fixed contamination, which is more difficult to remove than loose contamination. Examples of chemical methods include chelation products, solvent extraction methods, acids/alkali substances, and oxidation-reduction techniques. These methods are typically slow to apply and labor-intensive. Drake thought that chemical foams are the promising chemical technology. Foams can be used to address large areas and are relatively easy to apply. These materials, however, require rinse and recovery, possibly produce a mixed waste, and tend to be expensive—decontaminating a 10-block area would be costly. Strippable coatings have been used historically and can provide contaminant lockdown or prevent resuspension to minimize migration. These materials are also costly and labor-intensive, and do not address contamination in small cracks and crevices.

High-tech decontamination methods are under development and not available for deployment. These methods include microwave ablation, laser ablation, electro-kinetic technologies, and bacteria applications.

In summary, no universal solution is available to address an RDD threat event in an urban environment. Selecting an appropriate decontamination technology requires consideration of many factors, such as various substrates, multiple radionuclides, complex geometries, site access, restoration speed, decontamination cost, and acceptable cleanup standards.

Question and Answer Period

- *What decontamination methods would you recommend if a cesium event occurred in New York City today?* Drake responded that he was unable to answer that question because the options were limited. OSCs have information about available decontamination and demolition options used at DOE sites. Some of these technologies would be appropriate and others would not.

- *Does the radiation program consider water security?* NHSRC supports another group specifically tasked with water security. The radiation program sponsored scoping studies to assess the impacts of an RDD threat event on water, wastewater systems, and drinking water systems. For urban detonations, the drinking water supply would not be impacted because drinking water supplies are typically remote from the urban area. Drake noted that NHSRC would like to research technologies that would protect or mitigate radiological impacts to water and waste water systems. More basic research, however, is needed.

- *Do nuclear industries have response plans and technologies that would be relevant to an RDD event?* Nuclear industries have generated information that could be useful and NHSRC is gathering this information. Nuclear industries, however, typically address small contamination

events (*e.g.*, equipment decontamination) and not large scale-decontamination associated with an RDD threat event. Nuclear industry representatives have been involved in NHSRC workshops.

- One workshop participant noted that this presentation focused on decontamination. Crisis management and site characterization activities occur before decontamination begins. A multi-agency effort is required to understand the different aspects of an RDD threat event and discuss all phases of restoration, including crisis management and characterization.

- Another workshop participant described a scenario in which a 12-by-6 city block area becomes contaminated during an RDD event. An area this large would require 3 years for restoration, and during that time all inhabitants in the area would be evacuated. Decontamination would need to consider weather cycles (*e.g.*, rain, wind) and resulting contaminant migration. Efforts to prevent resuspension in wind or to capture rainwater runoff would be necessary. Strippable coatings may be useful, but an entire 12-by-6 block area could not be treated with a strippable coating. Cross-contamination and recontamination would make things more difficult and affect movement through the contaminated areas during decontamination efforts. These issues exemplify the complex nature of an RDD threat event.

Radiological Dispersion Device (RDD) Aerosolization Experiments: History/Applications/Results

Fred Harper, Sandia National Laboratory

Harper has applied his research to responder exposures (*e.g.*, inhalation, dermal penetration) to radioactive agents. Harper is not as concerned with low-level decontamination issues. Harper briefly reviewed the types of radiation and associated exposure concerns, which are based on the type of radiation particle and the size of the particle. For example, alpha particles are most commonly associated with ceramic materials. Alpha particles do not penetrate skin and pose the greatest concern when inhaled. Creating particles small enough for inhalation from a ceramic material (*e.g.*, strontium) is difficult. Harper also noted that smaller particles tend to migrate farther and pose a greater inhalation risk; larger particles do not migrate as far and pose a greater groundshine risk and dermal contamination risk. Harper presented results from several models to illustrate particle transport, dispersion, and deposition. Solubility will also influence exposures because highly soluble materials (*e.g.*, cesium) can dissolve in the lungs and reach the blood stream when inhaled.

In the past 20 years, SNL researchers have completed more than 500 RDD aerosolization tests with many different materials. Harper presented results from some of these studies. Based on study results and modeling information, a 500 meter buffer around a very large source detonation would prevent acute health effects from groundshine to first responders. In addition, a full respirator would not be necessary in these events. Additional modeling, however, estimates a very large impact area for lower level contamination. Modeling tends to overestimate the impact area. In reality, some areas within a radius around the detonation point will have high radioactivity and other areas will have very low activity. Harper played a video of an experiment to launch 100-micron particles. This experiment shows how quickly particles of a certain size leave the influence of the fireball. Most models assume that the particles are captured and dispersed in the thermal rise, resulting in a large impact area. The experiment indicated that the particles decouple from the thermal rise and actual dispersal is more localized than predicted.

For a 100-kilogram device, death occurs within 19 meters of the detonation point and survival occurs more than 890 meters from the detonation point. Between 19 and 890 meters, survival outcome depends on injury due to debris or possible isolated high radiological doses.

Harper provided several examples of likely RDD source materials. Although large sources exist, smaller sources will more likely serve as RDD source material. As such, SNL research has focused on materials typically found in these sources. Harper provided an overview of the SNL test system, which consists of a small test chamber and large, enclosed tent for detonations. Harper attempts to achieve 100% recovery of detonated materials to assess both large and small particle transport. Assuming that detonation creates a homogenous release of 1 micron particles is incorrect.

Material and device properties are critical when assessing aerosolization potential. Reaching the liquid phase or the vapor phase for metals depends on the material properties. If the liquid phase or the vapor phase is achieved, that portion will result in respirable-sized particles; the remainder will result in large fragments. The particles remain in a vapor for phase for only a very short period (*i.e.*, seconds). For salts, respirable and powder-size particles (*e.g.*, 400 microns) are formed. The powder-size particles do not disperse widely. For ceramics, materials tend to shatter. Creating respirable particles from ceramics is difficult—most are larger than 50 microns. The explosion and pressure created during detonation are important in creating respirable particles. Harper reviewed available explosives and pressures required to create respirable particles for various radionuclides.

Harper presented a number of examples of metal and ceramic aerosolization experiments. For ceramics, achieving a greater than 5% aerosolization is extremely difficult. Most particles are 100 to 150 microns; at this size transport beyond the detonation point is limited. Harper briefly mentioned the effect of radiation aging on dispersal. Aged materials will likely react differently, but these differences can be modeled and extrapolated from the experimental data with materials that have not been aged.

Cesium chloride is the easiest material to aerosolize without sophisticated detonation devices. A comparison of size distribution generated during detonation identifies two peaks—one within the respirable range and one beyond the respirable range. These data indicate that people close to a detonation of cesium chloride can be exposed through inhalation. Harper noted that relative humidity affects the explosive dispersal of cesium chloride. High-humidity environments result in larger particles, which impacts possible dispersal.

Harper noted that numerous additional studies have been completed at SNL, such as encapsulation studies and agglomeration/condensation studies. The presentation presented only a brief overview of one research area.

Question and Answer Period

- *Has your research examined deposition efficiency in the lung with particle size changes, specifically particles below 10 microns?* One of the research goals is to examine smaller particles and the change from non-respirable to respirable particle sizes. As such, the research typically focuses on particle sizes of approximately 1 to 2 microns.

- *What is the potential for aerosolizing microorganisms?* Dry microorganisms are easier to aerosolize than wet microorganisms. Significant local aerosolization can occur.

- *Existing models are inadequate at integrating various particle sizes. When will models be refined to include this information?* As new data are generated, these data are fed into existing dispersion models. Existing models, however, remain most appropriate for predicting distribution of small, homogenous particles. Unfortunately, RDD events involve a mixture of particle sizes.

- *Have you found any evidence of cobalt-60 igniting and burning during detonation?* Harper has not found evidence of cobalt igniting, but other materials (*e.g.*, aluminum) have ignited.

Water Decontamination

Water Distribution System Decontamination

Paul Randall, U.S. Environmental Protection Agency, National Risk Management Research Laboratory

The terrorist events of 2001 and beyond have heightened concerns about water safety, including drinking water, water distribution, and wastewater systems. The Water Security Research and Technical Support Action Plan, developed jointly by several EPA offices, outlines the issues, needs, and projects that research should address. The document considers drinking water and wastewater infrastructure and stresses physical, cyber, and contamination threats. Research and technical support needs include identifying likely scenarios for physical, cyber, and contaminant threats; improving analytical and monitoring systems; containing, treating, decontaminating, and disposing of materials; infrastructure dependencies; human and public risk; and risk communication.

Randall provided initial data generated during contamination and decontamination studies of a water distribution system. Contamination studies evaluated contaminant adherences to pipe surfaces, the effects of different pipe materials and flow rates, and the impact of biofilms. These studies considered varying concentrations of arsenic, mercury, and *B. subtilis* at three different flow rates. Pipes were made 5-year-old cement-lined iron and PVC. Decontamination studies assessed the methods specific to different contaminants, effects associated with different decontamination conditions (*e.g.*, pH, flow rate, decontaminant concentrations), and impact of pipe materials. These studies assessed simple flushing to treat arsenic, mercury, and *B. subtilis* contamination, as well as contaminant-specific technologies for each agent. Results from these studies can be used to optimize decontamination efforts.

EPA conducted studies in a pilot-scale drinking water distribution system simulator. This system consists of 75 feet of 6-inch diameter PVC pipe. The system has a 220-gallon capacity with a 100-gallon recirculation tank. The recirculation tank usually operates with 80 to 85 gallons. Flow rates can be adjusted from 0 to 500 gallons per minute (gpm). The system has a total surface are of 25,000 square inches. To test pipe materials, EPA sliced a cement-lined iron pipe, which was used in a distribution system for 5 years, into 1-inch-wide cross-section coupons. Coupons from a used distribution system pipe were used to simulate real-world conditions. The test system includes slots for 10 coupons. Randall provided a photograph and schematic of the test system.

Studies followed similar methodologies. EPA inserted 10 coupons into the test system and ran the system for 1 to 2 weeks to allow biofilm buildup. Two of the 10 coupons were removed from the system to analyze the biofilm; then the contaminant was injected. EPA allowed the contaminant to circulate for 2 days. Four of the remaining coupons were removed to assess contamination; then a decontaminant was injected. EPA removed the final four coupons after completion of decontamination.

Randall provided specific results from contaminant adherence studies. Arsenic and mercury adhered to the cement-lined pipe at laminar and turbulent flow regimes, with higher adherence rates observed under turbulent flow. Both adhered more strongly to the cement-lined pipe than the PVC pipe. Mercury adhered more strongly to the pipes than arsenic. *B. subtilis* adherence rates were similar for both pipes.

Randall also provided specific results from decontamination studies. Simple system flushing for 2 hours at a flow rate of 210 gpm removed 51% of the adsorbed arsenic and 57% of the adsorbed mercury from

the cement-lined pipe. Simple flushing resulted in no removal of *B. subtilis*. Additional studies are needed to assess removal rate variability.

EPA expanded decontamination studies to assess the impact of low-pH flushing and contaminant-specific decontaminants (phosphate buffer [arsenic], acidified potassium permanganate [arsenic and mercury], and shock chlorination [*B. subtilis*]). Randall presented details regarding the experimental design and the results for each of these studies. Removal rates for low-pH flushing with hydrochloric acid remained low for arsenic (36%) and mercury (23%) in cement-lined pipes. For arsenic, phosphate buffer flushing resulted in no removal, whereas the acidified potassium permanganate flushing resulted in partial removal (61%). For mercury, acidified potassium permanganate was highly effective, removing up to 96% of the adhered mercury. Shock chlorination was a very effective decontamination method for *B. subtilis* (96% removal). Randall noted that none of the decontaminants achieved 100% removal and results raise questions about acceptable cleanup levels.

Study results indicated that decontamination methods are contaminant specific. Randall noted that the test system and use of actual distribution system pipe provided information directly relevant to real-world situations, however, the experiments are time and resource intensive. EPA is evaluating modeling as a possible method for additional evaluations; however, more experiments are needed to provide better data for modeling. Future research will examine additional arsenic decontaminants, diesel fuel adherence and decontamination, and alternate pipe materials (*e.g.*, 70- to 80-year-old pipe).

Question and Answer Period

- *Did EPA inject the system with spores or vegetative cells?* EPA did not add any biological agents to the system to create the biofilm. *B. subtilis* spores were used.

- *Were the spores remaining after the shock chlorination viable? How long will they persist in the distribution system?* Studies did not examine spore viability or persistence.

- *What was the target cleanup level? A 96% removal rate would be considered extremely ineffective for building.* EPA did not establish a target cleanup level. No standards currently exist for pipe surfaces. EPA did not collect and analyze the bulk water for contaminants.

- *For the reduction of B. subtilis, what method did you use to determine a 96% spore reduction?* Heat treatment of the coupons removed the vegetative organisms and plate counts were used to assess spore reduction. Analysis required approximately 2.5 hours.

- *Do the decontaminants kill the biofilm and create mechanical problems from the biofilm floccing off the pipe surfaces?* Randall indicated that some impact to the biofilm is likely, but the studies did not examine long-duration impacts. Generally, water suppliers will want to decontaminate a system as quickly as possible.

- *Did the 50% reduction represent a plateau or would a greater reduction occur with a longer contact time?* These studies did not examine the affect of varying contact times.

Decontamination of Water Infrastructure

Greg Welter, O'Brien and Gere Engineers

Welter summarized information gathered and studies completed under a project to develop guidance for the decontamination of water system infrastructure following contamination with a persistent agent. A

number of agencies, industries, and individuals are involved in this project and results are being shared with others conducting parallel research. The project included a literature and historical case study review, adherence studies, and decontamination studies.

The literature review identified relevant historical case studies of system flushing to address pesticide, diesel fuel, and mercury contamination; and chemical cleaning to address pesticide and motor oil contamination. Welter described a specific case study in detail. In 1980, an individual intentionally released chlordane in a water distribution system. The water supplier discovered the contamination when customers complained about taste and odor problems. The water supplier isolated the impacted area and conducted sampling to characterize the contamination. Discovery of the location of the introduction of the contaminant, with a tested high concentration of 144,000 parts per billion (ppb), indicated that the event was intentional and created crime scene concerns. Decontamination was completed through simple flushing of the system continuously for 8 months. During that time, the approximately 10,000 affected customers were provided with an alternative water supply. Monitoring continued for 2 more years.

The experimental components of the project consist of contaminant adherence testing and laboratory assessment of chemical decontamination agents. Researchers selected the test agents that are difficult to remove from a wet surface, likely to be used in a threat event, or documented as part of an actual threat event. Microbial agents included a spore-forming bacillus and viral bacteriophage. Inorganics included four toxic inorganic species, and three non-radioactive isotope surrogates for radionuclides of concern. The two tested organics included a pesticide and an industrial chemical to span the water-octanol partition coefficient (K_{OW}) range. Studies were conducted at a water utility laboratory, which excluded testing of more toxic agents. In addition, other organizations are studying biotoxins and CWA. Researchers included 11 different pipe materials (*e.g.*, PVC, iron, galvanized steel, polyethylene, cement-lined iron, epoxy coated steel, copper). Some materials were tested with and without biofilms. Welter noted that the iron pipe is most common pipe material used in water distribution systems, with most iron pipe now being installed with a cement mortar lining. But he noted that older cities have a significant inventory of unlined iron pipe in service. The cement lining is present to prevent corrosion and new cement-lined iron pipe has a factory seal coat on the cement. Both sealed and unsealed cement-lined iron pipe were tested. Used galvanized steel pipe with heavy scaling and tuberculation served as a surrogate for older, unlined pipes.

Adherence studies consisted of filling a 12-inch pipe section with a stock solution, capping both ends of the pipe, and allowing the pipe to incubate for 7 days, with occasional shaking to encourage suspension of solutes. After 7 days, the pipes were decanted and rinsed with water. As a final extraction step for the pipe wall, the pipes were rinsed with ammonium chloride after inorganic incubation, methanol after organic incubation, and buffer water with test tube brushing after microbiological incubation. Results from these tests indicate that two of the radionuclide surrogates modestly adhered to pipes with tuberculation or biofilms (5% to 12%). The pesticide attached well to a number of pipe surfaces (30% to 45%). Bacillus spores attached best to iron pipe with a biofilm (27%). Adherence studies were also conducted to assess the differences in attachment between 1-hour, 24-hour, and 7-day incubation periods. In these tests, which were conducted using the organic contaminants, attachment increased over time, indicating that rapid decontamination is desirable.

Decontamination studies included treatment of microbials with chlorine; treatment of inorganics with chlorine, household cleaners, and chelators; and treatment of organics with surfactants, all under static conditions. Decontamination considered a variety of CTs. For microbial agents, results were complicated by difficulties in spore recovery from tuberculated pipes. Welter also noted that the chlorine had been exhausted at the end of the incubation period. Although chlorine seems like a promising decontamination agent, with high inactivation reported (up to 100%) as indicated by these static contact tests, maintaining adequate concentrations during real-world situations may be difficult, especially in older systems. For

some radionuclide surrogates, household cleaners achieved modest removals (up to 56%). Neither household cleaners nor chlorine were effective in removing two of the inorganic contaminants; however, it was noted that the initially adhered mass was quite low. For organics, surfactants were very effective for the high K_{OW} pesticide, but not for the low K_{OW} industrial chemical, although the latter had a much lower initially attached mass.

In summary, adherence studies found that attachment is largely a function of pipe type, and not significantly sensitive to ambient water characteristics (*e.g.*, pH, alkalinity, temperature). Pipes with a biofilm or tuberculation reported the greatest adherence, and polyethylene and coated cement reported little adherence. Organics with a high K_{ow} adhered strongly to several pipe materials, inorganics' adherence was minimal, and microbials adhered to pipes with biofilms. Adherence increased over time, indicating that rapid decontamination is desirable. Decontamination studies found that surfactants can be effective for organic agents and chlorine can be effective for microbials if CTs can be maintained. The decontaminants tested for inorganics were only moderately and inconsistently effective.

Question and Answer Period

- *For the decontamination tests with the microbials, what were the solution pH and exposure times?* A hypochlorite solution was used for the microbiological decontamination. Welter did not have the specific pH data, but noted that pH would be an important consideration, with lower pH conditions resulting in a more effective kill. Pipes were decanted to reach specific CT targets, so the exposure time varied. For the microbiologicals, only decontamination of old galvanized steel and iron pipe was tested. Removal rates varied from 43% to 100%.

- *What was the recovery efficiency?* Welter noted that the recovery efficiency was not as high as desired. Researchers measured concentrations in exposed pipes without decontamination and exposed pipe after decontamination as a variable. Some effort was made to increase recovery, and the chemical rinses did improve recovery.

Adherence and Decontamination of Chemicals and Biologicals

Sandip Chattopadhyay, Battelle

There is a growing concern over the potential use of chemical and biological agents to contaminate drinking water supplies. To provide support to NHSRC (U.S. EPA), Battelle conducted a series of studies to understand the adherence/attachment of various chemicals, bacteria, and toxins on various types of pipe materials commonly used for drinking water distribution systems. Tests were also conducted to evaluate the decontamination of these chemicals, bacteria, and toxins by selected decontaminants. Battelle has completed these studies and have submitted final reports to U.S. EPA.

Battelle designed these studies to answer questions about the extent of biological and chemical adherence to various substrates (pipe materials), the amount of adherence that occurs, the impact of rinsing with water, and the effectiveness of selected decontamination agents. The studies included various types of biological and chemical contaminants (*e.g.*, organophosphates, bacterial spores, neurotoxins, mycotoxins). A broad overview of the Battelle studies and specific results for sampling and analytical protocols of the test contaminants were also provided.

Battelle filled short pipe sections with a contaminated solution and capped the ends of the pipe. Tested pipe materials included aged black iron, copper, high-density polyethylene, PVC, cement-lined iron, and steel pipe coated with high solids epoxy. The filled pipe sections were equilibrated for 7 days at room temperature, for 24 hours at room temperature, or for 7 days at a lower temperature (2–8ºC).

Chattopadhyay described various factors, like chemical (*e.g.*, dissolution, pH, chemical form) and physical (*e.g.*, percolation, diffusion, scale formation) conditions that influence the adherence and release of contaminants from the pipe substrate. He also provided detailed information regarding initial concentrations for several chemicals, bacteria, and toxins tested. Testing focused on high concentrations. For some contaminants, the tested concentration was at or near the contaminant's solubility limit. Contaminants can adhere to a surface through a variety of chemical or physical means (*e.g.*, surface pore diffusion, occlusion in organic matter, solid state diffusion, precipitation). Chattopadhyay calculated an adherence coefficient based on the contaminant concentration in the pipe at equilibrium and contaminant concentration in the aqueous phase. This coefficient is expressed as adherence per unit of wetted pipe surface.

Battelle tested three different decontaminants: hypochlorite, Simple Green™ (a surfactant), and Pipe-Klean™ (an industrial cleaning agent). Hypochlorite is a bleaching agent that provides a kill step for reducing microorganism populations and oxidizes chemical contaminants or promotes transformation. Simple Green™ is a surfactant that removes contaminants by roll up or emulsification. Pipe Klean™ is a strong acid used to dissolve deposits in pipes. Battelle also tested some other agents, including hot water and organic solvents. Decontamination focused on solutions that are inexpensive, readily available, and relatively safe.

Battelle analyzed samples using several methods—liquid chromatography-mass spectrometry, ion chromatography, gas chromatography-mass spectrometry, induced couple plasma/mass spectrometry, and cold vapor atomic fluorescence spectrophotometry. Chattopadhyay indicated that Battelle employed a variety of analytical methods to account for interferences and ensure appropriate quantification of adherence.

Chattopadhyay provided a few examples of the test results from the tests conducted with mercury, mevinphos, and biologicals with several pipe substrates. Though mercury adhered to copper pipes, it was very effectively removed by a strong oxidizing agent. Mevinphos adhered to both the coated and uncoated cement-lined iron pipe. Microscopic examination of a pipe section indicated that the mevinphos was trapped in the micro- and macro-pores of the concrete. A decontamination agent that can penetrate these pores was found to be effective. The calcium present in these cement-lined pipes was very effective to inactivate bacteria and toxins. Battelle classified bacterial and toxin adherence as high (greater than 10% recovery in the extraction sample), medium (0.1% to 10% recovery), or low (less than 0.1% recovery).

In general, studies found that adherence and decontamination efficacy varied based on agent, pipe material, and decontaminant. Changes in pH and temperature did not impact bacteria and biotoxin viability. Lower adherence rates were found with the shorter exposure duration.

Question and Answer Period

- *What were the major differences observed in biological adherence on to different pipe materials?* Copper is toxic in nature and was effective in inactivating a number of microorganisms. As such, low adherence was observed on copper. Chattopadhyay noted that the surface properties of pipes and biological contaminants, and the capability of the biologicals to survive, have significant impact on the adherence test results. The adherence of bacteria was determined based on recoveries. The rapid toxicity of copper and high alkalinity of cement influenced the recovery from these pipe materials.

- *The presentation briefly discussed an adherence coefficient, but little information on this value was provided. Was more information generated during the experiments?* Chattopadhyay's presentation provided an overview of the Battelle studies and results within the allotted time. The adherence coefficient, which is similar to the partition coefficient in soil (or solid)–water system, quantifies the amount of chemicals adhered per unit wetted surface area. This parameter allows ranking of various pipe material–contaminant combinations and can be a very useful tool in predicting adherence and strength of decontamination agent needed. These coefficients also allow comparison of results of other research studies, which may have used different concentrations of contaminants or shape/size of pipe. The ranking of the chemicals and pipes were conducted based on these coefficients. However, the bacteria and toxins were categorized based on the recoveries.

- *Did Battelle vary the starting concentrations of contaminants for different tests?* A few tests were conducted to evaluate the impact of the initial concentration of the contaminant. For example, mercury adherence was tested using various concentrations of mercury. Chattopadhyay noted that the studies mostly examined the effect of high concentrations of contaminants (near solubility limits in water) on adherence.

- *What was the impact of the water chemistry (e.g., hard versus soft water)?* Battelle used drinking water from the Battelle plant for the studies. Water parameters, such as hardness, pH, and alkalinity, were measured and are provided in the final report.

Measurement and Analysis of Building Water System Contamination and Decontamination

Stephan Treado, National Institute of Science and Technology

The National Institute of Science and Technology (NIST), along with a number of collaborators, is in the middle of a 3-year project to address contamination and decontamination of water systems within buildings. Water systems within buildings pose unique challenges compared to water distribution systems. Building systems are complex, with small-diameter pipes (*e.g.*, less than 1 inch), short runs, numerous fittings and turns, dead ends, multiple materials, and low or intermittent water flow. The small-diameter pipes create a high surface area to volume ratio. In addition, buildings have appliances, such as hot water heaters, washing machines, and dishwashers. Hot water heaters often contain sediment that is hard to remove. Some building system components are open to the atmosphere and turning on faucets, showers, or appliances can release contaminants to the air.

NIST selected both chemical and biological agents for study. In general, studies conducted as part of this project range from well-characterized and controlled laboratory experiments altering primary variables (*e.g.*, contaminant concentration, pipe material, exposure time, flow velocity, water chemistry) to real-world situations with increased system complexity and design (*e.g.*, valves, fittings, appliances). Specific studies include small-scale static tests, small-pipe dynamic tests, full-scale plumbing and intermittent flow tests, and appliance tests. Treado noted that a real-world situation has too many variables to test. The information provided by these studies will feed into modeling programs.

Treado described the experimental approach for small-scale tests of biological contaminants and provided a photograph of the test system. He noted that biofilms on the pipe material are very important for understanding contaminant adherence and decontamination. Contaminants, especially biologicals, are prone to interacting and adhering to the biofilm. As such, pipe sections were pre-conditioned to allow for biofilm formation. The test systems consist of a low-flow system with a small section of the test pipe material and a bioreactor for use with test coupons. Treado provided results for tests of sodium hypochlorite decontamination of biological agents in a continuous loop system. Treado noted that the biofilm acts as a chlorine sink, so a new chlorine source was injected into the system. The results

indicated that higher chlorine concentrations increase biological inactivation. Treado also provided results from studying the impact of fluid shear on biological contaminant accumulation. Results indicated that higher accumulation occurred with higher fluid shear, which may be a result of greater contact between the contaminant and the biofilm at a higher fluid shear. Spore decontamination required higher chlorine concentrations compared to the vegetative bacterial agents. Copper pipes provided some self-decontamination because of the potentially toxic properties of copper to bacteria. NIST is currently assessing ricin and *F. tularensis* adhesion and removal and modeling surface adhesion forces for bacteria and spores.

Studies of chemical contaminants are also underway. The objectives of these studies are to identify the best analytical methods, develop adsorption isotherms, determine adsorption mechanisms, and appropriate decontamination methods. The test system for these studies consisted of a solution of contaminated water placed in a beaker with a glass-coated stir bar. Pipe material coupons and various pipe deposit materials (*e.g.,* calcium carbonate) were added to the mixture. Changes in contaminant concentration in the solution and on the pipe surface were measured over time. Treado listed the various contaminants and pipe materials tested, as well as the water parameters measured. Treado provided a photograph and schematic diagram of the test system used to evaluate impacts of fluid dynamics on contamination. The system includes a small, rectangular copper pipe section. Tests with diesel found that the thinnest diesel layers occurred at low and high flow rates; the thickest diesel layer formed on the copper pipe at an intermediate flow rate. Treado presented a plot detailing these results.

NIST has also begun full-scale laboratory testing. Treado provided a photograph and schematic diagram of the full-scale test system. This system consists of a five-floor structure that emulates plumbing in a typical building. The system includes multiple test loops. Computer systems control variables and gather monitoring data (*e.g.,* flow, temperature, pH). The system includes used copper and iron pipes and used water heaters. Data generated during full-scale testing will feed into fluid flow models. Treado presented a cross-section of rectangular pipe which illustrates that diesel remains in the corners of the pipe even when the sides are clean. In a real-world situation, contaminants will likely remain in areas where there are turns, valves, or other obstructions. Full-scale testing will include assessing decontamination methods, such as flushing, mechanical or ultrasonic cleaning, and surface treatment. Decontamination studies will also consider wastewater handling and decontamination verification issues.

NIST and collaborator studies will continue with more extensive tests with different contaminant, substrate, and exposure combinations. Additional tests will focus on specific decontamination methods and procedures. NIST aims to develop specific recommendations for building response plans for a water contamination event and then generalize these results for wider applicability.

Question and Answer Period

- *The fluid dynamics data provide interesting information about potential contaminant hot spots within a system. What were the units of measure presented for the deposits?* The data provide a relative measure that is unitless. The values do not represent absolute measurements.

- *Why were rectangular pipes, not round pipes, used?* NIST used the rectangular pipe because the measurement technique works best with a flat surface. NIST is trying to adapt the information to a curved surface. Treado recognized that real-world situations would involve a number of complex geometries.

- A workshop participant noted that a literature search for another project identified approximately four cases of accidental diesel contamination in water systems. In these cases, flushing removed

the diesel fairly rapidly (*e.g.*, within days). Treado stated that the laboratory study findings support the case study findings.

Water Decontamination and Detection

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

For the past 3 years, several EPA research offices and programs have been evaluating the ability of commercially available water quality sensors to detect changes in water quality resulting from contamination. The research seeks to answer questions about what happens when various contaminants (such as CWA) enter a water supply and what standard water quality parameters are most effective at indicating changes in quality.

To address these research questions, EPA conducted a series of studies with a single-pass pipe system. This system consists of a 1,200-foot length of 3-inch-diameter fiberglass-lined cast iron and PVC pipes with couplings at the pipe junctions. Some pipe chipping has occurred and some rust and biofilms are present in the system. The system has a velocity of 1 foot per second. Sensors are located at 80 and 1,200 feet from the contaminant injection point. Hall provided photographs of the test system.

Monitors sound an alarm when sensors report a change in a standard water quality parameter (*e.g.*, pH, temperature, total organic carbon [TOC]). Although the sensors could identify a change in water quality, they do not identify specific contaminants. Hall listed the various herbicides, insecticides, culture broths, microorganisms, inorganics, and other materials injected into the system. Four CWA were also tested through ECBC facilities.

Hall provided results for malathion, aldicarb, and nicotine injections. The injected contaminant traveled as a slug throughout the system. The sharp rise and fall in the data shows the rapid change that occurs in a short period after contaminant injection. Hall noted that these data illustrate the need for multiple sensors in a facility. Results indicated that chlorine and TOC were the most useful trigger parameters. Aldicarb (a fast-reacting contaminant) and nicotine (a slow reacting contaminant) provide examples of results from two very different contaminants. Hall noted that a TOC sensor costs about $20,000. He presented data from an S:Can sensor, which is a less expensive monitor at $15,000.

Hall provided schematic diagrams of two water sentinel systems. These systems can be used to sound an alarm with a change in water quality. The alarm triggers more detailed sample analysis to identify specific contaminants. EPA tests have proven that a sentinel system operates effectively in laboratory conditions. The next step is testing the system in the field. Field testing serves the dual purpose of improving water quality and identifying indicator parameters. Laboratory testing indicated that chlorine and TOC are primary trigger parameters. Hall noted that the monitoring system, as designed, costs about $50,000, primarily due to the cost of the TOC monitor. The system also does not detect changes associated with biological or radioactive agents. EPA hopes to conduct radiological studies in 2007. For field testing, EPA must also consider the sampling required after an alarm sounds and account for routine changes in the water system (*e.g.*, regular tank filling and emptying).

EPA also conducted decontamination studies using flushing and superchlorination. Flushing consisted of displacing the contaminated water with clean water, shearing adhered contaminants from the pipe walls, and delivering a decontaminant through the system. Superchlorination involves flushing and use of a high chlorine concentration—10 ppm, which is the highest concentration most systems can achieve. In-line sensors were used to determine when the bulk water returned to baseline conditions. Grab samples were used to verify decontamination. The sensors could not detect contamination in the pipe wall or biofilm. EPA found that some contamination remained adhered to biofilms and piping materials, and pipe conditions (*e.g.*, corrosion, tuberculation) affected the decontamination success.

Hall described a case study of *B. globigii* decontamination. EPA injected multiple samples of *B. globigii* in the single-pass pipe systems over 12 months. Basic flushing was used to decontaminate the system after each injection; however, *B. globigii* was detected in the blank samples after the third trial. EPA conducted more aggressive flushing, but the spores remained. Swipe sampling found spores remaining on the corroded iron pipe, but not PVC or fiberglass materials. EPA then injected additional spores to assess decontamination using superchlorination. The superchlorination only had a small effect on reducing spores adhered to corroded iron pipe. EPA concluded that some contamination remains after flushing and chlorine contact. Areas of rust and corrosion may require more aggressive decontamination methods. Additional health-based toxicity and infectivity data are needed to determine recommended decontamination levels.

Future research will consider biological agent persistence in drinking water pipes and associated decontamination needs. This research will include a recirculating pipe loop fabricated with corroded ductile iron. EPA will monitor spore concentrations over time and determine CTs for decontaminants.

Question and Answer Period

- *Biofilms are highly variable. How does the biofilm that forms in the test system vary from biofilms that form in real-world situations?* EPA has included studies with older pipe to consider real-world situations.

- *How much time is required between collecting a grab sampling and obtaining analytical results?* The time required to analyze samples varies, but can be as much as 24 hours (*e.g.*, plating culture methods). Hall noted that faster analytical methods are needed.

- *How do the CTs (concentration × time) observed in these studies correlate with other studies?* EPA tested very low values (*e.g.*, 1,500 ppm hours) as compared with other studies (*e.g.*, 30,000 ppm × hours).

Foreign Animal Disease/Avian Influenza Decontamination

Determining the Virucidal Mechanism of Action for Foreign Animal Disease

Jill Bieker, Sandia National Laboratory

Understanding the virucidal capacity of various decontaminants is critical to ensure proper efficacy claims, aid in disease containment, prevent disease transmission, and understand the impact of environmental factors (*e.g.*, temperature, humidity). Bieker provided the results from several studies to assess the efficacy of several decontaminants and methods used to evaluate viral inactivation.

Microorganism sensitivity to a decontaminant varies based a number of factors. Bieker listed several microorganism types and their sensitivity to decontaminants. Spores are traditionally the most resistant; enveloped viruses (*e.g.*, influenza) are the least resistant. Currently, EPA has guidelines, but no standards, for evaluating decontaminants against viruses. Standardized testing, however, is necessary for regulatory processes and for comparison. Bieker noted that initial testing is usually conducted with surrogates and not the target virus itself. Bieker provided a table of important considerations in virucidal testing. She noted that understanding cytotoxicity of the decontaminant is important because the treated viruses are injected into live cells to determine viability. Bleach, for example, is toxic to cells and would kill the cell before virus propagation could be determined. Removal of the decontaminant is necessary prior to injecting the virus into the test cells. The organic challenge is also important because it may protect the

virus or react with the decontaminating agent. In addition, some host systems are more sensitive than others.

A virus is a fairly simple organism composed of a lipid envelope (in some virus types), capsid protein, structural protein, and nucleic acid. Different virucides will act on these different components to cause virus inactivation. Understanding the virucide mechanism of action dictates appropriate analysis methods. For example, if a virucide disrupts the lipid envelope, resulting in virus inactivation, then DNA analyses may not be a useful technique. Bieker provided tables summarizing various virucide targets and possible analytical methods.

The SNL research sought to evaluate various disinfectants against several viruses, including avian influenza and closely related surrogates. Researchers hypothesized that closely related surrogate viruses will react similarly to decontaminants and that molecular-based diagnostics can be applied as a rapid verification tool. The studies followed the EPA guidelines for virucidal testing and considered eight different decontaminants. The tests consisted of mixing equal parts of a virus solution with a decontaminant and allowing 1-minute, 10-minute, or 20-minute exposures. For the organic challenge, either diluted bovine or poultry feces were added to the decontaminant. After exposure, the samples were prepared for efficacy testing by *in vitro* culture or real-time PCR. Western blot tests were also conducted for the influenza samples.

Bieker provided results for influenza decontamination. The 1-minute and 10-minute exposure times with different decontaminants reported no statistical difference in response between the test and surrogate virus. The real-time PCR analysis showed that not all of the decontaminants affected the virus RNA even though the virus had been inactivated. Overall, DF-200 and 10% bleach were most effective for the 1-minute exposure; Virkon S was effective for the 10-minute exposure. Only DF-200 and 10% bleach significantly degraded the viral RNA, though the performance of both of these decontaminants was greatly impacted by the organic challenge.

Bieker also provided results for the virus responsible for foot and mouth disease and a surrogate. Tests found that the surrogate was much more resistant to acidic decontaminants than the target virus. For the target virus, all of the decontaminants except 70% ethanol were effective in causing complete loss of infectivity based on culture analysis with hamster cells. For the surrogate, 10% bleach, EFT, and Virkon were most effective. As such, the virus evaluated as a surrogate for the foot and mouth disease virus may not be appropriate. Real-time PCR analysis found that the 10% bleach with the target virus and the EFT, 10% bleach, and 2% sodium hydroxide with the surrogate were most effective in degrading RNA. As such, real-time PCR could only validated decontamination with these agents.

In summary, the virus structure presents limited targets for decontaminants (*e.g.*, viral RNA, lipid envelope). Tests results found that the organic challenge reduced decontaminant efficacy. Real-time PCR was appropriate for determining viral inactivation due to viral RNA degradation. To address differences in viral susceptibility, SNL is planning additional live agent and surrogate testing. Bieker noted that these studies did not assess materials compatibility and application expense, which also must be considered when selecting decontamination methods. Bieker provided several outstanding questions resulting from this research—what assays are needed in the field to verify viral eradication; is standardized virucidal efficacy testing needed; are surrogates appropriate for validation studies; and can decontaminant claims cover specific viruses or whole virus families?

Question and Answer Period

- *Were the research findings consistent with clinical practice for infection control?* The research most importantly found that decontamination is highly dependent on the target virus strain. For

SARS, general good hygiene practices and cleaning with ethanol were highly effective. More resistant viruses would require more aggressive decontamination.

- *What is the persistence of viruses, specifically avian influenza, in the natural world?* A virus leaves an infected host as part of the natural life cycle. The way in which a virus leaves, such as in mucus, can extend the persistence so that survivability is measured in months or years. Workshop participants debated survivability information with reports of avian influenza remaining viable for up to 1 year. Bieker noted that information about virus persistence is incomplete. As such, detailed reporting of test conditions is critical.

- *Were the studies completed with suspension tests?* Bieker noted that results are from suspension tests. Surface tests are planned for 2007.

- *Could you provide more information about the organic challenge?* In its life cycle, a virus could be excreted with feces. The organic challenge examines possible protective effects and interactions with organic matter.

Protection of U.S. Agriculture: Foreign Animal Disease Threats

Bethany Grohs, U.S. Environmental Protection Agency, Office of Solid Waste and Emergency Response

Grohs is a veterinary medical officer at EPA. She acts as a technical resource for the emergency response program providing assistance to OSCs in addressing animal emergency response issues on their sites. She is currently addressing emergency preparedness and agro-terrorism issues. Agro-terrorism events require response and collaboration by multiple agencies, including USDA, FDA, and EPA.

Historically, USDA responded to agricultural incidents and EPA responded to oil/hazmat spills. Since 9/11, multiple diverse agencies respond jointly to all events. The anthrax events at Capital Hill, the use of 350 search and rescue dogs at the World Trade Center, the outbreaks of foot and mouth disease, and concerns about avian influenza raised the issue of animal health to a national security level.

Grohs defined bioterrorism as the use of biological agents to target morbidity and mortality in humans, animals, or plants. Agro-terrorism targets the financial infrastructure of agriculture through the use of biological, chemical, or radiological agents to affect animals or any agricultural components (*e.g.,* livestock, food supply, crops, agricultural workers). Although agro-terrorism can cause animal and public health issues, the economic impacts are the most destructive. U.S. agriculture is vulnerable to agro-terrorism because of concentrated animal feeding operations (*e.g.,* feed lots, CAFOs), herd susceptibility to foreign animal diseases, economic impact (*e.g.,* a halt to imports and exports), and threat agent availability in other endemic countries. Herds are susceptible to foreign animal disease because animals are exposed to these diseases infrequently and have lost immunity to these diseases. As such, a disease can spread rapidly through a population and cause high mortality. Foreign animal diseases (FADs) are endemic in other areas of the world and may be intentionally or inadvertently introduced to livestock in the United States.

Grohs listed several examples of agro-terrorism agents. Avian influenza, foot and mouth disease, and exotic Newcastle disease are of great concern. Grohs noted that an outbreak of Rift Valley fever is a risk in the Memphis area because Federal Express operations in the area may transport infected mosquitoes. Nipah/Hendra virus is an emerging disease first reported in Malaysia in the nineties. Asymptomatic fruit bats carry the disease in their urine, which may spread the disease to swine-raising operations near the bat caves. Nipah/Hendra virus causes a respiratory and neurologic disease in swine and encephalitis with a 40% mortality rate in humans. When the disease first emerged, PPE needs for humans were unknown and

several responders contracted the disease during depopulation efforts. This incident highlights concerns for worker safety and needs to understand human implications. Grohs provided examples of several recent outbreaks and resulting animal depopulation.

Grohs discussed several challenges faced during a foreign animal disease outbreak. She emphasized the need for preplanning to ensure rapid and effective responses.

- *Worker health and safety*. Often responders do not know what level of PPE is appropriate and necessary. Responders should know what level of PPE to use before arriving at a scene. Responders also must be aware of the impact of PPE when working with live animals (*i.e.*, PPE can scare animals).

- *Carcass handling*. The physical process of carcass disposal is huge problem. Large equipment may be needed to address large animals or large numbers of animals. The location of the animals on land or in water must be considered. In addition, workers may be wearing various levels of PPE that impede activities.

- *Depopulation methods*. When an outbreak is detected, depopulation through humane euthanasia often occurs. For smaller animals, such as birds, carbon dioxide gas has been the historical choice for humane euthanasia. Death from suffocation occurs in about 10 to 12 minutes. Recent research with fire-fighting foam found that foam physically blocks an airway and causes death within about 5 minutes. Discussions are ongoing to identify the most humane method. For larger animals, captive bolt and pithing may be used.

- *Disposal and decontamination*. Having a depopulation and disposal plan in place can drastically reduce the number of animals that need to be disposed of. The more time the disease has to spread, the more animals will require disposal. Timely depopulation and disposal is the current approach for stopping the spread of disease. Grohs presented a graph illustrating the rapid increase in affected animals as a function of time elapsing before implementing a depopulation plan. Ideally, an outbreak should be addressed within 24 to 48 hours. When determining disposal, the number, size, disease, degree of decomposition and other factors must be considered. Grohs briefly mentioned three disposal options. Many more options exist and should be considered during responses. Composting can be cost-effective and rapid, but it can also be difficult to successfully implement. Rendering requires no land disposal and is available through existing infrastructure. However, no surge capacity exists and FDA feed rules regulate the materials that can pass through a rendering plant and enter the food chain. Transportation biosecurity is also a concern. Landfilling (*i.e.*, commercial facilities) and burial (*i.e.*, onsite disposal) are also available. Landfills can handle a large capacity, but the landfill design slows decomposition and permitting concerns and capacity issues exist. Burial on site is inexpensive but can raise agent fate and transport concerns and impact the land value through deed restrictions. Decontamination for foreign animal diseases includes both biosecurity on non-infected farms and cleaning and disinfection after depopulation and disposal on infected farms. All the other farms in an area have increased biosecurity, which includes activities intended to prevent further spread of the disease (*e.g.*, cleaning trucks that enter and leave an area). During the foot and mouth outbreaks in the UK, entire towns were isolated through biosecurity measures. Grohs noted that much of the expense of an outbreak focuses on biosecurity (preventing the spread of the disease) versus the actual decontamination of the infected area, since most FAD agents are not environmentally persistent.

Various organizations and agencies are working toward addressing the challenges faced during foreign animal disease outbreaks. Grohs described four initiatives currently underway to improve preparedness:

- *Emergency Support Function (ESF) 11*. When the National Response Plan was first released, agricultural incidents were not included. ESF 11 is an annex to the plan that formally recognizes agriculture and natural resource incidents and responses. Grohs provided a flow chart illustrating the statutes and plans available to direct responses.

- *Federal Food and Agriculture Decontamination and Disposal Rules and Responsibilities*. This document focuses on decontamination and disposal and outlines the roles and responsibilities of different agencies involved in a response. Overall, the document concludes that agriculture and emergency management communities must work together to address animal health emergencies.

- *Foreign Animal Disease Threats Strategic Plan 2008–2012*. This is a White House–mandated project that involved three focus groups: modeling, countermeasures, and decontamination and disposal. Grohs chaired the decontamination and disposal group. This group focused on foreign animal diseases in livestock and identified necessary national, state, and local actions. Overall, the focus group determined that decontamination and disposal research and preparedness is significantly under-funded. A national operations system was not in place, so a different agency or organization responds to different incidents. Establishing a national system would provide a first step to facilitate information dissemination.

- *Avian Influenza Decontamination*. Grohs briefly discussed avian influenza. Salmonella has been used as a surrogate for avian influenza decontamination research, although other surrogates are available as well. The available industry stockpile of decontaminating chemicals and the translation of effectiveness in a laboratory to effectiveness in the field are large concerns. Research will be examining the effectiveness of common household agents (*e.g.*, soap, detergent, bleach) against avian influenza. Grohs noted that recent research found that some existing detection methods report false positives after use of known effective disinfectants. This research highlights the need to understand how disinfectants affect detection methods.

Question and Answer Period

- *Does the composting disposal option involve pre-shredding?* Pre-shredding is not necessary for birds because they are small. Grohs noted that the process of grinding and pre-shredding larger animals can release additional infectious agents, which is a concern. In rendering, carcasses are reduced in size.

III. Panel Discussion—Lessons Learned, Research and Development Needs, Technology Gaps

Participants in the 2006 Decontamination Workshop panel discussion considered lessons learned from decontamination events and research, identified research and development needs, and described technology gaps. The panel consisted of representatives from various agencies and disciplines involved in decontamination efforts. Participants provided a brief statement of their individual concerns and thoughts. The panel then considered submissions from workshop participants.

Ken Martinez (CDC) highlighted his surprise that CDC and other agencies were not as prepared as they could have been to respond to a New York City anthrax event that occurred in February/March 2006. Five years after the initial anthrax events, there should be a better understanding of method validation and sampling results. An understanding of the transition from sampling results to decontamination was still lacking. Martinez also noted the need for better communication and collaboration between agencies and organizations. Through collaboration and communication, data gaps (*e.g.,* method validation) can be better identified and addressed. Agencies and organizations are working to improve communication and Martinez applauds these efforts. Martinez noted several collaborative efforts and encouraged continued and expanded collaboration. Identifying funding sources for basic research is always a concern. As a specific example, Martinez noted that additional basic research to improve confidence in the BioWatch system is needed.

Lance Brooks (DHS) indicated that DHS uses a whole system approach when considering decontamination issues. The current research focus is on critical infrastructure and high-traffic facilities and identifying restoration time delays and data gaps. DHS is working toward creating baseline restoration plans in anticipation of a major threat event at these types of facilities. Brooks believes that there is value in preparing for low-probability/high-consequence events. Brooks noted that obtaining funding remains difficult; however, a shift is occurring. The recent events of Hurricane Katrina have highlighted restoration concerns and data gaps. Brooks noted that traditionally exercises and decision-making frameworks stopped at the response phase and did not focus on the recovery phase. Brooks listed a number of issues that are of concern (*e.g.,* characterization, agent fate, persistence, infective dose). DHS has not funded decontamination technologies and relies on other agency research in this area. Brooks also noted that cleanup levels drive sampling, decontamination, and clearance efforts. Not only are technology gaps an issue, but also logistical and political issues should be addressed. For example, standardized laboratory analysis methods should be in place before an event occurs. Restoration plans and concurrence with these plans is needed before an event occurs. Brooks provided an example of several poultry houses in which all the birds were killed. The operators knew the procedures to decontaminate and dispose of the carcasses, but the procedures were not pre-approved. Waiting for approval delayed the decontamination effort by months.

Anthony Intrepido (LLNL) has participated in a number of clearance committees and technical working groups. After the September 11, 2001, events, Intrepido spoke with a number of DOD officials about cleanup concerns. Reducing the time required for cleanup was a critical concern. DOD officials addressed decontamination needs in terms of hours versus weeks and months. At that time, completing decontamination within hours seemed inconceivable; however, that goal seems more achievable now. Technology needs force researchers to make technological leaps. Intrepido expressed concern about redundancy in efforts between organizations because research is progressing so rapidly. During the presentations, a workshop participant presented a scenario in which an entire Manhattan city block is contaminated. Intrepido agreed that researchers and policy-makers should consider this scenario and begin to discuss how decontamination of a diverse area would proceed. For example, how would

regulators prioritize and address multiple and conflicting stakeholder needs? Would decontamination proceed based on ability to fund decontamination or would another factor, such as public service, drive decontamination priorities?

Shawn Ryan (EPA/NHSRC) highlighted the value of ongoing research to improve methods in the laboratory combined with engineering experience conducting real-world fumigation. Gaps remain, however, in understanding sampling efficiencies, surface interactions, and spore transport. If researchers cannot understand the limitation of sampling efficiencies, then method validation is questionable. Ryan also noted that large data gaps exist in understanding aerosolization and sampling efficiencies, as well as agent extraction and removal from complex surfaces.

Jeff Kempter (EPA/OPP) addressed only biological agents. Kempter felt that many data gaps exist; however, he focused his comments on two specific concerns. Manufacturers should complete required testing and register products for decontamination uses to eliminate the need for crisis exemptions. Agencies and facilities should emphasize preparedness planning. Some preparedness planning is underway and national guidance is under development. As a nation, however, we should be ready for the next large, high-consequence event. Projects with SFO and in New York City are excellent first steps.

Michael Ottlinger (EPA/NDT) described an anthrax incident in New York City that involved a single residence and a large warehouse with multiple residences that were decontaminated. This incident involved multiple agencies working together in a high-pressure environment because of media involvement. Ottlinger noted that the owner of the larger building conducted the decontamination. When assessing the scenario in which an entire Manhattan city block is contaminated during a threat event, multiple major stakeholders may be involved (*e.g.*, department store chains, hotels, businesses). Decision-makers should examine these events with a business perspective and consider economic impacts. Ottlinger suggested that larger businesses develop plans for addressing threat events and decontamination needs. Government agencies can provide information regarding vendors and resources to these businesses to allow them to complete decontamination. The government should assume decontamination responsibilities for airports and transit systems, as well as small-scale facilities when owners lack the resources to conduct decontamination themselves.

Nancy Adams (EPA/NHSRC) noted that public perception has not been mentioned, though it often drives a decontamination effort. People often want cleanup levels to equal non-detect levels in order to feel safe. The detection limit, however, is based on instrument limitations. The government should examine methods for educating people and addressing public perceptions. In addition, technologies are available to complete decontamination, but these technologies often create extensive amounts of waste and may interact with and destroy non-target materials. Decontamination remains relatively expensive and often the decontamination agents are toxic. There is a need for safe, cheap, rapid, and non-destructive decontamination methods. Adams also noted that research should move beyond the anthrax focus and examine other possible threat agents. Research indicates that existing decontamination methods would address other biological threat agents, but data are needed to support this assumption. Additional efforts are needed in training first responders to confidently and appropriately employ various sampling and collection methods. Adams suggested that agencies, organizations, and disciplines collaborate to address the vast amount of research that still remains.

The panel considered two submissions from workshop participants.

- *In order to make appropriate restoration decisions, biological agent persistence in priority environments (e.g., transit systems, critical infrastructure, outdoor/wide areas) need to be determined. What is the strategy for addressing this need?* Adams responded that current research involves inoculating coupons with known amounts of agent. As part of this research, some of the

coupons are set aside from decontaminant exposures to assess persistence. Based on findings, the most appropriate decontamination strategy for organisms with low persistence may be to allow natural degradation. However, this information must be balanced with information about interactions with varied surfaces and substrates to ensure that the most conservative decontamination approach is applied. A workshop participant noted that NHSRC is planning to expand persistence studies to examine outdoor materials (*e.g.*, brick, soil). These studies are under discussion. NHSRC may also participate in a joint study that would address outdoor decontamination approaches. Ryan noted that NHSRC is also pushing to examine four or five additional agents in persistence studies on complex materials. Martinez noted that very little persistence information is available; however, some new information was presented during this workshop. Martinez believes that workshop participants are responsible for reporting new information to their colleagues. Information sharing is critical because no one agency has all the resources to address all the decontamination concerns. In fall 2005, CDC and EPA met to share information, share ideas, and encourage partnerships in research of environmental microbiology. CDC has also developed a working relationship with the FBI.

- *A noted data gap is the availability of real-time detection technologies that address many agents on many materials.* Adams agreed that this technology was lacking. A system that provides this capability would also need to be inexpensive based on the large number of sensors required to provide meaningful information. Issues of false positives and instrument sensitivity are also problems with real-time detection technologies.

IV. Agenda

Wednesday, April 26, 2006

8:00am Registration/Check-in

PLENARY SESSION

9:00am **Opening Remarks; Conceptual Timeline for Decontamination Events** *Blair Martin, U.S. Environmental Protection Agency (EPA)*

9:30am **Department of Homeland Security (DHS), Science & Technology Chemical/Biological Restoration Programs** *Lance Brooks, Department of Homeland Security (DHS)*

10:00am BREAK

10:15am **Evidence Awareness for Remediation Personnel at Weapon of Mass Destruction (WMD) Crime Scenes** *Jarred Wagner, Federal Bureau of Investigation (FBI)*

SESSION 1: GENERAL DECONTAMINATION ISSUES

10:45am **Validation of Environmental Sampling Methods: Current Research and Related Projects** *Ken Martinez, Centers for Disease Control (CDC)*

11:15am **Decontamination Research at the U.S. Environmental Protection Agency (EPA) National Homeland Security Research Center (NHSRC)** *Nancy Adams, EPA National Homeland Security Research Center (NHSRC)*

11:45am LUNCH

12:45pm **U.S. Environmental Protection Agency (EPA) Regulation of Biological Decontamination** *Jeff Kempter, EPA Office of Pesticide Programs (OPP)*

1:15pm **Test Method Update (Office of Pesticide Programs [OPP] Sterilant Registration Protocol Development)** *Steve Tomasino, EPA/OPP*

1:45pm **U.S. Environmental Protection Agency (EPA): Partner in Protecting the Homeland** *John Edwards, EPA, Office of Homeland Security*

2:15pm BREAK

2:30pm **Technical Support Working Group (TSWG) Decontamination Research and Development Activities** *Rebecca Blackmon, Technical Support Working Group (TSWG)*

3:00pm **A Decontamination Concept of Operations** *Michael Ottlinger*, EPA, National Decontamination Team

3:30pm **Decontamination and Consequence Management Division (DCMD) Disposal Research**.....*Paul Lemieux EPA/NHSRC*

4:00pm **A Sampling of Some of Canada's Decontamination Work**..... *Merv Fingas Environment Canada*

4:30pm **The Government Decontamination Service (GDS): The UK (United Kingdom) Perspective on Decontamination Approaches**.....*Robert Bettley-Smith UK Government Decontamination Service (GDS)*

5:00pm **Environmental Lab Response Network (eLRN) Support and Standard Analytical Methods** ..... *Rob Rothman EPA/NHSRC*

5:30pm ADJOURN

THURSDAY, April 27, 2006

SESSION 2: DECONTAMINATION TECHNOLOGIES

8:00am ***Bacillus anthracis* Spore Detection Using Laser Induced Breakdown Spectroscopy (LIBS)** .....*Emily Gibb EPA/NHSRC*

8:30am **Chlorine Dioxide Fumigation Developments** .....*John Mason Sabre Technical Services*

9:00am **Decontamination Technology Testing and Evaluation**.....*Joseph Wood EPA/NHSRC*

9:30am **Vapor Hydrogen Peroxide (VHP) Fumigation Technology Update**..... *Iain McVey STERIS Corporation*

10:00am BREAK

10:15am **Laboratory Decontamination of 65 Room New Animal Facility Using Chlorine Gas**..... *Mark Czarneski ClorDiSys Solutions, Inc.*

10:45am **Decontamination Research—A New Approach** ..... *Norman Govan UK Defense Science and Technology Lab*

11:15am **Decontamination of Toxins and Vegetative Cells Using Chlorine Dioxide** .....*Terrence Leighton IVD/CHORI*

11:45am LUNCH

12:30pm **Restoration of Major Transportation Facilities Following a Chemical Agent Release** .....*Mark Tucker Sandia National Laboratory*

1:00pm **The Development of Modified Vaporous Hydrogen Peroxide (mVHP) for Chemical- and Biological-Weapons Decontamination**..... *Stephen Divarco, Edgewood Chemical Biological Center (ECBC)*

1:30pm **Spore Contamination: What Concentration Deposits, What Resuspends, and Can We Inhibit Its Transport?** .....*Paula Krauter Lawrence Livermore National Laboratory (LLNL)*

2:00pm **Studies of the Efficacy of Chlorine Dioxide Gas in Decontamination of Building Materials Contaminated with *Bacillus anthracis* Spores***Vipin Rastogi, ECBC and Shawn Ryan, EPA/NHSRC*

SESSION 3: DECONTAMINATION R&D

2:30pm **U.S. Environmental Protection Agency (EPA) National Homeland Security Research Center (NHSRC) Ongoing Research Efforts in Understanding the Efficacy and Application of Decontamination Technologies** ..... *Shawn Ryan EPA/NHSRC*

3:00pm **Rapid Methods to Plan, Verify and Evaluate the Effectiveness of the Decontamination Process**..... *Tina Carlsen LLNL*

3:30pm BREAK

3:45pm **Agent Fate Program**.....*James Savage Defense Threat Reduction Agency*

4:15pm **Stakeholder Issues Surrounding Chemical Agent Restoration**.....*Ellen Raber LLNL*

SESSION 4: PANEL DISCUSSION

4:45 pm **Lessons learned, R&D needs, Technology gaps**

5:30 pm ADJOURN

FRIDAY, April 28, 2006

SESSION 5: RADIOLOGICAL DISPERSION DEVICE DECONTAMINATION

8:00am **Strategy for National Homeland Security Research Center (NHSRC) Radiological Decontamination Research and Development Program**.....*John MacKinney EPA/NHSRC*

8:30am **Decontamination Technologies for Urban Radiological Dispersion Device (RDD) Recovery** .....*John Drake EPA/NHSRC*

9:00am **Radiological Dispersion Device (RDD) Aerosolization Experiments: History / Applications / Results**.....*Fred Harper Sandia National Laboratory*

SESSION 6: WATER DECONTAMINATION

9:30am **Water Distribution System Decontamination**..... *Paul Randall*
EPA, National Risk Management Research Laboratory

10:00am **Decontamination of Water Infrastructure**.....*Greg Welter*
O'Brien and Gere Engineers

10:30am BREAK

10:45am **Adherence and Decontamination of Chemicals and Biologicals**.....*Sandip Chattopadhyay*
Battelle

11:15am **Measurement and Analysis of Building Water System Contamination and Decontamination**. ..... *Stephen Treado*
National Institute of Science and Technology (NIST)

11:45am **Water Decontamination and Detection** .....*John Hall*
EPA/NHSRC

12:15pm LUNCH

SESSION 7: FOREIGN ANIMAL DISEASE / AVIAN INFLUENZA DECONTAMINATION

1:15pm **Determining the Virucidal Mechanism of Action for Foreign Animal Disease** ..... *Jill Bieker*
Sandia National Laboratory

1:45pm **Protection of U.S. Agriculture: Foreign Animal Disease Threats** .....*Bethany Grohs*
EPA, Office of Solid Waste and Emergency Response

2:15pm WRAP UP

2:45pm ADJOURN

V. 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.

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Conceptual Timelines for Decontamination Events

By: G. Blair Martin, Shawn Ryan, Emily Gibb, and Nancy Adams

U.S. EPA, Office of Research and Development
National Homeland Security Research Center

Presented at: Decon Workshop 2006
Washington, DC
April 26 – 28, 2006

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

BACKGROUND

- Most experience with ClO_2 fumigation
- Brentwood P&DC – *B.a.* contaminated
  - 14,000,000 cubic feet
  - Liquid ClO2 generation with emitters in HVAC air handlers
  - HEPA filter/wet ClO2 scrubber/carbon unit
  - Whole building decontaminated at the same time
- Hamilton P&DC – *B.a.* contaminated
  - 7,000,000 cubic feet
  - Brentwood technology relocated/modified
- American Media International (AMI) Building – *B.a.* contaminated
  - 700,000 cubic feet
  - Carbon cells
- Utica, NY house – mold contaminated
  - 40,000 cubic feet
  - Termite tenting procedure
  - Small carbon cells
- Hudson Falls, NY Department Store – mold contaminated
  - 1,000,000 cubic feet
  - Single tarp
  - Small carbon cells

BACKGROUND

- **Elements of a decontamination event**
  - The **decision process** leading to the fumigation and final clearance of the building
  - **Characterization** of the extent of contamination **and monitoring** of the fumigation
  - **Building related activities** including, preparation and maintenance and surroundings for security, safety of the neighborhood, and the ultimate decontamination
  - Selection, design and performance of the **decontamination process**
  - **Disposal** of contaminated materials and/or wastes from the decontamination and building reconstruction
  - **Communication** with affected individuals and the community at large

BACKGROUND

- The body of experience generated provides guidance to improve the timeline for a decontamination event
- These improvements also have the potential to reduce the time and associated cost of the decontamination event
- Factors contributing to improvement include:
  - Cumulative experience with ClO2 fumigation events
  - Technology implementation advances
  - Availability of critical equipment
  - Improved technology for containment of the fumigant
  - Streamlining the approval process
  - Reduced materials removal prior to fumigation
  - Reduced removal/disposal of contaminated material possible

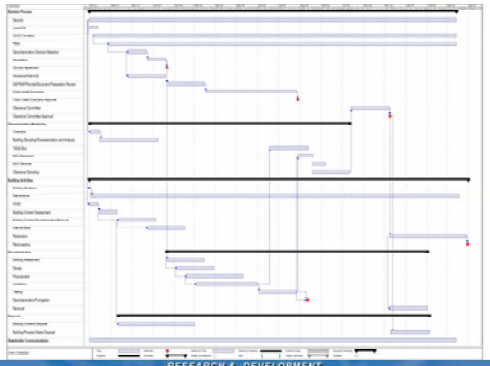
CONCEPTUAL TIMELINES

- This knowledge and experience provides a basis for conceptual timelines that might be achieved in future decontamination events
- **These timelines do not represent any specific event**
- **Conceptual timelines are based on engineering judgment**
- **Many timelines are possible dependent on duration of individual steps in the process**
- Three conceptual timelines are presented
- Principal improvements are:
  - Timeline #1- Original implementation of the technology
  - Timeline #2 -Technology advances with stockpiled equipment
  - Timeline #3 - FIFRA registered of fumigant
- Each one is based on a specific set of assumptions

CONCEPTUAL TIMELINE #1

- **This timeline does not represent any actual event**
- **It is a example based on the state of technology in 2001**
- Assumptions:
  - A large volume building has been contaminated
  - Aerosolized *B.a.* spores have spread throughout the facility
  - Fumigant is not registered under FIFRA – "Crisis Exemption" required
  - Formal plans (RAP, SAP, AAMP) are required
  - A Technical Working Group (TWG) is formed
  - Indemnification and/or insurance must be negotiated
  - Extensive forensic, characterization and clearance sampling are required
  - The technology has not been used for this purpose
  - The decontamination equipment must be procured/fabricated
  - Some materials and/or contents are removed prior to fumigation
  - Building re-occupancy is contingent on approval of a clearance report by the appropriate authority
  - Time for restoration will depend on a number of factors

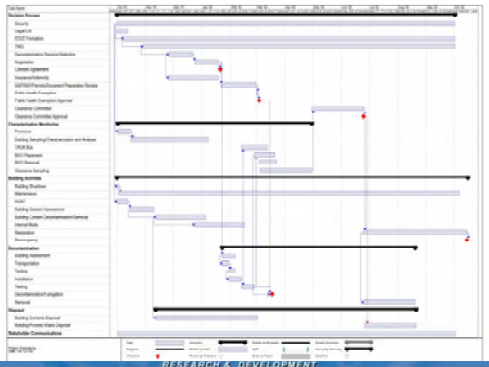
CONCEPTUAL TIMELINE#1



CONCEPTUAL TIMELINE #2

- Conceptual improvements based on the experience to date
- Assumptions:
  - ClO2 fumigation is an established technology
  - Past experience expedites FIFRA document preparation
    - "Generic" or previously prepared RAP, SAP and AAMP available
    - Current CAD drawings of building and HVAC are available to aid in assessment and sampling
  - Improvement in technology approach
    - Negative Air Units to contain spores
    - Tenting of building to eliminate or reduce need for sealing
    - Carbon units in place of wet scrubbers
  - Long lead time equipment has been stockpiled
    - Emitters
    - ClO2 generator

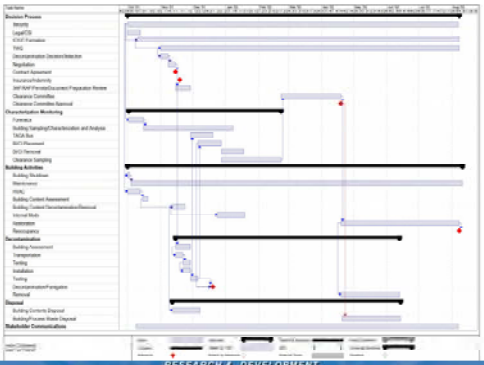
CONCEPTUAL TIMELINE #2



CONCEPTUAL TIMELINE # 3

- Additional improvements may be possible
- Assumptions:
  - ClO2 is a FIFRA registered fumigant
  - A full time TWG is convened to review documents
  - The owner or vendor can bind insurance in lieu of indemnification
  - Most building contents are fumigated in place
    - Sensitive items are removed
    - External decontamination minimized
  - Minimal removal of building structure
  - Minimum activity in building in high level of PPE

CONCEPTUAL TIMELINE #3



Conclusions

- These timelines do not represent any actual event
- Current experience is only for *B.a.*
- Conceptual timelines are based on engineering judgment derived from past experience
- These conceptual timelines show the potential for significant reductions in time for a fumigation event
- Additional improvements may be possible
  - Improving the linkage of forensic and characterization sampling
  - Optimizing the characterization and clearance sampling approach
  - Revising the criteria for number and placement of biological indicators (BIs)
- R&D can also lead to expanded applicability
  - Additional chemical and biological agents
  - Further improvement in containment techniques

DHS S&T Chem/Bio Restoration Programs

2006 Workshop on Decontamination, Cleanup, and Associated Issues for Sites Contaminated with C, B, or R Materials
Washington, DC

April 26, 2006

Mr. Lance Brooks
Biological/Chemical Countermeasures
Plans, Programs, & Requirements
Science & Technology

Homeland Security

Biological - Restoration of Airport Facilities

Goal: To reduce the overall time to restore a critical transportation facility following a biological attack.

- **NAS Study**
- **Sample Methodology & Planning Tools**
  - BROOM development and test
  - Rapid Viability Method Development
  - Sampling Efficiency Study
- **Final Restoration Plan**
  - Expert Review of Restoration Plan
  - Fumigation Implementation Plan

Demonstration of Rapid Restoration Techniques
- Field Demonstration of Rapid Viability Method
- Field Demonstration of Data Management Tools

Final Demo held January 2006

National Academy of Sciences Study

National Research Council Committee on Standards and Policies for Decontaminating Public Facilities Affected by Exposure to Harmful Biological Agents: How Clean is Safe?

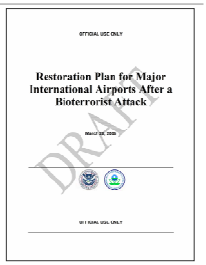
National Academy of Sciences Study:
Reopening Public Facilities After a Biological Attack:
A Decision-Making Framework (2005)

- **Infectious Dose**
- **Natural Background**
- **Quantitative Risk Assessment**
- **Past Cleanup Efforts**
- **Residual Contamination**

Restoration Plan for Airports

Chapters include:
- Characterization
- Remediation
- Clearance
- Recommendations for Pre-Planning

Appendices include:
- Considerations for the Notification Phase
- Considerations for the First-Response Phase
- Available Biological Sampling and Analysis Methods
- Considerations for Sampling Design
- Probability-Based Sampling
- Available Decontamination Technologies
- Handling Decontamination Waste at SFO
- Sampling Info Forms for Characterization and Clearance
- Annotated Characterization Sampling Plan Template
- Remediation Action Plan
- Annotated Clearance Sampling Plan Template
- Restoration Contact List



Currently leveraging this work to develop plans for Transit Systems

Biological - Wide Area Restoration

Wide Area Restoration Demonstration
- **Produce Plan for Demonstration in FY06**
  - **ID venue/partners (e.g. urban area, EPA, etc)**
  - **Draft management plan prior to the start of the demonstration program in FY07**
- **This planning in partnership with EPA, urban area, and other identified partners as needed**
- **Utilize SDST findings/guidance**

Large-Scale Restoration of Bio-Contaminated Areas
- ***Analysis/Policy*** **(HSI)**
- ***Technology/Protocols*** **(TSWG)**

Study results and developed protocols will be incorporated into the Wide Area Demo

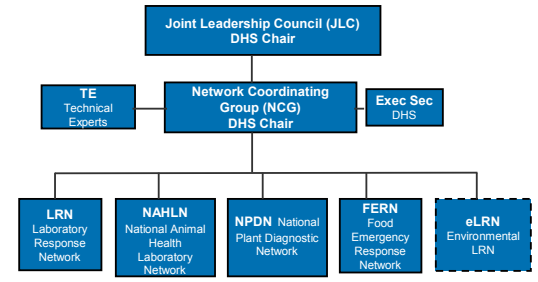
Chemical - Facilities Restoration Demonstration

Goal: To reduce the overall time to restore a critical facility following a chemical attack.

- **Establish**
  - -Partnerships (facility, federal, state, & local)
  - -Airport Partner (LAX)
  - -Threat scenarios
- **Survey and identify**
  - existing clean-up guidelines
  - existing / emerging sampling methods
  - existing / emerging decontamination technologies
- **Develop**
  - Pre-planning/rapid approval of restoration process
  - Methods for contamination characterization
  - Decontamination and verification for surfaces
  - Clearance Methods and decision tools

Conduct Tabletop exercises and demonstration

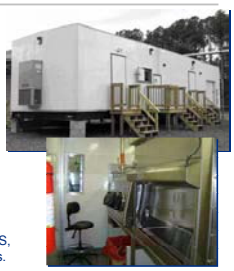
Integrated Consortium of Laboratory Networks



Homeland Security

All Hazards Receipt Facilities (Prototypes)

Purpose: Protect staff and infrastructure of analytical laboratories by ensuring correct handling of unknown samples through determination of potential highly toxic or dangerous chemical, radiological, or explosive content



- Capability comprises recommended analytical tools and protocols for use.
- Protocols are consistent with maintenance of evidentiary credibility.
- Protocols developed as interagency effort among DHS, DoD, EPA, FBI, CDC, and state public health lab reps.

Status: prototypes near completion and to be placed at Public Health Labs for one-year evaluation period.

Homeland Security

Mobile Laboratory (PHILIS) Prototype

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

- hundreds of environmental samples per day
- capable of full spectrum chem agent and TIC analysis
- quantify down to Permissible Exposure Level
- archive samples, maintain chain-of-custody consistent with forensic use

Field test conducted FY05

Homeland Security

Evidence Awareness for Remediation Personnel at WMD Crime Scenes

Presented to:

2006 Workshop on Decontamination, Cleanup, and Associated Issues for Sites Contaminated with Chemical, Biological, or Radiological Materials

Washington, DC

April 2006

By Jarrad R. Wagner, Ph.D.

WMD Crime Scenes are Complex

EPA photo of metal debris from WTC at Fresh Kills landfill

FBI photo of mail sorting operation from Capitol Hill Anthrax

What is a WMD Crime Scene?

- A crime scene where weapons of mass destruction have been prepared, used, or discovered.
- Weapons of mass destruction include chemical, biological, radiological, nuclear, and explosive materials.

WMD Incident Response Phases

- Tactical Phase
  - Removal of the hostile threat
- Operational Phase
  - Rescue / Control
    - Protect the Public
    - Identify and mitigate hazards:
      - Explosives, HazMat, Structural, Electrical, etc…
- Crime Scene Phase
  - Evidence Collection
  - Packaging
- Remediation Phase- mitigate toxic hazards

WMD Crime Scene Operations

- Contaminated Crime Scene Processing
  - FBI HMRU and FBI Hazardous Materials Response Teams
    - Other teams and personnel may be integrated with FBI personnel, depending on the circumstances

FBI processing of WMD crime scene

12 step process

1. Preparation
2. Approach the scene
3. Secure and protect scene
4. Preliminary survey
5. Evaluate evidence possibilities
6. Narrative description
7. Photograph the scene
8. Prepare Diagram/sketch
9. Conduct detailed search
10. Collect evidence
11. Final survey
12. Release crime scene

XII. Release the Crime Scene

- Advise owner of potential hazards
  - WMD/HazMat Clean-up
- Re-entry may require warrant
- Leave inventory
- Release scene to appropriate party

Three Critical Aspects of WMD Evidence Collection

- Personal and public safety #1
- Sample integrity and preservation
- Accurate documentation and chain of custody

Chain of Custody

- The movement and location of physical evidence from the time it is obtained to the time it is presented in court.

Forensic Evidence

- Anything that indicates a crime was committed
- Anything taken from scene or left at the scene by the suspects
- Anything taken from the scene or left at the scene by the victims

WMD Evidence

- Any Chemical, Biological, or Radiological materials collected during a WMD incident must be taken to an appropriate, accredited laboratory for analysis.
- Also, items contaminated with materials
- Coordinated by FBI HMRU Science Program and CBSU

Critical Evidence

- Improvised chemical, biological, or radiological device components
- Concentrated WMD material in solid or liquid form
- Paperwork detailing attack planning
- Identification documents discovered at scene

Notification Protocols

- Contact EPA on scene coordinator
- EPA coordinator should notify FBI case agent or WMD Coordinator
- FBI case agent will notify WMDOU and HMRU through WMD Coordinator
- Conference call will be conducted with WMDOU and HMRU to determine next steps

Collection Protocols

- Evidence needs to be collected with appropriate photographs and documentation
- Either HMRU will respond to scene with Hazardous Materials Response Team to collect or appropriately certified hazmat team can make entry for collection in coordination with FBI
- Collected materials will be over-packed, container decontaminated, and delivered to FBI case agent for entry into evidence database
- Materials will be transported to appropriate laboratory for analysis

Transition

- Evidence is recognized
- Clean-up is stopped, or steps are taken to preserve evidence while remediation continues elsewhere in scene
- Notifications are made
- Evidence is collected
- Remediation continues

Conclusions

- Remediation personnel play a critical role in WMD attack recovery.
- Critical evidence may still be present after crime scene phase and must be preserved.
- Appropriate procedures ensure safe collection and exploitation of the evidence and require communications between remediation agency (EPA) and crime scene agency (FBI).
  - Don't attempt to process a WMD crime scene without contacting the FBI
  - Don't take samples with the intent of giving them to the FBI as evidence

Validation of Environmental Sampling Methods: Current Research and Related Projects

CAPT Kenneth F. Martinez, MSEE, CIH
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National Research Council Key Issue

"Research should assess the efficiency of collection and analysis for each type of biological agent. Unless the sampling efficiency is known, the amount of contaminant deposited cannot be estimated with confidence."

National Research Council. *Reopening Public Facilities After a Biological Attack: A Decision Making Framework.* National Research Council Committee on Standards and Policies for Decontaminating Public Facilities Affected by Exposure to Harmful Biological Agents: How Clean Is Safe? The National Academies Press. Washington, DC. 2005. pg 134.

Government Accounting Office Key Issues

- How efficient are the various testing methods, and what minimum amounts of anthrax spores have to be present if anthrax is to be detected by these methods?
- How effective are the various methods for extracting material from samples for analysis?

Government Accounting Office. Report to the Chairman, Subcommittee on National Security, Emerging Threats, and International Relations, House Committee on Government Reform, House of Representatives. *Anthrax Detection Agencies Need to Validate Sampling Activities in Order to Increase Confidence in Negative Results.* March 2005. GAO-05-251. pg 76.

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

Goals

- Aerosolize *B. anthracis* (Sterne) into a chamber
- Low level target concentrations desired to determine sampling limit of detection
- Compare three surface sampling methods - vacuum, wipe, and wet swab on stainless steel and carpet
- Compare three air sampling methods – cascade impactor, PTFE membrane filters, gel filters
- Compare three laboratories
- Compare one sample pass to multiple passes

Requirements

- Develop a system to:
  - produce multiple identical samples of settled bacteria at several concentrations to test several surface sampling methods and
  - to produce airborne bacterial concentrations for comparison of air sampling methods.

Approach

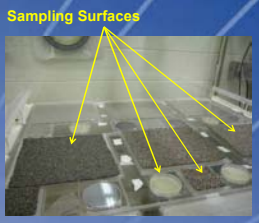
- Chamber constructed that used stirred settling to achieve a desired concentration. Sampling surfaces then exposed to allow particles to settle onto them.
- Stirred settling in a chamber with height H is described in Hinds (1999) using the following equation:

$$N(t) = N_o \exp(-V_{ts} \cdot t / H)$$

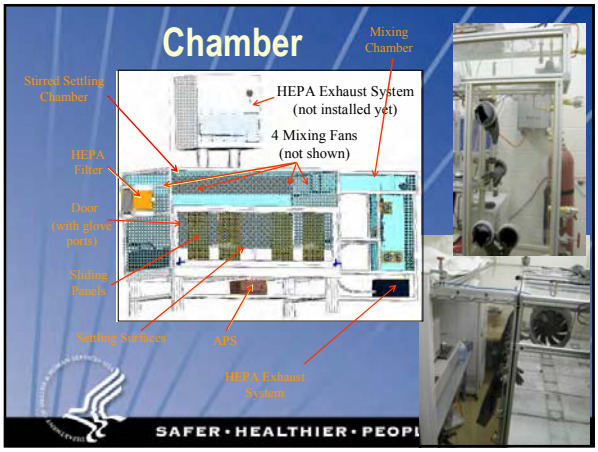
- For particles with a gravitational settling velocity V_{ts}, the initial number concentration in the chamber N_o is decreased to N(t) at time t.

Sample Surfaces / Samplers

- Agar plates as reference samples (8 each)
  - Test coupons (stainless steel or carpet)
    - 12' x 12' (18 each)
    - 4' x 4" (12 each)
  - Wipes
  - Swabs
  - Vacuum (with filter sock)



Chamber



Chamber Operation

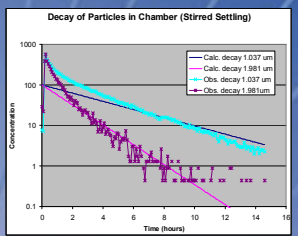
- Samples placed inside chamber and covered
- Chamber sealed
- Powder (about 2 mg) manually introduced to venturi tube from small sample vial
- Generation chamber sealed off from rest of system
- Air run through mixing system to clear out aerosol
- Fan cycling controller started

Chamber Operation - cont

- Chamber pump turned on for faster aerosol decay
- Chamber monitored with APS
- When desired concentration reached, sample covers removed
- When settling completed (4-12 hours), samples recovered
- Chamber vented to clear remaining aerosol
- Surfaces uncovered and sampled

Initial Results

- Chamber tested with BG bacteria
- Initial decay rapid (electrostatic losses?), but approaches theoretical decay after about 2 hours



Inter-sample Variability

Evaluated by comparison of measured inter-sample variability with that expected from Poisson variability, i.e., randomly deposited particles

Variability for 4 runs with 26 agar plates each

Average CFU/plate	44.385	66.577	60.462	28.240
Relative Standard Deviation	0.181	0.156	0.162	0.195
Poisson Rel. St. Dev.	0.150	0.123	0.129	0.188
Ratio of Observed to Poisson	1.205	1.275	1.258	1.035

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Current Status

- Paper on chamber design and function – drafted
- Finished characterization of the chamber
- Performed tests to characterize best reference sample (agar) treatment
- Solved problem of re-aerosolization of spores by covering (non-sample) surfaces with light oil
- Next: perform test to compare first pass surface sampling to multiple passes

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Evaluation of Surface Sample Collection Methods for *Bacillus* Spores on Porous and Non-Porous Surfaces

Gary S Brown
Sandia National Laboratories
Albuquerque, NM

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Study Objectives

Provide a robust scientific and statistical evaluation of current swab, wipe, and vacuum surface sample collection methods for *Bacillus* spores

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Study Objectives

Collection

Extraction

Recovery

collection η · extraction η = recovery η

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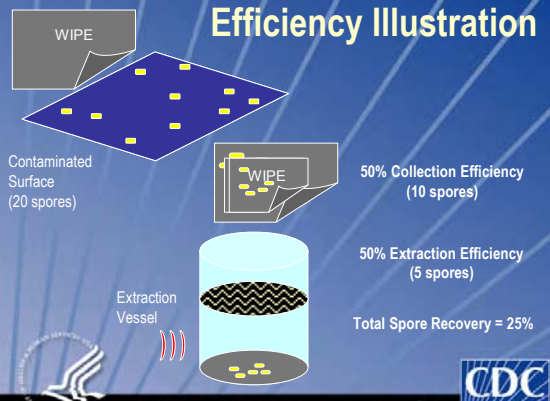
Efficiency Illustration



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Chamber

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Spore Deposition

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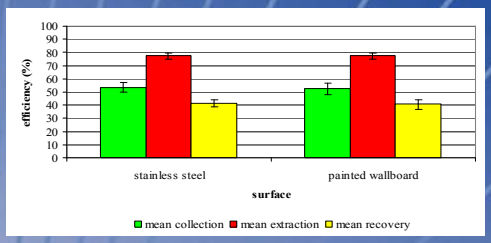
Swab Efficiency



No significant difference in efficiency (p>0.05) between surfaces

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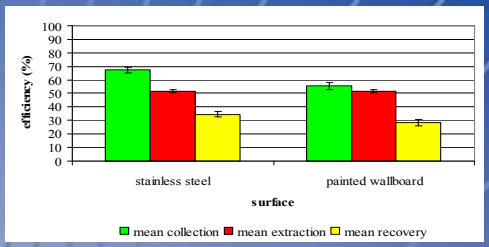
Wipe Efficiency



Painted wallboard significantly lower efficiency (p<0.05) than stainless steel

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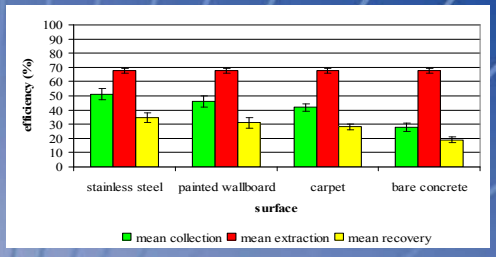
Vacuum Sock Efficiency



Concrete significantly lower efficiency (p<0.05) than other surfaces

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Characterization Sample Parameters

- Quantitative Result Required

Parameter	Collection Method		
	Swab	Wipe	Vacuum
LOD (CFU/sample area)	100-150	400-600	400-600
Sample Area (cm^2)	10-100	100-1000	1000-10,000
Sensitivity (CFU/cm^2)	1-1.5	0.4-0.6	0.04-0.06
Sensitivity (CFU/m^2)	10,000-15,000	4000-6000	400-600

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Clearance Sample Parameters
- Qualitative Result Required

Parameter	Collection Method		
	Swab	Wipe	Vacuum
LOD (CFU/sample area)	10-15	15-20	15-20
Sample Area (cm^2)	10-100	100-1000	1000-10000
Sensitivity (CFU/cm^2)	0.1-0.15	0.15-0.2	0.015-0.02
Sensitivity (CFU/m^2)	1000-1500	1500-2000	150-200

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Related Research

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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),TSWG, and Federal Protection Service

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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.

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Re-suspension of *Bacillus anthracis* Spores
(K. Martinez)

- *Purpose*: To elucidate factors affecting the extent of re-suspension of B. anthracis spores from contaminated envelopes during mail processing.
- *Main objective*: To develop standardized procedures for assessing exposure potential from cross-contaminated mail using simulants and later with actual material from 2001 attacks.
- *Collaborators*: US Army Edgewood Chemical and Biological Center, EPA, and FBI

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Re-suspension of *Bacillus anthracis* Spores

- Studies motivated by concern that cross-contamination during mail processing may have been the source of exposure for 2 anthrax cases where source of exposure was unclear.
- Preliminary studies with *Bg* have produced the following.
  - Very good uniformity among envelopes coated simultaneously
  - Predictable levels of contamination can be achieved
- Cross-contaminated letters from the anthrax attacks of 2001 have been sequestered.
- Results may allow a better understanding of the infection risk to those manipulating such cross-contaminated mail and aid in developing appropriate control recommendations.

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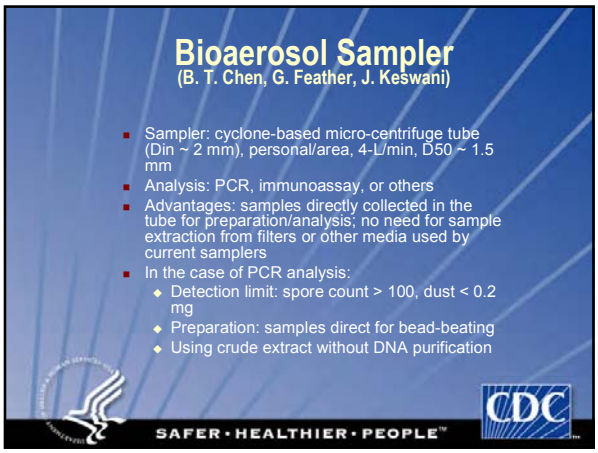
Bioaerosol Sampler
(B. T. Chen, G. Feather, J. Keswani)
Sampler: cyclone-based micro-centrifuge tube (Din ~ 2 mm), personal/area, 4-L/min, D50 ~ 1.5 mm
Analysis: PCR, immunoassay, or others
Advantages: samples directly collected in the tube for preparation/analysis; no need for sample extraction from 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
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Decontamination Research at the USEPA National Homeland Security Research Center

Nancy Adams, Director
Decontamination and Consequence Management Division
National Homeland Security Research Center
Office of Research and Development
US Environmental Protection Agency

National Homeland Security Research Center

- Organized in 2002 to address decontamination of buildings and water systems
- Announced as permanent on November 2004
- Three divisions
  - Water Infrastructure Protection
  - Threat and Consequence Assessment
  - Decontamination and Consequence Management
- Headquarters in Cincinnati, OH
  - DC staff
  - RTP staff
  - LV staff
  - Detailees (DOE, ORD, OSWER, other)

NHSRC Mission

Provide state-of-the-art scientific knowledge and technology to emergency responders, building owners, water utility operators, health departments, and others to:

- enhance their ability to quickly detect contamination,
- effectively respond, and
- safely restore areas contaminated by a terrorist attack.

Current Scope

Contaminants
- Pathogenic bacteria and viruses, biotoxins
- Chemical warfare agents
- Toxic industrial chemicals
- Radiological contaminants

Targets
- Buildings, open areas
- Water systems
- Transportation infrastructure

Technical Areas
- Enhance response capabilities
- Detection (sampling and analysis)
- Containing a release
- Decontamination/treatment methods
- Disposal of decontamination wastes

Selected External Collaborations

- Edgewood Chemical and Biological Center (DoD)
- Lawrence Livermore National Laboratory (DOE/DHS)
- Sandia National Laboratory (DOE/DHS)
- National Institute of Standards and Technology
- National Academy of Sciences
- Centers for Disease Control and Prevention
- Counterproliferation Research Committee (CPRC/DoD)
- Defense Intelligence Agency
- Central Intelligence Agency
- Immune Buildings Program (Army/Navy)
- Department of Homeland Security
- National Counterterrorism Center
- Office of Science and Technology Policy
- City of Cincinnati
- Federal Emergency Management Agency
- Army Research Laboratory
- Air Force Research Laboratory
- Naval Surface Warfare Laboratory
- Real Estate Roundtable
- Canadian Food Inspection Agency
- Department of Transportation
- Society of Toxicology
- Homeland Security Advanced Research Projects Agency
- Defense Advanced Research Projects Agency
- Technical Support Working Group
- Defense Threat Reduction Agency
- Numerous other private groups

Specialized Research Facilities

RESEARCH & DEVELOPMENT
Building a scientific foundation for sound environmental decisions

Current Research: Detection

- Microbe persistence
- Real-time spore identification
- Prion surrogates
- Adapting OP-FTIR technology
- Emissions sampling during incineration
- Sampling efficiency for *Bacillus anthracis* on surfaces
- Workshop on sampling issues
- Improved biological indicators (BIs)
- Laser-based methods for rapid chem/bio detection in air and on surfaces

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Current Research: Containment

EPA Test House

- Re-suspension studies
- Infiltration studies
- Sheltering-in-place
  - Residential
  - Large building
- Outdoor and indoor airborne dispersion
  - Human activities
  - Environmental conditions
  - Indoor sinks/re-emitters
- Retrofit guidance for safer buildings
  - Filters
  - HVAC use
- Graduate program in building protection

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Current Research: Decontamination

- Survey of available methods
- Optimization of fumigant procedures for buildings
- Reports on remediation of anthrax-contaminated buildings
- Fumigant studies
  - Tenting
  - Scrubbing
- Test coupons for decontamination (aerosol deposition)

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Current Research: Decontamination

- RDD and water system decon
- RDD surface clean-up and decon database
- Bacteriophage systems for decon
- Portable ClO_2 system evaluation
- Fumigant reaction kinetics
  - Decomposition
  - Penetration
  - By-products
- Systematic decon studies
  - **Concentration, temperature, RH, dwell time**
  - **Material demand**
  - **Material compatibility**

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Current Research: Disposal

- Thermal destruction research
  - Bench-scale reactor
  - Surrogates for bioagents
  - Ceiling tiles, carpet
  - Indoor/outdoor materials
  - Agricultural wastes
- Portable gasifier project
- Incinerator modeling of agent destruction, emissions
- Autoclave waste sterilization
- Development of test method for sampling/analysis of bacterial spores in incinerator stack gases

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Disposal Research

- Studies related to the disposal of waste materials contaminated with biological and chemical agents in landfill environments
- Decision Support Tool for decontamination wastes
  - Packaging
  - Transport
  - Thermal treatment locations
  - Disposal sites

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Building a scientific foundation for sound environmental decisions

Engineering Support and Guidance

- **Lessons learned from anthrax decontamination**
- **Economic and engineering analysis of options**
- **On-site support for anthrax decontamination**

American Media Inc., Boca Raton, FL

Brentwood P&DC

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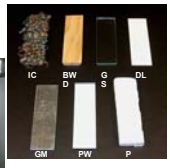
Technology Testing and Verification

- Commercially ready, or near-ready technologies
- Testing at vendor specified conditions
- Tests of air cleaners, filters, detection systems, decontamination systems



Industrial carpet
Bare pine wood
Glass
Decorative laminate
Galvanized metal
Painted wallboard paper
Painted concrete

Lab-scale testing

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Questions?

EPA's Regulation of Biological Decontaminants

Presented to

Workshop on Decontamination, Cleanup, and Associated Issues for Sites Contaminated with Chemical, Biological, or Radiological Materials
Sponsored by EPA's Office of Research and Development

Holiday Inn Capitol
Washington, D.C.

Carlton J. (Jeff) Kempter, Senior Advisor
Office of Pesticide Programs
Environmental Protection Agency
April 26, 2006

OVERVIEW

- Background
- Regulatory Issues
- Research Issues
- Preparedness Issues
- Summary

I. BACKGROUND

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

Background—Pesticides

- EPA approval for a pesticide under FIFRA is either by registration (i.e., license) or by exemption (i.e., emergency, quarantine or crisis use)
- *Registration*:
  - For a Section 3 registration, a registrant must submit an application to EPA along with required product labeling and data.
  - For a Section 24(c) registration, a registrant must submit an application to a state along with required labeling and data; the state issues a 24(c) registration but EPA has 90-day review period to accept or reject it.

FIFRA Exemptions

- *Exemption*:
  - For Section 18 exemptions (specific, public health or quarantine), a state or federal agency submits its request to EPA for review and approval. Exemption is effective for 1 to 3 years.
  - In event of a crisis, EPA, a state, or other federal agency may issue a crisis exemption. Exemption is effective for 15 days.
  - For anthrax cleanups, EPA issued 28 crisis exemptions and rejected 35 in response to 63 requests.

II. REGULATORY ISSUES

- **What efficacy data should EPA require to register an "anthrax" claim?**
- **What should EPA's labeling requirements be?**

Disinfectants

- Disinfectants must pass either the AOAC Use Dilution Test or Germicidal Spray Products Test to be registered (see http://www.epa.gov/oppad001/dis_tss_docs/dis-01.htm)
- Tests may include:
  - *Salmonella choleraesuis*
  - *Staphylococcus aureus*
  - *Pseudomonas aeruginosa*

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Disinfectant Claims for Non-Spore Forming Microorganisms

- To claim inactivation of a specific non-spore forming microorganism, a disinfectant must be successfully tested against that microorganism (e.g., Y. pestis) or an acceptable surrogate using one of the above tests.
- If EPA reviews and accepts the test results, the specific microorganism may be listed on the product's labeling.

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Sterilants and Sporicides

- To be registered as a sterilant or sporicide, a liquid, gas or vapor product must pass the AOAC Sporicidal Activity Test (SAT) (AOAC Official Method 966.04)
  - on both non-porous and porous surfaces,
  - for both *Bacillus subtilis* and *Clostridium sporogenes*, and
  - achieve no growth on all 720 carriers.

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Sterilant Claims for Specific Spore-Forming Bacteria

- To claim inactivation of a specific spore forming bacterium, a sterilant must be successfully tested:
  - the virulent agent (e.g., *B. anthracis* or an acceptable surrogate)
  - with the AOAC SAT
  - on porous and non-porous surfaces.
- If EPA reviews and accepts the test results, the specific spore-forming microorganism may be listed on the product's labeling.

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Gases/Vapors for Large Spaces

- A gas or vapor product intended for use in enclosed spaces larger than a glove box (40 cu. ft.) must also pass a simulated use test that includes using biological indicators.

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Possible New Sporicidal Product Category

- EPA is exploring a possible new product claim--"Decontaminant"
  - A claim of inactivation of specific spore-forming bacteria on inanimate surfaces (e.g., *B. anthracis*) could be based on data other than the complete AOAC SAT.
  - The product would be tested:
    - against a virulent agent (or acceptable surrogate),
    - using either the AOAC SAT or a quantitative sporicidal test method, and
    - on porous or non-porous surfaces (or both, if desired)

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Are AOAC SAT and Quantitative Methods Equivalent?

- Do AOAC SAT and quantitative sporicidal tests provide an equivalent challenge?
- EPA (Ft. Meade Lab) has run the AOAC SAT side-by-side with the Three Step Method (a quantitative sporicidal test).
- These tests may help EPA determine the performance standard that will need to be met for a "decontaminant" claim.

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"Decontaminant" Product Labeling Issues

- EPA will 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
- EPA will issue guidance in 2006 for the terms and conditions of registration
- EPA will seek public comment on a draft proposal of this approach before issuing it in final form

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III. Decontamination Research

- EPA's Office of Research and Development has initiated several decontaminant test programs:
  - Environmental Testing and Verification Program (ETV) (see http://www.epa.gov/etv)
  - Systematic Decon (nearing completion)
  - Technology Testing and Evaluation Program (TTEP) (getting started)
  - Water Security (underway)

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Decontaminant Testing Research Issues

- **How can projects be coordinated within EPA and with other agencies?**
  - Through direct discussions and through groups such as the Interagency Expert Panel on Anthrax Test Methods and Surrogates
- **What test protocols should be used?**
  - Preferably validated or well-developed methods that serve a regulatory purpose and are widely accepted
- **Should testing parameters be set according to manufacturer's directions or determined by researchers?**
  - Either can be done (e.g., ETV vs. Systematic Decon and TTEP), but researcher-determined parameters can lead to improvements.
- **How to minimize test variables and maximize number of products tested?**
  - The objectives of the project have to be clear and specific
  - Available data from previous related tests can help minimize the variables and allow testing of more decontaminants

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IV. PREPAREDNESS ISSUES

- **What guidance is available on preparedness planning for bio-terrorism?**
  - NRT Anthrax Technical Assistance Document
  - CDC's "Comprehensive Procedures for Collecting Environmental Samples for Culturing *Bacillus anthracis*"
  - National Response Plan and the Biological Incident Annex
  - Guidance tends to be sector specific (i.e., food/agricultural, buildings, transportation, water systems, outdoors)

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Preparedness Guidance

- New guidance on the way:
  - "Biological Restoration Plan for Major International Airports" (DHS/Lawrence Livermore Labs)
  - "Cleanup Decision-Making Guidance for Biological Incidents" (OSTP Sub-committee on Decontamination Standards and Technologies)
  - "Wide-Area Biological Restoration" (DHS)
  - "Protocols for Restoration of Large-Scale Bio-Contaminated Urban Areas" (TSWG)
- National Decontamination Portfolio (EPA)
- Quick Reference Guides (EPA)

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Overall Preparedness

- **How can the U.S. Government improve the Nation's overall preparedness to responding to a bio-terrorism event?**
  - The U.S. Department of Homeland Security is preparing a report on this topic to submit to Congress (as required by FY 2006 Department of Homeland Security Appropriations Act).
  - The report will address several areas relevant to this workshop—improving decontamination technologies, registering decontaminants, pre-positioning assets, etc.

How Clean Is Safe?

- Is guidance available on "How Clean is Safe?"
  - In June 2005, the National Academies of Science (NAS) issued "Reopening Public Facilities after a Biological Attack—A Decision-Making Framework" (http://books.nap.edu/catalog/11324.html)
  - Some key conclusions:
    - "Standard infectious doses for harmful biological agents…cannot be determined with confidence…."
    - "A contaminated facility cannot be guaranteed to be agent-free even after cleanup because it is impossible to prove the complete absence of an agent."
    - "…there is insufficient information to quantify a 'safe' amount of residual biological agent in a decontaminated facility."

V. SUMMARY

- **EPA has developed a significantly improved AOAC SAT and is working collaboratively to validate a quantitative sporicidal test method (i.e., the TSM).**
- **Registration of "Decontaminant" products (intended to kill spore-forming bacteria) will require agent-specific efficacy data and will have label limitations. Guidance is being developed.**
- **EPA is coordinating & leveraging its research on bio-decontaminants across several agencies.**
- **Guidance on planning for bioterrorism response is available and new key documents are coming soon.**

Test Method Update

(OPP Sterilant Registration Protocol Development)

2006 ORD Decontamination Workshop

Stephen F. Tomasino, Ph.D.
EPA Office of Pesticide Programs
Microbiology Laboratory
Fort Meade, Maryland

Overarching Goals

- Advance the science of efficacy testing and develop an alternative to the AOAC method with a quantitative carrier-based procedure
- Perform collaborative, standardized testing to develop and validate test methods acceptable across federal agencies
- Design studies to generate comparative efficacy data to aid in the development of regulatory guidance
- Identify a suitable surrogate for *B. anthracis*
- Set the stage for the evaluation of other biological agents

Tiered Approach

- Tier 1: Evaluate and improve selected methods using *Bacillus subtilis*
  - Select a quantitative method for surrogate studies
  - Improve the current method (AOAC method **966.04**)
- Tier 2: Evaluate surrogates of *Bacillus anthracis*
  - Select at least one surrogate using a quantitative method
- Tier 3: Conduct collaborative validation testing of selected test method/surrogate combination
  - Validate a quantitative method and at least one surrogate

Start-up Activities and Timeline

- 2003 - IAGs established
- 2003 - QAPP developed (category 2)
- ID priorities – formulations and surface type(s)
- Provide training and conduct readiness reviews
- 2004 - AOACI contract signed
- 2004 - Quantitative method research launched
- 2004 - TSM advanced
- 2005 - Surrogate (*Bacillus anthracis*) studies conducted
- 2005 - Collaborative to improve the AOAC method completed
- 2006 - Research initiated on other select agents (*Yersinia, Francisella*)
- 2006 - Validation of the TSM to be launched
- 2006 - Research on additional carrier materials and formulations

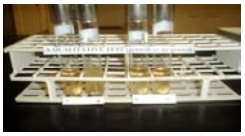
Topics (highlights) for Discussion

1. Modifications to the AOAC Sporicidal Activity Test, Method 966.04: Collaborative Study
2. Comparative Evaluation of Two Quantitative Test Methods for Determining the Efficacy of Liquid Sporicides and Sterilants on a Hard Surface
3. Comparative Study with *Bacillus anthracis*-Ames and Two Potential Surrogates (*Bacillus subtilis* and *Bacillus anthracis* – Δ Sterne)
4. Validation Protocol for the Quantitative Three Step Method
5. Comparison of AOAC SAT and TSM – performance standards
6. Future Projects

Modifications to the AOAC Sporicidal Activity Test, Method 966.04: Collaborative Study

Performance Standard for a Sterilant Claim (AOAC Method 966.04)

- Test challenge = *Bacillus subtilis* and *Clostridium sporogenes*
- Hard surface (Porcelain Carriers); porous surface (suture loops) - 60 carriers each
- Full study = 720 carriers
- Passing result = zero carriers positive
- Requires 21 days of incubation/heat shock
- Lacks standardization in several key steps



Proposed Modifications to the AOAC Method

- Replace the soil extract nutrient broth with a chemically defined medium for *B. subtilis* spore production
- Replace porcelain carriers with stainless steel carriers
- Add a carrier count procedure for enumeration of spore inoculum
- Establishment of a mean minimum spore titer per carrier
- Add a neutralization confirmation procedure

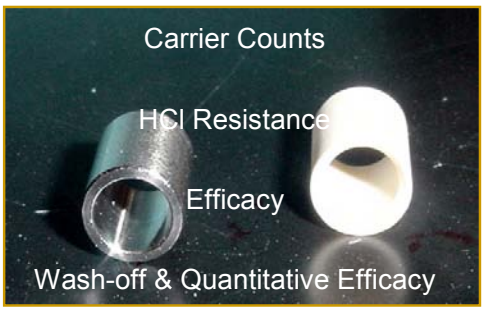
Timeline of Events

- EPA contract with AOAC signed in Sept. 2004
- AOAC Expert Review Panel (ERP) formed in Dec. 2004
- ERP convened on Jan. 10-11, 2005
- Study protocol was approved by AOAC *Official Methods* program in May
- Five-lab collaborative study launched in June
- Data submitted in August
- Data analysis completed in December
- Recommendations (Alternative Method) presented in manuscript to J. AOACI in March 2006

Comparing the Current Method and Proposed Replacements in the Collaborative Study

Sporulation Medium	**Carrier Type**	
	Current Method Porcelain (PC)	*Modified Method* Stainless Steel (SS)
Current Method Soil extract nutrient broth (SENB)	SENB/PC	SENB/SS (Not Studied)
Modified Method Nutrient agar with manganese sulfate(NA)	NA/PC	NA/SS

Parameters for Comparison



Chemical Treatments

Chemicals	**High (*passing*)**	**Low (*failing*)**
1.0% Hydrogen Peroxide & 0.08% Peroxyacetic acid	30 min contact	5 min contact
6.0% Sodium Hypochlorite	pH adjusted & 60 min contact	pH unadjusted & 10 min contact
2.6% Glutaraldehyde	8 hr contact	1 hr contact

Comparative efficacy results for high chemical treatments

Chemical Treatment	Medium/Carrier Combination[a]	Outcome and Number of Positive Carriers			
		Lab No. 1	Lab No. 2	Lab No. 3	Lab No. 4
Peracetic acid and hydrogen peroxide	SENB/PC	Fail (1+)	Pass (0+)	Pass (0+)	Pass (0+)
	NA/PC	Fail (1+)	Pass (0+)	Pass (0+)	Pass (0+)
	NA/SS	Pass (0+)	Pass (0+)	Pass (0+)	Pass (0+)
Glutaraldehyde	SENB/PC	Pass (0+)	Pass (0+)	Pass (0+)	Pass (0+)
	NA/PC	Pass (0+)	Pass (0+)	Pass (0+)	Pass (0+)
	NA/SS	Pass (0+)	Pass (0+)	Pass (0+)	Pass (0+)
Bleach	SENB/PC	Fail (2+)	Fail (2+)	Pass (0+)	Pass (0+)
	NA/PC	Fail (3+)	Pass (0+)	Pass (0+)	Pass (0+)
	NA/SS	Pass (0+)	Pass (0+)	Pass (0+)	Pass (0+)

Comparative efficacy results for low chemical treatments

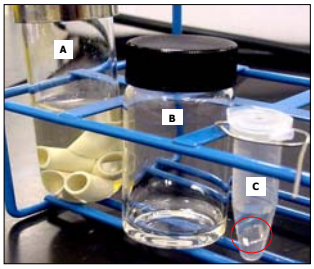
Chemical Treatment	Medium/Carrier Combination[a]	Outcome and Number of Positive Carriers			
		Lab No. 1	Lab No. 2	Lab No. 3	Lab No. 4
Peracetic acid and hydrogen peroxide	SENB/PC	Fail (16+)	Fail (28+)	Fail (21+)	Fail (28+)
	NA/PC	Fail (29+)	Fail (17+)	Fail (28+)	Fail (30+)
	NA/SS	Fail (20+)	Fail (30+)	Fail (30+)	Fail (20+)
Glutaraldehyde	SENB/PC	Fail (15+)	Fail (9+)	Fail (5+)	Fail (23+)
	NA/PC	Fail (17+)	Fail (26+)	Fail (22+)	Fail (21+)
	NA/SS	Fail (3+)	Fail (27+)	Fail (1+)	Fail (29+)
Bleach	SENB/PC	Fail (13+)	Fail (20+)	Fail (16+)	Fail (29+)
	NA/PC	Fail (28+)	Fail (24+)	Fail (6+)	Fail (2+)
	NA/SS	Fail (3+)	Fail (22+)	Fail (11+)	Fail (5+)

AOAC Official Method 966.04; Sporicidal Activity of Disinfectants

"Alternative" Method (Manuscript submitted to J. AOACI) *First Action 2006*

- Equivalency tests support the modifications
- Control counts/HCl resistance/efficacy were comparable
- Nutrient agar for spore production
- Target carrier count: 10^5 to 10^6 spores per carrier
- Neutralization confirmation procedure
- Numerous editorial changes
- Stainless steel *not* recommended

Comparative Evaluation of Two Quantitative Test Methods for Determining the Efficacy of Liquid Sporicides and Sterilants on a Hard Surface: A Pre-Collaborative Study



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. Volume is 10 mL per five carriers, 1 mL per carrier, and 400 µL per carrier for AOAC Method 966.04, ASTM E 2111-00, and TSM, respectively.

Mean log reduction (LR) Values and Method Performance Statistics for ASTM E 2111-00 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/peroxyacetic acid	**6.7**	0.45	0.52	**7.3**	0.25	0.75	0.25

[a] t test; two-tailed p-value for comparison of mean LR values between test methods
SD_r = repeatability standard deviation
SD_R = reproducibility standard deviation

Additional Attributes Necessary

- Questionnaire Submitted to Analysts
  - 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
- Manuscript (pre-collaborative study) submitted to J. AOACI

Comparative Study with *Bacillus anthracis*-Ames and Two Potential Surrogates (*Bacillus subtilis* and *Bacillus anthracis* – Δ Sterne)

Background and Goals

- The health and safety requirements for handling and testing virulent *B. anthracis* are difficult to satisfy for most laboratories, and without a surrogate, efficacy testing of virulent *B. anthracis* will be limited to a few laboratories.
- One important criterion is the resistance of spores to standard sporicides, i.e., the spores of an acceptable surrogate should exhibit comparable or higher resistance compared to the virulent strain of interest.

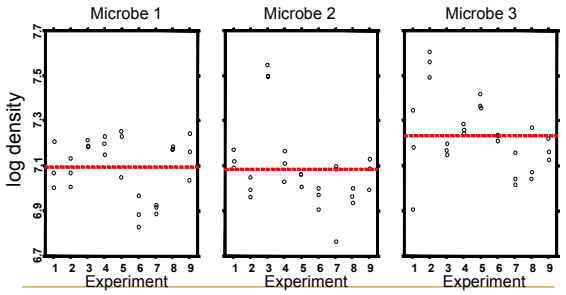
Microbes

- **Microbe 1:** *Bacillus subtilis* ATCC 19659
- **Microbe 2:** *Bacillus anthracis* (Ames)
- **Microbe 3:** *Bacillus anthracis* (Δ Sterne)

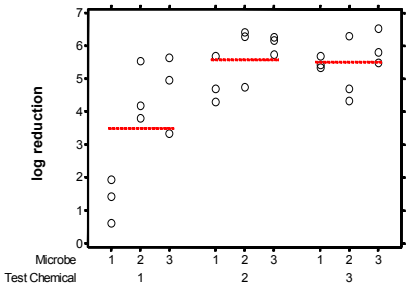
Chemical Treatments

- **Test chemical 1:** Sodium hypochlorite – unadjusted pH (pH ~10.0), 1:20 overall dilution (~3000 ppm)
- **Test chemical 2:** Sodium hypochlorite – adjusted pH (pH 7.0±0.5), 1:20 overall dilution (~3000 ppm)
- **Test chemical 3:** hydrogen peroxide (1.0%) and peroxyacetic acid (0.08%)

Control Carrier Counts



Treated Carriers: display of the 27 observed LR values



Mean LR (*RSD*)

Microbe	Sodium Hypochlorite unadjusted pH	Sodium Hypochlorite adjusted pH	Hydrogen peroxide/ peroxyacetic acid
B. subtilis	**1.3** (*0.66*)	**4.9** (*0.71*)	**5.5** (*0.18*)
B. anthracis - Ames	**4.5** (*0.91*)	**5.8** (*0.92*)	**5.1** (*1.0*)
B. anthracis - Δ Sterne	**4.6** (*1.2*)	**6.0** (*0.28*)	**5.9** (*0.53*)

With only one exception (sodium hypochlorite unadjusted/*B. subtilis* compared to *B. anthracis* - Ames; p=0.04), the pairwise comparisons of mean log reductions showed statistical insignificance.

Conclusions

- Based on this study, *B. subtilis* appears to be a conservative choice for a surrogate for *B. anthracis* - Ames.
- The Δ Sterne strain of *B. anthracis* also appears to be a suitable candidate.
- *B. subtilis* will be used as the test microbe for the validation of the TSM.
- The applicability of the study conclusions are limited to liquid sporicides applied to a hard surface.

Validation Protocol for the Quantitative Three Step Method

Overview of the TSM Validation

- AOACI under contract to facilitate
- OPP Microbiology Lab is the lead lab
- Draft protocol reviewed by AOACI in March 2006
- 8-10 lab validation study, volunteers available
- One microbe – *Bacillus subtilis*
- Three chemicals, each with three levels (treatments)
- Carrier type is glass
- Three replications per laboratory
- AOAC Method 966.04 as the reference method
- Launch in Spring/Summer 2006
- Potential outcome – a validated quantitative method for liquids on a hard surface!

Proposed TSM Testing Scheme

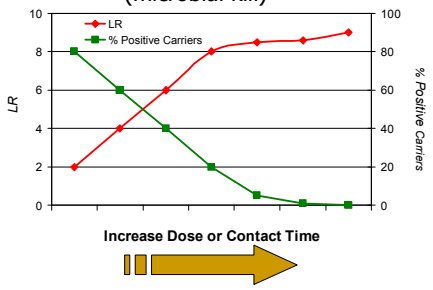
Rep	Treatment	Test Method Performed	
Rep 1 (Day 1)	Sodium Hypochlorite	TSM	AOAC 966.04
	1. High	Yes	Yes
	2. Medium	Yes	Yes
	3. Low	Yes	Yes
	4. Water Control	Yes	
Rep 1 (Day 2)	Hydrogen peroxide/peracetic acid	TSM	AOAC 966.04
	1. High	Yes	Yes
	2. Medium	Yes	Yes
	3. Low	Yes	Yes
	4. Water Control	Yes	
Rep 1 (Day 3)	Glutaraldehyde	TSM	AOAC 966.04
	1. High	Yes	Yes
	2. Medium	Yes	Yes
	3. Low	Yes	Yes
	4. Water Control	Yes	

Determining the Efficacy of Sporicidal Chemicals Using AOAC Method 966.04 and the Quantitative Three Step Method

Background and Objectives

- With the interest in adopting a quantitative test method to replace or augment the AOAC SAT, questions have been raised about the relationship between the outcome of the AOAC SAT (frequency of positive carriers) and log10 reduction (LR) values generated by a quantitative method.
- The main goal was to develop efficacy data, both quantitative and qualitative, and compare the outcomes for liquids tested on hard, non-porous surfaces only.
- In this study, a set of commercially available test chemicals were subjected to the AOAC SAT and the quantitative Three Step Method (TSM) in a side-by-side fashion.

Theoretical Response (microbial kill)



Experimental Highlights

- Test methods: AOAC Sporicidal Activity Test (SAT) and Three Step Method (TSM)
- Test microbe: *Bacillus subtilis* (ATCC 19659)
- The *B. subtilis* spore suspension was prepared using nutrient agar amended with manganese sulfate. A stock suspension of *B. subtilis* was used to inoculate both the porcelain penicylinders used in the AOAC SAT and the 5 x 5 mm glass coupons used in the TSM.
- Target carrier counts: AOAC SAT: 1.0 x 10^5 – 1.0 x 10^6 spores/carrier; TSM: 5.0 x 10^6 – 5.0 x 10^7 spores/carrier
- Petrifilm™ was used for spore recovery and enumeration.

Low Efficacy Treatment
3000 ppm bleach unadj. for 10 min

- AOAC SAT
  - 30/30 +
  - 30/30 +
  - 30/30 +

⟺

- TSM (LR)
  - 1.1
  - 0.1
  - 0.0

High Efficacy Treatment
6000 ppm bleach adj. for 60 min

- AOAC SAT
  - 0/30 +
  - 0/30 +
  - 0/30 +

⟺

- TSM (LR)
  - 6.8
  - 6.8
  - 7.1

Results

- When zero positives occurred in the AOAC SAT, the TSM LR was very high (≥ 6)
- When many positives occurred in the AOAC SAT, the TSM LR was very low (0-1)
- Study provided examples of medium to high LR (5-7) when the AOAC SAT failed with few to numerous positives

Future Projects

- *Bacillus* – application of the current modifications on testing against gases and porous material (silk and dacron loops)
- *Clostridium* – stainless steel and porous materials
- Evaluation study of surrogates of *Yersinia pestis and Francisella tularensis*
- Investigation of various coupon materials for quantitative efficacy evaluation of decontamination chemicals
- Comparative evaluation of quantitative test methods for fumigants

Acknowledgements
(Collaborators and Vendors)

- Edgewood Chemical Biological Center
- U.S. FDA (Denver District and Winchester, MA)
- Presque Isle Cultures
- AOAC International
- Volunteer Laboratories
- Dr. Martin Hamilton

U.S. Environmental Protection Agency:
Partner in Protecting the Homeland

Presented to

2006 Workshop on Decontamination, Cleanup and Associated Issues for Sites Contaminated with CBR

April 26, 2006

Presentation Summary

- EPA's Office of Homeland Security
- EPA's Homeland Security - **Responsibilities**
- EPA's Homeland Security - **Capabilities**
- EPA's Homeland Security - **Activities**
- EPA's Homeland Security Programs
  - Threat Response and Incident Management
  - Biodefense
  - Critical Infrastructure Protection
  - Food and Agriculture Security

EPA Office of Homeland Security

- Established on February 6, 2003
- Director reports to the EPA Administrator
- Leads and coordinates homeland security at EPA:
  - High priority and cross-media activities
  - Policy and budget development
  - Issue resolution

- Supports program offices and regions in taking on new homeland security responsibilities while carrying on traditional missions.
- Serves as primary liaison to White House, DHS, other Federal agencies, and external organizations on matters related to homeland security

EPA Office of Homeland Security -- Internal Roles

- **Leadership and Policy Development**
  - **Implements Administrator's homeland security agenda**
  - **Support Administrator's Policy Coordinating Committee**
    - Chaired by Administrator/Deputy Administrator, OHS is Executive Secretary, includes AAs/RAs
  - **Homeland Security Collaborative Network**
    - Chaired by Director of OHS and Includes senior managers in programs with homeland security responsibilities
    - Meets biweekly to address homeland security policy & budget development
- **Communication/Coordination**
  - **Brief Deputy Administrator regularly; meet with senior Agency officials, often**
  - **Receive and evaluate critical and time-sensitive Information for dissemination to those with a need-to-know**
  - **Lead and coordinate Agency interaction on intra- and inter-Agency workgroups**

EPA Office of Homeland Security -- External Roles

- Represent Administrator/Deputy Administrator on numerous inter-agency, high-level committees, workgroups, etc.

- Ensure appropriate program participation in White House and DHS activities.
- Point-of-contact on Homeland Security Presidential Directives (HSPDs).
- Primary liaison to external partners.
- Keep Administrator/Deputy Administrator informed and advised on external issues and progress.

EPA Responsibilities -- Homeland Security Presidential Directives (HSPDs)

- **HSPD 5 – Management of Domestic Incidents**
  - National Incident Management System
  - National Response Plan
- **HSPD 7 – Critical Infrastructure Protection**
  - "Sector-Specific Agency" for water
    - Vulnerability assessments
    - Best security practices for utilities
- **HSPD 8 – National Preparedness**
  - Nationally significant terrorist incidents
  - Assistance to first responders
  - Law enforcement/forensic support to DOJ/FBI

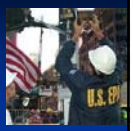
EPA Responsibilities
- - Homeland Security Presidential Directives (HSPDs)

- **HSPD-9 Defense of US Agriculture & Food**
  - National water quality surveillance & monitoring systems
  - Laboratory networks to support Water Sentinel
  - Licensing antimicrobials/pesticides for WMD agents (also for HSPD 10)
  - Biomass Disposal Strategies (Interagency Concept of Operations)
- **HSPD-10 Biodefense for the 21st Century**
  - Classified
  - Decontamination/Lab Capacity taskings
- **HSPD-12 Policy for a Common Identification Standard for Federal Employees and Contractors**
  - Integrate smart card, public key infrastructure, biometric technologies into our systems

EPA Homeland Security Capabilities
- - leveraging core competencies

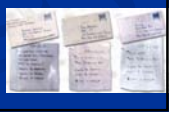
- EPA's mission: to protect human health and to safeguard the environment
- EPA has longstanding capabilities in its core programs that are directly related to homeland security
  - Emergency response
  - Water quality protection
  - Pesticides for crop, livestock, and human health protection
  - Hazardous materials cleanup
  - Radiation monitoring
  - Research & development
- In the last five years, we have been called upon to respond to domestic incidents and enhance our capabilities and role in several areas

EPA Homeland Security Capabilities
- - Enhancing Capabilities and Role



- **September 11, 2001**
  - World Trade Center - Technical Support/Sampling/Public Relations/Disposal
  - Pentagon - Air Monitoring/Health & Safety
  - Western Pennsylvania - Evidence Collection/Assessment
- **Anthrax Attacks**
  - Capitol Hill - Sampling/Assessment/Cleanup/Disposal/Clearance
  - USPS Brentwood, DC & Hamilton, NJ - Oversight/Technical Support
  - Other Federal buildings - Oversight/Post-cleanup Sampling /Technical Support/Clearance

- **Columbia Space Shuttle Disaster**
- **Ricin at Capitol Hill** - Technical Support/Cleanup /Disposal/Clearance



- **Hurricane Katrina**

EPA Homeland Security Program Office Activities

Office of Prevention, Pesticides, and Toxic Substances (OPPTS)
- Food and agriculture security support Emergency exemption requests
- Acute Exposure Guideline Limits (AEGL)
- Chemical data/expertise on pesticides and industrial chemicals
- Licensing authority for antimicrobials to inactivate pathogens and pesticides
- Establish rules for storage/disposal of pesticides and pesticide applicator certification program

Office of Research and Development (ORD)
- Water infrastructure protection research*
- Building and outdoor decontamination research*
- Threat and consequence assessment research*
- Lab

Office of Solid Waste and Emergency Response (OSWER)
- Emergency preparedness and response*
- National Response Plan/ National Incident Management System*
- Environmental Response Teams*
- National Response Support Corps*

Office of Solid Waste and Emergency Response (continued)
- Building and critical infra-structure decontamination*
- National Decon Team*
- Disposal
- Chemical industry infrastructure support
- Lab capacity and capabilities*
- BioWatch – Consequence management*
- Continuity of Operations Plan/Continuity of Government (COOP/COG)*

Office of Water (OW)
- Drinking water and wastewater infrastructure protection*
- Best water security practices
- Vulnerability assessments and emergency response plans*
- Tools for preparedness and emergency response*
- Monitoring/surveillance network pilot (Water Sentinel)*
- Financial assistance to states and tribes
- Information-sharing with sector and partners (secure Information Sharing and Analysis Center/ISAC)*

EPA Homeland Security Program Office Activities

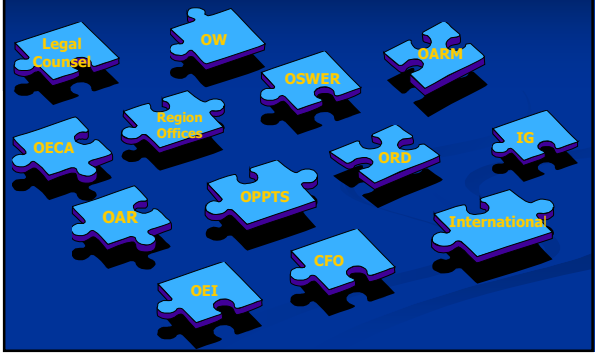
Office of Air and Radiation (OAR)
- Radiation emergency preparedness and response*
- Radiological Emergency Response Team (RERT)*
- RADNET
- Ambient air monitoring
- BioWatch – system deployment/enhancement*
- Building air protection

Office of Administration and Resource Management (OARM)
- Facility and employee security*
- Physical critical infrastructure protection *
- National Security Information – custodian and secure systems*
- Design and construction of Sensitive, Classified Information Facilities (SCIFs) and Secured Access Facilities (SAFs)
- Monitoring of Homeland Security Advisory System (HSAS) threat conditions*

Office of Enforcement & Compliance Assurance (OECA)
- Civil and criminal enforcement
- Forensic evidence collection and laboratory analysis
- National Counter-Terrorism Evidence Response Team (NCERT)*
- Counter-terrorism incident response support/ investigation*
- Administrator's protective detail

Office of Environmental Information (OEI)
- Information protection and access policy *
- Information infrastructure and cyber protection *
- Information technology
- Data management

EPA Office of Homeland Security Coordination of Activities



EPA Homeland Security Programs

- Threat Response and Incident Management
- Biodefense
- Critical Infrastructure Protection
- Food and Agriculture Security

Threat Response and Incident Management

EPA's Emergency Response Program

- Responds quickly and decisively to releases of hazardous substances or discharges of oil
- Supports state/local efforts
- National Oil and Hazardous Substances Pollution Contingency Plan (NCP) serves as the cornerstone of national HAZMAT preparedness and response system and is key element of National Response Plan
  - 250 EPA On-Scene Coordinators (OSCs) delegated authority to manage incidents
- EPA can also provide 24/7 scientific and engineering research technical support

Threat Response and Incident Management

Support for Our On-Scene Coordinators

- 1 National and 13 Regional Response "Teams"
- Federal Special Teams under the NCP, including:
  - **EPA's Environmental Response Team (3 locations, 2 Trace Atmospheric Gas Analyzer vans)**
  - **EPA's Decon Team**
  - **EPA's Radiological Emergency Response Team (in 2 locations, scanning vehicles, mobile labs)**
  - **Other Federal Special Teams, such as USCG Strike Teams**
- Immediate Access to Emergency Response Contractors
  - **contracts provide immediate access to field technical expertise & services**
  - **contracts for cleanup personnel, equipment, and services**
    - **Transportation and disposal of hazardous wastes is a mandated subcontracting activity**

Threat Response and Incident Management

EPA's Emergency Response Assets

Threat Response and Incident Management

Law Enforcement/Forensic Support

- Criminal Investigation Division
  - **Fully authorized law enforcement officers**
  - **235 special agents**
  - **Memorandum of Understanding (MOU) with FBI for Environmental Crimes; WMD MOU in Draft**
- National Enforcement Investigations Center
  - **Chemical analytical capabilities**
  - **Forensic and rapid public health assessments**
  - **Accredited and nationally recognized in forensic environmental analysis**

- National Counter-terrorism Evidence Response Team
  - **Core team based in Washington DC**
  - **Four five-member field teams nationwide integrating investigative expertise of EPA CID Special Agents and science/field expertise and fixed lab support from NEIC**

Threat Response and Incident Management

Environmental Labs Capacity and Capability

- 37 fixed and 8 mobile laboratories nationwide
  - Additional contract laboratory capability
- Labs support multiple missions
  - Oriented toward routine analysis of industrial chemicals, radioactivity, pesticides, and conventional pollutants
- EPA is prepared to help with a national need to build environmental laboratory capacity
  - Laboratory diagnostic surge capacity needed during crises – e.g., 9/11 and anthrax attacks
  - HSPDs require national interconnected lab networks for water surveillance, BioWatch, and food security
  - Signed MOU establishing the Integrated Consortium of Lab Networks (ICLN) (CDC, DHS, and others) including expert work groups
  - Developed compendium of lab capability

Threat Response and Incident Management

Broad-area Air Monitoring Capabilities

- More than 3,000 state-owned air monitoring stations are operated routinely
- Additional mobile air rapid response laboratory under development
- National Monitoring System under development to provide near real-time data on ambient radiation levels
  - Building on EPA's Environmental Radiation Ambient Monitoring System
  - Adding deployable component
- Airborne Spectral Photometric Environmental Collection Technology (ASPECT) air monitoring
  - Small airplane detects and provides GIS mapping of chemicals and several radionuclides

Biodefense

Decon Team

- Highly-specialized unit
- Equipped and trained to decon buildings, structures
- WMD focus
- Collaborate with EPA National Homeland Security Research Center and Pesticides Lab
  - Agent detection
  - Clean up methods and microbial products
  - Equipment
  - "How clean is clean" protocols

Technology/Research & Development

- National Homeland Security Research Center
- Threat assessment and simulation of biological attacks
- Development and validation of environmental sampling and analysis methods
- Evaluation of air filtration systems for buildings
- Evaluation of building and water system decontamination methods
- Evaluation and user guidance for disposal of waste
- Development of tools and data to assess public health risk

Biodefense

Antimicrobial Analysis and Certification

- Authority to license use of antimicrobial chemicals to inactivate human and animal pathogens on inanimate surfaces and in water
- Evaluating the safety and efficacy of decontamination chemicals and developing supporting laboratory test methods
- Coordinating with CDC to recommend antimicrobials effective for inactivating pathogens as outbreaks occur
- Working to complete anthrax testing
  - Need other decontamination chemicals to be tested and made available to address other threats

Biological Capabilities

- 2 Biosafety Level 3 facilities
- Primary role is with agents that are persistent in the environment

Critical Infrastructure Protection

Water Security—Federal Lead

- EPA has an effective water security program that is providing the tools and assistance that the water sector needs to prevent, detect, and respond to an attack

- Under the Safe Drinking Water Act and the Clean Water Act, EPA regulates conventional contaminants in drinking water and ambient water

- HSPDs 7, 9, and 10 (National Biodefense Policy) establish a key EPA role

Critical Infrastructure Protection

Drinking Water and Wastewater – Sector Specific Agency

- Ensured that drinking water systems prepare vulnerability assessments (VAs) and emergency response plans
  - 168,000 drinking water systems
    - 53,400 are community water systems
    - About 9,000 are required to do VAs and plans
  - 16,000 public wastewater treatment works
    - About 3,000 serve major metropolitan areas
- Provide technical assistance and training for VAs, emergency response plans, and security enhancements
- Provide critical response tools
- Develop best security practices

Critical Infrastructure Protection

Drinking Water and Wastewater – Sector Specific Agency

- Working with DHS to develop Sector Specific Plan (SSP) for water infrastructure in accordance with the National Infrastructure Protection Plan (NIPP)

- Developing a drinking water contaminant warning system (Water Sentinel)
  - Pilot monitoring and surveillance system to develop "proof of concept"
  - Collaborative effort with key federal and water sector partners

Critical Infrastructure Protection

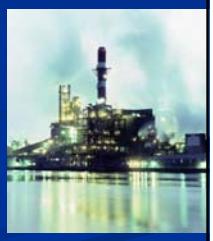
Technology/R&D—Water Security

- Threat assessment and simulation of attacks on water and wastewater systems
- Development and validation of sampling and analysis methods
- Evaluation of effectiveness of current treatment methods
- Evaluation of sensors for early warning systems
- Development and evaluation of decontamination methods for distribution systems
- Rapid health risk assessment expert system for attacks on water systems

Critical Infrastructure Protection

Chemical Sites now DHS Lead

- Risk Management Program provides relevant data
  - Prevent and prepare for accidental releases of hazardous chemicals to the air from facilities that make, use, or store such substances
- Other regulatory programs also relevant:
  - Regulate hazardous wastes from "cradle to grave"
  - Permit chemical facilities that generate or manage hazardous waste
  - Prevent and prepare for releases from petroleum facilities
  - Regulate safe manufacturing, storage and use of pesticides and industrial chemicals
- Providing data to DHS, FBI as requested



Food and Agriculture Security

Pesticide Protection

- License use of pesticide chemicals
- Establish safe levels of pesticides in food
- Collaborate with USDA to identify effective pesticides
  - Prepare rapid approval if needed
- Strengthen federal requirements for purchase of most toxic pesticides and for safe storage of large quantities

Animal Carcass Disposal

- Support USDA / DOI (e.g., AI) with expertise on the safe disposal of diseased animals and by-products
- Currently developing a carcass disposal guidance for AI
- Coordinating with USDA/FDA on emergency response plans animal health emergencies

Concept of Operations

- Decon/Disposal Plan developed in concert with USDA, FDA, and others (HSPD 9)
- USDA AI Playbook

Summary

- EPA Office of Homeland Security is leading and coordinating Homeland Security activities and programs
- EPA has responsibilities applicable to a wide range of homeland security threats
- Current EPA capabilities and activities are being leveraged to support critical Homeland Security priorities

A Decontamination Concept of Operations:

A good plan today is better than a perfect plan tomorrow.

Michael E. Ottlinger, PhD, DABT
US Environmental Protection Agency
Nat'l Decontamination Team

Purpose of Writing a CONOPS Document:

If you can't put it into words, you probably don't have a clear idea of what you are trying to do.

NDT Mission Elements

- Policy and Management
- Scientific and Technical
- Operational Employment
  (operational art)

Strategic Objectives

- Provide technical expertise in support of regions
- Focus on effective delivery of decon options
- Enhance planning and preparedness: END-TO-END decon planning
- Enhance technical partnerships - leverage
- Provide liaison (push and pull) between field and lab
- Identify operational shortfalls

Tasks

- Development of decon SOP's (TTP's)
- Liaison with fed, state, local partners
- Participation in key working groups
- Development of technical information
  - Decontamination science
  - Decontamination methods (pros and cons)
  - Decontamination **validation** (bench and field)
  - Decontamination resources (logistics)
  - Disposal solutions

US EPA Partners in Decontamination

Individual Training and Readiness

- Scientific, engineering, or medical disciplines
- First responder procedures and practices
- National Incident Management System
- NRP, NCP, and Federal Agency policies
- Regional plans and policies
- Sampling
- Risk assessment and risk communication
- Health and safety

How Does NDT Engage in a Response?

- Selected ICS staffing by NDT members:
  - Ops, EU, Health & Safety, Reg. Offices
- Technical reach back
  - Tox, Medical / HP, IH, Engineering, Sampling…
- Specialized Equipment
  - Communications vehicle, various field equipment
- Assistance with decon resource source selection
  - Effective, validated, available, cost effective
- Interagency coordination and technical working group participation

Why ICP and On-Scene Training and Experience?

- ICP participation benefits from field experience
- Field operations benefit from an ICP perspective (appreciation of management requirements)
- Reconnaissance is a crucial planning tool
- Flexibility of team employment (all experience matters)

NDT is an All Hazards Asset and *Not* a *Silver Tea Set*

A flexible and available resource

Elements of an End-to-End Decontamination Plan

- Agent identification
- Extent of contamination
- Avoidance and containment
- Priorities
- Tactics
- Logistics and cost
- Wastes and disposal
- Scheduling/Timeline
- Quality Assurance

Operational Art

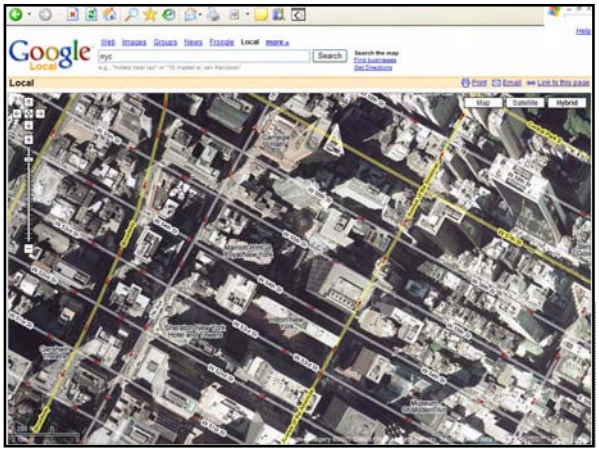
- ***The use of all available methods, techniques, tactics, and procedures to support effective END-to END decontamination planning.***

Scenario Testing:

Providing critical theoretical and practical analysis of the plan.

Anthrax Scenario

- Consider a large area persistent infectious agent release
- Envision an urban area with complex and varied infrastructure
- Begin planning for the restoration and remediation phase
- *Make some modest guesses and use some slight imagination*



Event Assumptions

- Detected by Biowatch 24-72 hours post release
- Agent released into the outside air and settled on ground and surfaces
- Spread inside buildings
- Public transit systems shut down
- Mandatory evacuation ordered
- Area secured (avoidance)

FEMA Milestones

We Join the Fight Here

CRISIS MANAGEMENT		CONSEQUENCE MANAGEMENT			
RESPONSE ACTIVITIES		RESTORATION ACTIVITIES			RECOVERY ACTIVITIES
NOTIFICATION	FIRST RESPONSE	CHARACTERIZATION	REMEDIATION/ CLEANUP	CLEARANCE	REOCCUPANCY
Receive and assess information Identify suspect release sites Relay key information to appropriate agencies	HAZMAT and emergency actions Forensic investigation Public health actions Screening sampling Determine agent type, concentration, and viability	Detailed characterization of biological agent Characterization of affected site Site containment Risk communication Characterization/ environmental sampling and analysis Initial risk assessment Clearance goals	Decontamination strategy Remediation action plan Worker health & safety Site preparation Source reduction Waste disposal Decontamination of sites and/or items Decontamination verification	Clearance sampling and analysis Clearance decision	Renovation Longer-term environmental and public health monitoring Reoccupation decision

Getting Started

- Initial sampling yields a crudely defined two dimensional picture of the contaminated area (a perimeter first)
- Ground level sampling is ongoing
- Three dimensional sampling plans are being discussed but are impractical to implement

Immediate Questions

- Can the agent spread further?
  - Wind?
  - Rain?
  - Inadvertent disturbances such as nearby highways, helicopters, operating subways?
  - Fires?
- Must we - can we - contain it?
- What do we do in near-by areas?
- How do we monitor for spread?

Tactical Decon Support

For teams entering the hot zone to:

- Collect evidence
- Look for unevacuated people
- Render buildings safe
  - Shut off gas lines
  - Turn off equipment
- Respond to emergencies
- Sample
- Exert presence
- Observe

Decontamination Planning

- What are the risks?
- What are the priorities?
- How do we do it?
- What do we need?
- Where do we begin?

Execution Steps

- Define goals (target levels)
- Organize tasks
- Select & obtain resources
- Plan and execute mission
- Chart progress (metrics)
- Document QA program
- Communicate (manage expectations)

Avoidance and Containment Priorities

- Avoidance
  - Area secured and access restricted
- Containment
  - Adjacent buildings sealed off
  - Aircraft and traffic exclusion zone
  - Surface water and sewer containment measures
  - Drift blocking barriers improvised

Possible Decontamination Planning Elements

- Multiple staging areas
- Hot zone – cold zone equipment?
- Hot zone routes and access decontamination
- Targeted exterior containment decon near sensitive, high risk, or high value areas
- Wide area exterior decontamination
- Building interior decontamination

Decontamination Resources and Logistics

Once a decon method(s) is selected:

- Who is the vendor and how do we contract for the resources we need?
- What is their capacity (equipment and people)?
- What are the consumable needs?
- How do they set up and operate?
- **Disposal of wastes?**

FEMA Phases of Recovery: with *putative* decontamination - goals stated explicitly

- Response: Safety – removal of population from areas where the level of exposure is deemed unacceptable
- Initial Recovery: Safe repopulation – levels deemed safe for chronic exposure
- Transitional Recovery: Self-sufficiency of local communities – long term remediation progressing
- Long Term Recovery: Permanent rebuilding – ultimate levels of remediation have been achieved

QA and Clearance

- Implement QA plan at outset and monitor
- Track progress (metrics)
- Avoid recontamination

End Game?

Do we ever have an end to environmental monitoring, remediation, population surveillance, and long term studies?

DCMD Disposal Research

Paul Lemieux
US EPA
National Homeland Security Research Center
Decontamination and Consequence Management Division

Waste Composition

- Porous building materials and furnishings (possibly wet)
- Office equipment (computers, desks, file cabinets, etc)
- Indirect residue from cleanup activities (e.g., rags, PPE, decontamination agents)
- Contaminated HVAC system residues (e.g., spent filter cartridges, contaminated HEPA filters)
- Aqueous residues
- Residues from cleanup of contaminated water systems
- Outdoor materials
- Agricultural residues

Program Goals

- Assure public that the selected disposal processes and procedures will be safe
- Give permitters guidance to accelerate disposal permitting activities and to select appropriate facilities and technologies
- Give facilities guidance to assure permit compliance, worker safety, protection of assets
- Give responders guidance to incorporate disposal plans, waste minimization, and balancing of disposal/decon costs into entire decision making process

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)

Guidance Documents

- The Disposal Decision Support Tool

Target Audience

- OSCs & other responders
  - ERT
  - National Decon Team
- Public agencies
  - Public Health
  - Environmental Protection
  - Transportation
- Facilities
  - Combustors/incinerators
  - Landfills
  - Building owners/managers
  - Water infrastructure

Current Features

- Web-based tool with restricted access
- Series of inputs defining scenario
- Estimates of decon residue mass & volume
- Database of combustion and landfill 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)

Databases in the DST

- Landfills
  - MSW
  - C&D
  - Hazardous Waste
- Combustion Facilities
  - MSW (WTE)
  - Hazardous Waste
  - Medical Waste
- Decontamination Wastewater Disposal Facilities
  - Publicly-Owned Treatment Works (POTWs)
  - Federally-Owned Treatment Works (FOTWs)
  - Liquid Hazardous Waste Combustion Facilities
  - Centralized Waste Treatment (CWT) Facilities

Back of the Envelope Estimator Setup

Back of the Envelope Estimator Sample Results

Sample BDR Character-ization

Sample Facility Info Query

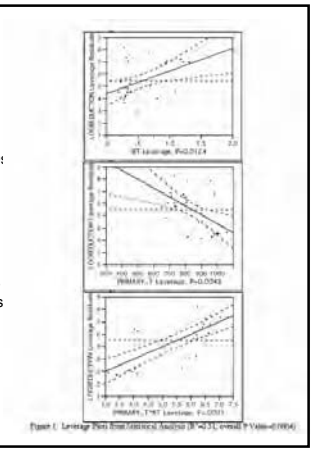
Access to the tool

http://www2.ergweb.com/bdrtool/login.asp

For first-time users, you will need to request a user ID and password – the link above has directions for making the on-line request. You get manually added to user database (by me) and your login ID and initial password are emailed back to you.

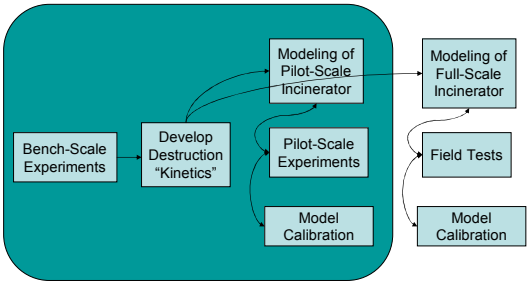
MWI Spore Survivability Tests

- 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

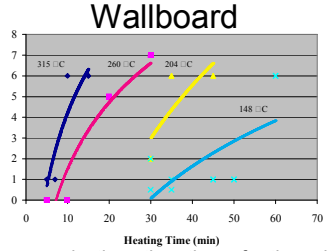


Source: Wood et al., 2004

Approach



Reduction of Geobacillus Stearothermophilus Spiked on Wallboard

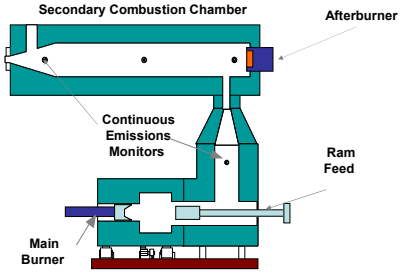


- Much slower reductions than those for the ceiling tile bound organisms
- Consistent with the slow heating rates observed for wallboard

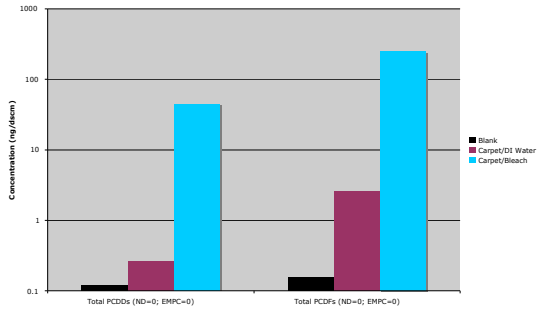
Pilot-Scale Thermal Destruction Studies

- Scale-up of bench-scale results
- Calibrate incinerator models
- Investigate thermal destruction issues
  - Time/temperature requirements for destruction
  - Emissions of conventional pollutants from combustion of building decontamination waste

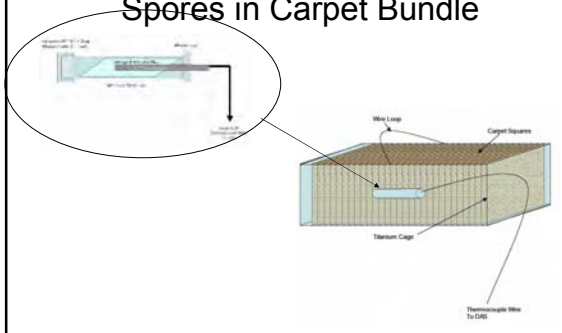
Experimental Apparatus



PCDD/F Emissions

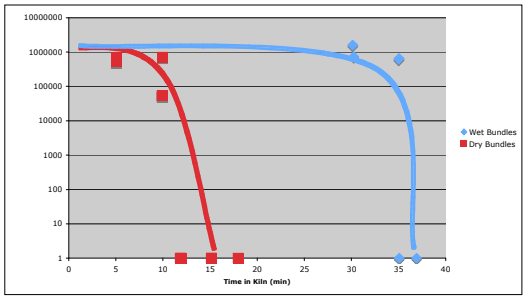


Geobacillus Stearothermophilus Spores in Carpet Bundle

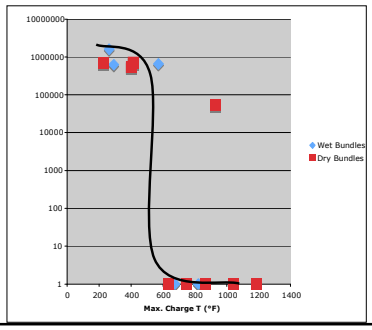


Source: Lemieux, 2005

Ceiling Tile Time vs Spore Count



Ceiling Tile Time vs Max T



Incinerator Modeling

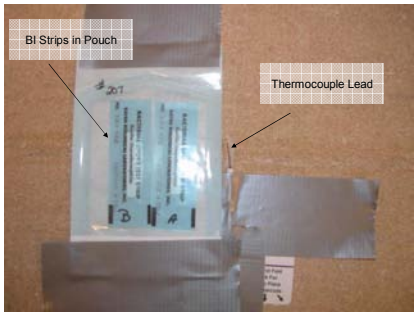
- Reaction Engineering International
  - Based on Army Chem-demil SBIR work
    - Combined CFD/kinetics
    - Detailed reaction mechanisms for GB, VX, HD
    - Analysis of failure modes and agent destruction
  - Expanded to include BW agents
  - Based on 3 thermal destruction systems
    - EPA rotary kiln incinerator simulator
    - Dual chamber med-path incinerator
    - Commercial haz-waste burning rotary kiln

Destruction of Spores on Building Decontamination Residue in a Commercial Autoclave

Background

- Autoclaves used to sterilize regulated medical waste
  - Sharps
  - Syringes
  - Gloves
- Can they be used to sterilize potentially BW contaminated building decontamination residue (BDR) that might be porous?

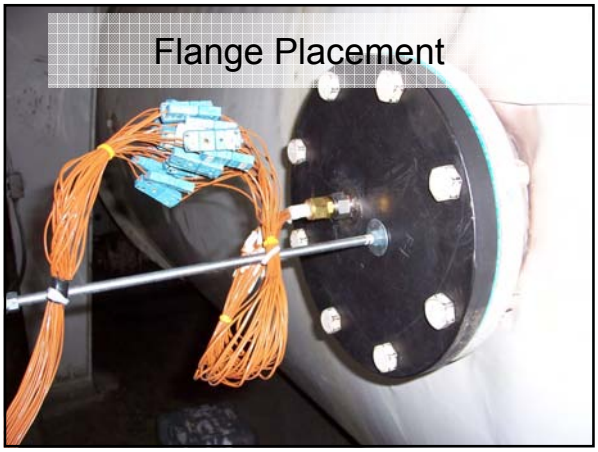
BI Strips (A and B)



"A" strips analyzed for viability

If viable spores, "B" strips analyzed for quantity of surviving spores

Flange Placement



BDR Delivered to Facility

Densely Packed Wallboard

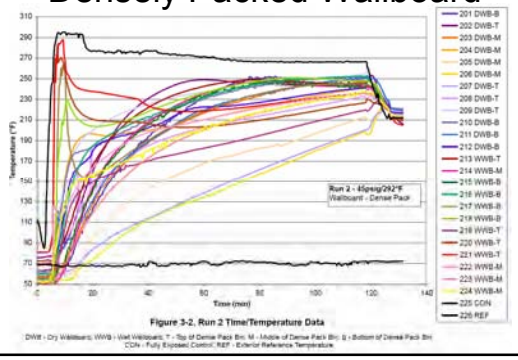


Figure 3-2. Run 2 Time/Temperature Data

Second Autoclave Cycle (Cut Bags)

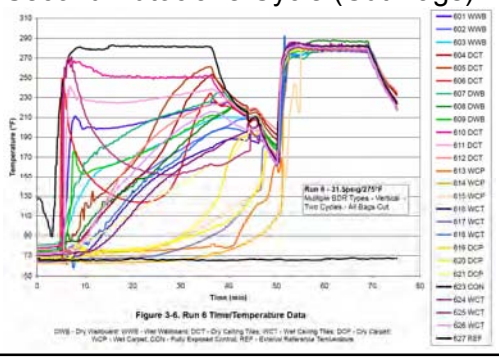


Figure 3-6. Run 6 Time/Temperature Data

Conclusions: General

- Achieving 250 ° F for 15 minutes resulted in no viable spores
- Best results obtained from:
  - Loose packing arrangement
  - Dry BDR material
  - Higher autoclave operating T/P
  - Multiple autoclave cycles in sequence
  - Bags cut open prior to loading

A Sampling of Some of Canada's Decontamination Work

Merv Fingas
Environment Canada

Overview

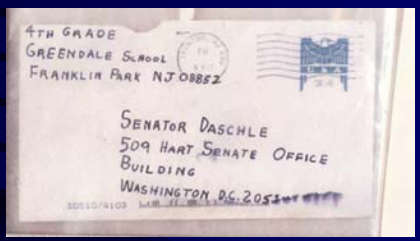
- Three Projects on Decontamination
- The Multi-agency Restoration Project
  - Radiation Decontamination
  - Chemical Decontamination
  - Biological Decontamination
  - Waste Management
- Demonstration project
- Standards Project

The Restoration Project

- Was a three-year, multi-agent project
- Focused on research, but combined existing knowledge into reports and manuals
- Effort was to look at facilities, inside and out and then deal with disposal as well
- Project has just been completed and many reports on its work are out

Agencies Involved

- Environment Canada – chemical and overall
- SAIC – EETO office – chemical
  Washington office – biological
  Ottawa office – radiological
- Public Health Agency Canada – Winnipeg lab
  Ottawa office of Laboratory safety
- US EPA – ERT – Edison, NJ
- DRDC – Ottawa – radiological
- DRDC – Suffield – chemical
- VLN Technologies – Ottawa – radiological
- Allen-Vanguard – Stoney Creek – chemical
- Hytec – Calgary - radiological



Restoration

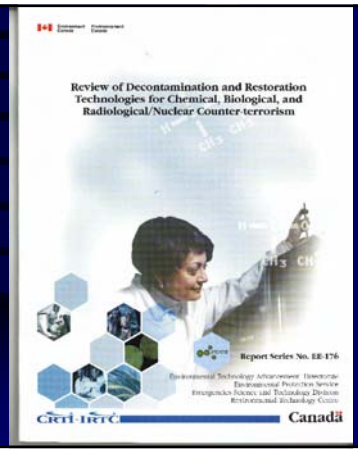
- Are using term ‘restoration’ to include decontamination to the end stage of disposal of contaminated material
- Restoration includes; decontamination, neutralization, sequestration, removal, disposal, etc.
- Is broader than the traditional ‘decon’ word
- Directed to sites such as buildings and exteriors

Study Results in Summary

- Extensive lab work has been carried out in several areas
- A major literature review has been completed and published
- A basic manual has been completed
- Three Lab reports are in publishing
- Over 12 papers published

Objectives

- Review possible and used methods for decontamination
- Combine all information on CBRN decon and restoration
- Test new potential methods on lab scale
- Prepare manuals for technical responders



Factors in Decon - generally

- Surface topography - characteristics
- Temperature
- Relative humidity
- Organic load
- Concentrations
- Contact time
- Oleophilic/hydrophilic agent/decon agent
- Other substances present

Generic Decon Agents

- Sandia Labs - decontamination foam
  DF-100, DF-200
- DRES - foams (some now NATO)
  CASCAD - general decontamination
  RSDL - skin decontaminating
  BLASTGARD -explosives and CBR
  SDF - surface decon - full strength
- Lawrence Livermore - L-Gel
- US Army - Decon Green
- German army agents

Generics

- Great concept
- But… one decon will not cover every situation and all the factors noted

Nuclear Decon

- Current procedure is to blast off the surface with high-pressure water and then catch contaminated water
- Nuclear material in water trapped with ion exchange columns or other means

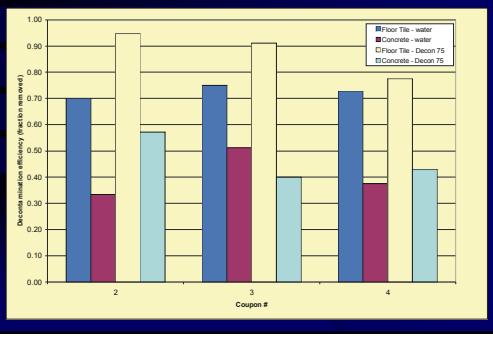
Typical Procedures

- 1. Remove from surface
- 2. Collect waste
- 3. Concentrate waste
- 4. Transport waste to facility
- 5. Store waste forever at a facility

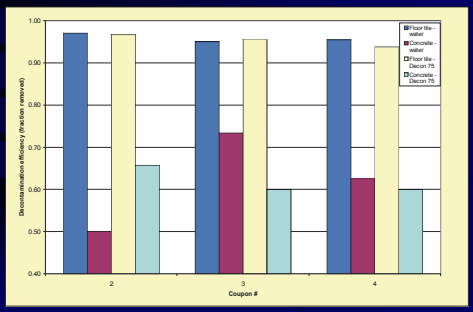
Radiological Alternatives

- Rather than blast off with water solubolize into water: acids, chelating agents
- After capture of water remove with zeolites, lignins or other material rather than ion exchange
- Some of these alternatives have been tested

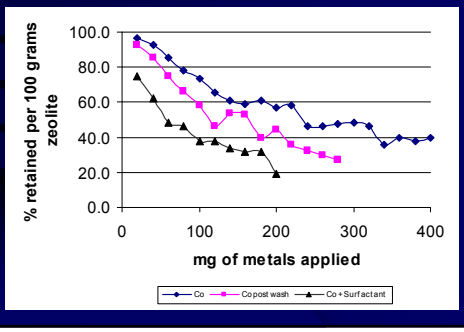
Decontamination Result Example



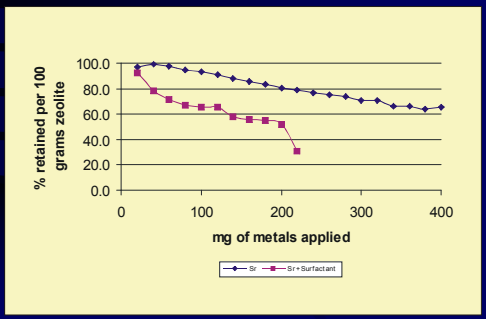
Tests of Removal



Radiological Waste Treatment Cobalt Adsorption to Zeolite



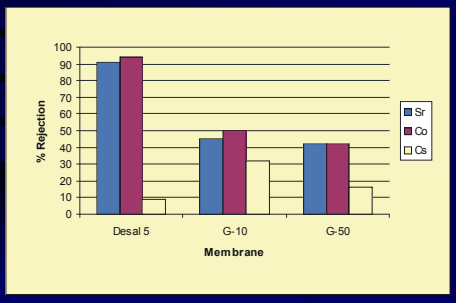
Strontium Adhesion to Zeolite



Studies of Membrane Rejection

- One way to treat waste is to use membrane filtration (reverse osmosis)
- One concern was to look at the effect of surfactants added to commercial decontamination agents – do they affect membranes?

Tests of Membranes for Metal Rejection



European Plate Test

Chemical Restoration

- Chemical weapons are also very old
- Decon by many means has been explored in the literature
- Generic decon agents – often directed at chemical warfare agents
- Many industrial chemicals now on target lists

Sarin – in Tokyo Subway

obviously management does not need respirators!!

Chemical Warfare Agents

- Most are very reactive - this means that those are relatively easy to neutralize
- Extensive work in the military to decon chemical warfare agents
- Several tests of procedures, and many lab studies in existence – so this study did not focus on CWA's

Research

- Major effort in this study at Environment Canada to test new ideas
- Peroxyacids found to be very effective and much work done
- Several tests to compare these to some other new concepts and existing agents
- 21 standard surfaces created

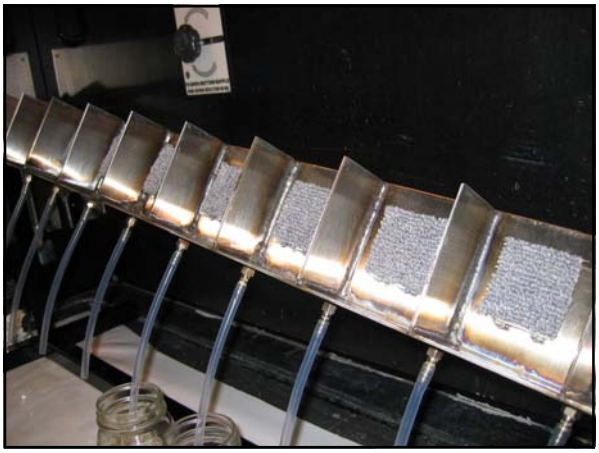
Special Preparations

- Cascad
- L-Gel
- Decontamination solution 2
- RSDL
- DAM (decontamination agent multipurpose)
- German Emulsion Decontaminant
- DANC (US Army)
- Easy Decon
- Sandia Foam

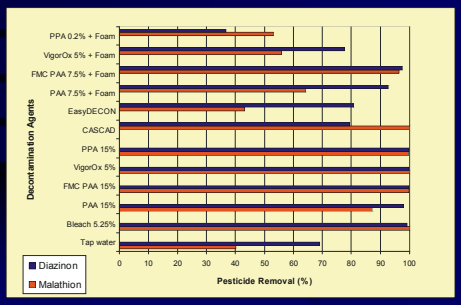
Traditional Foaming/Washing

Testing at Environment Canada

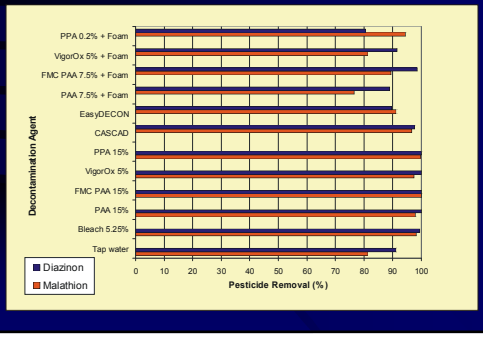
- Developed a new rack method
- Several surfaces tested – 6 most difficult – carpet, ceiling tile, etc



Results of Pesticide Removal from Carpet



Removal from Ceiling Tile



Biological Restoration

- Has drawn a lot of attention with Anthrax incidents in USA
- Has been studied for a long period of time
- Some information from hospital sterilization
- Two sets of studies – PHAC – Wpg. Gas sterilization – PHAC – Ott – liquid sterilization

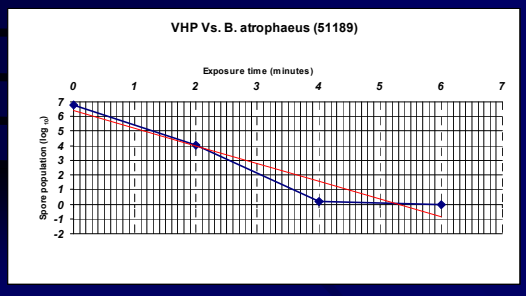
Vulnerability of Species

Lipid-coated viruses (eg. HIV)
Vegetative biota
Rickettsia
Fungi
Non-lipid viruses (eg. HEP A)
Myobacterium tuberculosis
Bacterial Spores (eg. Anthrax)
Prions (eg. BSE)

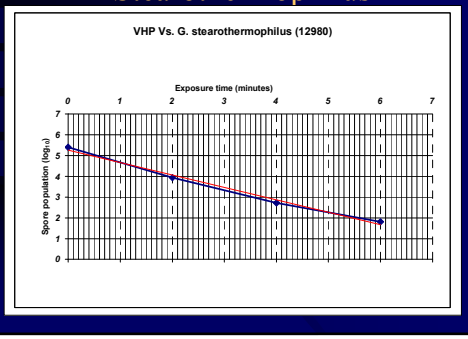
Traditional Decon

- Gas sterilization
- Formaldehyde – very frequently used –also in hospitals
- Chlorine dioxide
- Ethylene oxide – in closed chambers
- Solutions such as chlorine, hypochlorite

VHP – Vapour Hydrogen Peroxide Reduction of *Bacillus atrophaeus*



VHP Destruction of G. Stearothermophilus



Disposal

- Legal issues
- Pre-processing
- Neutralizing
- Landfilling
- Incineration
- Alternative treatment technologies

The Demonstration Project

- A major project on demonstrating on full scale, well-known decontamination methods
- Separate facilities will be built to separately test chemical, biological and radiological decon
- Purpose also to collect practical operational parameters such as time, cost, etc.

LHOP or LCHOP ?

Chemical Test

- Will use Surface Decontamination Formulation (SDF) foam to decontaminate Diethyl Malonate (DEM) – a surrogate for G agents – eg. Sarin
- A separate facility to represent a small office building will be built
- All work carried out at Suffield, Alberta

Biological Test

- Will be carried out using vaporous hydrogen peroxide (VHP) on *Bacillus Atrophaeus* (a surrogate for anthrax)
- A similar special-designed building as the chemical decon
- Tests will be carried out in July, August of 2006

Nuclear Decon

- Will be carried out using a variety of techniques on short-life radionuclides such as Na
- Techniques to be tried include: high pressure wash with zeolites, chelation, and regular washing techniques
- Will use the exterior of the 'Little House on the Prairies'

Schedule

- Tests to be completed in summer of 2006
- Reports by early spring of 2007

Development of Standards for Biological and Chemical Cleanup

- This study is a 5-year study with many partners to develop standards for decontamination end points
- Hope to answer the question "how clean is clean?" for several priority chemical and biological contaminants
- Goal is to develop procedures and specific guidelines for organisms and chemicals

Agencies Involved

- Environment Canada – chemical and overall
- SAIC – EETO office – chemical
- Public Health Agency Canada – Winnipeg lab
  Ottawa office of Laboratory Safety
- US EPA – ERT – Edison, NJ
- RHITOP – Volgograd, Russia – toxicological testing
- DRDC – Suffield – chemical
- Lawrence Livermore – California – chemical
- University of Leeds – United Kingdom – biological
- CREM – Ottawa - biological

Introduction to Standards

- A Hypothetical Example of the Effect of Cleanup Standards on Cost and Time
- Development of Chemical Standards
- Development of Biological Standards

Standards

- Are not well-developed at the moment
- But …. Are needed
- There are standards for radiological cleanup from international bodies
- Chemical standards are more elusive – biological standards still more elusive

Why Standards are Needed

- To make decisions on whether to clean or demolish
- To know how to clean
- To know when to stop cleaning
- Assure public
- Know when to re-occupy

Standards

- Are always a compromise between conservative views and practical considerations
- Lean toward a large safety factor
- Require extensive information on exposure and minimum toxicities to develop
- Are very scarce for biologicals and some chemicals

Study of An Example

- An example was created to provide a study on the effect of standards on costs and time to re-occupy a building – along with the variables of building size, dose of toxicant and cleanup effectiveness
- Standards were set for a surface contamination and were set at 0.01, 1 and 100 mg/M^2
- All values set to realistic values

Example .. Buildings

- A small building with 1000 m^2 surface area and one with 10,000 m^2 surface were chosen
- These correspond to buildings of area of about 170 and 1700 m^2 or equivalent to a house and a small building
- All surfaces assumed equal and of the same ease to clean

Example – Rebuilding Costs/time

- At a cost of 1000 m^2 (surface) and cost of demolition of \$150 /m^2 plus \$50/m^2 for deconing waste materials
- Small building estimated to cost \$1,300,000 and large building \$13,000,000 (very conservative and costly to make example real) and take 540 and 700 days

Example --- Decon costs/time

- Two methods chosen – one with 85% effectiveness and one with 95% effectiveness
- Presumed that if they are performed successively – will remove the same the next time they are used – some situations require several successive cleans
- High clean (95%) costs \$500 /m^2 and takes 1 day for 50 m^2 and low clean (85%) costs \$100 /m^2 and takes 1 day to do 100 m^2
- A base cost of \$100k and 10 days assigned – also for between decons

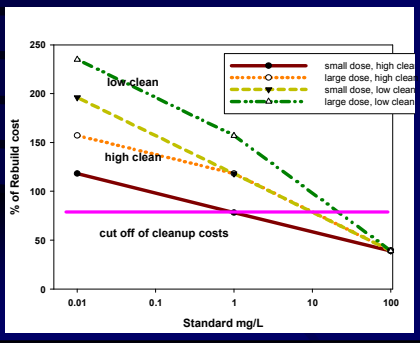
Dose

- Two doses chosen – low and high
- High dose is 1 mg /m^2 and low dose 0.1 mg/m^2
- These corresponded to about the level of the highest value standard
- These are presumed to be the maximum dose on the surfaces

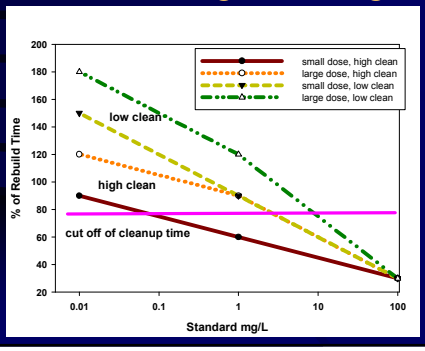
Results - Tabular

Option	Standard	Cost (K$)	Time (days)	Fraction of rebuild $%	Fraction of rebuild time %
small building	100 mg/m2	600	30	46	6
small dose	1 mg/m2	1200	60	92	11
high cleanup	0.01 mg/m2	1800	90	138	17
large building	100 mg/m2	5100	210	39	30
small dose	1 mg/m2	10200	420	78	60
high cleanup	0.01 mg/m2	15300	630	118	90
small building	100 mg/m2	600	30	46	6
large dose	1 mg/m2	1800	90	138	17
high cleanup	0.01 mg/m2	2400	120	185	22
large building	100 mg/m2	5100	210	39	30
large dose	1 mg/m2	15300	630	118	90
high cleanup	0.01 mg/m2	20400	840	157	120
small building	100 mg/m2	600	30	46	6
small dose	1 mg/m2	1800	90	138	17
low cleanup	0.01 mg/m2	3000	150	231	28
large building	100 mg/m2	5100	210	39	30
small dose	1 mg/m2	15300	630	118	90
low cleanup	0.01 mg/m2	25500	1050	196	150
small building	100 mg/m2	600	30	46	6
large dose	1 mg/m2	2400	120	185	22
low cleanup	0.01 mg/m2	3600	180	277	33
large building	100 mg/m2	5100	210	39	30
large dose	1 mg/m2	20400	840	157	120
low cleanup	0.01 mg/m2	30600	1260	235	180

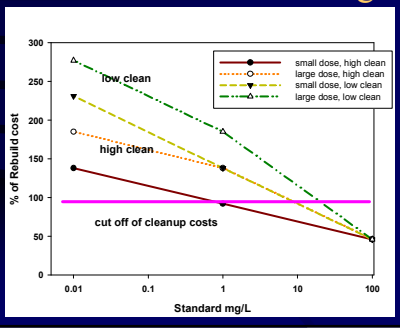
Results – Large Building Costs 2



Results – Large Building Time



Results – Small Building Cost



Rules of Thumb

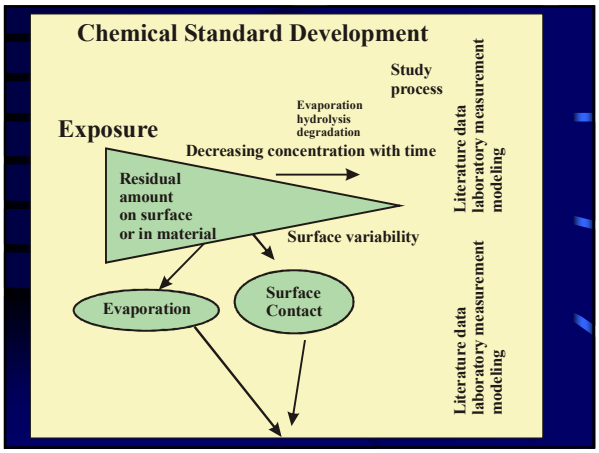
- If the standard is lower than one or two orders of magnitude less than the average maximum contamination on the surface – it is infeasible and uneconomical to decon
- There is a major difference between decon efficiencies of 85 and 95% - related to the time and number of times to decon

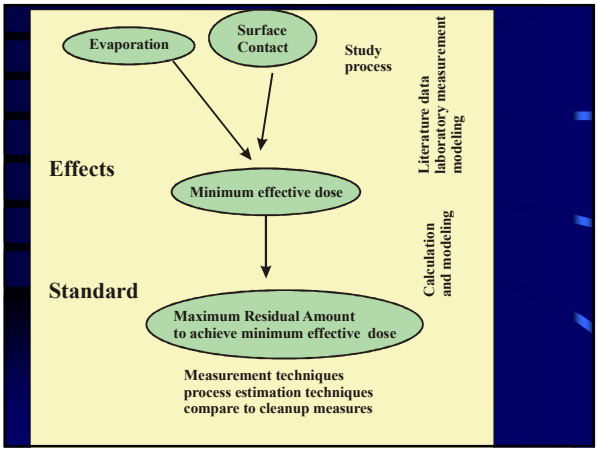
Major Factors in Setting Chemical Standards

- Exposure from surface contact
- Exposure from airborne contaminant
- Re-aerosolized from surface
- Minimum toxic dose (observable sub-lethal)
- Assigned safety factor

Concepts of Chemical Cleanup Standard Development

- Are shown in following diagrams





Summary of Chemical Standard Development

- Meld data from exposures along with minimum toxicity to yield standard
- Although may appear simple is difficult and is very data intense

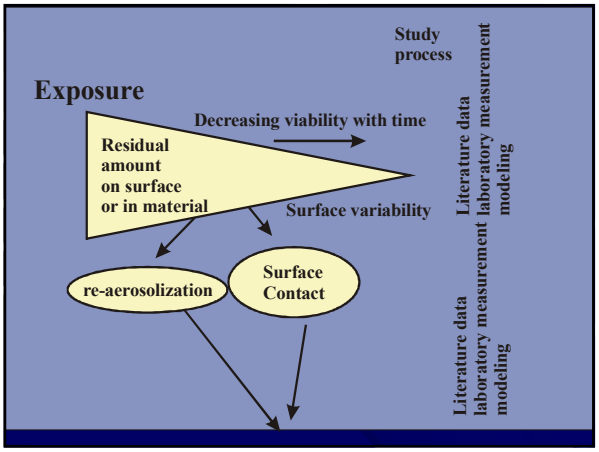
Biological Standard Development

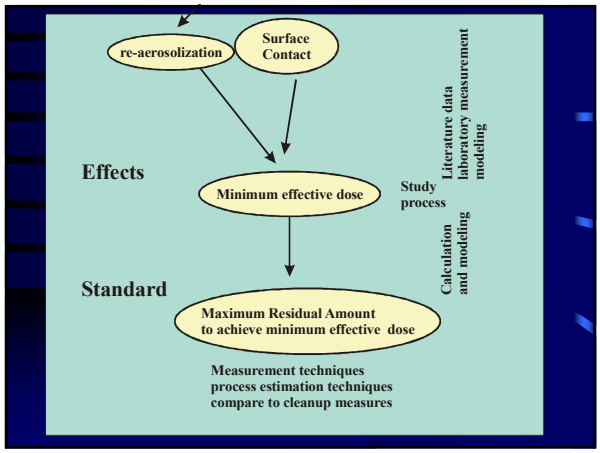
Major Factors in Setting Biological Standards

- Exposure from surface contact
- Exposure from airborne contaminant
- Re-aerosolized from surface
- Minimum infectious dose (observable sub-lethal)
- Assigned Safety Factor

Concepts of Developing Biological Cleanup Standards

- Follow in concept drawings





Summary of Biological Standard Development

- Meld data from exposures along with minimum toxicity to yield standard
- Although may appear simple is difficult and is very data intense – some data may have to be estimated or extrapolated

A Big Issue

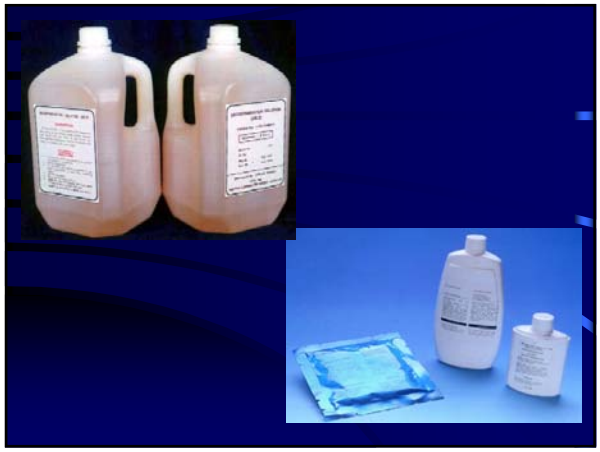
- Is it worthwhile to decontaminate as opposed to abandon?
- The trade-off should be borne in mind throughout any decontamination study

Standards Setting

- Setting cleanup standards will be an important exercise
- Economics already show that if the standard is an order or two in magnitude lower than typical maximum contamination – if widespread – then cleanup is not indicated

Closing Remarks

- These 3 projects are just examples of about 20 studies underway in Canada
- Other projects involve about 4 projects to extend the applicability of SDF, Cascad and Blastguard; projects to look at the environmental effects of some decontaminants; studies on CWA decontamination; and several studies on radiological decon



The Government Decontamination Service (GDS)

The UK Perspective on Decontamination Approaches

Robert Bettley-Smith, FRICS
Chief Executive

Department for Environment, Food and Rural Affairs (Defra)

UK Government Decontamination Service

The GDS (The Journey)

- The Strategy
- The Context
- The History
- The Findings

Government's CBRN Strategy

The aim of the Government's CBRN strategy is to ensure we are:

"capable of responding quickly and effectively to deal with and recover from the consequences of CBRN incidents, particularly those caused by terrorism"

The Context

- Uncertainty surrounding the global security.
- Cross-government effort to ensure UK is prepared for a range of emergencies.
- Chemical, Biological, Radiological, Nuclear (CBRN) resilience programme led by the Home Office.
- **The Government Decontamination Service Programme**

The History

- April 2003 – study commissioned **to assess** the UK's ability to deal with CBRN clean up
- December 2003 - **powerful case for** improving the UK's arrangements for decontamination
- 25 march 2004 – government **"actively considering setting up"** a decontamination service
- 25 January 2005 – government announces **"intention to establish"** a decontamination service
- 21 July 2005 – government announces **the launch** of the new service on 1 October 2005

The Findings

Options considered included a virtual approach and ranged from no function of the GDS within Government

… to the whole function of the GDS within Government

Strong logic in a "core approach" with a Command and Control team within Government Service

… with recognised, defined and agreed upgrade path

This approach has been used successfully for over 19 years in the UK by the MCA (*Maritime and Coastguard Agency*)

GDS (The Destination)

- The Concept
- The Organisation
- The Contractors Framework
- Reacting in an Emergency
- Future Developments

The GDS Concept is to:

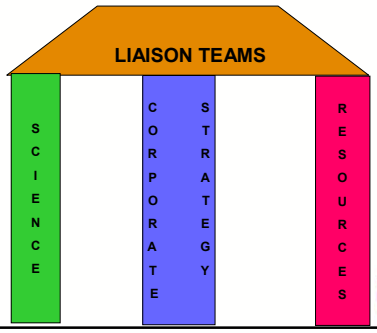
- ✓ **Provide** advice and guidance to Responsible Authorities when planning for emergencies, and help test their arrangements
- ✓ **Identify** and assess specialist contractors' ability to decontaminate, and ensure Responsible Authorities have access to them when needed
- ✓ **Advise** central government on national decontamination capability and on the decontamination options available following a CBRN (or Hazmat) event

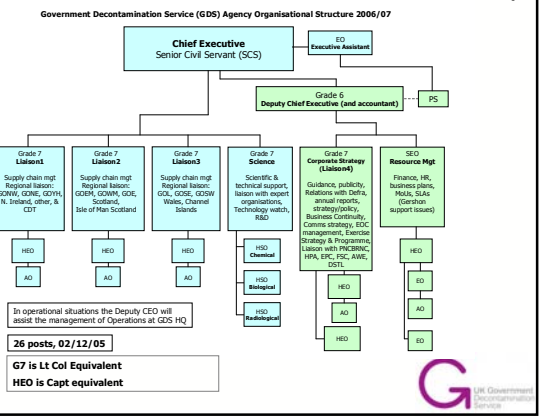
Some Exclusions

GDS Will Not …

- **Assume** responsibility for decontamination
- **Fund** decontamination
- **Deal with** humans, animals or their remains
- **Define** how clean is safe
- **Confirm** decontamination standards achieved

The Current Concept is 3 Liaison Teams Supported by……..





Procurement Aims

- GDS will establish a framework of specialist suppliers to decontaminate buildings and the open environment, and
- Make sure that responsible authorities can call on their services (at indicative cost) when necessary.
- Identify and assess suppliers ability to decontaminate buildings, infrastructure, mobile transport assets and the open environment: and ensure responsible authorities have ready access to them if needed

Who Can Use the Framework of Specialist Suppliers?

- Any Government Department or Public Sector Organisation
- "Responsible Authority" (Local Authorities)
- Private Sector organisations with responsibility for safety of buildings or infrastructure.

The GDS Will …

- ✓ Advise, provide guidance & facilitate a response
- ✓ Benchmark and test framework capability
- ✓ Exercise the framework suppliers
- ✓ Advise on contractual terms and conditions
- ✓ Advise on logistical requirements when required.
- ✓ Conduct the procurement process for the renewal of the framework contracts

The GDS Will Not …

- ✘ Accredit specialist supplier capability
- ✘ Guarantee or indemnify specialist supplier capability.

GDS Services – reacting in an emergency

Depending on the seriousness of the event and need, GDS may provide:

- advice and guidance
- advice, guidance and help securing contracts
- advice, guidance, help securing contracts and managing them

This is done on the basis of Tiers

Tier 0
Planning Advice and Guidance

- Advice and Guidance on Decontamination Preparedness (including Pre-event and Contingency planning)
- Strategic National Guidance
- Radiation Remediation Handbook
- (Chemical & Biological Remediation Handbook.)
  - currently being drafted

Tier 1
Provision of Information

- Advice and Guidance to the Public and Private Sector
- Advice and Guidance may be general or site/ specific

Tier 2

Provision of Advice and Facilitation at Incident (local response)

- **Assessment of the decontamination required**
- **Liaison with the specialist contractors**
- **Liaison with the relevant authorities including emergency planners**
- **Advice on decontamination aspects of media strategy**

(GDS Services in Tier 2 mainly advice based)

Tier 3
Provision of Advice and Facilitation at an Incident (Regional Response).

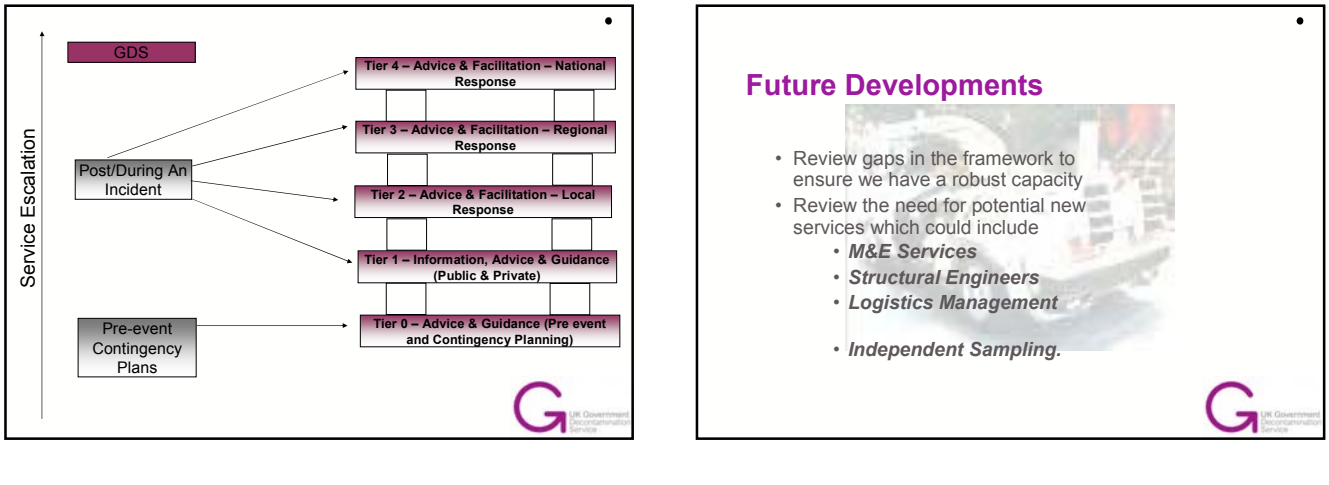
- **Assessment of the incident**
- **Liaison with the specialist contractor(s)**
- **Liaison with the relevant authorities including emergency planners**
- **Advice on decontamination aspects of media strategy**

(GDS Services in Tier 3 could involve facilitation and co-ordination)

Tier 4
Provision of Advice and facilitation at an Incident (National Response)

At this level the GDS will provide elevated amount of resource in line with the scale of the incident.

- Provision of advice to those who need it.
- Procurement of appropriate goods and services
- Provision of advice, scientific and logistical advice. (GDS services in Tier 4 could involve Project Management.



Future Developments

- Review gaps in the framework to ensure we have a robust capacity
- Review the need for potential new services which could include
  - ***M&E Services***
  - ***Structural Engineers***
  - ***Logistics Management***
  - ***Independent Sampling.***

Future Developments (Contractors)

- Further collaboration with international partners
- A second procurement round
- Scientific assessment of current technologies
- Further validation of contractors capabilities

Future Developments (Science)

- Evaluation of new decontamination methods
- Investigation of optional approaches
- Increased understanding of interactions
- Consideration of new technologies

SUPPLIER FRAMEWORK

If in the event of a need for GDS specialist suppliers, or advice & guidance following a CBRN or major HAZMAT incident contact:

GDS Duty officer on : 07990 780 032
General Enquiries: 01270 754255
Government Decontamination Service
Building 14
RAF Stafford
Beaconside
Stafford
ST18 0AQ

Government Decontamination Service
Building 14
RAF Stafford
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Stafford
ST18 0AQ

EPA's National Homeland Security Research Center

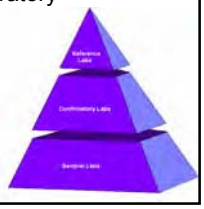
ELRN Support & Standard Analytical Methods

Rob Rothman
April 26th 2006

National Exposure Measurement Center

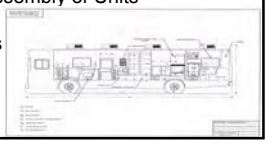
NEMC Headquartered in Las Vegas
- Chemical – Las Vegas

EPA's Reference Laboratory
Charged with :
- Methods Development
- Method validation
- Surge Capacity
- Quality Assurance
- Training
- PT Samples



Triage/All Hazard Receipt Facilities

- Design & Develop Modular Triage/All Hazard Receipt Unit for Unknowns
  - Combined Effort of EPA, DHS, DOD and other Agencies, to develop and test prototype designs
  - EPA development & testing of protocols and procedures
  - DOD design and assembly of Units
  - Draft Protocols out
  - Two field prototypes be delivered 06
  - Albany, NY
  - Region 1

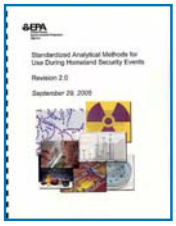


Portable High-Throughput Integrated Laboratory Identification System (PHILIS)

- Designed to identify and quantify TICs and CWAs
- Designed to analyze and report on at least 1,000 (vapor, liquid, solid, mixed state) samples per 24 hour period
- Field Testing of 3 Prototype Designs completed July 2005
- Final report showed all failed design specs
- Rapidly field-deployable lab analysis system
- Redesign of system with EPA response needs underway

SAM Document

- Compilation of Chemicals, Biologicals and Radionuclides
- Specific method for analyte and media
- Selection based on detection level, equipment availability and scope of method
- SAM Version II released September 29, 2005



SAM/SAP Process and Schedule

- Draft method gap analysis available
- Standard Analytical Protocols (SAPs)
  - 5 drafted to date
  - 6 more will be written by September 2006
- SAP Method validation
  - Semi-Volatile Organics Method validated during 2006
  - Degradation product validation using Method 8270 ongoing

CWA Concentration

Dilute concentration

- [1] Maximum amount of agent in the solution for each primary container, not to exceed the concentration indicated.

Ultradilute concentrations

- Working with DoD to allow EPA to handle ultradilute concentrations of CWA
  - Proposed ultradilute level is 1 mL of 10 ppm, 10 – 1 mL vials
- Quantities for calibration of instruments.

Dilute Solutions (AR 50-6)

Agent	Maximum Total Quantity[1]	Maximum Concentration
Tabun (GA), Sarin (GB), Soman (GD), Cyclosoman (GF)	20 mg	2.0 mg/mL (2000 ppm)
VX	10 mg	1.0 mg/mL (1000 ppm)
Mustards (H, HD, HQ, HT, Q, T)	100 mg	10.0 mg/mL (10,000 ppm)
Lewisite (L, HL)	50 mg	5.0 mg/mL (5000 ppm)

DHS CWA Lab Prototypes

DHS to sponsor two laboratories to analyze environmental samples containing ultradilute concentrations of CWA in 2006

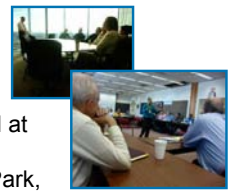
- Possibly, two more laboratories to be established 2007

Requirements for handling dilute CWA extracted from AR 50-6

- Details security, equipment, infrastructure, accountability, etc.

Red Team

Emergency advisory team to offer scientific guidance to senior management



Three teams located at Washington, DC, Research Triangle Park, NC, and Cincinnati, OH

Response Tools

Homeland Security Experts

COOP Tools DVD

CB Helpline

ECBC Reachback

Future Activities

- Support AHRF installation and testing
- Completion of additional SAPs
- Validation of first chemical SAP
- Complete laboratory screening project
- Support PHILIS activities

Questions?

Bacillus anthracis spore detection using laser induced breakdown spectroscopy (LIBS)

Emily Gibb and Brian Gullett
US Environmental Protection Agency
Office of Research and Development
Research Triangle Park, N.C. USA

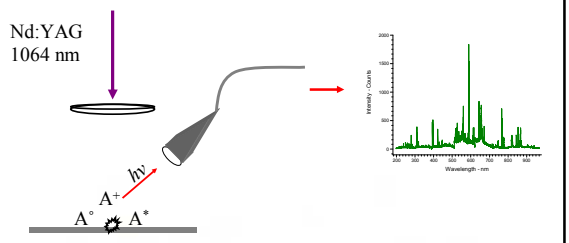
Chase A. Munson, Frank C. De Lucia, Jr., Jennifer L. Gottfried, and Andrzej W. Miziolek
Army Research Laboratory
ATTN: AMSRD-ARL-WM-BD
Aberdeen Proving Ground Maryland, MD 21005-5069

Decontamination Workshop
04-27-06

Outline

- Laser Induced Breakdown Spectroscopy (LIBS) for the detection of biological agent surrogates
  - Principles of operation
  - Man-portable system for the classification of white powders/mysterious substances (ARL)
    - Pure powders on building materials
    - Mixture studies
- Single Photon Time of Flight Mass Spectrometry
  - Principles of operation
  - Applications (initial and current)

Laser Induced Breakdown Spectroscopy (LIBS): Principle of Operation

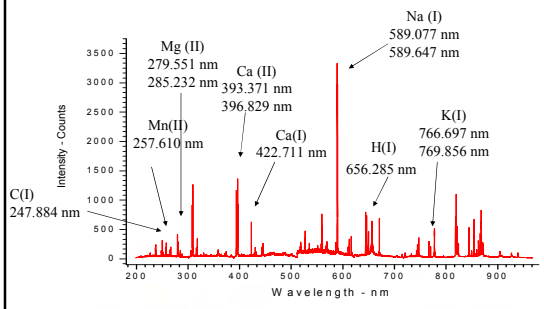


How does LIBS detect *Bacillus* spores – the environment within a spore

Molecule / Ion	Cells μmol/g	μg element/g spores	Spores μmol/g
ATP	3.6		<0.005
ADP	1		0.2
NADH	1.95		.002
DPA	<0.1		410-470
Ca2+	-	2100-5000	380-916
Mg2+	-	5000-7000	86-120
Mn2+	-	1900-3300	27-56
H+	7.5-8.2		6.3-6.5
AMP	1		1.2-1.3

Table adapted from: Setlow, P. "Mechanisms which contribute to the long term survival of spores of Bacillus Species" *Journal of Applied Bacteriology Symposium Supplement* 1994, 76 49S-60S.

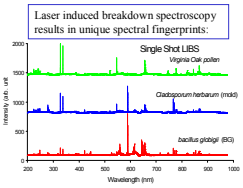
LIBS spectra of *Bacillus subtilis* (chosen surrogate for *B. anthracis*)



Why LIBS??

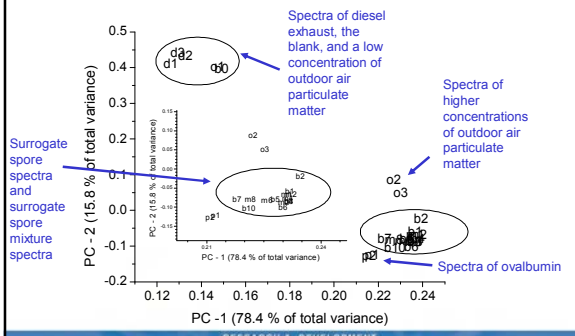
Advantages of LIBS:

- Little to no sample preparation
- Real-time in situ measurement
- Reagent free – low amount of maintenance
- Relatively cost effective instrumentation
- Simple to operate



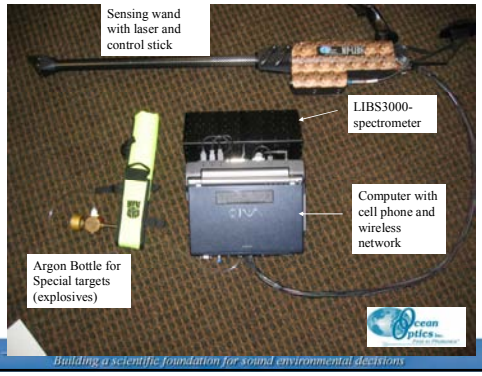
Spectra courtesy Army Research Laboratory

Average Spectra from the Ambient Air - Spore Mixtures - Principal Component Analysis



Man Portable (MP)-LIBS (version 1)

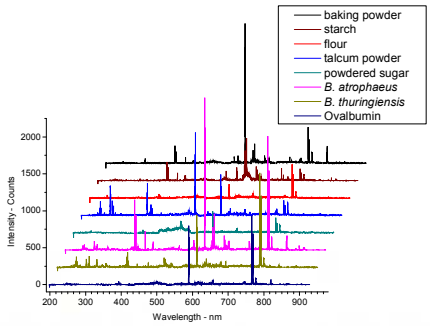
MP-LIBS Out of the Backpack



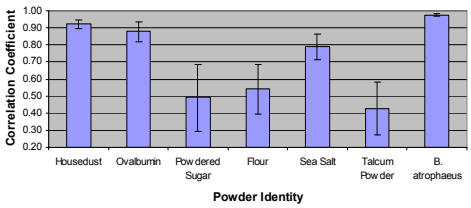
Important specs for the MP-LIBS

- Actively Q-switched – diffusion cooled laser
  - No need for an external water or gas supply for cooling the laser
- Needs 16 Volts to power laser (supply in backpack) and spectrometer is powered through USB
  - Battery operated
- Sony VAIO notebook
  - Commercially available – inexpensive
- Weighs less than 10 kg (~20 pounds)
  - Light enough for first responders to easily carry-designed to wrap around waist of hazmat suit
- Can operate at temperatures 0 ± 50 ºC
  - MP system can be used in Arizona during the summer and Minnesota during the winter
- Hermetically sealed (IN PROGRESS)
  - MP system can be easily decontaminated after use

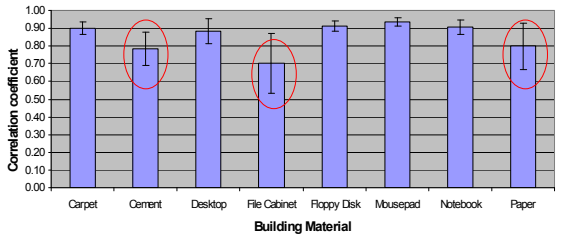
Spectra of Biological Agent Surrogates and Confounding White Powders



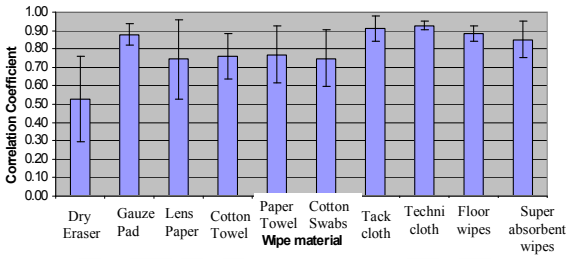
Average Correlation Coefficient of White Powders to library spectra of B. atrophaeus



Correlation of B. atrophaeus spores on building materials to library spectra of spores



Correlation of B. atropheaus spores on wipe materials



Spectra pre-processing

22,986 Intensity Channels/MP-LIBS spectrum

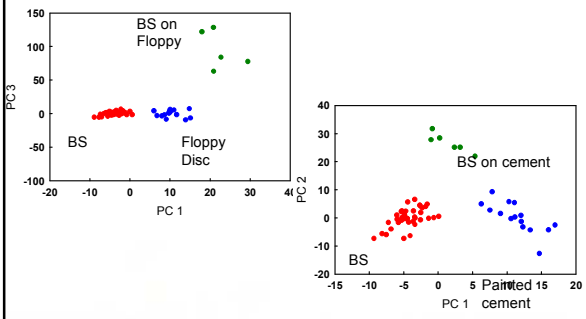
182 elemental and molecular intensities from BS and office surfaces

17 integrated intensities from summed elemental and molecular lines

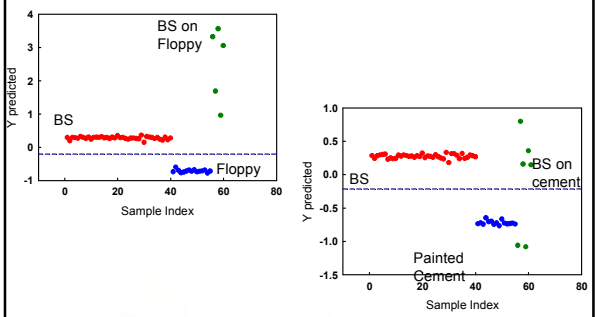
(Al, Ba, C, C_2, Ca, CN, H, K, Li, Mg, Mn, N, Na, O, Si, Sr, Ti)

136 elemental/molecular intensity ratios

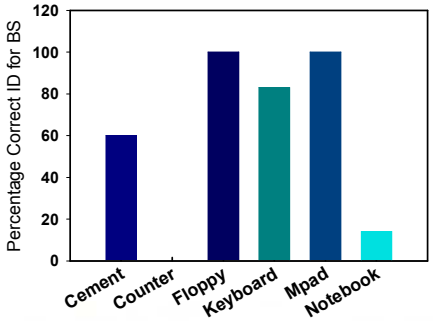
PCA of Bioagent Simulants and Interferents



PLSDA of Bioagent Simulants and Interferents



PLSDA results on Office Surfaces

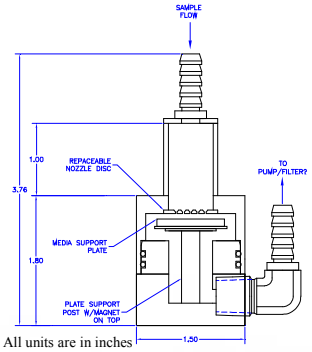


Conclusions from study of pure white powders on building materials

- LIBS is effective in classifying powders on many of the building surfaces
- The techni cloth is the most suitable wipe for LIBS analysis
- PLSDA works well for classifying sample spectra

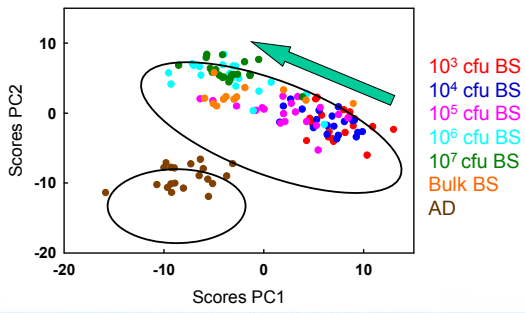
Future work

- Development of an impactor that could interface to the MP- LIBS system, use when analyzing powders on the more difficult building surfaces

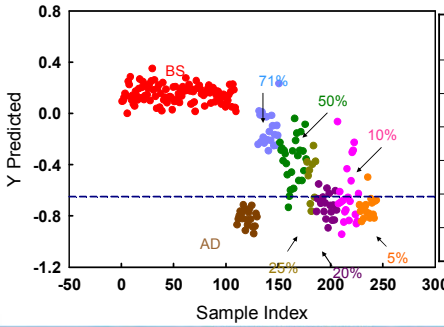


* All units are in inches

PCA of BS and Dust (pure compounds)



PLSDA of BS/Dust Mixtures

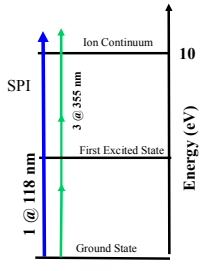


Sample	% Correct
71%	100
50%	96
25%	67
20%	20
10%	8
5%	6

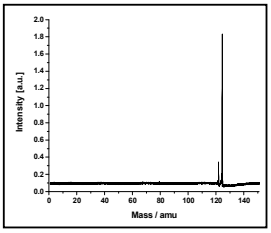
Conclusions and Future Work - Mixture Studies

- Spectral discrimination in mixtures is possible
- As expected, the potential for false negatives increases as the concentration of the spores (mixed with the interferent) decreases
- More mixture studies are needed and in progress

Single Photon Time of Flight Mass Spectrometry –Principles of Operation



DMMP Mass Spectrum
Single Photon Ionization using 118 nm



Gas phase ions created by SPI. Ions detected by Time-of-Flight Mass Spec

Goal of Project

- *Initial focus* - to monitor ambient air for chemical warfare agents and toxic industrial chemicals
- *New focus* - to determine fumigant by-products and to quantitate them (for modeling the kinetics of their formation)

Technical Progress

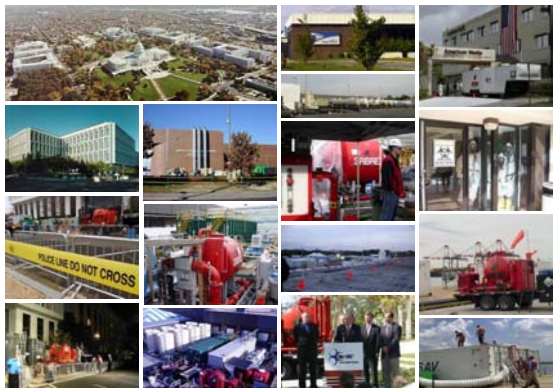
Single Photon Ionization (SPI) instrument

✓ Instrument built onsite
✓ Small gas tripling cell evaluated
✓ Waiting for new gas tripling cell

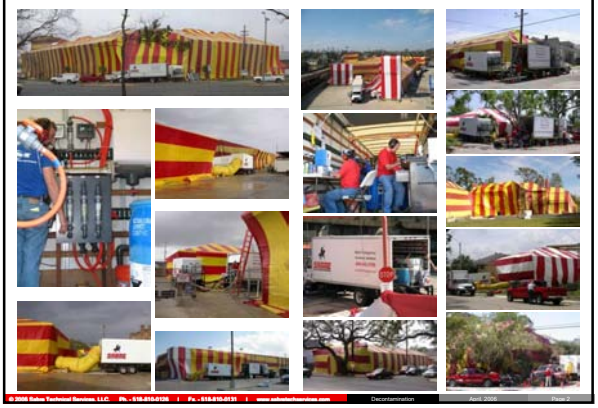
Future Work:
❑ Will evaluate permeation tubes as a way to calibrate the system
❑ Plan to sample from fumigation chamber onsite and look for by-products both during the fumigation and aeration process

RESEARCH & DEVELOPMENT
Building a scientific foundation for sound environmental decisions

Biological Incident Decontamination – The Next Day



Biological Incident Decontamination



Biological Incident Decontamination

- 2001, NYC Anthrax Response and Remediation Oversight
- 2001, Capitol Hill Anthrax Response and Remediation
- 2002, USPS Mail Facility at Brentwood Anthrax Response and Remediation
- 2003, USPS Mail Facility at Hamilton, NJ - Anthrax Response and Remediation
- 2003, DTRA – Chem Bio Containment & Destruction SOP Development
- 2003, DTRA - Iraq WMD Identification, Safety and Destruction as Necessary
- 2003-Present, DTRA - Russian Biological Weapons Proliferation Prevention
- 2004-Present, DTRA – Ukraine WMD Interdiction and Elimination
- 2004, AMI Building / Boca Raton, FL - Anthrax Remediation
- 2004, Port Newark – Suspect Container Decontamination
- 2004, Utica - Mold Decontamination and Building Encapsulation Demonstration
- 2005, AMI – Emergency Response Containment and Decontamination
- 2005, Hudson Falls – Mold Decontamination and Building Encapsulation Demonstration
- 2005-Present - Katrina / Rita Incident – Mold Decontamination
- 2006, Brooklyn NY, Anthrax Incident

The Big Debates

Skip: What do we do? Assume decontamination necessary. Chlorine dioxide gas phase treatment of structures and contents, and for the destruction of bulk agents.

- SAMPLING
- MONEY - AUTHORITY
- INSURANCE
- CONTENTS
- CLEARANCE
- THE “F” WORD

Biological Incident Decontamination

Event	Post Event	Hindsight
US Capitol Hill	Laws of Nature do not apply in DC Crisis Exemption? What Crisis Exemption Sampling Methodologies need improvement Humidity can be tough TAGA Essential for Project Automated PC Testing Needed Post event stress	DC allowed technology development Manual Titration is Just Fine Complete Fumigation is better than sampling
Brentwood & Trenton	Insurance and Indemnification Pre-establish clearance criteria Pre-establish clearance authority Big buildings leak QC and Training on Sampling Bleach is very corrosive	Pick your type of response Insurance Is source reduction required? Modular response approach
AMI	Tent, Tent, Tent Public involvement is great Third Party Contents are a problem	Visual Database Critical Asset Mobile Contents Destruction
Lemon Drop (Port Newark)	Preparedness is key Must rely on intelligence Curb Rumor Mill	MCAD Critical Asset
Utica and Hudson Falls	Single tarp tenting – TAGA no longer essential to fume	Eliminate source reduction practice
AMI COI	Resolve Contents Early	Need Policy or Law
Katrina / Rita	Contents, Tents, Contents, Logistics	A fume a day can be done
Brooklyn, NY Anthrax		

Restoration Accelerators

- Equipment Availability
- Prepared Event Response Software
- Enabling Agreements
- Site Agreements - Contents
- Pre-Engineered Insurance Product
- First Response Community Communication
- Draft RAP, SAP, ERP, and HASP
- Established Clearance Criteria and Draft CAP

Critical Assets

Regulatory / Procedural Assets

- Template HASP, RAP, ERP, CAP,
- Template Crises Exemption with Data Pack
- Pre-Authorized Wrap Around Insurance
- Contract Vehicle or Enabling Agreements

Personnel Assets

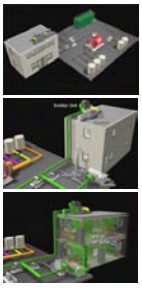
- Event Coordinator
- Science Team
- Regulatory Team
- Operations Team
- Technical Team
- Security Team
- Public Relations

Critical Assets

- ChemGen™ response system
  - Decon Solution
  - Gas Generation
- Mobile Critical Asset Decontamination
- Mobile Personnel Decontamination
- Mobile Containment Systems
- Mobile BSL 3 Labs
- Mobile Chem & Process Labs
- Mobile Process Control & Command Center
- Mobile Logistics Support Unit
- Wide Area Decon System
- BioDestruct On site contents destruction
- Rest and Recuperation Vehicles
- Mobile Self Contained Camp
- Chemical Stockpile
- SabreShield facility protection systems
- SabreClear™ sample tracking system and VR Database

Rapid Fumigation Sequence

1. Activate enabling agreements – regulatory / commercial
2. Activate pre-developed plans (HASP, RAP, SAP etc.)
3. Activate pre-installed Clearance Plan and Software (critical asset)
4. Seal or Tent building as required – install carbon based NAU's
5. Set up ChemGen™ & chem plant – (critical asset)
6. Install (park) emitters (critical asset)
7. Install air transfer fans for high energy areas such as power rooms
8. Install monitoring lines and temperature / relative humidity meters, connect to process control center (critical asset)
9. Perform low level chlorine dioxide test
10. Install BI's (critical asset)
11. Perform fumigation
12. Perform clearance tests

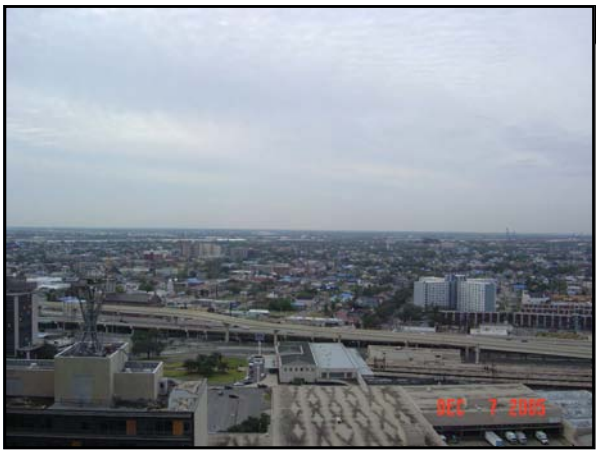


Post Katrina 700,000 Sq ft P&DC Cost Projection

Historical	- 440 days
	- 180 – 200 million
Start From Scratch	
Project Duration	- 180 to 270 days
Response Through Clearance Cost	- $35 to 45 Million
With BioRed Preparation	
Project Duration	- 30 to 60 days
Response Through Clearance Cost	- $10 to 15 Million

Post Katrina:

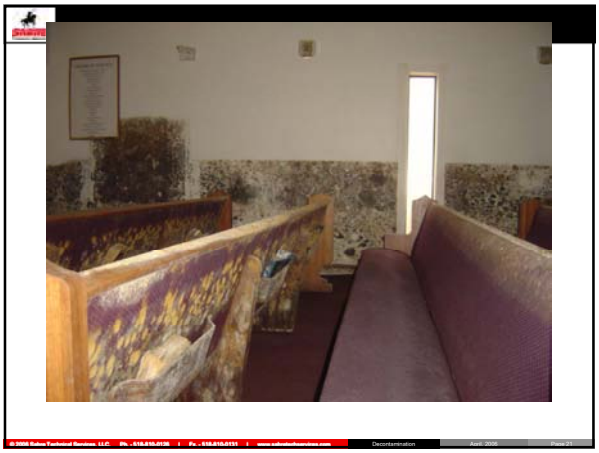
Decontamination – 1 to 5 days


DEC 7 2005

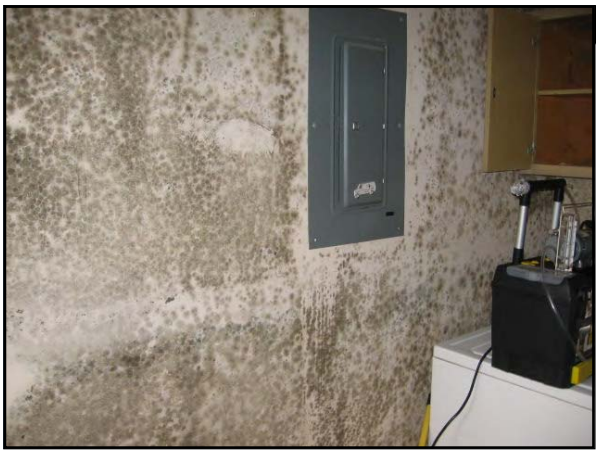

DEC 7 2005


DEC 7 2005


CHRIST TEMPLE CHURCH
of Christ (Holiness) U.S.A.
SUNDAY SCHOOL 10:00 AM
WORSHIP SERVICE 11:15 AM
WED PRAYER MEETINGS
& BIBLE STUDY 6:30 PM
Pastor: Eld. George Taylor

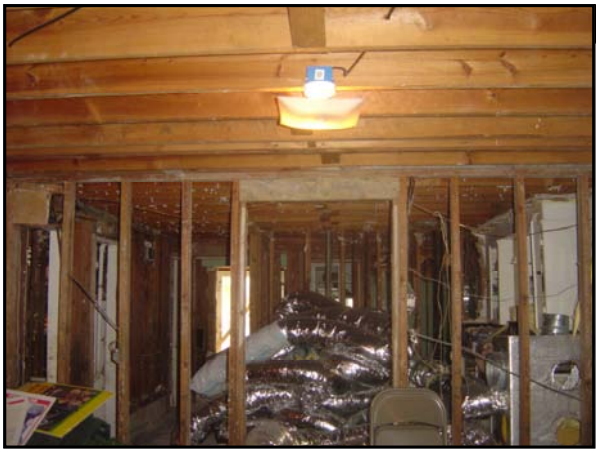

Decontamination
Page 21


09/14/2005




PEACE

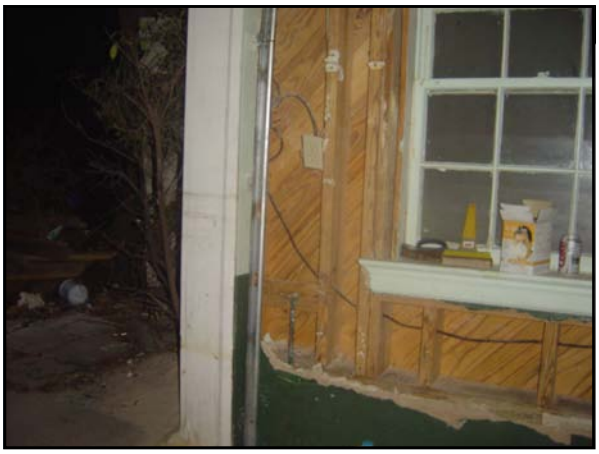

HUSKY
POPS




SABRE


SABRE


SABRE



Before and After ClO_2 Fumigation Photos

Before | After

Before and After ClO_2 Fumigation Photos

Before | After

After

Before | After

r ClO_2 Fumigation Photos

Before | After

Before and After ClO_2 Fumigation Photos

Before | After

Before and After ClO_2 Fumigation Photos

Before | After

Before | After

Before

After

Before and After ClO_2 Fumigation Photos

Before | After

Before and After ClO_2 Fumigation Photos

Before | After

Restoring New Orleans – Job Corps Center - Trenton in 3 Days

Restoring New Orleans – Job Corp Center – Trenton in 3 days

Restoring New Orleans –Bywater Station Post Office – State Dept in 2 days

Restoring New Orleans – Pascale's Manale Restaurant 7,000 SF

Restoring New Orleans – Large Residential 13,000 SF

Decontamination Technology Testing and Evaluation

2006 US EPA Decontamination Workshop

Joseph Wood
NHSRC

April 26-28, 2006

Outline of Presentation

- Technology Testing and Evaluation Program: Decontamination
  - Chlorine Dioxide Fumigant Technology
  - Liquid Spray/Foam Decontamination Technologies
- Portable Chlorine Dioxide Generation System, aka Mobile Decontamination Trailer

Some TTEP Background

- Primary objective is to evaluate building decontamination technologies that are commercially available (or near so)
- Historical focus has been on fumigants to decon *B. Anthracis* on indoor types of materials
- Started under US EPA's Environmental Technology Verification Program
- "Evaluation" implies one set of experimental conditions to demonstrate/verify efficacy
- More promising techs. would move on to more involved systematic investigation
- Typically done in collaboration with vendor, but not necessarily a prerequisite (as with ETV)
- Acknowledgements
  - Battelle is contractor for work described herein: Mike Taylor, James Rogers, et al.
  - EPA collaborators: John Chang, Eric Koglin, Shawn Ryan, Blair Martin

TTEP Background

Stakeholders

- Steve Tomasino, EPA OPP
- Jeff Kempter, EPA OPP
- David Stark, ECBC contractor
- Phil Koga, ECBC
- Paula Krauter, LLNL
- Lloyd Larsen, Dugway
- Rebecca Blackmon, TSWG
- Harry Mahar, Dept. of State
- Gregory Knudson, CIA

ClO_2 Fumigant Technology Evaluation

Sabre Technical Services

• Lab-scale testing (317 L chamber)
• Liquid inoculation
  - ~1.0 x 10^8 CFU spores in 100 uL water
  - applied in 16 droplets on coupon
• Calculation of Efficacy
  - Log Reduct. = log N/N'
    N= control (3)
N' = treated

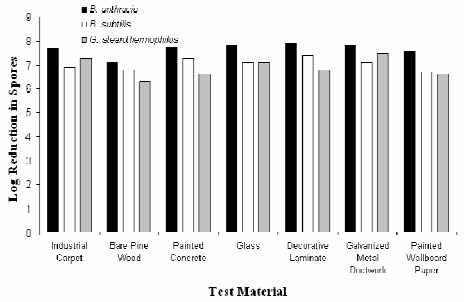
Industrial carpet
Bare pine wood
Glass
Decorative laminate
Galvanized metal
Painted wallboard paper
Painted concrete

T: 22 – 35 deg C
RH: 75% – 90%
Contact time: 3 hr
3,000 ppmv ClO2

ClO_2 Fumigant Technology Evaluation

- Spores: *B. Anthracis, B. subtilis, G. Stearothermophilus*
- ClO_2 measurement:
  - Sample from decontamination chamber removed at 1L/min for 2 min and drawn through impingers containing 15 mL of 5% KI in phosphate buffer (pH 7.0)
  - Sample acidified with 6N HCl and titrated using 0.1 N sodium thiosulfate
  - Titration every 20 minutes

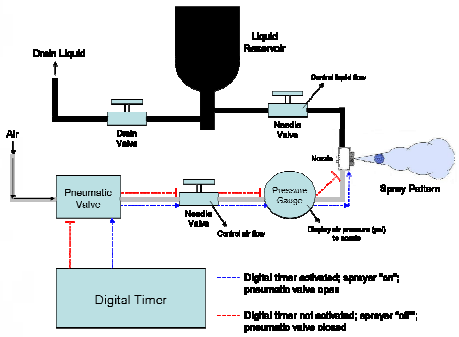
ClO_2 Fumigant Technology Evaluation - Results



Liquid Spray Decontamination Technology Evaluation

- Screen10 technologies (plus amended bleach) first, then sprays/foams with highest efficacy will be subjected to more in-depth testing
- Same microbiological procedures for both for in-depth and screening testing; 4 coupons as controls, 4 subject to decon agent
- Screening will involve only *B. Anthracis* Ames strain on glass coupons
- In-depth testing to be conducted on 4 technologies
  - Three organisms will be tested
    - *Bacillus anthracis* Ames
    - *Bacillus subtilis, Geobacillus stearothermophilus*
  - 3 materials will be tested (carpet, wood, metal)

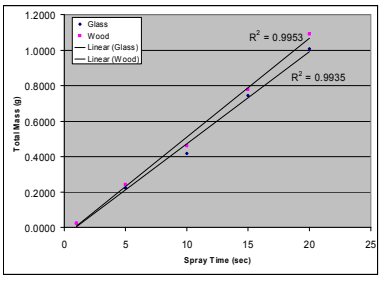
Liquid Spray Decontamination Technology Evaluation



Liquid Spray Typical Neutralization Results

Treatment	Inoculum (CFU)	Avg. Total CFU Recovered	% of Control
EFT + Spores	7.93E+07	0	0
EFT + PBS + Triton X-100 + Spores	7.93E+07	6.28E+07	83.2
PBS + Triton X-100 + Spores	7.93E+07	7.55E+07	-
EFT + PBS + Triton X-100 + 0.23% STS + Spores	7.93E+07	7.43E+07	98.3
EFT + PBS + Triton X-100 + 0.50% STS + Spores	7.93E+07	7.27E+07	96.2
EFT + PBS + Triton X-100 + 1.0% STS + Spores	7.93E+07	7.05E+07	93.4

Typical Spray/Weigh Results



Liquid Decon Technologies Undergoing Screen Testing

Technology	*Primary Ingredients*	*Decontaminating Agent*
EasyDecon 200 (foam)	7.9% H2O2, quartenary ammonium compounds: 5.5-6.5% ; diacetin 30-60%	H_2O_2, quat ammon.
Peridox Clean Earth Tech	H2O2 23-25%; peroxyacetic acid 1-1.4%; acetic acid 1-1.4%	H_2O_2,peroxyacetic acid
DeconGreen (foam)	Potassium molybdate, potassium carbonate, propylene carbonate, H2O2 (30%), Triton X-100	H_2O_2
HI-Clean 605	Sodium dichloroisocyanurate, trichloro- s- triazinetrone	HClO
CASCAD GCE 2000 (foam)	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%	HClO (Hypochlorous acid)
Selectrocide	Sodium chlorite 15-40%; activator 55-85%, inert ingredients <2%	ClO_2
Exterm-6	Inorganic acid (25-35%)Sodium chlorite 15-30%, Inorganic salt 35-45%, activator 5-10%	ClO_2
Frontier Dioxiguard	ClO2; sodium chlorite & chlorous acid; Phosphoric acid, lactic acid; catalyst	ClO_2, $HClO_2$
Klear Water Xinix	Concentrated aqueous ClO2	ClO_2
Biosafe Antimicrobial Polymer, HM-4100	Octadecylaminodimethyltrimethyloxysilylpropyl ammonium chloride; Chloropropyltrimethoxysilane, Dimethyl octadecylamine	Quat. ammonium

Portable Chlorine Dioxide Generation System

Objective

- Demonstrate the performance of a mobile chlorine dioxide decontamination technology in a building-size application

Portable Chlorine Dioxide Generation System

- Work being conducted through an IAG with Naval Surface Warfare Center
- NSWC has contract with SAIC and Battelle for engineering and construction
- DoD/JPEO, DHS, DARPA participating

Portable Chlorine Dioxide Generation System

Timeline

- October 2004: Initial test on a building
- January 2005 – May 2005: MDT redesign & overhaul
  - Redesign scrubber, add demister; new equip.
  - Emergency elec. shutdown, chlorine shut-offs
- May 2005 – "Cold" flow test
  - Pressurized leak check, 24-hr scrubber run

Portable Chlorine Dioxide Generation System

Next Steps

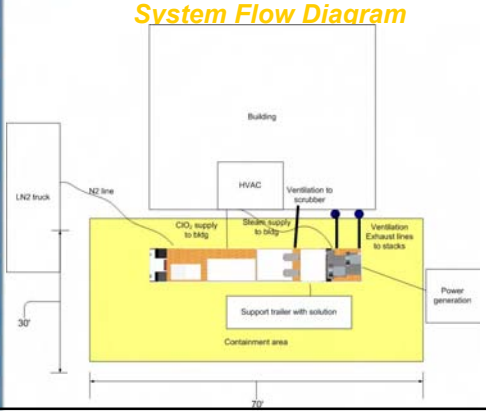
- Hot test
  - Test ClO_2 generation and scrubbing systems with chlorine (previous tests used only nitrogen) – ClO_2 ducted directly to scrubber
    - Leak check, interlock system, generation rate/capacity, scrubbing effectiveness (ClO_2 removal), capacity, negative pressure, fan flow rate, steam generation, emergency shut-off
- Building test
  - Measure and maintain ClO_2 concentration within the building
  - Also measure performance using dispersed B.g. spores and biological indicators within the building
  - Possibly conduct spore re-suspension studies and determine fumigation effectiveness via environmental sampling

Portable ClO_2 Generation System

Design Goals

- Generate about 75 lb/hr ClO_2 on site reacting chlorine gas with sodium chlorite
- Sustain a level of about 1000 ppm ClO_2 in a 350,000 cubic ft building for about 12 hours under slightly negative pressure
- Negative pressure maintained with an exhaust fan vented to a scrubber which removes ClO_2 < 0.1 ppm @ ~ 3600 ACFM
  - Utilizes sodium hydroxide and sodium thiosulfate as scrubbing reagents
- Transportable

Portable ClO_2 Generation System Flow Diagram



VHP Fumigation Technology Update

Iain McVey
STERIS Corporation
April 27, 2006

Corporate Overview

STERIS Corporation

- Develops, manufactures and markets infection prevention, contamination control, decontamination, microbial reduction and surgical and critical care support products.
- Serves healthcare, pharmaceutical, scientific, research, industrial, defense, aerospace, and government customers throughout the world.

Corporate Overview

- **MARKET FOCUS**
  - Healthcare Products and Services
    - Sterile Processing
    - Applied Infection Control
    - Surgical Support
  - Life Science Products and Services
    - Pharmaceutical Production
    - Research – Containment Level 3 and 4 Labs
    - Defense & Aerospace Chem-Bio Decontamination
    - Decontamination Services
  - Contract Sterilization Services
    - Medical Devices
    - Food Products
    - Material Modification

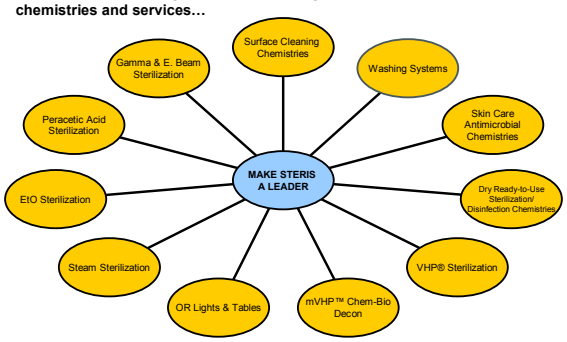
Corporate Overview

Capabilities

- Technology and Intellectual Property Development
- Microbiological and Chemical Sciences
- Formulation Chemistry
- Mechanical, Electrical, and Process Engineering
- Product Development
- Global Manufacturing
- Regulatory Compliance and Testing
- Customer Training and Education
- Field Services

A Technology Leader

Broad based technologies delivered through capital equipment, chemistries and services…



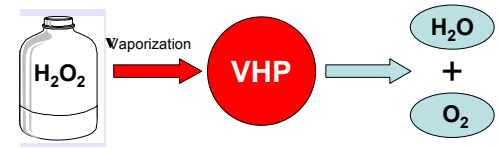
Defense & Industrial

- Scale-up and adapt an established biological sterilization/decontamination technology -- VHP -- for new applications.
- Recognize the national need for decontamination capability as a result of the anthrax attacks of October 2001.
- Commit to exploring national and homeland defense needs, as well as the need for a pathogen-free environment with DoD and other federal agencies.
- Established public-private partnership with the U.S. Army's Edgewood Chemical Biological Center (ECBC)

Decontaminant Requirements

- Effective decontaminant:
  - Rapid acting
  - Chemical and biological efficacy
  - Materials compatibility
  - No post fumigation residuals

VHP

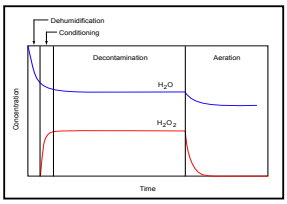


Vaprox®
35% H_2O_2
sterilant solution

Sporicidal at low concentrations
(>0.1 mg/L at ambient temperatures)
Odorless, colorless

Nontoxic
degradation
products

The VHP Decontamination Process



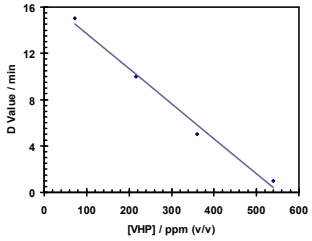
1. Dehumidification
- Reduce condensation formation of the hydrogen peroxide
- Recommended for high humidity and/or cold temperature application

2. Conditioning
- Initiation of hydrogen peroxide vapor
- High injection rate to rapidly reach target concentration

3. Decontamination
- Timed phase at target concentration to ensure site is exposed to decontaminant for at least the min. exposure time

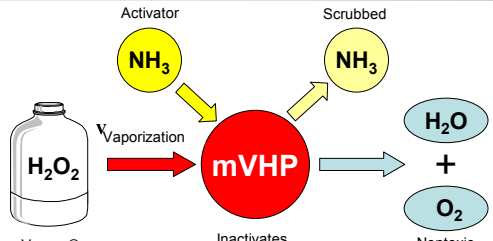
4. Aeration
- Hydrogen peroxide injection stopped
- Dried air purge of hydrogen peroxide from the site

VHP Antimicrobial Efficacy



**B stearothermophilus* D-values were determined at various VHP concentrations. The average D-value is shown for each concentration, as determined from an initial spore population innoculated onto stainless steel coupons, exposed to VHP over time and D-values determined by direct enumeration. The D-value is the average time in minutes for a single log reduction of spores. For example, at 250 ppm (0.35 mg/L) of hydrogen peroxide a 6 log reduction will take 48 minutes.

mVHP™ - Chemical and Biological Decontamination

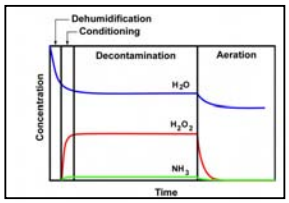


Vaprox®
35% H_2O_2
sterilant solution

Inactivates
biological and chemical warfare agents
at low concentrations
(>0.1 mg/L at ambient temperature)
Odorless, colorless

Nontoxic
degradation
products

The mVHP™ Decontamination Process



1. Dehumidification
- Reduce condensation formation of the hydrogen peroxide
- Recommended for high humidity and/or cold temperature application

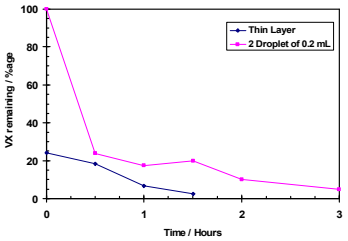
2. Conditioning
- Initiation of ammonia and hydrogen peroxide vapor
- High injection rate to rapidly reach target concentration

3. Decontamination
- Timed phase at target concentration to ensure site is exposed to decontaminant for at least the min. exposure time

4. Aeration
- Ammonia and hydrogen peroxide injection stopped
- Dried air purge of ammonia and hydrogen peroxide from the site

ECBC data - Data vs. droplets and films of chemical agents

VX / mVHP Reaction Kinetics, effect of droplet size



Data from G. W. Wagner et al., Modified Vaporized Hydrogen Peroxide (mVHP) Decontamination of VX, GD and HD. Presentation - Decon 2005.

mVHP Materials Compatibility Testing

- Testing was performed by METSS for the Air Force Research Laboratory
- A list of C-17 aircraft materials was reviewed and discussed with engineers at the C-17 Program Office, Boeing and AFRL to determine the materials most likely to come in contact with mVHP during and after test exposure
- Materials tested included a selection of:
  - Metals
  - Rigid Plastics
  - Flexible Plastics
  - Elastomers
  - Composites
  - Adhesives
  - Textiles
  - Wiring
  - Printed Circuit Boards
- mVHP was generated using a Steris VHP-1000ED. Materials were exposed to mVHP (275 ppm VHP, 15 ppm NH_3 for 24 hours, or 500 ppm VHP, 30 ppm NH_3 for 12 hours)
- All testing was compliant with ASTM and SAE standards
- With the exception of nylon webbing (whose tensile strength was reduced 10-15%), mVHP had little to no effect on metals, plastics, elastomers, composites, adhesives, and wire insulation

Aircraft Materials Compatibility

Testing to study the effects of exposure to mVHP using ASTM methods

Investigators: Air Force Research Lab / METSS
Location: Wright Patterson AFB, OH / Westerville, OH
Equipment: mVHP 1000ED

Completed July 2004

Exposure: 275 ppm VHP / 10 ppm NH_3 (24 hour exposure)
Materials:
Al 2024-T3 (sheet)
Al 7050 (extrusions, forgings, sheets)
Al 7075-T6
303 CRES Steel (sheet)
300M Steel (forging)
15-5PH Steel
Ti-6Al-4V (forging)
Ti-10V-2Fe-3Al (forging)
Acrylic (cast and stretched)
Cast Polycarbonate
Kapton®
FEP/Kapton®
FEP/Kapton®/FEP
Isultab® 330 Film
Silicone (sheet and closed cell foam)
Honeycomb composite wall panel
Self-stick anti-skid patches
Patching tape
Nylon webbing
Wiring (MIL-W-81381, MIL-W-22759)
Encapsulated printed circuit boards

September 2005 to February 2006

Exposure: 500 ppm VHP / 30 ppm NH_3 (12 hour exposure)
Materials:
Aluminum 2024-T3 (sheet)
Aluminum 7050 (extrusions, forgings, sheets)
Aluminum 7075-T6
4340 Steel
303 CRES Steel (sheet)
300M Steel (forging)
Ti-6Al-4V (forging)
Ti-10V-2Fe-3Al (forging)
Acrylic (cast and stretched)
Polycarbonate (Lexan®)
Kapton® wire insulation
Nomex® flexible insulation
Insulfab® 330 Film
Silicone (sheet and closed cell foam)
Polysulfide sealant (chromated and non-chromated)
Nylon reinforced Rubber (Tire)
Nitrile Rubber O-Ring
Mil-W-4088 Nylon Webbing
Honeycomb composite wall panel
Carbon Fiber /Epoxy Composite
Carbon Fiber / Bismaleimide
Thermoplastic Polyester 30% glass
Self-sticking anti-skid patches
Patching Tape
JSF and F-16 Applique on Composite Substrate
Wiring (MIL-W-81381, MIL-W-22759)
Encapsulated printed circuit boards
MIL-C-85285 Polyurethane Topcoat Paint
Rain Erosion Coating (FP-240F and LMA-MR173)
APC Water-based Acrylic Paint
JSF OML Substrate with Topcoat

Delivery System Requirements

- Effective delivery system:
  - Portability
  - Deployability
  - Modularity
  - Scalability
  - Capability

Sensitive Equipment Decontamination

SED Unit

•250 cu ft

•160 sq ft Shelving

•463L pallet mounted

Gator-Mounted Man Portable System

•36 cu ft.

•24 sq ft Shelving

•Man portable

Tactical Vehicle Decontamination

- 10,000 cu ft
- 720 sq ft shelving
- Whole vehicle decontamination

Healthcare Related Decontamination




STERIS

F-16 Aircraft Decontamination



STERIS

C-141 Aircraft Decontamination

- Self Contained Truck Mounted mVHP system
- Mounts on 5 ton truck and trailer
- Small vaporizer modules provide flexibility
- All removable components man portable


STERIS

Testing – Results Pending

- ECBC
  - Sensitive equipment compatibility
  - Materials Compatibility
  - Cycle time optimization – Agent testing
  - F16 biological decontamination
- AFRL
  - Materials compatibility
- JPL
  - Efficacy and materials testing
- LLNL
  - HVAC decon

STERIS

Ongoing Research and Development

- Room decontamination
  - Consortium of North East Ohio Hospitals (CCF, UH, VA, Metro etc.)
  - *C. diff.*, MRSA, VRE / CCF
- Cycle time optimization
- Field forward generation of hydrogen peroxide
- High temperature mVHP delivery systems
- Large Scale mVHP systems for building decontamination
  - Designed to leverage locally available rental equipment
  - Compatible with commercial air shipment
- Systems for Wide Area Decontamination

STERIS

Lab Decontamination of 65 Room New Animal Facility Using Chlorine Dioxide Gas

Mark A. Czarneski
Director of Technology
CSI ClorDiSys Solutions, Inc.

CSI ClorDiSys Solutions, Inc.

Overview

1. Define Chlorine Dioxide
2. Define Chlorine Dioxide Sterilization Parameters
3. Chose Decontamination Agent
4. Decontamination Event
5. Advantages / Conclusions

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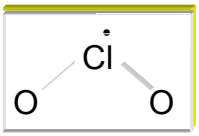
What is Chlorine Dioxide (CD) ?

Properties:

- Yellow-Green Gas[1]
- Water Soluble[2]
- Boiling Point 10°C[3]
- Tri-atomic Molecule
- Molecular Weight 67.5



1. Ability to be monitored in real time with a photometric device.
   Not subject to condensation or affected by temperature gradients.
2. Ability to penetrate water (not all sterilants can penetrate water, *vapors can not*)
3. Chlorine dioxide is a "true gas" at room temperatures.

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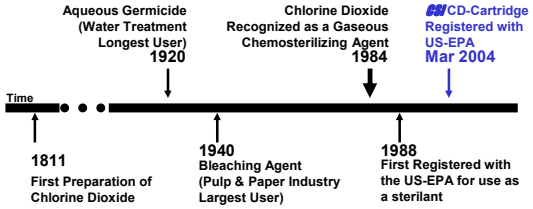
Chlorine Dioxide Time Line



- World wide consumption of chlorine dioxide – 4.5 million lbs/day.
- 743,000 lbs released to atmosphere in 2000.
- Example: Maine allows 3 lb's / hour of CD to be emitted

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Chlorine Dioxide Generation Technology

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

- Performed in solid phase (no liquids)
- Gas generated on demand
- Self-Contained reagents
- Simple to replace consumables
- Small portable generators
- Generator capacity 1-60,000 cu ft

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The Decontamination Process Steps

- **Pre-Conditioning**
  Raise RH 65%-75%
- **Conditioning**
  Dwell time at RH SP
- **Charge**
  Raise CD Concentration (1mg/L)
- **Exposure**
  Dwell time at CD SP
- **Aeration**
  Remove CD Gas 12-15 air exchanges

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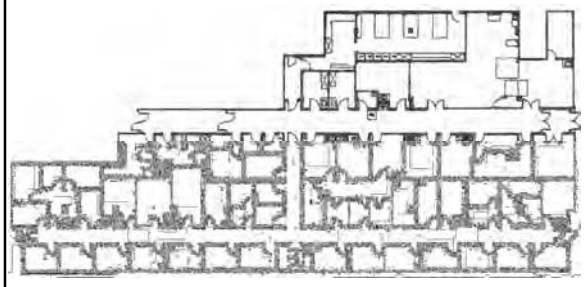
65 Room New Animal Facility
180,000 cubic feet Total Volume



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65 Room New Animal Facility
Chemistry Labs

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65 Room New Animal Facility
Changing Stations and BSC's

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65 Room New Animal Facility
Storage Rooms

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65 Room New Animal Facility
Animal Holding Rooms

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Why Decontaminate?

- New Facility Decontamination (3-log reduction required)
- Decontaminate before bringing in research animals
- Decontamination performed to prevent contamination or cross contamination
- Decontaminate equipment (some new and some used from another facility)
- Equipment Decontaminated all in place including:
  - Rodent cages
  - Rodent racks
  - BSC's
  - Bedding changing stations
  - Video cameras
  - Microscopes
  - Various electronic monitoring devices

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How to Decontaminate a 180,000 cu ft facility

Four (4) decontaminating techniques were considered for the space decontamination (3 fumigants and 1 liquid based)

1. formaldehyde gas
2. hydrogen peroxide vapor
3. chlorine dioxide gas
4. Manual wiping with liquid high level disinfectant

First three were known to be effective decontaminants to spore and non-spore forming bacteria under standard laboratory conditions.

i.e., clean flat surfaces lacking porous materials or potential dead-legs with which fumigant penetration might be retarded.

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Formaldehyde Gas

- Formaldehyde requires the heating of paraformaldehyde to release the gas
- Formaldehyde involves the neutralization, post exposure with ammonia gas
- A residue is commonly left after such treatment, consisting of polymerized formaldehyde (paraformaldehyde) and the neutralization product (methenamine)
- Removal of such a residue was considered problematic for this facility
- Residual formaldehyde from off gassing was also of concern, due to its odor and its perceived toxicity.
- Formaldehyde is considered a potential carcinogen by the EPA and an actual carcinogen by the International Agency for Research on Cancer.

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Formaldehyde Cleanup

- Formaldehyde neutralization is done using ammonia bicarbonate
- Too little is causes more formaldehyde residuals
- Too much is causes a lot of bicarbonate residual cleanup
- Try to balance the two, not wanting formaldehyde residuals and also not wanting to cause too cleanup
- If balance is not correct then there will be residuals
  - Residual can affect research performed facility
  - Residuals add load to HEPA filters
  - Residual can affect worker safety (tearing, coughing, breathing issues…)
- Large space decontamination is troublesome due to cleanup required, can all surfaces realistically be wiped to remove all residues

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Hydrogen Peroxide Vapor

- Hydrogen peroxide vapor is generated by boiling/vaporizing 35% liquid hydrogen peroxide
- Currently 2 camps of thought for VHP, Wet and Dry
  - Dry - wants no amount of condensation
  - Wet - wants "micro-condensation"
- Dry Process - difficult to eliminate condensation
- Wet Process - difficult to obtain uniform condensation
- Both of these issues were believed too restrictive for the current application, when decontaminating entire volume
- It was believed that it would have been difficult to distribute and maintain an appropriate concentration of vapor hydrogen peroxide within the many rooms

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Hydrogen Peroxide Scalability

Hydrogen Peroxide decontamination of 13,000 sq ft (130,000 cu ft) [1]

- Had to break into 3 zones and decontaminate separately
- Zone 1, 2, 3 - 2hr 10 min exposure cycle + overnight aeration
- Total Decontamination time - 3 day period (does not include setup)
- Equipment used 31 vapor generators
- 1 generator for every 1398 cu ft and 22 aeration modules
- If same system as described is used for 180,000 cu ft, then 128 vapor generators would be required to decontaminate this facility

1. Herd, Michael and Warner, Adam. Hydrogen Peroxide Vapor Bio-decontamination of The Jackson Laboratory's New Animal Facility, Animal Lab News, Vol 4 No. 7, November/December 2005.

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Manual wiping with liquid high level disinfectant

- Fogging spray liquids around the room
- Foggers create small droplets that are affected by gravity
- Droplets do not reach:
  - Under side of equipment or components
  - Behind equipment
  - Ceilings
  - Ventilation grills
- Large space decontamination is troublesome, can all surfaces be realistically be sprayed and wiped

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Chlorine Dioxide Gas

- Chlorine Dioxide is a true gas
- True gasses distribute
- True gasses have good penetration abilities
- Not affected by temperature
- Does not condense on surfaces
- Does not require neutralization
- Does not require post exposure wipe down

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How to do Chlorine Dioxide Gas

- Seal the facility, including all doorways, exhaust vents and supply vents
- Fill all drains with water
- Deactivate air supply
- Place circulation fans throughout facility (60 used)
- Install gas generators and sensing tubing
- Place Biological Indicators throughout facility

- Start Decontamination Process

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Equipment Used

- 5 chlorine dioxide gas generators (total 10 Injection points
- 20 chlorine dioxide gas sensing points

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Injection and Sensor Locations

10 *Injection Locations*
20 *Sensor Locations*

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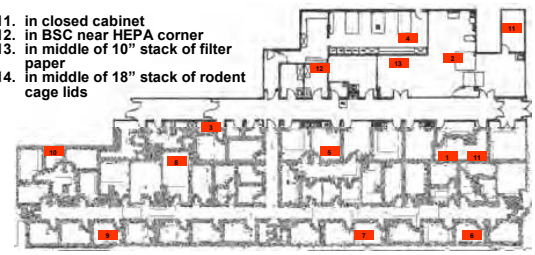
Biological Indicator Locations Total Kill of all BI's

14 b. *Atrophaeus* Locations

11. in closed cabinet
12. in BSC near HEPA corner
13. in middle of 10" stack of filter paper
14. in middle of 18" stack of rodent cage lids



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Decontamination

- Condition raise humidity to minimum 65% RH
- Charge
  - Target Concentration 1 mg/L
  - Actual concentration 0.5-0.8 mg/L
- Exposure
  - Target 2 hour
  - Actual 6 hours charge/exposure exposure
- Aeration

- Loss of gas in ventilation system (up stack)
- No measurable concentration outside facility
- No other leaks detected

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Concentration Readings (mg/L)
DMS-1 Decontaminating Monitoring System

Time	1	2	3	4	5	6	7	8	9	10	
12:20	0.1	0.2	0.1	0.2	0.1	0.2	0.2	0.2	0.2	0.2	charge
1:05	0.3	0.4	0.3	0.4	0.3	0.4	0.4	0.4	0.3	0.4	
2:00	0.4	0.5	0.4	0.5	0.5	0.5	0.5	0.5	0.5	0.6	
2:45	0.5	0.6	0.5	0.6	0.5	0.6	0.6	0.6	0.6	0.7	
3:25	0.6	0.7	0.6	0.7	0.6	0.7	0.7	0.7	0.7	0.8	
4:00	0.6	0.7	0.7	0.7	0.7	0.7	0.7	0.8	0.7	0.9	
4:45	0.6	0.7	0.7	0.7	0.7	0.7	0.7	0.7	0.7	0.7	
5:35	0.7	0.8	0.7	0.7	0.7	0.7	0.7	0.7	0.6	0.6	
6:15	0.7	0.8	0.7	0.7	0.7	0.7	0.7	0.6	0.6	0.6	
7:00	0.7	0.7	0.7	0.6	0.7	0.6	0.5	0.6	0.6	0.6	
7:35	0.2	0.2	0.2	0.1	0.1	0	0	0	0	0.1	Aeration
7:50	0	0	0.1	0	0	0	0	0	0	0	Aeration
8:00	0	0	0	0	0	0	0	0	0	0	Aeration
avg mg/L	0.567	0.656	0.589	0.622	0.6	0.622	0.611	0.622	0.589	0.656	
avg ppm	205.1	237.3	213.2	225.2	217.2	225.2	221.2	225.2	213.2	237.3	
ppm hrs	1231	1424	1279	1351	1303	1351	1327	1351	1279	1424	
										1332	Avg ppm hrs

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Concentration Readings (mg/L)
DMS-2 Decontaminating Monitoring System

Time	11	12	13	14	15	16	17	18	19	20	
12:25	0	0	0.1	0.1	0	0	0	0	0	0	charge
1:10	0.4	0.4	0.5	0.4	0.3	0.3	0.4	0.3	0.3	0.3	
2:15	0.5	0.5	0.5	0.5	0.4	0.5	0.5	0.3	0.3	0.5	
2:50	0.6	0.6	0.6	0.6	0.5	0.5	0.5	0.3	0.3	0.5	
3:35	0.7	0.7	0.7	0.6	0.6	0.6	0.6	0.4	0.4	0.6	
4:00	0.8	0.7	0.8	0.7	0.6	0.6	0.6	0.4	0.5	0.6	
4:50	0.9	0.8	0.8	0.6	0.5	0.5	0.5	0.4	0.4	0.6	
5:35	0.9	0.9	0.8	0.6	0.5	0.5	0.5	0.4	0.4	0.6	
6:15	0.9	0.9	0.9	0.6	0.5	0.5	0.6	0.4	0.5	0.6	
7:00	0.9	0.8	0.8	0.6	0.5	0.6	0.6	0.5	0.5	0.5	
7:35	0	0.1	0	0	0	0	0	0	0.1	0	Aeration
7:50	0	0	0	0	0	0	0	0	0	0	Aeration
avg mg/L	0.733	0.7	0.711	0.578	0.489	0.511	0.533	0.378	0.4	0.533	
avg ppm	265.5	253.4	257.4	209.2	177	185	193.1	136.8	144.8	193.1	
ppm hrs	1593	1520	1545	1255	1062	1110	1158	820.5	868.8	1158	
										1209	Avg ppm hrs

(1332 + 1209) / 2 = 1271 Avg ppm hrs

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Chlorine Dioxide Process Advantages

- Biocidal at Low Concentration and Ambient Temperature
- Gas Distributes Rapidly
- Process Tolerates Temperature Fluctuations
- Non-flammable at Use Concentrations
- No Liquids
- Self-contained Reagents
- Short Cycles
- Size Scalable
  - Range of Target Volumes
  - Long Distances
- Low Residuals
- Rapid Aeration (Low-Use Concentration and Minimal Adsorption)
- Gas Concentration is Easily and Accurately Monitored
- No manual wiping required
- No neutralization required
- No mixing of solutions

ClorDiSys Solutions, Inc.

Conclusions

- Complete kill of all Biological Indicators
- No physical residue observed as would be if formaldehyde was used.
- No visible indication of material degradation on any of the metal containing equipment left within the building including the ventilated racks, BSC's, various electronics, etc.
- No visible indication of material degradation on any electronics
- CD has proven itself to be a practical and effective method for decontaminating large facilities
- Low Chlorine Dioxide Concentrations (Less than 330 ppm)
- 1271 total average ppm hours

ClorDiSys Solutions, Inc.

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Minidox-M
Chlorine Dioxide Gas Generator

Cloridox-GMP
Chlorine Dioxide Gas Generator

Revision Date: April 26, 2006

ClorDiSys Solutions, Inc.

Chlorine Dioxide vs. Hydrogen Peroxide Cycle Times

Isolator Decontamination	Volume	Cycle Time
Steris VHP	≈ 25 ft³ (0.7m³)	3-6 hours [1]
Bioquell Clarus	≈ 25 ft³ (0.7m³)	3-3.5 hours [1]
Chlorine Dioxide	31 ft³ (0.88m³)	1.3 hours [2]

Room Decontamination	Volume	Cycle Time
Steris VHP	300 ft³ (8.5m³)	7.5 hours [3]
Steris VHP	760 ft³ (21.5m³)	4.25 hours +overnight aeration[4]
Bioquell Clarus	2500 ft³ (70.8m³)	10-11 hours [5]
Chlorine Dioxide	2700 ft³ (76.5m³)	3.5 hours [6]

1. Caputo Ross A. and Jim Fisher. Comparing and Contrasting Barrier Isolator Decontamination Systems. Pharmaceutical Technology, Vol 28, No 11, p 68-82, November 2004.
2. Czarneski Mark A. and Paul Lorcheim. Isolator Decontamination Using Chlorine Dioxide Gas. Pharmaceutical Technology, Vol 29, No 4, p124-133, April 2005.
3. Steris Case Study M1456, VHP Case Study #1 – Hydrogen Peroxide Gas Decontamination of A Material Pass-Through (MPT) Room, Publication ID #M1456(8/99), Steris, August, 1999.
4. Steris Case Study M1455, Case Study #3 - VHP 1000 Decontamination of a 760 ft³ room Containing Blood and Urine Analyzers, Publication ID#M1455/990810 (8/99), Steris August 1999.
5. Room Decontamination Presentation to Council on Private Sector Initiatives, Washington, DC, by Henry Vance PE of Alpha Engineering, February 11, 2002.
6. Lorcheim Paul. Decontamination using Gaseous Chlorine Dioxide, A case study of automatic decontamination of an animal room explores the effectiveness of this sterilization system. Animal Lab News, Vol 3 No. 4, p25-28, July/August 2004.

Decontamination Research - A New Approach

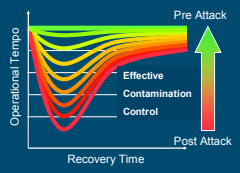
Dr Norman Govan

Defence Science & Technology Laboratory, UK

DSTL/CP19722

Battlefield Hazard Management

- Aims to maintain operational tempo by preventing the spread of hazardous materials, reducing casualties and minimising the time that personnel need to spend in IPE.
- This requires a synergistic approach
  - detection
  - avoidance
  - weathering
  - chemical hardening
  - Decontamination
    - Immediate
    - Operational
    - Thorough
    - Clearance

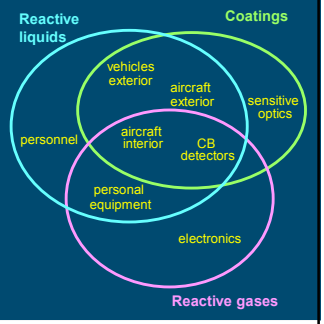


Research Aims

- To develop decontaminants, decontamination equipment and processes
  - **that clean to the required level**
  - **reduce burden on the user**
  - **can be used on sensitive and personal equipment towards a broader range of contaminants**
  - **discloses the presence of contamination and verifies the required level of clean has been achieved**
- Best achieved in a system of systems
  - **UDC, AANSTO, MLD….**

Decontamination Technology Options

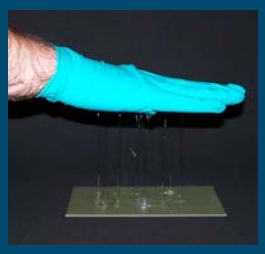
- No single technology applicable to everything
- Lowest risk approach
  - Requires combined use technologies
- The new binary approach
  - Combines use of reactive liquid decontaminants and absorbent strippable coating



Reactive Liquids

Solubility properties of chemical agent

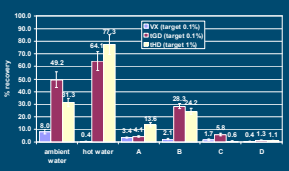
- "Oily" liquids, eg HD
  - Hydrophobic
  - Poorly soluble in water
  - Excellent penetrants
    - Capillary entrapment
- Polymer thickened
  - 5% methacrylate polymer added to aid dissemination and persistence
  - Not soluble in water
  - Renders agent highly viscous
    - Difficult to break-up without mechanical agitation.

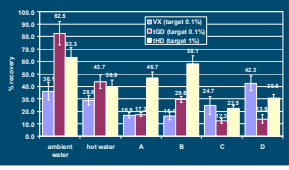


Thickened G agent simulant

Decontamination test and evaluation

Entrapped agent

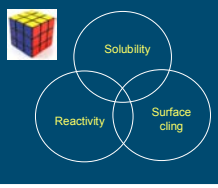




- No COTS system tested could accomplish Thorough decon using military procedures
- No current technology addresses problem of entrapped agent

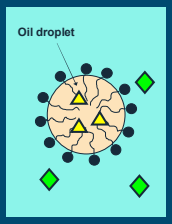
New Reactive Liquids

- Aim to develop next generation RLs (foams, gels, wipes) in support of planned EPs



- Wide range of mild decon chemistries explored for potential use in future systems
  - peroxides, peracids, novel oxidation catalysts and enzymes
- New microemulsion formulation and delivery system has been developed in support of UDC
  - 3 part formulation
  - trailer sized
  - supplied as GFI to UDC ITT

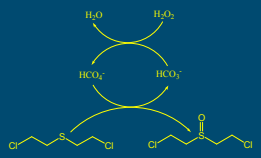
Microemulsions



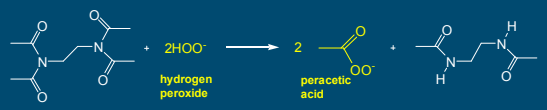
▲ Hydrophobic CW agent

◆ Anionic reagent

- Enhance solubility of hydrophobic materials in high water content systems
  - form spontaneously
  - thermodynamically stable
  - high interfacial area for decon reaction



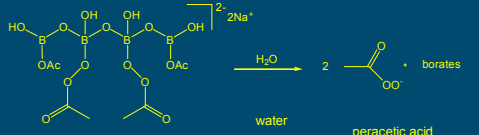
Peracetic acid from TAED



TAED (tetraacetyl ethylenediamine)

- TAED has limited solubility (~ 3g/l or 0.3% m/v)
- Requires specific conditions for activity
  - 2.5:1 ratio of peroxide to TAED
  - High pH
  - Elevated temperature
- Difficult to formulate for battlefield use

Acetylated perborate (APB)

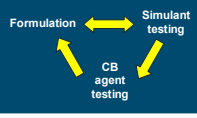


acetylated perborate (APB)

- Simple hydrolysis generation reaction
  - Less specific conditions
- APB is very soluble
  - High concentrations of peracid possible
- Potential for battlefield use
  - However, not currently available industrially

Formulation - F54

- Move away from "one-pot" approach to achieve the required efficacy
- F54 liquid concentrate, complex blend of solvents surfactants and co-surfactants
  - spontaneously forms microemulsion, diluted up to to 20% in water
  - powdered magnesium monoperoxyphthalate added to effect decon of HD and BW
  - powdered sodium percarbonate added to effect decon of nerve agents
  - effective at solvating thickened chemical agent
  - industrially viable
  - environmentally benign
  - 50 iterative generations

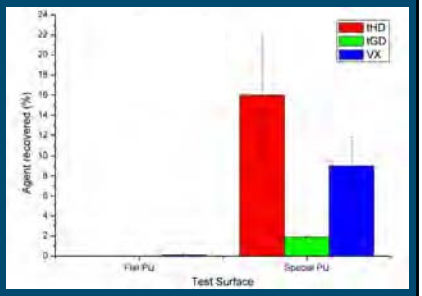


Prototype equipment, final build

New Microemulsion Liquid Decon – F54


Flat PU


Complex PU

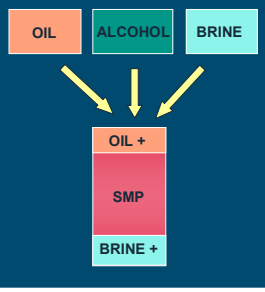


Novel Colloids (reactive liquid penetrants)

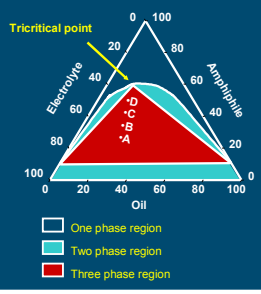
Novel Colloids

- OIL - organic liquid to dissolve CW
- ALCOHOL - soluble in both water and oil (amphiphilic)
- BRINE - aqueous electrolyte (including reactive ingredients)

- Forms three layers
- Each layer has some of each component
- Middle phase has special detergency properties



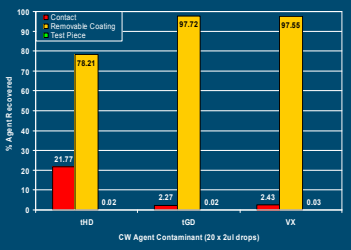
Surface Interfacial Turbulence



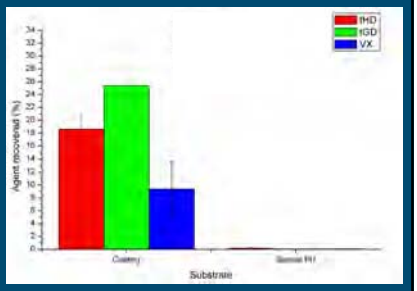
New Binary Approaches
(using coatings to aid hazard management)

CW Agent Absorption

- Coating materials have been identified that
  - Readily absorbs liquid agents
  - Reduces contact hazard
  - Prevent contamination ingress of treated surfaces



F54 in Combination with Coatings



Binary Approaches using Strippable coatings

- Rapidly maturing technology for land vehicles
  - Extensive laboratory/field trials conducted on prototype coating
  - Plans to replace in service temporary camouflage coating with dual purpose coating
  - Looking to extend concept to other equipment

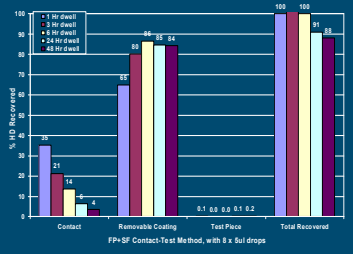
Next Generation Coatings

- Passive coatings, Phase 1
  - Research on coatings with improved absorption properties that can be easily removed (and reapplied) where required
- Active coatings, Phase 2
  - Research of coatings incorporating active materials capable of neutralising/disclosing contamination on (or in) the coating, in a binary progress

Passive Coatings

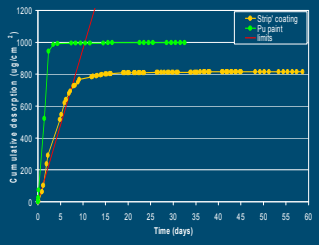
Absorption

- Aim to enhance absorption properties
  - Without loss of mechanical and signature properties
- Current research looks to increase the capacity and speed of agent uptake
  - Through control of coating porosity



Removal

- Ability to effectively remove the coating (in theatre) is key to the binary process
- A reduced vapour hazard extends the time period where coating removal delivers real benefit



Simultaneous Coating Removal and Decon

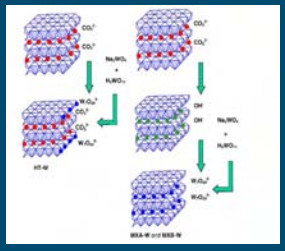
- Wide range of methods being considered
- Plan to conduct a systematic study on potential removal methods
  - Chemical (tailored decontaminants)
  - Manual stripping
  - High pressure water
  - Blast media
  - Thermal (CO_2 pellets)

- Prototype UDC F54 dispensing equipment

Active Coatings

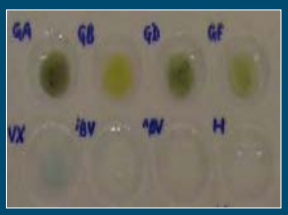
Active Coatings

- Incorporate reactive components into coating
  - To reduce eliminate off-gassing
- Wide range of active materials being considered
  - Nanoparticle
  - Reactive micro gels
  - Pillared - smectic supports
  - Microporous and mesoporous
  - Enzymes
  - Biocides, biostats



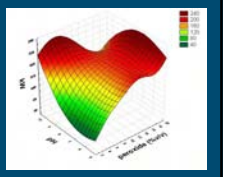
Disclosure

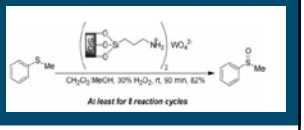
- Incorporate active components into coating
- Transduction
  - Induced fluorescence
  - Forster transfer
  - Holographic polymers
  - SERS
- Triggering
  - CW specific chemistries



Alternative Binary Approaches

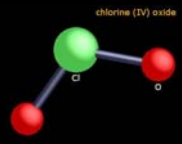
- Coating in combination with liquid activators
- Catalysts or disclosing materials embedded in the coating could be activated during decon process
  - Softening or embrittlement to facilitate removal
  - Selective oxidation of sulfides using applied liquid peroxide
  - Activated disclosure chemistries





Questions?

Decontamination of Toxins and Vegetative Cells using Chlorine Dioxide



Terrance Leighton & Katie Wheeler

Children's Hospital Research Institute

Background

- Chlorine dioxide has been used successfully for large-area *Bacillus anthracis* spore decontamination of the Brentwood (18 million cu. ft) & Trenton (6 million cu. ft.) USPS Processing and Distribution Centers and the AMI building (Boca Raton, Florida)
- A single chlorine dioxide fumigation of these buildings resulted in no culture positive post-remediation environmental samples
- These anthrax letter attack recovery operations have shown that chlorine dioxide is an effective gas-phase sporicidal decontamination technology and generated interest in the use of this fumigant as a large-area vegetative cell, viral and toxin sterilization technology

Background

- Existing data sets are only relevant to ClO_2 treatment of environmentally persistent and resistant bacterial spores
- There was a need to develop comparable data sets for non-spore forming surrogates of priority infectious agents and toxin surrogates
- We will present ClO_2 killing data for a representative suite of vegetative cell threat surrogates (plague, cholera, Q fever, food poisoning, brucellosis, melioidois, glanders, tularemia, typhoid and highly desiccation resistant vegetative threats) and toxin threat surrogates (ricin, botulism, etc.)

Surrogate

- ***Escherichia coli* ATCC 10536**
  - Gram negative
  - Rod shaped
  - Used as a surrogate for plague, cholera, Q fever and food poisoning
    - Surrogate and agents are notoriously difficult to dry to acceptable viability

Surrogate

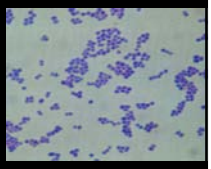
- ***Alcaligenes faecalis* ATCC 8750**
  - Gram negative
  - Rod shaped
  - Used as a surrogate for brucellosis, melioidois and glanders
    - Conditions for surrogate desiccation to acceptable viability not established

Surrogate

- ***Salmonella typhimurium* ATCC 14028**
  - Gram negative
  - Rod shaped
  - Multidrug resistance
  - Used as a surrogate for tularemia, typhoid fever and food poisoning
    - Conditions for surrogate desiccation to acceptable viability not established

Surrogate

- ***Streptococcus pyogenes*** **type strain ATCC 10403**
  - Gram positive
  - Coccus shaped
  - Extremely desiccation tolerant and can be transmitted by aerosol infection
  - Used as a surrogate for formulated vegetative bacterial agent



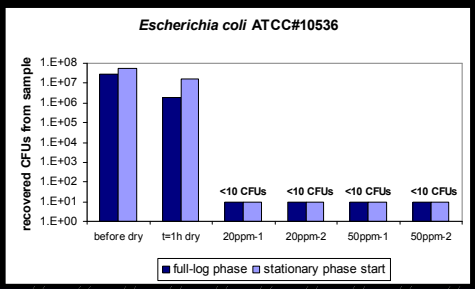
Surrogate

- ***Staphylococcous aureus*** **type strain ATCC 12600**
  - Gram positive
  - Coccus shaped
  - Aerosol transmission and multidrug resistant
  - Extremely desiccation tolerant
  - Used as a surrogate for high-quality formulated vegetative bacterial agent

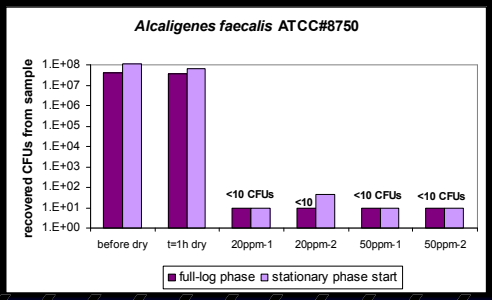
Experimental Procedures

- Samples (10µl) were placed on sample coupons (glass & plastic) and allowed to dry for two hours
- Sample coupons were placed in a test chamber and exposed to a range of ClO_2 gas concentrations for 1 - 2 hours at 80% relative humidity
- Control coupons were left at room temperature in the absence of ClO_2 gas
- *Bacillus subtilis* spore SteriCharts were also placed in the test chamber and exposed to ClO_2 gas for 1 hour

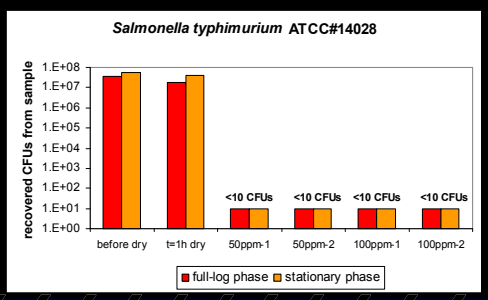
E. coli ClO_2 killing



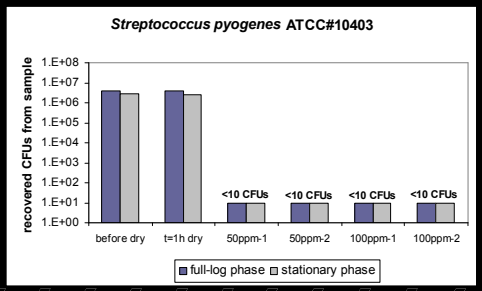
A. faecalis ClO_2 killing



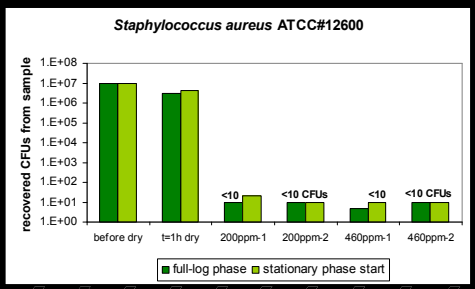
S. typhimurium ClO_2 killing



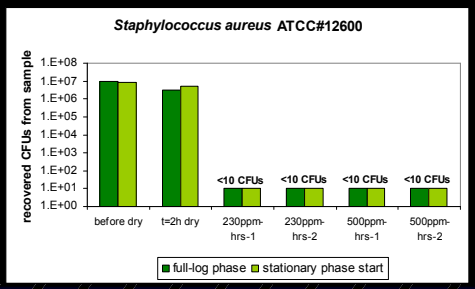
S. pyogenes ClO_2 killing



S. aureus ClO_2 killing 1 hr Contact Time



S. aureus ClO_2 killing 2 hrs Contact Time



Conclusions

- *S. aureus* is the most ClO_2 resistant surrogate and sets an upper boundary for ClO_2 Cts required for formulated vegetative agent killing - 230 ppm·hrs (2 hrs exposure)
- *S. pyogenes* is highly desiccation resistant but is considerably more ClO_2 sensitive - 100 ppm·hrs (1 hr exposure)
- The Gram-negative surrogates *E. coli*, *A. faecalis* and *S. typhimurium* were considerably less desiccation resistant and were very ClO_2 sensitive - 50 ppm·hrs (1 hr exposure)
  - These surrogates required specialized conditions for desiccation survival

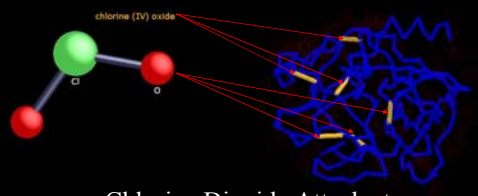
Conclusions

- These studies establish that chlorine dioxide is a very effective gas-phase sterilizing agent for a broad range of vegetative threat surrogates dried to a state of high viability
- A Ct of 230 ppm•hrs of ClO_2 resulted in a six log reduction in surrogate viability
  - Food-borne pathogens (gastroenteritis and typhoid fever), tularemia, plague, cholera, Q fever, brucellosis, melioidois and glanders
  - A desiccation resistant pathogen spread by airborne transmission (*Streptococcus pyogenes*)

Conclusions

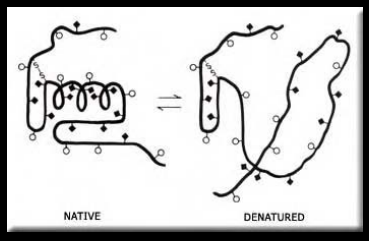
- A Ct of 230 ppm•hrs of ClO_2 is likely to be the lowest practical treatment level achievable in large-area decontamination scenarios
  - Generation and measurement of gas concentrations below this level are problematic
- A Ct of 230 ppm•hrs of ClO_2 would have very minimal effects on corrosion sensitive electronics and optics
- Other DARPA and USG data establish that a Ct of 200 ppm•hrs of ClO_2 would also be sufficient for DNA and RNA virus sterilization

Modes of Toxin Inactivation Disulfide Bond Attack



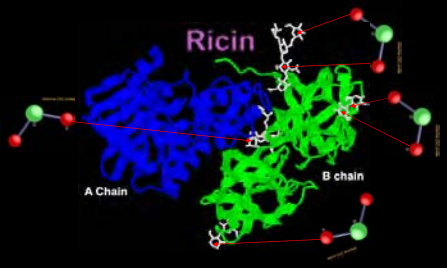
Chlorine Dioxide Attack at Essential Functional Sites in Toxins

Modes of Toxin Inactivation Denaturation



Chlorine Dioxide Causes Toxin Unfolding and Denaturation

Modes of Toxin Inactivation



Chlorine Dioxide Attack at Ricin Functional Sites

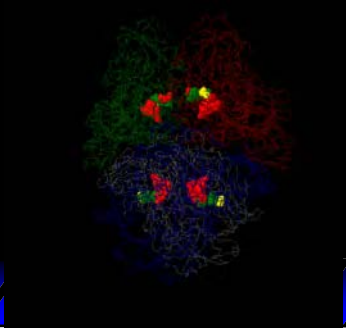
Protein Toxin Inactivation by ClO_2

- Analysis of ClO_2 killing effects on enzyme toxin surrogates
  - Utilize enzyme surrogates that have been extensively characterized biochemically and structurally
  - Utilize enzyme surrogates where the complete amino acid sequence, three-dimensional structure and reaction mechanism is known
  - Utilize real-time spectrophotometric assays to measure ClO_2 effects on enzyme activity and biochemical reaction rate constants
    - Utilize assays with near single-molecule sensitivity and very low background

Protein Toxin Inactivation by ClO_2

- Analysis of ClO_2 killing - enzyme toxin surrogates
  - *E. coli* β-galactosidase
    - Botulism toxin surrogate
  - Calf alkaline phosphatase
    - Resistant protein toxin surrogate - SEB
  - Saporin
    - Ricin surrogate

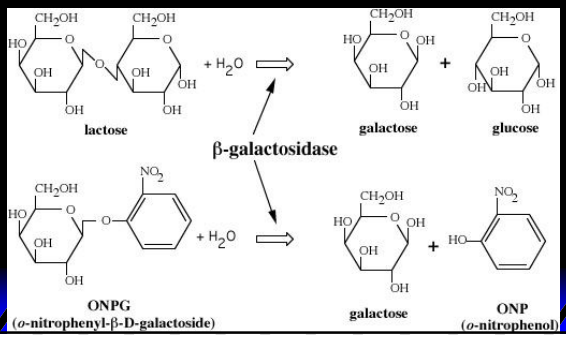
β-galactosidase



Protein Toxin Inactivation by ClO_2

- *E. coli* β-galactosidase
  - β-Galactosidase hydrolyzes the colorless substrate ONPG (o-nitrophenyl-beta-D-galactopyranoside) to o-nitrophenyl, which is yellow
    - ONPG has a very low spontaneous hydrolysis rate
  - The reaction is terminated by addition of sodium carbonate
    - Absorbance is read at 420nm

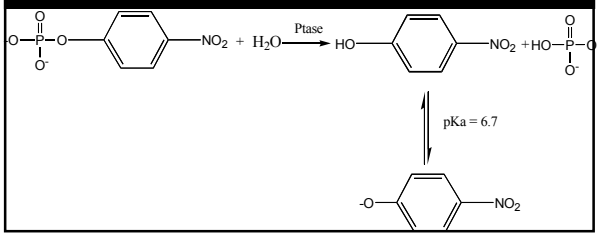
β-galactosidase Reaction Mechanism



Alkaline Phosphatase

Alkaline Phosphatase

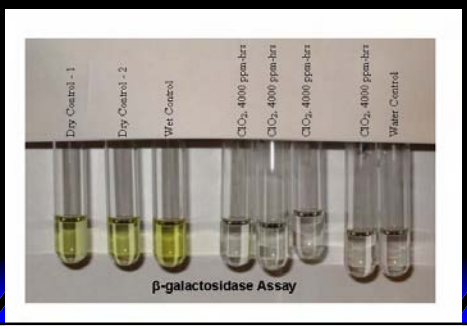
p-Nitrophenyl Phosphate + Alkaline Phosphatase ↔ p-Nitrophenol (yellow) + Pi



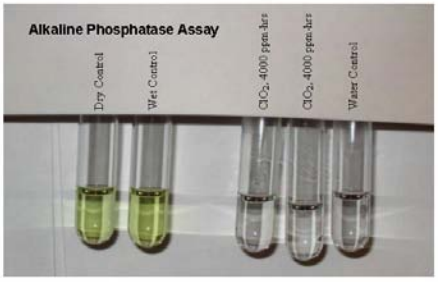
Protein Toxin Inactivation Methods

- Biochemical bioeffects
  - Dried films and gels to assess gas-phase ClO_2 bioeffects on coupon substrates
    - Deposit surrogate matrix onto coupons
    - Dry films to RH equilibrium
    - Expose to ClO_2
    - Extract surrogates
    - Determine ClO_2 effects on activity, reaction mechanism and kinetic parameters by spectrophotometric or other sensitive assays

Protein Toxin Surrogate Qualitative Inactivation Studies



Protein Toxin Surrogate Qualitative Inactivation Studies



E. coli β-galactosidase Quantitative Inactivation Studies

Beta-galactosidase 2350 ppm chlorine dioxide, 80% RH, 2 hour exposure

	Specific Activity	Average activity reduction due to drying
Wet Control	4755	
Dry control	620	**0.12**
Dry control	514	
		Average activity reduction due to ClO_2
4700 ppm-hours ClO2	0.075	
4700 ppm-hours ClO2	0.059	**4.85E-06**
4700 ppm-hours ClO2	0.059	
4700 ppm-hours ClO2	0.050	

E. coli β-galactosidase Quantitative Inactivation Studies

Beta-galactosidase 200 ppm chlorine dioxide, 80% RH, 2 hour exposure

	Specific Activity	Average activity reduction due to drying
Wet Control	6122	
Dry control	311	**0.05**
Dry control	329	
Dry control	345	
		Average activity reduction due to ClO_2
400 ppm-hours ClO2	0.531	
400 ppm-hours ClO2	1.062	**2.02E-03**
400 ppm-hours ClO2	0.796	

Calf Alkaline Phosphatase Quantitative Inactivation Studies

Alkaline Phosphatase 2350 ppm chlorine dioxide, 80% RH, 2 hour exposure

	Specific Activity	Average activity reduction due to drying
Wet Control	2028	
Dry control	951	**0.47**
		Average activity reduction due to ClO_2
4700 ppm-hours ClO2	0.051	
4700 ppm-hours ClO2	0.042	**7.05E-05**

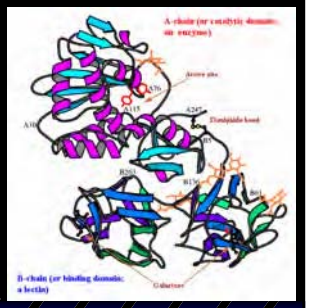
Calf Alkaline Phosphatase Quantitative Inactivation Studies

Alkaline Phosphatase 200 ppm chlorine dioxide, 80% RH, 2 hour exposure

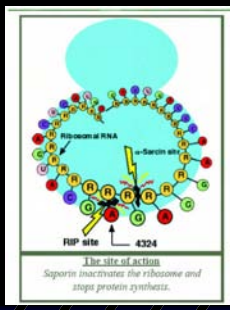
	Specific Activity	Average activity reduction due to drying
Wet Control	2973	
Dry control	3185	**0.98**
Dry control	2818	
Dry control	2709	
		Average activity reduction due to ClO_2
400 ppm-hours ClO2	0.129	
400 ppm-hours ClO2	0.143	**1.21E-05**
400 ppm-hours ClO2	0.157	

Ribosome Inactivating Proteins - RIPs

- RIPs are cytotoxic RNA N-glycosidases that inactivate ribosomes by depurination of an adenosine at position 4324 in 28 S rRNA
- RIPs occur as single chain (Type 1 - Saporin) or two chain (Type 2 - Ricin) proteins



Saporin
Ricin Related Plant RIP



SAP FACTS

Saporin
(from the seeds of the plant *Saponaria officinalis*)
29.5 kDa

SO6 isoform
Single-chain
ribosome-inactivating protein (RIP)
Extremely stable
Non-glycosylated
Most active RIP
Safely handled in the laboratory

RIP Assay

- Two step *in vitro* β-galactosidase transcription/translation system
  - Transcription of a plasmid containing the β-galactosidase gene
  - Programming of a translation system with the β-galactosidase mRNA to produce active enzyme
  - Assay of β-galactosidase activity

RIP Assay

- Assay Performance
  - >8 log sensitivity for saporin inactivation of translation activity
    - Saporin concentration and time of interaction dependent
    - Single molecule sensitivity
      - Poisson fluctuation of inhibition at high saporin dilutions
  - No background due to endogenous β-galactosidase translation system activity
  - Direct enzymic assay for ricin type RIPs

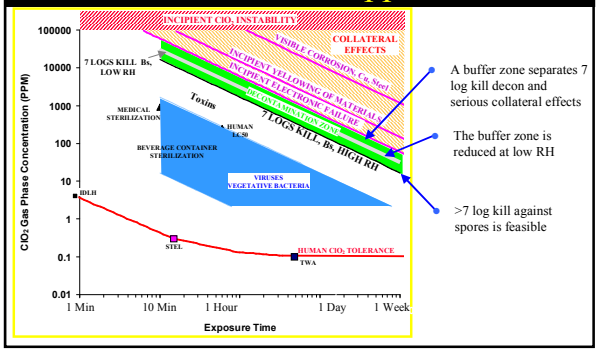
Saporin Inactivation by ClO_2

ClO_2 ppm•v	Log Activity Reduction
Untreated Dried Control	0
400 ppm•v	10^2
2400 ppm•v	$4x10^7$

Conclusions

- These studies establish that chlorine dioxide is a very effective gas-phase sterilizing agent for a broad range of toxin threat surrogates dried to a state of high activity
- A Ct of 4300 ppm•hrs of ClO_2 resulted in a six log reduction in dried toxin surrogate activity
  - Ricin, BoNT & SEB surrogates
  - ClO_2 inactivated surrogates do not renature to active forms under the conditions studied
- A CT of 2400 ppm•hrs of ClO_2 resulted in a six log reduction of crude BoNT & SEB toxin surrogate activity

Chlorine Dioxide Deployment for Wide-area Decon Applications



A buffer zone separates 7 log kill decon and serious collateral effects

The buffer zone is reduced at low RH

>7 log kill against spores is feasible

Acknowledgements

- This research was supported by the DARPA Immune Buildings Program and the FBI
- We are grateful to our many colleagues at DARPA, FBI, EPA, SAIC and SWRI for their scientific support and collaboration

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Restoration of Major Transportation Facilities Following a Chemical Agent Release

The Chemical Restoration Operational Technology Demonstration (OTD)

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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

- OTD Background and Overview
- OTD Project Activities
  - **Restoration Plan Development**
  - **Partnerships**
  - **Threat Scenarios**
  - **Clean-up Guidelines**
  - **Sampling Methodologies**
  - **Decontamination Technologies**
  - **Decision Support Tool Development**
  - **Experimental Studies**
- Summary
- Decon Activities at Sandia

The Project supports the DHS S&T Chemical Countermeasures Strategic Objectives

The strategic objectives of DHS S&T's Chemical Countermeasures Program are to:

- **Develop a national chemical defense architecture**
- **Enhance rapid recovery from chemical attacks**
- **Develop pre-event assessment, discovery, and interdiction capabilities for chemical threats**
- **Minimize loss of life and economic impact from chemical attack**
- **Enhance the capability to identify chemical attack source**

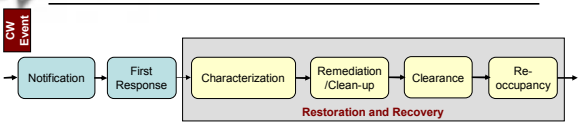
The Chemical Restoration Operational Technology Demonstration (OTD) will address these objectives.

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 restoration challenges
- The primary focus of the Chemical Restoration OTD is on major airports
  - Project is focusing on interior restoration only
  - Project is serving as a 'template' for other airports to follow

We are working in close collaboration with a partner airport (LAX) and regulatory agencies

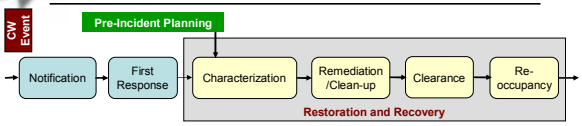
The activities following a chemical agent release are complex



Objectives:

- **Advance the state-of-the-art in facility restoration 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**

Pre-planning and implementing a systems approach will decrease the time required for restoration



Objectives:

- **Advance the state-of-the-art in facility restoration 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**

To achieve these objectives, we are focusing on:

- **Pre-planning the restoration process**
- **Reducing the overall restoration time by reducing the time of each activity**
- **Selecting the "best-available" methods for each activity**

A major deliverable for this project will be a complete restoration plan for our partner airport.

The Chemical Restoration OTD will build off of the recently completed Bio 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**
  - **Decon formulation 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 Chemical Restoration OTD utilizes experts from the National Laboratories and other federal agencies

Collaborators

Sandia National Laboratories – Mark Tucker, PI
Lawrence Livermore National Laboratory – Ellen Raber, PI
Los Alamos National Laboratory
Pacific Northwest National Laboratory
Oak Ridge National Laboratory

DHS Project Manager

Julius Chang, ORD

External Advisory Panel

Nancy Adams, US EPA
Veronique Hauschild, US CHPPM
Dennis Reutters, US DHS
Joe Wood, US EPA

Partner Airport

Los Angeles International (LAX)

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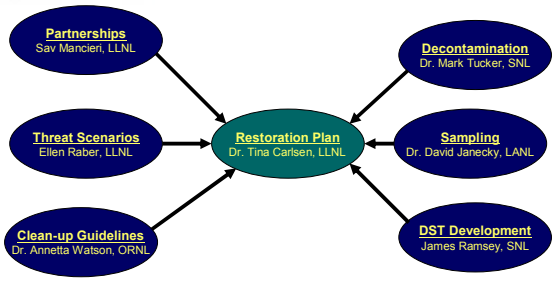
The Chemical Restoration OTD team has been divided into a series of Working Groups



Restoration operations will involve a wide range of stakeholders:

Stakeholders in the Restoration Operation:

- 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
  - LAX, DHS, SNL, LLNL
- Meetings with Partner Airport
  - Ongoing
- Regulatory Agency Meetings
  - Los Angeles – May 2005
  - Ongoing
- Tabletop Exercise (Tentative)
  - Objective: To demonstrate pre-planning capabilities and other tools
  - Spring 2007

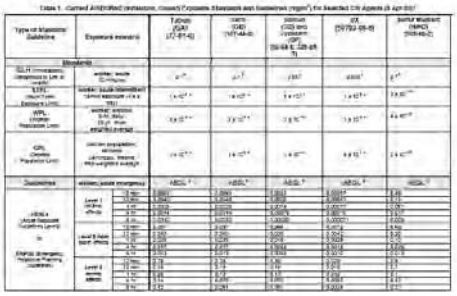
The Partnership Working Group is developing a table of roles and responsibilities for inclusion in the Restoration Plan.

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 Restoration Plan
  - To support the Tabletop Exercise
- CW Agent List Defined
  - CW Agents (VX, G agents, HD)
  - TICs (HCN, Cyanogen Chloride, Phosgene)
- Release Scenario Defined for Tabletop Exercise
  - Location – International Terminal at LAX
  - CONTAM modeling exercise in progress to support tabletop exercise

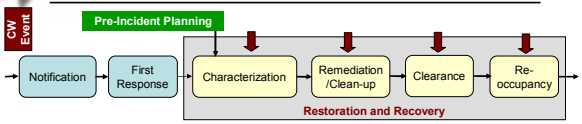
Threat scenarios developed with input from other DHS projects and other federal agencies

The Clean-up Guidelines Working Group is using historic data to develop a set of recommended clean-up standards



Example of clean-up guidelines being developed by the Chemical Restoration OTD for inclusion in the Restoration Plan

The Sampling Working Group is developing recommendations for sample collection and analysis



- Working Group is focusing on four sampling phases:
  - Characterization
  - Remediation Verification
  - Clearance Sampling
  - Monitoring
- In addition, the Working Group is also focusing on:
  - Statistical sampling methods to reduce number of required samples and to increase confidence in negative results
  - Utilization of EPA protocols, the LRN, and mobile laboratories for analysis of chemical samples

Recommended sampling methods for each agent on the threat list will be included in the Restoration Plan

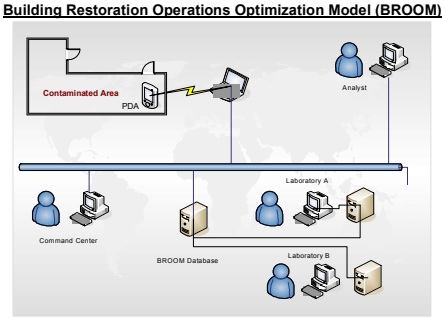
The Decontamination Working Group is identifying and recommending methods to decontaminate agents on the threat list

- 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 Restoration Plan

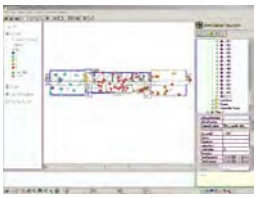
The Decision Support Tool Working Group is adapting the BROOM Tool for chemical use and integrating additional tools (VSP)

Building Restoration Operations Optimization Model (BROOM)



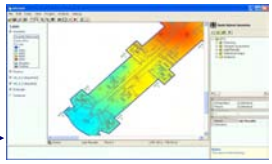
BROOM can be used for pre-event planning and post-event operations

BROOM can collect, manage, visualize, and analyze the large amounts of data associated with a chemical agent release



Data Management and Visualization

- **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 Analysis

A pre-developed restoration plan will reduce one of the major delays in previous restoration projects

General Restoration Plan

1. Introduction
2. Characterization
3. Remediation
4. Clearance
5. Recommendations for pre-planning

Appendices

A. Notification Phase
B. First Responder Phase
C. Sampling and Analysis Methods
D. General Sampling Design
E. Probability-based Sampling Design
F. Decon Technology
G. Handling Decon Waste
H. Sample Unit Forms
I. Characterization Template
J. Remedial Action Plan Template
K. Clearance Plan Template

Facility Specific Data Supplement

A. Facility Command Structure
B. Facility Description
C. Facility Ventilation
D. Facility Decon Capabilities

The restoration plan covers all aspects of the restoration process

The Project is also addressing data and technology gaps critical to the restoration process (in collaboration with other agencies)

- Surface Sample Collection Efficiency and Detection Limits for CW Agents (Reynolds, LLNL and Brown, 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 (Alcarez, 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 and Verce, 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.

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For FY06-FY07, the focus of the Chemical Restoration OTD is to…

- Complete the Restoration Plan template for major airports
- Complete the site-specific Restoration Plan for our partner airport (LAX)
- Conduct a series of tabletop exercises and workshops to engage the user community (i.e., transportation facility owners, regulatory agencies) in the process of developing restoration plans for critical transportation facilities
- Address data and technology gaps critical to the restoration process that were identified in FY04-FY05 (in collaboration with other agencies)
  - Surface Sample Collection Efficiency and Detection Limits for CW Agents
  - Interaction of Chemical Agents on Interior Surfaces and Natural Attenuation/Decay Rates
  - Gas/Vapor Decontamination Method Scale-up Evaluation
  - Statistical Sampling Algorithm Validation

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Evaluation of Surface Sample Collection Methods for *Bacillus* Spores

- Surface sample collection methods
  - Swab, wet, synthetic
  - Wipe, wet, synthetic
  - Vacuum, HEPA filter sock, synthetic
- Surfaces
  - 2 Non-porous (stainless steel and painted wallboard)
  - 2 Porous (carpet and bare concrete)
- Unique experimental method
  - Dry deposition surface seeding
  - Co-located reference coupons (99.97% recovery of spores)
  - 1 m^3 chamber
- Sonication extraction method
- Culture based analysis
- Statistically valid sample size
  - 24 samples / surface loading
  - 3 surface loadings / surface (1 log, 2 log, and 4 log per sq cm)

Collection Method	Surface	Mean Recovery Efficiency (n=24)	Median Recovery Efficiency (n=24)
Swab	Stainless Steel	0.461 ±0.154	0.455
	Painted Wallboard	0.483 ±0.224	0.442
Wipe	Stainless Steel	0.590 ±0.173	0.573
	Painted Wallboard	0.460 ±0.291	0.377
Vacuum	Stainless Steel	0.174 ±0.138	0.118
	Painted Wallboard	0.268 ±0.030	0.022
	Carpet	0.253 ±0.068	0.248
	Bare Concrete	0.181 ±0.072	0.173

$\eta_r = \eta_c \times \eta_e$

Work in FY06 is focusing on dirty surfaces

Canadian Forces Decontaminant Testing

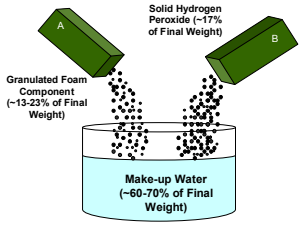
Decontaminants were tested against VX, GD, HD, and anthrax spores. Material compatibility and biodegradability were also considered. For qualification, decontaminant must meet efficacy, material compatibility, and biodegradability requirements. Based on this criteria, EasyDECON-200 and MDF-200 (the two commercial versions of DF-200) were the only decontaminants qualified.

Decontaminant	Manufacturer	Qualification
EasyDECON-200 (DF-200)	Envirofoam Technologies (EFT)	Qualified
MDF-200 (DF-200)	Modec, Inc.	Qualified
All-Clear	Kidde Firefighting	Not Qualified
B-C Emulsion	OWR	Not Qualified
BX 24	Dew Engineering	Not Qualified
CASCAD	Allen Vanguard	Not Qualified
Decon Shield	Cetec	Not Qualified
Di60	Karcher	Not Qualified
GDS 2000	Karcher	Not Qualified
SDF	Allen Vanguard	Not Qualified

CFNBCDS Phase 1 Decontaminant Qualification Results

‘Dry’ DF-200 Formulation Development for the US Military

The objective of this project is to develop a configuration of DF-200 that can be packaged with all water removed. This will reduce the packaged weight of DF-200 by 60-75% significantly lowering the logistics burden on the warfighter. Water (freshwater or saltwater) can be added to the formulation at the time of use from a local source.



Parameters being considered:

- Weight savings achieved
- Projected cost of materials
- Efficacy
- Ease of use (i.e., dissolution rate, requirements for agitation, etc.)
- Stability under storage conditions
- Packaging considerations
- Ease and cost of manufacture

The Development of Modified Vaporous Hydrogen Peroxide (mVHP) for Chemical- and Biological-Weapons Decontamination

Presented by Dr. Stephen R. Divarco

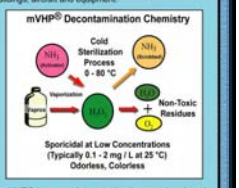
Principal Investigator, Decontamination Sciences
Edgewood Chemical Biological Center

Mark Brickhouse, Steve Divarco, Teri Lalain, Brian MacIver, Jerry Pfarr, Larry Procell, Mike Schultz, David Sorrick, George Wagner (ECBC); Lew Schwartz, Iain McVey, Tim Meilander, Paul Wiget (STE, Inc.); David Stark (EAI Corp)

Introduction to the mVHP Project Timeline

2002 PROOF OF CONCEPT
2003 LARGE-VENUE TESTS
EQUIPMENT IMPROVEMENTS SENSORS AND DISTRIBUTION
2005 INTRODUCTION TO SENSITIVE EQUIPMENT
LABORATORY OPTIMIZATION STUDIES
2006 LARGE-VENUES WITH IMPROVED CAPABILITIES
FUTURE OF VHP / mVHP

The STERIS VHP® technology has been used for more than a decade to sterilize pharmaceutical processing equipment and clean rooms. In Oct. 2001, the VHP technology was adapted to decontaminate two anthrax-contaminated buildings in the Washington, D.C. area. Over the past three years the VHP system has been significantly improved for the decontamination of materials contaminated with chemical agents such as VX, GD and HD. In addition, system improvements enable mVHP application for a wide number of applications such as buildings, aircraft and equipment.



*mVHP® is a proprietary technology co-developed by ECBC and the STE division of Steris Corp.

mVHP Project Timeline

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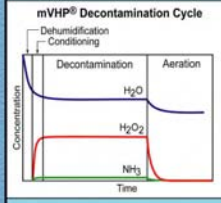
FUTURE OF VHP / mVHP

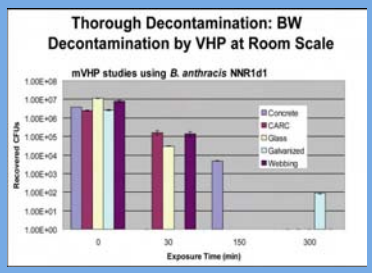
VHP is proven for biological decon. mVHP created for broad application decon to include chemical agents.



Lab tests demonstrate VHP / mVHP application to both biological and chemical agents

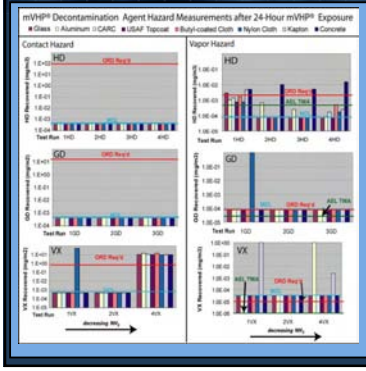
*mVHP® is a proprietary technology co-developed by ECBC and the STE division of Steris Corp.

mVHP Suitable for Biological Agent Decontamination



Laboratory studies of the biological warfare agent *B. anthracis* and surrogate *G. Stearothermophilus* showed mVHP at 250-ppm hydrogen peroxide and 15-ppm ammonia can decontaminate biological contamination on a wide variety of substrates.

mVHP Applicable for Chemical Agent Decontamination



Chamber tests confirmed that a similar mVHP treatment was effective against GD, HD and VX on both absorptive and non-absorptive surfaces.

In most cases, the hazard was reduced to below the JPID ORD for both contact and vapor hazard in 8 - 24 hours.

mVHP Project Timeline

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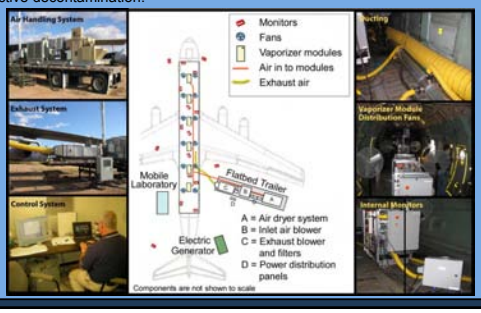
FUTURE OF VHP / mVHP

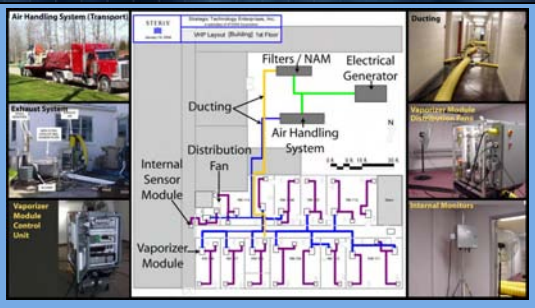
mVHP can be generated and maintained in large venues such as a C-141 aircraft and an office building

Application of the Modular mVHP System to Aircraft Interiors

Two large-venue tests demonstrated that the improved modular mVHP system could be used to generate and maintain the mVHP fumigant at concentrations for effective decontamination.



Application of the Modular mVHP System to Building Interiors



4 hours was required for kill *G. stearo.* innoculated coupons and BI's.
Thorough kill of *G. stearo.* and HD simulant CEPS achieved within 5 - 10 hrs.

mVHP Project Timeline

2002 — PROOF OF CONCEPT

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EQUIPMENT IMPROVEMENTS

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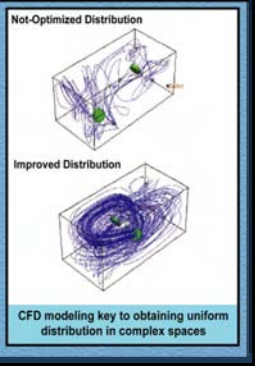
LABORATORY OPTIMIZATION STUDIES

2006 — LARGE-VENUES WITH IMPROVED CAPABILITIES

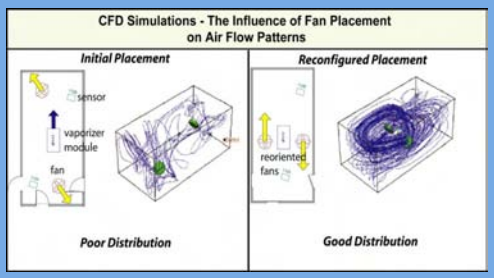
FUTURE OF VHP / mVHP



CFD modeling key to obtaining uniform distribution in complex spaces

CFD Dynamics Improves System Adaptability for Complex Spaces

Computational Flow (or Fluid) Dynamics (CFD) was employed to develop an improved strategy for placement of the fans and vaporizer modules within the interior space for effective vapor distribution.



mVHP Project Timeline

2002 — PROOF OF CONCEPT

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EQUIPMENT IMPROVEMENTS SENSORS AND DISTRIBUTION

2005 — **INTRODUCTION TO SENSITIVE EQUIPMENT**

LABORATORY OPTIMIZATION STUDIES

2006 — LARGE-VENUES WITH IMPROVED CAPABILITIES

FUTURE OF VHP / mVHP

The modular mVHP system could be applied to a sensitive equipment decontamination (SED) prototype

mVHP Sensitive Equipment Decontamination Prototype

- Initial studies in a modified SAMS box showed biological simulant could be decontaminated on sensitive equipment within four hours.
- In June 2005, the mVHP SED apparatus was successfully demonstrated at the limited objective evaluation (LOE) at Tyndall AFB.
  - •LOE formal report indicates that mVHP has potential applicability for thorough decon of sensitive equipment primarily in rear echalon applications as currently configured on the 463L pallet.

mVHP Prototype Undergoing CB Surrogate Evaluation

A fully operational prototype is currently being evaluated at ECBC. The ECBC tests will determine:

- The spacing requirements between articles of sensitive equipment
- The decon time required for both a 1-g/m^2 challenge (JPID ORD) and a 10-g/m^2 challenge (JSSED ORD) of chemical agent simulant
- The effect of prewipe on decon time especially at higher challenges
- The highest fumigant concentration and shortest cycle time possible without negatively impacting sensitive equipment.

mVHP Project Timeline

2002 — PROOF OF CONCEPT

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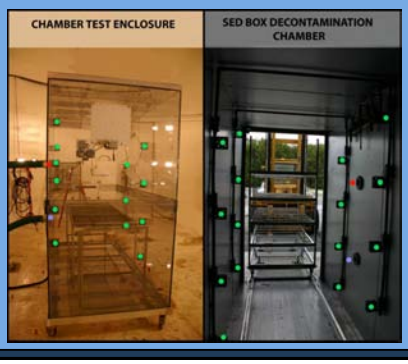
LAB. OPTIMIZATION STUDIES

2006 — LARGE-VENUES WITH IMPROVED CAPABILITIES

FUTURE OF VHP / mVHP

Current tests will identify the time and mVHP concentration required for thorough biological and chemical decontamination at optimized fumigant distribution

mVHP Prototype Replicated for Chemical Agent Testing



Evaluation of mVHP against CB Agents on Complex Materials

The testing utilizes a thorough matrix of representative materials, statistical replicates and controls. The ECBC tests will determine

- The decon time required for biological surrogate kill.
- The decon time required for live chemical agent at both a 1-g/m^2 challenge (JPID ORD) and a 10-g/m^2 challenge (JSSED ORD).
- The effect of prewipe on decon time especially at higher chemical agent challenges.

mVHP Project Timeline

2002 — PROOF OF CONCEPT

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EQUIPMENT IMPROVEMENTS SENSORS AND DISTRIBUTION

2005 — INTRODUCTION TO SENSITIVE EQUIPMENT

LABORATORY OPTIMIZATION STUDIES

LARGE-VENUES IMPROVED CAPABILITY

2006 — FUTURE OF VHP / mVHP

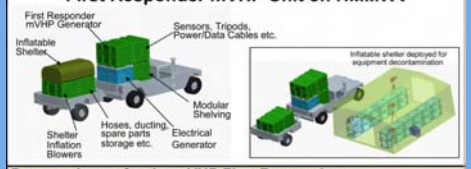
Improvements to fumigant distribution, equipment logistical demands (size and weight) and design (tents) to be evaluated during upcoming demonstrations

Large-Venues and Tent-Based Systems for Interior and Exterior Decon

- The building / C-141 modular mVHP system has been scaled down to fit on the bed and tactical trailer of an FMTV.
- Current systems utilize tents to enable simultaneous decontamination of interior and exterior spaces.
- The first large-scale tent decon demo utilized an inflatable tent and an F-16 at Davis-Monthan AFB.
  - 250-ppm VHP was achieved in avionics bays, cockpit and exterior of plane.
  - Complete kill on 20 of 25 BI's was accomplished in 4-hour test.
  - Surviving BI's in low distribution areas (to be addressed Jan. 2006.)

Tent-Based System Scaled for a HMMWV

First Responder mVHP Unit on HMMWV



Proposed uses for the mVHP First Responder

- Vehicle Interiors (and optionally exteriors when used with a shelter)
- Moderate sized rooms
- Sensitive equipment (when used with a shelter)

mVHP Project Timeline

2002 — PROOF OF CONCEPT

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LABORATORY OPTIMIZATION STUDIES

2006 — LARGE-VENUES WITH IMPROVED CAPABILITIES

FUTURE OF VHP / mVHP

Current tests will provide a detailed body of work demonstrating mVHP as a potential technology for both JPID and JSSED application

Spore Contamination- What Concentration Deposits, What Resuspends and Can We Inhibit its Transport?

April 26-28, 2006
EPA Decontamination Workshop

Paula Krauter

Lawrence Livermore National Laboratory
Chemical & Biological Nonproliferation Program

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.

Once a Biothreat Agent is Identified, the Question Becomes Where is It?

We arrived at our understanding of biothreat agent (BTA) transport based on a series of tests over a 4-year period

1. **Deposition Velocity FY02-03**
2. **Transport Efficiency FY03-04**
3. **Reaerosolization FY04-05**
4. **Copolymer Complex to Inhibit Aerosol Transport FY05-06**

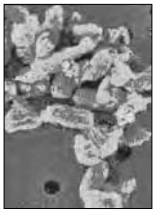
Where is the BTA?
How much settles?
How much resuspends?
Can we find all, any, none?
How to inhibit resuspension?

What Do We Know……Investigators have Studied Particle Distribution Using Several Materials

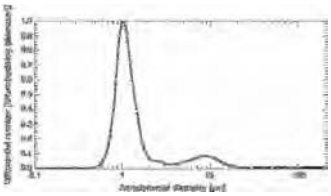
Investigator	Particle Material	Particle dia.(μm)
Alexander & Coldren '51	water	27
Chamberlain '67, '84	polystyrene	5.0
	Ragweed pollen	19.0
	Lycopodium spores	32.4
	Tricresyl phosphate	1.0
	Aitken nuclei	0.08
	Iron oxide	2-5
Shemel '70, Hahn et al '85	Uranine	6.0-14
Montgomery & Corn '70, Shemel '68	Uranine-methyl blue	0.44-2.16
Kvasnak et al '93	Glass, rust, dust	5-45
Adams et al '93, Cheong '97	Oil smoke	0.5-2.0
Lai '97	Porous silica	2.5-7.1
	Indium acetylacetonate	0.7
Forney & Spieman '74	Pecan pollen	48.5
	Ragweed pollen	19.5
	Polystyrene	32
	Lycopodium spores	30.9
Muyshondt et al '96	Oleic acid	5-20
El-Shobokshy '83	Fluorescein	1.0-6.2
Liu & Agarwal '74	Olive oil	1.4-21
	Zinc sulfide	2, 4

(Sippola, 2002)

Fluidized Surrogate Spores were Used In All Our Transport Studies

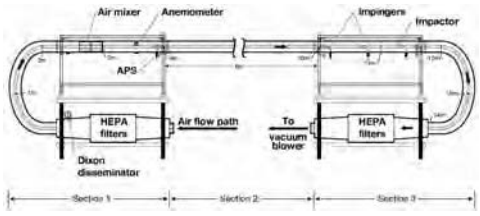


Fluidized *B. atrophaeus*



B. anthracis found in the Brentwood mailroom

1. Transport Efficiency & Deposition Velocity of Spores in Ventilation Ducts

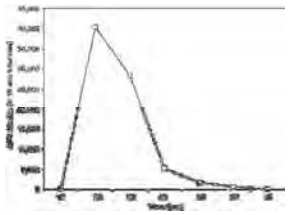


The test system included:

1.Two 90° bends and a 1.5m rise to 14m of 15cm diameter duct
2. Off-the-shelf duct materials *
3. Powdered surrogate BTA released into turbulent airflow
4. Seven analytical instruments

Data Suggest that the Spore Plume was Generally Limited to a Finite Time Frame

- According to NIOSH (2002) air sampling may be of limited value in areas that are undisturbed, or in which ventilation systems have continued to function for long periods after a release.



The spore plume moved through the ventilation duct in about 25 sec (airflow ~3m^3/min)

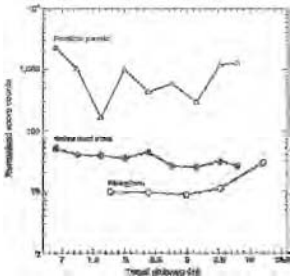
Spores in Transit Will Deposit

Deposition was different in the three duct materials tested

Each duct type was tested twice

Normalized surface conc. to air conc. [(number/cm^2/number/cm^3)]

We had expected the fiberglass to trap and hold the greatest number of spores, however, plastic was about 100-fold higher

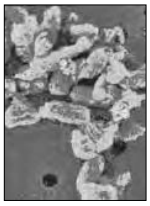


Duct Descriptions and Roughness Measurements

Duct Material	Duct Description	Material Roughness Height[a] (mm)	Static Measurement (nC/g)
Flexible plastic	Smooth, two layers of polyester film encapsulating a galvanized steel wire helix; multiple 0.1- to 0.3-cm folds	0.005 ± 0.002	-5.84 ±0.56 -6.29 ±0.62
Galvanized steel	Smooth, steel sheet, galvanized with a zinc coating; a thin film of corrosion forms when exposed to the atmosphere	0.15 ± 0.05	+0.01 ± 0.01 +0.01 ± 0.01
Fiberglass	Rough, internal fiberglass wool insulation on board coated with acrylic polymer and a protective agent to protect coating from potential growth of fungus and bacteria	1.5 ± 0.9	+ 0.015 ± 0.10 +0.020 ±0.08

[a]Difference between the highest and lowest points within the sampling length.

Electrostatics greatly influences small particles



Spores aerosols were not neutralized and were likely charged as a function of the nature of the powder dissemination

Static measurement of fluidized spores

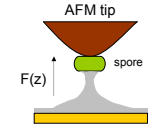
Material Tested	Charge[1] (nC/g ± SD)
Powdered spores	+31.5 ± 1.1
Powdered spores	+31.3 ± 1.1

[1]Static monitor and Faraday pail, Detection level was 0.01 nC

Characteristics such as size, coatings, electrostatics are useful information to determine biothreat agent transport behavior

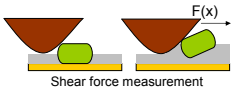
Adhesion Strength of Spores on Plastic is Stronger than Glass or Metal

- Effort to recover spores off surfaces could be more related to adhesive forces of particle to surface than sampling efficiencies
- Adhesion Force Measurements (a combination of optical and atomic force microscope, AFM) is a direct measurement of shear force



Normal force measurement

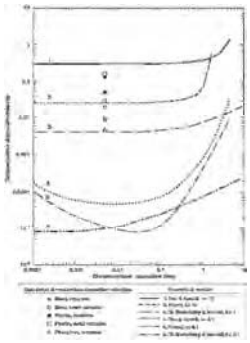
Adhesion force
Glass = 6.4 nN
Plastic = 40 nN



Shear force measurement

Lateral Shear force
Glass= <20 pN
Plastic= 150 pN

Spore Deposition Velocities Compared Against Predictions from 3 Particle Models



- Deposition velocity for plastic = 1.4 cm/s, steel = 0.16 cm/s, fiberglass = 0.067 cm/s
- Free-flight, turbophoretic and sublayer predictive models
- Size, density, velocity, duct dimensions and surface roughness
- Spore deposition rates were bounded by all 3 curves in the rough (k^+=10) by not in the smooth (k^+=0.1) as expected
- Calculations for deposition of aerosols in turbulent flow is from Fuch

Aerobiologia (2005) 21:155-172

2. Transport Efficiency in New Ventilation Ducts

Duct Material	Aerosol Dissemination Efficiency (%)	Total Dissemination Efficiency (%)
Plastic	1	4
Galvanized steel	10	12
Fiberglass	12	13

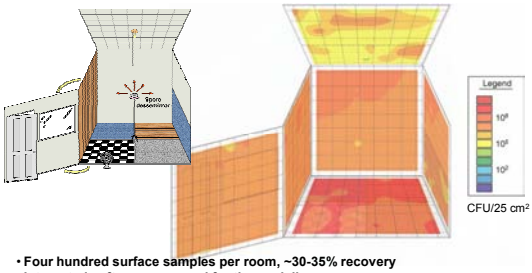
Values were calculated as follows:

Total dissemination efficiency = $100\frac{T_A + T_S}{T_E}$,

where T_A is the total CFU passing through as aerosol, T_S is total CFU surface deposition, T_E is total CFUs in powder preparation

- Transport efficiency is defined as the total dissemination efficiency
- The geometry of the system, airflow and environmental conditions will influence transport efficiency
- Surface interactions of electrostatics, Van der Waals, hydrophobicity and others influence spore recovery

Spore Deposition in 14.5 m³ Mock-Office



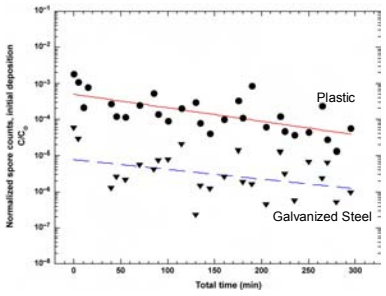
- Four hundred surface samples per room, ~30-35% recovery
- Integrated software was used for the modeling
- Spore loss may also be attributed to (1) sampling and culturing techniques, (2) nonviable spores, (3) reaerosolization and (4) overcoming spore-surface adhesion forces

3. Spore Reaerosolization Potential in Ventilation ducts

Spore Reaerosolization Tests Determined:

- Short-term reaerosolization potential
- Long-term reaerosolization potential
- On/Off reaerosolization potential

Particles Reaerosolized Over Time



Seven Fifteen Minute Airflow Cycles

Simple flux model

$$F_m = \frac{C_m Q}{A}$$

Particles entering

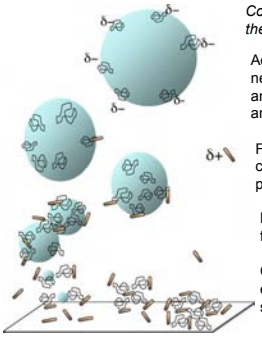
$$F_m + F_r = F_{out}$$

Particles exiting

$$R = \frac{F_{out} - F_m}{S}$$

Resuspension rate of particles deposited on the duct surface

4. Can We Inhibit Spore Transport?



Concept: Copolymer(s) Interact with the Coulombic Forces on the Particles

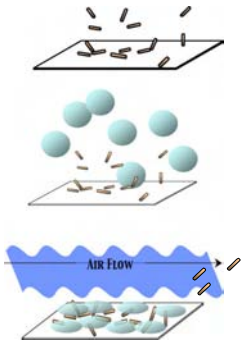
Aerosol droplet (~100 µm) containing negatively charged copolymers (400 angstrom) attach to particles on surfaces and in the boundary layer

For example, an aerosol droplet containing copolymer may attract positively charged spores (1-3 µm)

Non-charged ends of the polymer flocculate.

Copolymer coagulate as solvent evaporates adhering particles to the surface

Experimental Plan- Laboratory Tests

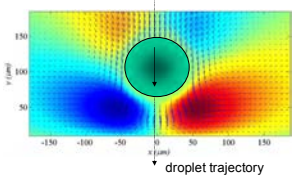


1. Deposit spores onto surface material(s)
2. Deposit copolymer solution onto spore/surface material
   - Deposition Velocity
3. Measure resuspension under conditions of varying airflow and mechanical action
   - Resuspension Velocity

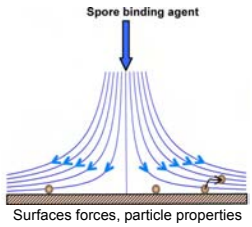
Application of a Liquid, Mist or Vapor Decon Agent Has the Potential to Shear, Lift or Roll a Spore

Spore-Surface Forces: What Does it Take to Move a Spore?

Velocity field created by sedimenting droplet near a surface

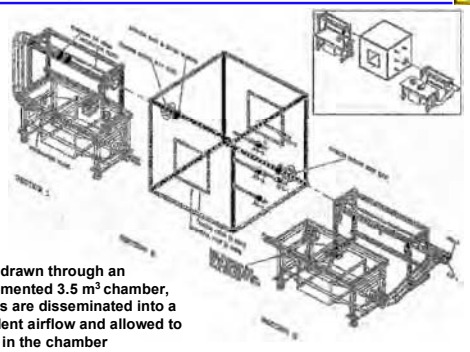


Lattice-Boltzmann calculation on computer cluster, approach velocity U=1.3 mm/s



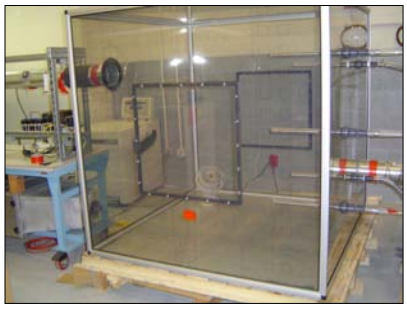
Surfaces forces, particle properties & flow field effect spore resuspension

Field Test Apparatus



Air is drawn through an instrumented 3.5 m^3 chamber, spores are disseminated into a turbulent airflow and allowed to settle in the chamber

Antistatic Aerosol Test Chamber



- **Four impingers located at 0.5, 0.75 and 1.4m from the floor & effluent**
- **Three APS ports; 2 in the chamber and one on the effluent**
- **Airflow to mix or to resuspend**
- **Spore deposition velocity & reaerosolization**
- **Results pending**

More Questions than Answers……

- Will refined spores ever deposit?
  - Forces of particle transport: thermal conduction
- What airflow & environmental conditions will reaerosolize spores?
  - Shear force measurements
- Can we make the predictive models more useful with processes derived from experimental data?

Summary

- **Spore 'enhancement' greatly influences deposition velocity and transport efficiency**
- **Characterization of particles & surfaces will aid understanding of deposition and adhesion**
- **Knowledge of spore-surface interactions and processes will enhance predictive models**
- **Resuspension was greater than predicted**
- **We can inhibit spore reaersolization with a copolymer-based, film-forming solution**

Bioaerosol Project Investigators

Art Biermann, Aerosol Physicist

Mark Hoffman, Polymer Scientist

Lloyd Larsen, Microbiologist

Alex Vu, Biochemist

Todd Weisgraber, Fluid Dynamist

Dave Zalk, Industrial Hygienist

Tim Ratto, AFM Engineer

Don Schwartz, Designer

Funded by the Departments of Homeland Security and Energy

Questions?

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2006 Decontamination Workshop

Studies of the Efficacy of Chlorine Dioxide Gas in Decontamination of Building Materials Contaminated with *Bacillus anthracis* Spores

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April 26 - 28, 2006

Background Motivation

- In the fall of 2001, a number of buildings were contaminated with *B. anthracis*
- Three buildings, ranging from 700,000 – 14,000,000 cubic feet, were decontaminated via chlorine dioxide fumigation
- Building clearance was based on "no growth" of any environmental samples
  - Over 10,000 clearance samples taken
  - No sample positive for *B. anthracis*

Background Motivation

- In all fumigation decontamination events for *B. anthracis* to date, biological indicator/spore strips (BIs) have been used extensively to indicate that target fumigant concentrations were reached "throughout" the building
- Sampling plan designed to locate placement of BI
  - Random/stratified locations
  - Biased in locations of known contamination
  - "Hard to reach places"
- Criterion was one per 100 square feet, but up to three per 100 square feet were required to cover sampling plan

Background Motivation

- Few positive BI returns from some locations
  - spot cleaning performed
- On-going debate regarding sampling strategies
  - Number and intended use of BI
  - Appropriateness of steel-backed BI
  - Approach to the environmental samples for site characterization and clearance
- What should the criteria be for building clearance?
- How do you determine that the established criteria were met?

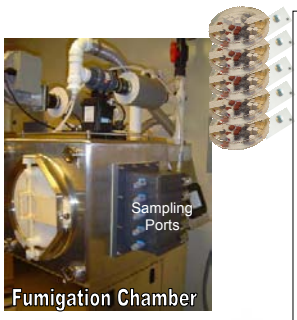
Objectives

1. Determination of the log reduction in viable avirulent *Bacillus anthracis* (*B.a.*) spores as a function of chlorine dioxide (CD) dose, concentration x fumigation time (CT value), on five porous and one non-porous indoor building materials
   - Liquid inoculation
   - 7 log spores per coupon
   - Coupons (1.3x1.3-cm) of non-uniform porosity
2. Comparison of the CT to achieve "no growth" on BI to the "no growth" of *B.a.* in the spores extracted from coupons of six building materials
   - 6 log spores per BI
   - Evenly dispersed

Experimental Procedure

- 13 x 13 mm coupons (5 reps per dish)
  - raw wood, unpainted cinder block, carpet, painted I-beam steel, ceiling tile, wallboard
- Inoculated with ~10^7 spores of avirulent *B. anthracis* (NNR1Δ1) in 7 x 7.1 μL drops
- Inclusion of 0.5 % Horse serum as organic bioburden
- Biological Indicator spores strips *B. atrophaeus* (≥1x10^6) on stainless steel backing in Tyvek pouches (APEX)

Experimental Procedure

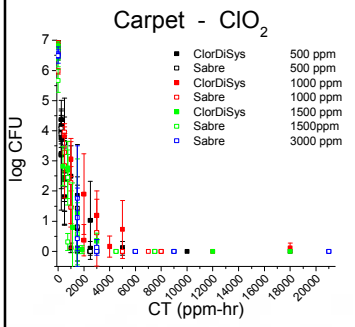


- 5 plates, each containing 1 BI, 30 inoculated, and 6 uninoculated, placed in the chamber per fumigation experiment
  - one plate withdrawn per time point
- CD generation by:
  1) ClorDiSys GMP generator
     $Cl_2 + 2NaClO_2 \rightarrow 2NaCl + 2CD$
  2) Sabre Technologies
     stripping CD from solution
- Constant CD concentrations maintained @ 500, 1000, or 1500 ppm
- Temperature and RH maintained at ~75ºF and ~75% RH throughout the fumigation

Test Matrix for Each CT Experiment

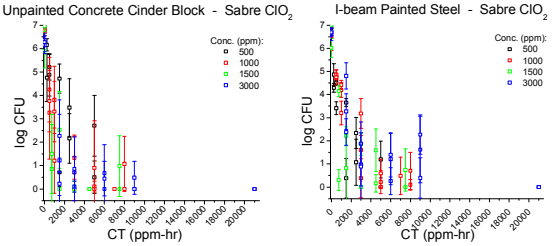
Per Time Point		Per 5 Time Points
6 Types of Test Coupons	30	
+ 6 positive + 6 negative coupons	12	210 Coupons
50-mL Tubes with 10-mL Sonicated 10-min & Vortexed 2-min	42	210 50-mL tubes
2 Dilutions/test sample & 1 Dilution each from controls	60 12	300 Dilutions tubes/test sample 60 Dilution tubes/controls
3 Plates/dilution	180	900 PLATES/Test samples + 180 PLATES/control samples
For samples with low viable spore #, 1x3-mL samples pour-plated		100-200 PLATES for pour-plates

Decon of *B. anthracis* from Carpet



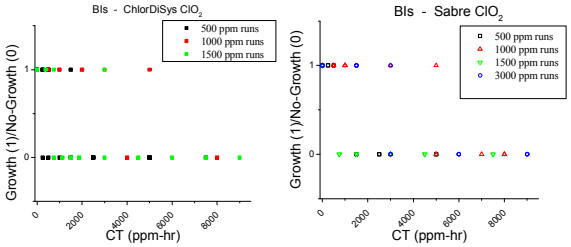
- Large variability in data at low CT
- Kill curve and variability not a function of CD generation method
- Optimal CT not affected by 2-fold increase in CD concentration
- No growth from any sample after fumigation with a CT ≥ 6000 ppm-hr for ALL three concentrations tested

Effect of Material Type on Decon Efficacy



- "No growth" criterion not achieved before 9000 ppm-hr dose on unpainted cinder block or painted I-beam steel
- Log reduction is dependent on CT, no distinct differences noted at increasing CD concentrations (500 - 3000 ppm)

Effect of CD CT on BI



- No growth from any BI after a dose of 5000 ppm-hr; note variability
  - not consistent with results of *B. anthracis* (NNR1Δ1) on cinder block or wood
  - BIs can not be used to indicate that a CT of 9000 ppm-hr has been achieved
- BI results are also independent of CD generation method
  - consistent with observations made regarding log reductions on materials

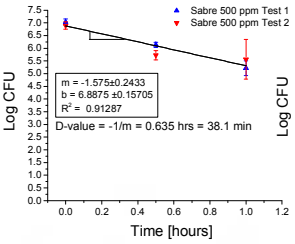
Some Definitions & D-Value Concept

- **Sterilization is removal or destruction of all viable organisms**
- **Disinfection is killing, removal or inhibition of pathogenic organisms: disinfectants are chemical agents used on inanimate objects**
- **Sanitization is reduction of microbial population to levels deemed safe, based on public health standards**
- **Microorganisms are not killed instantly and microbial population death usually occurs exponentially**
- **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 for a disinfectant or fumigant to reduce the number of viable spores to 1-million (6-logs) or 90% reduction is the D-value**
- **Another measure of efficacy is CT, i.e. dose (concentration x time) required for achieving a 6-log-kill reduction or no growth**
- **We can define a D1 value, the time it takes for the first log reduction, as one measure of efficacy of a sporicidal agent. Can this value be used to extrapolate a D6 or time required for a 6-log reduction?**
- **For building cleanup, the ONLY acceptable standard by EPA is "no growth" of pathogenic spores from environmental samples!**

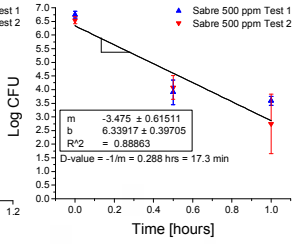
Computation of D-Values

Two Examples of D-value Derivation

Unpainted Pine Wood



Carpet



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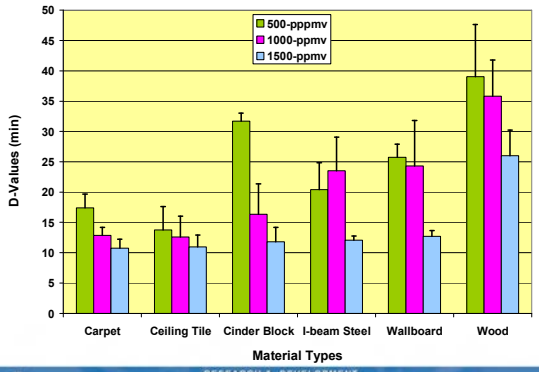
D-values with Increasing CD Conc. (Sabre)



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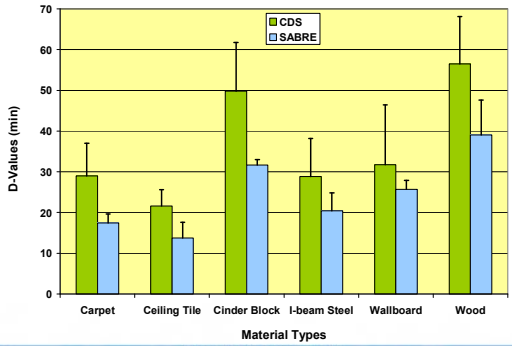
Estimated D-values Using CD Gas Generated via ClorDiSys & Sabre Technologies



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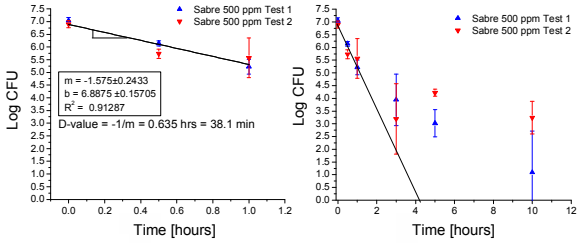
Non-linear D-Values

Example for the reduction of viable spores on unpainted pine wood



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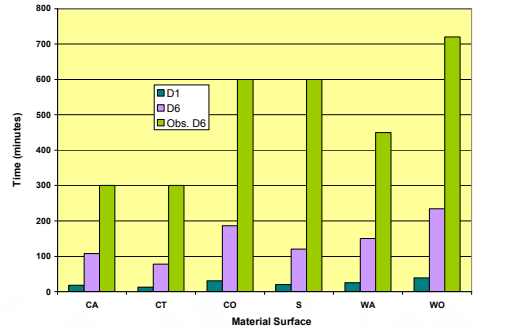
Extrapolation of D-values to Estimate D6 vs. Observed Values



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Unique Features & Conclusions

- Two of the five porous materials, ceiling tile and wallboard, resulted in particulate debris, which necessitated use of 3 replicate plates instead of 1 or 2 plates per dilution to assay for viable CFU
- Since kill curves were determined for sub-optimal CT dose, where significant variability is expected, 5 replicate coupons (instead of 3) were set up to better assess this variability
- For assuring low detection limit of viable spores (1-5), 1/3rd of the recovered sample was pour-plated from each sample with low number of viable spores

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Unique Features & Conclusions

- A lack of correlation between ease of spore decontamination of BI compared to anthrax spores (dried after liquid deposition) on building materials was clearly evident
- CD gas generated by two distinct methods is similar in its decontamination efficacy (i.e., CT required for "no growth")
- Carpet and ceiling tile materials are relatively easy to decontaminate compared to wallboard, steel, and wood
- The kill curves of avirulent *B. anthracis* on all materials tested are non-linear, and therefore, require a non-linear D-value expression

Future Work

- Further testing in design and use of a more "realistic BI" for building cleanup efforts
- Decontamination efficacy of CD gas against higher spore inoculum challenge levels, i.e. 8 or 9-logs
- Comparison of decontamination efficacy of CD gas using coupons inoculated with aerosolized vs. liquid spore deposition
- Decontamination efficacy of CD gas at sub-optimal process parameters, i.e. 40% RH and/or 50ºF temperature
- Optimization of process parameters for CD gas to mitigate material damage

2006 Decontamination Workshop

EPA/NHSRC On-going Research Efforts in Understanding the Efficacy and Application of Decontamination Technologies

Shawn P. Ryan, Joe Wood, Emily Gibb and G. Blair Martin
U.S. Environmental Protection Agency
National Homeland Security Research Center

Harry Stone, James Rogers, Emily Marsh, Young Choi, William Richter, and Jack Waugh
Battelle Memorial Institute

Matt Clayton and Abderrahmane Touati
Arcadis G&M

April 26 - 28, 2006

Presentation Overview

- **Systematic Decontamination Program**
  - Technology Testing and Evaluation Program
  - Collaborative Interagency Agreement with ECBC
- **Supporting Decontamination Technologies Research**
  - Fumigant kinetics studies
    - Material demand
    - Residual by-products
  - Material compatibility
  - Fumigant containment

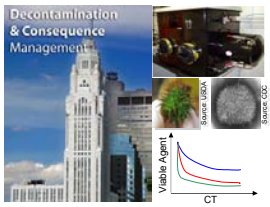
Building Decon Technologies Studies TTEP: Systematic Decontamination

Investigation of commercially ready, or near-ready, technologies to decontaminate biological/chemical agents in indoor/outdoor scenarios

- parametric studies of most promising technologies at non-optimal conditions

- systematic investigation of efficacy against multiple chemical and biological agents

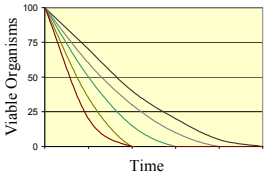
- investigation of agent/substrate (material) and decon agent/material interactions



Systematic Decontamination Studies

- Determine decrease in viable biological organisms or the decomposition of chemical agents as a function of time

Parameters:
- Agents
- Materials
- Technologies
  - Concentration
  - Temperature
  - RH



Determine optimal concentration x time (CT) values for agent/material combinations and the effect of non-optimal conditions on the CT required for effective decontamination

Technical Approach

1. Agent Persistence

- Manipulation of Environmental Conditions to Alter Persistence (MECAP)
  - Is the agent persistent on an array of building materials at achievable HVAC conditions or decontamination phase environmental conditions?
  - Screening approach for decontamination study
    - Can we distinguish the effect of the decontamination technology from the "natural" attenuation?

2. Decontamination Technology Parametric Study

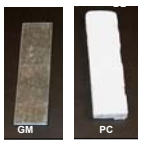
- Unlike evaluation, systematic decon work involves:
  - Efficacy on an array of agents as a function of concentration x time (CT)
  - Efficacy at "non-optimum" conditions (T, RH)

Persistence Screening

Determine the natural decrease in bioactivity of biological warfare agents applied to building surfaces as a function of time under building HVAC system parameters

Vaccinia virus (Smallpox vaccine strain)
Ricin toxin
Coxiella burnetii
**spores not included due to their known persistence

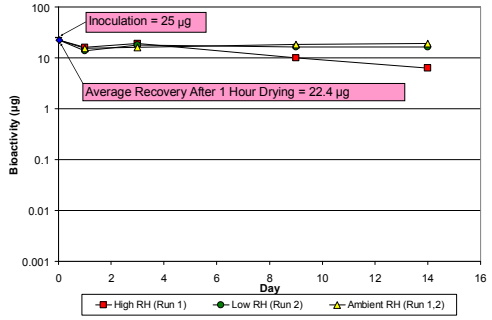
Painted concrete
galvanized metal ductwork



ambient conditions (20 °C, 40 % RH)
higher T, lower RH (30 °C, < 40 % RH)
higher T, higher RH (30 °C, > 70 % RH)

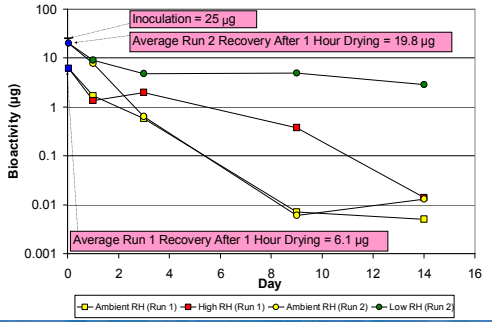
MECAP Results: Ricin Toxin

Persistence of Ricin Toxin on Painted Concrete



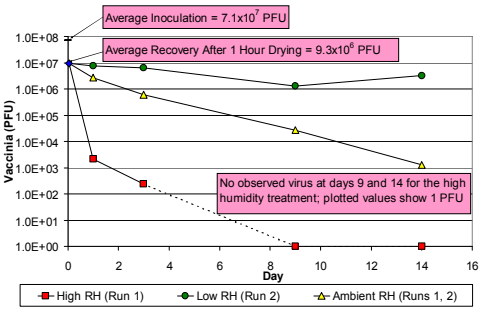
MECAP Results: Ricin Toxin

Persistence of Ricin Toxin on Galvanized Metal



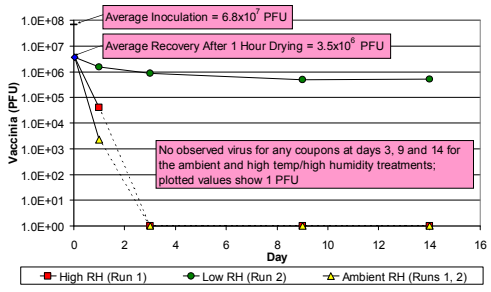
MECAP Results: Vaccinia Virus

Persistence of Vaccinia Virus on Painted Concrete



MECAP Results: Vaccinia Virus

Persistence of Vaccinia Virus on Galvanized Metal



On-going and Planned Studies

1. **Biological Agents:**

- Agents: *Bacillus anthracis* Ames, ricin toxin, vaccinia virus
- Fumigant Technologies: SABRE ClO_2, MeBr
- Liquid Technologies: amended bleach, 2 additional

2. **Chemical Agents & TICs:**

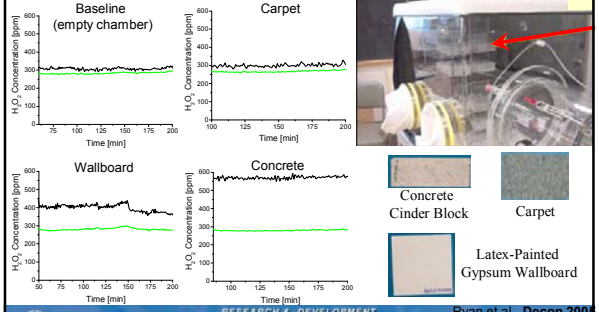
- Agents/TICs: Malathion, DMMP, TNT
  Sarin, thickened Soman, thickened VX
- Fumigant Technologies: SABRE ClO_2
- Liquid Technologies: TBD

Decontamination Technologies Fundamental Research

- Material Compatibility and Material Demand
  - Collaborative Interagency agreement with ECBC
    - STERIS VHP®
      - Material demand work completed (presented at Decon 2005)
      - Material compatibility report in-progress
    - CDG ClO_2
      - Material demand and compatibility work in-progress

Material Demand Results

- STERIS VHP®



Concrete Cinder Block

Carpet

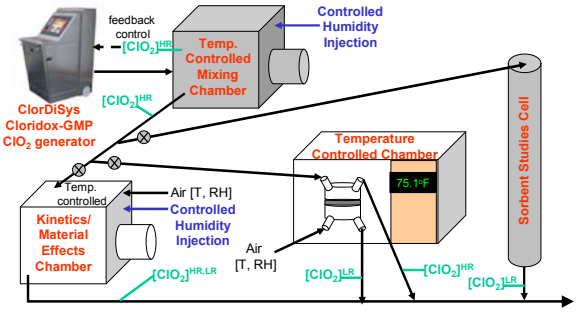
Latex-Painted Gypsum Wallboard

Ryan et al., **Decon 2005**

Decontamination Technologies Fundamental Research

- EPA/ORD/NHSRC/DCMD's (RTP, NC) Decontamination Technologies Research Laboratory
  - Initial focus on ClO_2 (ClorDiSys Cloridox GMP generator)
    - Decomposition kinetics (homogeneous and heterogeneous)
    - Residual reaction product analysis (MS-MS) from materials
    - Material compatibility testing (incl. sensitive equipment)
    - Fumigant containment research
      - Permeability through materials (e.g., tenting)
      - Adsorption (e.g., carbon filters)

Decontamination Technologies Research Laboratory



Decontamination Technologies Research Laboratory

ClO_2 Measurement Methods

- ClorDiSys EMS/GMP
  - Real-time detection using spectroscopy; 50-10,000 ppm
- AWWA SM 4500-ClO_2-E
  - Modified for gaseous sample, ClO_2 oxidizes iodide, which is then titrated with sodium thiosulfate
  - Detection range depends on gas volume sampled
- Dräger Electrochemical Sensors
  - Real-time electrochemical detection; 0-20 ppm
- OSHA ID-202
  - Ion chromatographic detection of ClO_2 reduced by KI, ClO_2^-
  - It also detects reduction product of chlorine gas
  - Detection range dependent on gas volume impinged

Decontamination Technologies Research Laboratory

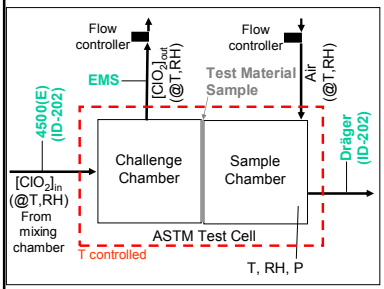
ClO_2 Measurement Methods

Monitoring Method	Description	Concentration Range (ppm)	
EMS or GMP Monitor	Real-time Spectroscopic detection of gas sample	50-10,000	$[ClO_2]^{HR}$
Modified 4500-ClO_2 E	Wet Chemistry: titration of impinged sample	32-32,000	
Dräger sensor	Real-time Electrochemical detection of gas sample	0-20	$[ClO_2]^{LR}$
ID-202	Wet Chemistry: Ion Chromatography of impinged sample	0-100	

$[ClO_2]^{HR}$ (ID-202)

Decontamination Technologies Research Laboratory

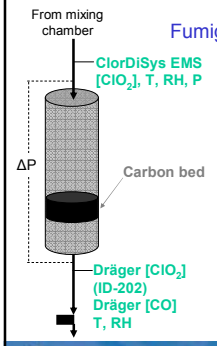
Fumigant Permeability



- ASTM method F 739-99A
- Modified to also test material under negative pressure (-0.05" H_2O)
- Permeation as a function of time and ClO_2 challenge concentration

Decontamination Technologies Research Laboratory

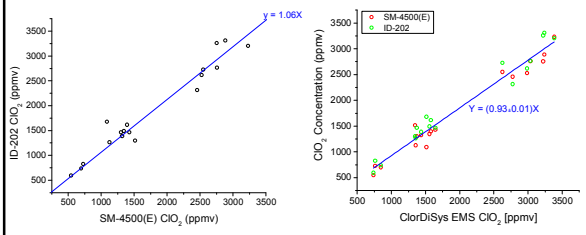
Fumigant Adsorption Studies



- ASTM Method D 5060-95 (re-approved 2003)
  "Standard Guide for Gas-Phase Adsorption Testing of Activated Carbon"
- Breakthrough time (when $[ClO_2]_{out}$ = 0.05 ppm) as a function of bed depth
  - Determine dynamic adsorption capacity and critical bed depth of potential sorbents
- Effect of RH and T

Decontamination Technologies Research Laboratory

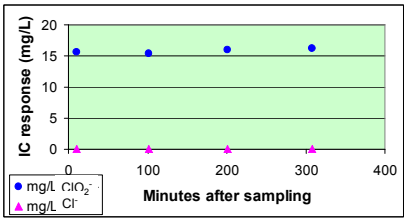
ClO_2 Measurement Methods Comparison



- F-Test results from comparison of fits; At the 0.05 significance level the two datasets are NOT statistically different.

Decontamination Technologies Research Laboratory

ClO_2 Measurement Methods Comparison



- No detection of chlorine in sample (DL = 0.001 ppm for 120 L purge)

Rapid Methods to Plan, Verify and Evaluate the Effectiveness of the Decontamination Process

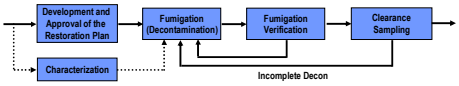
Tina Carlsen, PhD
Staci Kane, PhD
Matthew Verce, PhD
Paula Krauter
Lawrence Livermore National Laboratory

April 27, 2006
USEPA Decontamination Workshop

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-220802

Great need to reduce the time required to resume facility operations after a bioattack



- LLNL has conducted research in two areas with high potential to save time in the fumigation process:
  - Methods to plan and evaluate the fumigation process
  - Methods to reduce sample analytical time for fumigation verification and clearance

#2

We are working on a simple fumigation engineering design/ guidance tool

Chamber studies:
No transport effects
(USEPA/ECBC material & viability study)

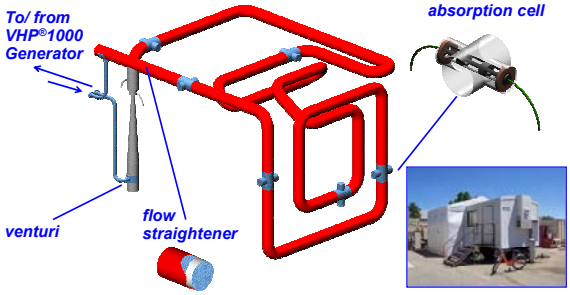
Room - scale studies:
Incorporate transport
(STERIS/ECBC mVHP® study; LLNL/LBNL/STERIS VHP® study)

Computational Fluid Dynamics:
"Untangles" transport terms for easy use
(STERIS/ECBC mVHP® study; LLNL/LBNL/STERIS VHP® study)

GOAL: An (existing) zonal model with enhanced capabilities
–Estimates CT values
–Includes materials effects
– Zonal model: easy to use (e.g. not CFD!)
– Existing model: familiar (Don't reinvent the wheel!)

#3

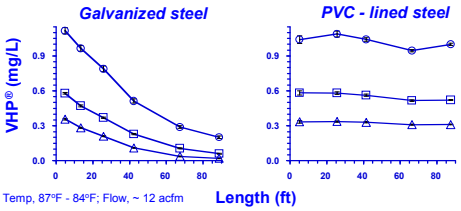
Completed a series of experiments on ducts study effect of materials on decomposition



Both galvanized steel and PVC - lined steel were tested

#4

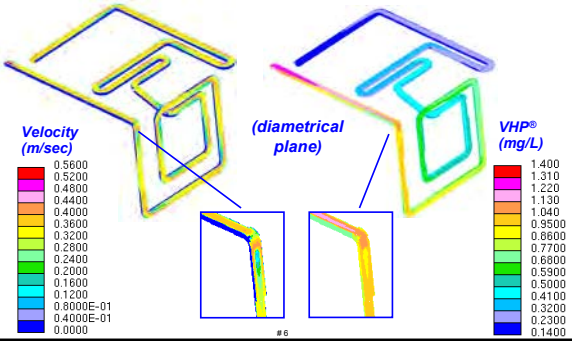
VHP® concentration markedly different in galvanized versus PVC-lined steel duct



- Galvanized steel duct catalyzes surfaces decomposition of VHP®
- Rate of catalysis decreases markedly with decrease in temperature
- Increasing flow rate will increase exit VHP® concentration
- PVC - lined steel is essentially inert toward VHP®

#5

CFD reveals lower velocities, lower VHP® concentrations at bends



#6

Room experiments are underway

- Validated CFD simulations will be used to develop simpler analytical models
- Goal is to enhance existing zonal models with new capabilities
  - Estimating CT values
  - Includes material effects
- Simple, easy to use
- Provide an ability to evaluate fumigation options

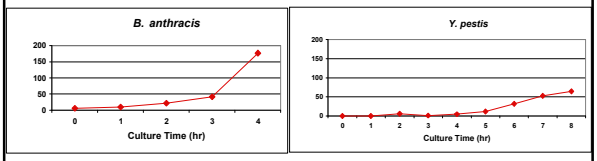
Current state-of-the-art for sample processing and analysis for *B. anthracis*

- CDC/LRN methods available for spore recovery from swabs, wipes and HEPA vacuum socks
- Current throughput is about 30 samples/day
- Methods are labor- and time-intensive
  - Excessive sample handling including centrifugation
  - Includes multiple transfer steps
  - Requires preparation of dilution series and plating
- Viability determination based on growth on culture plate
- Requires confirmation by biochemical tests

Rapid, high-throughput viability method reduces analytical time for verification and clearance

- Rapidly determines viability of *B. anthracis* or its surrogate
  - Improves on current turn-around time and sample throughput
- Methods for surface samples
  - Compatible with CDC/NIOSH samples and protocols
- Methods for biological indicators
- Development leveraged the resources of BioWatch and earlier work supported by DARPA

Basis of RV-PCR method is increasing DNA copies over time through cell replication

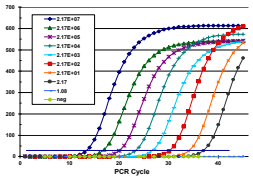


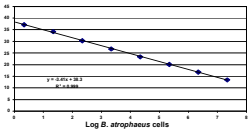
K. Smith, P. Coker, K. Montgomery, P. Imbro, P. Fitch
Funding support from DARPA

There is a rapid increase in DNA copy number during growth

RV-PCR based on specific and sensitive real-time PCR assays

- Assays are specific for
  - *B. anthracis*
  - *B. atrophaeus (B. globigii)*
- 8 log linear range
- Detection limit < 5 cells
- Results in < 40 min

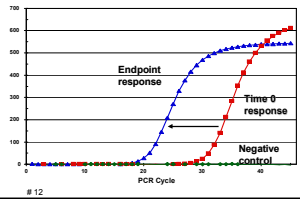




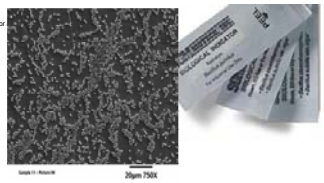
Real-time PCR assays work in environmental backgrounds

Criteria were developed & tested to accurately distinguish live cells from dead spores

- Shift in fluorescence response curve indicates increase in DNA and thus, cell number
  - Accurately distinguishes live cells from dead spores
- Validated with spores killed by chlorine dioxide, irradiation, steam sterilization
- 14 hr endpoint for surrogate validated with large sample set
- Results confirmed with culture-based methods



Biological Indicators (BIs) used for fumigation efficacy testing and as a model for spores on surfaces



- < 9 mm diam. stainless steel disc in Tyvek/Tyvek package (Apex Labs)
- *B. atrophaeus* ATCC #9372, 10^6 spores/disc
- Uses 96 well plates for culturing and high-throughput sample processing
- More representative of hard surface than paper strips

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Rapid, high-throughput protocols for sample processing

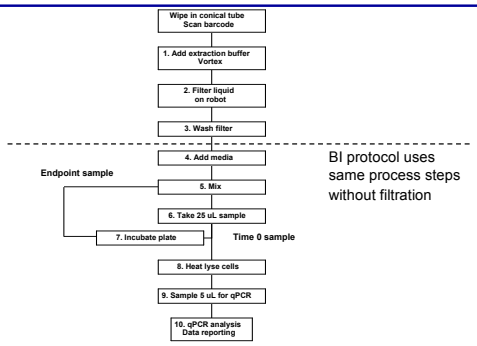
Manual, semi- and fully-automated protocols depend on sample type

Sample Type	RV-PCR Target Sample Volume (# processed/day)
Wipe	High 100's
HEPA Sock	Low 100's
Swab	1000's
Filter Cartridge	High 100's
Air Filter	Mid-High 100's
Biological Indicator	Mid to High 1000's

CDC processed ~30 samples/day for Brentwood (wipe or sock)
With automation can improve by factor of 10-100
BIs can be processed in volume of 1000's (~100/block)

14

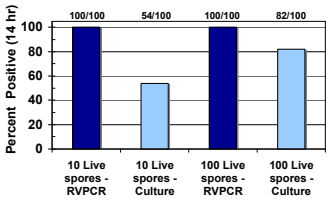
Automated protocols differ at the front end



BI protocol uses same process steps without filtration

15

RV-PCR consistently detects ~10 spores in high dead spore background



Controls	RV-PCR	Culture
100 live	50/50	47/50
10 live	50/50	26/50
10^6 dead	0/78	0/78

- Detected 100% of spore samples in 10^6 dead spore background at 14 hr
- RV-PCR gives specific detection; culture is non-specific

16

ClO_2 Field Test of RV-PCR demonstrated accuracy and rapid, high-throughput capacity

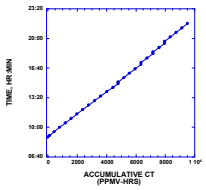
Analytical Method	Spore conc.	ClO_2 exposure time (hrs) (750 ppm/hr) 0	1	2	4	6	8	10	12	Number of discs
Approx. CT (ppm)		0	750	1500	3000	4500	6000	7500	9000	
RV-PCR Method	10^6	50	50	50	50	50	50	50	50	400
	10^4	10	10	10	10	10	10	10	10	80
Standard Method	10^6	50	50	50	50	50	50	50	50	400
	10^4	10	10	10	10	10	10	10	10	80
Subtotal		120	120	120	120	120	120	120	120	960
Total w/ controls										**1130**

- 10% blind positive controls (prepared in field)
- Inhibition studies conducted for highest exposure
- 10% positive and 10% negative controls for PCR
- All samples bar-coded and tracked through each process step
- Sabre ClO_2 technology used to demonstrate RV-PCR

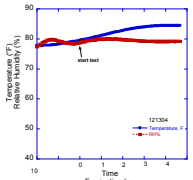
17

Chlorine dioxide concentration, temperature and RH were carefully controlled during testing

Consistent ClO_2 exposure

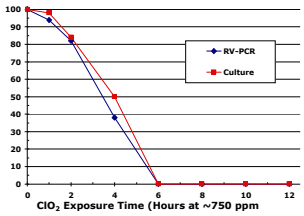


Average 79-85 ° F and 78-81% RH



18

RV-PCR method (< 17 h) was accurate with culture method (7 d)



- Hundreds of samples exposed to non-lethal levels of ClO_2
- No significant difference between RV-PCR and culture results, P>0.05
- 10^4 BIs RV-PCR results agreed with culture results
- Culture method had 1.5% false positive rate determined by qPCR

RV-PCR method showed no cross contamination or false negatives

- No false negatives for RV-PCR method
  - based on visual growth at 2, 4, and 7 days
- No cross contamination
- No influence of 'residual' ClO2
- Web-based sample tracking/ data analysis tools allowed rapid reporting

Plate: FPL000M

Well	SporeStrip	Results Set 1 5- Dec-04 11:53 AM	Results Set 2 5-Dec-04 02:38 PM	Verdict
A1	B00248 0	37.80	25.68	Positive
B1	B00273 7	39.02	34.71	Negative
C1	B00274 6	34.15	21.79	Positive
D1	B00284 7	0	22.18	Positive
E1	B00273 8	0	35.84	Negative
F1	B00248 6	0	34.92	Negative
G1	B00305 3	0	36.01	Negative
H1	B00285 1	0	25.12	Positive
A2	B00249 1	0	22.31	Positive
B2	B00273 5	40.47	23.71	Positive
C2	B00101 9	34.45	19.79	Positive
D2	B00249 3	31.84	23.20	Positive
E2	B00101 5	38.13	20.14	Positive
F2	B00305 5	36.99	22.56	Positive
G2	B00049 2	40.44	33.20	Negative
H2	B00285 2	0	24.70	Positive

RV-PCR uses high-throughput processing protocols for environmental samples

- Compatible with CDC/NIOSH sample types and real-time PCR analysis
- Handles high levels of environmental backgrounds (dirt, debris, etc)
- For 2" x 2" dirty wipe samples:
  - 96 samples processed in 4-8 hour depending on filtration method
  - Spore recovery efficiencies ≥ than those from CDC protocols
- Additional protocols designed for other sample types

Protocols are compatible with swabs, vacuum socks, and filters

Several field tests successfully demonstrated RV-PCR environmental wipe protocols

- Dugway Proving Grounds
  - 8' x 8' mock office sampled after release of aerosolized *B. atrophaeus* spores
  - 100 wipe samples and controls
  - Method handled high levels of background debris
- LLNL Chemistry Building
  - >1000 floor and wall samples spiked with low spore numbers
  - ~10 spore detection limit
- ClO_2 exposed and killed spores
  - Consistently distinguished live cells from dead spores on dirty wipes

RV-PCR technology performed well for fumigation efficacy testing and clearance sampling

- Fumigation Efficacy Testing: >1000 BIs exposed to 8 levels of ClO_2 to compare RV-PCR to standard culturing
  - RV-PCR results at ~17 hr matched culture results (7 days)
  - Automated protocols allow processing of 1000 BIs/day
- Clearance Sampling: 100 wipe samples from DPG, 100's of wipes from LLNL buildings (floors and walls)
  - All DPG samples were positive via RV-PCR despite presence of high levels of background debris
    - Good correlation with plate counts
  - Detection limit on spiked dirty wipes consistently ~10 spores
  - Automated protocols allow processing of ~200 wipes/day

Next Steps for RV-PCR development: Vegetative cell pathogens

- Viable vegetative cell pathogens can be detected in hours rather than days

Analysis time for:	Rapid Viability PCR	Conventional Assay
Y. pestis	6-8 hr	3-5 days
Brucella sp.	6-8 hr	5-7 days
F. tularensis	8-10 hr	7 days

K. Smith & M. McBride et al., DARPA supported

- *Y. pestis* in ≤8 hr in background of HEPA vacuum sock filled with debris

Development will focus on high-throughput sample processing while maintaining viability and quantitative RV-PCR

RV-PCR Additional Next Steps

- Demonstrate RV-PCR methods for other environmental sample types in high-throughput
  - HEPA vacuum socks, filters, swabs
- Develop and evaluate quantitative RV-PCR
  - Determine initial viable spore or cell density for characterization and fumigation efficacy testing
- Integrate sample processing protocols with BioWatch/LRN detection protocols

RV-PCR has great potential to reduce the time to resume facility operations

- Rapid high-throughput viability methods available for environmental wipes and BIs
- The analysis time for BIs was reduced from 7 d to ~17 hr
  - < 24 hr for wipe samples
- RV-PCR showed the same sensitivity as culturing
  - Highly accurate in multiple field tests
- Automated and manual protocols available
  - Protocols for other sample types are ready for field testing

Agent Fate Program

Presented at
2006 Decontamination Workshop
Environmental Protection Agency
(EPA)

27 April 2006

Dr. James Savage, DTRA, 410-436-2429
james.savage@us.army.mil

What is the Objective of the Agent Fate Program?

Improve model predictions of agent persistence

Objectives:
- Measure and understand the agent/substrate interactions
- Develop predictive algorithm module

Payoffs:
- Support all capability areas:
  detection, protection, decontamination
- Augments operational and mission area analysis tools
  Joint Effects Model (JEM)
  Joint Operational Effects Federation (JOEF)
- Direct feed to Low Level Toxicology DTO (CB.51)

Why Do We Need an Agent Fate Program?

Models give varying and inaccurate persistence predictions

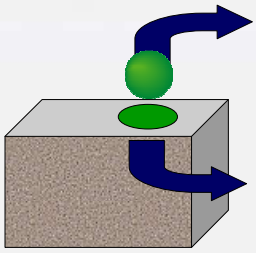
Field manuals and models built from limited data sets & questionable data

CONFLICTING

Temp 10-30 °C	FM 3-4 Liquid	FM 3-4 Vapor	FM 3-9 Liquid	FM 3-9 Vapor
GD	Not Avail	7 - 20+	Not Avail	5 - 48
HD	Not Avail	20+	Not Avail	6 - 168
VX	Not Avail	18 - 20+	Not Avail	1800 -3600

Analysis Tools Chosen to Match System Under Study

Best tools applied with strict quality control for high-fidelity



Evaporation
Wind Tunnels

Sorption
Agent/Substrate Interaction Measurements

Agent Fate Concept and Approach

Three Major Thrusts

Predictive Modeling
Statistical Design of Experiments

Lab / Wind Tunnel
Surface Evaporation

Methodology Development
Understanding of Agent/ Surface Chemistry

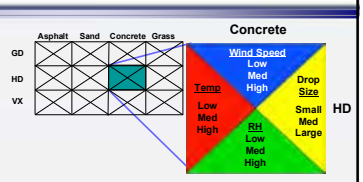
Science Based Predictive Capability for Agent Persistence

Secondary evap. model for JEM
Interim VLSTRACK
CHEMRAT/JOEF
Field Manuals

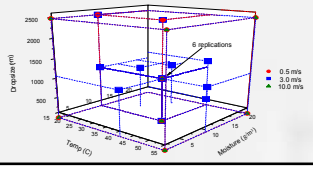
Design of Experiments Minimizes the Number of Experiments

- About 10,000 experiments for full factorial approach – infeasible!
- Now, about 1500 experiments with CCD approach
  - 24 agent/substrate combinations
  - 3 levels for each parameter (temp., drop size, wind speed, humidity)

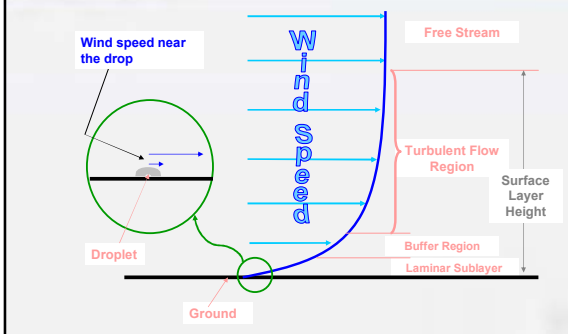
- Created central composite design (CCD) experimental test matrix
- Developed surface evaporation assessment tool
- Incorporated 26,115 new data elements into evaporation database
- Completed phase II literature analysis
- Fielded CHEMRAT phase I



HD on Concrete CCD Experiments

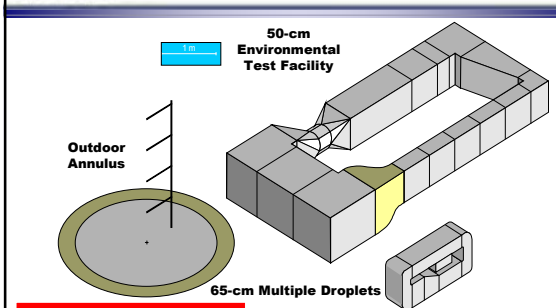


Atmospheric Surface Layer



7

Range of Wind Tunnel Sizes Used in Agent Fate



Scale Independence of Agent Fate Wind Tunnels

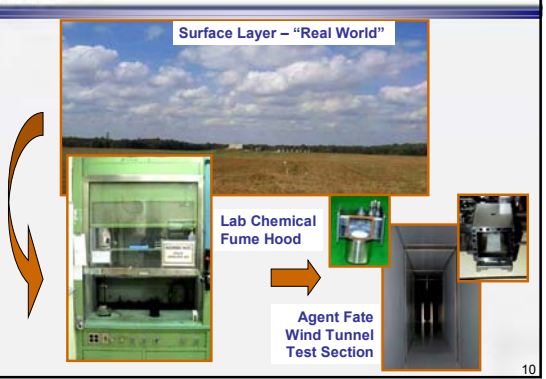
- No scaling corrections are required between the various sizes of wind tunnels used in the Agent Fate Program. Since the tunnels all possess the same velocity profiles (based on realistic wind conditions), the agent/substrate combinations being tested experience the same air flow and evaporation environment.
- Accordingly, identical data should be obtained for identical agents/substrates tested in any of the tunnels. This finding allows the results from the tunnels to be directly compared and also eliminates the need to perform duplicate tests in the different tunnels.

NO SCALING CORRECTIONS ARE REQUIRED

- **Based on assessment by**:
  Dr. Klewicki, University of Utah
  Recognized expert in theoretical and experimental atmospheric boundary

9

Shrinking Down the Atmosphere

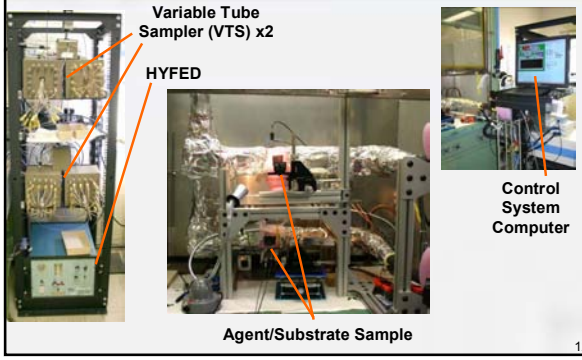


10

3rd Generation ECBC Wind Tunnel

11

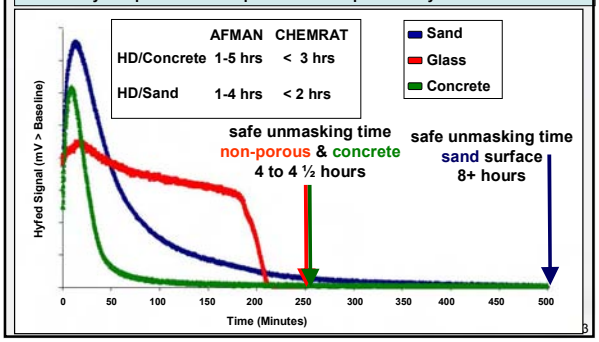
5 x 5-cm Wind Tunnel Operational Arrangement



12

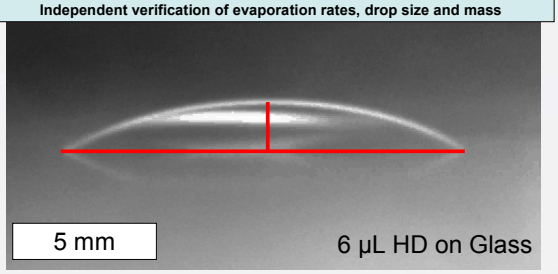
Preliminary Persistence Estimates HD on Concrete / Sand Vapor Hazard

Preliminary comparisons of evaporation from operationally relevant substrates



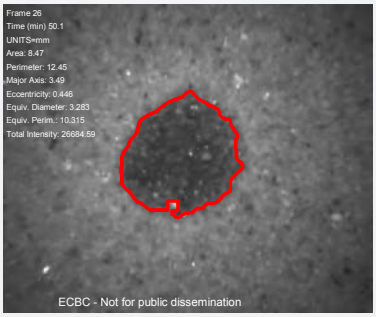
Quantitative Image Analysis Determines Drop Volumes

Independent verification of evaporation rates, drop size and mass



$$\text{Sessile Drop Volume} = \frac{1}{6}\pi \,\text{Height}\left(3\left(\frac{\text{Diameter}}{2}\right)^2 + \text{Height}^2\right)$$

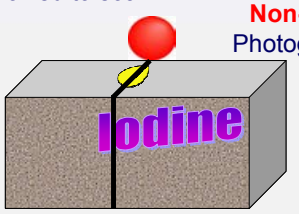
Image Analysis Determines Drop Spread Automatically



Measuring Drop Shape Within a Substrate

Concrete sample
Exposed to Agent
Allowed to soak in

Concrete is broken
Exposing cross-section
Developed with Iodine
Non-perturbing process
Photographed



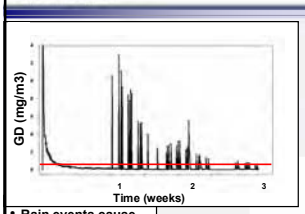
Imaging Systems Display Agent / Substrate Interactions

Imaging techniques quantify agent penetration into porous media

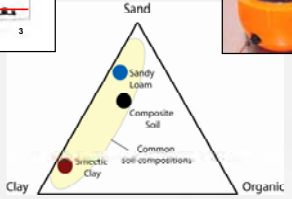
Asphalt – 4 days

Concrete – 4 hours

Agent / Surface Interaction Studies

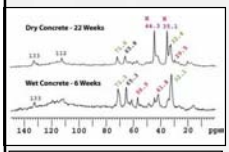


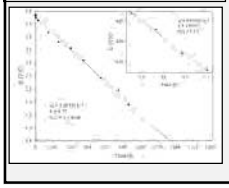
- Rain events cause resurgence of agent vapor
- 34 events over 3 weeks
- Verified by independent methods:
  - HS-SPME
  - Field Trial



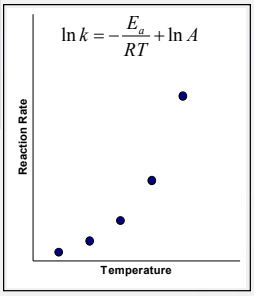
Agent / Surface Interaction Studies

NMR determines reaction rates and product identity in materials



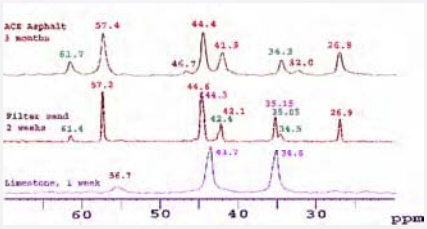


$$\ln k = -\frac{E_a}{RT} + \ln A$$



HD* and Water on Asphalt, Sand & Limestone

- The sulfonium ion H-2TG (toxic) was the major product, >75%.
- An alcohol – thiodiglycol (non-toxic) and/or chlorohydrin - was also formed.
- Half-lives: ~1 month for asphalt and limestone, 1-2 weeks for sand.



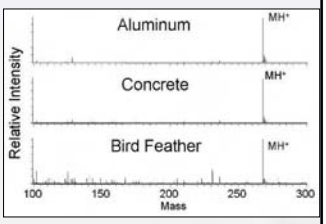
Methodology Development

Results: Degradation of HD* on Ambient Substrates

Substrate	Dry	With Water
Limestone	No reaction in 7 months	1 month
Asphalt	No reaction in 2 months	1 month
Sand	No reaction in 7 months	1-2 weeks
Mortar	Half-lives of weeks to years	3-9 days
Concrete	Half-lives of weeks to years	3-9 days

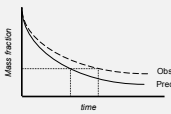
Direct Analysis in Real Time (DART)

Revolutionary ion source for prep-free surface analysis with MS



Open Air Testing

The Challenge - Generate realistic agent fate data in a controlled laboratory environment



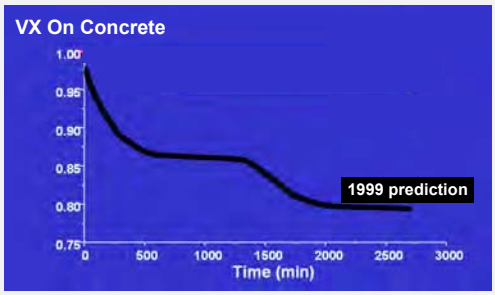
Laboratory model corrected and validated against open air field trials

CY 2006 Open Air Field Trials

HD on asphalt, VX on glass, VX on concrete, VX on sand

Improving Secondary Evaporation is Key to Improving Hazard Prediction!

Reducing the error between predictions and observations



Improving Field Persistence Estimates

AFMAN 10-2602

-50 → +50 °C

Surface	HD Distilled Mustard	R-33 (Russian VX Isomer	VX
Glass	0	0*	0*
Bare Metal	0-0.8	0*	0*
Wood	0*	0*	0-1

Agent Fate Model Predictions

(HD on Non-porous Surface)

Temp (°C)	2-m Height Wind speed (m/s) 0.5	3.0	6.0
15	24	7	6
35	4	1	1
55	1	0.5	0.5

More accurate and precise contact hazard estimates

Agent Fate Transitions Knowledge

Augmenting TTPs & Field Manuals

Agent Fate DTO → Low-Level Toxicity DTO

Follow-on DTO for NTAs

Transitioning to Acquisition Programs

JEM, JOEF, VLSTRACK

JEM	Joint Effects Model
JOEF	Joint Operational Effects Federation
TTP	Techniques, Tactics and Procedures
VLSTRACK	Vapor, Liquid, and Solid Tracking

Agent Fate is a Team Effort!

QUESTIONS ?

UCRL-PRES-220774

Homeland Security

Stakeholder Issues Surrounding Chemical Agent Restoration (Selected Viewgraphs)

Ellen Raber[2] and Annetta Watson[3]

in collaboration with
Linda Hall[2], V. Hauschild[4], John Sorensen[3], Robert Ross[3], Karen Folks[2]

Apr 26-28, 2006

[1]Work supported by DHS Office of Research and Development, [2]Lawrence Livermore National Laboratory, [3]Oak Ridge National Laboratory, [4]U.S. Army Center for Health Promotion and Preventive Medicine

This presentation will cover key aspects for transit facility chemical agent restoration

- General cleanup issues and decision framework
- Stakeholder concerns
- Regulatory requirements and cleanup recommendations

Cleanup requirements and restoration issues are site-specific

Outdoor (i.e., stadium, mall)

- Many environmental variables must be considered
- Dilution/natural attenuation may be the solution

Semi-enclosed (i.e., airport, subway)

Indoor (i.e., office, hotel)

- Public perception issues are key
- More amenable to ventilation interventions
- Alternate facilities available

Understanding cleanup requirements is key to guide a risk-informed decision-making process

- Determines if an actual or potential impact to health, property or the environment exists
- Guides necessary actions to restore essential facilities and/or operations
- Guides whether or not decontamination is needed
- Provides for understanding of potential secondary contamination and waste generation issues
- Impacts other decisions for long-term regulatory and stakeholder review

- Whether or not cleanup criteria have been met
- Whether or not to reoccupy or resume operations
- Whether longer term monitoring should be employed

CW Agent Reentry and Decontamination

- Topic addressed by Programmatic EIS for Chemical Stockpile Disposal Program (Jan 1988) for DA Program Manager for Chemical Demilitarization (Aberdeen Proving Ground, MD)
- Emergency response planning underway at CW disposal site host communities under Chemical Stockpile Emergency Preparedness Program (CSEPP) (approx. 1991-present) (FEMA and DA)
- Planning Guidelines for Recovery Phase Activities for Chemical Stockpile Disposal Program (FEMA and DA,1997)
- CW agent-specific Reference Doses to establish basis for clean up of both active and formerly used defense sites (NRC, 1999; DA 1998, 2001); used to develop soil screening levels by USACHPPM (1999)

Ongoing focus area for DHS Chemical and Biological Countermeasures Program as part of Chemical Restoration OTD

"Decontamination issues for chemical and biological warfare agents: How clean is Clean Enough?" first published in 2001

How Clean Is Clean Enough?

How Clean Is Safe?

Raber, E., Jin, A., Noonan, K., McGuire, R., and Kirvel, R.D.

New updated article Vol. 14, Issue 1, February , 2004, but guidance has been updated since paper composition

Additional sources used in this study

- Opresko, D., R. Young, A. Watson, et al 2001. Chemical warfare agents: Current status of oral reference doses. *Rev. Environ. Contam. Toxicol.* 172: 65-85.
- Watson, A., K. Bakshi, D. Opresko, et al 2006. Cholinesterase inhibitors as chemical warfare agents: Community preparedness guidelines. Ch.5 in R. Gupta (ed) *Toxicology of organophosphate & carbamate compounds.* Associated Press.
- Watson, A., D. Opresko, R. Young, et al 2006. Development and application of acute exposure guideline levels (AEGLs) for chemical warfare nerve and sulfur mustard agents. *JTEH, Part B* 9: 173-263.

More available upon request

Overall objective for this work has been aimed at addressing 5 key areas for CW related incidents

- Implement an effective framework with recommendations to address key stakeholder issues
- Summarize existing chemical warfare agent and toxic industrial chemical exposure guidelines and apply to airports
- Survey existing regulatory guidelines for agent and agent-waste disposal requirements
- Recommend facility restoration and site clearance guidelines applicable to workers and the general public (transit passengers)
- Apply standard assumptions and procedures to develop interim exposure guidelines where guidance is lacking

Cleanup levels drive all consequence management activities within decision framework

CRISIS MANAGEMENT		CONSEQUENCE MANAGEMENT			
RESPONSE ACTIVITIES		RESTORATION ACTIVITIES			RECOVERY ACTIVITIES
NOTIFICATION	FIRST RESPONSE	CHARACTERIZATION	REMEDIATION/ CLEANUP	CLEARANCE	REOCCUPANCY
Receive and assess information Identify suspect release sites Relay key information and potential risk to appropriate agencies	HAZMAT and emergency actions Forensic investigation Public health actions Screening sampling Determine agent type, concentration, and viability Risk communication	Detailed characterization of agent Characterization of effected site Site containment Continue risk communication Characterization/ environmental sampling and analysis Initial risk assessment Clearance goals	Decontamination strategy Remediation action plan Worker health & safety Site preparation Source reduction Waste disposal Decontamination of sites and/or items Decontamination verification	Clearance sampling and analysis Clearance decision	Renovation Longer-term environmental and public health monitoring Reoccupation decision

Study has focused on multiple compounds of concern

- Nerve and blister chemical warfare (CW) agents
  - Nerve agents GA, GB, GD, GF, VX
  - Blister agents H/HD
- Selected Toxic Industrial Compounds (TICs) with history of deployment by terrorist groups
  - Hydrogen Cyanide, Cyanogen Chloride, Phosgene
- Critical Degradation Products from agents and TICs
- Compounds with key toxicological characteristics
  - Either immediate or delayed effects following short-term exposure to toxic concentrations
  - Range of potency with potential for large scale impact
  - Multiple effects; compound-specific organ/system targets
  - Compounds designed for rapid and severe action on combatants; most dissipate rapidly and chronic exposure not an issue

Input to the restoration process has involved review/development of key exposure guidelines

- Ambient vapor concentrations (inhalation/ocular, dermal)
  - *Occupational*
  - *General Public*
  - *Transit passengers*
- Skin vapor exposure (occupational)
- Surface contact
- Ingestion guidelines
- Critical agent degradation products
- Waste disposal regulatory guidelines and disposal path options
- Long-term monitoring approaches

Principal chemical warfare agent degradation products have been reviewed

Agent	Key Degradation Products
Sulfur Mustard (H, HD)	Thiodiglycol
Tabun (GA)	None of concern
Sarin (GB)	Methylphosphonic acid Isopropyl methylphosphonic acid
Soman (GD)	Methylphosphonic acid
VX	Methylphosphonic acid Ethyl methylphosphonic acid S-(diisopropylaminoethyl)-methylphosphonothioate (EA 2192)

Additional research underway to understand environmental degradation as a function of surface chemistry

Post-incident environmental monitoring may be important for stakeholder confidence

- Monitoring should focus on both persistent and more volatile compounds
  - Degradation and/or intermediate breakdown products need to be considered
  - Since event short-duration (non-continuous source) release; long-term persistence not expected
- Worker monitoring should utilize existing protocols/guidelines from industrial releases and CW agent related facilities
  - Utilize compound specific TWAs (WPLs) or STELs as established by NIOSH/OSHA and CDC
  - Tooele Chemical Agent Disposal Facility Monitoring Plan
  - Newport Chemical Depot
- Skull Valley VX Incident (Dugway Proving Ground) degraded after 6 months

Remediation/cleanup decisions are site-specific and must address stakeholder concerns

- Site-specific parameters and usage are key
- Likelihood of effect on exposed population(s):
  - Potential acute and long-term chronic impacts
  - Relevant exposure (e.g., inhalation, dermal, secondary ingestion) routes
  - Mobility, fate and multimedia transport of contaminants
- Damage and associated costs to land, water, property and equipment
- Cost/availability of remediation/decontamination options with time constraints
- Potential secondary contamination and waste generation issues
- Confidence in remediation methods; including sampling/verification

Public perception and stakeholder issues will drive cleanup requirements ⇄ **Economic drivers and inconvenience influence stakeholders to accept higher risks**

Restoration requirements for the civilian sector are very demanding/conflicting

Economic Drivers are significant with regard to critical transportation infrastructure ⟷ **Stakeholders want high assurances that facilities/areas are "safe" for reoccupancy**

Fast	Safe
Adequate	Best
Reduced Cost	Cost Effective
Utilize more hazardous approaches if faster/adequate	Employ noncorrosive/ nonhazardous strategies

For additional information, please contact:

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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

Strategy for NHSRC Radiological Decon R&D Program

2006 Workshop on Decontamination, Cleanup, and Associated Issues for Sites Contaminated with Chemical, Biological, or Radiological Materials

Washington, DC

April 28, 2006

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

RESEARCH & DEVELOPMENT
Building a scientific foundation for sound environmental decisions

Overview

- Background on Rad. Clean Up
- 2005 Initiatives
  - Strategy
  - Literature Search Efforts
  - RDD Workshop
  - Nuke Workshop
- 2006+ Technology R&D
- INDs and Other Initiatives

RESEARCH & DEVELOPMENT
Building a scientific foundation for sound environmental decisions

Rad/Nuc Attacks

- There are three general types of attack involving radiological or nuclear materials about which we are concerned:
  - Radiological dispersal device (RDD)
  - Nuclear weapon, of improvised nuclear device (IND)
  - Attack on a nuclear facility (which we will not cover)
- The urban dirty bomb is more likely, thus the higher R&D priority
  - Dirty bomb intelligence, perceived imminence based on ease of deployment
- Primary focus – **decontamination technologies for an urban RDD**
  - Including basic supporting science

RESEARCH & DEVELOPMENT
Building a scientific foundation for sound environmental decisions

Background – Urban RDD

- Radiological Dispersal Device (RDD): Any device used for the dissemination of radioactive material in the environment with the intent to cause harm
- Approach: **The 80% Solution** - focus on R&D for rapid urban RDD decontamination technologies
- Will begin work on IND impacts, remediation strategies

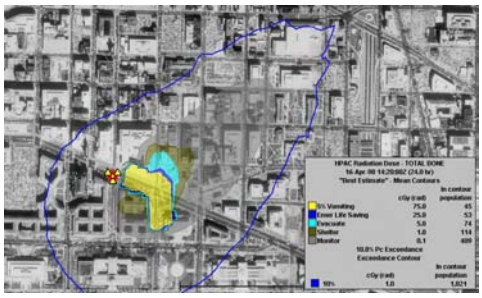
RESEARCH & DEVELOPMENT
Building a scientific foundation for sound environmental decisions

Some Things Not Considered at This Stage for R&D

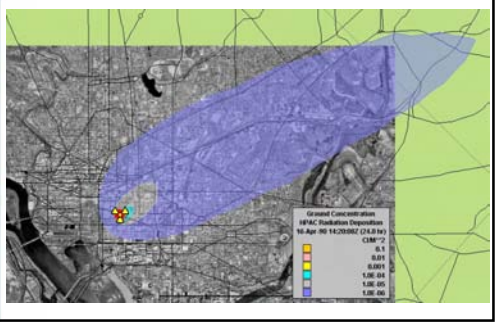
- Response, except as relates to decontamination, control, mitigation technology needs
  - i.e., not detection/measurement, sampling, communications, PPE,…
- Food, agriculture, or other non-urban scenarios/environments
- Groundwater remediation
- Indoor decontamination
- Risk or risk analysis
- Worker H&S

RESEARCH & DEVELOPMENT
Building a scientific foundation for sound environmental decisions

3000 Ci Cs^{137}, 1000lb HE Washington, DC



3000 Ci Cs^{137}, 1000lb HE Washington, DC



Background- Clean Up Today

- Current U.S. experience in radiological decon and site restoration is bounded by commercial and Federal sector legacy site clean ups
  - Done under CERCLA, 10CFR20, state regs
- Generally, modus is demolition, or removal of surface layer
  - Decontamination used more for waste minimization than free release of structures
- Technologies are designed for specific purposes; the more high tech, generally the fewer applications

Background – New Problem

- Presumption: *after an RDD, restore the area leaving infrastructure intact and preserved*
- Technically, "we can clean up anything," but, dirty bombs pose unique challenges
  - Occupied urban environment
  - Significant logistical problems
  - Significant cost, time, political and economic pressures
- Size is the issue: *small* particles; *large* area
  - Tiny particles travel farther, harder to decon
  - Surface area to be decontaminated, outdoor/indoor, is potentially *enormous* (millions of sq. meters); becomes the driving factor
- Clean-up strategies driven by time, cost, dose considerations, and public acceptability
- Challenge – decontaminate *faster, better, cheaper*

2005 - Literature Search

- Search out decon technologies
  - Library/database search; DOE, commercial sources
  - Vender requests
  - Work by others; Nat'l Labs, ORIA, OSWER
  - Other data sources
- Will add technologies to NDT Portfolio

2005 – RDD Workshop

- RDD Clean-Up Workshop
  - Scenario-driven look at clean-up needs for a major RDD incident
  - Describe the operational environment, practical considerations, and technology needs for decon and clean up
  - *Focus and prioritize* R&D project funding
- Technologies were being evaluated in isolation, not in "real-world" context
- Goal: identify, fund development of promising RDD decon/clean-up technologies and tools (the 80% solution), that meet the "real-world" need

2005 RDD Workshop

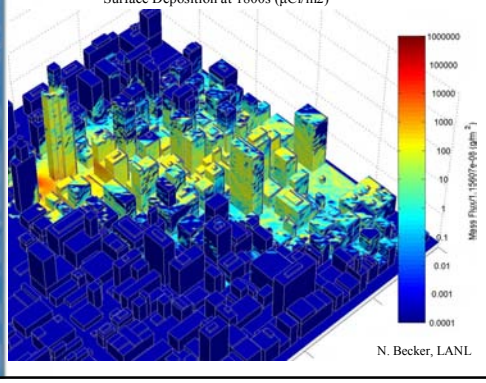
- Approach – assemble federal and private sector experts to compare/contrast current technologies and approaches needed in order to identify technology R&D directions/opportunities
- Problem Assessment
  - Used HSC Scenario #11; LANL provided deposition modeling
  - Attempted to describe the *operational environment* of RDD clean up and site restoration
  - Assumed DHS RDD/IND optimization clean-up approach and implementation plan
- Focus on procedural/technology transferability, parallels and gaps; what works; what doesn't? what needs/gaps exist?
- Participants – EPA field and HQ, DHS, DOE, USACE, DARPA
- Speakers – EPA, Nat'l Labs, private sector

Training-Workshop Topics

- RDD Scenario, and DHS clean up optimization and implementation plan
- Overviews of Superfund, commercial clean ups
- Administrative - planning and management, record keeping, cost estimation, personnel issues
- Worker health and safety (industrial and rad.)
- Site deactivation, preparation
- Site characterization/final status surveys
- Dismantling technologies
- Decontamination technologies
- Emerging technologies
- Waste management; shipping, packaging, disposal
- Case studies – WTC, Cintichem, Ir-192 refinery fire, TMI (concrete decon)

RDD Workshop Scenario

Surface Deposition at 1800s (μCi/m2)



N. Becker, LANL

2005 RDD Workshop

- Preliminary Conclusions -Practical:
  - A *large size* makes site clean up extremely complicated
  - Project management will be very difficult
  - Site characterization will need better methods
  - Speed may be critical to successful decon
  - Decon approaches will change - ^{137}Cs binding, rain, decon water, cross-contam, local priorities
  - High vertical surfaces require specialized approaches
  - Contam spread, cross-contam and recontam are inevitable and a major problem
  - Technologies must be faster, better, cheaper
  - New software tools may be useful time/cost savers
  - No waste disposal options are evident

2005 RDD Workshop

- Preliminary Conclusions –Technological:
  - Current decon technologies are inadequate
  - Radio-compound, PSD, surface chemistry are critical factors in decon technology selection
  - Leading approach, strippable coatings, is not the answer (very limited use), neither is sealant
  - An assortment of technologies will be needed
  - Low-tech approaches may be most valuable; brush and vacuum systems, aqueous washing, scabbling
  - Cannot avoid destructive, removal techniques
  - Remote operation, automation techs needed to minimize worker doses, manpower
  - Need engineering to reach high surfaces
  - Special attention needed for nooks and cracks
  - Subsurface effects cannot be overlooked
  - Waste generation must be managed, minimized; preplanning is critical

2005 RDD Workshop

- Workshop helped define how decon technologies can meet clean-up needs
- Technology must:
  - Technology must fit into urban dirty bomb clean-up operational environment, procedures, requirements
  - Be selected for a specific task in a specific environment
  - Be part of the whole clean up plan, acceptable to regulators and the public
  - Meet clean-up criteria
  - Minimize waste
  - Prove speedy and cost-effective
  - Be demonstrated in the field
- (No silver bullets, but a number of promising directions)

Current NHSRC Initiatives

- Literature search and technology Dbase *FY05-*
- RDD Rapid Decon – identify and test promising technologies on cont'd urban substrate *FY06-10*
- RDD water/wastewater impacts analysis *FY04-06*
- RDD Waste Estimator (TSWG) *FY06-07*
- RDD particle-surface chemistry analysis *FY06-09*
- RDD infiltration characterization *FY06-08*
- Alpha/Beta detector for in-line water monitoring (TSWG) *FY05-07*

Potential Technology Initiatives

- Other potential RDD projects include:
  - Characterize RDD urban deposition
  - Develop technologies for rapid 3D characterization of urban contamination
  - Adapt existing technologies that are scalable to meet unique dirty bomb environment – high heights, automated, efficient waste management
  - Develop technologies to decon underground pipes, subsurface areas
  - Develop and/or test technologies for large volume water capture and treatment
  - Develop software tools to estimate RDD clean-up costs
  - Develop and test indoor decon techniques (for very low level contamination)
  - Develop guidance for indoor/outdoor decon approaches

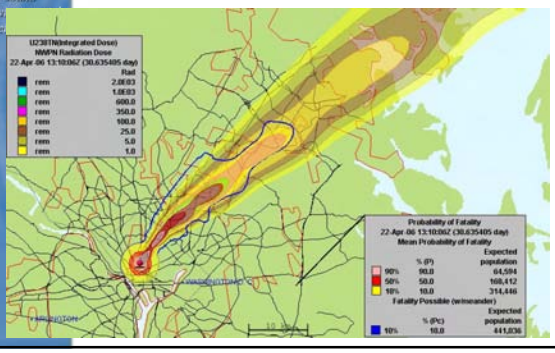
Longer Term Goal

- Summer 2010?; Hold a large-scale, live-agent dirty bomb technology T&E
- Potential goals; test, evaluate, validate –
  - Dirty bomb particle formation, urban dispersion modeling, deposition
  - Efficacy of selected decon technologies on common urban substrates (concrete, brick, marble, asphalt, ...) in a large scale, outdoor environment
- Possible location; Nevada Test Site
- Partners; EPA/OSWER, DHS/S&T, HSARPA, National Labs

Nuclear Weapon R&D

- *You thought RDDs were bad?*
- Historically, nukes not an EPA issue
  - But, it is under the NRP, Nuc/Rad Annex
- Held a 1-day EPA-only introductory nuclear weapons workshop, May '05
  - Basics - science, health, protection
  - Basic nuke design and physics (U)
  - Nuclear weapons effects
  - Recovery role and needs
- Discussed EPA's role/responsibility, clean-up gaps/needs, potential for R&D

50 Kt, Washington, DC



Nuclear Weapon R&D

- Basic R&D Needs
  - Effects on a modern urban environment (DHS)
  - Nature of fallout from an urban det.
    - Physical/chemical characteristics of fallout particles
      - various sources, zones of the torus
    - Radionuclide partitioning in particles
    - Urban deposition
  - Decontamination, mitigation, control, remediation technology R&D

Summary

- Focus on large urban RDD
  - The 80% solution
- RDD Workshop helped define the operational environment for RDD clean up and guide technology R&D investment
- Several initiatives underway
- Nuke clean up R&D a *major* challenge

Decontamination Technologies for Urban RDD Recovery

John Drake
NHSRC/DCMD

28 April 2006

If an RDD event occurred today, how would we recover?

What cleanup tools do we have?

Primer on Rad Contamination

- **RDD contamination is most likely particulates dispersed as aerosol**
- **Must be removed - cannot be neutralized**
- **"Loose" (smearable) - wiped, vacuumed, scrubbed, washed**
- **"Fixed" – chemically extracted** *(chelation, solvents, gels)* **or mechanically removed** *(scabbling, grit blasting, grinding)*
- **Worst case is demolition**
- **Disposed as rad waste**

Decon or Demolish No Other Choices

- Choose Decon?
  - Time consuming
  - Costly
  - Scope/size (e.g. multi-story)
  - Multiple technologies needed
  - Cracks, crevices, nooks, crannies
- Decon Waste Disposition
  - Primary - small volume compared to demolition waste (e.g. rinsate)
  - Secondary (e.g. grit, chemical methods)
  - Disposal sites
  - Transport

Decon or Demolish No Other Choices

- Choose Demolish?
  - Economic decision
  - Political decision
  - Historic significance
- Dust/debris management
- Demolition Waste
  - Large volumes
  - Disposal site
  - Transport
- Demo not the best answer for most situations

Decon Challenges Drive Technology Selection

- **No "Silver Bullet" -** Myriad technologies exist – toolbox approach
- **Timing** - Decon is more difficult as time passes
  - Absorbed into substrate
  - Increased footprint (spread by response activities, traffic, weather, resuspension)
- **Substrates**
  - Multiplicity of materials/properties
  - Cracks/crevices
  - Surface condition (deposits/pollutants, weathering, etc)
- **Geometry** of buildings
  - Access (multistory, alley size, etc)
  - Ornate architecture, nooks and crannies
- **End state** issues (significance, cost/benefit, etc)
- Other Issues

Decon Technologies Developed for Nuclear Industries

- Mechanical
  - Water Washdown
  - Wiping
  - Vacuuming (wet/dry/steam)
  - Abrasion (grinding, brushing)
  - Abrasive Blasting
  - Scabbling/Scarifying
- High-Tech
  - Microwave Ablation
  - Laser Ablation
  - Electro-Kinetic
  - Bacteria
- Chemical
  - Chelation
  - Solvent Extraction
  - Acid
  - Alkali
  - Oxidation-Reduction
  - Capture chemicals
    - Foams/gels
    - Strippable coatings

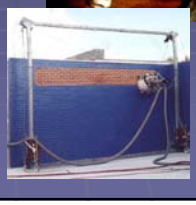
Water Washdown? Opinions Differ

- Pros:
  - Cheap and fast
  - Knocks down removable
  - Simple equipment/skills required
  - "Dilution is the solution"
- Cons:
  - Increases mobility of contaminants
  - Increases footprint (wastewater treatment systems, stormwater systems, streets, reservoirs, etc)
  - Produces huge "secondary waste"
  - Does not remove fixed contamination
  - Exacerbates fixed contamination problem

Mechanical Methods

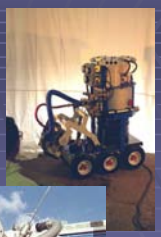
Characteristics

- Destructive to some degree
- All dry mechanical methods produce dust
- Many produce secondary waste (especially wet methods)
- Vacuuming assist required
- All are slow (ft^2/hr)
- Mostly "low-tech"
- Difficult to automate
- Effective on "smooth" surfaces
- Ineffective on crevices
- Sooner is better



Mechanical: Abrasive Methods

- Grinding
  - Minimal destruction
  - Mostly for smooth surfaces
- Scarifying
  - More destructive (fraction of inch removed)
  - Needle guns
- Scabbling
  - Most destructive (inches of substrate removed)
  - Carbide blades



Mechanical: Abrasive Methods

- Hard Media Blast
  - Grit blast (wet/dry)
- Soft media blast (e.g. sponge)
  - Captures contamination
  - Reusable media
- High Pressure Water blast
  - Effluent recovery
- CO_2 (dry ice blast)
  - No secondary waste

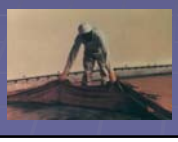
Mechanical: Vacuum Methods

- Dry vacuum
  - Loose material only
- Wet vacuum
  - May include detergent
- Steam vacuum
  - Combines steam jet
  - May include solvent
  - Mixed waste?
- All utilize HEPA filters
- May be brush or air blast assisted
- Adapt from commercial

Potentially adaptable commercial equipment

Chemical Methods

- Various methods
  - Chelation
  - Solvent Extraction
  - Acid
  - Alkali
  - Oxidation-Reduction
  - Capture chemicals
    - Foams/gels
    - Strippable coatings



Chemical Methods

- Chelation
  - Vendor proprietary
  - EDTA (TSWG developed)
  - Non-destructive
  - Mixed waste?
- Solvent extraction
  - Multi-step process
  - Some success with porous surfaces
- Acids/Alkali
  - Minimally destructive
  - Mixed waste
  - Need to neutralize wastes
- Oxidation-Reduction techniques
  - Best on metal surfaces
- These are mostly slow, labor intensive

Chemical Methods: Foams/Gels

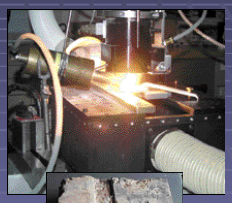
- Foams/Gels
  - Vendor proprietary
  - Non-destructive
  - Requires rinse and/or recovery (e.g. vacuum)
  - Possible mixed waste?
  - Some success with porous surfaces
  - Relatively fast to apply to large surfaces
  - Relatively easy to apply

Chemical Methods: Strippable Coatings

- Strippable coatings
  - Vendor proprietary
  - Non-destructive
  - Some with extractant
  - Require recovery (labor intensive)
  - Possible mixed waste?
  - Limited success with porous surfaces
  - Relatively fast to apply to large surfaces
  - Provide initial lockdown
  - Some inhibit re-suspension

Other Methods
(High-Tech)

- Microwave Ablation
  - Exfoliates concrete
- Laser Ablation
  - Thermal vaporization
  - ANL
- Electro-Kinetic
  - Electrical field induces migration of ions
- Bacteria
  - "Eats" concrete surface
- Not yet commercialized, no near term RDD applications



So what is NHSRC doing?

- Information Collection
- Technology Demonstration (existing methods)
- Technology Fostering (development)
- Collaboration/Communication

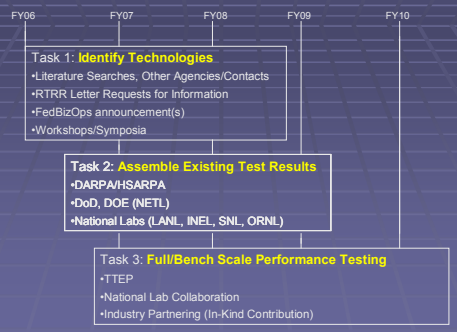
Information Collection

- Technology Survey is underway, including
  - Tech libraries
  - Internet
  - User stakeholders (NDT, first responders, OSC's)
  - Vendors
- Sources Sought Notice – FedBizOps (published Jan 06)
- Response Technologies Ready Reference (RTRR) current info gathering project with website for users
- Providing input to NDT's "Decon Portfolio"
- Near future: RFI & RFP for bench and full scale demonstration of promising technologies (FY06-10)

Technology Demonstration

- Rapid Decon 2006-2010 (next slide)
- Collaboration with other Agencies underway
  - DARPA
  - DHS/HSARPA
  - DOE
  - Natl Labs (Argonne, Sandia, Los Alamos, INL, ORNL)
  - TSWG
- EPA Technology Testing & Evaluation Program (TTEP) existing chem/bio program will be expanded to support radiological
- EPA in-house

RDD Rapid Decon Project 2006-2010



Technology Fostering

NHSRC radiological projects ongoing and/or planned

- RDD Waste Estimator (with TSWG) *FY06-07*
- RDD Surface Chemical Interaction *FY06-08*
- Alpha/Beta Detector for In-line Water Monitoring (TSWG) *FY05-07*
- RDD Infiltration Characterization *FY07-08*
- Nuclear Fallout Characterization (DHS,DTRA) *FY07-09*
- Water/Wastewater System Capture/Decon (TSWG) *FY07-08*

Collaboration/Communication

- Decon Workshops (2005, 2006)
- RDD Workshop (2005)
- Nuclear Consequence Management Workshops (2005, 2007)
- EPA (NHSRC/WIPD, ORIA, OW, NDT)
- Other Agency contacts
- FedBizOps (Sources Sought, RFP for tech demo)
- Participation on other agency stakeholder groups

Summary
NHSRC Technology Program

- **Commercial decon technologies exist – none universal – few ready for urban deployment**
- **EPA/NHSRC pursuing low-tech, "tool box" approach**
- **R&D aimed at near-term deployable technologies**
- **Pursuing collaboration with other stakeholders**

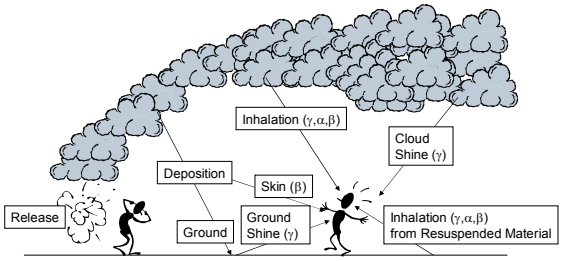
Summary
Factors Affecting Technology Choice

- **Many substrates** *(differing properties affect decon performance)*
- **Many radionuclides** *(most likely ^{137}Cs)*
- **Geometry** *(size, shape, cracks/crevices)*
- **Access** *(multi-story, tight spaces, other recovery activities)*
- **Speed**
- **Cost**
- **End state required** *(difficult decision, cost-benefit, other factors)*

RDD aerosolization experiments History/Applications/Results

Fred Harper
Sandia National Laboratories

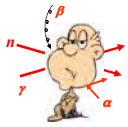
Major pathways from release



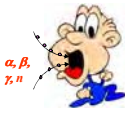
Background

Types of Radiation and Exposures

- **Alpha (*α*) radiation**
  - External: no skin penetration, no health risk
  - Internal: damage soft tissue, health risk
  - Examples: Pu-238, Am-241
- **Beta (*β*) radiation**
  - External: some penetration, skin burns
  - Internal: damage soft tissue, health risk
  - Examples (pure *β*-emitter): Sr-90
- **Gamma (*γ*) radiation**
  - Highly penetrating
  - External and internal health risk
  - Examples (β and γ) : Cs-137, Co-60, Ir-192
- **Neutron (*n*) radiation**
  - Highly penetrating
  - External and internal health risk
  - Cf-252, Am-241/Be (small sources)



External



Internal

Background

Background

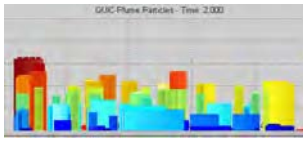
Some basic concepts

- Small particles (< 10 μm) -- primarily an inhalation problem, but can also be a shine problem
- Large particles (> 100 μm – primarily a shine problem)
- To be an inhalation problem, particles must be in the vicinity of people

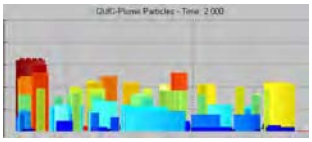
Particle Size Effect
From Mike Brown (LANL)

Transport & Dispersion

5 micron particles



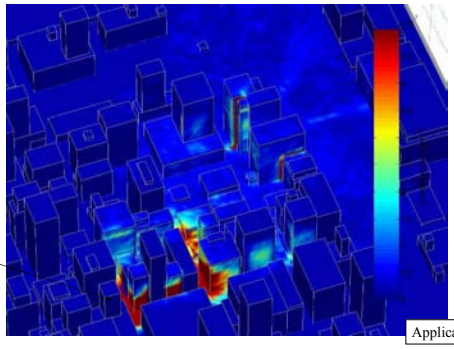
250 micron particles



Applications

5 micron particles lofted high into the air, 250 micron particles settle towards ground

Deposition Patterns on buildings (calculations using QUIC, Mike Brown, LANL)



Applications

Background

Goiania Brazil 1987: RDD Lessons

Source
~ 2.5 cm dia.
~ 1400 Ci, Cs-137
CsCl salt (powder)

- ~ 60 gm of Cs-137 (1400 Ci) generated 40 tons of radwaste for disposal
- Main Cleanup effort: 755 persons x 3 months = 68,000 person-days
- Cleanup threshold: ~ 10 Ci/km^2 (ground contamination)
- Significant psychological effects on the immediate population
- 4 deaths

Background

More Basic Concepts

- Alpha emitters much more of a problem if inhaled
- Most of the alpha emitting radiological sources are in ceramic form (low solubility – pneumonitis if inhaled)
- Most of the large Sr sources are in the ceramic form (low solubility – pneumonitis if inhaled)
- Most of the large Cs sources are in the salt form (high solubility – haematopoietic syndrome if inhaled)
- Most of the large Co sources are in the metal form

More than 500 RDD aerosolization tests have been performed at SNL in the last 20 years

Have semi-empirical models for metals in different geometries, liquids, salts ceramic powders, and preliminary models for ceramics ceramics

Past funding organizations
DOE NEST program
DOD DTRA
DOE international programs
Intel community
NRC
CDC

Material	Physical Form	Device Strategies Tested
Ag	Metal	17
Al	Metal	5
Bi	Metal	3
Co	Metal	1
Cu	Metal	2
Mo	Metal	1
Pb	Metal	1
Ir	Metal	3
Stainless Steel	Metal	2
Ta	Metal	1
U	Metal	1
CeO_2	Ceramic (2 densities for each device)	7
$SrTiO_3$	Ceramic (3 densities for each device)	8
Tb/Pd	Cermet	1
Co	Liquid	2
CsCl	Liquid (several different relative humidity and temperature	6
$BaSO_4$	Slurry	1
CeO_2	Ceramic powder	7
MnO_2	Ceramic powder	4
UO_2	Ceramic powder	1
CeO_2	Pressed powder	3
CsCl	Powdered salt	7
$BaSO_4$	Powdered salt	2

Summary of Sensitivity Studies Performed

Nuclide	Primary Radiation Type (half-life)	Primary Form	Size of Source for Calculation, in GBq (Ci)	Application that Forms the Basis for Size of Source
Sr-90	Beta (28.6 y)	Ceramic ($SrTiO_3$)	1.11 x 10^7 GBq (300,000 Ci)	Large radioisotopic thermal generator (RTG) (Russian IEhU-1)
Cs-137	Beta + Ba-137m Gamma (30.17 y)	Salt (CsCl)	7.4 x 10^6 GBq (200,000 Ci)	Irradiator
Co-60	Beta, Gamma (5.27 y)	Metal	1.11 x 10^7 GBq (300,000 Ci)	Irradiator
Pu-238	Alpha (87.75 y)	Ceramic (PuO_2)	4.92 x 10^6 GBq (133,000 Ci)	RTG used for the Cassini Saturn space probe
Am-241	Alpha (432.2 y)	Pressed ceramic powder (AmO_2)	7.4 x 10^2 GBq (20 Ci)	Single well-logging source
Cf-252	Alpha (2.64 y)	Ceramic (Cf_2O_3)	7.4 x 10^2 GBq (20 Ci)	Several neutron radiography or well-logging sources
Ir-192	Beta, Gamma (74.02 d)	Metal	3.7 x 10^4 GBq (1000 Ci)	Multiple industrial radiography units
Ra-226	Alpha (1600 y)	Salt ($RaSO_4$)	3.7 x 10^3 GBq (100 Ci)	Old medical therapy sources

Applications

Realistic RDD Hazard Boundaries for Varying Device Designs (Areas of highest concern for early response)

		Int. Size Source, Basic Eng'g	Very Large Source, Basic Eng'g	Very Large Source, Soph. Eng'g
Groundshine dose of 100 rad, 24-hour exposure assumed	Acute groundshine threshold	0	~ 300 m	~ 300 m
Inhalation dose of 100 rad to the bone marrow (30-day committed dose)	Acute haematopoietic syndrome threshold	0	0	~ 200 m
Inhalation dose of 270 rad to the lung (30-day committed dose)	Acute pneumonitis threshold	0	0	~ 2 km
Lifetime inhalation dose of 100 rem (50-year committed dose)	Chronic radiation sickness threshold	0	0	~ 7 km
5 rem groundshine dose (5-hour exposure assumed)	Workers can work unrestricted for 5 hours	~ 100 m	~ 600 m	~ 600 m
10 * ALI for inhalation	Use of Prussian Blue DTPA highly recommended	0	0	< 10 km

Applications

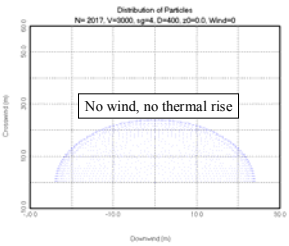
Realistic RDD Hazard Boundaries for Varying Device Designs (Areas of concern for intermediate response)

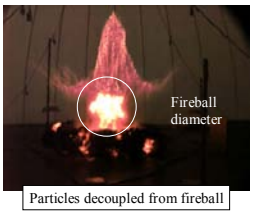
		Int. Size Source, Basic Eng'g	Very Large Source, Basic Eng'g	Very Large Source, Soph. Eng'g
50 rem (50-year committed dose)	Evacuation	< 150 m	< 1 km	~15 km
5 rem (50-year committed dose)	Sheltering	< 600 m	< 3.3 km	< 100 km
1 rem (50-year committed dose)	EPA suggests protective actions initiated	2 km	~10 km	> 100 km
2 rem in one year – derived deposition limit	EPA prescribes relocation	8 km	~ 100 km	> 100 km

Note: Scenario analysis performed with ERAD model which includes buoyant rise, small and large aerosol transport, but is not building aware

Applications

Distribution of CsCl large powder scattered ballistically



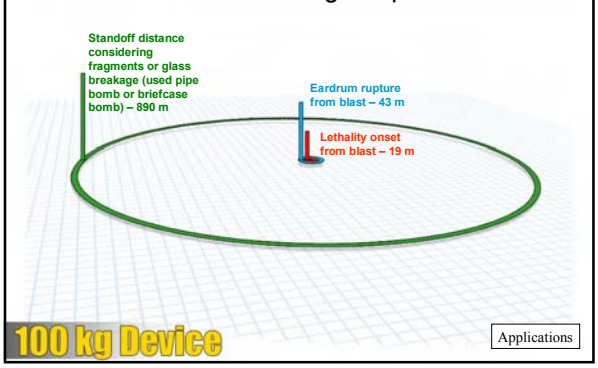


Particles decoupled from fireball

Particle size (µm aerodynamic)	100
Initial measured velocity (m/s)	≈ 550
Extrapolated stopping distance (m)	4.3
Observed stopping distance (m) [particles did not hit ceiling]	7.62
Single particle stopping distance in still air (m)	0.75

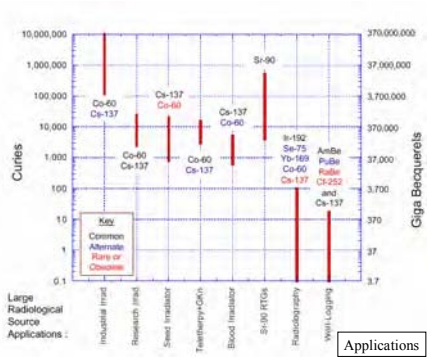
UCNI

Range of Blast Effects from Selected Quantities of High Explosive



Applications

Large Radiological Source Applications (from G. Van Tuyle, LANL)



Applications

Results of study dominated by large source scenarios

Self-Contained Cs-137 Blood Irradiators

Machine

Canister

Sealed Source

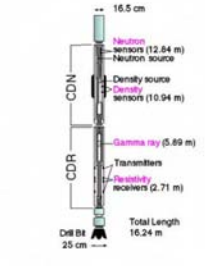
- Used to reduce risk of Graft-Versus-Host Disease (GVHD)
- Source: Cs-137, 500 to 5000 Ci
- Number in US: ~ 1000, ~ 20 in NY, ~10 NYC
- Machine weight: 1150 kg

Radiological Sources

Small/Medium Radiological Sources

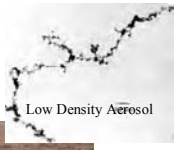
1 μCi Smoke Detector

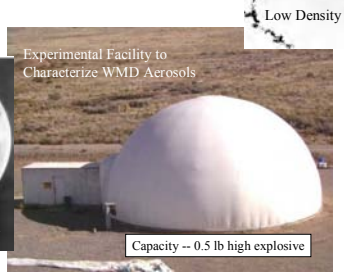
15 – 20 Ci Well Logging Sonde



Radiological Sources

Quantity, Size, and Shape of Particulate Released is Critical to WMD Consequences





1000 m^3 explosive aerosolization chamber

50 m^3 full sample recovery explosive aerosolization chamber

Capacity -- 0.125 lb high explosive

Characterization of aerosolization efficiency and particle size distribution

Hanging cascade impactors and total mass samplers (< 30 μm AED)

Cyclone separators (> 30 μm and < 100 μm)

Witness wires, plates, and papers

Aerosolization Experiments

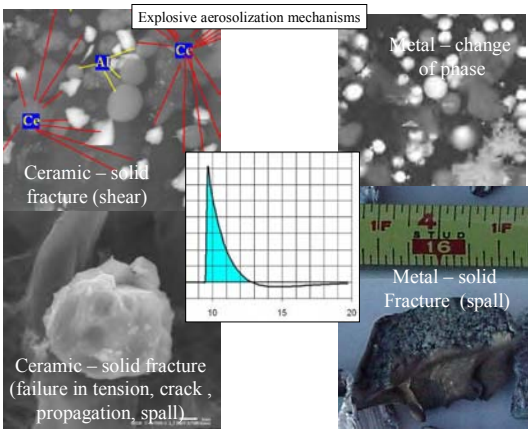
And other strategies…

What is important to aerosolization potential

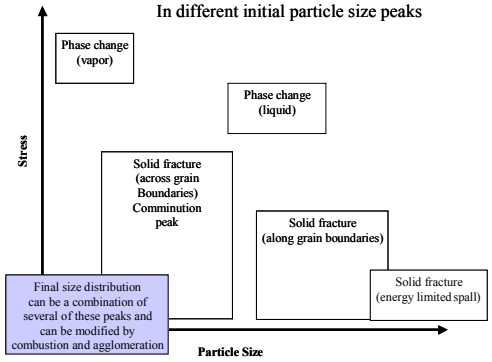
- Device design
- Material form
  - Metal
  - Ceramic
  - Liquid
  - Powder
- Material properties
  - Thermal properties
  - Shock physics properties
  - Vapor pressure, surface tension, viscosity, etc.

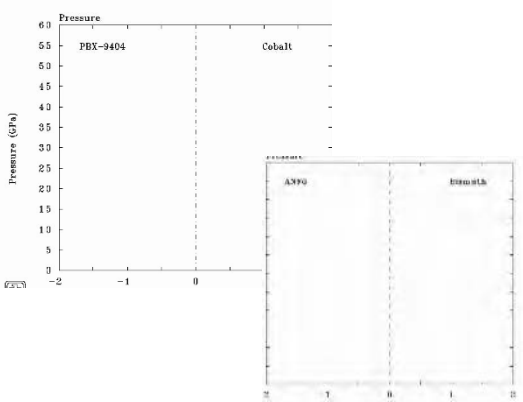
Aerosolization

Explosive aerosolization mechanisms



Stress induces different mechanisms which results
In different initial particle size peaks



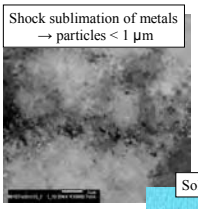


Some explosive values of interest to explosive RDDs

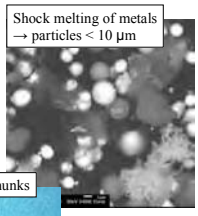
	CsCl	$SrTiO_3$	Co metal	Bi metal	U metal
Pressure required to melt (GPa)	13.1	83	208	20	96
Pressure required to sublimate (GPa)			571	81	445
Interface pressure (PBX 9404) (GPa)	41.6	56	62	53	69
Interface pressure (TNT) (GPa)	25.4	34	37	32	40
Interface pressure (C4) (GPa)	33.0	44	48	41	53
Interface pressure (ANFO 100 % reacted) (GPa)	13.2	17	18	15	18
Interface pressure (ANFO 75 % reacted) (GPa)	7.4				
Interface pressure (ANFO 50 % reacted) (GPa)	4.7				

Phenomena: Explosive aerosolization of metals

Shock sublimation of metals
→ particles < 1 μm



Shock melting of metals
→ particles < 10 μm



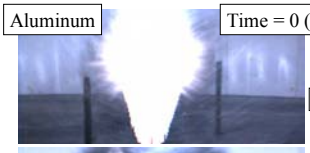
Solid fracture → chunks

- Fractions depend on material properties and device geometries
- Respirable aerosol ranged from .2 % to 80 %
- Very little aerosol generated between 30 μm and 200 μm

1000 Ci (20 g) Co pellet

Aluminum

Time = 0 (± .002 s)



Post on left is 131 cm from detonation

Time = .002 (± .002 s)

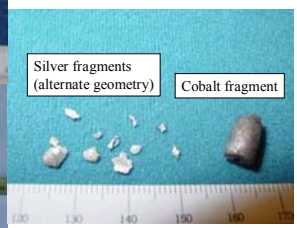
Time = .004 (± .002 s)

Form of metal chunks dispersed depends on material properties and device geometry

Silver fragment

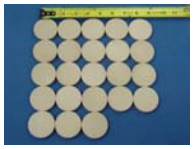
Silver fragments
(alternate geometry)

Cobalt fragment



Aluminum fragments

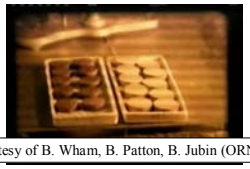
Aerosolization of ceramics



Sintered $SrTiO_3$ pellets used in SNL and DF shots

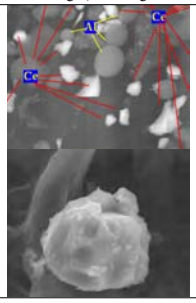
Phenomena: Explosive aerosolization of ceramics

- Fractions depend on material properties and device geometries
- Respirable aerosol ranged from 2 % to 40 %
- No phase change
- A lot of aerosol generated between 30 µm and 200 µm



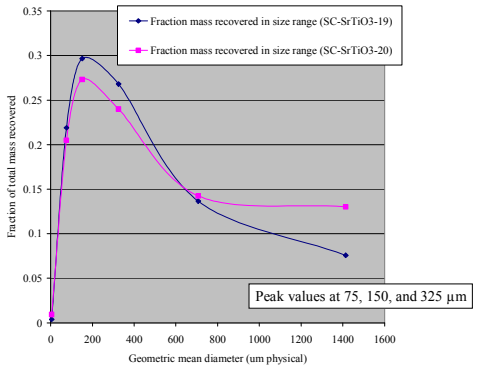
Courtesy of B. Wham, B. Patton, B. Jubin (ORNL)

CeO_2 fluorite crystal structure – octahedral cleavage (flat triangular wedges)



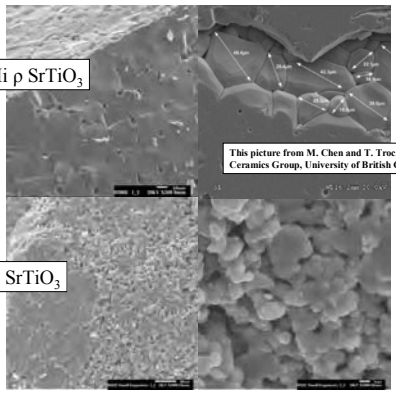
$SrTiO_3$ – perovskite crystal structure – no cleavage planes (dimpled spall surface)

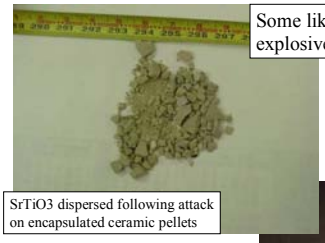
Large Particle distribution from SC-$SrTiO_3$ 19 and 20



Peak values at 75, 150, and 325 µm

Images of the fracture surface of high and low density $SrTiO_3$





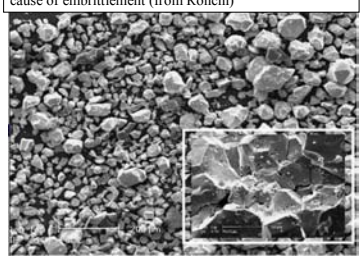
Some likely physical forms following explosive dispersal of ceramics

SrTiO3 dispersed following attack on encapsulated ceramic pellets

Pile of $SrTiO_3$ powder dispersed following inefficient explosive aerosolization device

Examples of impact of radiation aging on ceramics

Disintegration of a PuO_2 pellet over 40 years stored under a Nitrogen environment (He accumulation is the likely cause of embrittlement (from Ronchi)



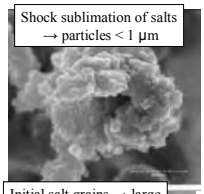
PuO_2 Impact test resulted in 10 % respirable fraction

Internal sputtering results in spontaneous translocation if $^{238}PuO_2$ particles with two size peaks: < 1 nm and ≤ 10 nm (from Cheng et. al, LRRI)

Four $SrTiO_3$ capsules opened after 5.5 yr:
* 6 of 9 hi density pellets broke, 2 of 15 lo density pellets broke
* 4 g loose powder, 1124 g sintered material
(from Shor et. al., ORNL)

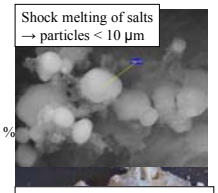
Phenomena: Explosive aerosolization of powders

Shock sublimation of salts → particles < 1 µm

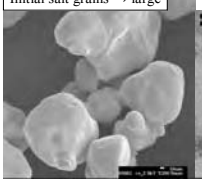


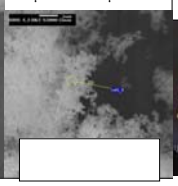
- Fractions depend on material properties and device geometries
- Respirable aerosol ranged from 20 % to 80 %
- Very little aerosol generated between 30 µm and 200 µm

Shock melting of salts → particles < 10 µm



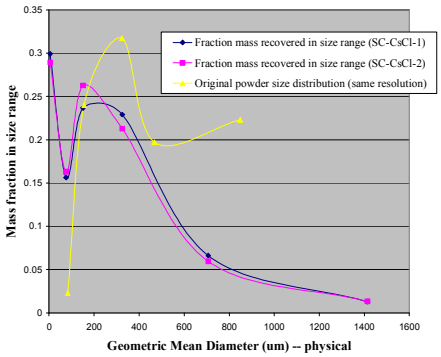
Initial salt grains → large

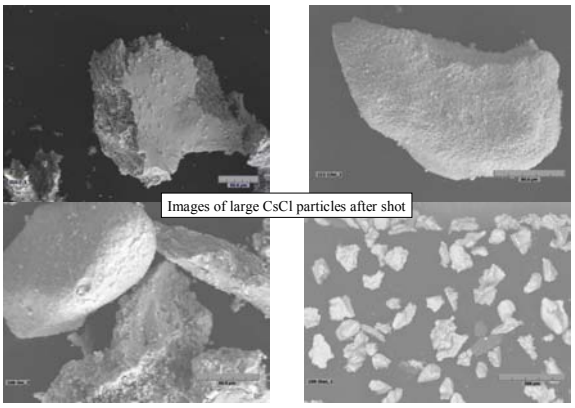




Shock sintered ceramic powder

Comparison of size distribution from sampling and sieving of SC-CsCl-1 to original CsCl powder size

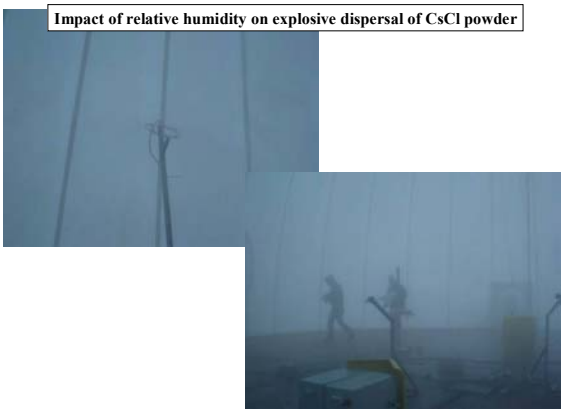


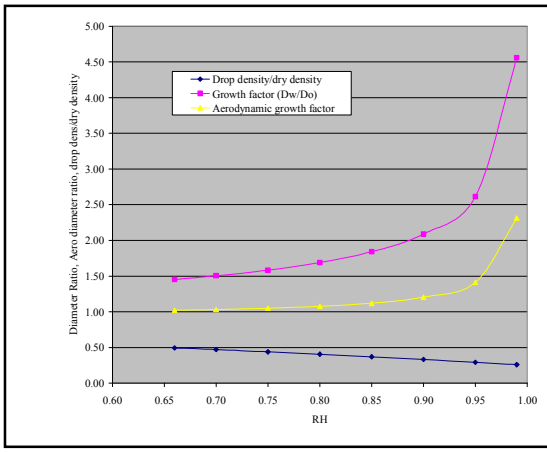


Images of large CsCl particles after shot

Note evidence of plastic deformation and evidence of bimodal size distribution

Impact of relative humidity on explosive dispersal of CsCl powder



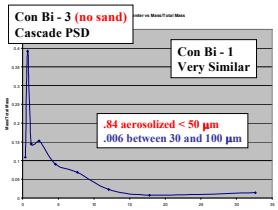


Insights from encapsulation studies

- **Encapsulation worth > factor of 10 if change of phase required for aerosolization**
- **No reduction in aerosolization if small powder is encapsulated**

Agglomeration/condensation studies

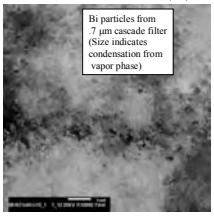
Con Bi - 3 (no sand)
Cascade PSD



Con Bi - 1
Very Similar

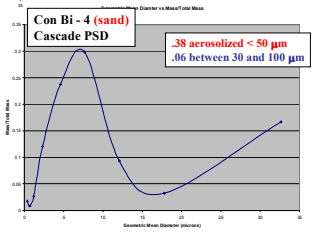
.84 aerosolized < 50 µm
.006 between 30 and 100 µm

Observations:
a) Bi implosion resulted in Bi vapor
b) Hi concentration of vapor within fireball stagnation radius resulted in condensation and agglomeration to .7 µm (aerodynamic)
c) Agglomeration on sand reduced atmospheric Bi loading and modified particle size distribution

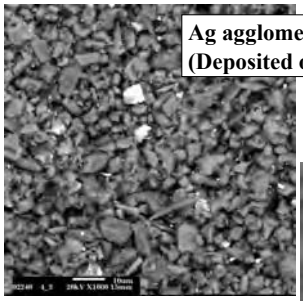


Bi particles from .7 µm cascade filter (Size indicates condensation from vapor phase)

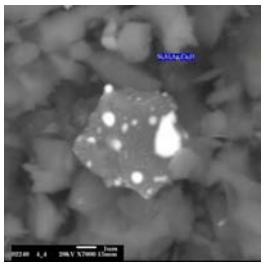
Con Bi - 4 (sand)
Cascade PSD



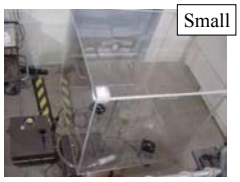
.38 aerosolized < 50 µm
.06 between 30 and 100 µm



Ag agglomerated on sand
(Deposited on stage 4 -- GMD 8 µm)



A variety of chambers available to characterize non-explosive aerosol behavior for model validation and development



Small

Medium

Large

Water Distribution System Decontamination

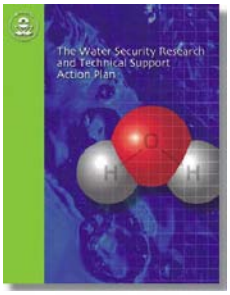
Paul M. Randall
U.S. EPA

E. Radha Krishnan, P.E.
Shaw Environmental

Haishan (Helen) Piao, Ph.D.
SBR Technology Inc

presented at
2006 Workshop on Decontamination, Cleanup, and Associated Issues for Sites Contaminated with Chemical, Biological, or Radiological Materials
Washington DC
April 28, 2006

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

Drinking Water System Protection and Security

Research and Technical Support Needs

- Physical and cyber threats
- Threats, contaminants, and threat scenarios
- Improving analytical methods and monitoring systems
- Containing, treating, decontaminating, and disposing of contaminated materials
- Contingencies and infrastructure dependencies
- Impacts on human health
- Informing the public about risks

Project Objectives

- Contamination
  - Adherence to pipe surface
  - Effect of pipe materials
  - Effect of flow regimes (laminar, turbulent)
  - Biofilm effect
- Decontamination
  - Decon methods specific to contaminant
  - Decon conditions (pH, flow rate, Cl_2 conc., etc)
  - Effect of pipe materials on decon technique

Experiments Conducted to Date Adherence Study

- Contaminant adherence study
  - *Contaminants: Arsenic, Mercury, and Bacillus Subtilis*
  - *Contaminant concentration:*
    - *Arsenic/Mercury: 10 mg/L*
    - *Bacillus Subtilis: 10^3 cells/mL*
  - *Flow rates: 1, 15, 60 GPM*
  - *Pipe materials: 5-year old Cement-lined ductile iron, Clear PVC*

Experiments Conducted to Date: Decontamination Study

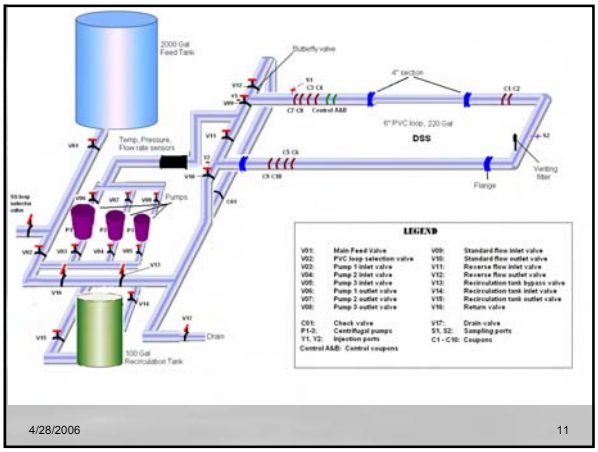
- General Decontamination Study
  - Simple flushing for arsenic, mercury, and *Bacillus Subtilis*
  - Low pH flushing for arsenic and mercury
- Contaminant: Arsenic (sodium arsenite)
  - Phosphate buffer flushing
  - Acidified potassium permanganate flushing
- Contaminant: Mercury (mercuric chloride)
  - Acidified potassium permanganate flushing
- Contaminant: *Bacillus Subtilis*
  - Shock chlorination

Pilot-Scale Drinking Water Distribution System Simulator (DSS)

- 75 feet 6” diameter PVC pipe (includes one 4” diameter section, 10 feet long)
- 220 Gal capacity
- Recirculation tank, 100 Gal capacity
- Operable at 0-500 GPM
- 25,000 in^2 surface area

Used Pipe Integration into DSS

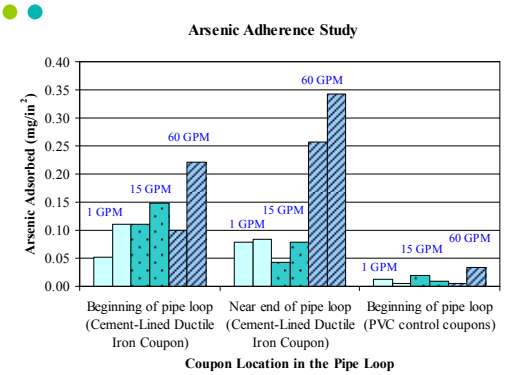
- Used pipe sections from the T & E pipe loop system
  - Cement lined ductile iron
  - In service for ~5 years
- Cut sections of used pipe & make 1”-long coupons
- Integrate coupons into PVC DSS



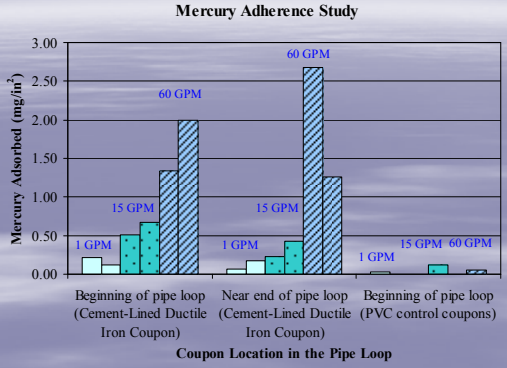
Contaminant Adherence Study Experimental Design

- Coupon insertion
- Build biofilm in pipe loop system for 1-2 weeks (quantify via HPC assay)
- Inject contaminants into pipe loop
- Recirculation flow mode: Laminar/Turbulent
- 2 days contact time (Sample bulk water/collect sensor data)
- Sample coupon walls

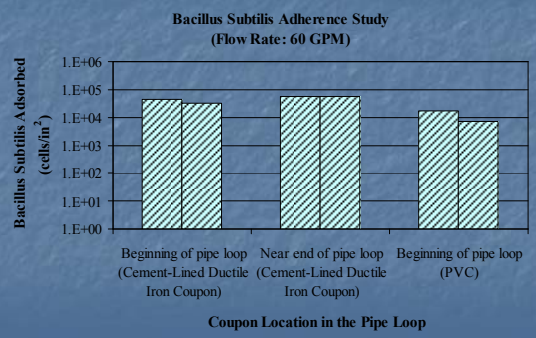
Arsenic Adherence Study Results



Mercury Adherence Study Results



Bacillus Subtilis Adherence Study Results



Lessons Learned: Adherence Study Summary

- Arsenic and mercury adhere to the cement-lined ductile iron pipe surfaces at both flow regimes, laminar and turbulent.
- The adherence of arsenic and mercury to pipe surfaces is higher under turbulent flow conditions.
- Arsenic and mercury showed stronger adherence to cement-lined ductile iron pipe surfaces as compared to the clear PVC pipe surfaces.
- Mercury has stronger adherence to cement-lined ductile iron pipe surfaces compared to arsenic.
- *Bacillus Subtilis* showed similar strong adherence to both the cement-lined ductile iron and clear PVC pipe surfaces.

Decontamination Study – Simple Flushing

- Velocity: 2.5 fps
- Flow Rate: 210 gpm
- Time: 2-hour flushing
- Flow Mode: Recirculation

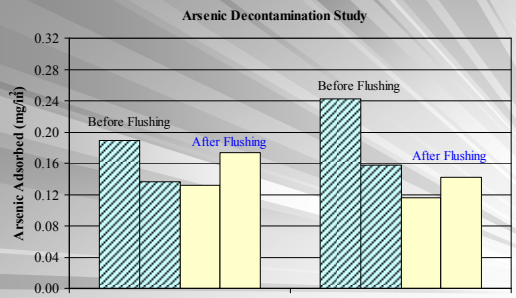
Lessons Learned: Simple Flushing Decontamination Technique Summary

- Simple flushing could remove up to 51% of adsorbed arsenic from the cement-lined ductile iron pipe surfaces.
- Up to 57% of adsorbed mercury could be removed from the cement-lined ductile iron pipe surfaces by using simple flushing.
- Simple flushing resulted in no removal of *Bacillus Subtilis.*
- Further evaluations on more rigorous decontamination techniques are necessary to determine if higher removal efficiencies can be achieved.

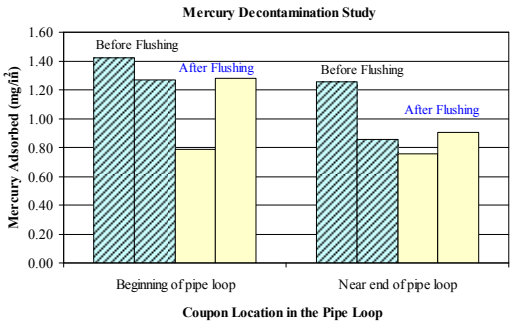
Decontamination Study – Low pH Flushing

- Acid: Hydrochloric acid
- pH: ~ 4
- Velocity: 0.7 fps
- Flow rate: 60 gpm
- Time: 4-hour
- Flow Mode: Recirculation

Low pH Flushing Results for Cement-Lined Ductile Iron: Arsenic



Low pH Flushing Results for Cement-Lined Ductile Iron: Mercury



Efficiency of Low pH Flushing for Cement-Lined Ductile Iron: Arsenic

Coupon Location	Beginning of pipe loop		Near End of pipe loop	
Coupon ID	C3	C4	C5	C6
Arsenic adsorbed (mg/coupon)	3.6	2.6	4.6	3
Average (mg/coupon)	3.1		3.8	
Coupon ID	C7	C8	C9	C10
Arsenic remaining (mg/coupon)	2.5	3.3	2.2	2.7
Average (mg/coupon)	2.9		2.5	
Decon Efficiency (%)	6%		36%	

Efficiency of Low pH Flushing for Cement-Lined Ductile Iron: Mercury

Coupon Location	Beginning of pipe loop		Near End of pipe loop	
Coupon ID	C3	C4	C5	C6
Mercury adsorbed (mg/coupon)	27.0	24.1	23.9	16.3
Average (mg/coupon)	25.6		20.1	
Coupon ID	C7	C8	C9	C10
Mercury remaining (mg/coupon)	15.0	24.3	14.4	17.2
Average (mg/coupon)	19.7		15.8	
Decon Efficiency	23%		21%	

Lessons Learned: Low pH Flushing Decontamination Technique Summary

- Decontamination efficiency for arsenic and mercury from cement-lined ductile iron pipe surfaces is not improved by using low pH flushing as compared to simple flushing.
- Low pH flushing removed up to 36% and 23% of adsorbed arsenic and mercury from the cement-lined ductile iron pipe surfaces.

Experimental Design – Decontamination

- **Phosphate Buffer Flushing for Arsenic**
  - Decontamination Reagent:
    1 mM Phosphate buffer (K_2HPO_4:KH_2PO_4 1:1)
  - Velocity: 0.7 fps
  - Flow rate: 60 gpm
  - Time: 4-hour
  - Flow Mode: Recirculation

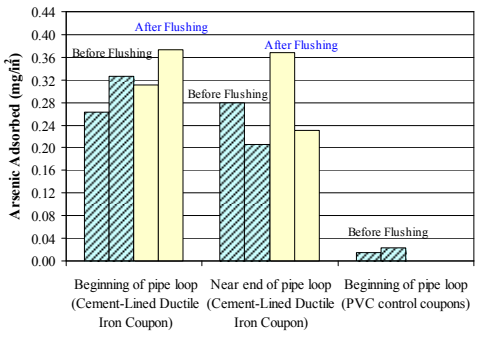
Experimental Design – Decontamination

- **Acidified Potassium Permanganate Flushing for Mercury/Arsenic**
  - Decontamination Reagents:
    - 0.4% Potassium permanganate
    - 1% Sulfuric acid
  - Velocity: 0.7 fps
  - Flow rate: 60 gpm
  - Time: 4-hour
  - Flow Mode: Recirculation

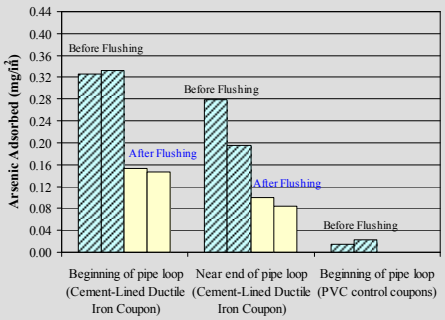
Experimental Design – Decontamination

- **Shock Chlorination for *Bacillus Subtilis***
  - Decontamination Reagent:
    200 ppm chlorine
  - Time: 2.5-hour
  - CT: 30,000 mg/L-min
  - Velocity: 0.7 fps
  - Flow rate: 60 gpm
  - Flow mode: Recirculation

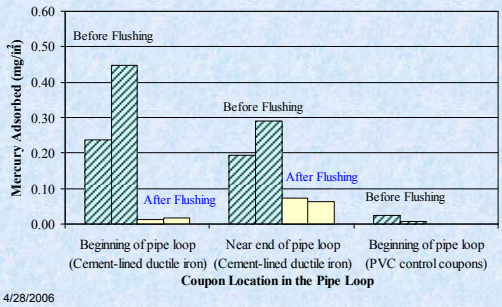
Phosphate Buffer Flushing Results for Arsenic



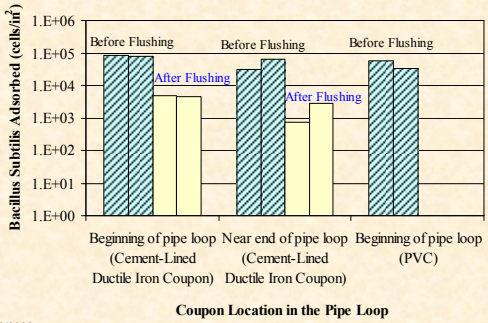
Acidified Potassium Permanganate Flushing Results for Arsenic



Acidified Potassium Permanganate Flushing Results for Mercury



Shock Chlorination Results for *Bacillus Subtilis*



Lessons Learned: Summary of Results

- **Arsenic**
  - **Phosphate buffer flushing resulted in no removal of arsenic.**
  - **Acidified potassium permanganate flushing is effective in partial decontamination of arsenic (up to 61%).**
- **Mercury**
  - **Acidified potassium permanganate flushing is very effective in decontamination of mercury (up to 96%).**
- ***Bacillus Subtilis***
  - **Shock chlorination is a very effective decontamination method for *B. Subtilis* (up to 96%).**

Conclusions

- **All contaminants tested, i.e. arsenic, mercury, and bacillus subtilis, showed strong adherence to cement-lined ductile iron pipe surfaces. Bacillus Subtilis also adheres to PVC pipe surfaces.**
- **Simple flushing or low pH flushing is effective in partial decontamination of cement-lined ductile iron pipe surfaces for arsenic and mercury. Simple flushing is ineffective for decontamination of bacillus subtilis from pipe surfaces.**
- **Phosphate buffer flushing resulted in no removal of arsenic.**
- **Acidified potassium permanganate flushing is effective in partial decontamination of arsenic (up to 61%) and is very effective in decontamination of mercury (up to 96%).**
- **Shock chlorination is a very effective decontamination method for B. Subtilis (up to 96%).**

Future Experiments

- Decontamination study for arsenic
  - NSF Standard 60 drinking water treatment chemicals
    - NW-310/NW-400 (Johnson Screens, Inc)
    - Floran Catalyst/Neo-Line (Floran Technologies, Inc)
  - Chelating agents (DMSA, EDTA)
- Diesel fuel adherence/decontamination study
- Evaluation of alternative pipe material
  - 70-80 years old, heavily tuberculated iron pipe

Questions ??? Comments ???

US Environmental Protection Agency
Decontamination Workshop
April 28, 2006

Decontamination of Water Infrastructure: AwwaRF Project 2981

presented by: Gregory Welter

O'BRIEN & GERE

Project Participants

- Frank Blaha - AwwaRF Project Manager
- O'Brien & Gere Engineers
  - Gregory Welter, PE DEE, Principal Investigator
  - George Rest, PE, Project Officer
- Consultants and Co-investigators
  - Dr. Joseph Cotruvo - consultant, (formerly w/ EPA Office of Drinking Water, and Office of Pollution Prevention and Toxics)
  - Dr. Mark LeChevallier - Director of Research, American Water
  - Richard Moser - consultant, (formerly Vice-President of Water Quality, American Water Works Service Company)
  - Stacey Spangler - Senior Analyst, American Water
- Principal funding by AwwaRF and American Water

Project Objectives and Activities

- Objective: To develop guidance for the decontamination of water system infrastructure following contamination with a persistent contaminant
- Project Activities
  - Literature reviews and case studies
  - Collaboration with parallel research studies (e.g., EPA-HSRC, Army-CERL, Army-ECBC, NIST)
  - Experiments on contaminant attachment and removal options

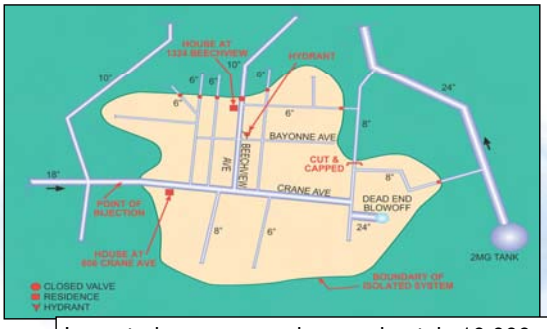
Relevant Historical Cases

- Use of system flushing in response to incidents involving pesticides, diesel fuel, mercury.
- Use of chemical cleaning systems to accelerate decontamination in incidents involving a pesticide and motor oil.

1980 Intentional Contamination Incident

- Intentional injection of chlordane into water distribution system
- Discovered on the basis of customer taste and odor complaints
- Initial response was to isolate the system and begin purging operations
- Initial sampling found concentrations up to 144,000 ppb.

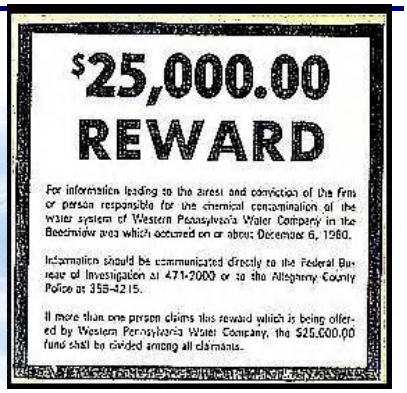
Impacted water distribution system area



Impacted area covered approximately 10,000 persons

Finding of Intentional Contamination

- **Determined point of injection at remote pipe pressure tap on 200 psi main**
- **Sample at injection tap of 0.27% chlordane.**
- **Notified FBI and local police**



$25,000.00
REWARD

For information leading to the arrest and conviction of the firm or person responsible for the chemical contamination of the water system of Western Pennsylvania Water Company in the Beechview area which occurred on or about December 6, 1980.

Information should be communicated directly to the Federal Bureau of Investigation at 471-2000 or to the Allegheny County Police at 355-4215.

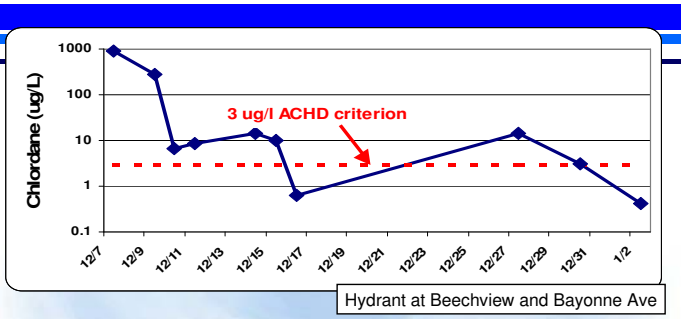
If more than one person claims this reward which is being offered by Western Pennsylvania Water Company, the $25,000.00 fund shall be divided among all claimants.

Goals set by Health Department

- 3 ppb in one month (the MCL)
- 1 ppb in two months
- 0.3 ppb in four months
- 0.05 ppb in seven months

Alternative water provided to customers during until remediation completed

System and household testing



Hydrant at Beechview and Bayonne Ave

- 0.05 ppb achieved in August 1981 (8 months)
- Testing continued into 1983

Project Experimental Strategy

- Phase 1 - Contaminant Adherence Testing
  - 1a: Establishment of experimental / analytical protocols, and critical test conditions (limited substrate set)
  - 1b: Testing of contaminant suite against full substrate list
- Phase 2 - Lab assessment of chemical decon agents

Experiments conducted at facilities of American Water

Review of Potential Contaminants

- significant potential for a decontamination problem
  - (tendency to adhere to wetted surfaces)
- likely candidate for use (or hoax) because of actual or perceived potential hazard
- contaminant was part of a documented actual attack or threatened use
  - (documented in AwwaRF #2810 - "Actual and Threatened Security Incidents at Water Utilities")

Tested Contaminants

- Microbiologicals (a bacterial spore and a virus)
- Inorganics
  - four toxics (an inorganic, an metalloid, and two metals)
  - three non-radioactive surrogates for radionuclides of concern
- Organics
  - A high Kow pesticide (log Kow = 6.2)
  - A low Kow industrial organic (log Kow = 3.4)

Not included in AwwaRF tests; coordinated with decon research projects by other agencies

- Biotoxins
- Chemical Warfare Agents

Tested Pipe Substrates

1. CPVC (control)
2. CPVC (w/ biofilm)
3. Iron (control)
4. Iron (w/biofilm)
5. Galvanized pipe (used and heavily tuberculated; w/ biofilm)
6. Galvanized (new)
7. Polyethylene
8. Cement lined ductile iron (w/o factory seal coat)
9. Cement lined ductile iron (w/ std factory seal coat)
10. Epoxy coated steel
11. Copper

Phase 1b Pipe Materials

Used Galvanized Pipe

- Used galvanized pipe tested as a surrogate for older unlined cast iron pipe. (Note heavy scale and tuberculation.)

Basic Experimental Protocol

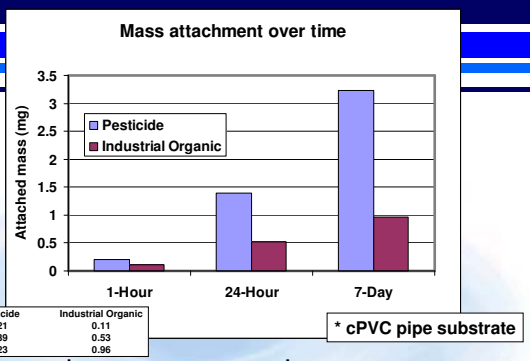
- 12-inch pipe segments filled w/ contaminant stock solutions, and incubated for 7 days
- Pipes decanted, and rinsed multiple times with base water (both decant and rinses analyzed)
- Final "getter" extractant step for pipe wall
  - 0.1 M ammonium chloride for inorganics
  - 50% / 100% methanol for organics
  - buffer water and test tube brushing for microbes

Attachment Phase Results

Contaminant	PIPE SUBSTRATE PERCENT ATTACHMENT (attachment calculated based on the mass of the washes and the getter) CPVC	CPVC w/ biofilm	iron	Iron / biofilm	Galvanized (new)	Galvanized (tuberculated)	Copper	Cement lined DIP	Cement lined DIP (sealcoat)	PE	Epoxy lined Steel
Toxic Inorganic #1	0.0	0.0	0.7	0.9	2.6	0.0	0.0	1.2	0.0	0.0	0.3
Toxic Inorganic #2	0.0	0.0	0.3	0.3	0.4	0.2	1.4	0.9	0.2	0.2	1.0
Radio surrogate #1	0.0	0.0	0.1	4.6	0.0	12.0	0.0	1.3	0.1	0.1	0.0
Radio surrogate #2	0.1	0.1	3.5	8.0	2.0	8.1	0.1	2.3	0.6	0.2	0.0
Toxic Inorganic #3	0.4	2.6	1.2	0.8	0.2	0.7	1.7	0.5	0.5	4.9	0.7
Radio surrogate #3	0.0	0.2	0.6	1.4	6.7	3.4	0.2	0.1	3.7	1.4	0.2
Toxic Inorganic #4	0.0	0.0	6.6	1.8	3.1	7.5	0.0	0.8	0.2	0.4	0.0
Pesticide	45.8	32.4	15.7	23.2	28.9	27.7	18.3	1.5	2.3	1.5	18.3
Industrial organic	1.3	0.9	1.1	5.4	9.1	5.7	0.1	2.7	9.3	0.4	16.2
Bacillus spore	0.0	0.0	2.0	27.0	1.0	3.0	0.0	0.0	2.0	0.0	1.0
Virus	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0

- **Inorganic Contaminants** - Tw radionuclide surrogates attached modestly to pipes with tuberculated and biofilmed pipe (5 -12%)
- **Organic Contaminants** – The pesticide attached well to a number of pipes; up to 30%-45% for CPVC and biofilmed iron pipe
- **Bacillus spores** – attached best to iron pipe with biofilms (27%)

Contaminant attachment vs exposure duration



	Pesticide	Industrial Organic
1-Hour	0.21	0.11
24-Hour	1.39	0.53
7-Day	3.23	0.96

* cPVC pipe substrate

- Attachment increases over time
- Suggests early system purging desirable

Phase 2 Experiments

- Bacillus decontamination with chlorine
- Inorganics removals with chlorine, household cleaner, and chelators
- Surfactant removals of organics (Pesticide and Industrial chemical)
- Mass attachment as a function of duration of exposure (Pesticide and Industrial chemical)

Bacillus spore decon with chlorine

Percent inactivation of Bacillus spores at end of chlorine contact time

Target Chlorine CT *	Galvanized - biofilm / tuberculated Attached spore count 69,000 ct	Iron w/ biofilm 500 ct
300 mg/L-min	65%	100%
3000 mg/L-min	43%	100%
30,000 mg/L-min	84%	50%

* Chlorine dosed at 25, 50 and 100 mg/L, for varying contact times
* Cl residual essentially exhausted during the contact periods

- Results complicated by difficulty in spore recovery from tuberculated pipe and maintained chlorine residual.
- In field application, particularly with old unlined cast iron pipe, maintaining adequate chlorine concentration for target CT may be difficult
- Supplemental methods may also be needed. Consider NSF-60 certified "pipe cleaning aids."

Two Radionuclide Surrogate % removals

Percent by various decontamination agents for two Radionuclide Surrogates

Pipe Substrate	Decontamination Protocol	Radio Surrogate #1 removal (%)	Radio Surrogate #2 removal (%)
Galvanized - biofilm / tuberculated	Attached mass (mg)	0.99 mg	0.67 mg
	30,000 CT Chlorine *	23%	- 7.8%
	1% Simple Green	- 21%	- 24%
	10% Simple Green	47%	56%
Cement-lined DIP (w/o seal coat)	Attached mass (mg)	34.1 mg	14.2 mg
	30,000 CT Chlorine *	26%	35%
	1% Simple Green	36%	53%
	10% Simple Green	45%	56%
Cement-lined DIP (w/o seal coat)	Attached mass (mg)	40.0 mg	20.3 mg
	1% Na-EDTA	-15%	6.3%
	1% Na Citrate	-14%	34%
	10% Simple Green	18%	26%

* Chlorine dosed at 25 mg/L for 20 hours for targetted 30,000 contact time
** Negative removals indicate better removal w/ experimental control (i.e. water wash)

- Modest removals achieved with readily available household cleaner containing surfactants and chelators; static contact.

Other inorganic % removals

Percent removal by various decontamination agents of two inorganic contaminants

Pipe Substrate	Decontamination Protocol	Radio Surrogate #3 removal (%)	Toxic Inorganic #4 removal %
Iron	Attached mass (mg)	0.035 mg	1.187 mg
	30,000 CT Chlorine *	- 58%	- 32%
	1% Simple Green	- 280%	70%
	10% Simple Green	- 110%	6.70%
Galvanized - new	Attached mass (mg)	0.045 mg	0.030 mg
	30,000 CT Chlorine *	- 270%	- 87%
	1% Simple Green	- 100%	- 171%
	10% Simple Green	- 150%	- 681%

* Chlorine dosed at 25 mg/L for 20 hours for targetted 30,000 contact time
** Negative removals indicate better removal w/ experimental control (i.e. water wash)

- Neither chlorination nor household cleaner were effective; however, the attached mass to be removed was very low.

Surfactant removal of organics

Surfactant percent removals of two organic chemicals

Decon Protocol	cPVC pipe		Galvanized -biof & tuberculated		Epoxy coated steel pipe	
	Pesticide	Industrial Organic	Pesticide	Industrial Organic	Pesticide	Industrial Organic
Attached mass (mg)	3.23 mg	0.96 mg	3.13 mg	0.245 mg	13.52 mg	6.58 mg
0.05% N-60	55%	- 5.4%	28%	5.7%	18%	14%
0.5% N-60	79%	- 5.4%	62%	42%	34%	- 29%
5% N-60	88%	14%	80%	19%	52%	- 29%
0.05% TDA-6	50%	- 6.8%	17%	54%	32%	5.70%
0.5% TDA-6	80%	2%	65%	22%	43%	- 29%
5% TDA-6	88%	14%	89%	68%	61%	- 0.2%
0.05% LZV	0%	- 9.5%	51%	- 8.8%	- 16%	- 18%
0.5% LZV	54%	- 8.1%	- 16%	15%	54%	- 17%
5% LZV	50%	12%	89%	15%	74%	- 11%

** Negative removals indicate better removal w/ experimental control (i.e. water wash)

- Tested surfactants are effective in removal of the pesticide; however, were generally not effective in removal of industrial chemical.

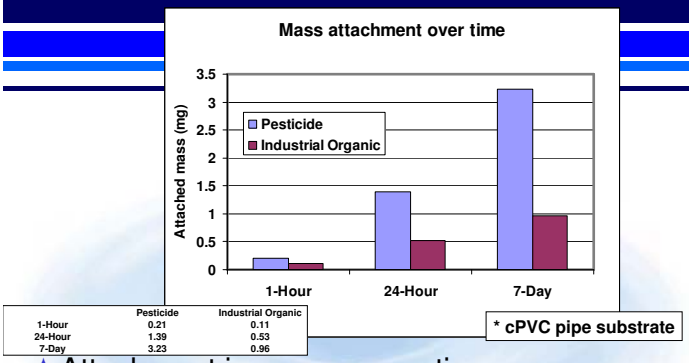
Summary Observations

- Attachment studies
- Decontamination studies

Attachment inconsistent, but some trends

- Attachment not significantly sensitive to ambient water characteristics (temperature, pH, alkalinity, TOC).
- Substrate (pipe) sensitivity
  - Biofilm and pipe tuberculation/scale increased attachment for several contaminants
  - Polyethylene and clean cement lined pipe exhibited little attachment
- Contaminant sensitivity
  - The high K_{OW} organic pesticide attached strongly to several pipe substrates
  - Inorganic chemicals tested tended not to attach, although two of the Radionuclide Surrogates had moderate attachment to tuberculated and biofilmed pipes
  - Bacillus spores seen to attach to biofilmed pipe.

Contaminant attachment vs exposure duration



	Pesticide	Industrial Organic
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24-Hour	1.39	0.53
7-Day	3.23	0.96

*** cPVC pipe substrate**

- Attachment increases over time
- Suggests early system purging desirable

Decontamination observations

- **Organic contaminants** - Tested surfactants found to be effective. Basic field tests of commonly available solvents would be effective in selecting specific surfactant and dosage.
- **Bacillus spores** can be killed with high doses of chlorine, consistent with standard AWWA water main disinfectant practice. However, in the tested static system the presence of heavy scale/tuberculation targeted concentration/time (CT) was difficult to achieve. Supplemental cleaning measures (pigging, or use of NSF-60 rated “pipe cleaning aids”) may be indicated.
- **Inorganic contaminants** - Although little tendency to attach was observed, decontamination chemicals tested were only moderately and inconsistently effective.

Battelle
The Business of Innovation

Adherence and Decontamination of Chemicals and Biologicals

Task Order Manager: Kim Fox, NHSRC, U.S. EPA

Task Order Leader: Sandip Chattopadhyay, Battelle

Workshop on Decontamination, Cleanup, and Associated Issues: April 26-28, 2006

Objective

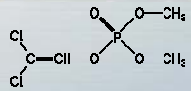
- The objective of this work is to understand adherence/attachment of various contaminants on materials commonly used for drinking water distribution systems and their decontamination by using selected chemicals.

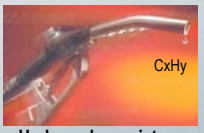
Expected Questions to be Answered

- ❑ Do the selected biological and chemical contaminants adhere to the pipe surfaces?
- ❑ If the contaminants adhere to the plumbing surfaces, can the amount of contaminant that adheres be estimated?
- ❑ If significant adhesion occurs, can the contaminant be removed by rinsing the surface with water?
- ❑ Are select decontaminating agents effective in neutralizing or inactivating the adhered contaminant?

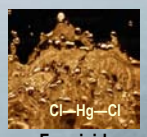
Examples of Chemical Tested

Organophosphates

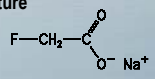




Hydrocarbon mixture



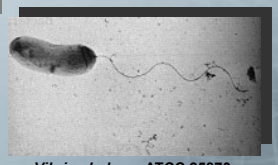
Fungicide



Rodenticide

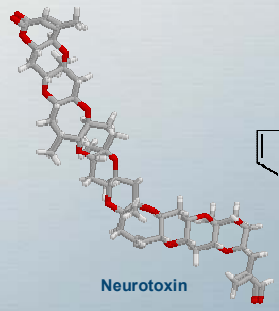
Examples of Bacterial spore and Bacteria

Bacillus anthracis Sterne

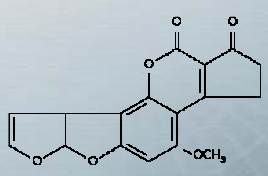


Vibrio cholerae ATCC 25870

Toxins

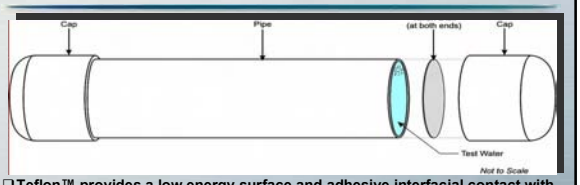


Neurotoxin



Mycotoxin

Schematic Diagram of Test Pipe



- ❑ Teflon™ provides a low energy surface and adhesive interfacial contact with test liquid (wettability) is expected to be minimal.
- ❑ One end of the container was capped and the container was filled with the test liquid to as close to the top as possible to provide maximum coverage of the internal pipe surface. The containers were sealed by covering the liquid with a Teflon™ sheet and securing with an end cap with hose clamp and/or cable ties.
- ❑ Pipe segments were sized at the smallest diameter available to maximize the surface to volume ratio while taking into account the practicality of laboratory handling (like, volume of analyte required).

Pipe Materials

2″ Aged Black Iron Pipe Schedule 40 (Steven Steel Supply)

ACI

I.D. 2.12 inch X O.D. 2.38 inch X L 3.00 inch

1″ Copper Type M (Westwater Supply Corp.)

Copper

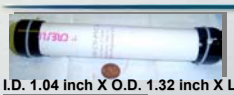
I.D. 1.06 inch X O.D. 1.12 inch X L 8.06 inch

1″ High density poly ethylene (Westwater Supply Corp.)

HDPE

I.D. 1.02 inch X O.D. 1.21 inch X L 8.00 inch

Pipe Materials (continued)



1″ Poly vinyl chloride Schedule 40 (Westwater Supply Corp.)

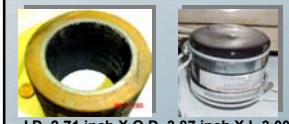
I.D. 1.04 inch X O.D. 1.32 inch X L 8.00 inch

PVC

3″ Cement lined Ductile iron pipe DIP53 without seal (Ferguson Waterwork)

DIO

I.D. 2.75 inch X O.D. 4.00 inch X L 3.06 inch



3″ Cement lined Ductile iron pipe CL53 TYTON JT with seal (Ferguson Waterworks)

DIW

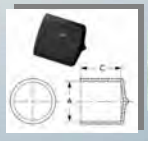
I.D. 2.71 inch X O.D. 3.87 inch X L 3.00 inch

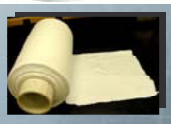
Pipe Materials (continued)

2″ Steel pipe coated with high solids epoxy (Martin Painting & Coating Co.)

DIE

I.D. 2.06 inch X O.D. 2.37 inch X L 3.06 inch





Test Conditions

7-day hold test at room temperature (18-22°C)

24-hour test at room temperature (18-22°C)

7-day test at 2-8ºC

Hypochlorite, surfactant (Simple Green™), and Pipe-Klean™ to test the efficacy of removal/degradation of selected contaminants-pipe combinations at room temperature.

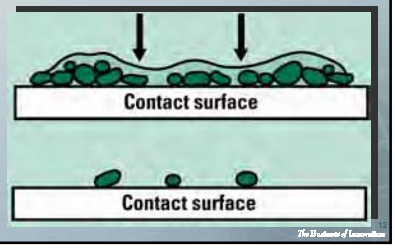
Key Factors Influence the Adherence/Release

Chemical Processes	Physical Factors
❑ Dissolution ❑ pH ❑ Alkalinity ❑ Chemical form ❑ Total composition/availability ❑ Oxidation—reduction potential ❑ Presence of organic matter (dissolved and total) ❑ Biological activity ❑ Temperature ❑ Time after contamination occurred (residence time) ❑ Stability in the operating environment	❑ Percolation ❑ Diffusion ❑ Scale formation ❑ Surface roughness and porosity ❑ Wettability ❑ Erosion ❑ Presence of particles/colloidal matters

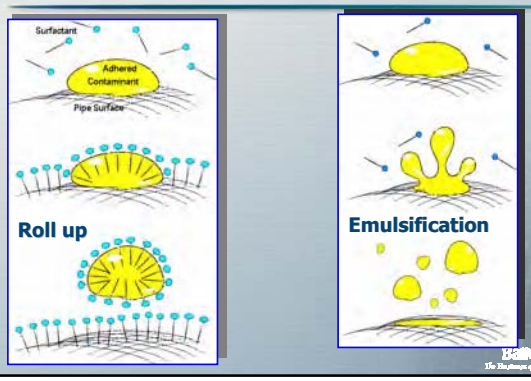
Hypochlorite

Applying NaOCl (sanitizer) to clean pipe surfaces

- ❑ provides a "**kill**" step for reducing number of microorganisms
- ❑ **oxidizes** the chemical contaminants and promotes transformation

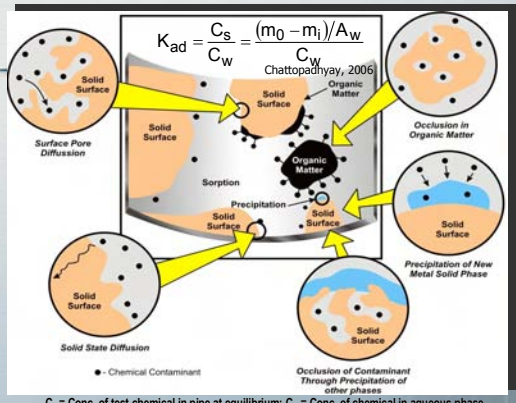


Roll up or Emulsification of Contaminants from Pipe Surfaces by Surfactant (Simple Green™)



Chemical Cleaner (Pipe Klean™)

- Pipe Klean™ is acidic in nature.
- Strong acid is expected to dissolve deposit.
- Sometime such chemical cleaners may contain some metals and other chemicals, which may interfere during contaminant analysis.



$$K_{ad} = \frac{C_s}{C_w} = \frac{(m_0 - m_i)/A_w}{C_w}$$

Chattopadhyay, 2006

C_s = Conc. of test chemical in pipe at equilibrium; C_w = Conc. of chemical in aqueous phase
m_0 = amount of chemical in water added to pipe; m_i = final amount of chemical present in water after interacting with pipe
A_w = wetted surface

Typical Initial Concentrations of Some of the Chemicals, Bacteria and Toxins

Chemicals	Initial Concentration	Bacteria and Toxin	Initial Concentration
Fungicide (e.g., $HgCl_2$)	7738-28,800 mg/L	*Bacillus anthracis* Sterne	10^6 CFU/mL
Organo-phosphates	230-2035 mg/L	*Vibrio cholerae*	10^6 CFU/mL
Gasoline	10 mL in each pipe segment	Neurotoxins	50-80 µg total
Drug	4 mg/L	Mycotoxin	3 mg total

Chemicals, Type of Bottles, Solvents

Chemical	Sample Bottle	Preservative	Extraction Solution
Fungicide (e.g., $HgCl_2$)	100 mL Plastic	HCl	10%H_2SO_4, 4%$KMnO_4$
Rodenticide (e.g, Fluoroacetate)	20 mL Plastic	None	Hot Water (50°C DI water)
Gasoline	3 40-mL Glass VOAs	HCl	Methanol followed by Hot Water (50°C DI water)

$Na_2S_2O_3$ = sodium thiosulfate; $(CH_3)_2CO$ = acetone;
CH_2Cl_2 = methylene chloride

Liquid Chromatography-Mass Spectrometry

Ion Chromatography

Gas Chromatography-Mass Spectrometry

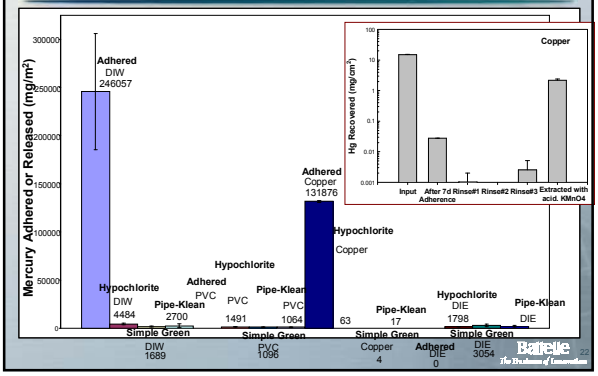
GC-MS has been used for analyses of **organophosphates**

Induced Couple Plasma/Mass Spectroscopies and **Cold Vapor** Atomic Fluorescence Spectrophotometry

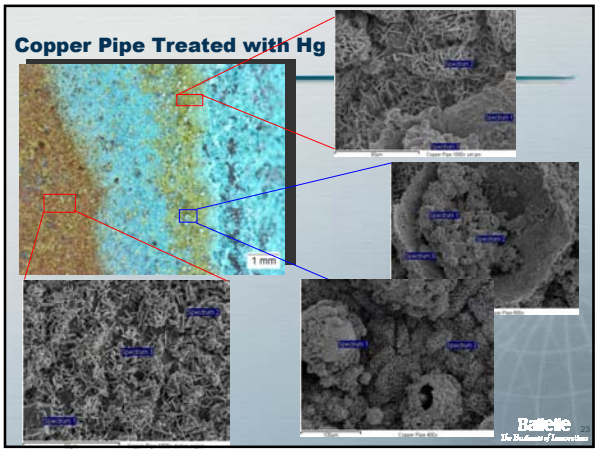
ICP/MS (upto 0.5 µg/L) and CVAFS (upto 0.5 ng/L) was used for analyses of Hg.

Adherence or Release of Hg by DIW, PVC, Copper and DIE Pipes

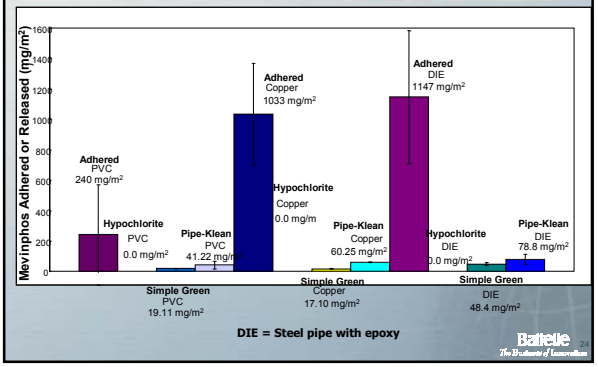
DIW = Cement lined ductile iron with seal, DIE = Steel pipe with epoxy



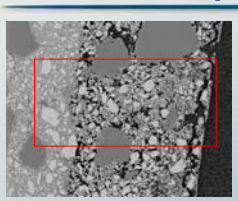
Copper Pipe Treated with Hg



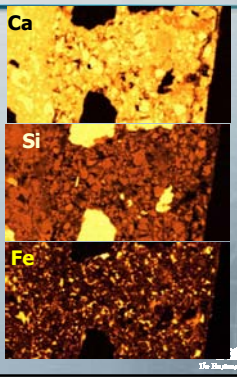
Adherence or Release of Mevinphos by PVC, Copper and DIE Pipes



Elemental Map of Mevinphos Treated Cement Lined Pipe

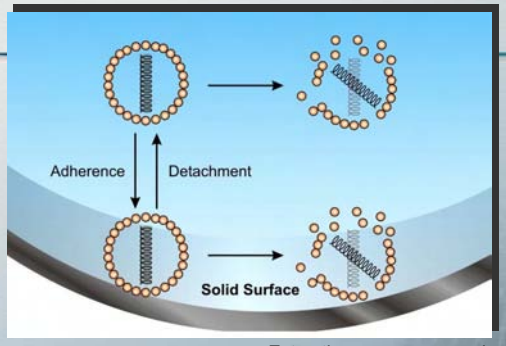


Backscatter Electron Image (240x)



Ranking of Pipe with Chemical Contaminants (example)

Contaminant	Pipe
Organophosphate	DIO > DIW > Copper > ACI ≈ DIE ≈ HDPE ≈ PVC
Rodenticide	DIW > DIO > ACI > DIE > Copper > PVC > HDPE
Fungicide	ACI > DIW > DIO > Copper > HDPE > PVC = DIE
Gasoline	ACI > DIE > DIW > DIO > PVC > HDPE > Copper



$$\text{Adherence} = \frac{\text{Extraction conc. recovered}}{\text{Total conc. recovered}} \times 100$$

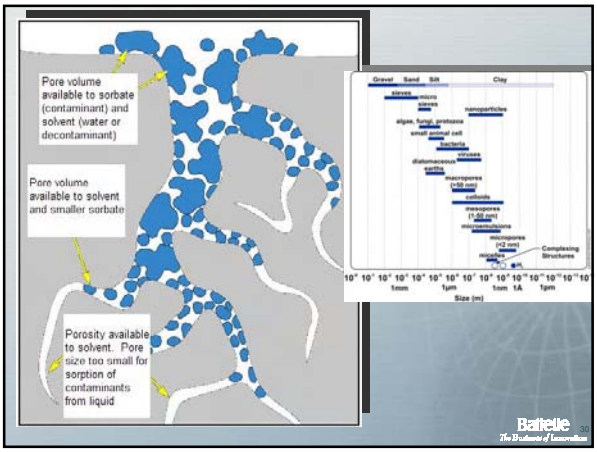
Bacterial and Toxin Adherence Criteria

Based on % Contaminant extracted from pipe when compared to the total amount of contaminant recovered from water, rinses, and extraction samples

Adherence Criteria	Recovery From the Extracted Samples
High	>10% recovery in the extracted sample
Moderate	0.1% to 10% recovery in the extracted sample when compared to the total recovery
Low	<0.1% recovery in the extracted sample when compared to the total recovery

Adherence Classification and Recovery (Avg. Adherence %, Classification)

Pipe Material	*B. anthracis*	*B. thailandensis*	*V. cholerae*	*S. typhi*	Botulinum	Alfatoxin	Brevetoxin
PVC	x (52%, High)	x (65%, High)	x (2.3%, Moderate)	x (2.6%, Moderate)	Unstable	x (16%, High)	
HDPE	x (63%, High)	x (51%, High)	x (0.68%, Moderate)	x (0.01%, Low)		x (13%, High)	x (31%, High)
Copper	x (26%, High)					x (2.9%, Moderate)	
DIE	x (55%, High)	x (7.6%, Moderate)	x (0.8%, Moderate)	x (7.4%, Moderate)		x (6.3%, Moderate)	
ACI	x (0.44%, Moderate)	x (0.27%, Moderate)	x (1.8%, Moderate)	x (0.35%, Moderate)		x (ND)	
DIO	x (5.6%, Moderate)						
DIW	x (6.4%, Moderate)		x (ND)				




Acknowledgements
• Environmental Restoration Dept.
• Biotechnology Division
• Environmental Assessment & Exposure Division
• Chemical & Biological Defense - Analytical Chemistry Division
For additional information, please contact:
Dr. Sandip Chattopadhyay, chattopadhyays@battelle.org
Battelle

Measurement and Analysis of Building Water System Contamination and Decontamination

Stephen Treado
Building and Fire Research Laboratory
National Institute of Standards and Technology
April 28, 2006

Sponsor: U.S. Environmental Protection Agency
National Homeland Security Research Center

Project Team

- Multi-disciplinary team:
- **Building and Fire Research Laboratory**
  - *Building Environment Division*
    - Stephen Treado
    - Mark Kedzierski
  - *Building Materials and Construction Research Division,*
    - Stephanie Watson
    - Nick Martys
    - Dale Bentz
- **Chemical Science and Technology Laboratory**
  - *Biochemical Science Division*
    - Kenneth Cole

Unique Aspects of Project Scope

- Small pipes <1 inch diameter. High surface area to volume ratios
- Many short runs, fittings, obstructions, gaskets, sealants, faucets, showerheads
- Low or intermittent water flows, vertical runs, dead ends
- Wide range of materials
  - Copper, PVC, iron, stainless steel, rubber
- Appliances
  - Hot water heaters, water softeners, dishwashers, toilets
- Drainage side
  - Waste water disposal
- Atmospheric transition between water supply and drain
  - Volatilization issues

Technical Approach

- Conduct measurements and analyses to develop a scientific understanding of the mechanisms and processes related to the accumulation and elimination of chemical and biological contaminants in building piping systems
- Small-scale “static” tests
- Controlled dynamic tests for simple geometries
- Small pipe run dynamic tests
- Full-scale plumbing system intermittent flow tests
- Water-using appliance tests, “new” and “used”
- “Clean” pipes, pipes with biofilms and deposits, “used” pipes
- Modeling of surface/contaminant interactions

Contaminants of Interest

- Selection criteria
  - Hazardous
  - Available
  - Difficult
- Chemicals
  - Solvents, fuels, poisons, pesticides, herbicides
- Biologicals
  - Bacteria, spores, toxins (simulants or non-hazardous variants

Measurement Philosophy

- Well-characterized and controlled laboratory experiments, highlighting primary variables:
  - Contaminant concentration
  - Pipe material
  - Exposure time
  - Flow velocity, regime
  - “Synthetic” water, tap water
- Real-world testing configurations with typical plumbing system design and operation:
  - Valves, fittings, fixtures, appliances
  - Tap water

Biochemical Science Division: Biological Threats in Building Water Systems

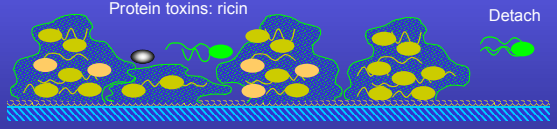
Biological Threats and Simulants

Bacteria: E. coli O157:H7 (strain lacking toxin)

and *Francisella tularensis (vaccine strain)*

Spores: *Bacillus anthracis (B. thuringiensis)*

Protein toxins: ricin



Mature Biofilm Conditioned Pipe Surface

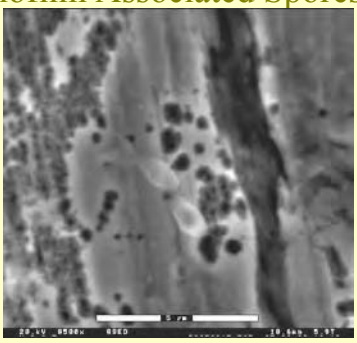
Experimental Approach

Bench top pipe system with creeping flow of synthetic water with 24 mg/L humic substance as growth media, completely open system

CDC Bioreactor for controlled shear impact studies of pathogen deposition on biofilms established on PVC and copper coupons

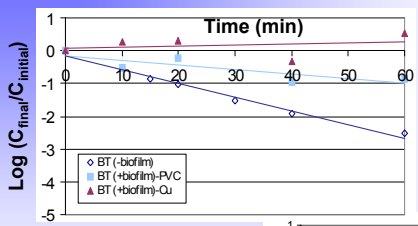
(Biosurface Technologies Corp)

Biofilm Associated Spores



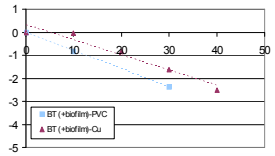
Environmental Scanning Electromicroscopy of biofilm contacted with BT spores.

Sodium Hypochlorite Disinfection of Spores Associated with Pipe Surfaces with

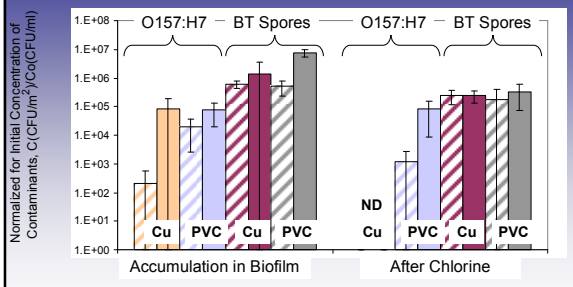


11 mg/l free chlorine results in < 1 log reduction in spores when associated with biofilm

110 mg/l free chlorine results in similar reduction of viable spores when associated with biofilm compared with inactivation of free spores



Impact of Fluid Shear on Contaminant Accumulation in CDC Bioreactor



Shear: Hatched bar = 60 RPM, Solid = 180 RPM

Chlorine Dose: 10 mg/L for *E. coli*, 100 mg/L for BT Spores

Hydrophobicity: ΔG_{iwi} BT Spores = 17.3 vs. ΔG_{iwi} O157:H7 = 30.8 mJ/m^2

Work in Progress on Additional Threats

- Developing Ricin adhesion and removal measurements using biofilms grown in microtiter plates and detection using fluorescent-labeled antibody
- Obtaining *Francisella tularensis* (vaccine strain) from ATCC to begin adhesion and disinfection experiments
- Modeling surface adhesion forces for bacteria and spores to biofilms

Chemical Contaminants

Determine:

- The best methods to measure chemical contaminants in water
- Adsorption isotherms for chemical contaminants in water and pipe materials
- The mechanism of adsorption by analyzing water solutions and pipe materials after contamination
- Appropriate methods for decontamination

Measurement Objectives

- Determine rates and mechanisms of contaminant accumulation
  - Adsorption
    - Wetting thermodynamics and molecular interactions
    - Physisorption versus chemisorption
  - Modeling to guide the experimental path
  - Control experimental complexity
    - Static flow versus dynamic flow
    - Pure compounds for deposits
  - Limit variables
    - Contaminant type and concentration, flowrate, temperature, pH

Materials

Chemical Contaminants

- Dichlorvos
- Cyanide Salts (Sodium and Potassium)
- Phorate
- Strychnine
- Diesel, Toluene

Pipe Substrates

- Pipe
  - Copper, PVC, used pipes
  - Samples cut for coupons
    - 1.5 cm x 1.5 cm
- Deposits
  - Powder Materials
  - Calcium carbonate, iron oxide, copper oxides

Experimental Procedure

- 500mL of contaminant/water solution placed in 600mL beakers or 500mL capped jar
- Stirring with glass coated magnetic stir bar
- Pipe added as coupons
- Deposits added as powder (3 grams)
- Measure change in contaminant concentration over time
  - in solution and on pipe surface

Measurement Methods

Water Characterization

- pH, temperature, conductivity, chlorine (free and total), turbidity
- Ion Selective Electrodes (ISE)
  - CN-, Cl-
- GC/MS
  - Purge and trap separation
- Ion chromatography

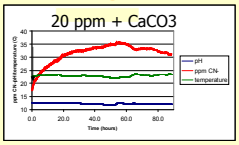
Pipe Surface Analysis

- Fourier transform infrared spectroscopy (FTIR)
  - Diffuse reflectance, micro-IR
- X-ray photoelectron spectroscopy
- Microscopy
  - Optical, scanning electron
- X-ray diffraction (XRD)

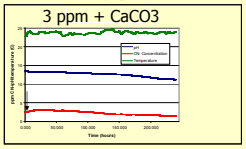
Adsorption Isotherms

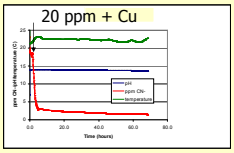
CN- ISE

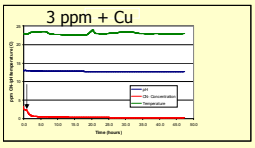
KCN



NaCN

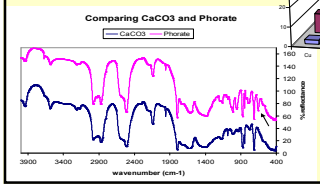




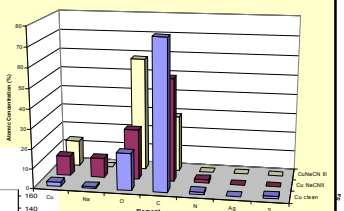


Pipe Material Analysis

DRIFTS



XPS Analysis



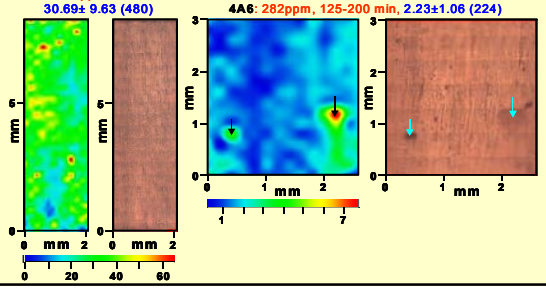
IR Microscopy

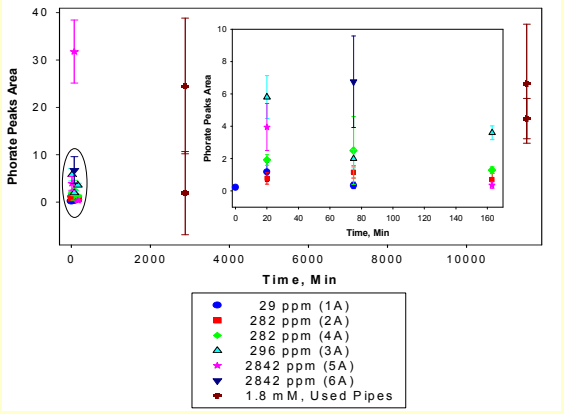
Pipe Analysis

FTIR microspectroscopy maps of Cu pipes with Phorate

5A4: 2842ppm, 70-80 min, 30.69± 9.63 (480)

4A6: 282ppm, 125-200 min, 2.23±1.06 (224)

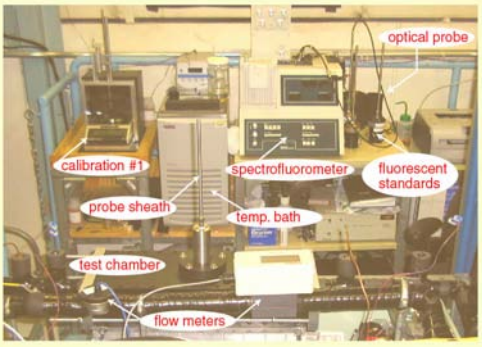




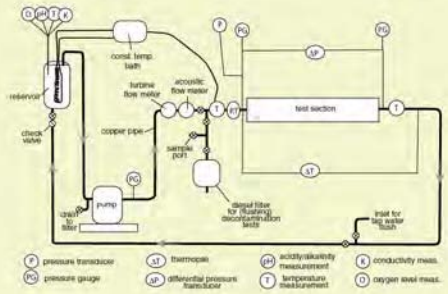
Path Forward

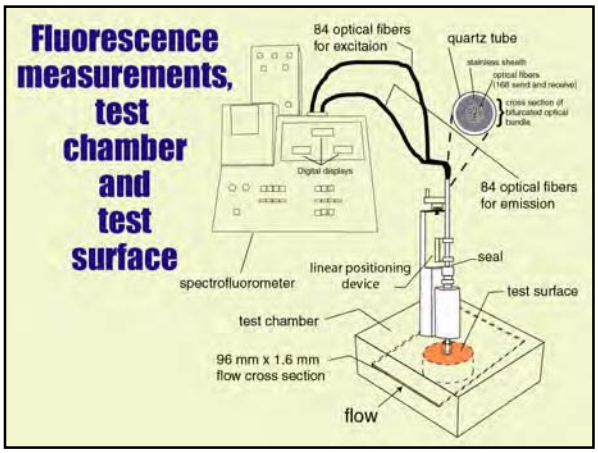
- Isotherm Analysis
- Aqueous Cyanide Species Analysis
- Organic Chemical Studies
  - Purge and Trap
- Contaminant exposure to:
  - Other pipe types
  - Other oxides
  - Pipe and deposits
- Use of tap water

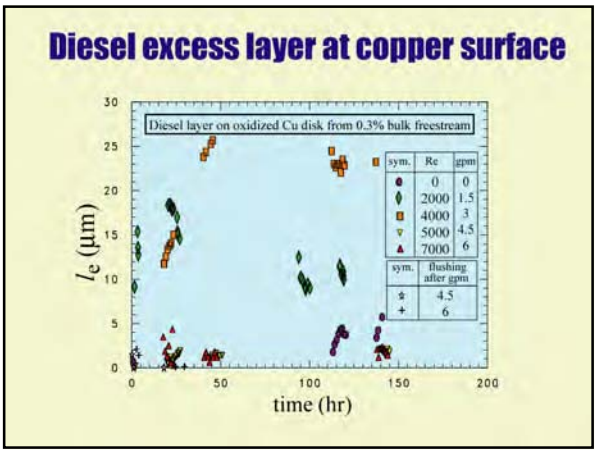
Dynamic Contamination Measurements



Flow Contamination Test Loop



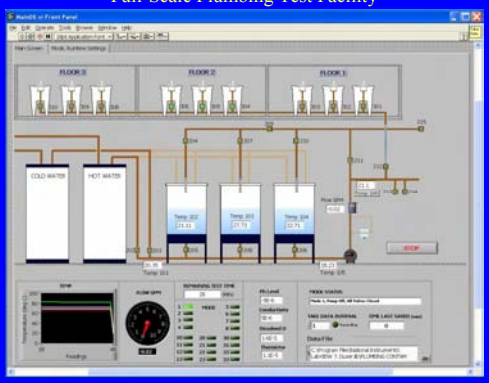




Plumbing Test Facility

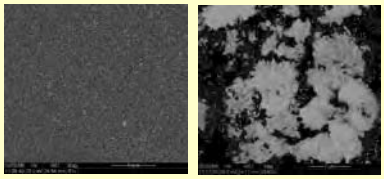
- Full scale, five floor structure
- Emulates a typical building plumbing system, including supply and drainage
- Multiple test loops
- Computer data acquisition and control system for running tests and monitoring sensor readings (flow, temperature, pH, conductivity, chlorine, turbidity, etc.)

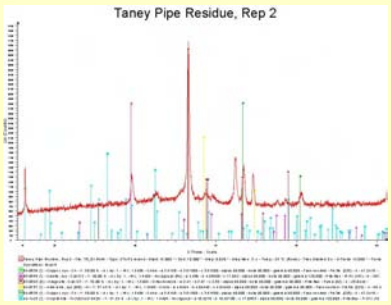
Full-Scale Plumbing Test Facility



Characterization of Pipe Deposits

- Used water pipes collected from several locations in Maryland and Virginia, including copper and iron
- Used water heaters

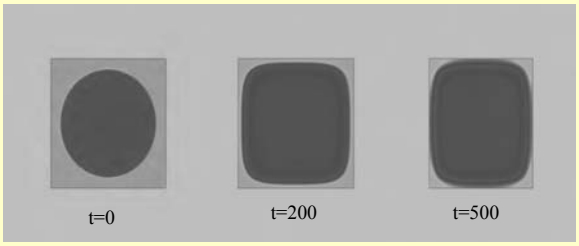




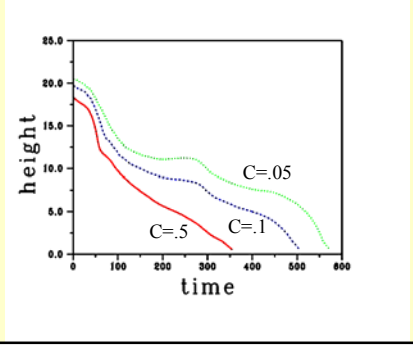
Modeling of Fluid Flow

- Mimics the dynamic flow measurements with diesel fuel contaminant

Cross section of pipe



Interface Height



Decontamination Methods

- Flush with water, cold or hot
- Flush with cleaning solution
- Back flush
- Mechanical or ultrasonic cleaning
- Remedial surface treatment
- Handling of waste water
- Verification of cleaning effectiveness
- Must deal with worst-case

Conclusion

- Continuing more extensive tests with different contaminant/substrate/exposure combinations
- Focusing more on specific decontamination methods and procedures
- Develop specific recommendations for response plans for water contamination events
- Generalize the results for wider applicability

Water Decontamination and Detection

2006 Decontamination Workshop
April 28, 2006

John Hall and Jeff Szabo
EPA/NHSRC

Greg Meiners
Shaw Environmental

Disclaimer

- Any opinions expressed in this presentation are those of the author(s) and do not, necessarily, reflect the official positions and policies of the EPA.
- Any mention of products or trade names does not constitute recommendation for use by the EPA.

Background

- EPA has been conducting research over the last 3 years at EPA Test and Evaluation (T&E) Facility via:
  - Water Assessment Technology Evaluation Research and Security (WATERS) Center
    - Recirculating distribution system simulator loop 6
    - Single pass line
  - Engineering Testing and Verification (ETV) Program
  - Technology Testing and Evaluation Program (TTEP)

Research Purpose

- Evaluate the ability of commercially available water quality sensors to detect changes in water quality resulting from contamination
  - What happens when various contaminants are introduced into the water supply ?
  - What standard water quality parameters are the most effective for detecting changes in water quality ?

Single Pass Pipe

- 1200 feet of 3 inch fiberglass lined cast iron pipe with PVC sections
  - Flow is 1 ft/sec
  - Sensors are located at 80 and 1100 ft from the injection point
  - Sensors only see the contaminants once
  - Contaminants injected with a pump

Monitor Test Rack with Event Monitor

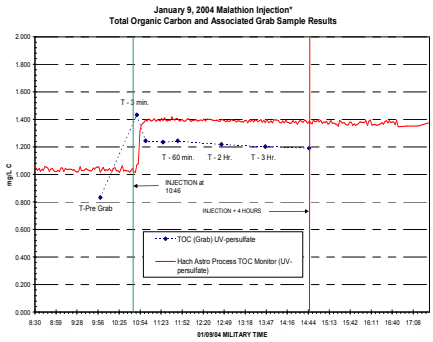
Online Standard Water Quality Test Parameters

- pH, temperature
- ORP, specific conductance
- dissolved oxygen
- turbidity
- free & total chlorine
- TOC
- ammonia (NH_4^+-N)
- nitrate (NO_3^--N)
- chloride (Cl^-)

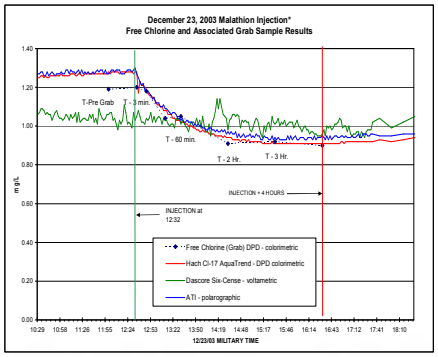
Injected Contaminants

- **Herbicides**
  - Aldicarb
  - Glyphosate
  - Dicamba
- **Insecticides**
  - Dichlorvos
  - Malathion
- **Culture Broths**
  - Nutrient
  - Terrific
  - Trypticase Soy
- **Microorganisms**
  - *E.coli*
  - *B.globigii*
  - (w/ and w/o media)
- **Others**
  - DMSO
  - Nicotine
- **Inorganics**
  - Lead Nitrate
  - Mercuric Chloride
  - Arsenic Trioxide
  - Potassium Ferricyanide
  - Sodium Thiosulfate

Malathion vs. TOC

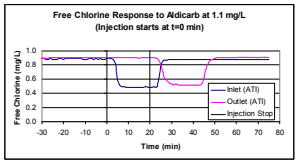


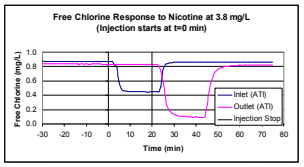
Malathion vs. free chlorine



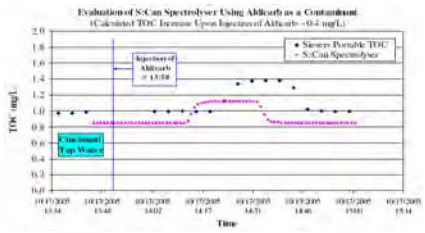
Single Pass Data

- Free and Total Chlorine and TOC were the most useful trigger parameters
- Contaminants travel as a slug in pipe
- Aldicarb and Nicotine are examples of two very different contaminants
  - Aldicarb=fast reacting
  - Nicotine=slow reacting

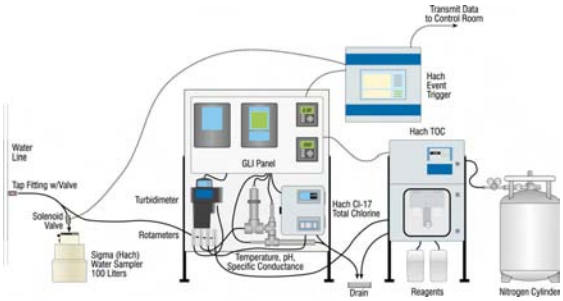




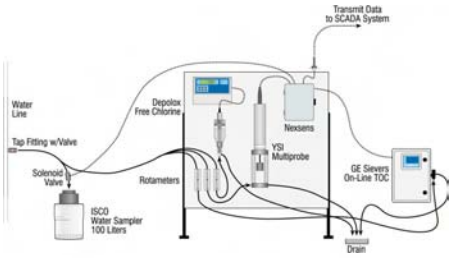
S::CAN on the Single Pass



Hach Configuration



Non-Hach Configuration



General Issues

- Pros
  - Improving water quality (dual benefit)
  - TOC and free/total chlorine are proven primary trigger parameters
- Cons
  - Cost (Capital and Operational)
  - False positives (algorithm development)
- Gaps
  - Biological and Radiological contaminants

Other Factors

- Event detection algorithm (e.g., development, use, and selection)
- SCADA (field equipment, communication, data storage and access)
- Field testing and sampling requirements for triggered sample
- Historical knowledge of routine distribution system water quality changes

Post Contamination Event Decontamination factors

- Contaminated water is displaced by clean water (Flushing)
- The bulk phase of the water returns to baseline conditions established prior to contamination event as determined by on line monitors and grab sampling (parameters and contaminants)

Common Decontamination Methods

- Flushing
  - Contaminated water is displaced by clean water
  - Adhered contaminants are sheared from the pipe wall
  - Delivers higher disinfectant concentration to the biofilm and pipe wall
- Superchlorination
  - Higher chlorine concentration in the bulk provides more disinfectant at the pipe wall

Role of Water Quality Sensors

- Water quality sensors detect when baseline water quality levels are reestablished in the bulk phase
  - Grab samples will verify absence of contaminants in the bulk phase
  - Sensors monitor superchlorination levels and when residual returns to normal
- Cannot detect contamination on the pipe wall or biofilm

What's Left Behind

- Some contaminants observed to adhere to biofilms and piping materials of construction
- Pipe conditions such as corrosion and tuberculation also affect the ability to decontaminate

A Case Study with Bacillus globigii

- Multiple injections of *B. globigii* at 10^4-10^6 cfu/ml were made in the single pass pipe over a 12 month period
- Basic flushing between test runs (20 gpm, 1 ft/s)
- After the 3rd trial, *B. globigii* began showing up in the bulk water blanks
  - Spores only detected by ultraconcentration (approximately 400X)

Case Study (cont'd)

- More aggressive flushing was implemented (75 gpm, 3.5 ft/s, 2 hours)
- *B.globigii* still remained in bulk phase blanks after flushing
- Swipe sampling was implemented
  - PVC, fiberglass and corroded ductile iron surfaces were all in the pipe
  - Spores remained on the corroded iron, but not the other surfaces

Decontamination Study

- *B. globigii* was injected at 10^6 cfu/ml for 20 min at 5 gpm for chlorination studies
  - Concentration on the coupons immediately after *B. globigii* injection was $3x10^3$ cfu/cm^2
- *B. globigii* was in contact with tap water (1 mg/L free chlorine) for 9 days at 5 gpm
  - Reduced levels by 80% of initial coupon concentration (Ct approx 13,000 mg/L min)

Decontamination Study (cont'd)

- Decontamination was undertaken using superchlorination
  - Elevated chlorine disinfection was implemented (10mg/l for 80 min)
  - Small effect of superchlorination on corroded iron samples (drop of 500 to 400 cfu/cm^2)

Conclusions

- Some contaminants remain after flushing and chlorine contact in the bulk phase (ultraconcentration) and on the corroded iron surfaces (swipe samples)
- Additional health based toxicity and infectivity data needed
- Areas of rust and corrosion may require more aggressive decontamination than flushing and or chlorination

Future Work

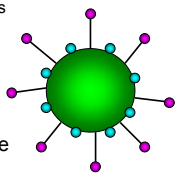
- Persistence of biologicals in drinking water pipes and decontamination
  - Recirculating pipe loop with corroded ductile iron will be used
  - Spore concentration will be monitored over time
  - CT values for decontamination will be determined

Determining the Virucidal Mechanism of Action for Foreign Animal Disease

J.M. Bieker[1,2*], W. Einfeld[1], M.D. Tucker[1], T. Beckham[3], A. Shuler[2], R.D. Oberst[2]
[1]Sandia National Laboratories, Albuquerque, NM.
[2]Dept. of Diagnostic Medicine/Pathobiology, College of Veterinary Medicine, Kansas State University, Manhattan, KS
[3]Plum Island Animal Disease Center, Plum Island, NY

Virucidal Validation

- Proper validation is necessary for efficacy claims
  - Differences in resistance exist among viruses
- Virus inactivation important to aid in disease containment
  - Disrupt transmission cycle
  - Dependent on mechanism of inactivation
- Preventative measure to help control reservoirs or vehicles involved in disease transmission
- Environmental factors can effect efficacy
  - Organic matter, temperature, humidity, UV



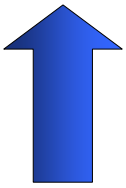
Virus Sensitivity to Disinfectants

Virus Type	Category	Distinguishing Features	Examples
Enveloped	A - marked sensitivity	Nucleic acid, capsid protein, lipid envelope	Influenza, SARS, Vaccinia, HIV
Small Non-enveloped	B - slight sensitivity	Nucleic acid, capsid protein,	Polio, FMDV, Rhino, Coxsackie
Large Non-enveloped	C – moderate sensitivity	Nucleic acid, capsid protein,	Adenovirus, Rotavirus

Klein

Overall Microbial Susceptibility

Most Resistant



Least Resistant

- Bacterial spore formers
- Protozoa (cysts/oocysts)
- Mycobacterium & Non-enveloped viruses
- Fungi
- Vegetative bacteria
- Enveloped viruses

Virus Methodologies

- No US standards currently exist for evaluating disinfectants against viruses
  - EPA guidelines, ASTM
  - International Standards: AFNOR, DEFRA
- Standardized tests are necessary for regulatory processes and comparing data
- Initial work often conducted using surrogate viruses
  - Member of same virus family but less pathogenic

Parameters in Virucidal Testing Methods

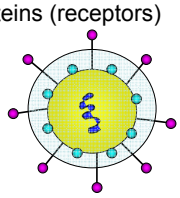
Parameter	Description
Test Configuration	Suspension vs. Carrier
Test Virus	Enveloped, Non-enveloped, Surrogate
Cytotoxicity	Washing, purification step
Organic Challenge	Addition of feces, serum, etc…
Exposure Interval	Exposure contact time (resistance)
Host Cell System	Virus specific, titer differences
Viral Enumeration	Endpoint dilution vs. plaque assay
Alternative Diagnostics	Nucleic acid, viral proteins, etc…

EPA Guidelines for Virucidal Testing

- Must follow use-directions (surface, liquid, or spray disinfection) at a specified exposure length at RT
- Untreated control should recover a minimum of 10^4 infectious viral titer
- Protocol must include:
  - 4 determinations for virus recovery (endpoint)
  - Cytoxicity controls
  - Activity of germicide for each test dilution
  - Any special methods to increase recovery or reduce toxicity
  - 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

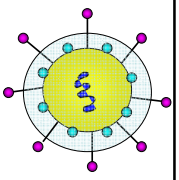
Evaluating Mechanism of Action

- Viruses present limited targets:
  - Lipid envelope
  - Capsid protein
  - Structural proteins (receptors)
  - Nucleic acid



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



Evaluating Mechanism of Action

Virus target	Alternative Diagnostic
Capsid Protein	SDS-PAGE Western blot ELISA
Structural Proteins	SDS-PAGE Western blot ELISA
Nucleic Acid	PCR RT-PCR

Experimental Design

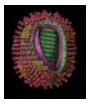
Objective: to evaluate various disinfectants against FMDV, Avian Influenza (AI), and closely related surrogate viruses

Hypotheses:

- A closely related surrogate virus will react similarly to disinfectants
- Molecular based diagnostics can be applied as rapid verification tools

Experimental Design

- Bovine enterovirus-2 (BEV) selected as surrogate virus for FMDV
  - Also a member of *Picornaviridae*
- Mammalian A/WSN/33 was selected as a surrogate for AI (low pathogenic)
- Testing conducted at KSU or at Plum Island Foreign Animal Disease Center (FMDV)
  - Following EPA guidelines
  - Using RT-PCR to show RNA degradation



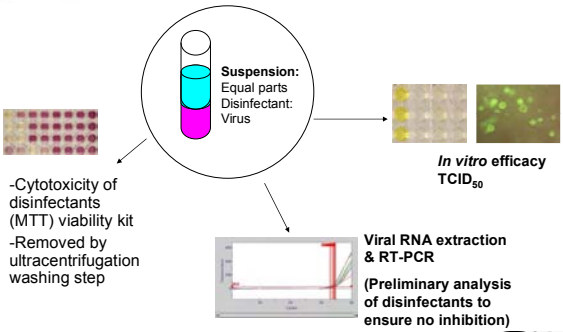
Test Disinfectants

- 10% bleach (pH ~10)
- Sandia Decon Formulation, (EFT, pH ~9.7)
  - Surfactant, peracid, hydrogen peroxide
- 2% Sodium Hydroxide (NaOH, pH ~11-12)
- 4% Sodium Carbonate (NaCarb, pH ~11.5)
- 5% Acetic Acid (AA, pH ~2.5)
- 0.4% Oxy-Sept 333 (Oxysept, pH ~3)
  - Peroxyacetic acid, hydrogen peroxide
- 1% Virkon® S (Virkon, pH ~2.5)
  - Potassium peroxymonosulphate
- 70% Ethanol (EtOH, pH ~6.8)

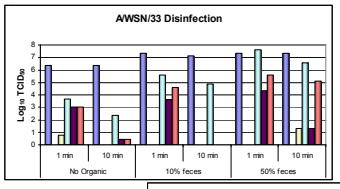
Methodology

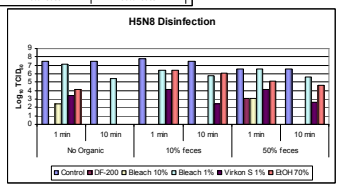
- Equal parts virus:disinfectant were mixed and exposed for 1, 10, or 20 min at RT
- For organic challenge, either bovine or poultry feces were diluted 10% (wt/vol) and added to the disinfectant at 10% or 50% conc.
- Following exposure, samples were diluted with PBS, ultracentrifuged, and prepared for infecting $TCID_{50}$ plates or RNA extraction for RT-PCR
- Western blot was conducted on influenza samples to visualize effect on nucleocapsid protein

Experimental Design

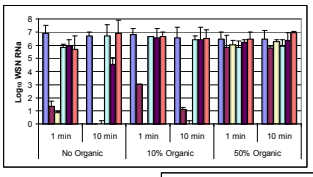


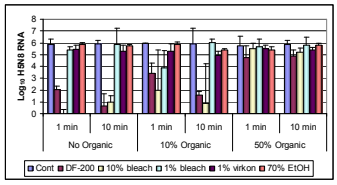
Inactivation of Influenza A ($TCID_{50}$)



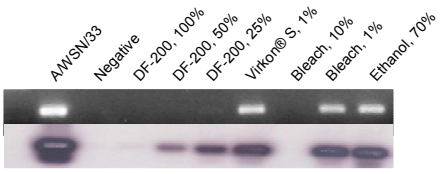


Inactivation of Influenza A (RT-PCR)





Effect on Viral RNA (RT-PCR)

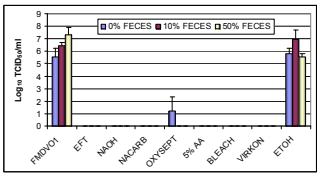


1 min treatment, no org

Conclusions (Influenza A)

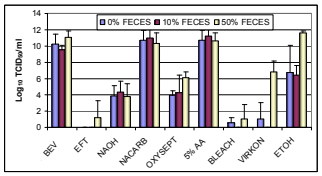
- Both mammalian influenza A/WSN/33 and low pathogenic H5N8 reacted similarly to each test disinfectant (no statistical differences observed for $TCID_{50}$ or RT-PCR)
- DF-200 and 10% bleach were most effective for 1 min exposure, and Virkon S was completely effective at 10 min for each organic challenge level (0, 10, 50)
- Only DF-200 and 10% bleach degraded significant amounts of viral RNA, but were greatly impacted with the presence of organic challenge

Results (Infectivity)

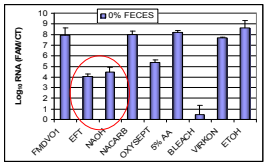


FMDV O1 Bruge propagated in BHK-21 cells

BEV propagated in MDBK cells

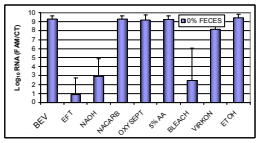


Results (RT-PCR)



FMDV RNA

BEV RNA



Conclusions (infectivity)

- Although BEV and FMDV are both picornaviruses, BEV was much more resistant to acidic disinfectants (AA, Oxysept, Virkon) than FMDV
- For FMDV, all disinfectants except EtOH were effective in complete loss of infectivity based on $TCID_{50}$
- For BEV, 10% bleach, EFT, and Virkon were most effective
- BEV, because of its enteric nature and resistance to pH may not be best surrogate virus

Conclusions (RT-PCR)

- 10% bleach was most effective at degrading FMDV RNA (~ 7.5 log_{10})
  - EFT, NaOH, & Oxysept resulted in ~ 4 log_{10} level RNA degradation
  - Remaining disinfectants resulted in ~ no degradation
- EFT, 10% bleach, and NaOH were most effective at degrading BEV RNA (~7-8 log_{10})
  - Remaining disinfectants resulted in ~ no degradation
- Conclusion: only 10% bleach, EFT, or NaOH could be validated by RT-PCR (based on this mechanism of action)

Concluding Remarks

- Viruses present limited targets for disinfectants
  - Viral RNA
  - Viral proteins (surface proteins, nucleoprotein)
  - Lipid envelope (Influenza A)
- Organic challenge does reduce effectiveness of disinfectants tested
- Continued live agent testing with H5N1 and FMDV (at remaining time contacts) are next steps for determining the validity of using surrogate test viruses

Concluding Remarks

- Real time RT-PCR is being validated for a rapid field assay for determining viral inactivation due to degradation of viral RNA
  - If mechanism is against RNA, RT-PCR could verify disinfection within hours vs. days
- What assays need to be done from field samples to verify eradication efforts prior to re-introduction of susceptible animals?

Concluding Remarks

- After establishing efficacy, some consideration needs to be given to the material for application
  - Effect of corrosiveness of chemical disinfectants
  - Reusability
  - $$$ equipment

Concluding Questions

- Does virucidal efficacy testing need to be standardized in this country?
- Can surrogates be used for validation of disinfectants?
- Do disinfectant claims need to be made for each specific virus or can they cover a virus family?

Contact & Acknowledgements

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(505-977-7924, jmbieke@sandia.gov)

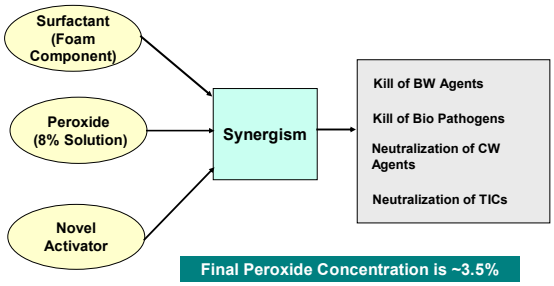
Acknowledgements:
- Joe Anderson, Heather Wisdom, Kansas State University, Manhattan, KS
- Ruben Donis, CDC, Atlanta, GA
- Rita Betty, Gary Brown, J. Bruce Kelley, Sandia National Laboratories, Albuquerque, NM
- Meri Rosco, Max Rasmussen, Plum Island Animal Disease Center, NY

Sandia Decontamination Chemistry

Formulation developed by Sandia National Laboratories
- Surfactant/peroxide blend developed initially against both chemical and biological agents of potential mass destruction
- Non-corrosive, non-toxic, enhanced physical stability
- Deployable as Liquid, Foam, Fog, Aerosolized Mist
- Currently 2 existing commercial licensees/producers
- More information available at www.sandia.gov/SandiaDecon

Sandia Decon Foam

How Does it Work?



Protection of U.S. Agriculture: Foreign Animal Disease Threats

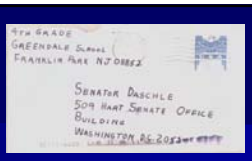
Bethany Grohs, V.M.D.
HSRC Decontamination 2006

Stating the Problem

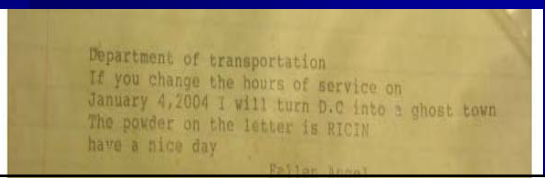
- Death is a sad but inescapable fact of farming life. Sheep especially have a quite remarkable propensity for dropping dead at a moment's notice, but any farming operation involving livestock, no matter how well ordered, will have its share of casualties.

Historic Solution

New Paradigms



U.S. Capitol Response: Anthrax and Ricin



World Trade Center

Foot and Mouth Disease

A worker in England patrols the perimeter of a pyre of burning cattle carcasses culled to stop the spread of foot-and-mouth disease. U.S. DVMs report heightened awareness of the disease and are prepared to keep the European epidemic at bay from U.S. shores.

"What it really did for us is raise the importance of animal health to an issue of national security"

Dr. Marc Mattix, MT Dept Livestock

Bio vs Agro?

Bioterrorism
Biological agents targeting humans, animals, or plants

Agroterrorism
Bio, chem, rad agents targeting agriculture or its components

- Livestock
- Food Supply
- Crops
- Industry
- Workers

U.S. Agriculture Vulnerable

- Dispersed geographically, concentrated operations
- Herd susceptibility
- Economic impact – diseases halt import/export
- Agents are easy to obtain & disseminate
- Non-attributional

Potential Livestock BW Agents

Avian influenza
Foot and mouth disease
Exotic Newcastle
Bovine spongiform encephalopathy
Anthrax
Classical swine fever
Rift Valley fever
Nipah/Hendra virus

Recent Disease Outbreaks

- 1971 US—8 million birds killed (END)
- 1983 US—17 million birds killed (AI)

Recent Disease Outbreaks

- 1997 Taiwan-- 4 million hogs killed (FMD)
- 1998 Netherlands—11 million hogs killed (CSF)

Recent Disease Outbreaks

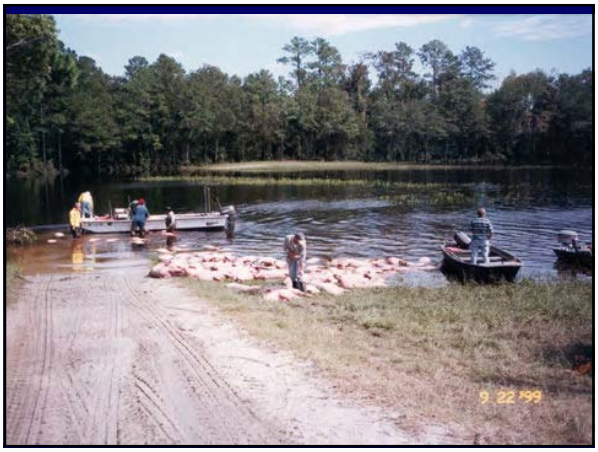
- 2001 UK – Foot and Mouth Disease 10 million animals

Challenges…..to mention a few

- Worker Health and Safety
- Carcass Handling
  - Hazmat
  - Location
- Depopulation
- Disposal/Decontamination

Worker Health and Safety

Carcass Handling

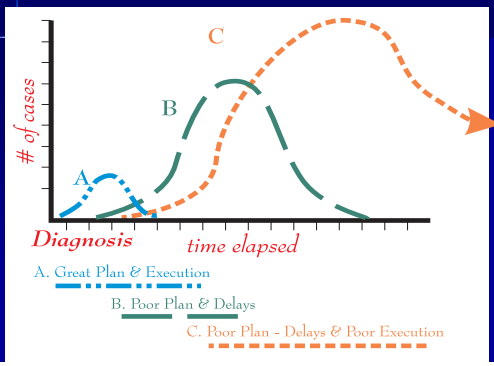


Hazmat

Location

Humane Euthanasia

DISPOSAL: Disaster Plans Affect Number of Animals Needing Disposal



Number, size, location, disease, type, degree of decomposition

Composting

- Cost efficient
- Quick
- High temp destruction of disease agent
- On farm alternative to burial, mounding
- Cover vital
- Art + Science

Rendering

- No land disposal
- Commercial value offsets costs
- Existing infrastructure
- Fewer Plants
- FDA Feed Rule '06
- Capacity/day – 20 tonnes/hr
- Not decomposed
- Transportation biosecurity

Rendering Pick up Closed during surge capacity….

Landfill - Burial

Commercial Landfill (Subtitle D)

- Existing facilities
- Off producers premise
- Wide availability/lg capacity
- Regulated and inspected
- Recognized by public

- Facility indemnification concerns
- Transportation biosecurity
- Permit concerns
- Decomposition long term
- Volume limits
- Premium charge due to PR concerns

Burial

- Inexpensive
- On-site – no movement required
- Large capacity

- Fate and Transport unknown
- Site deed restrictions

Decontamination

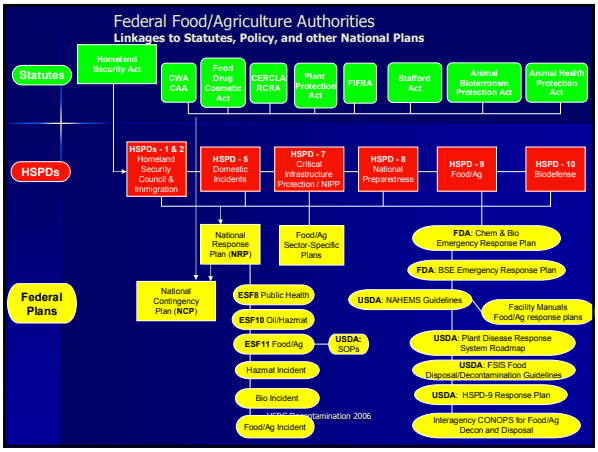
- Bio-Security
- Cleaning and Disinfection

Are we making progress in D.C.....

- ESF #11
- Food/Ag CONOPS
- FADT Strategic Plan
- Avian/Pandemic Influenza

ESF #11

- New Annex to our National Response Plan
- Formal recognition of Agriculture Incidents
- Food/Ag Incident Annex

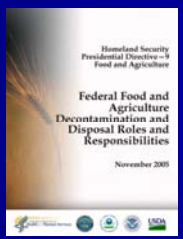


"Federal Food and Agriculture Decon and Disposal Roles and Responsibilities"

- Focus on decontamination and disposal
- Who does what, order of activities, and outcomes
- Summaries of laws & homeland security plans
- Contacts in Federal agencies
- Help State, Tribal, Local agencies and industry plan and respond
- www.epa.gov/homelandsecurity

Food/Ag CONOPS

Agriculture and emergency management communities must be prepared to work together closely to deal with an animal health emergency



FADT Strategic Plan 2008-2012

- White House OSTP Product
- 3 focus groups
  - Modeling
  - Countermeasures
  - Decontamination and Disposal

Top-level drivers

National Veterinary Stockpile (NVS)
Priorities of NVS Steering Committee (AI, FMD, RVF); 'Customer' for deployment of vaccines & immunomodulators

National Animal Health Laboratory Network (NAHLN)
'Customer' for deployment of validated diagnostics

NBII Wildlife Disease Information Node
'Customer' for data acquisition, management, archiving, curation, and distribution

D + D Scope

- FAD livestock
- Not prions
- Not CBRNE
- Not oil/hazmat
- Not pets
- Not agent-specific

Decontamination & Disposal

"Decontamination is essential to contain the spread of disease and is an integral part of the eradication plan. If items cannot be adequately cleaned and disinfected, they must be disposed of using appropriate disposal methods. Decontamination and disposal actions are iterative during the course of a response."

Wisdom from the Field

- Dee Ellis, Texas AHC
- Cody Wilson, DHS Center Excellence
- Kathy Lee, Iowa DNR
- Kent Fowler, CA Dept Food Ag
- Jim Howard, NC Dept Ag

Actions Needed at National Level

- EPA – R+D on disposal methods (clearinghouse)
- USDA – finalize carcass disposal guidelines, disease-specific biosecurity guides
- DHS
  - payment policies in advance for carcass disposal as debris
  - ODP funding for state agencies to hire staff, Ag can't compete with ER personnel or academia

Actions Needed at State Level

- Include disposal in all plans
- ID respective rules and regulations
- Clear guidelines for producers and local responders

Actions Needed at Local Level

- Disposal planning incorporated into prevention, response, mitigation plans (EOP)
- Include Industry in planning
- Pre-identify mass burial locations

Top-level issues

Decontamination and Disposal (D+D) is significantly under-funded, and authorities map to multiple agencies (confluence of interest). A national system of operations not yet in existence remains the critical first-step in the utilization of R&D products

Requirement:

An effective national response to an FAD outbreak requires a coordinated operations base, surge capacity, and clearinghouse for disposal decisions including cost-benefit analysis and human health, animal, and environmental risk assessment, all while actively pursuing alternate strategies in disease management to reduce disposal requirements

Objectives:

Establish a carcass disposal operations base;
Create a clearinghouse for disposal decisions including agent fate and transport;
Register inexpensive, readily available, environmentally sound decontamination agents;
Establish quality environmental decontamination procedures for FMD, AI, and RVF

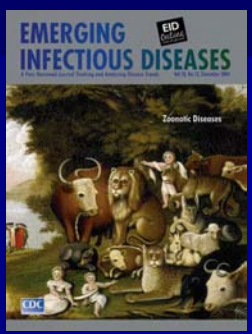
D+D budget requirements

(FY $ million , new $ in each of 2008-2012)

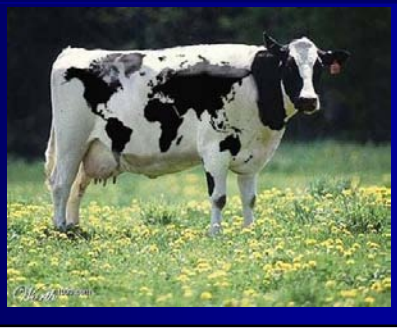
Program	2007 base	2008	2009	2010	2011	2012	Total 08-12
Ops Base	0.00	8.00	8.00	6.00	4.00	4.00	30.00
Fate and Transport	0.00	8.00	8.00	10.00	12.00	12.00	50.00
Decon Regist.	0.00	4.00	4.00	0.00	0.00	0.00	8.00
Envir. Decon	0.00	0.00	0.00	4.00	4.00	4.00	12.00
Sub-total	0.00	20.00	20.00	20.00	20.00	20.00	100.0

One Medicine

- Zoonotic diseases underscore the important relationship between public health and animal health



Globalization



Avian Influenza Decontamination

- Surrogates (salmonella for flu)
- Industry stockpile issues
- Exemptions: FMD (bleach, lye, soda)
- Relation between lab data and on-farm use (false sense of security)
- Soap/Detergent data

Avian Disease, 2003

- 5 disinfectants effective at inactivating AIV; RNA still detected by RT PCR in samples inactivated with phenolic and quaternary ammonia (false +)
- RTPCR can be used to assure proper cleaning and disinfection with certain disinfectants

Avian/Pandemic Influenza

United States
Environmental Protection
Agency

PRESORTED STANDARD
POSTAGE & FEES PAID
EPA
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