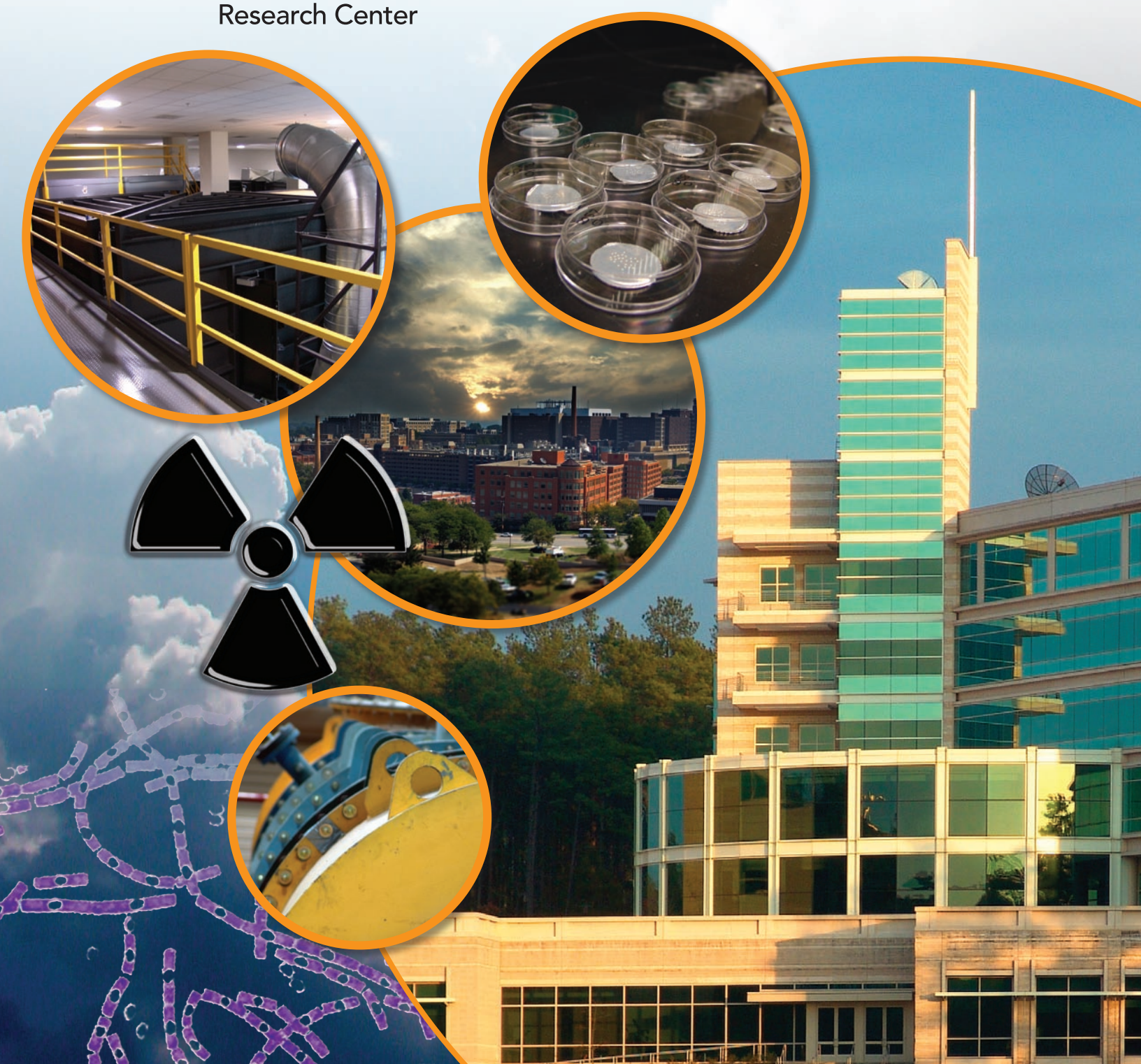
United States
Environmental Protection
Agency

RESEARCH REPORT

# Decontamination, Cleanup, and Associated Issues for Sites Contaminated with Chemical, Biological, or Radiological Materials

Office of Research and Development
National Homeland Security
Research Center



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EPA/600/R-05/083
October 2005

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

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Contract No. EP-C-04-056
Office of Research and Development
U.S. Environmental Protection Agency
Cincinnati, OH 45268

# Note

The majority of this report was prepared by Sarah Dun of Eastern Research Group, Inc. (ERG), an EPA contractor, as a general record of discussion for the "Workshop on Decontamination, Cleanup, and Associated Issues for Sites Contaminated With Chemical, Biological, or Radiological Agents." Joseph Wood was coauthor and editor of technical content. 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.

The production of this document has been funded wholly by the United States Environmental Protection Agency under Contract No. EP-C-04-056 to ERG.

# Table of Contents

# List of Abbreviations and Acronyms

| | |
|---|---|
| ANL | Argonne National Laboratory |
| ARL | Army Research Laboratory |
| ASTM | American Society for Testing and Materials |
| ATSDR | Agency for Toxic Substances and Disease Registry |
| BASIS | Biological Aerosol Sentry and Information System |
| °C | degrees Celsius |
| CARC | chemical agent resistant coatings |
| Ci | curie |
| CDC | Centers for Disease Control and Prevention |
| $cm^2$ | square centimeter |
| CWA | chemical warfare agent |
| DCMD | Decontamination and Consequence Management Division |
| DDAP | Domestic Demonstration and Application Program |
| DEFRA | Department for Environment, Food, and Rural Affairs |
| DHS | Department of Homeland Security |
| DIMP | diisopropyl methylphosphonate |
| DoD | Department of Defense |
| DoE | Department of Energy |
| ECBC | Edgewood Chemical Biological Center |
| eLRN | Environmental Laboratory Response Network |
| EPA | Environmental Protection Agency |
| ETV | Environmental Technology Verification |
| °F | degrees Fahrenheit |
| FBI | Federal Bureau of Investigation |
| FIFRA | Federal Insecticide, Fungicide, and Rodenticide Act |
| $ft^2$ | square foot |
| $ft^3$ | cubic foot |
| g | gram |
| GC | gas chromatograph |
| GDS | Government Decontamination Service |
| HVAC | heating, ventilation, and air conditioning |
| JPL | Jet Propulsion Laboratory |
| kg | kilogram |
| L | liter |
| LANL | Los Alamos National Laboratory |
| LBNL | Lawrence Berkeley National Laboratory |
| LLNL | Lawrence Livermore National Laboratory |
| LRN | Laboratory Response Network |
| $m^3$ | cubic meter |
| min | minute |
| mg | milligram |
| mrem | millirem |
| mVHP | modified vaporous hydrogen peroxide |

| | |
|---|---|
| NAS | National Academy of Science |
| NHSRC | National Homeland Security Research Center |
| NIOSH | National Institute for Occupational Safety and Health |
| NMRC | Naval Medical Research Center |
| NRT | National Response Team |
| OPCW | Organization for the Prohibition of Chemical Weapons |
| OPP | Office of Pesticide Programs |
| ORD | Office of Research and Development |
| OSHA | Occupational Safety and Health Administration |
| OSC | on-scene coordinator |
| PCR | polymerase chain reaction |
| PNNL | Pacific Northwest National Laboratory |
| ppb | parts per billion |
| ppm | parts per million |
| PROTECT | Program for Response Options and Technology Enhancements for Chemical/Biological Terrorism |
| PVC | polyvinyl chloride |
| RDD | radiological dispersion device |
| RIMNET | Radiation Incident Monitoring Network |
| RVTP | Rapid viability test protocol |
| Sabre | Sabre Technical Services |
| SAFTEY Act | Support Anti-terrorism by Fostering Effective Technologies Act of 2002 |
| SNL | Sandia National Laboratory |
| STERIS | STERIS Corporation |
| TAGA | Trace Atmospheric Gas Analyzer |
| TSM | Three-Step Method |
| TSWG | Technical Support Working Group |
| UK | United Kingdom |
| USAMRIID | U.S. Army Medical Research Institute of Infectious Diseases |
| USAR | Urban Search and Rescue |
| USCG | U.S. Coast Guard |
| USPS | U.S. Postal Service |
| UV | ultraviolet |
| VERIFIN | Finnish Institute for Verification of the Chemical Weapons Convention |
| VHP | vaporous hydrogen peroxide |

# Executive Summary

The Decontamination and Consequence Management Division (DCMD) of EPA's National Homeland Security Research Center (NHSRC) held its first "Workshop on Decontamination, Cleanup, and Associated Issues for Sites Contaminated With Chemical, Biological, or Radiological Materials" at the International Trade Center Building in Washington, D.C., February 23–25, 2005. The workshop opened with a plenary session. The subsequent 31 presentations addressed 5 topics: the decontamination process, decontamination technologies, research and development, lessons learned, and radiological contamination. The speakers represented national laboratories and federal agencies such as EPA, the Department of Homeland Security, the Postal Service, the Department of Defense, the Centers for Disease Control and Prevention, and the FBI; academia; and key companies conducting research or providing decontamination technologies and services. Representatives from Great Britain provided the United Kingdom perspective on decontamination issues.

## Plenary Session

Blair Martin, of EPA's National Risk Management Research Laboratory, moderated the workshop and gave the opening remarks. Martin participated in most of the decontamination activities for the buildings that were contaminated with *B. anthracis* spores sent through the mail in the fall of 2001. These bioterrorist events were the primary impetus for forming EPA's NHSRC, and the majority of discussion at the workshop was related to building decontamination. All of the affected buildings have now been successfully decontaminated. Martin discussed the elements of a decontamination event and noted that the actual destruction of spores (accomplished mostly via fumigation) represents only a small portion of the overall time and cost of a decontamination event. The elements of building decontamination also include establishing a decision-making process; characterization, sampling, and monitoring of contaminants and decontamination chemical levels; building preparation; the decontamination; materials disposal plan; and overall communications

Lance Brooks discussed the Department of Homeland Security (DHS), Science and Technology Directorate's biological and chemical restoration programs (referred to as DDAP, i.e., Domestic Demonstration and Applications Programs). He discussed some of the projects under way or being planned, most of which focus on transportation systems and wide urban areas. These projects involve (or will involve) technology demonstrations, tabletop exercises, and the development of template response plans and protocols for particular scenarios, all designed to reduce the time to get critical facilities or areas restored and operational. One completed project discussed was the Biological Aerosol Sentry and Information System (BASIS), a precursor to the Biowatch program, which is a network of monitors (with subsequent laboratory analysis) set up in major urban areas as an early warning system to detect aerosolized biological agents.

The Federal Bureau of Investigation (FBI) faces many challenges with forensics sampling and crime scene management following an incident involving chemical, biological, or radiological weapons, according to Benjamin Garrett of the FBI. These challenges include determining that a deliberate release (as opposed to a natural event) has occurred, knowing where to sample, and conducting analyses of evidence without harming the investigator or damaging the evidence. The primary purpose of sampling by the FBI is to gather evidence. By contrast, EPA conducts sampling to characterize the extent of contamination and determine the effectiveness of decontamination. The FBI should share its data with other agencies such as EPA and the Centers for Desease Control and Prevention (CDC), but the involved parties need to devise a process for doing so without harming the FBI's investigation.

## Session 1: The Decontamination Process

Nancy Adams, Director of the DCMD/NHSRC, noted that her division conducts research and develops technologies related to incidents involving biological, chemical, and radiological agents. Efforts focus on decontamination science and technology, sampling methods, contaminant containment, tracking contaminant movement, and disposal. Adams's presentation detailed the methods used by NHSRC to rank threats. These involve the identification and ranking of high-priority agents, identification and ranking of likely terrorist targets, and identification of terrorist goals (e.g., loss of life, economic damage, and inducing fear). These

components are combined to couple threat agents with target facilities and to develop likely terrorist scenarios. She compared the DCMD threat-ranking approach to those developed by other agencies and noted that NHSRC uses the ranking results primarily to guide decontamination research efforts.

The CDC's Kenneth Martinez explained that although the primary purpose for environmental sampling is to address public health concerns, sample collection and analytical methods are similar regardless of whether the data will be used for public health decisions, scene characterization, or crime scene investigation. Environmental sampling may identify agent sources, assess the nature and extent of contamination, support risk assessment and public health decisions, identify people needing medical treatment, and guide reoccupancy decisions. The three sampling phases in a response are screening, characterization, and restoration. The CDC has developed a sampling protocol for *B. anthracis* spores and is investigating and validating sampling and analytical methods for bio-contaminants, focusing in particular on surface sample collection efficiencies, air sampling, methods comparison, and variability issues.

Steve Tomasino described EPA's Office of Pesticide Programs (OPP) research and development of biological agent analysis methods, in particular OPP's evaluation of laboratory sporicidal efficacy test methods. EPA regulations require the Association of Official Analytical Chemists (AOAC) sporicidal activity test to register and approve the use of a chemical to be used as a decontaminant for a particular microorganism such as *B. anthracis*. This test has a number of limitations, for example, the results are qualitative, the test requires 21 days for incubation, and the test lacks standardization. OPP has identified potential modifications to the existing AOAC method and two new promising methods that they are currently testing with surrogates: one developed by the American Society for Testing and Materials (ASTM) and one referred to as the three-step method (TSM). OPP submitted the study results to an expert panel, which selected TSM as the preferred method. As part of ongoing efforts, OPP will conduct additional surrogate studies with TSM beginning in April 2005. The TSM will undergo a multi-laboratory validation study in September 2005, and a summary report of findings is due in December 2005.

Registration of bio-decontamination chemicals requires test data regarding product chemistry, product toxicity, and product efficacy using the AOAC test, according to Jeffrey Kempter of EPA's OPP. When the anthrax attacks occurred in September and October 2001, no products were registered for use against *B. anthracis*. Accordingly, crisis exemptions had to be issued for each decontamination chemical for use at each contaminated site. Crisis exemption requests had to include remediation action plans, sampling and analysis plans, and ambient air monitoring plans. OPP granted crisis exemptions for four liquid *B. anthracis* sporicides for use on hard, nonporous surfaces only: aqueous chlorine dioxide, hydrogen peroxide/peracetic acid, sodium hypochlorite, and hydrogen peroxide/quarternary ammonium foam. Five gases have received crisis exemptions: gaseous chlorine dioxide (for buildings), vaporized hydrogen peroxide (for buildings), paraformaldehyde (for equipment in tented enclosures), methyl bromide (for laboratory and field study), and ethylene oxide (for specialized off-site treatment of specific items). Although no chemicals have yet been registered for *B. anthracis* decontamination, OPP is moving toward that goal.

Mark Durno and Tony Intrepido gave a joint presentation on building sampling and clearance issues. A technical assistance document prepared by EPA's National Response Team details a sampling approach for any biological incident. Other agencies are conducting studies related to sampling approaches and analytical techniques. For collecting field data, there are several methods, including hand-held assays, infrared sensors, and rapid polymerase chain reaction (PCR) testing. Verification sampling (following decontamination, to determine efficacy and to allow for reoccupation of the building) typically has been exhaustive, but as research advances and laboratory techniques become more relevant to field applications, this process will become more efficient.

Dave Mickunas, of EPA's Environmental Response Team, discussed the Trace Atmospheric Gas Analyzer (TAGA) for real-time monitoring of chemical warfare agents (CWAs) and fumigants (such as chlorine dioxide) in ambient air. EPA's TAGA consists of an Atmospheric Pressure Chemical Ionization (APCI) source coupled to a three-quadrupole mass spectrometer. Mickunas is developing CWA spectra and calibration curves and conducting other analyses, such as verifying detection limits, determining the dynamic linear range, establishing surrogates, and identifying interferences. The TAGA is situated in a mobile unit (a van) and has been successfully used at *B. anthracis* decontamination events to detect fumigant leaks.

In the decontamination of postal facilities, the United States Postal Service (USPS) accepted full liability and assigned broad indemnity to the decontamination contractors, according to Jerry Robinson, an attorney for the USPS. To minimize their risk, the USPS then obtained a $100 million insurance policy, which cost $4 million. However, in a future incident, most government agencies will not be able to indemnify decontamination vendors because these agencies are not allowed to enter into the open-ended contracts required for indemnification. Decontamination contractors should obtain a SAFETY Act designation and certification for their technologies, which would allow them to be immediately available to perform decontamination services. To be certified, however, vendors must purchase insurance.

Marty Powell explained that an EPA on-scene coordinator (OSC) has two primary responsibilities: to determine whether the contaminant poses a threat to the public or environment and to ensure that the threat is mitigated. Oddly enough, "on-scene" indicates involvement in an event *without* requiring a physical presence. The OSCs are coordinators, not commanders; they direct federal response assets. OSCs draw from a large tool box of resources (e.g., contractor support, scientific support, special units, and public relations support teams) and provide these resources to local and state agencies. The OSCs ensure that the remediation work at a site is completed properly. They have the ability to make decisions at a site without obtaining a permit.

Robert Bettley-Smith, of the UK Department for Environment, Food, and Rural Affairs (DEFRA), described his country's Government Decontamination Service (GDS). The GDS will be a DEFRA agency and will be formally established in summer 2005. The GDS will provide guidance and identify resources, such as information about vendors, their capabilities, and their technologies. In the UK, authorities at the county level are responsible for hazardous events and have experience with chemical transport and releases, but they lack experience with biological events. Therefore, GDS will focus its efforts on such events and develop a response plan. The agency is considering establishing a centralized data system to facilitate the sharing of knowledge across nations and to prevent research overlap.

Rob Rothman, of EPA/NHSRC, addressed the development of standard analytical methods and laboratory capacity issues. EPA has identified 109 priority agents and specific analytical methods for various matrices. Revisions to these standard analytical methods are scheduled for June 2005. They will include updates to existing methods and will add new methods for analysis of drinking water, CWA degradation products, and four radiological agents. Laboratories must have the capacity to handle thousands of samples collected over the course of a response, from initial identification of the threat agent to cleanup, clearance, and surveillance. Most of the samples will be taken in the first few months, but some sampling will be conducted years after the event. To address capacity concerns, EPA is working with the CDC to develop a three-tiered Environmental Laboratory Reference Network (eLRN), similar to CDC's existing LRN. The network would include screening or sentinel labs, confirmatory labs, and reference labs.

## Session 2: Decontamination Technologies

John Mason gave an overview of his company's technology. Sabre Technical Services (Sabre) has experience with *B. anthracis* decontamination, using chlorine dioxide fumigation at the AMI building in Boca Raton, Florida; on contaminated containers in Newark Harbor; and at a facility in Utica, New York, where tenting was used to seal the building. With the Sabre technology, sodium hypochlorite is reacted with HCl to produce chlorine gas; the chlorine gas is then reacted with sodium chlorite solution to produce aqueous $ClO_2$, which is then stripped to the air. At AMI, Sabre used the building's HVAC system to distribute the fumigant in order to achieve a concentration of 750 parts per million (ppm) for a 12-hour period. Approximately 200 biological indicator test strips were placed throughout the building, and in post-treatment sampling, all strips indicated no growth. Tracking sample locations and communicating results were two concerns when dealing with hundreds of samples. Sabre has developed software that produces a three-dimensional sampling map to address these concerns.

Most of STERIS Corporation's decontamination experience involves using vaporous hydrogen peroxide (VHP) for bio-decontamination in pharmaceutical and clean room applications, according to Iain McVey. Because of this, his company was selected to fumigate two *B. anthracis*-contaminated government buildings. STERIS is currently collaborating with the DoD to demonstrate decontamination of chemical agents, using "modified VHP," and to develop a mobile VHP generating system. A

benefit of VHP is that it decomposes to water and oxygen so residual contamination is not a concern. However, the rapid decay of VHP also means that repeated injections are needed to ensure that the proper concentration is reached. Multiple injection points may be the best option for optimal distribution.

Mike Herd, of BIOQUELL, Inc., discussed his company's hydrogen peroxide vapor technology for room and building decontamination. The technology works by flash evaporating a 30 percent to 35 percent aqueous hydrogen peroxide solution until a micro-condensate forms on surfaces within the treatment area. Data showed that the micro-condensate greatly improves the kinetics of decontamination. The system is designed to apply to buildings of any size and consists of self-sufficient units that can be chained together. Hydrogen peroxide vapor tends to form strong hydrogen bonds between the molecules, which limits its movement in air, so the BIOQUELL system uses a rotating nozzle system that distributes the vapor dynamically. BIOQUELL participated in tests by EPA's Environmental Technology Verification (ETV) program to determine its technology's effectiveness in destroying *B. anthracis* spores on seven different building materials. Herd discussed several case studies to illustrate the application and effectiveness of the technology.

Methyl bromide is commonly used for termite control and for fumigation of imported produce, according to Rudolf Scheffrahn of the University of Florida. In conjunction with EPA, he has conducted laboratory and field studies to assess methyl bromide as a fumigant for *B. anthracis.* In the 2004 field study, a 30,000-$ft^3$ home was first sealed using tenting, as is commonly done for termite treatments in Florida. Gaseous methyl bromide was generated by passing the liquid through a heat exchanger. Better destruction efficiency with methyl bromide is achieved with higher temperatures, so fans and heaters maintained a target temperature of about 35° C within the house. After fumigation for two days, essentially all 50 spore strips placed throughout the house indicated no growth. No damage to electronic equipment was observed. Schaffrahn opined that the advantages to methyl bromide are that it diffuses readily; is very stable, easily detected, and low in cost; can be used with any humidity level; has already been approved to treat some bacteria; and treats porous and other types of materials with minimal damage. A disadvantage is that it depletes stratospheric ozone.

Rita Betty of Sandia National Laboratory (SNL) presented a report on the testing of a decontamination formulation (DF-200) for CWAs, toxic industrial chemicals, and biological agents and for combating aerosolized chemical and biological agent clouds. DF-200 is an aqueous-phase formula that has been used successfully by the military. The commercial product is a mixture of surfactant, hydrogen peroxide solution, and a novel activator. After mixing on site, the final hydrogen peroxide concentration is about 3.5 percent. DF-200 is less corrosive than bleach and other available decontamination materials. SNL tested DF-200 with GD (soman), HD (mustard gas), and the nerve agent VX in stirred reactor studies and achieved 100 percent decontamination of live agents after a 60-minute exposure period. In other studies, DF-200 rapidly (within a 15-minute exposure period) neutralized nerve agents, sodium cyanide, phosgene, and carbon disulfide, as well as biologicals (*B. anthracis* and *Y. pestis*). Mustard agents required more time (a 30-minute exposure period) because of mustard's low solubility. The DF-200 residue in indoor areas can be removed using a wet-dry vacuum.

According to Jack Kelly, of EPA, ricin is a white powder that can be made fairly easily from the proteins of castor plant beans. Ricin is considered extremely toxic by any exposure route, and no vaccines or antidotes are available. On February 2, 2004, ricin was found in the mail room attached to a United States senator's office. EPA et al. had collected at least 670 samples from three affected rooms and identified 19 positive results, all from one room. EPA removed and stored personal and office items from the affected room. Large hard-surface items were left in place and decontaminated with a sodium hypochlorite solution. Post-treatment testing found no ricin activity. Clothing and office materials, along with indicator vials of crude and pure ricin, underwent heat treatment, which resulted in 100 percent deactivation of 13 of the 14 purified ricin vials and 94.4 percent to 99.7 percent deactivation for 14 of the 28 crude ricin vials. Another set of office materials underwent a single heat treatment and/or ethylene oxide treatment. Results from test vials undergoing ethylene oxide treatment alone or heat followed by ethylene oxide treatment indicated that the combined treatment was most effective.

Richard Orlusky highlighted the USPS's experiences in restoring the Trenton mail facility after completing decontamination. Although *B. anthracis* contamination of the Trenton facility occurred in 2001, the building was not reopened until March 2005. Fumigation with

chlorine dioxide gas did not occur until October 2003, and restoration activities began in February 2004. The USPS kept the HVAC systems running after closing the building, but over time, components of the system failed, resulting in interior temperatures reaching 100°F. Restoring environmental controls is key to creating a comfortable work environment (repairs were conducted by workers wearing personal protective equipment) and to minimizing equipment and building degradation. If fumigation is the selected decontamination method, then surface cleaning with a bleach agent should be conducted sparingly, since it is highly damaging to many materials. Additional chlorine dioxide research may show effective decontamination at lower concentrations and reduced contact times, which may reduce damage caused by the fumigant itself.

Paula Krauter, of Lawrence Livermore National Laboratory (LLNL), presented research on developing a rapid viability test protocol (RVTP), which is a 15-hour method for processing biological indicator strips using real-time PCR. They compared the RVTP against the standard culture method, which requires 7 days for results. Testing involved exposing more than 1,000 biological indicator strips to 750 ppm of chlorine dioxide for up to 12 hours (a number of these strips were exposed for less than 12 hours). Half of the strips were analyzed by RVTP and half by the standard culture technique. In general, no significant difference in results provided by the two methods was identified. The standard culture method reported a 1.5 percent false positive rate. No false negatives or positives were observed for RVTP. Tests to compare stainless steel and paper strip biological indicators were also conducted. At non-lethal doses of chlorine dioxide, LLNL found a significantly higher number of positive results for the paper strips, i.e., better kill was indicated with the stainless steel disks.

## Session 3: Decontamination Research and Development

Mark Brickhouse, of the U.S. Army's Edgewood Chemical and Biological Center (ECBC), described the work with public- and private-sector researchers to evaluate a number of emerging decontamination technologies. These include modified VHP, which contains ammonia as an activator for both chemical and biological decontamination. "Forced hot air" acts to accelerate weathering and increases off-gassing for chemical agents but is insufficient for treating biological agents. Decon-Green is an environmentally friendly decontaminant based on commercial chemicals and is designed to replace DS2 and DF-200 in military use. Studies have proven Decon-Green to be effective against chemical and biological agents, but it is disruptive to surfaces. Surface coatings are being developed to either resist or react with and destroy chemical or biological agents. Enzymes to decontaminate nerve agents, sulfur mustard, and biological agents and toxins are being investigated. Supercritical carbon dioxide is an effective cleaning and sterilizing agent and is being investigated as a decontamination technology.

Phil Koga, of ECBC, discussed a systematic decontamination study funded by EPA. This study will assess the impact of fumigant (chlorine dioxide and hydrogen peroxide vapor) concentration, exposure time, building material (porous and nonporous), temperature, and relative humidity on destruction of different microorganisms (e.g., avirulent and virulent *B. anthracis* spores and surrogates). In addition, testing seeks to provide information about the effects of six different building materials on the decay of fumigant concentration in test chambers (e.g., velocity deposition will be quantified) and the effects of the fumigants on the integrity of the building materials.

Tina Carlsen, of LLNL, discussed research on examining both decontamination of HVAC systems using hydrogen peroxide vapor and the use of HVAC systems in the fumigation process. Tests with VHP in a medium-scale HVAC system indicated that galvanized steel reduced the hydrogen peroxide concentration, whereas PVC had less of an effect. In another test, using 90 feet of galvanized steel ductwork with sensors located throughout, the hydrogen peroxide concentration decreased as a function of distance traveled along the ductwork, and VHP decreased with increasing temperature and decreasing flow rate. Ongoing research will include biological indicator tests within the ductwork to characterize kill rates and optimize VHP efficacy as well as characterization tests with alternate ductwork materials.

Research at the University of Texas is focusing on building material impacts on fumigant levels and gaseous byproduct production, in a project lead by Rich Corsi. Corsi stated that the research includes an evaluation of the chemical interactions of ozone, chlorine dioxide, methyl bromide, and hydrogen peroxide vapor with 24 common building materials; quantification of deposition velocities; identification of building decontamination

byproducts; and incorporation of the results into a novel software application. Results show significant differences among disinfectants. Byproduct persistence was also likely, as indicated by 5-day and 1-year tests of off-gassing. For most materials, with the exception of ceiling tiles and HVAC system components, ozone was more reactive than chlorine dioxide.

Mark Buttner discussed the research at the University of Nevada Las Vegas (UNLV) to test the efficacy of two decontamination products (DF-100 and chlorine dioxide gas); compare surface sampling methods (swipe, heavy wipe, and swab sample processing kit); and compare analytical techniques for biological agents, using cultures, quantitative polymerase chain reactions (PCRs), and hand-held assays. Other experimental parameters included the effects of building material and environmental background (e.g., dust) on the decontamination method. Each of the three sampling methods demonstrated comparable spore collection efficiencies. After decontamination with DF-100, post-decontamination samples found no culturable spores although the quantitative PCR analysis indicated that spore DNA remained. Similarly, after decontamination with chlorine dioxide, post-decontamination samples found no culturable spores in 24 of 27 samples, but quantitative PCR analysis indicated that spore DNA remained. The hand-held assay results were positive for all samples. Neither decontamination method was affected by environmental background, although the quantitative PCR analysis method was inhibited by the dust.

An overview of EPA's Environmental Technology Verification (ETV) program for decontamination technologies was presented by Mike Taylor of Battelle Memorial Institute. Three decontamination technologies (all fumigants) have been verified so far: BIOQUELL, Inc.'s hydrogen peroxide gas; Certek, Inc.'s formaldehyde gas, and CDG Research, Inc.'s chlorine dioxide gas. The verification procedure consisted of connecting the decontamination technology to the test chamber, inoculating test material coupons (representing seven different materials) with 108 spores of *B. anthracis* or surrogates, placing the coupons in the test chamber, implementing the decontamination technology, removing the test material coupons, and analyzing the coupons. Decontamination efficacy was quantified by calculating the log reduction in viable spores on the test materials and by identifying positive or negative bacterial growth on the biological indicators and spore strips. It was noted that homeland security related technologies would no longer be verified under ETV but would be tested under a new EPA NHSRC program called the Technology Testing and Evaluation Program (TTEP).

According to Rebecca Blackmon, the Technical Support Working Group (TSWG) is an independent federal agency, with oversight from DoD and the Department of State, that does rapid R&D and prototyping to support federal agency requirements. The Chemical, Biological, Radiological, and Nuclear (CBRN) subgroup focuses on agent detection, decontamination, protection, and information collection, with ongoing projects. The biological background in critical facilities is being investigated, since it may interfere with detection of actual bio-agents. A statistical design tool for sampling contaminated buildings is under development. In conjunction with others, TSWG is developing a real-time, portable sensor system to monitor CWAs and toxic industrial chemicals. Another sensor web is being developed to monitor and control building temperature, humidity, light intensity, and decontaminant agent concentrations for a facility undergoing decontamination. Decontamination technologies using plasma and electrostatics are being developed. Other technologies are being developed to mitigate the spread of radiological releases and remove radiological contaminants from building materials.

## Session 4: Lessons Learned and Research and Development Needs

Panelists and other participants at the workshop provided numerous examples of lessons learned from the decontamination activities that took place following the *B. anthracis* incidents in 2001. These are summarized below in four main categories. During this discussion, several participants also noted research that is needed; a summary of these items follows.

**Interagency coordination and information/data sharing** Workshop participants emphasized the importance of information/data sharing and coordination not only during a response action, but also during ongoing research. They provided examples of information sharing and coordination efforts, suggested tools to improve these efforts, highlighted the benefits of sharing information while addressing research needs, and noted security concerns to consider. Several workshop participants (primarily OSCs) emphasized the need for

information (e.g., on decontamination methods) when responding to an event. Several participants suggested the development of databases or repositories of information on technologies, agents, available laboratories, test methods, technical experts, etc. Others noted that this workshop was a great way for information exchange and that this type of workshop should be continued.

**Preparedness** Workshop participants all agreed that planning and preparing for the aftermath of a terrorist event is critical to responding quickly and appropriately. They suggested a number of ways facilities and agencies could prepare. Workshop participants repeatedly suggested exercises (especially tabletop) as a means of identifying possible threat scenarios, developing response plans, and pinpointing data gaps. They suggested interagency panels and peer reviews for these exercises. The focus of such exercises typically becomes the technical aspect of the response plan, but in a real-world situation, the technical side of a response may be easy compared with regulatory or communication issues. Examples of materials that would help prepare agencies and facilities include a matrix to link threat agents with appropriate decontamination methods and site conditions, template response plans, and standards/protocols (e.g., for sampling).

**Sampling issues** Workshop participants expressed diverse views regarding sampling issues. Some suggested minimizing sampling requirements to streamline a decontamination event because it consumes much of the overall response time. Others believed that eliminating one or more of the sampling phases (characterization, verification, or clearance) would be detrimental to the process. Participants also voiced differences of opinion over the utility of biological indicators in assessing environmental contamination. Decontamination events rely on biological indicators (e.g., spore strips), but results from these tests may not correlate well with environmental conditions (i.e., actual levels of spores). One participant noted that no positive environmental samples were found in the *B. anthracis* decontamination when the biological indicators were negative and desired fumigant concentration had been achieved.

**The decontamination process** A number of buildings have now been bio-decontaminated, and participants noted many specific lessons learned. When fumigation is the selected decontamination method, the fumigation itself is only a small portion of the overall decontamination timeline. Sealing a building can be costly and time-consuming, but tenting is an effective technique. Preserving sensitive and valuable materials should be considered when one is selecting a decontamination technology. Leave as much material as possible inside a building for fumigation to alleviate disposal concerns. Agencies working with an OSC need to understand the command structure at a decontamination event. An environmental clearance committee supports local agency decisions about when it is safe to reoccupy a building by providing information and credibility. The clearance committee itself does not make decisions. To support an OSC, however, technical working groups should consist of people who are authorized to make decisions for their agencies.

The following is a compilation of suggested research and development needs, as discussed during the R&D panel discussion, as well as during the Lessons Learned discussion. Nancy Adams noted that some of the suggested research items are currently being investigated or are already planned for future investigation.

**Decontamination**

- Real-time monitoring of fumigants
- Tenting as a means of sealing a building
- Cost analysis of an overall decontamination event, including the disposal and restoration
- The chemical interactions and reaction products between decontaminants, threat agents, background (e.g., dust, organic material), and materials (common building materials but also sensitive/valuable equipment)
- Risk and exposure assessment of biological agents to establish safe levels for reoccupation

**Sampling and Analysis**

- Correlating environmental samples to biological indicators; understanding the basic science of biological indicators (BIs); developing new BIs using more common materials such as carpet, or worse-case materials, in lieu of typical BI materials such as paper or steel
- Real-time monitoring technology (e.g., developing faster, cheaper, and better technologies) for all types of agents
- Background levels of live bio-agents

- Comparison of surface sampling methods for bio-agents
- Using statistics for sampling design and standards
- New analytical techniques, such as rapid testing protocols
- Methods for sampling irreplaceable items (e.g., paintings or historical documents)
- Identification of better surrogates

**Other threat agents**

- Interactions of chemical and radiological agents with various materials
- Applicability of chelaters, HEPA filters, and other decontamination technologies to radiological agents

Most of the information presented during the workshop applied to *B. anthracis*. A number of workshop participants mentioned the need to expand research related to the decontamination of other chemical, biological, and radiological threat agents. Agents specifically mentioned included ricin.

**Containment**

- Aerosolization, dispersion, and resuspension of biological and radiological agents
- Surface coatings and building materials that serve as biocides or limit chemical infiltration
- Smart building systems, e.g., specially designed HVAC systems to limit agent spread

**General**

- Research is needed to address decontamination of wide, outdoor areas, including agricultural product decontamination and disposal, and multiple agent attack events.
- Identifying dual-use technologies would help us prepare by allowing us to develop technologies and manufacture equipment before the next event occurs.
- Biotechnology-based decontamination approaches (bacteria, enzymes) are needed.
- A panel of experts distant from ongoing decontamination discussions and research should be convened to independently review the collective research efforts ongoing at various agencies and facilities.

## Session 5: Radiological Dispersion Device Cleanup

Fred Holbrook and John MacKinney, from EPA's NHSRC, each presented information related to radiological dispersal devices (RDDs). RDDs use conventional explosives to disperse radioactive materials. It is expected that these devices would cause low-level radiological contamination and cause psychological and economic harm but that fatalities would be low. Among the radiological agents that are potential components of RDDs, cesium fluoride is of particular concern because it is a fine, talclike powder, which is easily dispersed over a broad area.

Worldwide control of radiological materials is a problem, as evidenced by the large amounts of missing and unaccounted-for radioactive material. Because of this, most experts believe an RDD event is the most probable homeland security threat. Tests are being conducted to examine whether a radiological agent will aerosolize and how the shape of the charge may affect dispersion; models are being developed to predict possible dispersion patterns. Studies of particle dispersion have shown that indoor particulate concentrations following an event may be high. Using threat scenarios, we can create standard response and mitigation procedures, plan possible cleanup actions, and evaluate existing technologies. DHS is assessing possible optimized approaches to decontamination and restoration after an RDD release and considering cleanup criteria based on societal needs, expected land uses, and decontamination technologies. Radiological decontamination techniques are based on mechanical, chemical, or biological removal; some chemical methods include the use of acids, chelants, foams, gels, oxidizers, and polymers.

According to Malcolm Wakerley, after the Chernobyl nuclear incident, the UK created the Radiation Incident Monitoring Network (RIMNET). This system consists of 92 gamma detectors (located approximately 30 kilometers apart) that supply data to a group of laboratories. Information from these sensors helped the UK identify areas of contamination after the Chernobyl accident. The RIMNET system includes a modeling component that can assess short-, medium-,and long-range impacts and is linked with meteorological data to backtrack from an alarmed detector to a radiation source. Additionally, the UK has created a handbook in response to a review of decontamination and remediation technologies conducted

following a series of other radioactive accidents. The handbook includes a simple logic diagram and 22 tables on decontamination technologies and considerations.

The UK plans to maintain the handbook over the next three years and add lessons learned from exercises and case studies.

# 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 February 23–25, 2005, in Washington, D.C. The workshop objectives were to:

- Allow agencies, organizations, and individuals to share information about the decontamination of chemical, biological, and radiological releases. Specific topics addressed included elements of a decontamination event and ways to reduce the response time and cost; decontamination technologies used in real-world situations (e.g., anthrax events in the United States, hospital decontamination projects worldwide); and research and development projects underway or planned by various organizations and agencies.
- Discuss some of the lessons learned about the decontamination process and suggest steps to improve that process.
- Identify research needs to fill data gaps and articulate opportunities for improving the current understanding of the decontamination process.

Workshop participants included representatives from federal agencies and laboratories (e.g., the Environmental Protection Agency, the Department of Homeland Security, the Centers for Disease Control and Prevention, the Federal Bureau of Investigation, Lawrence Livermore National Laboratory, and Edgewood Chemical Biological Center), academia, and decontamination technology companies. During the workshop, speakers gave presentations on specific topics, including decontamination event experiences, decontamination technologies, current and planned research projects, and radiological agent concerns. Following each presentation, speakers held a brief question and answer period. On the third day of the workshop, participants engaged in two free-flowing discussion sessions. During the first session, participants were asked to share the lessons learned during research projects and real-world decontamination events. The second session focused on areas and topics in need of further research. Both discussion sessions allowed participants to elaborate upon the questions and issues raised during the presentations.

This report summarizes the information provided and issues raised during the workshop presentations and associated question and answer periods. It also summarizes the content of the discussion sessions. The technical content of this report is based entirely on discussions at the workshop.

Although workshop presentations and discussions addressed a number of individual topics, workshop participants raised several key issues to consider during ongoing research and future decontamination efforts:

- **Information sharing and interagency coordination** Workshop participants repeatedly emphasized the importance of information sharing and coordination during a response action, as well as ongoing information sharing among researchers. During presentations, speakers provided examples of both effective and ineffective information sharing. They consistently indicated that better information sharing leads to faster, cheaper, and easier decontamination efforts. During the discussion sessions, workshop participants suggested tools for improving the sharing of information, highlighted the benefits of sharing information while addressing research needs, and noted security concerns to consider.
- **Preparedness** Workshop participants agreed that planning and preparing for threat events is critical to responding quickly and appropriately to these events. Presentations highlighted a number of research projects that focus on preparing facilities, specifically airports and transportation centers, for future terrorist events and identifying possible response actions. During the discussion sessions, workshop participants suggested a number of ways facilities and agencies could prepare for a terrorist event.
- **Sample methodology and design** Workshop participants discussed sampling concerns related to research projects and decontamination events. When discussing research projects, workshop participants voiced concerns about developing standardized sampling methods so that results were comparable across projects, as well as concerns about identifying appropriate surrogates. When discussing decontamination events, workshop

participants emphasized the need for clear sampling objectives, the utility of different sampling methods, and the need to streamline the sampling process. Some conflicting views were raised. For example, some suggested minimizing sampling requirements to streamline a decontamination event, whereas others believed that eliminating sampling phases would be detrimental to the process. Participants also voiced differences of opinion about the utility of biological indicators and spore strips in assessing environmental contamination.

- **Research needs** Workshop participants identified a number of research needs from basic research in fumigation chemistry and effectiveness to advanced research on sampling methods (e.g., developing cost-effective, real-time sampling methods). See the "Panel Discussion—Research and Development Needs" section of this report for further details.

# Opening Remarks

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

The Decontamination and Consequence Management Division (DCMD) of the U.S. Environmental Protection Agency (EPA) National Homeland Security Research Center (NHSRC) organized this workshop so that agencies, organizations, and individuals could share information about the decontamination of chemical, biological, and radiological releases. Specific topics included:

- Elements of a decontamination event and ways to reduce the response time and cost
- Decontamination technologies used in real-world situations (e.g., anthrax events in the United States, hospital decontamination projects worldwide)
- Research and development projects under way or planned by various organizations and agencies
- Lessons learned during real-world situations and research projects
- Additional research and development needs.

In fall 2001, *Bacillus anthracis* spores sent through the mail contaminated several United States Postal Service (USPS) buildings. Using a variety of methods, the USPS decontaminated these buildings. The removal and off-site decontamination of building contents, surface cleaning, and fumigation provided the backdrop to this workshop.

Drawing on his personal experience, Martin explained the elements of the decontamination process:

- **Selecting a decontamination technology** When selecting a decontamination method, considerations include building security, interagency relationships, incident command structure, preparation and review of technical documents, contractor selection, and crisis exemption applications and approvals. The last three items are pacing items that affect the project schedule.
- **Building characterization and monitoring** Characterization and monitoring, which can occur simultaneously, are conducted for several reasons. Forensic sampling, which tracks the movement of an agent from the release point, addresses the criminal aspects of an event. Characterization sampling identifies the nature and extent of contamination. Biological indicators, fumigation sampling, and environmental conditions sampling (i.e., temperature, humidity, and pressure) are used to ensure a successful fumigation. Outdoor monitoring of the fumigant ensures safety. Clearance sampling confirms successful decontamination and allows reuse of the building.
- **Decontamination** The decontamination event includes procuring, installing, testing, operating, disassembling, and finally removing the decontamination equipment. Procurement and testing are pacing items that affect the project schedule. Considerations during the decontamination event are system safety; the heating, ventilation, and air conditioning (HVAC) systems; and possible fumigant leak areas. The EPA trace atmospheric gas analyzer (TAGA), which is discussed in detail in a later presentation, is a mobile testing unit that was useful for identifying leaks during actual decontamination events. Over the course of a 2- to 3-year process, the actual decontamination or fumigation is a 1-day event. The fumigation may increase to 2 to 3 days if a no-growth endpoint is selected as the building clearance requirement. The cost of the fumigation itself is also only a fraction of the overall cost of the entire decontamination process.
- **Materials disposal** Materials may be removed from a building before or after decontamination. The decision whether to remove materials depends on their value, the ease of decontaminating them, their impact on the decontamination agent, and the impact of the decontamination agent on them. Final disposal options must also be considered. What special handling is needed to dispose of material removed from a building prior to decontamination? Can materials that are removed after decontamination be sent to nonhazardous waste landfills or incinerators? Waste disposal

also includes any wastes generated from the decontamination or fumigation effort itself.

- **Communication systems** A successful decontamination event relies on successful communication. Communication plans should include law enforcement agencies, health agencies, environmental regulatory agencies, advisory groups, contractors, on-scene coordinators (OSCs), building workers and occupants, as well as residents and businesses in the surrounding communities.

Martin also listed a number of building-related activities that need to be considered: orderly building closure; contamination containment, especially within the HVAC system; documentation to guide decontamination; and equipment storage needs. A building content assessment is needed to identify items that might be affected by treatment.

Finally, Martin indicated that workshop participants have a broad range of experiences with and perspectives about decontamination events. He hoped that they could openly share their knowledge over the course of the meeting.

# Presentations and Associated Question and Answer Periods

2

## DHS S&T Biological and Chemical Restoration Programs

*Lance Brooks, Department of Homeland Security*

This presentation provided a brief overview of restoration programs under way at the Department of Homeland Security (DHS).

Decontamination is being researched and evaluated by a number of agencies, such as EPA's Office of Research and Development (ORD), DHS's Homeland Security Advanced Research Projects Agency (HSARP), and the Systems Engineering and Development Office. DHS's role in researching, testing, and evaluating decontamination processes is outlined in the National Response Plan, which is scheduled for release on April 14, 2005. DHS hopes to coordinate efforts with EPA. More information is available at *www.HSARPAbaa.com*.

At the beginning of a project, DHS works with the decontamination-user community to identify and address their needs. The stated program goal is to provide "integrated field demonstrations of the next-generation solutions, which bring together the user, technology, and ConOps in a real-world test of a particular solution." In other words, DHS personnel are looking to answer the question of how biological or chemical agent decontamination will be conducted in the future. They work with off-the-shelf or government-owned technologies. Although DHS does not intend to develop technologies, it will, if necessary, work to further develop technologies near completion.

Projects conducted by DHS include:

- **Biological Aerosol Sentry and Information System (BASIS)** BASIS is geared toward providing enhanced biological security at special events and determining whether a biological release event has occurred. The system is easy to set up and deploy but has a limited operational period and covers a fixed location. It served as a platform for a newer program called BioWatch. Results reported from BASIS and BioWatch initiate treatment and response. BioWatch was used successfully during the Salt Lake City Winter Olympics and is now in place in about 30 metropolitan areas.
- **Program for Response Options and Technology Enhancements for Chemical/Biological Terrorism (PROTECT)** Developed in partnership with transit facilities, the project provides response plans and solutions for events in such facilities, for example, the sarin release in the Tokyo subway. DHS found that implementing the technology component of a response is often easier than addressing the response's regulatory, communications, and other aspects. In a demonstration project, PROTECT placed agent detectors and televisions in strategic positions in a transit facility. The system includes a laptop from which an incident commander could log into the system, control cameras, access software, and examine alarmed detectors to coordinate a response. The program also includes a formalized plan for operating the system and creates incident commander transparency. Using the system reduced response time from as much as 40 minutes down to 5 minutes.
- **Restoration of Large Airport Facilities** This program is in progress and focuses on the coordination and understanding of the restoration process for a large airport. San Francisco International Airport, for example, loses $80 million a day if closed. This is not a technology-driven project but focuses on condensing the decontamination timeline. The goal of the project is to reduce the time and money needed to restore a critical transportation facility after an attack. Under this project, DHS brought together stakeholders to conduct tabletop exercises, including a large-scale demonstration exercise to identify and address critical aspects of the response (e.g.,

development and approval of a decontamination plan, fumigation verification, facility clearance, and overall coordination and communication). Project products include templates that provide guidelines for developing response plans and protocols that are then pre-approved by EPA and other regulatory agencies. The project has specifically examined improving the verification step (i.e., rapid verification mechanisms), assessing sample placement to improve sampling clearance, using rapid bioviability sampling technologies, and developing decision support software. A project report is scheduled for release in late spring 2005.

The following projects are in the planning phase, and DHS is looking for a partner agency or organization:

- **Restoration of a Transit System** This project focuses on transit facilities, such as subways, that have open platforms, tunnels, and transport from below to above ground. These facilities present many different challenges. The overall project goal is to reduce time between the event and restoration. Revenue loss and street traffic impacts are problems when these systems shut down. This project will draw from the large airport facilities project and create templates for response plans and protocols (e.g., restoration plans, contamination characterization methods, decontamination and verification sampling for surface, clearance methods, decision tools) that apply to urban transit systems. A large-scale demonstration project is planned.
- **Restoration of a Wide Area (Urban)** This project focuses on open areas but will likely include indoor areas as well. In these areas, contamination migration to enclosed and semi-enclosed areas is a concern. The project goal is to reduce the overall time to restore a large outdoor urban area following a biological attack. As for other projects, DHS will develop strategies, templates, response plans, and protocols for addressing an event. Two smaller ongoing programs lead into this project. One focuses on technologies and protocols; the other examines overall policies. A large-scale demonstration project is planned.
- **Facilities Chemical Restoration Demonstration** The goal of this project is to reduce the overall time to restore a critical facility following a chemical attack. DHS will develop strategies, templates, response plans, and protocols for addressing a chemical release event. A large-scale demonstration project is planned.

## Questions, Answers, and Comments

- **How will DHS reduce the time required to complete a decontamination event?** DHS projects are geared toward understanding what aspects contribute to the time and personnel needed to complete decontamination and how these aspects can be adjusted to reduce the time frame. DHS is also exploring sampling software that can speed up the decontamination process.
- **Has DHS partnered with contractors or is DHS working to identify technologies to be used in place?** Demonstration projects are run through DHS and NHSRC. These agencies will partner with industries, as identified in the pre-demonstration phase.
- **What performance measures were used to declare BioWatch a success?** BioWatch has been implemented in partnership with EPA and the Centers for Disease Control and Prevention (CDC). The agencies determined BioWatch's success by reviewing a matrix of criteria. They concluded that the system was operational, reported no false positives, and had minimal downtime. BioWatch strives to provide biological security for as large an area as possible.
- **When detection systems are installed, when and how do you respond to a positive alarm? How does this procedure apply to BioWatch?** DHS works with EPA, CDC, and the FBI to confirm positive responses. When an alarm sounds, several layers of testing begin. In the first layer, the alarm is reported and agencies provide guidance to local organizations. Secondary testing occurs in areas around the positive sampler. Organisms, if detected, are checked for viability. Agencies then determine whether they can confirm that an event has occurred. Once an incident is identified, investigations move to the FBI and CDC. Participants should note that BioWatch is only one tool for determining whether an event truly has occurred.

# Crime Scene Management and WMD Terrorism

*Ben Garrett, Federal Bureau of Investigation*

When the FBI becomes involved in a decontamination event, its goal is to manage the crime scene and handle weapons of mass destruction. It is concerned about the criminal aspects of the event. As such, the FBI focuses on forensics, which is the collecting and gathering of evidence for the identification, prosecution, and conviction of the perpetrators.

Garrett identified four phases to an incident response:

- **Tactical** The tactical phase includes entering the affected building or area and removing the threat. A plan to enter the area without harm must be in place.
- **Operational** This phase involves protecting the public and mitigating hazards. The FBI involves local emergency response agencies in these efforts.
- **Crime scene** Evidence collecting, packaging, and transporting make up this phase.
- **Remediation** The FBI is not responsible for the cleanup or decontamination of a building or scene. EPA and other partners address that phase of a response.

Some considerations associated with the forensic aspects of an event include:

- **Detection** To prove that a crime occurred, the FBI must be able to detect the crime. For example, when anthrax is detected, the FBI must separate natural occurrences of anthrax from an intentional release.
- **Sampling** The FBI's focus is on gathering evidence in a manner that will withstand legal challenge. In the case of a biological release, the evidence is microscopic. How do you find the crime scene? How do you collect microscopic evidence? How do you preserve the evidence's integrity?
- **Traditional exams** Fingerprints, fibers, genetics, and toolmarks are examples of traditional forensic evidence. The FBI must consider collecting and evaluating this evidence while protecting people from the biological or chemical threat. The traditional exams are key to linking the evidence to the perpetrator. Therefore, the FBI prefers to use decontamination methods that preserve the integrity of the evidence. They must consider questions such as "Will the decontamination agent remove fingerprints?"

Biological and chemical agents pose unique challenges for detecting, sampling, and evaluating evidence. These challenges arise before the FBI arrives at a scene, and responses to these challenges may compromise evidence. Similar problems arise when addressing radiologicals.

Garrett provided two examples that illustrate FBI concerns and considerations.

- The FBI responded to an incident involving three family members who had a history of dealing with ricin and blaming each other for the crime. While evidence was being collected, miscommunication led to improper evidence handling, which destroyed traditional evidence along with the toxin threat.
- A local public health agency investigated a number of cases of salmonella poisoning in Oregon. Rumors speculated that the illness had been intentionally spread in order to influence election results. The public health agency determined that the event was a natural occurrence, the result of poor hygiene. Later, several people confessed to intentionally spreading the illness.

## Questions, Answers, and Comments

- **During a weapon of mass destruction event and FBI investigation, does the FBI help address the public health ramifications?** Historically, the FBI has been reluctant to share evidence about ongoing cases, even when evidence or data may be useful for addressing public health concerns. The Bureau, however, has made strides to improve information sharing. It has a public health agent at CDC to serve as a conduit for information and includes local, state, and federal public health agencies in conference calls discussing investigation results. For example, in August 2002, a New Jersey post office box tested positive for anthrax. The FBI provided information about this event to the New Jersey CDC and other public health officials. Although the FBI has working relationships with CDC and local and state public health agencies, a concern that information sharing will compromise an investigation will always exist.

- **What are your thoughts about sharing evidence data with EPA and others assessing the extent of contamination and planning the decontamination?** Garrett believes that the FBI should share data, but the involved parties need to devise a process for sharing information without harming the FBI's investigation. From experience, the FBI has learned that it must strike a balance between sharing information and maintaining the integrity of the investigation to successfully prosecute.

## CDC/NIOSH and Health Response to Biothreat Agents: Environmental Monitoring

*Capt. Kenneth F. Martinez, Centers for Disease Control and Prevention, National Institute for Occupational Safety and Health*

Agencies involved in a bioterrorism event hold many different perspectives about sampling needs. For CDC, sampling addresses public health concerns. Sample collection methods and analysis results, however, are similar regardless of the data's end use for public health decisions, scene characterization, or crime scene investigation, so information sharing between agencies is important.

When the first events occurred, communication between agencies was strained. Agencies now understand the value of working together and are moving toward sharing information more freely. They must, however, remember that each has to address its unique mission.

Environmental sampling may identify exposure locations, determine agent sources and exposure pathways, characterize pathogens and agents, assess the nature and extent of contamination, support risk assessment and public health decisions, identify people needing medical treatment, and guide reoccupancy decisions. Public health sampling may examine the paths for agent spread in order to limit that spread. For example, CDC considered whether postal employees exposed to anthrax transported spores home on their clothing.

The National Institute for Occupational Safety and Health (NIOSH) has also been involved with sampling at bioterrorism events. NIOSH has focused on understanding ventilation systems, transport of agents by people, and safety and health issues. Over the course of the anthrax outbreaks, agencies collected approximately 10,000 samples. In conducting sampling and obtaining results, agencies must remember that no numeric criteria exist to interpret biological sampling data. Sample results cannot be extrapolated to predict exposure. Developing standards, however, is currently under way.

Martinez highlighted the importance of planning environmental sampling at biological or chemical events. Environmental sampling can be the driving force behind public health decisions. CDC's existing sampling plans are clinically based. When planning sampling, agencies must consider the need for continuity of operations at a facility during a response.

CDC has identified three sampling phases:

- **Screening** Screening occurs in the first few days following the incident. For the anthrax events, agencies needed assurance that an event had occurred (i.e., an agent had been released). Sampling plans should optimize finding sources and assessing their concentrations as soon as possible.
- **Characterization** Sampling for contaminant characterization is conducted to prepare for remediation. False positives and negatives are not as much of a concern during characterization.
- **Remediation/restoration** Agencies must have a high level of confidence in sampling results. Results are used to confirm that the agent was removed.

CDC responded to anthrax releases in Florida, New Jersey, New York, Connecticut, and Washington, D.C. In all but two cases, CDC identified the sources of the anthrax release. (CDC never found the source of anthrax affecting a health care worker in New York City or an elderly woman in Connecticut.) To identify sources, CDC followed a consistent sampling strategy. They followed the trail of the source and considered dissemination methods (e.g., air, personnel). For anthrax delivered through the mail, CDC sampled the mail-sorting machines and electrostatic collection points (e.g., computer monitors). At Capitol Hill, CDC collected samples from elevators, furniture, floors, ventilation systems, vehicles, and clothing. CDC personnel collected primarily bulk samples or surface samples. They rarely collected air samples. At the time no method to validate spore sampling results existed. Confidence in sampling results comes from experience with industrial hygiene sampling and past disease sampling.

After the 2001 events, CDC developed a sampling protocol (which will be updated) and conducted validation studies. CDC also evaluated validation studies by Sanderson et al. (collection efficiencies), McCleery et al. (air sampling), Dugway Proving Ground (biological agent simulants), and Sandia National Laboratory (anthrax simulants). The Dugway Proving Ground study, conducted with EPA, involved releasing an agent in an air chamber, letting the agent settle, and then collecting and sending the sample to a laboratory for analysis. This study allowed method comparison and evaluation of inter-laboratory variability.

CDC applied the lessons learned during the anthrax events to a ricin event in South Carolina (October 2003), the BioWatch program agent identification in Texas (October 2003), and the SARS outbreaks (spring 2003). CDC coordinated with other agencies to share data, based sampling strategies on potential agent transport pathways, and applied updated sampling methodologies.

### Questions, Answers, and Comments

- **When CDC conducted subway sampling, what were some of the sampling challenges?** To assess the incident of the health care worker in New York City who contracted anthrax, CDC was asked to sample as many potential sources as possible. CDC could not identify a clear contamination pathway but did know the exact subway line that the worker rode. Using police department personnel trained in sampling techniques, CDC sampled the subway line. Each sampling person was accompanied by a strategist to help identify appropriate sampling locations. None of the samples collected in the subway were positive for *B. anthracis*. Because *B. anthracis* out-competes other organisms, interferences were not a concern.
- **Has CDC considered the impacts of nonculturable but viable organisms?** CDC researchers are currently examining this concern. They have completed some research with *B. anthracis*; the information gathered for this organism, particularly validation studies, is applicable to other organisms. CDC has methods for identifying organisms. Bioviability and its impact on infectivity are critical issues.
- **What validation methods do you plan to use in the future?** Agencies are currently debating validation methods and techniques. At the same time, a number of novel technologies are also becoming available. CDC research focuses on methods that are cost-effective and easily accessible to first responders. CDC is also concerned about collection and recovery systems. Some specific research has examined sampling methods such as swabs, wipes, and vacuuming.

## Ranking Threats for Decontamination Research

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

NHSRC/DCMD provides research to support decontaminating and restoring facilities by working with decontamination teams, emergency response teams, and on-scene coordinators. One aspect of NHSRC's research is to identify agents of greatest interest and to examine ongoing research to address these agents.

This presentation focused on the methods used by NHSRC to identify and rank threat agents. In addition to ranking agents, NHSRC/DCMD conducts research on sampling methods, contaminant containment, tracking contaminant movement, and decontamination and disposal issues. NHSRC does not focus on collecting evidence.

Adams discussed four different methods used to rank threat agents. Specific results of the ranking processes were excluded from the presentation because of security concerns. NHSRC is continually updating ranking results to ensure that its research has the proper focus.

- **DCMD approach** This ranking approach identifies and ranks high-priority threat agents, identifies and ranks likely terrorist targets, and identifies terrorist goals (e.g., loss of life, economic damage, and inducing fear).

To identify and rank threat agents, NHSRC examined the ranking schemes and results of other agencies and organizations, including CDC, DoD, EPA, the State Department, and the intelligence community. NHSRC then developed a list of ranking factors: infective dose, persistence, availability (e.g., small pox is well guarded), prior use, ease of detection, severity

of effects, transmission, preventives/treatments, ease of decontamination (e.g., fumigation, latent desiccation), latency, and ease of airborne dispersion. NHSRC is more concerned with airborne dispersion, but they are beginning to address water distribution. Each ranking factor is given a weight (1 to 5) for relevance. The weights are somewhat arbitrary and can be changed. Each agent is assigned a value (0 to 4) for each ranking factor. NHSRC has clearly defined the agent-specific values (e.g., for the ranking factor "severity of effects," 0 is mild and 4 is death). The overall threat agent rank is the sum of the products of the ranking weight and the agent-specific value.

NHSRC identified a number of target buildings (e.g., shopping centers, convention centers, airports, hospitals, museums, and federal agencies). The building ranking factors are building access, HVAC access, potential for infiltration outdoors, room size, and people traffic. Each of these factors is then weighted (1 to 5). Infiltration has a low weight because buildings are typically either entirely open or closed. Each building is assigned a value (1 to 5) for each ranking factor. The overall building rank is the sum of the products of the ranking weight and the building value.

NHSRC combines the agent rank, building rank, and terrorist goals to link agents to events and develop threat scenarios. NHSRC calculated a threat value by summing individual ranking factors (e.g., agent availability, agent hazard index, ease of agent use, people traffic, and non-health impacts). Agent availability refers to the ease of obtaining an agent and prior use of an agent. The agent hazard index involves the infectious dose, lethality, severity of effects, contagiousness, latency, and treatment availability. Ease of use refers to dispersion options and the potential for infiltration, and people traffic refers to the number of people who use an area. Non-health impacts include economic, symbolic, political, and psychological impacts. NHSRC then ranked different threat scenarios according to visual patterns and statistical cluster analyses to help focus work on a small number of persistent agents with severe potential effects.

- **Science Applications International Corporation (SAIC) ranking approach** SAIC researchers completed a similar but independent ranking process for NHSRC. They considered threats (physical contaminants and "cyber" threats), targets (buildings, water systems, and wastewater systems), and impacts (health, economic, and environmental). SAIC developed a ranking algorithm that calculated a risk number based on the probability and consequences of an event. The risk index was the product of agent availability, event feasibility, and the sum of possible health impacts, economic impacts, and environmental impacts. Values for each of these variables were identified using a series of decision trees. SAIC calculated risk indices ranging from 0 to 300,000. At the conclusion of the project, SAIC found results similar to those of the DCMD approach.
- **Expert systems approach** This approach considered the open literature, classified reports, NHSRC reports, and EPA lists of contaminants and threats. Experts then gathered in a threat scenario meeting and developed a list of priority agents. This list was similar to those developed by NHSRC and SAIC.
- **Battelle systematic decontamination effort** This effort employed a method similar to the DCMD approach and achieved similar results.

NHSRC received input from a number of agencies to ensure that the final threat list would be all-encompassing. NHSRC (including DCMD and the Threat and Consequence Assessment Division), DHS, DoD, EPA Office of Water, EPA Office of Solid Waste, and EPA Emergency Response Team members all provided input.

## Questions, Answers, and Comments

- **How does the NHSRC ranking scheme compare with the rankings and categorizations developed by other agencies?** NHSRC uses the ranking results primarily to focus research efforts. Ranking schemes and categorizations are based on agency-specific missions. For example, CDC is concerned with health effects, so it may rank small pox as a threat agent because of its drastic health consequences. NHSRC is concerned with decontamination; since small pox is fragile in the environment, NHSRC would rank it as a low priority.
- **NHSRC should add a category for technical surprises (e.g., non-cultural but viable organisms).** NHSRC is researching methods for determining organism viability as well as bioengineered organisms and newer chemical threats.

# OPP Sterilant Registration Project: Improving the Association of Official Analytical Chemists (AOAC) Sporicidal Activity Test and the Evaluation of Quantitative Methods

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

EPA's Office of Pesticide Programs (OPP) is researching and developing biological analysis methods. This presentation updated workshop participants about the method development project status and OPP's evaluation of laboratory sporicidal efficacy methods. OPP operates a microbiological laboratory, which is the home of this OPP project, at Fort Meade, Maryland. This laboratory is registered with CDC's select agent program and may become part of CDC's Laboratory Response Network (LRN).

As part of the method development project, OPP is developing methods that allow laboratories to simulate real-world conditions. The methods consider the threat agent or surrogate, types of materials, application methods, and carrier systems. Goals of the project include advancing the science of efficacy testing, standardizing methods, creating comparable efficacy testing results, identifying a surrogate for *B. anthracis,* and building a platform for testing additional biological agents.

OPP's ultimate goal, however, is to design comparable efficacy data to help develop regulatory guidance. The AOAC sporicidal activity test is the standard test currently employed. A single carrier contains $10^5$–$10^6$ spores, and a full study uses 720 carriers. This test has a number of limitations: results are qualitative, the test requires 21 days for incubation, and the test lacks standardization. A passing result means that none of the carriers was positive. OPP is following a four-tiered approach to developing a method that is easier to run and understand:

- **Tier 1** OPP evaluated methods, including modified AOAC tests, with the agent *B. subtilis*.
- **Tier 2** Activities under tier 2 will be launched soon and will include evaluating surrogates for *B. anthracis*.
- **Tier 3** Collaborative and validation testing will occur under tier 3.
- **Tier 4** This step involves identifying, developing, and conducting comparative evaluations of field-test methods. OPP is currently focusing on laboratory assays and is not pursuing field-testing.

Ensuring that performance standards are maintained is critical when developing new methods or making changes to an established method. OPP has identified modifications to the existing AOAC method and two new promising methods, which they are testing with surrogates.

**Modified AOAC Method** The current AOAC tests use a liquid extract from raw garden soil (soil extraction nutrient broth) as the test medium. To standardize the test, OPP recommends replacing the extract with a synthetic broth manufactured to standard specifications. OPP also recommended replacing porcelain carriers with stainless steel carriers, adding a carrier count procedure with a minimum of five to six logs per carrier, adding a neutralization confirmation procedure, and replacing the egg-meat medium.

OPP tested the current AOAC method against the modified AOAC to examine whether changes in the test medium and the carrier material affected the text performance. Tomasino presented a number of slides detailing these test results. Overall results were comparable. As part of ongoing efforts, OPP completed a final study protocol for the modified AOAC method in March 2005 and will begin validation testing in April 2005. The validation report is due in July 2005, and approval of the report is expected in August 2005.

The two new methods under evaluation are quantitative methods with inoculated vials serving as the carriers. When identifying new test methods, OPP considered a number of attributes, such as available protocol, validation, previous use for testing sporicides, readily available equipment, expertise, flexible contact times and temperatures, enumeration approaches, percent recovery results, deactivation of the agent, reproducibility, turnaround time, suitability for various product forms, and adequate controls. Two methods met these criteria:

- **ASTM E 2111-00 Standard Quantitative Carrier Test Method** The ASTM method uses a glass vial as a carrier. Following exposure, the vial's contents are syphoned through a filter to capture spores. The filter is then plated to assess spore growth, which indicates that spores remain.

- **Three-Step Method (TSM) (Sagripanti et al., 1996)** TSM employs a glass coupon as the carrier. To determine whether spores remain, the coupon undergoes a three-step process: centrifuge, sonicare, and incubation.

OPP focused tests on liquids and hard surfaces. Each test method required a different amount of sporicide. To assess the variability and repeatability of each method, three separate laboratories completed three replicates of tests following each method.

Repeatability studies highlight inconsistencies within a laboratory. Reproducibility studies highlight inconsistencies between laboratories. Repeatability and reproducibility standard deviations were acceptably small for all test methods. Tomasino presented slides detailing the test methods and conditions (e.g., pH, sporicide concentration, and exposure period) and the results achieved for each method (expressed as the control carrier log density or the log reduction). OPP's study results did not show any method to be clearly superior. OPP submitted the study results to an expert panel, which selected TSM as the preferred method. As part of ongoing efforts, OPP will conduct additional surrogate studies with TSM beginning in April 2005. TSM and two to three surrogates will undergo a multi-laboratory validation study in September 2005, and a summary report of findings is due in December 2005.

### Questions, Answers, and Comments

- **What fumigants are you testing?** To date, OPP has tested only liquid fumigants. However, OPP believes that TSM can be modified to test other fumigants and other surfaces.
- **What are the surrogate selection criteria?** OPP began testing with virulent anthrax. The surrogate selection criteria will be straightforward and may be used by other researchers.

## Crisis Exemptions for Products Intended to Inactivate *Bacillus anthracis*

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

Crisis exemption is the process of receiving approval to use an unregistered chemical as a decontaminant for a particular microorganism, such as *B. anthracis*. This presentation provided background information about the crisis exemption process, considerations for evaluating and selecting sporicides, issues that demand attention, and the current state of the registration process.

A number of groups (e.g., researchers, regulators, chemical producers, first responders) and the public are involved in deciding what chemicals should be used to decontaminate an anthrax event. First responders want chemicals that are safe and act quickly. The public looks for chemicals that are safe to use but provide adequate decontamination.

In the United States, decontamination agents fall under the Federal Insecticide, Fungicide, and Rodenticide Act (FIFRA). FIFRA applies to chemicals sold for inactivating biological agents. These chemicals are considered pesticides and must be registered. When anthrax attacks occurred in 2001, no chemical had been registered for decontaminating *B. anthracis*. As such, the government created the crisis exemption process to allow chemical decontamination. A crisis exemption was needed for each decontamination event. Of the 63 requests, OPP approved 28 and rejected 35. Both federal agencies and private companies submitted requests and each request included remediation action plans, sampling and analysis plans, and ambient air monitoring plans.

When evaluating and selecting sporicides, OPP considers both safety and efficacy issues.

- **Safety** Concerns regarding safety include containment of the contamination area and fumigant, fumigant toxicity and potential human exposure, fumigant generation method, ability to achieve negative pressure in a building, post-treatment aeration and scrubbing needs, system backups, and ambient air monitoring needs. A key concern is that the fumigation be successful after the first treatment. Air treatment systems are also a key concern when considering containment and post-treatment cleanup.

- **Efficacy** Issues associated with treatment efficacy include fumigation processes (e.g., treating the building as a whole or in sections), fumigant distribution (e.g., using fans), reaching and holding decontamination process parameters, monitoring process parameters (e.g., concentration, time, and relative humidity), biological indicator sampling, and clearance sampling. Sealing a building to prevent or minimize leaks is a time-consuming part of ensuring the fumigation efficacy.

**Liquids** OPP has granted crisis exemptions for four liquid *B. anthracis* sporicides: aqueous chlorine dioxide, hydrogen peroxide/peracetic acid, sodium hypochlorite, and hydrogen peroxide/quarternary ammonium foam. These liquids were approved for use on hard, nonporous surfaces only. The exemption for DF-100 was withdrawn because the fumigant failed tests with the AOAC method. DF-200, which is the improved version of DF-100, has reportedly passed testing.

**Gases/Vapors** Five gases and vapors have received crisis exemptions: gaseous chlorine dioxide (buildings), vaporized hydrogen peroxide (buildings), paraformaldehyde (equipment in tented enclosures), methyl bromide (laboratory and field study), and ethylene oxide (specialized off-site treatment of specific items). Several vendors offer hydrogen peroxide as a decontamination agent.

OPP is moving toward registering chemicals for *B. anthracis* decontamination, but several regulatory issues must be addressed first. EPA needs to establish standard efficacy test methods. The registration data requirements need to be rigorous but reasonable. EPA must also consider the question of how clean is clean. A National Academy of Sciences (NAS) study focusing on anthrax, plague, and small pox is pending. This study will likely include several recommendations for regulatory requirements, such as a site-by-site risk assessment. The study will also address natural versus residual exposures, past decontamination efforts, and enclosed versus semi-enclosed facilities.

Registration requires test data regarding product chemistry, toxicity, and efficacy. These tests are straightforward and are guided by the concept that a product registered for use against an agent must be tested against that agent. OPP may accept surrogate data if the surrogate is proven to be equally susceptible to a product. Product labeling includes details regarding the product use and safety precautions. For registration, a product may be labeled for restricted use and require a substantial technical use manual.

To address efficacy testing, EPA is leveraging interagency cooperation. EPA and others participate in an expert panel to share information and prevent redundancies. They are trying to identify one set of tests that is acceptable to all the agencies. These tests could then be used for regulatory and/or registration purposes. Kempter highlighted the OPP method testing discussed in Tomasino's presentation.

Kempter discussed "Lemon Drop" as an example of a crisis exemption situation. The United States Coast Guard (USCG) identified a shipment of lemons with a viable threat for biological contamination. USCG needed, and OPP provided, a crisis exemption within 24 hours.

OPP and others have been successful at completing decontamination. Certain decontamination methods are safe and effective, some personnel and equipment can be mobilized quickly, and OPP can quickly issue crisis exemptions for known decontamination methods.

## Questions, Answers, and Comments

- **For sporicidal testing, is there a standard for material compatibility?** Material compatibility standards have not been required. If OPP identifies a chemical that passes toxicity and efficacy tests but has known compatibility problems, OPP will require the manufacturer to label the product accordingly. OPP is unlikely to fail a chemical based on compatibility. A workshop participant noted that many concerns are associated with material compatibility and fumigation. Material compatibility involves more than just damage to a material; it also involves the impact of a fumigant on materials, the impact of a material on a fumigant, and the ability of a fumigant to penetrate a material.
- **Have all the chemicals that were used to decontaminate *B. anthracis* been registered?** No chemicals have been registered for use against anthrax. Decontamination is still conducted under crisis exemptions and each situation is reviewed on a case-by-case basis. Some of the chemicals used in anthrax decontamination, however, are registered for other uses. OPP is working with laboratories and others to prepare for crisis exemption submissions, if needed.

# Sampling and Clearance Lessons Learned

*Mark Durno, U.S. Environmental Protection Agency*

*Tony Intrepido, U.S. Army Center for Health Promotion and Prevention Medicine*

Durno is an OSC and end-user of decontamination technologies. He was involved in the Capitol Hill anthrax incident and has participated in technical working groups. This presentation discussed many of the approaches presented earlier but provided an end-user's perspective.

The basic sampling approach is the same for chemical, biological, and radiological agents. The anthrax technical assistance document prepared by the National Response Team (NRT) (available at *www.nrt.org*) provides immediate response actions for first responders at a scene. The approach outlined in that document is consistent with other terrorism response or hazardous release situations. The specifics of a sampling plan, however, change from site to site. Parameters to formalize before sampling begins include objectives, approaches, sampling and analytical methods, transportation concerns, coordination efforts, and data interpretation.

Considerations when developing sampling objectives include:

- **Defining goals** Sampling goals may include assessing risk, characterizing contamination, supporting decisions, or verifying decontamination.
- **Establishing data quality objectives** Even if expressed as notes in a log book, data quality objectives are critical to a successful sampling event.
- **Identifying standards** No decontamination standards are currently available.

In addition, professionals (e.g., from the medical, environmental, laboratory, and public health communities) involved in the decontamination process should be consulted. Sampling event objectives for first responders may include real-time monitoring, screening, bulk material sampling, or unknown material sampling. As the sampling effort moves toward assessing the extent of contamination or decontamination, the objectives may shift to forensics or the effectiveness of decontamination. Transitional sampling, an Occupational Safety and Health Administration (OSHA) approach, clears a building for safe reoccupation.

Regardless of the objectives, Durno emphasized, the sampling approach must be logical. An approach devised in the heat of the moment is destined to have problems. A carefully designed approach is more likely to lead to a smooth sampling event. Two examples of sampling approaches are:

- **Known source** When *B. anthracis* was transported in the mail, the contaminated letters were the known sources. For each room where a contaminated letter may have been, sampling occurred at the areas through which it most likely passed. If a positive result occurred, sampling in the affected area was expanded.
- **Known contamination with an unknown source** In this instance, statistical analysis of an area can improve the probability of finding a positive detection and identifying a source. A negative result, however, does not necessarily indicate that the agent is absent from an area.

Intrepido continued the presentation with a discussion of lessons learned from the sampling efforts.

In April 2004, Intrepido participated in a workshop to discuss sampling and detection issues. During that workshop, discussions included topics such as hazard identification, field detection, sampling efficacy, analytical capabilities, and post-decontamination sampling. The first topic applied to first responders and the last three topics applied to characterization and remediation activities.

- **Hazard identification** Hazard identification is critcal for first responders because their actions may spread contamination. Like hazardous materials, biological agents must be contained. Assessing and establishing the credibility of the threat is key.
- **Field detections** Several methods for collecting field data are available (e.g., hand-held assays, infrared sensors, and rapid polymerase chain reaction testing). Misuse of these tools, however, can lead to poor decisions. Intrepido discouraged using these methods without proper training. Other field detection technologies are under development and testing.
- **Sampling efficacy** Intrepido listed a number of available guidance materials and references, as well as several studies by NIOSH, USPS, and others, that address sampling efficacy concerns. Further efficacy studies, however, are needed to identify acceptable detection limits.

- **Analytical capabilities** Laboratories are working to improve analytical capabilities and analytical support for decontamination projects. CDC has established the Laboratory Response Network (LRN) and is working to standardize analytical methods used throughout the LRN. DoD is establishing a similar environmental LRN (eLRN) to harmonize sampling.
- **Post-decontamination sampling** To date, verification sampling has been exhaustive. As research advances and laboratory applications become more relevant to field applications, clearance will become more efficient.

To provide better guidance, the NRT technical assistance document should consider first responder needs, include a matrix of appropriate sampling strategies and methods (including statistical tools), encourage the use of relevant professionals, and develop consistent nomenclature.

Two examples illustrate different factors that affect a sampling strategy.

- **Hart building** A clear understanding of contamination avenues was present. Sampling was planned using this knowledge.
- **USPS buildings** People were working for days and weeks after the initial release. A dynamic sampling plan considered movement of the agent and objects in the building, and so sampling included lifting some objects and sampling underneath them. Appeasement sampling became part of the approach to assuage people's fear. Additional sampling also became necessary when one laboratory provided quantitative sampling results and other laboratories reported only qualitative results (i.e., positive or negative). The quantitative and qualitative results were not comparable.

## Questions, Answers, and Comments

- A workshop participant expressed concern about false negatives. Statistical design, if correct, can consider data risk. In research at the Edgewood Chemical Biological Center (ECBC), differences in kill efficacy were based on differences in surfaces. Most tests use a stainless steel surface, which does not account for surface variability in real-world situations.
- **Did you conduct any high-volume air sampling?** NIOSH and the Agency for Toxic Substances and Disease Registry (ATSDR) helped EPA develop an aggressive high-volume air sampling protocol, which was similar to asbestos sampling protocols. They sealed several rooms and passed one to two room volumes of air through a dry filter unit. Although the data were insufficient for statistical verification, the results improved EPA's confidence in other data, such as surface sampling data. EPA also augmented sampling data using other sampling methods (e.g., gelatin filters) that can detect low concentrations. Overall, the dry filters from the high-volume sampling reported positive results but not with the same frequency as other sampling methods. EPA hopes that more research in this area will be conducted.
- **When designing a statistical sampling approach for *B. anthracis*, the agent's specific aerosol properties are considered. When designing a statistical sampling approach for two or three different agents, how do you consider agents' different aerosol properties?** When searching for unknowns, targeting specific areas for sampling is difficult. As more information becomes available and you begin to understand the nature of contamination, you can target areas and change sampling approaches.
- **When identifying the logic behind a sampling sequence, should you consider clearance sampling needs?** At the Hart Building, vertical and horizontal grid-style sampling with air sampling was conducted. Clearance sampling at this building was more involved than clearance sampling at other buildings because an extended period had lapsed between exposure and decontamination. Sampling included redundancy, extensive horizontal (i.e., surface) sampling, and consideration of airborne movement. Intrepido noted that the decontamination process at the Hart Building helped to develop a new sampling nomenclature. The technical language regarding the decontamination process is also continuing to evolve.

# The Use of the Trace Atmospheric Gas Analyzer (TAGA) to Qualitatively and Quantitatively Monitor Ambient Air for Chemical Warfare Agents (CWAs) and Decontamination Agents in Real Time at Parts per Trillion by Volume Levels or Below

*Dave Mickunas, U.S. Environmental Protection Agency, Environmental Response Team*

The presenter and others are developing and testing methods for real-time, low-level monitoring for chemical warfare agents (CWAs) and decontamination agents in ambient air. EPA's TAGA consists of an Atmospheric Pressure Chemical Ionization (APCI) source linked to a three-quadrupole mass spectrometer. This project included developing CWA spectra and calibration curves, developing chemical ionization capabilities to detect CWA's, verifying detection limits, determining the dynamic linear range, establishing surrogates, identifying interferences, and demonstrating methods. Mickunas presented a series of slides detailing the test methods, test conditions, test materials, chemicals of interest, and some unique test conditions.

Chemical agents of interest throughout the task included GA (Tabun), GB, GD, GF (cyclosarin), VX, HD, and the nitrogen mustard agents $HN_1$, $HN_2$, and $HN_3$. Chlorine dioxide and chlorine were the decontamination agents of interest. Initial testing occurred in a laboratory chamber. EPA used diisopropyl methylphosphonate (DIMP) as a surrogate for G and B agents and half mustard as a surrogate for mustard.

One aspect of the testing was to assess how well agents would transfer through a glass sampling tube without being adsorbed or reacting with the tubing. Because laboratory testing must be conducted under a hood, researchers could test only a limited tubing length. Results showed that the glass tubing was not entirely inert. EPA is considering additional test conditions, such as adding heat, to assess reactions with the glass tubing.

After testing the systems in a fixed laboratory, EPA moved the system to a mobile laboratory, which consisted of a TAGA mounted in a bus. The APCI uses electrons and protons to ionize a chemical. Ambient air enters the instrument; molecules are ionized and then passed through the three-quadrupole mass spectrometer. TAGA measures charges and creates a unique spectral "fingerprint" as the result for each chemical. Information gathered in the mobile laboratory can then be sent to an incident command location via satellite.

Mickunas presented the TAGA fingerprints for a number of the agents of interest. The technology considered the molecular weights of the parent and daughter ions. TAGA can even detect low concentrations of chemicals with low vapor pressures, such as VX. Ion counting is key to the success of this method. For the tested agents, EPA recorded between 200 and 7,000 ion counts per part per billion (ppb), which indicates a good response.

Overall, TAGA is a good testing method for the agents of interest. The mobile unit can identify an evacuation area, but it is not currently configured for sampling high concentrations. At a decontamination event, TAGA can be used to detect fumigant leaks and identify concentrations exceeding shutdown levels (e.g., chlorine dioxide concentrations of 25 ppb for three 15-minute periods, or 100 ppb for one 15-minute period).

## Questions, Answers, and Comments

- Workshop participants commented that TAGA and the mobile laboratory can serve as a leak-detection technology. The detection limits for hand-held sensors are too high to detect leaks. Mickunas agreed and noted that the TAGA technology is about six times more sensitive than hand-held instruments.
- **Is the method applicable to high-molecular-weight compounds (e.g., ricin)?** The pharmaceutical industry, which deals with high-molecular-weight compounds, uses this technology. Air monitoring was not the original end use of the technology. The method works with these compounds because it examines charges on molecules.
- **Are there concerns about using this technology at fumigations in high rises?** Downwash is a concern. Overall, many opportunities exist to

research the logistical implementation of TAGA and the mobile laboratory.

- **Does vehicle exhaust interfere with the results?** Vehicle exhaust interference is minimal, less than 30 percent.
- **Are fixed monitoring stations in a community required with TAGA and mobile laboratories?** From experience, this workshop participant has found that fixed stations are costly and time-consuming to use. Mickunas agreed that fixed monitoring stations have limited value. A contamination plume from a leak can be very narrow and can pass between fixed stations without detection. The mobile monitoring unit provides more information and more ways to identify and resolve leaks.

## Insurance and Indemnity Issues

*Jerry Robinson, U.S. Postal Service*

This presentation examined insurance and indemnity issues at decontamination sites. The USPS is concerned not with industrial accidents but with terrorist actions. Therefore, some of the insurance and indemnity options mentioned in the presentation apply only to terrorist attacks. An act of terror can be broadly defined as anything unlawful that causes harm or attempts to use weapons of mass destruction. A terrorist group does not need to be identified and the act may be conducted by a domestic or foreign group.

In October 2001, anthrax releases contaminated the USPS Brentwood and Trenton facilities. The attacks caused illness in 22 people and the death of 5 people. The attacks also rendered the facilities unusable, damaged mail-sorting equipment, and instilled fear in postal workers and the public. The USPS contracted with vendors to fumigate and restore the facilities.

As the property owner, the USPS needed to protect contractors from undesirable outcomes occurring as a result of the decontamination process (e.g., explosion, unsuccessful fumigation, and harm to postal or vendor workers). Obtaining this protection comes at great cost and great delay.

Addressing liability for harm to people is the most difficult aspect of protecting the vendors and the USPS. Involved parties may try to distribute the liability to minimize each party's risk. For the decontamination events, the USPS reluctantly accepted full liability and assigned broad indemnity with few exceptions (e.g., outcomes occurring as a result of gross vendor error). Many months, however, passed before the USPS reached the decision to accept liability. To minimize their risk, the USPS then obtained some insurance coverage—a $100 million policy costing $4 million. Decontamination of one facility, however, cost more than $100 million, so this policy did not cover the USPS completely.

The USPS course of action has two problems. First, most government agencies cannot indemnify decontamination vendors because these agencies are not allowed to enter into the open-ended contracts required for indemnification. DoD has exceptions to this restriction for issues related to weapons. The current administration is also very reluctant to grant terrorism exceptions; the USPS has an indefinite income stream and, for this reason, was able to accept indefinite liability. Second, insurance is not an available standby solution and much time is needed to negotiate an insurance policy after an event occurs. Most insurance companies will not hold an open insurance policy without payment, but opening an unnecessary insurance policy is not a smart business practice. Nonetheless, the USPS is looking for an available standby solution.

Robinson suggested that contractors obtain a SAFETY Act designation and certification for their technologies. This would allow contractors to be immediately available to perform decontamination services. The SAFETY Act—that is, the Support Anti-Terrorism by Fostering Effective Technologies Act of 2002—is part of the Homeland Security Act. The SAFETY Act covers decontamination technologies because these technologies are a response to a terror act. As well as fostering the deployment of more anti-terrorism technologies, the Act creates a system of litigation and risk management for those technologies. Litigation management restricts punitive and non-economic damages to government contractors; risk management restricts liability to the extent that insurance allows.

The SAFETY Act, however, requires a vendor to purchase insurance, determined by DHS, in order to be certified. The insurance level is supposed to be the maximum amount that can be purchased without unduly raising product price. This is a vague standard for DHS to follow. The SAFETY Act also includes a government contractor liability exemption. This exemption absolves

contractors from responsibility for undesirable outcomes of the decontamination (e.g., damage to property or personal injury). Some attorneys are concerned that the government contractor liability exemption will not stand up in court. For example, a judge faced with a person harmed during a decontamination event and responsible for overwhelming medical bills may deem the contractor liable because no other responsible party is available.

### Questions, Answers, and Comments

- **Does the SAFETY Act cover decontamination at private companies?** Private companies are covered as long as a terror act, and not an industrial accident, caused the damage.
- **Is federal insurance an option?** The atomic power industry has used a federal insurer model, but the federal government is the insurer of last resort. The current Congress has not adopted a federal insurance policy for terror acts.
- **Do you see companies investing in insurance because they want decontamination and response business?** Robinson stated that there is a limited market for decontamination services and suggested that more insurance options might be available if more contractors entered this market.
- **Is the contractor liability exemption rebuttable?** This exemption is only rebuttable if there is proof of fraud in the application to DHS.

## The Role of the On-Scene Coordinator in the Process

*Marty Powell, U.S. Environmental Protection Agency*

Powell has worked for EPA for 20 years and served as an OSC for about 10 of these years. This presentation provided an overview of an OSC's two responsibilities:

1. To determine whether there has been a release of an oil, hazardous substance, pollutant, or contaminant and whether the release poses a threat to the public or environment.
2. To ensure that the threat is mitigated. These responsibilities remain the same on all projects, although project specifics change.

An OSC's role in a project is defined by the title "on-scene coordinator" itself. "On-scene" implies a different role from "on-site." "On-site" implies a federal presence at a specific threat location; "on-scene" indicates involvement in an event without requiring a physical presence. OSCs are coordinators, not commanders. Commanders control site actions, whereas coordinators play a number of roles to provide information and support remediation efforts. The command structure at a site may seem complex, so the OSC can act as a liaison within this structure.

OSCs direct federal response assets. They draw from a large tool box of resources (e.g., contractor support, scientific support, special units, and public relations support teams) and provide these resources to local and state agencies to ensure that these agencies are not overwhelmed by the remediation process. They also ensure that remediation work at a site is completed properly. For example, the USPS commanded decontamination efforts at the postal facilities contaminated with anthrax. The OSC simply supported the USPS's efforts.

Many workshop participants may be contacted by an OSC. Researchers may act as information resources for an OSC, or technology vendors may work with OSCs to identify resources for testing their technology. OSCs may also evaluate the remediation equipment used for decontamination.

### Questions, Answers, and Comments

- One workshop participant has worked with OSCs over the past three years. The OSCs understood available federal information and assets and obtained them as necessary and worked behind the scene of the decontamination to ensure success. Another participant agreed that the OSC is a valuable source of information, which can be used to support decisions. Powell emphasized that OSCs can access many EPA resources and facilitate obtaining these resources. They provide a link between scientific research and implementation of technologies.
- Another participant noted that an OSC has a broad range of authority and power. For one site, the OSC determined the chlorine concentration needed for decontamination. Powell responded that an OSC has the ability to make decisions for a site without obtaining a permit. Regulations requiring permits often do not consider emergency response needs.

In addition, OSCs have no liability and cannot be sued for their decisions. The role of the OSC is complicated by the needs of different agencies, such as other offices within EPA, the United States Coast Guard (USCG), and the Department of Energy (DoE). Regardless of agency, though, an OSC's roles and responsibilities remain unchanged: they work toward an end goal of threat identification and mitigation.

- One participant, who works as an OSC, noted that a shortcoming in many responses is coordinating government and academic research to solve problems. An OSC may seek more information about a compound, but the literature may provide scattered and conflicting information. The OSC is then charged with making decisions based on this information. This participant emphasized the need for more research, planning, and preparedness information.
- **What triggers the appointment of an OSC?** A notification of some kind of release, for example, a call to EPA or the National Response Center, triggers the appointment. (An industry call to EPA about a spill is a notification.) An OSC may respond by granting responsibility to state or local agencies but is still responsible for ensuring mitigation. Sometimes the response includes a full-scale investigation.
- **In the remediation phase, does the OSC act as the incident commander under the Federal Response Plan? In Florida, when the FBI completed investigations and released the building for decontamination, did EPA establish a command structure?** An OSC is unlikely to become the incident commander. The OSC considers site operations, such as what vendor is providing what services. The command structure, however, can vary. The USCG strike team is one resource available to an OSC. Typically, this team serves as the incident commander at coastal sites. Agencies involved in a decontamination event may work together to formalize the incident command structure. EPA is currently working toward developing a more uniform approach.

# Introduction to the Government Decontamination Services

*Robert Bettley-Smith, Department for Environment, Food, and Rural Affairs, Government Decontamination Service*

Bettley-Smith presented the United Kingdom (UK) approach to threat events and subsequent decontamination and provided a history of events that have occurred. The UK is examining possible future threats and building its arsenal of technologies to address them. These efforts consider global uncertainty and draw on a cross-government effort to ensure preparedness.

In April 2003, the UK commissioned a study to assess the need for an agency to address chemical, biological, and radiological threats. The study recommended actions to improve the UK's ability to respond to threat events. In January 2005, the government announced its intention to establish the Government Decontamination Service (GDS). Currently, the government is balancing efforts to improve the UK's capability to address an event and establish the organization to implement this capability.

GDS must consider current government structure and authority. In the UK, authorities at the county level are responsible for hazardous events. They are well prepared for chemical events because of their experience with chemical transport and releases. They also have experience with radiological events (e.g., the Chernobyl event). They lack, however, experience with biological events, so GDS will focus its efforts on these threats. GDS considers biological event decontamination as a specialized field with expertise available from the private sector. There is a concern that local authorities could be overwhelmed by the exigencies of decontamination following an attack and could respond inappropriately.

The UK hopes to learn from the U.S. anthrax events and other countries' responses to biological threats. The Australian response plan was evaluated in November 2003. This plan is grounded in military actions, a precondition that is not applicable to the UK. Also reviewed was the French plan, which includes public notification as required by French laws. Again, this plan is not wholly applicable to the UK. Bettley-Smith emphasized the importance of understanding the background for a response plan model, including

constitutional restrictions and responsible parties. The UK has also considered establishing a centralized data system for facilitating and sharing knowledge across nations and preventing research overlap.

In addition to developing a response plan, GDS may provide information about vendors and technologies capable of biological decontamination. This information may be presented in the form of a catalog of available goods and services, including long-term, durable responses and proven technologies. GDS may also enter agreements requiring that vendors offering these services be available to the government when necessary.

Overall, GDS will serve three primary functions:

- **Provide advice and guidance** GDS will guide responsible authorities as they plan for emergencies and test these plans. It will prepare a strategic national guidance document; provide *ad hoc* advice; review case studies; and participate in exercises that test command and coordination abilities, identify solutions, and highlight response plan weaknesses. Individuals have already evaluated three case study events (a cesium release and two bombings) to assess responses and suggest actions to improve responses.
- **Identify resources** GDS will provide information about vendors, their capabilities, and their technologies and facilitate interactions between local authorities and vendors. Some interim arrangements, modeled on the response to the U.S. anthrax events, are in place, but the public demands more confidence in vendor relationships and technology success. The lack of technology field-testing is a concern because a technology must work when needed.
- **Advise the central government** GDS will track the UK's decontamination capabilities and report to the central government.

GDS will not assume responsibility for decontamination, fund decontamination, or handle humans, animals, or their remains. If an event occurs in the UK today, GDS will likely provide advice and guidance and help secure contracts. It may also be able to provide an OSC.

### Questions, Answers, and Comments

- **Is there a perception of urgency to address decontamination capabilities and preparedness in other European communities?** Bettley-Smith was most familiar with activities in the UK and was unable to provide an overview of actions occurring throughout Europe. Concern has been high in Australia since before the Sydney Olympics. France is also working to address decontamination concerns. Some of the UK actions have been driven by threat assessments, and the UK is working to ensure that event responses are proportional to the risk.
- **Does the UK face the same insurance and indemnity issue as the U.S.?** In the UK, the government serves as the insurance underwriter, with certain reinsurance provisions. The government is working with the insurance industry to quantify risks. Once insurance providers can quantify the risk, they can underwrite it. Key contractors will likely carry insurance for a variety of situations. After a terror event has occurred, the risks during the remediation phase of the event are the same as the risks during the remediation phase of a hazardous materials release. These are insurable risks. Insurance may be difficult, but not impossible, to obtain.

## Laboratory Capacity Issues

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

This presentation addressed laboratory capacity issues as they relate to homeland security. A homeland security presidential directive requires that "federal agencies be prepared to respond to chemical, biological, and radiological attacks."

Laboratories face several issues with regard to meeting this directive:

- **Validation** Validated sampling methods provide a level of confidence in reported sampling results and in answering the question "How clean is clean?" These methods are lacking for some priority chemical, biological, and radiological agents.
- **Expertise** Laboratories must have expertise in handling CWAs, which may degrade quickly.
- **Capacity** A laboratory may be called to analyze thousands of samples quickly, especially if an attack affects city operations.

Creating standardized analytical methods is one way to address these issues. Standardized methods would ensure consistent and proficient sample analysis across laboratories. In September 2004, EPA identified 109 priority agents and specific analytical methods for gas, solid, oily solid, and aqueous samples.

Revisions to the standard analytical methods are scheduled for June 2005. This revision will include updates to existing methods and will add new methods for analyzing drinking water, CWA degradation products, and four radiological agents (strontium-90, cesium, iridium, and cobalt-60).

Research with CWAs must occur under high-security conditions and within laboratories under the rigorous personnel-reliability program. Only a finite number of laboratories meet these conditions. Rothman listed some of the available analytical methods for CWAs, which include a joint U.S. and Finnish method, Organization for the Prohibition of Chemical Weapons (OPCW) methods, Finnish Institute for Verification of the Chemical Weapons Convention (VERIFIN) Blue Books, and the Wiley Encyclopedia of Analytical Methods. EPA not only needs to package this existing information in the standardized analytical methods document but also needs to develop new methods. Some chemical-specific concerns in the development of methods are that GS degrades quickly (within 24 hours) and VX, mustard, and lewisite are relatively persistent. Methods, therefore, must be able to detect either the primary agent or degradation products.

In addition to developing analytical methods, laboratories must have the capacity to handle samples collected during a response. Samples to identify the threat agent and assess the nature and extent of contamination are collected at the greatest rate within days of the event. Thousands of samples, collected within days or weeks of the initial event may need to be analyzed. Cleanup, clearance, and surveillance samples taken weeks, months, and possibly years after the event may be collected in greater numbers, but likely at slower rates, than initial sampling.

To address capacity concerns, EPA is working with CDC to develop the environmental Laboratory Response Network (eLRN). CDC's existing LRN serves as a model for the three-tiered eLRN. Screening or sentinel laboratories will provide analyses and participate in sampling surges. Confirmatory laboratories will coordinate with the sentinel laboratories and first responders. These laboratories will also provide method validation. Reference laboratories will provide definitive agent identification for an event, develop methods and guidance, and provide quality assurance. Tentatively identified reference laboratories include the EPA ORD laboratories in Las Vegas (chemical focus) and Cincinnati (biological focus). These two laboratories are currently working toward identifying preferred analytical methods for all priority agents in all media, developing validated methods for CWAs, and preparing a nationwide quality assurance program.

Optimally, these laboratories will operate under the same system to provide as much consistency as possible. The network would also be able to address all hazards, provide rapid sentinel screening, employ high-confidence methods, and offer surge capacity. Laboratories will add real-time technologies to their capabilities when these methods are validated and supported by research. Through the eLRN, EPA hopes to eliminate problems of analytical inconsistencies and lack of sample comparability.

### Questions, Answers, and Comments

- One workshop participant provided additional details about CDC's LRN. CDC developed the LRN to support medical responses. Sentinel laboratories are given cleared status to conduct analyses; they include hospitals and others with access to biological analysis methods. Confirmatory laboratories are part of a secure system addressing public health concerns (i.e., state and federal public health laboratories). Confirmatory laboratories undergo proficiency testing and follow a quality assurance/quality control program. Reference laboratories include the CDC laboratories. The impetus for creating the LRN was the need for high-quality, interpretable results that support public health decisions. Security at these laboratories is critical. Rothman agreed with the participant about security: it is critical, especially when laboratories are handling CWAs. EPA is currently discussing security issues and will likely limit security clearance to a small number of laboratories that will develop protocols and then distribute these protocols throughout the network. Use of surrogates

and degradation products may also facilitate material handling and address security concerns.

- **Is EPA considering geographic distribution of the laboratories for the eLRN?** Geographic distribution is one of the many factors under consideration. For example, EPA is considering using the 10 EPA regional laboratories as part of the eLRN.
- **How did EPA select the four radiological agents for inclusion in the revised standardized analytical methods document?** These four radiological agents represent a starting point. They are high-energy gamma emitters that are readily available.
- **Will the eLRN include private laboratories?** Private laboratories may be included in the eLRN as sentinel laboratories.

## Chlorine Dioxide Fumigation and Liquid Chlorine Dioxide

*John Mason, Sabre Technical Services*

Sabre Technology Services (Sabre) fumigated the AMI building in Boca Raton and containers involved in "Lemon Drop." (USCG identified a shipment of lemons with a viable threat for biological contamination.) USCG needed, and OPP was able to provide, a crisis exemption within 24 hours. Mason presented information about the chlorine dioxide fumigation technology used at these locations and the lessons learned from conducting these fumigations.

At these events, Sabre sought options to accelerate the decontamination and clearance process. Options included minimizing wastes generated, minimizing liquid pre-treatments, applying mobile fumigation technologies, streamlining the clearance process, ensuring proper sample tracking and quality control, and communicating clearly with the affected community. At both events, Sabre demonstrated its mobile fumigation technology. At the AMI building, streamlining the clearance process would have been the best option to reduce time. A tremendous effort was also exerted to describe and discuss the fumigation process to the public and regulatory agencies.

To illustrate the process, Mason described the fumigation at the AMI building in detail. The fumigation itself lasted 7 days from equipment setup to complete fumigation. However, 30 days of planning preceded the actual fumigation. Before fumigation could start, Sabre considered whether *B. anthracis* contamination remained after 2.5 years of vacancy. Contamination followed the mail route and affected the HVAC system above the mail areas. Sampling protocols developed for the Capitol Hill anthrax event were applied to the AMI building.

Having confirmed the presence of *B. anthracis,* Sabre demonstrated the technology to ensure that the fumigant would reach all areas requiring decontamination. Sabre used the building's HVAC system to distribute the fumigant. For the demonstration, about 1,500 biological indicators and 15 test strips were placed throughout the building. Sabre released the fumigant to achieve a concentration of 750 parts per million (ppm) for a 12-hour period. The building remained at a minimum of 75° F and 50 percent relative humidity. The indicators and test strips confirmed that the fumigant would reach all targets.

The Sabre technology involves transforming liquid chlorine to gas. The technology passes the liquid through packing material to achieve the phase change. They controlled for the necessary temperature and humidity level using the building's HVAC system. In Boca Raton, dehumidifying the air was necessary.

During the full-scale AMI fumigation, Sabre placed approximately 200 log-8 test strips throughout the building. In post-treatment sampling, all strips showed a no-growth response. Tracking sample locations and communicating results were concerns, so Sabre developed a three-dimensional sampling map of the AMI building. The software enabled people to visualize the sampling locations and track the sample chain of custody.

As Sabre completed the AMI building fumigation, the company was called to apply the same technology to the contaminated containers identified in Newark Harbor. Sabre used this event to test its mobile equipment. The total transit time from Boca Raton to Newark was about 20 hours. Within 48 hours of leaving Boca Raton, Sabre was ready to begin fumigation. Insurance and a crisis exemption were both obtained within 24 hours because the agencies involved in Newark had worked with Sabre at the Boca Raton building and were familiar with the Sabre technology. The fumigation in Newark was completed within 10 days.

These two projects illustrate the need for pre-planning. The planning phase can be streamlined when agencies and organizations are familiar with a technology. Data tracking is also critical. Demonstrations of the

decontamination technology at the AMI building were needed partially to ensure that the fumigant was contained within the building. Sabre has since conducted tests of tenting with negative pressure to contain fumigants at a facility in Utica, New York. Obtaining insurance also contributed significantly to project delays. The AMI building fumigation was delayed from November to May because of insurance issues.

### Questions, Answers, and Comments

- **When decontaminating the containers in Newark Harbor, were you told what the target agent was? Can you discuss project considerations for conducting decontamination for an unknown?** Sabre received minimal information about the target agent in this situation. They were told to treat the containers for an unknown biological agent. This situation highlights the need for better testing and method development. The containers had been tested for only three elements, but treatment was needed quickly because of the critical location of the containers. Agencies involved did not know whether the biological threat was real or a hoax. The containers had tested positive for narcotics. For the safety of all involved, they assumed that the threat was real. Before a bomb squad or customs officials could enter the containers, decontamination for the biological threat had to occur.
- **Can you elaborate on your sampling, specifically the different sampling at the AMI building points used to track fumigant levels?** Sabre placed thousands of fumigant indicators to confirm that the fumigant reached desired areas. The indicators change color once they reach a certain concentration.
- **How did you gain community support for fumigation of the AMI building?** Sabre included the community early in the decontamination process. A public relations firm provided community relations support. In addition, the project had the mayor's support. Sabre was open about their activities and made themselves available to community groups and media outlets. Sabre held process demonstrations and arranged a round-table discussion for the community the day before the scheduled fumigation. More than 100 people from the community attended this event.
- **Because the original contamination occurred long before building closure, how did you ensure treatment of surfaces that had since been covered?** For surface-to-surface mates, Sabre inserted a geoplate between the two surfaces to allow fumigant penetration. They considered items such as coffee cups on a surface, dictionaries on tables, and surfaces within chair cushions.
- **How was electronic equipment handled?** The equipment that could run was kept running during fumigation. About 60 percent of the equipment was nonfunctional by the time of fumigation. Since fumigation, Sabre has not observed soft metal corrosion. In high-humidity areas, rust films are forming, but this would occur in any facility left vacant for a long period.
- **What was your approach to insurance?** Sabre combined insurance with a no-growth standard for two reasons: 1) a no-growth standard decreases the number of possible questions in the clearance process, and 2) it combines clearance with a standard. As a private company, Sabre must have insurance. Immediately following the events of 9/11, insurance was unavailable because insurance companies had mold and biological exclusions to protect themselves from costly mold situations. Suppliers and vendors on a biological decontamination project would have lost their base insurance because of the mold and biological exclusions. Companies are working to remove this exclusion for bio-weapons, and standby insurance is now available.
- **At the AMI building, Sabre used tubing to check fumigant concentrations inside. Have you considered telemetry systems?** Sabre selected the tubing approach—a simple technology—to keep the overall process simple. Telemetry tied to titration results is desireable but cost-prohibitive at this point.

# STERIS Chem-Bio Decontamination

*Iain McVey, STERIS Corporation*

STERIS Corporation (STERIS) provides technologies to prevent infection and contamination. Their technologies are used in the pharmaceutical industry but also apply to decontamination following biological terror events.

Vaporous hydrogen peroxide (VHP) decontamination methods have widespread use in pharmaceutical companies and clean rooms. A pharmaceutical company may house manufacturing equipment in a chain of glove boxes. Decontamination, which may occur monthly or even daily, consists of simply injecting VHP into the boxes in this chain.

After the events of 9/11 and the anthrax attacks, STERIS began modifying its technologies to apply to anthrax. STERIS used its proprietary VHP to fumigate two buildings contaminated with anthrax:

- **GSA Building 410** This 1.4 million-ft$^3$ building was an office supply storage area and a mail-sorting facility for the White House. STERIS conducted fumigation with the building contents in place. The building was separated into 200,000-ft$^3$ fumigation zones because no data for fumigation of a whole building were available. The HVAC systems were treated as separate zones. The decontamination took 3 weeks.
- **Building SA-32** STERIS simplified the decontamination system based on information gathered during the GSA Building 410 decontamination. This 1.5 million-ft$^3$ building was also separated into 200,000-ft$^3$ zones. All of its contents were removed for easier decontamination. Decontamination at this building took 2 weeks.

At both of these buildings, STERIS successfully employed its VHP technology. McVey stated that a benefit of hydrogen peroxide is that it decomposes to water and oxygen so residual contamination is not a concern. However, the rapid decay of VHP also means that repeated injections are needed to ensure that the proper concentrations are reached. Multiple injection points, not a single point, may be the best option for optimal distribution.

In collaboration with the ECBC, STERIS continues to study the VHP technology. ECBC operates an abandoned building as a large-scale test site. The building houses former office and lab areas, which provide a variety of surfaces and materials for testing. When conducting efficacy tests, STERIS places the VHP units in a sealed room. Sensors on the unit track the vapor concentrations. Because the whole unit is within the room, the unit is self-decontaminating. Bench- and chamber-scale tests have shown modified vaporous hydrogen peroxide (mVHP™) (patent pending) to be effective against chemical agents as well as biological agents.

Because contamination of the cargo air fleet is a concern, STERIS also completed a demonstration project to test mVHP for decontaminating a C-141 cargo aircraft. STERIS set up the hydrogen peroxide system in a cargo plane slated to be scrapped. Project setup took 2 days. STERIS tested different fumigation time periods and concentrations and conducted chemical and biological sampling in on-site mobile units. STERIS also exposed aircraft materials to 100 hours of hydrogen peroxide to investigate concerns about structural integrity. Tests showed that VHP did affect structural components but that there were no ill effects on avionics.

STERIS is working to reduce the system size so that the system will fit on a cargo plane. STERIS is also working to develop a mobile/modular system, spacecraft decontamination systems (with NASA), and an integrated mVHP/HVAC system.

## Questions, Answers, and Comments

- **Has STERIS tested the different effects of VHP on fabrics, materials, paintings, wood, and irreplaceable historical artifacts?** The GSA Building 410 storage area contained personal items of the President and Vice President, including several paintings. No problems with the paintings have been reported to STERIS. Fumigating carpet is a concern. The deeper the carpet, the longer the exposure period needs to be. Most chemical agents make very good plasticizers, so they will soak into materials such as paint. When hydrogen peroxide is introduced as a gas, it works in a similar fashion.
- **Is relative humidity control required?** STERIS personnel use a 35 percent hydrogen peroxide aqueous solution for bioefficacy, so they introduce water with the hydrogen peroxide. If humidity is too high, the hydrogen peroxide gas just condenses. STERIS uses a system to keep humidity below the condensation level.

- **At the NBC offices in New York City, was a crisis exemption needed for VHP?** STERIS obtained a crisis exemption for the NBC decontamination. There was a concern about releasing VHP in an occupied building. Affected rooms, therefore, were treated by liquid decontamination. At this site, the effect of hydrogen peroxide on personal items was also a great concern. STERIS removed personal items and fumigated them with VHP off-site.
- **What was involved in emptying Building SA-32?** STERIS removed the old mail-sorting machine, which was autoclaved for decontamination and incinerated for disposal. STERIS personnel also removed the wallboard down to the studs, so they really fumigated an empty shell of a building.

## Hydrogen Peroxide Vapor for Room/Building Decontamination Following a Chemical or Biological Agent Attack: Overview of Efficacy and Practical Issues

*Mike Herd, BIOQUELL, Inc.*

BIOQUELL, Inc., is a company with experience using hydrogen peroxide vapor for decontamination applications in the healthcare, bio-defense, pharmaceutical, and environmental industries.

Hydrogen peroxide vapor forms a condensate at a submicron level. By nature, it is residue-free because it degrades to oxygen and water. A treated area can be reoccupied when the concentration there reaches a time-weighted average of 1 ppm. Users must remember, however, that decontamination using any type of fumigant does not replace actual cleaning and is not appropriate for use on spills that must be physically removed.

The BIOQUELL system was designed to apply to any size room or location. The system consists of self-sufficient units that can be chained together to form an infinitely scalable system, although Herd noted that practical application would limit the number of connected units. The units operate independently of a building's HVAC system. They are self-sanitizing because they are sealed in the treatment area.

The technology works by flash evaporating a 30 percent to 35 percent hydrogen peroxide solution into the environment. The hydrogen peroxide then creates a micro-condensate on surfaces within the treatment area. The micro-condensate greatly improves the kinetics of decontamination; the D-value is less than 2 minutes when the micro-condensate occurs and 2 hours without the micro-condensate. BIOQUELL uses an optic condensation monitor to detect the onset of the micro-condensation. Relative humidity has not been a factor in the use of this technology; success has been achieved in environments ranging from 5 percent to 85 percent humidity. Modeling is necessary for planning decontamination events and ensuring success. In 2002, BIOQUELL published a paper detailing the physical chemistry behind the process.

Hydrogen peroxide tends to form strong hydrogen bonds between the molecules, which limits its movement. To ensure proper distribution, BIOQUELL releases hydrogen peroxide vapor from a self-contained unit with a rotating nozzle system that distributes the vapor dynamically.

BIOQUELL is currently examining material compatibility issues associated with using hydrogen peroxide vapor on different substrates. Initial efficacy tests under EPA's Environmental Technology Verification (ETV) program for decontamination and destruction of anthrax have been conducted on seven materials (carpet, bare wood, glass, laminate, galvanized metal ductwork, painted wallboard, and painted cement). The first four of these materials are nonporous; the last three are porous. Some spore reduction occurred on each of these materials, which was unexpected—no reduction was expected on porous materials, such as the carpet. A report summarizing the results of this study is available at *www.epa.gov/etv*. Further efficacy testing with other pathogens is planned. Herd indicated that BIOQUELL hopes to conduct research with CWAs and would like to identify a partner for this research.

Herd discussed several case studies to illustrate technology applications. The presentation slides provided specific details regarding these case studies. In one incident, BIOQUELL personnel responded to the SARS incident in Singapore. Within 3 days they arrived on-site and began decontamination. In this instance, they treated 88 rooms without having to modify the building. Medical equipment was included in the treatment. No material compatibility issues arose after treatments at these or other hospitals.

### Questions, Answers, and Comments

- **Using the workshop meeting room as an example, would you recommend removing the contents before fumigating with hydrogen peroxide vapor? Would you recommend pre-cleaning?** Herd estimated that three of the BIOQUELL model R machines would suffice to fumigate the meeting room. Decisions about material removal or pre-cleaning are made on a case-by-case basis and depend on the end use of the room (e.g., reuse or replacement of the contents).
- **How do you seal a hospital room, how long does it take, and do you train hospital people to apply the technology?** Hydrogen peroxide is a "lazy" gas and does not move readily. BIOQUELL tapes a room and then conducts sentinel monitoring to identify possible leaks. BIOQUELL manufactures a small decontamination unit for hospitals. Hospital staff could be trained to use the technology, but they would likely need assistance for room-level decontamination.
- **Does concrete or the concrete surface coating interact with hydrogen peroxide vapor? Have you seen any interaction with smooth, hard surfaces in hospital applications? Were your material compatibility tests representative of real-life conditions?** To Herd's knowledge, tests found no interaction with concrete. He thought that researchers had identified the surface geometry of concrete as a key factor in concrete interactions. A workshop participant noted that the later presentation describing research conducted under the EPA ETV program would discuss material compatibility findings with regard to concrete.
- **Has BIOQUELL hung spore strips in the air to test whether decontamination of airborne (vs. surface) spores also occurs?** Some testing of air kill has been conducted to assess how HVAC systems may affect decontamination. Herd volunteered to share the data upon request.

## Whole-Structure Decontamination of Bacterial Spores by Methyl Bromide Fumigation

*Rudolf Scheffrahn, University of Florida*

Scheffrahn is an entomologist with the University of Florida. His expertise with termite fumigants and fumigation events research is relevant to decontamination. He discussed a laboratory and field study of methyl bromide fumigation and tenting techniques as they apply to decontamination following a terror event.

Every day in Ft. Lauderdale, fumigants are used to clear quarantined fruit and vegetables. Ship containers, each holding $50,0000 to $60,000 worth of product, are sealed and fumigated for 2 to 4 hours. Methyl bromide, which has served as an agricultural chemical for more than 60 years, is one fumigant used. Methyl bromide diffuses readily and is very stable, which means that clearing a treated building is necessary. Methyl bromide can be used with any humidity level and has already been approved to treat some bacteria. However, methyl bromide is a stratospheric ozone depleter.

In partnership with EPA, Scheffrahn conducted laboratory and field studies to assess methyl bromide as a fumigant for anthrax. In laboratory trials, spore strips were placed in desiccation chambers and exposed to methyl bromide. The spore strips were then incubated to assess the kill rate. After 48 hours at 37° C, complete kill was observed for *B. anthracis* and *G. stearothermophilus*. However, *B. atrophaeus* and *B. thuringiensis* experienced only partial kills.

Research continued with a 2004 field study at a 30,000-ft$^3$ home in the Florida Keys. The house represented a typical residential environment with the addition of computers and electronic equipment to assess collateral damage. Researchers placed spore strips (*G. stearothermophilus* on paper, *B. thuringiensis* on paper, *B. atrophaeus* on paper, and *B. atrophaeus* on stainless steel) throughout the structure (e.g., on walls and carpeting, inside a computer CD drive, in chair fabric, wall plates, light fixtures, hanging files, and a sealed refrigerator). They also established eight real-time monitoring locations within the house. The house was then sealed, using tenting—as is commonly done for termite treatments in Florida.

The fumigation involved passing liquid methyl bromide through a heat exchanger to create the gas. At EPA's request, the researchers tested a higher gas concentration than truly necessary. (More than 600 pounds of methyl bromide were used to reach the mean concentration of 312 milligrams per liter [mg/L]. Scheffrahn estimated that 150 pounds of methyl bromide would have sufficed.) Reactions with methyl bromide are temperature dependent; higher temperatures result in better kill efficacy. As such, fans and heaters maintained a target temperature of 35° C within the house. The fans moved the heat through the house but were not necessary to diffuse the methyl bromide. After a 48-hour exposure period, the researchers aerated the structure to remove the methyl bromide, and after 4 days, methyl bromide was not detected around the house. At 48 of 50 spore strip locations, no growth was observed. Growth occurred on all controls. The two failure locations were the refrigerator and at an improperly mounted spore strip location. No damage to electronic equipment was observed.

Advantages to the methyl bromide and tenting system included the low cost (approximately $150 per 1,000 $ft^3$); rapid turnover to completion (approximately 200 hours); treatment of all porous material, voids, and HVAC systems; application at any humidity; and absence of collateral damage. To demonstrate how quickly a home can be sealed with a tent, Scheffrahn showed an example of a four-man crew in Ft. Lauderdale installing a tent around a 3,000-$ft^2$ home in about 40 minutes.

Scheffrahn also suggested some future research avenues: real-time infrared methyl bromide detectors; air displacement with materials (e.g., nylon 66) to reduce the total treatment volume; silicone ground seals, and methyl bromide scrubbing. At quarantine locations, scrubbers are used to treat methyl bromide.

### Questions, Answers, and Comments

- **What was the temperature inside the refrigerator?** [Room temperature.] The refrigerator was off to prevent recirculation, and the door was closed tightly during the fumigation.
- **If sulfuro fluoride is a substitute for methyl bromide, why not use that against anthrax?** Sulfuro fluoride treats only insects and has limited use against insect eggs. Methyl bromide, however, can treat bacteria.
- **Does methyl bromide present an explosion hazard?** No, methyl bromide was once used as an ingredient in fire extinguishers.
- **What are the long-term availability and costs of methyl bromide?** Methyl bromide will remain a quarantine fumigant until a suitable replacement can be found. Researchers have been searching for a replacement for 10 years or so. Suitable replacements are already available for other methyl bromide uses.
- **How would scrubber waste be disposed of?** Scheffrahn thought that the scrubber waste would be treated as a hazardous waste and incinerated.
- **Can methyl bromide be used on wet surfaces?** There have been some studies with damp (free water vs. high-humidity) wood treatment. Methyl bromide has low solubility—about 1.5 grams per 100 milliliters of water.
- **Was there an attempt to have methyl bromide approved for treatment of the anthrax releases?** Scheffrahn understood that Great Lakes, the company that manufactures methyl bromide for fumigation, was contacted. Research found during a literature review indicated that methyl bromide could kill anthrax, but the data were unclear. The primary study examined anthrax kill in woolens and tested only pure methyl bromide. The uncertainties of the data eliminated methyl bromide from consideration. More recent research has found that a 2 percent methyl bromide by volume is sufficient for efficacy.

## DF-200 Decontamination of CBW Agents, Other Biological Pathogens, and Toxic Industrial Chemicals

*Rita Betty, Sandia National Laboratory*

Sandia National Laboratory (SNL) is testing a decontamination formulation (DF-200) for neutralizing CWAs and toxic industrial chemicals, killing biological agents, and combating aerosolized chemical and biological agent clouds.

DF-200 is an aqueous-phase formula that has been used successfully by the military. The commercial product is mixed on-site as a tertiary system of surfactant,

a 7.9 percent hydrogen peroxide solution, and a novel activator. The hydrogen peroxide solution is below 8 percent to allow for easy shipping. After mixing, the final hydrogen peroxide concentration is about 3.5 percent. DF-200 is less corrosive than bleach and other available decontamination materials.

SNL tested DF-200 and DS2 (a corrosive decontaminant used by the military in the past) as decontaminants for GD, VX, and HD in stirred reactor studies. Results were similar, with DS2 performing only slightly better at the 1-minute exposure period. Both chemicals achieved 100 percent decontamination of live agents after a 60-minute exposure period. In other studies, DF-200 rapidly (within a 15-minute exposure period) neutralized nerve agents, sodium cyanide, phosgene, and carbon disulfide, as well as biologicals (*B. anthracis* and *Y. pestis*). Mustard agents required more time (a 30-minute exposure period) because of mustard's low solubility. A benefit of using DF-200 to neutralize VX is that it cleaves the phosphorous-sulfur bonds to create less-toxic byproducts. Overall, SNL has completed a number of tests of DF-200. Specific results are classified, but generally the results demonstrate a high efficacy. Betty provided contact information for those seeking to learn more.

Laboratories at Kansas State University have tested DF-200 and biofilms. Samples consisted of six- to seven-log biofilms that underwent a 1-minute exposure to DF-200. The biofilms were allowed to grow for 1, 3, 7, and 14 days prior to treatment. The 1-minute exposure to DF-200 successfully decontaminated the sample biofilms. DF-200 was also completely successful in eliminating infectivity and viral RNA integrity in influenza tests.

Toxic industrial chemicals, which are an increasing threat, provide unique challenges for decontamination because of the variety in their chemical and physical properties. They also attack by differing mechanisms: nucleophilic attack, oxidation, reduction, or buffering. Foam is a highly effective treatment method, except against toxic metals or strong acids and bases that may react violently.

SNL is also conducting a feasibility study of using foam (e.g., DF-200) for knocking down an aerosol agent cloud intended to drift to target areas. The study explores methods for cloud knockdown and neutralization. SNL does not intend to design a system for implementing treatment.

DoD considers DF-200 to be the best available decontamination technology. SNL developed DF-200 to enable rapid and safe neutralization of agents. Currently, DF-200 is available in a variety of sizes and dispersal techniques (e.g., 5-gallon backpack size) to meet multiple needs. DF-200 is available to first responders addressing a terror event. In 2004, EPA registered DF-200 for disinfecting hard, nonporous materials. Applications beyond decontaminating threat events may also exist.

### Questions, Answers, and Comments

- **What remains after decontamination with DF-200, and how is it treated?** The residue and cleanup depend on the release scenario. After the foam collapses, a wet-dry vacuum will remove it from indoor areas. After an outdoor release, the foam dries to a light, silky residue, which may weather in a short period of time.
- **What is created in air when the foam mixes with the agent? Is the air still dangerous after the kill? When is it safe to reoccupy an area?** To be effective as knockdown, the foam is deployed as small droplets that eventually fall to the ground. The droplets maximize the capture efficiency of the agent. No gas is involved. Overall, the process creates a neutral cloud.
- **In the subway example, what is the active spray duration?** The foam spray is not necessarily continuous. In chamber tests, 1-minute spray durations were used. For the 8-cubic-foot chamber, about 2 liters of DF-200 are deployed in this time.

## Capitol Hill Ricin Incident: Decontamination Dilemmas

*Jack Kelly, U.S. Environmental Protection Agency, Emergency Response Team*

The ricin incident at Capitol Hill provides a real-world example of issues faced at a decontamination event. The Capitol Police responding to the ricin event had little information about ricin, so they called in OSCs, whose primary purpose at this event was to gather information. This presentation reviews OSC actions. In the end, the OSCs themselves were forced to make decisions about ricin based on limited information.

Ricin was first developed as a weapon during World War I. It is a white powder that can be made fairly easily from the protein toxins of castor plant beans. Worldwide, more than a million tons of castor beans are processed for castor oil annually. Castor oil production in the United States, however, ceased in the 1970s. Ricin is composed of two toxins that act together to cause toxicity by inhibiting protein synthesis in cells. Ricin is considered extremely toxic by any exposure route (inhalation, ingestion, or injection). No vaccines or antidotes are available.

On February 2, 2004, ricin was found in the mail room attached to a senator's office in the Dirksen Building. The Capitol Police contacted an OSC that day and requested assistance. Field sampling and follow-up laboratory analysis confirmed the presence of ricin. EPA was asked to receive, inventory, and store mail from the building; conduct additional characterization; perform decontamination of the affected areas and their contents; and conduct clearance sampling. A February 9, 2004, deadline for decontamination was established.

By February 8, 2004, EPA had containerized approximately 80 drums of unopened mail and stored clothing from 32 potentially exposed individuals. EPA, the FBI, and Capitol Police had collected at least 670 samples from three affected rooms and identified 19 positive results—all from one room. From the affected room, EPA removed and stored personal and office items. Large hard-surface items were left in place.

The mail room was clearly contaminated. Bordering rooms on either side were considered buffer rooms and potentially contaminated. EPA looked toward existing research and data to devise a decontamination plan. The U.S. Army Medical Research Institute of Infectious Diseases (USAMRIID) Blue Book served as the primary resource. Technologies considered were chlorine dioxide fumigation, heat treatment, and sodium hypochlorite solution cleaning.

EPA chose to decontaminate with a sodium hypochlorite solution. This decision was based on the small size of the decontamination area, the extent of ricin contamination, knowledge of ricin properties, a literature review, and input from an advisory group. Decontamination occurred in the mail room that was known to be contaminated; the two buffer rooms; the room that held evacuees; and the common hallways, elevators, and mail drops. EPA covered the mail room with the solution and effectively cleaned the room. Post-treatment testing found no ricin activity. The building was reopened on February 9, 2004, with the mail room and buffer rooms remaining closed for renovations.

EPA considered several options for decontaminating the clothing, office items, mail, and mail equipment that had been removed from the building. A decontamination team researched the options and suggested heat treatment. If the heat treatment were unsuccessful, ethylene oxide fumigation would follow. Chlorine dioxide fumigation was the third option.

The decontamination team considered packaging items for decontamination, setting sterilization specifications, and establishing efficacy measurements. The team also considered ricin concentrations, ricin locations on materials, and ricin toxicity values. Because of the unknowns surrounding ricin, EPA decided that near 100 percent denaturation of ricin was needed.

In cooperation with ECBC and the Naval Medical Research Center (NMRC), EPA obtained crude and purified ricin to test treatment efficacy. Clothing and office materials, along with indicator vials of crude and pure ricin, underwent heat treatment. Temperature probes in the treatment bags tracked the temperature (82–88 °C). Treatment resulted in 100 percent deactivation of 13 of the 14 purified ricin vials. For the crude ricin, 14 of the 28 vials reported 94.4 percent to 99.7 percent deactivation. EPA was unable to determine why crude ricin was more difficult to denature than purified ricin. The vials that did not achieve 100 percent deactivation underwent a second heat treatment. Some of the vials were reanalyzed within 4 days of treatment and others 3 weeks after treatment. The crude ricin reported 99.8 percent to 99.99 percent deactivation after 4 days and greater than 99.99 percent deactivation after 3 weeks. The purified ricin reported 100 percent deactivation after 4 days and only 99.92 percent to 99.99 percent deactivation after 3 weeks. EPA believed this reactivation may have been due to protein refolding. The decontamination team documented their findings in a brief memorandum. Recommendations for the fate of the clothing and office materials that underwent the single heat treatment were left to the OSC.

EPA received a second set of materials, including paper items, mail, and vacuum cleaner contents, for decontamination at the end of March 2004. These materials underwent a single heat treatment. In addition, EPA conducted ethylene oxide pilot tests to assess efficacy. The pilot test resulted in deactivation up to 99.9 percent, so EPA decided to expose the heat-treated materials to ethylene oxide. Results from test vials undergoing ethylene

oxide treatment alone or heat followed by ethylene oxide treatment indicated that the combined treatment was most effective. In the combined treatment, 9 of the 11 crude ricin vials experienced 100 percent deactivation, with the other 2 samples reporting 99.995 percent and 99.997 percent deactivation. All 11 purified ricin vials were 100 percent deactivated. Again, the decontamination team documented findings in a memorandum and the OSC provided recommendations for reuse.

Kelly noted several lessons learned from this decontamination event:

- **Documentation** EPA correctly assumed that they would receive requests to retrieve information for the criminal investigation. Documenting the materials held in each container was critical.
- **Communication** The decontamination team first considered simply disposing of replaceable personal items (e.g., clothing) and reimbursing the owners. However, the owners were emphatic about having items returned. An effective communications program might have persuaded owners to accept reimbursement as a solution.
- **Coordination** Interagency groups and the decontamination groups worked well together and may have a place in a response. Large groups, however, may suffer delays simply because of the group size. Collaboration with other agencies, such as ECBC and NMRC, was critical for the research projects conducted as part of decontamination. This collaboration allowed the involved OSCs to focus on managing the response and avoid becoming bogged down by the technology.

### Questions, Answers, and Comments

- **How do the percentages reported for deactivation relate to kill?** The mammalian cell assays assess reduction in activity and provide results as the percent of toxicity inactivity. Crude and purified ricin were used as surrogates for the ricin actually found during the event.
- **What was the ricin particle size?** This information was never made public.
- **Ricin is a considerable concern for the USPS. Have fumigation vendors looked at decontaminating ricin?** Some studies of ricin fumigation have been conducted. Vendors, however, are unable to obtain ricin for testing their decontamination technologies. They have conducted some studies of protein degradation that may be applicable to ricin. Vendors also hypothesize that if a fumigant can destroy a prion, it should be able to destroy ricin. Overall, ricin should be a priority agent for further research.

## Restoration From Decontamination: USPS Experience

*Richard Orlusky, U.S. Postal Service*

In October 2001, the USPS Trenton facility closed as the result of an anthrax event. This presentation highlighted the USPS's experiences in restoring this building after decontamination.

Although contamination occurred in 2001, the Trenton facility was closed until offices in Washington, D.C., had been decontaminated. Construction of the fumigation system in Trenton began in April 2003, and fumigation with chlorine dioxide gas occurred in October of that year. An environmental clearance committee recommended reoccupancy in February 2004. At that time, the USPS and the vendor began removing the fumigation equipment, conducting limited building restoration (e.g., cleaning the HVAC system), and meeting with restoration contractors to plan restoration activities. The USPS began restoring the mail machinery in March 2004 and restoration contractors mobilized at the site in May 2004. The building reopened in March 2005.

Critical factors that impacted the restoration included:

- The building's age and the type and condition of the equipment
- The effects of the decontamination effort (e.g., surface cleaning with bleach damages equipment and flooring)
- Building degradation from inoperable control systems (e.g., shutting down the HVAC system led to high temperatures and high humidity)
- Equipment degradation from a lack of preventive maintenance (e.g., mail-sorting equipment requires extensive preventive maintenance and performs poorly after sitting idle)

Orlusky noted that if the USPS had known the extent of damage caused by fumigation with chlorine dioxide, they would have used a different, less damaging material. They would have reserved bleach for surface decontamination only. Orlusky also noted that the longer a building and its equipment are left idle, the longer it takes to restore the equipment. At the Trenton facility, the interior temperature reached 90 to 100 °F, which resulted in a harsh working environment. Restoring environmental controls is key to creating a comfortable work environment and minimizing equipment and building degradation.

Restoration considerations included:

- The cost of inspecting and servicing components versus replacing components
- The service life of existing building equipment
- Necessary building upgrades
- Building aesthetics

Inspecting and servicing equipment are hidden costs of decontamination and restoration. These costs should be weighed against the cost of simply replacing equipment. Aesthetics also carry hidden costs, but the importance of aesthetics, which impact worker relations and public relations, should not be underestimated. The USPS spent considerable money replacing bathroom fixtures, renovating the lobby, and replacing locking devices (e.g., employee lockers and P.O. boxes).

At the Trenton facility, restoration included rebuilding the mail machinery; inspecting electrical wiring, circuit breakers, motor controls, and transformers to identify replacement versus repair points; laying new flooring over workroom floor tiles and replacing carpet in office areas; replacing components of the HVAC systems; and addressing building aesthetics.

Orlusky discussed the following lessons learned from the USPS's experiences:

- **Prepare up-to-date as-built plans.** Many delays experienced by the USPS stemmed from the lack of accurate as-built plans and drawings. These plans are critical to ensuring successful decontamination and restoration.
- **Consider the facility.** The age of the building, maintenance status, and type of equipment are major determinants of cost, time, and scope. These factors should be considered when planning the decontamination and restoration.
- **Plan restoration actions early.** Including the restoration contractor in discussions with the fumigation contractor can help with planning a comprehensive scope of work.
- **Select the decontamination technology wisely.** If fumigation is the selected decontamination method, then surface cleaning with a bleach agent should be conducted sparingly. Additional chloride dioxide research may show effective decontamination at lower concentrations and reduced contact times, which may reduce damage caused by the fumigant itself.
- **Maintain the facility.** Restoring environmental controls as quickly as possible, maintaining equipment, and reducing the downtime before and after fumigation reduce the overall time needed to restore a facility.
- **Estimate hidden costs.** Costs beyond the decontamination and fumigation event themselves can be substantial. In addition to aesthetic and equipment-servicing costs, industrial hygiene activities, such as health and safety training, emergency response and evacuation planning, as well as site security, add to the overall cost.

## Questions, Answers, and Comments

- A workshop participant stated that bleach alternatives have been approved under crisis exemptions. In instances of heavy contamination, however, some pre-cleaning is necessary to reduce biocontaminants to levels that will respond to additional treatment. Orlusky agreed that bleach cleaning is necessary in some instances. After several attempts, the decontamination crew developed a successful bleaching technique. Bleach cleaning, however, was a labor-intensive practice.
- **How were the HVAC systems addressed?** The USPS kept the HVAC systems running after closing the building, but over time components of the system failed. Workers wore personal protective equipment while conducting repairs.
- **Did the USPS conduct OSHA restoration sampling?** OSHA has posted a guidance document for restoration sampling on its Internet site, and the USPS submitted a restoration sampling plan to OSHA. The agencies worked closely together to conduct restoration sampling, which was a major effort. The facility employees appreciated this relationship with OSHA.

# Another Look at Chlorine Dioxide Fumigation: Concentration-Times, Efficacy Tests, and Biological Indicators

*Paula Krauter, Lawrence Livermore National Laboratory*

Lawrence Livermore National Laboratory (LLNL) and SNL, in partnership with the San Francisco International Airport, have been collaborating in a Domestic Demonstration and Application Program (DDAP) to develop and demonstrate procedures, plans, and techniques for the rapid restoration of a major transportation facility. DDAP consists of many components. This presentation focused on research, development, and evaluation of rapid efficacy tests to improve the verification and clearance phases of decontamination. LLNL specifically studied fumigation with chlorine dioxide.

Researchers developed a rapid viability test protocol (RVTP), which is an overnight method for processing biological indicator strips using real-time polymerase chain reaction (PCR). LLNL's research sought to demonstrate this method's ability to test thousands of samples and demonstrate a tracking and data analysis tool. The research compared the RVTP against the standard culture method, which requires 7 days for results, to assess the accuracy of the RVTP. The research included a rigorous quality assurance program to evaluate potential cross-contamination, to determine the RVTP's ability to detect blind positives, and establish assay sensitivity. In testing the RVTP, LLNL included a number of blind positives, degradation products that would interfere with the methods, and positive and negative controls.

LLNL conducted testing over the course of 2 days. Testing involved exposing more than 1,000 biological indicator strips to 750 ppm of chlorine dioxide for up to 12 hours. A number of strips were also exposed to nonlethal concentrations of chlorine dioxide by varying the contact times. (LLNL used a test chamber and technology provided by Sabre.) Researches were able to tightly control the chlorine dioxide concentration, temperature, and humidity within the test chamber. The chlorine dioxide was generated by combining sodium hypochlorite and hydrochloric acid to produce chlorine. The chlorine was then combined with sodium chlorite. Half of the strips were analyzed by RVTP and half by the standard culture technique. LLRN barcoded each to track sample locations in the test chamber and test results. The barcode maintained the sample chain-of-custody.

Krauter presented details of the RVTP and standard culture test conditions. Results of the standard culture are determined by visual turbidity, which is a subjective endpoint. RVTP results are less subjective; positive results are based on a specific number of DNA detections. At a dose of 750 ppm of chlorine dioxide for 6 or more hours, no viable growth was identified by either RVTP or standard cultures. No significant difference in results provided by the two methods was identified. The standard culture method reported a 1.5 percent false positive rate. No false negatives or positives were observed for RVTP.

Both stainless steel and paper strip biological indicators were tested. At nonlethal doses of chlorine dioxide, LLNL found a significant difference in number of positive results identified for the stainless steel versus paper strips. These biological indicators differ in several qualities: porosity, spore viability, purity, and spore piling. These results highlight considerations for selecting a decontamination method (gas or liquid) applicable to conditions (porous versus hard surfaces).

Overall, LLNL's research met the objective of developing an analytical method that can provide accurate results in 15 hours. Continuing research includes testing RVTP with a high-throughput automation mode and applying RVTP to a variety of environmental samples (e.g., wipes and filters).

## Questions, Answers, and Comments

- LLNL's results found better kill on the stainless steel disks versus paper strips. These results conflict with other research with glass and paper. Krauter noted this inconsistency. LLNL used a different fumigant generation process and a different technology to apply spores to the stainless steel disks. These differences may have affected the results.
- **What kind of variability was there in the replicates?** For each test concentration and time period, LLNL tested 50 individuals and identified positives within the test group. They then conducted the standard student T-test on results.
- **How were nonlethal doses achieved?** The study

consistently exposed test strips to 750 ppm of chlorine dioxide, but the exposure period varied to achieve a nonlethal dose. The test results indicated a need for more information on the 3- to 5-hour exposure periods and for log-8 versus log-6 test strips.

- **What is the cost of RVTP?** Krauter did not have specific information about analysis costs, but another workshop participant indicated that RVTP costs about 5 cents per sample.

## Innovative and Emerging Decontamination Technologies

*Mark Brickhouse, Edgewood Chemical and Biological Center*

This presentation provided an overview of ECBC activities. Public- and private-sector researchers are evaluating a number of decontamination technologies, such as mVHP, forced hot air, Decon Green, chlorine dioxide, enzymes, solvent suspensions and wipes, ionic liquids, and supercritical carbon dioxide. ECBC and DoD are seeking replacements for liquid decontaminants, such as bleach because of problems with corrosivity.

Congress funds most ECBC projects, which have focused on field-testing technologies. The following summarizes ongoing efforts.

- **Modified vaporous hydrogen peroxide (mVHP)** ECBC and STERIS co-developed this decontamination technology, which includes ammonia as an activator. They have conducted field-testing at an abandoned building and in a C-141 cargo plane, as described during the presentation by McVey of STERIS. Field-testing proved efficacious against biological and chemical agents. The C-141 cargo plane served as a demonstration of the mobile technology. For bare metal coupons, greater than 99.9 percent kill rates were found for biologicals and a mustard simulant was reduced to less than the 8-hour time-weighted average in 5-, 10-, and 24-hour test runs. On more absorptive surfaces, however, longer exposure periods and higher concentrations were required for success.

These tests also examined methods for distributing the VHP and provided data for modeling efforts. Ongoing research with mVHP includes reducing the equipment size to a system transportable on military vehicles; assessing material compatibility and equipment sensitivities; expanding aircraft studies; and assessing applications for ambulances, hospitals, or hotel suites.

- **Forced hot air** Injecting an area with forced hot air acts as accelerated weathering. Past tests were unsuccessful because of uneven heating; even heating prevents recondensation. ECBC has conducted more recent testing in aircraft using airflow strategies that achieve consistent target surface temperatures. Results indicated that forced hot air increases off-gassing for chemical agents but is insufficient for treating biological agents. Studies consistently found that longer cycle times are needed for more absorptive materials. Considerations for forced hot air systems include material compatibility, treatment volume, and air distribution. ECBC believes the system could be modified to treat other vehicles.
- **Combined VHP and forced hot air** A combined system takes advantage of the benefits of both technologies. The forced hot air enhances hydrogen peroxide vaporization, controls heat and relative humidity, and enhances the diffusion of VHP. The forced hot air also improves desorption of chemical agents. The effluent from treating an aircraft can be routed through a carbon-based filtration system, catalytic oxidation, or thermal oxidation treatment system. ECBC may conduct further research on the combined technology in fiscal year 2007.
- **Decon Green** ECBC is also developing Decon Green, an environmentally friendly decontaminant formulated using commercial chemicals. Decon Green is designed to replace DS2 and DF-200 in military use. Studies have proven Decon Green to be effective against chemical and biological agents, but the chemical is disruptive to surfaces. To improve material compatibility, reformulations have slightly reduced kill efficacies. Decon Green has a number of benefits: it is ready for use 15 minutes after mixing, applicable in a variety of weather conditions, effective for 12 hours after mixing, compatible with protective clothing, and disposable as a nonhazardous material after hydrogen peroxide degradation.

- **Resistant coatings** Traditional chemical agent resistant coatings (CARCs) are nonreactive, durable and nonmarring, weather resistant, and flexible. Research for next-generation CARCs has been funded.
- **Reactive coatings** These materials actively destroy surface chemical agent contamination either by hydrolysis or oxidation. Research information on reactive coatings is readily available, and reactive materials such as these are widely used in industrial processes. Identifying and studying materials resistant to biological and chemical agents will likely be a strategic research area in the next few years. Potential agents for reactive coatings include metal oxides, activated carbon, zeolites, microporous membranes, novel polymers, dendrimers, and microencapsulation materials. Current research with reactive coatings aims to identify a coating that could achieve 99.999 percent decontamination when partnered with other standard decontamination technologies. ECBC is partnering with the Army Research Laboratory (ARL) to study hyperbranched polymers and polyoxometalates. ECBC will perform the efficacy and material compatibility tests.
- **Other research materials** ECBC and others are conducting research on several other materials. In a joint venture with NATICK, ECBC is evaluating active moieties in uniforms for personal protection. Catalysts, such as metal oxides, activated carbon, and polyoxometalates would be included in uniform fabrics to improve personnel protection from chemical agent vapors. ECBC is also investigating self-decontaminating coatings (e.g., polyoxometalates and other inorganic catalysts) for water infrastructure protection and zeolite-based systems that would apply to a wide variety of situations.

In addition to researching specific decontamination agents, ECBC is conducting several other research projects:

- **Comparative decontamination** The object of this study is to compare the efficacy of three different commercial fumigation products and study the effects of parameters such as temperature and relative humidity.
- **Enzyme decontamination** ECBC and Genencor International have partnered to investigate the use of enzymes to decontaminate nerve agents, sulfur mustard, and biological agents and toxins. They have signed an exclusive patent license agreement to begin commercial production of viable enzyme products. These products are available to first responders.
- **Sensitive equipment decontamination** ECBC is also researching small-scale decontamination systems that are capable of treating a wide range of chemical and agent materials. Two research areas are sorbent/reactive suspensions and solvent wipes. Ongoing tests of these technologies are planned. Nonreactive wipes also play a role in reducing gross contamination.
- **Ionic liquid-based decontamination** Ionic liquid has been a productive research area for the past 5 to 10 years. Researchers have identified a broad class of ionic liquids for decontamination of CWAs. Ionic liquids would replace traditional solvents by combining solvent, surfactant, buffer, and oxidizing agent functionalities. Further tests are planned.
- **Supercritical carbon dioxide decontamination** ECBC developed a bench-scale supercritical carbon dioxide reactor to test this decontamination technology. This material seems to be an effective cleaning and sterilizing agent. Supercritical carbon dioxide is also environmentally friendly and recycles carbon dioxide, thus preventing the release of greenhouse gases. The technology is readily available for garment cleaning, hard-surface cleaning, and sterilization.

## Questions, Answers, and Comments

- **What technologies apply to wide-area decontamination, such as large cities?** Foam and base-activated technologies can both be developed for wide areas. GL1800 is modified airport de-icing equipment that can be used for deploying a liquid over a large area.
- **Is the forced hot air technology effective against virus contamination?** ECBC has tested decontamination technologies against virus contamination, but a decontaminant must be able to kill a spore to be considered a biological

decontaminant. A first responder will not necessarily know the differences among viruses, biological agents, and spores.

- **When conducting aircraft research, why was the HVAC system excluded from study?** ECBC researchers excluded the HVAC system because they were considering contamination scenarios that may not involve the HVAC system. Contamination of the main cargo area was seen as the more likely scenario.

# Systematic Decontamination Project: Homeland Security Verification of Chemical and Biological Decontamination Technologies

*Phil Koga, Edgewood Chemical and Biological Center*

When decontaminating an anthrax-contaminated building, one must consider treatment options (e.g., surface treatment versus fumigation), efficacy data, and material impacts. ECBC, in conjunction with NHSRC, is conducting systematic studies on the performance of chlorine dioxide and VHP for decontamination.

As part of its research, ECBC is conducting a bioefficacy study to assess concentration and exposure time, evaluate six types of materials (porous and nonporous), and test avirulent and virulent *B. anthracis*. The study also examines sub-optimal temperatures and relative humidities as well as *B. anthracis* surrogates. The test design included three fumigants (STERIS's VHP, ClorDiSys, Inc.'s chlorine dioxide, and Sabre's chlorine dioxide), six microorganisms, and test coupons made of six different materials. The two chlorine dioxide fumigants differed in that ClorDiSys, Inc., uses a dry generation process and Sabre uses a wet process.

ECBC conducted range-finding tests to assess optimal fumigant concentrations and exposure periods and examine the effects of temperature and humidity. Koga presented specific test details. Testing seeks also to provide information about the effects of six different building materials on the fumigant concentrations and the effects of the fumigants on the integrity of the building materials. This testing is linked with the bioefficacy studies. ECBC is looking to use American Society for Testing and Materials (ASTM) standards for strength and other characteristics. Deposition velocity testing has begun, and material compatibility testing is slated for April 2005.

### Questions, Answers, and Comments

- When generating chlorine dioxide, determining whether chlorine gas is present is critical. Other researchers used ammonia-based analytical tests to identify chlorine dioxide.
- One workshop participant suggested that ECBC use corrosivity tests developed in the telecommunications industry when conducting material compatibility tests with circuits. This test includes exposing a copper plate to an agent and counting the holes that form. Koga indicated that ECBC considered testing the circuit function, as well as material compatibility.
- **Has ECBC considered pore symmetry tests or other methods to assess surface degradation?** ECBC has considered a number of methods but is open to other recommendations.
- **Is there a need for a secondary scrubber for chlorine gas when fumigating with chlorine dioxide?** ECBC is testing for the presence of chlorine gas in the chlorine dioxide gas stream and addressing this concern.
- **What was the spore recovery material for the coupons?** ECBC used a water-based material.

# Use of HVAC Systems in Building Decontamination

*Tina Carlsen, Lawrence Livermore National Laboratory*

LLNL and Lawrence Berkeley National Laboratory (LBNL) became involved in decontamination research after the sarin release in the Tokyo subway. This presentation describes their HVAC system decontamination studies.

After the Tokyo subway incident, three potential attack scenarios were identified: open air (e.g., a stadium), semi-enclosed (e.g., a subway), and enclosed (e.g., a building or an airplane). In two of these scenarios, HVAC systems are involved, so LLNL's research focuses on HVAC systems and gaseous fumigants used in decontamination.

Specifically, the research examines both decontamination of HVAC systems and use of HVAC systems in decontamination. The research includes a medium-scale, well-instrumented demonstration with hydrogen peroxide (generated using the STERIS technology).

The LLNL test facility consists of an office trailer split into two rooms: a test room and a control room. The test room contains an HVAC system created with 6-inch-round galvanized steel ductwork, aged to remove organics. Preliminary experiments involved injecting the test room with hydrogen peroxide through the ductwork. The decontamination cycle consisted of four steps: dehumidify to reach 30 percent relative humidity, condition by injection with hydrogen peroxide at 7.3 grams per minute (g/min) for 12 minutes, sterilize by injection with hydrogen peroxide at 4.2 g/min for 3 hours, and aerate for 4 hours.

LLNL expected a hydrogen peroxide concentration of 1 mg/L during the sterilization phase. In testing, however, the hydrogen peroxide concentrations were significantly lower. Concentrations dropped near one corner of the room. A test with biological indicators supported this finding; some positive indicators were found. LLNL hypothesized that the galvanized steel was affecting the hydrogen peroxide concentrations. A subsequent study using polyvinyl chloride (PVC) ductwork supported this hypothesis. The bulk hydrogen peroxide concentration was much greater when introduced with PVC than with galvanized steel.

LLNL created a new circular ductwork configuration that included 90 feet of galvanized steel with sensors located throughout. After injecting this system with hydrogen peroxide, LLRN found that the hydrogen peroxide concentration decreases as a function of flow rate, temperature, and distance traveled along the ductwork. These results indicate a need for increased injection rates or multiple injection points. Condensation is a concern when increasing the injection rate.

In conjunction with LBNL, LLNL is creating a computational fluid dynamic model to characterize decomposition in the ductwork. Available test data indicate that the VHP degradation process is third order. Once this model is created and validated, it can be used to assess longer systems and larger configurations.

LLNL is also conducting surveys of buildings with HVAC systems. The surveys identify the features that have the greatest impact on hydrogen peroxide. LLNL collects real-world data about these features. Information collected includes square footage, interior materials, layout, HVAC system operation modes, injection point locations, humidity controls, HVAC system returns, and areas not serviced by the HVAC system. An HVAC engineer can help to address architectural concerns. LLNL has collected HVAC system information from three federal buildings (a two-story, modern office building; an older, multistory office building; and an indoor arena). Collected information is classified because these are federal facilities. The surveys identified architectural features that would be difficult to decontaminate. LLNL also concluded that an HVAC engineer should be involved in the building surveys. The results may support a database of information needed for developing remediation strategies and individual building assessments.

Ongoing research will include biological indicator tests within the ductwork to characterize kill rates and optimize VHP efficacy, characterization tests with alternate ductwork materials, and completion of the modeling program. Ongoing room-scale studies include characterization of VHP distribution and development of predictive models. During characterization tests, LLNL researchers will evaluate different modes of fumigant introduction and dispersal. They will also increase the sensor density in the test room to provide additional data.

### Questions, Answers, and Comments

Workshop participants commented on the application of the research to real-world situations. Several participants commented that larger office buildings often use fiberglass-lined ductwork and that returns may be lined with papier-mâché or fiberglass. Another participant noted that the presence of slime and dirt in HVAC systems would affect study results. And yet another participant noted that the iron content of the ductwork would also affect results. Carlsen agreed that any lining, material, or dirt in the ductwork would affect results. An initial project goal was to provide information for airports, which usually have HVAC systems made of unlined galvanized steel. LLNL obtained their galvanized steel ductwork from a commercial business and did not test for iron content. LLNL researchers have not yet studied lined ducts, but they would welcome additional research to add to the body of knowledge. LLNL started its research with a basic, clean system. Subsequent efforts could involve expanding the system or testing a dirty system. Because of funding limitations, LLNL researchers selected room scaling as a

next phase. They hope to conduct dirty system testing in the future.

## Building Disinfection Byproducts: Experimental Evaluation and Decision Tool

*Richard Corsi, University of Texas*

Corsi's research focuses on the effects of building materials on fumigants and the production of gaseous byproducts. The research investigates how materials affect the amount of fumigant needed for decontamination and provides anecdotal evidence regarding material compatibility.

In conducting building decontamination, a disinfectant must reach a specific dose to ensure efficacy. The dose is based on the disinfectant concentration, as well as on exposure time, and can be expressed as ppm-hours. Disinfectant consumption by materials in the treatment space (e.g., a room) affect the dose. Consumption may reduce the disinfectant air concentration, increase the time to the threshold concentration, suppress doses, and require greater mass injection rates and increased injection times. Another concern of fumigation is the production and persistence of disinfectant byproducts. Byproducts themselves may be toxic, persist in a building, compromise worker safety, and increase the time to reoccupation.

Researchers have evidence that a fumigant can enter and react with porous materials. The term *deposition velocity* describes the mass transport of a disinfectant in or out of material and chemical reactions. Corsi presented an equation describing disinfectant concentration in a room over time, which is a function of injection rate, gas-phase decay, and velocity deposition. The deposition velocity is a function of time and materials.

Issues regarding byproduct formation and release include byproduct identification, formation factors, and persistence. Factors affecting byproduct formation include the disinfectant, disinfectant concentration, material, relative humidity, and exposure time.

Corsi's research evaluated 4 disinfectants and 24 materials, quantified deposition velocities, and identified byproducts and release rates. Some byproducts are volatile while others are more persistent. This research tried to identify and quantify byproduct formation. Data from this research feed several tools: a software application that will support decisions regarding fumigant applications (DADS); a database of experimental results (e.g., deposition velocities, byproducts); and screening calculations that facilitate fumigation system design, consider fumigant consumption, and rank byproducts.

The test included 96 combinations of materials and disinfectants that served as standard conditions. Relative humidity and dose remained consistent. Relative humidities, disinfectant doses, and disinfectant and material combinations were then adjusted, yielding 36 variations. Tests were replicated 14 times. The research generated more than 3,000 samples. The four disinfectants tested included ozone, chlorine dioxide, hydrogen peroxide, and methyl bromide. The 24 test materials included commonly purchased construction materials (e.g., concrete, carpet, wallboard, ductwork).

The experiment system consisted of four closed chambers that were simultaneously injected with a single disinfectant. The system included controls to maintain specific disinfectant concentrations, temperatures, and relative humidities. The four chambers vented to a single monitored exhaust point and then passed through a potassium iodide scrubber. In the tests, one of the four chambers remained empty as a control and the other three chambers contained test materials. Each test run of the system consisted of a 9-hour background phase, a 4- to 16-hour disinfection phase, and a persistence phase of at least 20 hours. During the background phase to identify chemical emitters from the test materials, test temperature and relative humidity were reached, but no disinfectant entered the system. The disinfectant was injected into the system during the disinfection phase.

Overall, tests conducted so far have identified significant materials effects for ozone and chlorine dioxide, significant disinfectant effects, significant concentration effects, rapid decay in consumption rates (for ozone and chlorine dioxide), and non-zero endpoints. Corsi provided specific test data to illustrate the findings. Ceiling tiles and office partitions continued to be consumers of chlorine dioxide and ozone throughout the disinfection phase. Concrete was almost completely passivated. Most materials had low deposition velocities after 16 hours, but all materials had non-zero endpoints.

Byproduct formation is highly dynamic and produces unique material/disinfectant fingerprints. There were significant differences among disinfectants. Byproduct persistence (off-gassing) was also likely; 5-day and 1-year tests showed persistence in some byproducts. For most materials, with the exception of ceiling tiles and

HVAC system components, ozone was more reactive than chlorine dioxide. Ozone byproducts included 16 saturated carbonyls and about 50 additional, unquantified chemicals. Chlorine dioxide byproducts also included 16 saturated carbonyls, 6 unknown chlorine compounds, and a number of additional unquantified compounds. The chlorine dioxide reaction with latex paint created significant quantities of an unknown chlorine compound. The reaction behind this byproduct formation remains unknown. VHP created only a small amount of volatile byproducts. Methyl bromide itself was a greater concern for building reoccupation than byproduct formation.

Reports summarizing research findings are slated for release in July 2005. Completion of the software supporting decisions regarding fumigant applications (DADS) is scheduled for June 2005.

### Questions, Answers, and Comments

- **How were materials placed in the test chambers?** For carpet or flooring, the bottom of the test chamber was completely covered. Other materials with edges that would not be exposed in a real-world situation were sealed with sodium silicate along the edges. Paper, however, was simply stacked in the chamber as it would be stacked on a desk.
- **Was the presence of hexanol due to residual levels or continual emissions?** Hexanol may have been residual. Compared with the amount involved in the persistence phase of the test, the amount emitted in the background phase was small.
- **How were blanks considered?** The beginning of each experiment was considered a blank. The 9-hour background phase was used to identify background chemical concentrations.
- **Were the chambers sealed from light?** Chambers were sealed from light.
- **How were air concentrations considered?** Flow rates and air concentrations were used to find mass per volume. The results are reported as relative emissions. Had the tests lasted longer, higher masses would have been reported. A workshop participant also commented that the test identified only volatile byproducts.
- **What efforts were made to establish that no chlorine gas was formed?** The chamber exhaust was tested to prove that chlorine gas was not formed.

## Evaluation of Two Biological Decontamination Methods in a Room-Sized Test Chamber

*Mark Buttner, University of Nevada, Las Vegas*

Researchers at the University of Nevada, Las Vegas, conducted research to test the efficacy of two decontamination products (DF-100 and chlorine dioxide gas) and compare surface sampling methods and analytical techniques for detecting biological agents, using cultures, quantitative PCR, and hand-held assays.

DF-100 is a Modec, Inc., decontamination foam with two liquid components. Product ingredients include cationic detergents, fatty alcohols, stabilized hydrogen peroxide, water, and inert materials. DF-100 has since been replaced by DF-200. The Gas:Solid technology by CDG Research Corporation produced the chlorine dioxide for testing. Spores of *B. atrophaeus* served as the test organism and TSAC cultures, hand-held assays, PCR primer/probe sequences, and TaqMan assay (7700 Sequence Detection System) served as the analysis methods. The 7700 Sequence has since been replaced by a 7900 Sequence system.

Researchers conducted tests in a controlled chamber. They placed the test surface materials in the chamber, ran the chamber HVAC system, introduced dry spores (using a Pitt-3 dry aerosol generator), stopped the HVAC system, and allowed the spores to settle overnight. They conducted sampling the next day. Test surface materials included wood laminate (desk material), vinyl tile (flooring), and painted metal (a metal file cabinet). Predecontamination samples were collected using readily available methods: swipe, heavy wipe (damp cloth), and swab sample processing kit (foam swab). After initial sampling, researchers injected the decontaminants and collected post-decontamination samples. Samples were analyzed using the three test methods (culture, quantitative PCR, and hand-held assay).

During spore injection, the average airborne concentration was $1.5 \times 10^6$ spores per cubic meter. The culture and quantitative PCR methods reported $10^5$ to $10^6$ spore per square foot in the predecontamination samples. Each of the three sampling methods demonstrated comparable spore collection efficiencies. Similar levels of spores were found on each of the three test surface materials as well. The results from the predecontamination

served as the control for the post-decontamination sampling.

After decontamination with DF-100, post-decontamination samples found no culturable spores although the quantitative PCR analysis indicated that spore DNA remained. Earlier studies of DF-100 with viral agents identified no viral RNA after treatment, however, a virus is more fragile than a spore.

After decontamination with chlorine dioxide, post-decontamination samples found no culturable spores in 24 of 27 samples. Of the three positive samples, each supported only one colony. The quantitative PCR analysis indicated that spore DNA remained. The hand-held assay results were positive for all samples.

Researchers also conducted one environmental background trial for each decontamination method to determine the impact of dust on the effectiveness of the decontamination method and the analytical method. They collected dust from the outdoor air filters of several commercial buildings and then aerosolized 10 grams of this dust in the test chamber. They found an approximate soiling level of 2 milligrams of soil per 100 square centimeters. Researchers then injected spores into the chamber and conducted decontamination. Spore culture data were comparable between the predecontamination samples with and without environmental background. The dust, however, did inhibit the quantitative PCR results. Culture data for post-decontamination samples were similar with or without environmental background. Quantitative PCR results indicated that spore DNA remained in post-decontamination samples.

Buttner listed some practical considerations for each of the decontaminants tested. DF-100 is fast and easy to use, but it is limited to use on nonporous, washable surfaces. It also resulted in material damage (e.g., it dissolved floor polish, stripped paint, and caused bubbling of wood laminate). Chlorine dioxide gas can decontaminate an entire space with contents in place. This method, however, requires specialized equipment, training, and personnel. It also causes material damage (e.g., it yellowed wall paint and corroded aluminum).

In conclusion, both decontamination methods were effective in reducing the number of culturable spores and neither method was affected by environmental background. Spore DNA remained after treatment with both decontaminants. The quantitative PCR analysis method, however, was inhibited by environmental background. This study did not assess the infection potential of nonculturable pathogens.

Buttner provided the following references for this research:


- Buttner, M.P., P. Cruz, L.D. Stetzenbach, A.K. Klima-Comba, V.L. Stevens, and T.D. Cronin. 2004. "Determination of the efficacy of two building decontamination strategies by surface sampling with culture and quantitative PCR analysis." *Appl. Environ. Microbiol.* 70:4740–4747.
- Buttner, M.P., P. Cruz, L.D. Stetzenbach, A.K. Klima-Comba, V.L. Stevens, and P.A. Emanuel. 2004. "Evaluation of the Biological Sampling Kit (BiSKit) for large-area surface sampling." *Appl. Environ. Microbiol.* 70:7040–7045.


### Questions, Answers, and Comments

- **Would you expect similar material compatibility concerns with DF-200?** Buttner indicated that speculating about results for DF-200 would be inappropriate. Nonetheless, a workshop participant speculated that material compatibility issues would be fewer for DF-200 than for DF-100 because DF-200 has a lower solvent content.
- **Did you have a biocide neutralization step post-sampling?** No biocide neutralization step was conducted.

## Verification of Commercial Decontamination Technologies in Bench-Scale Studies Using *B. anthracis* Spores

*Mike Taylor, Battelle Memorial Institute*

EPA's ETV program verifies environmental technology performance and objectively reports results to end-users such as permitters and buyers. The program performs tests as outlined in quality assurance plans developed in conjunction with technical experts, stakeholders, and vendors. ETV does not purposely try to fail technologies. Battelle works as a contractor to ETV. This presentation provided results from testing three decontamination technologies: BIOQUELL Inc.'s hydrogen peroxide gas; CERTEK Inc.'s formaldehyde gas, and CDG Research Inc.'s chlorine dioxide gas.

The testing apparatus consisted of the technology under evaluation and a test chamber. The test chamber is a compact glove box with a decontaminant injection port, sensors, and an exhaust port. In this system, Battelle used spore strips to assess biological efficacy and construction material coupons to assess material compatibility. Researchers tested seven material coupons (carpet, bare wood, glass, laminate, galvanized metal ductwork, painted wallboard, and painted concrete). The painted concrete coupons consisted of sawed and painted cinder block. Each coupon measured 0.75 by 5 inches. Battelle evaluated biological efficacy by assessing the log reduction in viable spores on the test materials and identifying positive or negative bacterial growth on the biological indicators and spore strips. The biological indicators and spore strips provided a link to real-world events, which rely on these indicators for decontamination sampling. Changes in coupon appearance, color, texture, and other parameters indicated coupon damage and material compatibility concerns.

The general test procedure consisted of connecting the decontamination technology to the test chamber, inoculating test material coupons and placing them in the test chamber, implementing the decontamination technology, and removing and analyzing the coupons. Before inoculating the coupons, Battelle wiped each one with isopropyl alcohol. Coupons were not autoclaved, so some microbes remained and Battelle observed microbe growth. Each coupon was inoculated with $10^8$ of the biological test agents. *B. anthracis* analyses were conducted with a 15-minute extraction followed by 1- and 7-day growth assessments. The supernatant from the extraction process underwent a 1-hour heat shock and dilution plating for enumeration. Efficacy data (log reductions) were calculated as the log of the viable spores recovered from control samples minus the log of the remaining spores on the decontaminated samples. Battelle also conducted several statistical analyses to assess results variability.

Taylor presented the specific study conditions for each of the three technologies tested, as well as the specific study results, including mean efficacy for spore reduction on each test material, statistical analyses for each test material, and growth on the biological indicators and spore strips. Results for the efficacy tests and statistical analyses are expressed as log reductions from 1 to 8, with 8 indicating 100 percent kill. Battelle found that surrogate results did not compare to *B. anthracis* results. Results for the biological indicators are qualitative; positive results indicate growth and negative results indicate an absence of growth. Some of the biological indicators and spore strips were positive after decontamination with the CERTEK Inc. formaldehyde. The indicators and strips were placed in a pouch and the positives were likely the result of uneven gas penetration into the pouch. Testing with the CDG Research Inc. chlorine dioxide gas is undergoing repeat testing and verification.

## Questions, Answers, and Comments

- One workshop participant commented that ETV originally intended to test technologies volunteered by vendors, with vendors sharing the costs. For homeland security related technologies, this format changed to a new program called Technology Testing and Evaluation Program (TTEP) and is fully funded by EPA, which allows flexibility in testing.
- A number of research projects with chlorine dioxide gas are ongoing. Additional areas of research may examine chlorine gas and reactions in gas chromatograph (GC) columns and study flow rates through the test chamber. Chlorine dioxide can be as much as 50 times more soluble in organics than in water. This is a trait that should be considered.
- A workshop participant noted that studies need to consider air exchange rates. The laboratory studies should mimic the air exchange rates found in real-world situations.
- **Why was methyl bromide excluded from testing?** Battelle discussed including methyl bromide, but EPA funding and approval, which was not received, is necessary. Battelle, however, is willing to discuss various technology options with vendors interested in the testing program.
- **What were the replicates for each decontaminant?** Because tests began after the anthrax incidents following 9/11, Battelle was pushed for results. The tests examined a single dose (concentration × time) with three replicates.
- **Are you anticipating any major changes in protocol as new projects start?** Some minor changes may occur, but the overall study design should remain the same. Battelle may add monitors to examine the rate of volatilization and to identify degradation products. It will likely change the

protocol for cleaning the test material coupons and move away from the isopropyl solution wipes.

## Technical Support Working Group Decontamination Research and Development Activities

*Rebecca Blackmon, Technical Support Working Group*

The presentation provided an overview of projects underway by the Technical Support Working Group (TSWG). These projects, which can last from 7 months to 2 years, focus on methods that speed up the decontamination process. The presentation was organized by projects that affect activities before, during, and after decontamination.

Under TSWG, the Chemical, Biological, Radiological, and Nuclear subgroup identifies user needs related to these materials and conducts rapid research, development, and prototyping. Their focus areas are agent detection, decontamination, protection, and information collection. TSWG and the subgroup projects include:

- **Biological backgrounds in critical facilities** The intent of this two-phase project is to determine seasonal and diurnal variations in existing background bacterial and viral aerosol load with a focus on threat agents (e.g., *B. anthracis*). The project will provide information about the bacterial background at critical locations, which will help responders identify possible interferences if a bioterrorist event occurs. As part of the project, researchers collect integrated and time-resolved samples at multiple locations and link these samples with HVAC systems and environmental data. Samples undergo analysis with classic microbiology and microassay methods. The University of Minnesota and Los Alamos National Laboratory (LANL) are partners in this project.

Phase I of the project serves as a demonstration for Phase II. Under Phase I, the research partners completed a 1-month sampling program at local airports to assess sampling protocols. Phase I also included developing extraction protocols and developing and evaluating low-cost microassay methods. Phase II is in the planning phase. Over the course of 1 year, researchers will conduct quarterly sampling and analyze the samples using the microassays identified or developed during Phase I. The data from Phase II will provide an understanding of the variability and prevalence of biological background as affected by season, weather, activity level, and geographic location.

- **Statistical design tool for sampling contaminated buildings** Under this project, TSWG, in partnership with Pacific Northwest National Laboratory (PNNL), will develop a user-friendly software tool that will design statistically valid surface sampling protocols for determining the extent of contamination following a chemical or biological terrorist attack. Users will input specific statistical requirements and tailor the program's generic floor plan to meet specifics of the facility and HVAC system under investigation. The program includes decision criteria that affect sampling protocols (e.g., providing the user the confidence intervals that the sampling protocol will identify hot spots and maximum agent concentrations). Users, however, should discuss statistical sampling needs (e.g., level of confidence) before an event occurs. The software will also help users estimate costs associated with sampling. The project is slated for completion in June 2005.
- **Wireless multisensor environmental monitors** In conjunction with Esensor, Inc., and SUNY Buffalo, TSWG is developing a real-time sensor system that is lightweight, portable, inexpensive, and battery-operated. The system contains eight interchangeable sensors that monitor CWAs and toxic industrial chemicals. The sensors use wireless or Internet/Ethernet connections compatible with other wireless systems to communicate results. This type of system is especially relevant to decontamination events. A bomb squad could also use the system to assess suspicious packages. TSWG is targeting a cost of $3,000 to $5,000 for the system. A prototype has been designed, and production of a system for testing is under way.
- **Jet Propulsion Laboratory (JPL) sensor web** Although similar to the wireless multisensor monitors, the JPL sensor web has unique applications. This project responds to an EPA requirement for monitoring chlorine dioxide during decontamination. The system may also apply to urban search-and-rescue operations (e.g., searching

collapsed buildings) when inserting a sensor is safer than inserting a person to assess environmental conditions. This wireless network monitors and controls temperature, humidity, light intensity, and decontaminant agent concentrations in a facility undergoing decontamination. The system is self-networking and has proven reliability from field-testing (e.g., monitoring for explosives along the Alaska pipeline). JPL has built a 40-pod network and demonstrated this network for sensing chlorine dioxide. The pod sensors consist of a single pass sample cell with no mirrors or reference beams. The sensors are easy to calibrate and have a wide detection range (80 to 1,000 ppm for chlorine dioxide). The sensors are also inexpensive to produce and require little power to run. As a next step, JPL aims to miniaturize the chlorine dioxide sensor and develop an Urban Search and Rescue (USAR) gas sensor.

- **Electrostatic decontamination system** This is an effective, safe, and logistically efficient decontamination system now in its fifth generation. Clean Earth Technologies demonstrated chemical and biological agent decontamination without damaging surfaces. The technology is within the EPA regulatory processes, with the biological aspect undergoing verification testing.

The decontamination unit for this technology has a rugged, compact, modular design. A single operator can easily use the system. Without brushing, scrubbing, mopping, or scraping, the decontaminant provides a greater than log-6 kill for *B. anthracis* spores within seconds. Compared with foam technologies, approximately six times less of this decontaminant is needed to achieve success. The decontaminant also has high material compatibility; a paper document can be submersed in the decontaminant for 24 hours without harming the print. The system can be employed with or without ultraviolet (UV) light. UV light increases the kill rate when used with the biological decontaminant. Testing has shown that the system is effective against biological agents, chemical agents, and viruses (e.g., flu, polio). The decontamination process does not destroy DNA and therefore does not compromise DNA evidence.

- **Atmospheric plasma decontamination** This decontamination method provides effective and efficient neutralization of biological agents but minimizes damage to high-value items (e.g., items of historical interest). The technology has been demonstrated with oil paintings, tapestries, black and white photographs, and ink on paper. AOAC sporicidal testing has also been successfully completed. TSWG completed this project in July 2004. A report summarizing results is available on request.
- **Expedient mitigation of radiological releases** The project examines methods to minimize the spread of radioactive particles from a radiological dispersion device (RDD). A strippable polymer coating would be applied to surfaces after rescue operations and during the decontamination planning phase. The polymer coating developed by TSWG requires 24 hours for curing. Demonstrations have shown that it is durable yet easy to strip. The coating can also be applied using equipment familiar to first responders (e.g., hoses and backpack systems). Ongoing efforts under this project include testing the coating with radiologicals and investigating a dual use with dust re-entrainment mitigation.
- **Radiological decontamination technologies** In conjunction with Argonne National Laboratory (ANL), TSWG is examining a chemical process to nondestructively remove cesium-137 from porous building materials. The process applies an ionic wash followed by a superabsorbent gel that captures the cesium-137. The gel is then vacuum-removed from the surface. The process is particularly applicable to concrete decontamination. ANL has completed laboratory testing and may conduct field-testing in 2005. ANL is also modifying the gel formation for other materials and examining application technologies. Commercialization negotiations are in progress.
- **Mass personnel decontamination protocol** TSWG has completed the guidance document "Best Practices and Guidelines for Mass Personnel Decontamination." This document, which is available for order on the Internet (***www.cbiac.aprea.army.mil***), includes information for decontamination of chemical, biological, and radiological agents on people. A first edition was completed in 2003, and a second edition was released in September 2004.

### Questions, Answers, and Comments

- **What is the minimum detection levels on the monitors and sensors (ppm/ppb/ppt)?** TSWG is involved with two sensor projects—one uses existing sensors placed in pods, the other requires developing a new technology. Blackmon believes these sensors detect contamination to the ppm level.
- **For the electrostatic decontamination system, what was the test substrate and how was the biological solution applied?** Blackmon did not have immediate access to the project details but said she would obtain the information for the workshop participant. Blackmon provided her contact information to workshop participants.

## "Dirty Bombs" (Radiological Dispersion Devices [RDDs]) and Cleanup

*Fred Holbrook, U.S. Environmental Protection Agency*

RDDs, or "dirty bombs," use conventional explosives (e.g., TNT, RDX) to disperse radioactive materials. These bombs would cause low-level radiological contamination and cause psychological and economic damage. Fatalities from RDD events, however, would be expected to be low. Holbrook listed several radiological agents that are potential components of RDDs and specified the half-life of each. (The more radioactive materials have shorter half-lives.) To cause the worst health effects, the radiological agent must enter a person's lungs. Cesium fluoride is of particular concern because it is a fine, talclike powder, i.e., it is easily dispersed.

An improvised nuclear device is a crude nuclear weapon that can cause vast destruction (e.g., destroy buildings, start fires, and cause tremendous loss of life). Enriched uranium can be a fuel source for a nuclear device; approximately 1,300 to 2,100 metric tons of enriched uranium throughout the world have questionable controls. The two bombs dropped on Japan to end World War II are examples of nuclear devices. Little Boy, which was dropped on Hiroshima, used 60 kilograms (kg) of enriched uranium as a fuel source. Fat Man, which was dropped on Nagasaki, used 6 kg of plutonium as a fuel source.

About 90 percent of specialized radiological materials, such as weaponized radionuclides (e.g., uranium, plutonium), are under government control. Academic, industrial, agricultural, and medical settings use radiological materials for many different applications. Medical treatments, specifically, require thousands of curies. Of the 2 million sources of radiological agents, about 5,000 are susceptible to becoming orphaned (lost, stolen, etc.) each day. Worldwide control is a problem (e.g., the former Soviet Union contains many "orphans").

Radiation is described in terms of alpha and beta particles and gamma rays. Alpha particles move short distances and can be blocked by paper or skin. Beta particles are higher energy but can be shielded by aluminum foil or skin. These particles can travel several feet and exposures can result in deep, serious burns. Gamma rays consist of high-energy, short wavelength protons. These particles are pure energy and can travel many feet. They are very penetrating and can cause severe health effects. Radiation is measured as the number of nuclei decay per second. One curie (Ci) is considered a large radiation source; 100 Ci is considered very dangerous.

Radiation doses are reported as rems. Holbrook listed several radiation doses and associated health effects. At 25 to 50 rems, a person may have decreased numbers of white blood cells. An RDD event is unlikely to produce a dose above 25 rem.

A 1987 event in Brazil provides an example of a nonterror event that nonetheless resulted in a terrible endpoint. Scavengers found cesium in an abandoned radiotherapy clinic. The scavengers took the material home to their village. As a result, 20 people received a high radiation dose, 129 people were contaminated, and thousands more were monitored for radiation sickness. In another event, a young girl found cesium (a glowing blue powder), painted her body with it, and then ate food without washing her hands. She died within 30 days. This event occurred in a tourist and agricultural area and caused economic disaster in that area. The cleanup cost about $20 million.

High cleanup costs are a consideration for addressing radiological agent events. An obvious first step would be to reduce the possibility of an event. Holbrook suggested programs that would encourage users to return radioactive materials to the manufacturer to minimize the number of orphan sources. A public health campaign to educate people about radiation and radioactive releases

may reduce the extent of cleanup required by political pressures. Holbrook illustrated impact areas from the release of a 2-Ci source of cesium-137. A large number of people would receive a dose of 150 millirems (mrems), which is equivalent to the difference in background radiation between Washington, D.C., and Denver, Colorado. However, that small increase in risk may seem unacceptable if not properly communicated.

Decontamination options include acid dissolution of a radiological agent from the contaminated substrate, chelant bonding for excretion from organisms (including humans), and blasting with abrasive materials for removal of the contaminated material. Holbrook highlighted several specific decontamination technologies in his presentation. He noted that one strain of bacteria can consume as much as 0.5 inches of concrete per year when a sulfur gel is applied to the concrete. He also noted that DoD and power plant authorities have successfully used foams on a variety of surfaces.

### Questions, Answers, and Comments

- **What is the difference between a low-level and high-level radioactive waste facility?** These two types of facilities are vastly different. Only about three facilities in the United States currently accept low-level radiological wastes, so disposal of radiological wastes after decontamination is a substantial problem.
- **Will radioactive waste facilities accept mixed wastes? Will some of the decontamination technologies mentioned produce mixed waste?** Wastes that contain both radioactive and hazardous chemical materials are a huge problem. Radioactive waste facilities do not accept mixed wastes. When reviewing available technologies, many characteristics and factors must be considered, including cost, feasibility, life cycle, performance, maintenance, and safety. Strong acid technologies can be hazardous to the people deploying the technology and may create a mixed waste.

## Radiological and Nuclear Terror: Technical Aspects and Implications for Decontamination and Site Cleanup

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

RDDs and nuclear weapons are vastly different. An RDD (i.e., a "dirty bomb") may consist of radiological agents injected into an HVAC or water system, dispersed from a crop duster, or disseminated covertly. A nuclear weapon may include smuggled weapons or improvised devices produced with smuggled weapons-grade materials. This presentation not only discussed issues associated with RDDs but also identified a nuclear weapon event as a worst-case scenario.

The United States and other countries have experience with radiological agents from activities with uranium and plutonium in commercial and defense facilities; remediation at hazardous waste sites; running waste management facilities; and operating commercial, test, and research reactors and laboratories. These facilities are in fixed locations where accident prevention and response programs are in place. Facilities may also provide a long warning period before releases occur. Conversely, terror events are unpredictable. They can occur anywhere without warning. As such, RDDs present new challenges for local and federal responders. Most people, however, believe an RDD event is the most likely threat, especially considering the abundance of missing and unaccounted-for radioactive material.

The question becomes how do we prepare for an RDD event. One solution is to develop many different release scenarios and plan accordingly. The radiation released from a device is unlikely to result in fatalities, although the actual explosion may cause harm. A principal effect of RDDs is to deny access to places. An RDD may consist of an explosive device or any means of dispersing radiological agents (e.g., spraying from an automobile or aircraft, injecting into a building or water system). A device may distribute radiation in a small area (e.g., the size of the meeting room) or a much larger area (e.g., tens of city blocks).

Chernobyl was the worst nuclear disaster in history. This event released more than 100 million Ci of contamination. For contrast, MacKinney presented a realistic radiological release example. Within 24 hours, a small radiological device (10 Ci of cesium-137) would disperse about a 1-rem dose of radiation to an area several tens of city blocks, based on a simple gaussian dispersion model.

Currently, researchers at SNL are examining explosives and radiological devices. The tests are being conducted in igloos (50 $m^3$ in size) formerly used to examine explosions at plutonium pits. Current tests are small and use 0.5 pound of explosive with solid metal bars or ceramic disks of radiological materials. The research examines whether a radiological agent will aerosolize and how the shape of the charge may affect dispersal. Aerosolized or in vapor form, a radiological agent can enter a person's body and cause harm. Researchers tested a number of materials to examine how the material properties affected aerosolization (e.g., form or shape, thermal properties, shock physics, vapor pressure). Entrainment is not inherent to the radioactive materials but is another complication because the explosion will entrain dirt and particles of concrete.

Stress levels induce different material reactions and different particle sizes. In a worst-case scenario, an explosion will impart enough stress to change a radiological element to a vapor form. (The vapor then condenses as sub-micron particles, which are readily dispersed.) For most of the metal bars tested, the explosion dispersed large chunks of metals. Tests found that bismuth, however, aerosolizes very well: 80 percent is aerosolized into the respirable range because the bismuth passes to the vapor stage during the tests. A carefully configured charge can also aerosolize cobalt. Ceramics, including strontium 90, used in the former Soviet Union shipping beacons, also tended to create large chunks. (A large chunk is 12 to 15 microns in diameter and a very large chunk is 1 inch in diameter.) Cesium chloride poses another threat because it passes through the liquid to the vapor phase during an explosion.

Several factors influence the dispersion pattern of an RDD. Larger chunks remain local to the impact area. Smaller particles disperse more widely depending on particle dynamics (e.g., phase changes, size, shape, and aerodynamics). Buoyant rise—the lift from the heat of the explosion—and meteorology also play roles in dispersion. Smaller particles can be caught on air currents. Models can predict possible dispersion patterns, however, further research is needed. MacKinney showed examples of dispersion patterns with and without buildings. With the buildings, materials disperse in patterns that are not necessarily intuitive. In addition, studies of particle dispersion have shown that indoor particulate concentrations following an event may be high.

Returning to the topic of preparing for an RDD event, MacKinney provided several suggestions. Organizations should develop threat scenarios—much has been done and is ongoing in this area. Using these scenarios, we can create standard response and mitigation procedures, plan possible cleanup actions, and evaluate existing technologies. Additional research is needed to adapt existing technologies to threat scenarios and to develop and test new technologies. When developing decontamination technologies, research organizations should avoid rushing to invest in solutions that address a single problem and should invest only in technologies with sound scientific support and real-world experience. Research should target technologies that fill gaps.

The decontamination and restoration periods after an event follow a similar pattern, regardless of the threat agent (e.g., chemical, biological, or radiological). The first step is the safe shutdown of the affected building or area. A shutdown has huge implications when involving city blocks and private properties. Through work groups, DHS is assessing possible optimized approaches to decontamination and restoration after an RDD release. This approach would be flexible in selecting cleanup criteria based on societal needs, expected land uses, and decontamination technologies.

Nuclear devices present another radiological threat. They include improvised devices, as well as weapons bought or stolen from a nuclear state. A nuclear device has a likely yield of 0 (failure) to 50 kilotons. The most likely event would involve a device with a 5- to 20-kiloton capacity. A 10-kiloton device, which is considered small, has the explosion capacity of nineteen 100-ton coal cars. The bomb exploded at Hiroshima was 13 kilotons; the bomb exploded at Nagasaki was 22 kilotons.

After detonation, temperatures soar within a fraction of a second with the fireball reaching millions of degrees. The extreme rise in heat is followed immediately by incredible winds (measured near 700 miles per hours during historic testing events). Most deaths after detonation are caused by burns. In addition to proximity to the detonation point, an individual's specific injuries depend on location within a building and building

materials. DHS modeling estimated that a nuclear detonation in Washington, D.C., would result in 50,000 deaths from the initial blast and another 50,000 to 100,000 deaths due to radiation. Radioactive fallout could extend hundreds of miles.

In conclusion, an RDD detonation is a likely threat. Organizations must understand possible threat scenarios and can use models to help simulate urban impacts. Decontamination technologies must mesh with larger remediation and renovation goals. Although a large nuclear device attack is unlikely, this threat cannot be ignored because of the severity of the impact.

### Questions, Answers, and Comments

- **When creating an RDD, why not grind the radiological material?** Because of the radiation dose, grinding may be fatal. If the proper safety precautions are used, grinding may work to further distribute the ceramic-form radiological materials, but grinding metal-form radiological materials might prevent the shock wave that creates the phase change. A number of technical issues are involved in creating successful RDDs.

## UK Approach to RDD Cleanup

*Malcolm Wakerley, Department for Environment, Food, and Rural Affairs*

The UK learned lessons about radiological contamination as the result of past nonterrorist, nuclear incidents (e.g., the U.S. B-52 bomber accident in Spain, Chernobyl reactor fallout, and Brazil's cancer therapy unit wastes). These incidents provided information about contaminant movement resulting from an RDD detonation. The Chernobyl incident and the events of 9/11 in the United States prompted the creation and upgrade of a radiation monitoring network and radiation response handbook. This presentation focused on these two items.

After the Chernobyl incident, the UK created the Radiation Incident Monitoring Network (RIMNET). This system consists of 92 gamma detectors, located approximately 30 kilometers apart, that supply data to a group of laboratories. The sensors are very simple and cannot detect alpha-emitting materials. Many of the sensors have been in service for more than 20 years. Information from these sensors helped the UK identify areas of contamination after the Chernobyl incident. For example, contamination was patchy because of heavy rains within the fallout area. The UK identified some areas that were no longer safe for grazing sheep.

RIMNET provides a vast amount of data regarding local background levels of radiation, which can be used to identify irregular events. The system is linked to government departments, and all departments can access the data simultaneously. Agencies can use RIMNET as a tool for communicating with politicians, communities, and international partners. For example, an incident occurring in the UK will also impact nations on mainland Europe. In an exercise with sensors in Scotland, the RIMNET database was able to upload years' worth of sampling data within 30 minutes.

Updates to the RIMNET system include a modeling component that can assess short-, medium-, and long-range impacts. The system is also linked with meteorological data. With these components, the system can backtrack from an alarmed detector to a radiation source. If a release occurs anywhere in world, the system can also calculate when radiation will reach the UK. If the release occurs in the UK, the system can calculate when radiation will reach other countries. The UK also has the ability to run models that, within 10 minutes of a release, can identify areas to shut down to prevent contaminant movement.

A model output in the presentation illustrated releases associated with a 6,000-Ci cobalt bomb that aerosolized. The map shows the inhalation dose from the passing cloud. The predominant dose, however, results from deposition. The area closest to the release presents the greatest concern. Doses are lower farther from the release point, but a public relations concern exists regarding communicating dose impacts to communities. Commonly, communities want doses to return to levels present before an event. Determining how and to what level decontamination occurs becomes a political question. As such, releases become instruments of economic as well as health destruction.

In 1996, the UK created a radiological handbook in response to a review of decontamination and remediation technologies conducted after a series of additional radioactive accidents. The review identified trees, soil, and grass as contributing substantially to exposure doses. Vertical surfaces were only minor contributors to overall dose. The existing response system is predicated

on equipment available to local authorities, but specialized military equipment would be available for decontamination. The radiological handbook includes a simple logic diagram and 22 tables on decontamination technologies and considerations. It also includes an example release incident and discusses the UK inventory of decontamination equipment.

After the events of 9/11 in the United States, the UK expressed increased interest in the 1996 review and handbook. The handbook has grown since 1996 and now includes radiological agents that terrorists might use. (The radiological threat agents addressed by the UK are similar to the priority radiological threat agents selected by the United States) The handbook provides reliable, consistent, and comprehensive information to help decision makers select the most practical decontamination methods and to guide them through the decontamination process. The UK is currently working to expand the handbook to address various climates and crops so that it is relevant to all of Europe and potentially to the United States.

Emergency planners use the handbook during threat event exercises so its use will be intuitive during a real event. The handbook follows a 10-step decision process outlined in detail in the presentation. Generally, these steps involve considering the nature and extent of the contamination, the availability and applicability of decontamination methods, and the land uses of affected areas. Each land use area is then considered and evaluated individually. Land use areas in an inhabited area, for example, may include residential, commercial, and recreational areas.

The UK plans to maintain the handbook over the next 3 years and add lessons as they are learned. In exercises, the UK has examined case studies of accidents using the handbook as a resource and considering advances in technologies to reassess what actions should have been taken. The UK is willing to share the information it has gained, as well as the radiological handbook, with the United States.

Wakerly concluded with his thoughts on a potential RDD attack. The attack will likely occur in an urban setting. Ground surfaces, such as soil and grass around homes and work areas, will provide the predominant radiation routes of exposure after the initial attack. Removing radiation from those areas will provide the best reduction in dose.

### Questions, Answers, and Comments

After his presentation, Wakerly commented that the UK is examining the practical side of using the handbook and decision trees. The handbook has worked well for tabletop exercises. In real-world situations, however, many additional concerns exist (e.g., seals for vehicles conducting decontamination). Wakerly asked how the United States was addressing the many radiological issues. A workshop participant responded that RDDs are a new research area for the United States Some investigations, however, are under way. For example, a TSWG project examines the next generation of materials for personal protective equipment. These materials will be lightweight and breathable because heat is a substantial issue when using personal protective equipment.

# Panel Discussion—Lessons Learned

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Several bio-decontamination events are now complete. Workshop participants shared their experiences at these events with others in order to discuss lessons learned about the decontamination process and to suggest steps that would improve that process.

## Information Sharing and Agency Coordination

Workshop participants uniformly agreed that improving coordination and information sharing efforts among federal, state, and local agencies, as well as private companies and communities, would improve responses to chemical, biological, and radiological threat events. They agreed that sharing information early when a threat event occurs would result in responses that are faster and better.

- **Examples of existing efforts** Although information sharing and coordination efforts can be much improved, workshop participants provided examples of current efforts among agencies.
  - EPA ORD recently published two reports as a means of sharing information with others. The first summarizes EPA data from decontamination events. The second compiles building decontamination data and reviews decontamination options beyond crisis exemption options. EPA has not been proactive in distributing these reports, but they are available to workshop participants upon their request.
  - DoD requires annual internal agency research updates and coordinates efforts with EPA.
  - Participants from the UK noted that they publish information on the Internet. They also encouraged ongoing coordination between the United States and UK.
- **Security concerns** When sharing information, agencies must be cautious that information is not used against us. Data security must be considered when sharing information. One participant suggested that CDC and EPA detail employees to the FBI to facilitate information sharing for decontamination and public health concerns without compromising the criminal investigation aspect of an event. For example, a whole report may be classified, but only a small portion contains classified information. Security and classification issues will likely continue to be a problem.
- **Suggestions for information sharing methods** One workshop participant suggested that DHS spearhead efforts toward better information sharing. Another recognized the benefit of this workshop and suggested that NHSRC and others regularly host workshops of its type for government, private, civilian, and military groups. Others also provided suggestions for data repositories. One workshop participant suggested creating virtual repositories containing electronic documents and paper-copy documents converted to electronic forms to maximize information sharing. These repositories would serve as centralized information centers and might include:
  - **Research and priority agent repositories that list completed, ongoing, or planned research efforts and priority agents for research** If agencies and researchers had a clear understanding of efforts underway by others, they could reduce potential redundancies, address priority issues quickly, and appropriate funds properly. EPA has launched an internal campaign to track research projects. This effort will not only prevent research redundancies but also feed into budgeting decisions.
  - **Decontamination portfolios that link threat agents with decontamination technologies** The repository should list technologies that are validated as well as those under development. A workshop participant noted that the National Decontamination Team may be creating this type of repository.

- **Agent repositories that list threat agents linked with laboratories able to analyze these agents** This repository could also include acceptable surrogates for research projects and methods for preparing these surrogates to provide consistency across research studies.
- **Databases that list people with expertise in areas pertaining to decontamination** Such a database could list training and work experience. One workshop participant noted that this database exists and is available through EPA.

Several workshop participants who work as OSCs emphasized the need for information when responding to an event. They need information about decontamination methods that work or do not work and why. They also need information in order to address the specific concerns of agencies from multiple levels of government (e.g., local boards of health, mayors' offices).

## Preparedness

Organizations can prepare for a chemical, biological, or radiological agent event in a number of ways. Workshop participants repeatedly suggested tabletop exercises as a way to identify possible threat scenarios, develop response plans, and pinpoint data gaps. They suggested interagency panels and peer reviews for these exercises. The exercises should illustrate the pressures of the event and the complexity of decontamination planning (e.g., addressing HVAC systems). Workshop participants suggested focusing these exercises on airports and transportation facilities. One workshop participant noted that exercises can become complex and attempt to address worst-case scenarios. In these exercises, the focus becomes the technical aspect of the response plan. In a real-world situation, the technical side of a response may be easy compared with regulatory or communication issues.

Materials that would help prepare agencies and facilities include:

- **Matrix of responses** Similar to a decontamination database, this matrix would link threat agents with appropriate decontamination methods and site conditions (e.g., a contained building contaminated with anthrax). All known decontamination agents and material compatibility issues should be included. Some of this information may be subjective or anecdotal. Nonetheless, having this information readily available would likely streamline the response.
- **Response plans** Workshop participants agreed that exercises should encourage organizations to prepare plans. For example, plans could identify methods to treat irreplaceable objects (e.g., paintings, historical documents) or process large volumes of personal items. FEMA has published a radiological response plan that addresses communication and preparedness concerns. All response plans should include communication strategies (e.g., protocol for notifying the President and other government officials).
- **Standards** Research and planning for pieces of the response is under way or complete, but a means for looking at the overall response process is lacking. A protocol that outlines a systematic way to assess an event would be useful. This protocol should cover both simple indoor and complex indoor/outdoor situations and should include standards. A workshop participant noted that the process of writing and preparing standards may identify potential problems and force decisions before an event.
- **Up-to-date drawings** In one participant's experience, the lack of accurate building plans led to delays and increased expense in decontaminating an impacted building. Having accurate plans readily available is critical for rapid response.

One workshop participant noted that prepositioning decontamination equipment may be appropriate. Others thought that this action was not economically viable. If the government buys the infrastructure for a technology now, the technology may be obsolete when needed. Having the equipment in the right place at the right time and ensuring that it would operate after years on standby are also concerns. A participant suggested that technology vendors research dual uses of decontamination technologies, such as applications in agricultural decontamination for insects and mold, responses to hazardous material releases, or uses in hospital settings. Dual-use technologies would provide a sustainable business model and provide technologies for addressing agents if needed. Another workshop participant noted that the military often develops technologies and then turns them over to the commercial market. They are then available commercially when needed.

## Sampling and Analytical Issues

Workshop participants discussed several topics regarding sampling utility and sampling methods. These topics included:

- **Streamlining the sampling process** Several workshop participants noted that sampling (for characterization, verification, and clearance) took up much of the response timeline. They suggested streamlined sampling (e.g., minimize or eliminate characterization sampling when fumigation is the planned response; only screen samples to determine viability). When characterization sampling is minimized, verification and clearance sampling become more important. Individual workshop participants noted that the clearance samples were most important when reoccupying a building and that good communication with the affected community (e.g., workers in a building) is necessary to minimize clearance sampling.

  Other workshop participants strongly believed that no sampling phase should be eliminated. One participant believed that characterization sampling took up only a small segment of the response timeline and should not be compromised.
- **Using biological indicators** Decontamination events rely on biological indicators (e.g., spore strips), but results from these tests may not correlate to environmental conditions (i.e., actual levels of spores). Several workshop participants identified correlating these tests as a research need. Having participated in five or six decontamination events, one participant noted that no positive environmental samples were found when the biological indicators were negative and desired fumigant concentration had been achieved. Another noted that establishing a link between indicators (e.g., paper or stainless steel strips) and environmental samples may help speed reoccupation of sensitive areas. Several other participants noted that pharmaceutical companies already use biological indicators to confirm sterilization. Decontamination research may be able to draw from this experience. In termite fumigation, vendors also rely on indicators to confirm complete fumigation.

  Other workshop participants were more hesitant about linking different types of indicators to environmental samples. One noted that spores on steel coupons or paper strips will not respond the same as spores on desks, fabric, or other materials in a building. As such, hospital and pharmaceutical practices may be of limited usefulness. Currently, biological indicators and spore strips confirm that a decontamination agent was present, but indicators and strips do not directly confirm that decontamination of agents in the environment has occurred.
- **Improving sampling methods** Workshop participants noted lessons learned and identified concerns regarding sampling methods.

  **Lessons learned:**
  - Calibrating sampling instruments and ensuring proper operation before sampling is critical.
  - Fixed sampling points are costly and difficult to site, and they provide a limited amount of information. A mobile unit (e.g., TAGA) can be more useful.
  - Remotely monitoring a building with a titration system can be difficult. In one participant's experience, the system required 5,000 feet of tubing and months for setup and operation.

  **Concerns raised:**
  - Many questions arose from a lack of understanding. For example, additional environmental sampling was required at one facility to address workers' concern about the safety of their workstations.
  - Rapid screening and sampling may overlook multiple-agent attacks. For example, a terrorist may use a single event to drive people toward a common area and a second event.
  - Any sampling protocol should address multi-agent attacks. Once an agent is identified at an event, agencies may race toward decontamination. Other agents may be overlooked.

## Decontamination Process

Workshop participants provided comments based on their experience at decontamination events.

- When fumigation is the selected decontamination method, the fumigation itself takes up only a small segment of the decontamination timeline. For example, a 1-week fumigation requires 6 weeks of preparation and several months of post-fumigation activities.
- Knowing the target agent is critical for properly planning a response. One workshop participant noted that time and money could have been saved at one site if the decision makers knew that the target agent was a weaponized biological agent. They would have selected fumigation immediately instead of spending time considering alternative decontamination technologies.
- Sealing a building can be costly and time-consuming. In addition to the cost of sealing the building, budgets must also include inspection costs. A project in Utica, New York, found tenting to be an effective means of sealing a building.
- Preserving sensitive and valuable materials is a concern when one is selecting a decontamination technology. One workshop participant suggested innovative research grants to businesses or academics as a way to address concerns about preserving materials.
- One workshop participant suggested leaving as much material as possible inside a building for fumigation to alleviate disposal concerns.
- CDC is concerned about the public health side of an event and facility safety for reoccupation. However, decisions about reoccupation are made by the local health agencies, so CDC responses to an incident must be carefully crafted and must respect the command structure. CDC only supports the local agencies and must be careful not to say anything that could be construed as policy.
- A representative from CDC indicated that historically a clear understanding of the different phases of a response was lacking. Participants in a decontamination event should recognize that the response phases are not separate and distinct; however, activities are becoming clearer as agencies gain more decontamination experience.
- An OSC provides information to agencies involved in a decontamination event. Agencies use this information to support their decisions. (One OSC at the workshop indicated that many of the technical experts present could be called upon to provide information to support a decontamination event.) Agencies working with an OSC need to understand the command structure at a decontamination event.
- An environmental clearance committee supports local agency decisions about when it is safe to reoccupy a building by providing information and credibility. The more the local agencies know, the better able they are to make decisions. The committee itself does not make decisions.
- One workshop participant served on several environmental clearance committees. This participant noted that the facility operator at one site supported the committee as an independent group assessing clearance for reoccupation.
- An OSC attending the workshop voiced support of environmental clearance committees and technical working groups. To support an OSC, however, technical working groups should consist of people who are authorized to make decisions for their agencies. Environmental clearance committees should recognize that they serve as advisory bodies, recommending cleanup values to the local agencies that make the decisions.

# Panel Discussion—Research and Development Needs

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Over the course of the 3-day workshop, presenters described a number of ongoing research projects. During the second panel discussion, workshop participants suggested many additional research needs. Again, workshop participants emphasized the need for agency coordination to maximize research efforts. The following is a list of suggestions provided during the second panel discussion, as well as research needs identified during the lessons learned panel discussion.

- Both basic and applied research are needed. Researchers must ensure that their efforts translate to real-world situations. Small-chamber studies provide a systematic approach, but these studies do not assess real-life concerns. Studies should simulate responses in real buildings. Issues of scale and engineering may be a concern when moving from laboratory to field-testing. For example, real-world situations often include greater surface areas and volumes for decontamination. Workshop participants provided several specific suggestions for applied research topics:
  - Real-time monitoring technology (e.g., developing faster, cheaper, and better technologies) for agents and fumigants
  - Appropriate sampling methods (e.g., determining whether cotton wipes or rayon wipes are better for surface sampling) for bio-agents (e.g., spores)
  - Validation of decontamination technologies
  - Tenting as a means of sealing a facility for fumigation
- Most of the information presented during the workshop applied to *B. anthracis*. A number of workshop participants mentioned the need to expand research related to other chemical, biological, and radiological threat agents. Most agreed that additional basic research on radiological agents is needed. Specifically, participants suggested research topics including:
  - Interactions of chemical and radiological agents with building and environmental materials
  - Movement of fine radiological particles
  - Aerosolization and re-aerosolization of biological and radiological agents
  - Effects of heat and humidity on the deactivation of ricin
  - Applicability of chelaters, HEPA filters, and other decontamination technologies to radiological agents
  - Activated reagents and their use on CWAs
  - Decontamination of infectious agents in an environment with a heavy organic load
- In addition to expanding research on specific threat agents, workshop participants thought research should expand to consider more threat scenarios, such as a large, outdoor contamination event. Events that may cause agricultural contamination or economic damage are also of concern.
- Research efforts should assess the whole cost of a decontamination event, including the disposal and restoration components. These efforts should identify potential savings areas that would reduce the expense and time required for decontamination and restoration. Gathering information and conducting decontaminations quickly could cut costs. A workshop participant noted that removing building contents before decontamination requires consideration of the restraints of working in a contaminated environment as well as packaging and transporting waste materials pulled from the building. If materials are removed after decontamination, perhaps they could be handled as relatively innocuous materials. Waste products from the decontamination process itself must also be considered.
- Dual-use technologies should be identified or developed before the next threat event occurs. Technologies for decontaminating biological agents, specifically, could have many uses (e.g., decontaminating mold-infested buildings, hospitals, and manufacturing facilities). As an added benefit, research on dual-use technologies can also foster collaboration between public and private sectors.

- Workshop participants also encouraged research into biotechnology-based decontamination approaches (e.g., bacteria-eating anthrax). One workshop participant mentioned an existing project studying viruses that attack anthrax. Another discussed a personal experience with a past project researching a bacterial virus for remediating a pathogen threat. This research was difficult to pursue because of concern that this project could be construed as biological warfare. Rather than using a bacterial virus, an enzyme extracted from the virus could destroy *B. anthracis* and other pathogens very quickly. (This technique also has a hospital application.) Current research is pursuing enzymes as a means of addressing chemical and biological agents.
- Several workshop participants mentioned the need for better surrogates. One participant noted that identifying surrogates is more complex than identifying a single surrogate for a single threat agent. Surrogates can change based on the threat agent, decontamination methods, and material characteristics. Researchers should consult microbiologists to consider whether biological indicators, spore strips, glass disks, and other media truly simulate *B. anthracis* releases. Identifying successful surrogates would enable academic institutions and others without clearance to work with threat agents to advance decontamination technologies.
- Workshop participants repeatedly mentioned biological indicators and spore strips as an area of uncertainty. For example, the test coupons need to better represent real-world situations (e.g., carpet coupons versus steel disks). The participants suggested additional research to improve available indicator and strip technologies and to develop new methods for ensuring that agent deactivation occurred. One workshop participant specifically mentioned the need for understanding the biology behind these technologies. Decontamination events rely heavily on biological indicators and spore strips, but information from these tests is not directly comparable to environmental samples. As during the lessons learned panel discussion, workshop participants held conflicting opinions about whether relating biological indicators and strips to environmental conditions (actual spores) was appropriate.
- During the lessons learned panel discussion, workshop participants mentioned specific research needs regarding existing sampling methods. One participant identified the need for research to address several questions: How much sampling is enough? What samples are truly necessary? How clean is clean? Other research topics specifically mentioned were rapid testing protocols, methods for sampling irreplaceable items (e.g., paintings or historical documents), accurate and inexpensive real-time monitors, and sampling standards (e.g., 1 spore strip per 100 $ft^2$).
- Several workshop participants suggested additional research to develop surfaces and coatings that are easy to clean, serve as biocides, or limit chemical infiltration. Specifically, studies could develop a way to seal porous materials, which can be difficult to decontaminate. Some research of surfaces and coatings is under way.
- Architects and engineers are notably absent from this meeting. These experts can provide information about designing buildings with smart systems—using building materials to combat contamination. A workshop participant mentioned that comprehensive planning at a State Department building resulted in a structure that minimizes the potential impact of a contamination event. For example, the mail room has a self-contained HVAC system with HEPA filters. Mail is processed through holding areas that can be tested for threat agents before the mail enters the building.
- Many of the presentations given during the workshop discussed material compatibility issues. Workshop participants agreed that additional research to understand interactions between decontaminants (e.g., fumigants), threat agents, and building materials is needed. Much remains unknown about chemical off-gassing, for example, or decontaminant impacts on sensitive equipment (e.g., computer components, aircraft systems). A workshop participant noted that the IBM facility in Rochester, New York, has a laboratory for testing sensitive equipment. IBM is open to having others use this laboratory for research. One presenter found that a number of carbonyls formed during chlorine dioxide fumigation tests. Very little of the reacted chlorine from those tests was recovered. The fate of the remaining chlorine remains unknown. More

information is needed to understand chemical reactions during fumigation and the formation of fumigation byproducts.

- Workshop participants suggested research to characterize background (e.g., dust, filth, grime) to understand how these materials may impact decontamination, especially fumigation technologies. LLNL plans to test and characterize grime in subways, and DoE seeks to characterize background characteristics of airborne materials that could be threat agents. For example, live anthrax spores can be found everywhere. Understanding these background levels should prevent unnecessary fumigation.
- Several workshop participants suggested additional research to address the question "How clean is clean?" They suggested conducting risk-based modeling to understand the aggregate risk before, during, and after a decontamination event. For example, if no growth is reported for $10^6$ spore strips, is a building safe for reoccupation? From a risk-based perspective, how should we address intact, nonviable spores?
- Nonculturable but viable organisms have not been addressed. Citing personal observations, a workshop participant noted that biological indicators report positive results on different days (i.e., some are positive on day 1, some on day 4, and occasionally some on day 6). The reason for this is unknown. Perhaps results vary based on different culture media.
- One workshop participant suggested convening a panel of experts distant from ongoing decontamination discussions and research to independently review the collective research efforts ongoing at various agencies and facilities. This panel may be able to identify topics that have been overlooked or projects that are redundant. They may also be able to determine whether current research is focusing on too few decontamination technologies or identify other areas of interest. The panel would meet periodically (e.g., to observe the presentations and discussions at this workshop). Their input may prevent us from being blindsided by an unexpected terrorist attack.

# Appendices

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## Appendix A: Agenda

### WEDNESDAY, FEBRUARY 23, 2005

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

#### PLENARY SESSION

9:00am **Opening remarks; decontamination timeline; summary of all events thus far** ..... *Blair Martin*
U.S. Environmental Protection Agency (EPA),
National Homeland Security Research Center (NHSRC)

9:30am **DDAP program** ..... *Lance Brooks*
Department of Homeland Security (DHS)

10:00am BREAK

10:15am **FBI/Forensics sampling** ..... *Ben Garrett*
Federal Bureau of Investigation (FBI)

#### SESSION 1: The Decontamination Process

10:45am **CDC approach to sampling** ..... *Ken Martinez*
Centers for Disease Control (CDC)

11:15pm **Agents of interest** ..... *Nancy Adams, EPA/NHSRC*

11:45am LUNCH

12:45pm **AOAC sterilant registration method** ..... *Steve Tomasino, EPA*

1:15pm **Crisis exemptions** ..... *Jeff Kempter, EPA*

1:45pm **Sampling issues** ..... *Mark Durno, EPA Region 5*

2:15pm BREAK

2:30pm **Ambient monitoring for fumigants/CW agents–TAGA van** ..... *Dave Mickunas, EPA*

3:00pm **Insurance and indemnity issues** ..... *Jerry Robinson*
United States Postal Service (USPS)

## WEDNESDAY, FEBRUARY 23, 2005 (continued)

### SESSION 1: The Decontamination Process (continued)

3:30pm **The role of on-site coordinators in the process** ..... *Marty Powell, EPA*

4:00pm **The UK perspective on decontamination approaches** ..... *Robert Bettley-Smith* (GDRS)

4:30pm **Lab capacity issues** ..... *Rob Rothman, EPA/NHSRC*

5:00pm ADJOURN

## THURSDAY, FEBRUARY 24, 2005

### SESSION 2: Decontamination Technologies

8:30am **$ClO_2$ fumigation, liquid $ClO_2$/bleach** ..... *John Mason* Sabre Technical Services

9:00am **$ClO_2$ system test Aniston** ..... *Tom McWhorter* CDG Technology

9:30am **VHP fumigation, liquid HP, and sporeclenz** ..... *Iain McVey* STERIS Corporation

10:00am BREAK

10:15am **VHP fumigation** ..... *Mike Herd* Bioquell, Inc.

10:45am **Methyl bromide fumigation** ..... *Rudi Scheffrahn* University of Florida

11:15am **Foam decontamination technologies** ..... *Rita Betty* Sandia National Laboratory

11:45pm LUNCH

2:30pm **Ricin** ..... *Jack Kelly, EPA/ERT*

1:00pm **Restoration from decontamination** ..... *Rich Orlusky, USPS*

1:30pm **Evaluating $ClO_2$ fumigation efficacy** ..... *Paula Krauter* Lawrence Livermore National Laboratory

2:00pm **Innovative/emerging decontamination technologies** ..... *Mark Brickhouse* Edgewood Chemical Biological Center (ECBC)

## THURSDAY, FEBRUARY 24, 2005 (continued)

### SESSION 3: Decontamination R&D

2:30pm **Systematic decontamination studies** ..... *Phil Koga (ECBC)*

3:00pm **Use of HVAC systems in building decontamination** ..... *Tina Carlsen*
Lawrence Livermore National Laboratory

3:30pm BREAK

3:45pm **Impact of materials on disinfection and byproduct formation** ..... *Rich Corsi*
University of Texas

4:15pm **Chamber studies** ..... *Mark Buttner*
University of Nevada, Las Vegas

4:45pm **Decontamination ETV program** ..... *Mike Taylor*
Battelle Memorial Institute

5:15pm **TSWG R&D activities** ..... *Rebecca Blackmon*
Technical Support Working Group

5:45pm ADJOURN

## FRIDAY, FEBRUARY 25, 2005

### SESSION 4: Lessons Learned

8:30am **PANEL DISCUSSIONS**
- Lessons learned from building decontamination work

10:30am BREAK

10:45am
- Research and technology development needs

12:00pm LUNCH

### SESSION 5: Radiological Dispersion Device Cleanup

1:00pm **Scenarios** ..... *Fred Holbrook*
**(DOE) EPA/NHSRC**

1:30pm **Dirty Bombs** ..... *John MacKinney, EPA*

2:00pm **Radiological cleanup** ..... *Malcolm Wakerley*
DEFRA/Radio Active Substances

2:30pm **Wrap-up** ..... *Blair Martin, EPA*

# Appendix B: List of Participants

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

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# Appendix C: Presentation Slides

## *Decontamination Workshop Overview*

Presented by:

G. Blair Martin
USEPA, ORD, MRMRL, APPCD

Presented at:

**NHSRC Workshop on Decontamination, Cleanups, and Associated Issues for Sites Contaminated with CBNR Materials**

**Washington, DC**
**February 23 to 25, 2005**

## *WELCOME*

The Decontamination and Consequence Management Division of National Homeland Security Research Center welcomes you to our first workshop on decontamination

## *PURPOSE OF WORKSHOP*

- The purpose of the workshop is to share information on a variety of subjects related to decontamination of CBNR releases in buildings, including:
  - ✓ The elements of a decontamination event
  - ✓ Technologies that have been used in actual decontaminations
  - ✓ Research and development to understand and improve technologies for additional CBNR agents
  - ✓ Discussion of "lessons learned" that might reduce the time and/or cost of any future decontaminations
  - ✓ Identification of research needs to fill gaps in the knowledge base and extend the range of applicability of technologies

## *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 40,000 to over 14,000,000 cubic feet

## *ELEMENTS OF A DECON 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

## *BUILDING RELATED ACTIVITIES*

- ✓ Orderly shut down and worker safety
- ✓ Containment of contaminant
- ✓ Documentation of building and HVAC design
- ✓ Content assessment
- ✓ Safe removal of contaminated contents and materials for decontamination/disposal
- ✓ Site plan for Decon equipment and reagent containment
- ✓ Restoration and return to service

## DECISION PROCESS

- ✓ Site and structure security
- ✓ Interaction with Federal State and Local Agencies
- ✓ Incident command structure
- ✓ Regulatory and technical document review processes
- ✓ Selection of contractors
- ✓ Decision on approaches to decontamination
- ✓ Documentation for crisis exemption
- ✓ Issuance of crisis exemption
- ✓ Final documentation for clearance

## CHARACTERIZATION AND MONITORING

- ✓ Forensic sampling
- ✓ Characterization sampling
- ✓ Biological indicators
- ✓ Ambient monitoring
- ✓ Fumigant Concentration monitoring
- ✓ Temperature, Relative humidity, and delta pressure monitoring
- ✓ Clearance sampling

## DECONTAMINATION PROCESSES

- ✓ Design interface with building
- ✓ Design decontamination system
- ✓ Design interface with heating, ventilation and air conditioning systems
- ✓ Procurement and fabrication of equipment
- ✓ Installation of system and support equipment
- ✓ Testing
- ✓ Fumigation
- ✓ Disassembly and removal

## DISPOSAL

- ✓ Materials may be removed prior to fumigation
  - ➢ High value materials that must be preserved
  - ➢ Materials that may be hard to decontaminate
  - ➢ Materials that may accelerate decomposition of fumigant
  - ➢ Machines or electronics that the fumigant may damage
  - ➢ Equipment that may be replaced before building is returned to service
- ✓ Additional material may be removed after fumigation
- ✓ Wastes from the fumigation system also may require disposal

## COMMUNICATION

- ✓ Law Enforcement Agencies
- ✓ Workers and Occupants of the Building
- ✓ Residents of Surrounding Community
- ✓ Commercial Establishments
- ✓ Federal, State and Local Health agencies
- ✓ Environmental and Regulatory Agencies
- ✓ Advisory Groups
- ✓ Contractors
- ✓ OCSs

# DHS S&T Biological & Chemical Restoration Programs

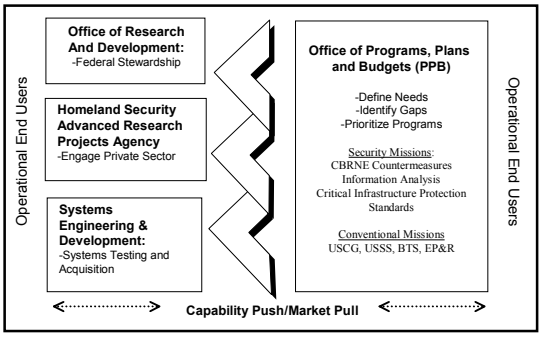
February 23, 2005
Lance Brooks

Dr John Vitko,
Biological Countermeasures Portfolio Manager

Dr. Randolph Long,
Chemical Countermeasures Portfolio Manager

Homeland Security

## Research, Development, Testing and Evaluation




Homeland Security

## Domestic Demonstration & Application Programs

**Program Goals**

**Integrated field demonstrations of next generation solutions which bring together the user, technology, and ConOps in a real world test of a particular solution.**

Homeland Security

## ogical Aerosol Sentry and Information em (BASIS)

**nced biological security at events**

**deployment and setup**

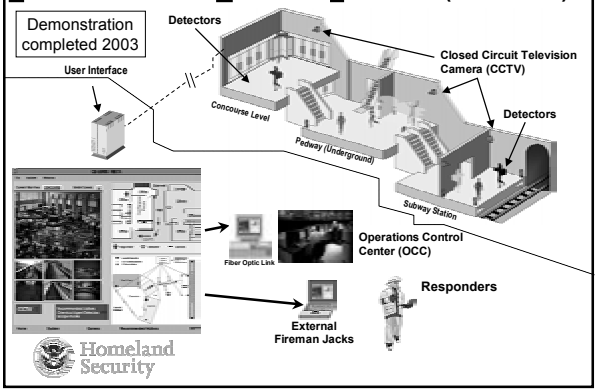
**ed operational period**

**rage for fixed sites – point on**

**essfully deployed at Winter c Games in Salt Lake City**

Homeland Security

## Program for Response Options and Technology Enhancements for Chem/Bio Terrorism (PROTECT)

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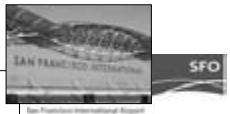
## ration of Large Airport Facilities

**To be Completed FY05**

**o reduce the overall time to a critical transportation facility ng a biological attack.**

**hed**
tnerships (federal, state, & local)
O
**n Critical Path**
elopment and approval step
igation verification step
arance sampling step
rall coordination and understanding

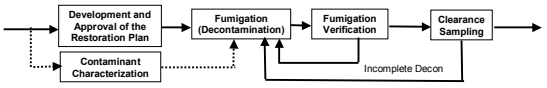
toration "templates" that provide guidelines
rge airports




Conduct Tabletop exercises and Large scale demonstration

Homeland Security

## Restoration of Large Airport Facilities




- ✓ Improve the development and approval step by pre-planning the restoration process
  - ➢ development of a 'pre-approved' restoration plan (i.e., EPA crisis exemptions)
  - ➢ pre-event identification of roles and responsibilities
- ✓ Improve the fumigation verification step
  - ➢ use of rapid viability determination methods for spore strips
  - ➢ use of statistical sampling methods and a sampling database
- ✓ Improve the clearance sampling step
  - ➢ NAS study to determine "how clean is clean?"
  - ➢ improved understanding of sample collection efficiencies
  - ➢ use of rapid viability determination methods
  - ➢ use of statistical sampling methods and a sampling database
- ✓ Improve the overall coordination and understanding of the restoration process
  - ➢ conduct workshops and tabletop exercises with stakeholders
  - ➢ development of decision support software (BROOM)

**Note that the program is not addressing the fumigation step**

Homeland Security

## Pre-Demonstrations

**Goal: To plan, coordinate and establish partnerships for Transit Facility and Wide Area Restoration Demonstrations**

- **Establish**
  - Partnerships (federal, state, & local)
- **Focus**
  - Concept of Operation/Protocols
  - overall coordination and understanding
  - Utilize HSI Study, TSWG Protocols, FTA Study
- **Collaboration**
  - EPA for Pre-review of sampling & decon plans
  - FTA for Transit systems Tech Transfer

**Develop**
- Restoration "templates/guidelines" for Transit Systems & Urban Areas

**DHS S&T will utilize resources and experience for conducting a coordinated system demonstration.**

Homeland Security

## Restoration of a Transit System

**To be Initiated FY06**

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

- **Partnerships**
  - facility, federal, state, & local
  - FTA (Restoration Analysis, CBRN)
  - WMATA (Restoration Plan)
- **Leverage Airport Restoration DDAP**
  - existing clean-up guidelines
  - existing / emerging sampling methods
  - existing / emerging decontamination technologies
- **Develop**
  - Pre-planning/rapid approval of restoration process (Template)
  - Methods for contamination characterization
  - Decontamination and verification for surfaces
  - Clearance Methods and decision tools

Conduct Tabletop exercises and Large scale demonstration

Homeland Security

## Restoration of a Wide Area (Urban)

**To be Initiated FY06**

**Goal: To reduce the overall time to restore a large outdoor urban area following a biological attack.**

- **Partnerships**
  - Urban area, federal, state, & local
- **Identify & Survey**
  - existing clean-up guidelines
  - existing / emerging sampling methods
  - existing / emerging decontamination technologies

**Develop**
- Pre-planning/Approval of restoration process
- Methods for contamination characterization
- Decontamination and verification for surfaces
- Clearance Methods and decision tools

**Clean Earth Tech. Workshop – Protocols/Technology**
**HSI Workshop – Analysis/Policy**

Conduct Tabletop exercises and Large scale demonstration

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## Wide Area Restoration

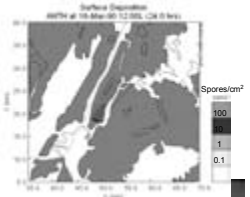
***Large-Scale Restoration of Biologically Contaminated Areas - Technology/Protocols***

- Develop science- and consensus-based protocols to restore large-scale urban areas to safe levels for unrestricted reoccupation following a bioterrorism attack.

***Large-Scale Restoration of Biologically Contaminated Areas - Analysis/Policy***

Analysis of:

- Transition from crisis response to consequence management
- Community involvement and societal values
- Interagency cooperation
- Regulatory and technical issues
- The psycho-social and economic impacts of a wide-area biological incident




**Study results and developed protocols will be incorporated into the Wide Area DDAP .**

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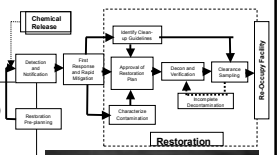
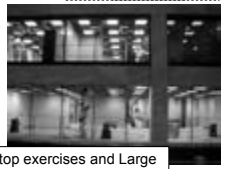
## Facilities Chemical Restoration Demonstration

**Initiated FY05**

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




- **Establish**
  - Partnerships (facility, federal, state, & local)
  - 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 Large scale demonstration

Homeland Security

# Crime Scene Management & WMD Terrorism

*Presented to*
EPA Workshop on Decontamination, Cleanup & Associated Issues
February 2005

## Presentation Contents

- Overview of Crime Scene Management
- Forensic Challenges
  - Detection
  - Attribution
  - Traditional Exams

← FBI crime scene, Seattle, Washington, April 2004

Items include (1) bag of castor seeds; (2) hydrogen-filled rockets; (3) 9-mm handgun; (4) spilled mercury; & (5) loose cash.



## Response to WMD Terrorism

- Tactical Phase
  - Removal of the hostile threat (FBI & other SWAT, FBI HRT)
- Operational Phase
  - Provide Rescue / Control (protect the public; identify & mitigate hazards)
- Crime Scene Phase
  - Evidence Collection, Packaging & Transport
- ~~Remediation Phase~~



## Detection

- In this context, *Detection* means "determining that a crime has occurred"
  - A crime must be *detected* in order to be investigated
- WMD Terrorism Challenge: Differentiating natural event from a deliberate release or other criminal event



## Detection

- Consider: Victim found with gunshot wound determined to be fatal
  - Not necessarily apparent that foul play occurred
- Consider: Victim found dead with bacterial illness determined to be cause
  - Not necessarily apparent that foul play occurred

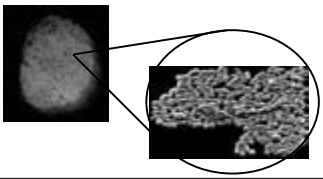


## Sampling

- In this context, *Sampling* is the term the public uses for what Law Enforcement considers "gathering evidence"
  - Knowing when, where, what & how to sample

## Sampling

- Challenge: Pathogens are microscopic, limiting visual clues to assist in knowing:
  - Where to collect evidence
  - What items to collect
  - Whether an item or area is connected to the crime scene
  - How best to collect the evidence



← It is a matter of size: Magnified area (lower right) shows a clump of bacteria that might be hidden within a single line of a human fingerprint



## Sampling

- Consider the gunshot victim
  - We can see the gunshot wound
  - We can see a gun
  - We can see a bullet
- Consider the pathogen victim
  - We cannot see the disease
  - We cannot see the pathogen
  - If we cannot see the disease or the pathogen, then we might fail to find the scene altogether



## Traditional Exams

- In this context, *Traditional forensic examinations* refers to the conduct of fingerprint, toolmark, question document, trace evidence, and related exams that are the classical tools of forensic sciences



## Traditional Exams

- Challenge: Conducting traditional examinations on evidence contaminated with biological pathogens without
  - harming the examiner
  - losing evidence
- Factors to consider:
  - Methods for rendering the pathogen harmless are destructive
  - Examining contaminated evidence is hazardous



## Summary - 1

- Crime of "Bioterrorism" presents unique challenges with regard to
  - Detection
    - *versus* natural outbreaks
  - Sampling
    - Finding microscopic organisms
  - Traditional Forensics
    - Protecting examiners and exhibits
- Similar challenges exist for crimes related to toxic chemicals and radiological materials



## Summary - 2

- Traditional Forensic Examinations are likely to yield the most useful clues
  - Fingerprints
  - Handwriting
  - Toolmarks
  - Trace evidence
  - Questioned documents

## Summary - 3

- Despite the novel nature of WMD terrorism, classical police work is still the most likely means of solving the case



## Questions or Comments?

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## CDC/NIOSH Response to Biothreat Agents: Environmental Monitoring

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National Institute for Occupational Safety and Health

*Acknowledgement: Max Kiefer*
*Karl Sieber*

NIOSH CDC


CDC

## Purpose of Environmental Sampling

- Determine agent sources, characteristics, and exposure pathways
- Determine the extent and degree of contamination
- Contribute to risk assessment and data-driven recommendations
- Support medical treatment and clean-up decisions
- Provide guidance on re-occupancy

CDC


CDC

## Initial Public Health Goals

- Characterize contaminant
  - Physical properties (size, morphology)
  - Ability to aerosolize (moisture, additives)
  - Purity
- Limit Spread of Contamination (after dispersal)
  - Fomite transport
  - Personnel transport
  - Air movement (HVAC)
- Determine who may have been exposed and what remedial actions are taken

CDC

## Some Questions…

- Is preventive personal decontamination needed after an exposure event?
- Could clothing act as a vehicle to carry spores offsite and to worker home environments?
- If so what precautions should be recommended?

CDC

## Partnerships

- Multiple Agency Involvement
  - FBI, EPA, OSHA, CDC, Coast Guard, ACOE, USPS, Unions, State Agencies
- Defining Roles/Expertise
- Strong Views and Personalities
- Public Scrutiny, Agency Pressure
- Agency Conflicts
  - Technical and programmatic

CDC

## NIOSH Role

- Emergency Response
  - Assist Epidemiological Team
  - Environmental Assessment, Safety and Health
- Consequence Management
  - Technical Resource
  - Advise re: Sampling, PPE, Risk Communication
- Approximately 10,000 environmental Samples
  - Between 4%-50% from a given site were positive

CDC

## Some Underestimations

- Importance of environmental sampling
  - Driving force behind public health decisions
- Existing plans clinically based
- Need for maintaining continuity of operations during a response

CDC

## Phase of a Response

- Screening
  - Law enforcement and public health partnership
  - Analysis confined to validated methods
  - Targeted sampling approach
- Characterization
  - Federal (with state and local) and industry partnership
  - Analysis more flexible
  - Probabilistic (with some targeted) sampling approach
- Remediation/Restoration
  - Federal (with state and local) and industry partnership
  - Analysis confined to validated methods
  - Probabilistic (with some targeted) sampling approach

CDC

## CDC Responses

***Anthrax 2001***

- Florida – AMI
- NJ – Hamilton PD&C
- NYC – multiple sites
- Washington, DC – Capital Hill and Brentwood PD&C
- Outliers
  - NYC healthcare worker
  - CT elderly woman

CDC

## Investigative Sampling Strategy

***Anthrax Outbreak Investigation***

- Follow the mail
- High traffic areas
- Ventilation system
- Areas that collect dust

CDC

## Consider…

- Dissemination
  - Air
  - Fomites
  - Personnel
- Surfaces
  - Porous versus non-porous
- Validated sampling protocols
- Methods of analysis

CDC

## What Was Sampled?

***Anthrax Outbreak Investigation***

- Furniture (equipment)
- Floors
- Ventilation system
  - Filters
  - Return air grills
- Vehicles
- Clothing

Source: EPA photos during Capitol Hill Clean-up

CDC

## Environmental Sample Types

Bulk

Surface

→ Air

CDC

## Environmental Sampling Protocols


CDC

## Validation Studies

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

CDC

## Distribution of Samples by Geographical Location

| Area Investigated | Number of Samples Collected |
|---|---|
| Florida | 1224 |
| Hartford area | 891 |
| Kansas City | 72 |
| Trenton area | 1353 |
| New York City | 449 |
| Washington, D.C. (Capitol) | 4112 |
| Washington, D.C. (other) | 1360 |
| ***Total*** | ***9461*** |

CDC

## Distribution of Samples by Type of Facility

| Type of Facility | Number of Samples Collected |
|---|---|
| Office Building | 4611 |
| Postal Processing and Distribution | 3299 |
| Post Office | 492 |
| Subway | 215 |
| Other Business | 217 |

CDC

## Some Applications of Lessons Learned

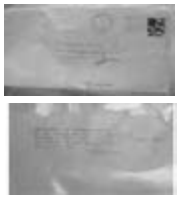
- Ricin – Greenville, SC
  - October, 2003
- BioWatch – Houston, TX
  - October, 2003
  - Tularemia
- SARS – Toronto, Canada
  - Spring of 2003

CDC

## Ricin Event

***October 2003***

- Greenville, SC
- Threat letter with ricin found
- FBI/local health department/ CDC Investigation
- Coordinate with CDC RRAT lab
- Determine sampling and analytical methodology



CDC

## Sampling Strategy based on….

- Interviews with:
  - Postal Manager, Union official and employees
  - Postal Inspectors, FBI, and Law Enforcement
  - Medical Officers regarding health issues, absenteeism
- A detailed walkthrough of the facility to identify all points where package was delivered, moved, stored, etc., until discovered by alert postal employee

CDC

## Conveyor and Controls

CDC

## Results

- 70 Surface swab and 5 vacuum samples collected overnight
- Samples air shipped to CDC after collection for immediate processing via TRFI and PCR
- Results available by 3 pm – all negative
- Results significant in decision to reoccupy the facility

CDC

## Houston, Texas – BioWatch

***October, 2003***

- Tularemia detected (and confirmed) on BW monitors
- Investigation launched….
  - Syndromic surveillance
  - Laboratory review
  - Environmental
    - Rodent trapping
    - Surface sampling

CDC

## NIOSH Investigation

- Inspected all sites where positives were detected (reviewed construction, excavation, lawn mowing, etc.)
- Reviewed laboratory procedures, sample handling, sample transport, opportunities for cross contamination
- Collected 68 environmental samples (swabs, filters, etc) from multiple co-located sampling devices and other potential sources
- Provided additional air sampling equipment for increased density of sample locations

CDC

## Findings

- All environmental samples were negative
- Heavy rainfall impeded ability to collect additional air samples
- Opportunities for cross-contamination possible but an unlikely explanation
- Environmental activities adjacent monitors were unremarkable and unlikely to explain results

CDC

## SARS

***Spring of 2003***

- Toronto, Canada
  - First outbreak
    - Community
    - Various hospitals
  - Second outbreak
    - North York General Hospital
      - Nosocomial
      - Includes a large occupational component

CDC

## NIOSH Investigation

- Focus on occupational safety and health issues
  - PPE
  - Controls
  - Environmental assessment
- Exposure characterization
  - Wipe samples
    - Swabs
    - Wipes
  - Air samples
    - 37-mm filter cassettes

CDC

## Ranking Threats for Decontamination Research

Nancy H. Adams, PhD, Director
Decontamination and Consequence Management Division
National Homeland Security Research Center
Office of Research and Development
US Environmental Protection Agency
Research Triangle Park, NC

## Multiple Approaches

- DCMD ranking methods
- SAIC rankings
- Expert Panel
- Battelle rankings for decon methods studies
- Constant updates

## DCMD Approach

- Identification and ranking of high-priority threat agents
- Identification and ranking of buildings as terrorist targets
- Identification of terrorist goals
- Coupling threat agents and buildings
- Scenario development

## Chemical and Biological Threat Agents - Sources

- CDC Category A list
  - Chemical warfare agents
  - Toxic IndustrialChemicals
- Department of State
- Department of Defense
- EPA
- Intelligence community

## Ranking Factors for Threat Agents

- Infective dose (biologicals)
- Persistence
- Availability
- Prior use
- Ease of detection
- Severity of effects
- Transmission between persons (biol)
- Preventives/treatments
- Ease of decontamination
- Latency
- Ease of airborne dispersion

## Ranking Method

1 - Each factor given a rating (1-5) for relevance

2 - Each threat agent ranked for each factor (0-4)
- 0 = not applicable
- 4 = highest effect

3 - (Factor rank) x (Threat rank for factor) = Product

4 - Summed products = Ranking for threat agent

| Factor | Weight |
|---|---|
| Infective dose (biologicals) | 5 |
| Persistence | 2 |
| Availability | 4 |
| Prior use | 2 |
| Ease of detection | 3 |
| Severity of effects | 5 |
| Transmission (biologicals) | 4 |
| Preventives/treatments | 3 |
| Ease of decontamination | 2 |
| Latency | 3 |
| Ease of airborne dispersion | 3 |
| Lethality (chemicals) | 5 |

## *Definitions of Factor Rankings*

Each factor's numerical ranking defined.

For example, for *Severity of Effects*:

0 = mild, temporary impairment
1 = More severe effects in susceptible group(s)
2 = Serious illness of med-long duration
3 = Permanent impairment
4 = Death

## *Example Ranking*

- Factor = Severity of Effect
- Factor ranking = 4
- Anthrax ranking = 4
- 4 x 4 = 16

This product added to the other product values for anthrax to obtain a ranking value

## *Building Types*

- Shopping centers
- Convention centers
- Subways
- Airports
- Domed stadiums
- Hotels
- Theaters
- Residences
- Aircraft
- Schools
- Hospitals
- Office buildings
- Apartments
- Presidential offices
- Congress
- Military bases
- Embassies
- CDC
- Museums

## *Building Ranking Factors*

- Building access
- HVAC access
- Potential for infiltration for outdoors
- Small rooms
- Large rooms
- People traffic

| Factor | Weight |
|---|---|
| Building access | 5 |
| HVAC access | 4 |
| Potential for infiltration for outdoors | 2 |
| Small rooms | 3 |
| Large rooms | 3 |
| People traffic | 4 |

## *Ranking Method*

- Factor Weights (1-5)
- Building ranks (1-5)
- Sum of products (Weight x rank)

## *Terrorist Goals*

- Health impacts
- Economic
- Symbolic
- Political
- Psychological

## *Coupling Threats with Buildings*

- Method of introduction
  - In-room
  - In-duct
  - Outside/proximal

## *Coupling Threats with Buildings – cont'd*

- Threat Value = 1+2+3+4+5
  - 1 = Amounts available
  - 2 = Hazard index
  - 3 = Ease of use
  - 4 = People traffic
  - 5 = Non-health impacts

## *Coupling Threats with Buildings – cont'd*

- Term 1- Amount available
  - Availability
  - Prior use
- Term 2 – Hazard index
  - Infectious dose
  - Lethality
  - Severity of effects
  - Contagious
  - Latency
  - Availability of treatments

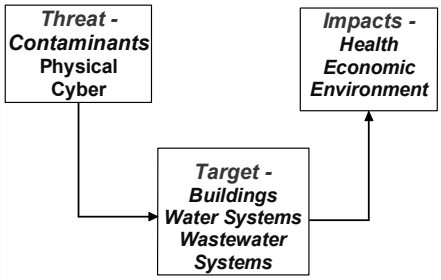
## *Coupling Threats with Buildings – cont'd*

- Term 3 – Ease of use
  - Ease of dispersion
  - Potential for infiltration
- Term 4 – People traffic
- Term 5 – Non-health impacts
  - Economic
  - Symbolic
  - Political
  - Psychological

## Scenario Development

- Methods of Introduction (3)
- Terrorist goals (5)
- Rankings for each
  - agent,
  - building type,
  - method of introduction,
  - terrorist goal
- Rankings analyzed by
  - Visual patterns
  - Cluster analysis

## SAIC Approach




## Quantitative Ranking of Threat Scenarios

Risk = Probability * Consequence

| Probability depends on: | Consequence depends on: |
|---|---|
| Availability of agent | Toxicity of agent |
| Capability of terrorists | Amount of agent |
| Past terrorist action | Contagiousness |
| Ease of dissemination | Impact on infrastructure |
| Latency | Availability of treatment |
| Persistence | Ease of detection |
| Existing security | Ease of decontamination |

Requires an artful blend of quantitative and qualitative information.

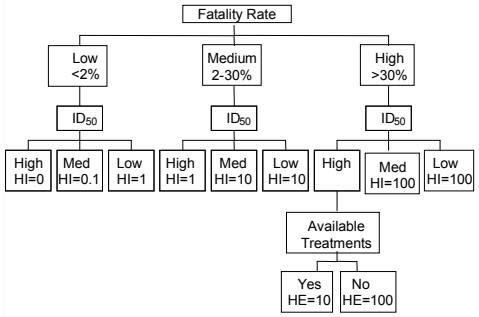
## Selected Algorithm

**Risk Index = A x F x (HI + EI + NI)**

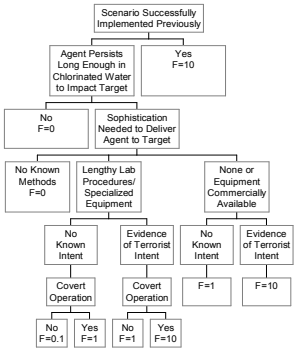
A = Availability
F = Feasibility
HI = Health Impacts
EI = Economic Impacts
NI = Environmental Impacts

Risk Index varies from 0 to 300,000.

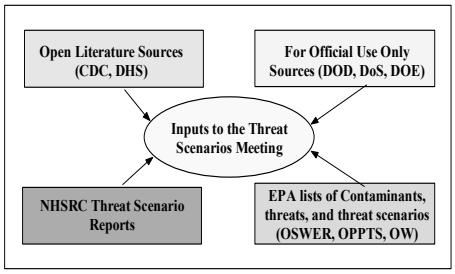
## Health Impacts: Biological




## Feasibility Decision Tree



## Expert System Approach




## Battelle Systematic Decontamination Effort

- Approach similar to DCMD
- Includes updated information
- Provided rankings for study of decontamination methods

## EPA-Wide Rankings

- Includes input from:
  - EPA Office of Homeland Security
  - Department of Homeland Security
  - Department of Defense
  - EPA Office of Water
  - DCMD
  - Threat and Consequence Assessment Div.
  - Office of Solid Waste
  - EPA Emergency Response Team
    - On-scene coordinators
    - Decontamination Team

## Summary

- Constantly updated listings
- Inputs from multiple sources
- Commonality among rankings

## Path Forward

- **Threat Scenario Simulations**
- **Detailed Risk Assessments**
- **Development of Play Books**

ORD Workshop on Decontamination

**OPP Sterilant Registration Project**

(Task SB 3.2 - ORD Safe Buildings Program)

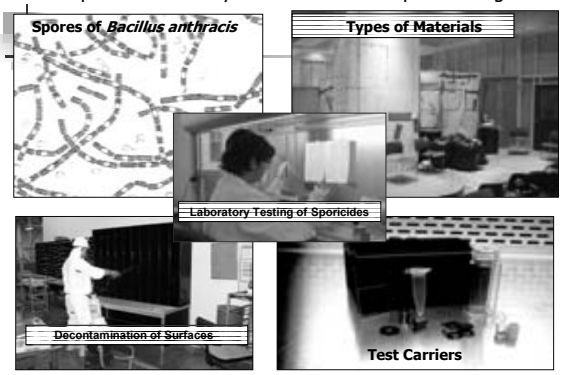
Improving the AOAC Sporicidal Activity Test and the Evaluation of Quantitative Methods

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

## OPP Microbiology Laboratory

EPA Environmental Science Center, Ft. Meade, MD

Renewed Interest in the Evaluation, Research and Development of Efficacy Test Methods for Sporicidal Agents




## Project Goals

- OVERARCHING GOALS
  - Advance the science of efficacy testing and replace 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 future regulatory guidance
  - Identify a suitable surrogate for *B. anthracis*
  - Set the stage for the evaluation of other biological agents

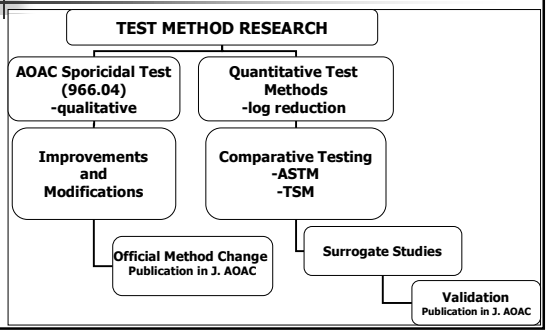
## OPP's Role - Regulatory

- Performance Standard for Sporicidal Claim = AOAC Sporicidal Activity Test
  - Test Challenge = *Bacillus subtilis* and *Clostridium sporogenes* ($10^5$ - $10^6$ Spores/Carrier)
  - Hard Surface (Porcelain Carriers); Porous Surface (Suture Loops) - 60 Carriers Each
  - Full Study = 720 carriers
  - Partial Study (*B. subtilis* only) = Range Finding (30 carriers/surface/contact time) and Confirmation (60 carriers/surface)
  - Passing Result = zero carriers positive

## A Tiered Approach

- Tier 1: Evaluate selected methods using *Bacillus subtilis* (includes modifications to the AOAC method)
- Tier 2: Evaluate surrogates for *Bacillus anthracis*
- Tier 3: Conduct collaborative validation testing of selected test method/surrogate combination
- Tier 4: Identify, develop, and conduct comparative testing of field test methods

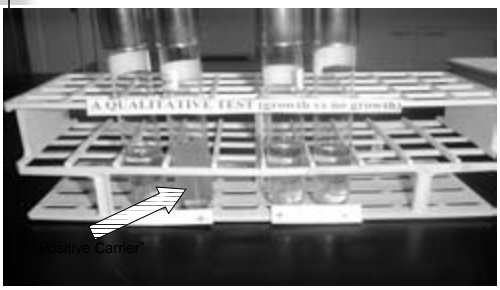
## Two Approaches



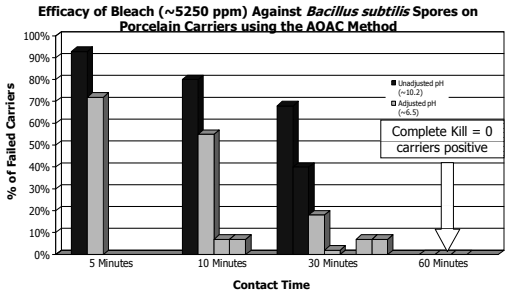

## AOAC Sporicidal Activity Test

- A qualitative, carrier-based assay
- Spore-forming bacteria (*Bacillus subtilis, Clostridium sporogenes)*
- Simulates hard (porcelain carriers) and porous (suture loops) surfaces
- Each test is composed of 60 carriers (EPA requirement)
- HCL resistance test
- Passing result = no carriers with surviving spores
- Requires 21 days of incubation
- Lacks standardization in several key steps

## Qualitative Assessment



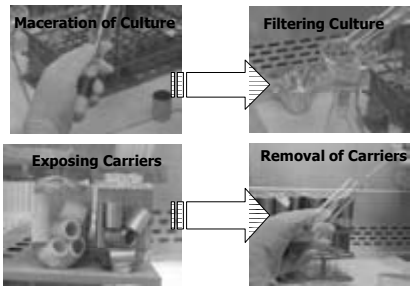

## AOAC Sporicidal Activity Test
### Qualitative Data



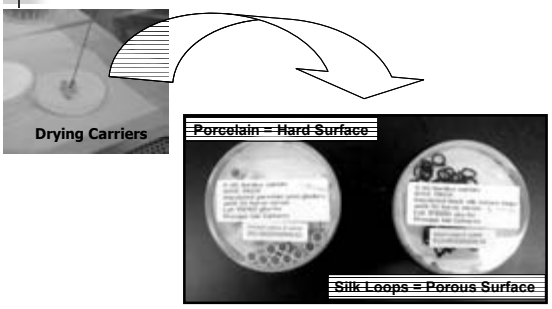

## Recommended Modifications

- Chemically defined medium for *B. subtilis* spore production to replace the soil extract nutrient broth
- Replace porcelain carriers with stainless steel carriers
- Addition of a carrier count procedure for enumeration of spore inoculum
- Establishment of a minimum (average) spore titer per carrier
- Addition of a neutralization confirmation procedure
- Replacement for the Egg Meat Medium for *Clostridium sporogenes*

## SENB & Carrier Inoculation



## Preparing Carriers




## Parameters used to Measure the Impact of the Modifications*

| | Carrier Type | |
|---|---|---|
| **Spore Production Medium** | Current: Porcelain | Modified: Stainless Steel |
| Current: AOAC SENB | *Spore Counts*<br>*HCL Resistance*<br>*Efficacy Results* | *Not Applicable* |
| Modified: Amended Nutrient Agar | *Spore Counts*<br>*HCL Resistance*<br>*Efficacy Results* | *Spore Counts*<br>*HCL Resistance*<br>*Efficacy Results* |

*Differences in spores counts can be measured statistically; pass/fail criteria are established for the HCL resistance and efficacy tests and will be used to assess differences.

## AOAC Method Modifications
Extramural Contributors

- U.S. Air Force Research Laboratory, Aberdeen, MD
- FDA - Winchester Engineering and Analytical Center
- FDA - Denver District Laboratory
- Dr. Martin Hamilton, Professor of Statistics, Montana State University

## Pre-collaborative Data
Bleach @ 3000 ppm –unadjusted pH/10 mins

| Medium/Carrier | Primary + | Secondary + | Total + |
|---|---|---|---|
| NA/SS | 28/30 | 30/30 | 30/30 |
| NA/P | 24/30 | 29/30 | 30/30 |
| SENB/SS | 6/30 | 3/30 | 7/30 |
| SENB/P | 8/30 | 11/30 | 16/30 |

**NA = Nutrient Agar amended with 5 µg manganese sulfate**

**SENB = AOAC Soil Extract Nutrient Broth**

**SS = Stainless Steel Carriers**

**P = Porcelain Carriers**

**Spore Load: NA/SS ($1.1 \times 10^6$); NA/P ($6.2 \times 10^6$); SENB/SS = $4.0 \times 10^6$); SENB/P = $1.1 \times 10^6$)**

## HCL Resistance

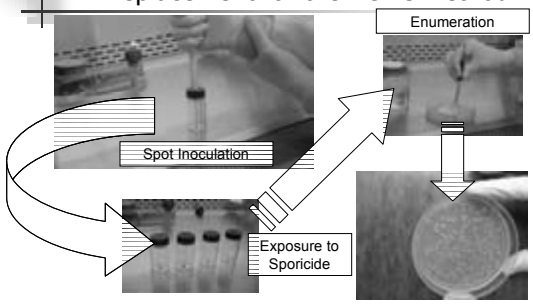
| Medium/Carrier | 2 mins | 5 mins | 10 mins | 20 mins |
|---|---|---|---|---|
| NA/SS | **+/+** | +/+ | 0/0 | 0/0 |
| NA/P | **+/+** | +/+ | 0/0 | 0/0 |
| SENB/SS | **+/+** | 0/0 | 0/0 | 0/0 |
| SENB/P | **+/+** | 0/0 | 0/0 | 0/0 |

**Spore Load:** **NA/SS = $6.8 \times 10^5$**
**NA/P = $1.9 \times 10^6$**
**SENB/SS = $3.1 \times 10^5$**
**SENB/P = $2.2 \times 10^5$**

## Timeline for the Modifications Project

- Contract with AOAC signed in Sept. 2004
- AOAC Expert Review Panel formed in Dec. 2004
- Study protocol submitted in Jan. 2005
- AOAC ERP completed review in Feb.
- Final study protocol will be submitted to AOAC by March 11
- Conduct validation study in late April/early May
- Complete and submit validation report and analysis-July 1
- AOAC review and approve validation report-August 26

## A Replacement for the AOAC Method



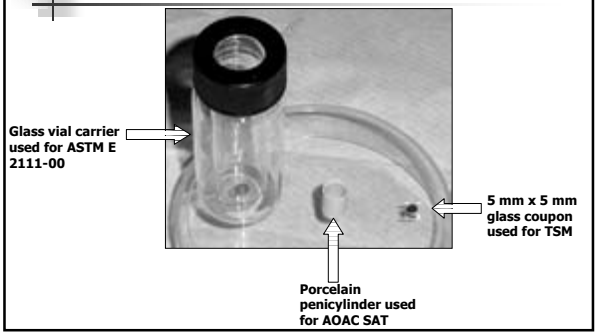

## Test Method Selection - Attributes

- Available Protocol
- Validation
- Previous use for testing sporicides
- Readily available equipment
- Expertise
- Flexible contact times and temperatures
- Enumeration method
- Percent recovery
- Deactivation of product
- Reproducibility
- Turnaround time
- Suitability for various product forms
- Adequate controls

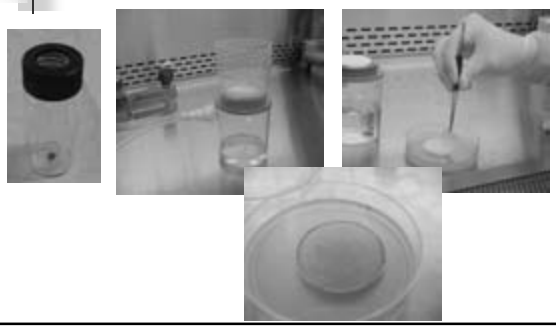
## Test Methods Selected for Evaluation

- AOAC Sporicidal Activity Test
- Standard Quantitative Carrier Test Method-ASTM E 2111-00
- A quantitative micro-method as reported by Sagripanti et al., 1996. (Sagripanti, J.L. & Bonifacino, A. 1996. *Am. J. Infect. Control* 24, 364-371) – referred to as the Three Step Method (TSM)

## Carriers used in Sporicidal Efficacy Testing

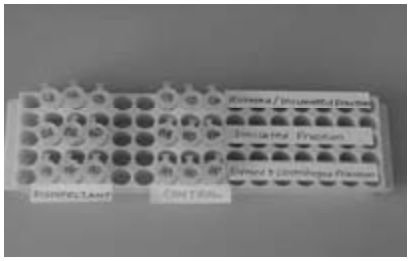



## ASTM 2111-00



## Three Step Method (TSM)

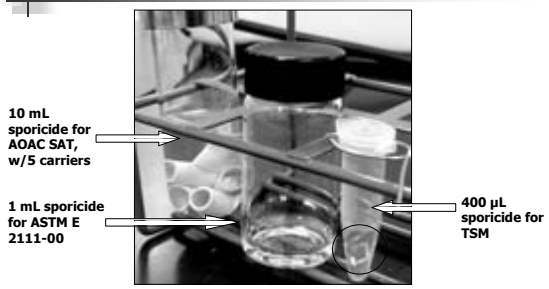
## TSM - fractions



## Formulations and Materials

- Liquids
- Gases & Vapors
- Sprays, Foams and Gels
- *Devices and Other Technologies*
- Hard (metal, plastics, glass)
- Porous
- Other (specialized)
- (Water)

## Volume of Sporicide per Test Method




## Important Components of the Test Method Collaborative

- Limited to glass surface x liquid sporicides x spores of *B. subtilis*
- Three labs/three replications
- Identify/implement quality control activities
- Training and readiness review

## Test Method Comparison
### Chemicals & Test Conditions

- pH-adjusted bleach; 3000 ppm/10 minutes @ 20C
- Commercial product (0.8% hydrogen peroxide, 0.06% peracetic acid); undiluted/10 minutes @ 20C
- pH-unadjusted bleach; 3000 ppm/10 minutes @ 20C
- pH-adjusted bleach; 6000 ppm/30 minutes @ 20C for the AOAC test

## Test Method Comparison
### Extramural Contributors and Responsibilities

- U.S. Army Edgewood Chemical and Biological Center, Aberdeen, MD, and FDA (Denver District Office Laboratory) will provide expertise and technical support in the collaborative testing of sporicidal chemicals using efficacy methods selected by OPP.
- Dr. Martin Hamilton, Professor of Statistics, Montana State University, is the statistician assisting on this project. Dr. Hamilton is currently under contract with the OPP Antimicrobials Division.

## Quantitative Results

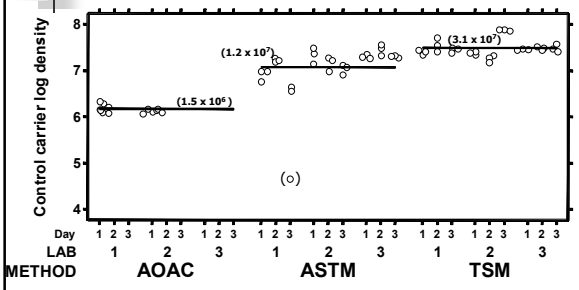
- **control:**
  recoverable, viable spores per control carrier; specifically, $\log_{10}$(cfu/control carrier)
- **log reduction (LR):**

  LR = $\log_{10}$(cfu/control carrier)
  - $\log_{10}$(cfu/treated carrier)

## Statistical Goals for the LR Data and Control Data

- within-laboratory variance
  (*independent repeats of the same test*)
- between-laboratory variance
  (*measures the variability between labs*)
- total variance
  = within-laboratory variance
  + between-laboratory variance

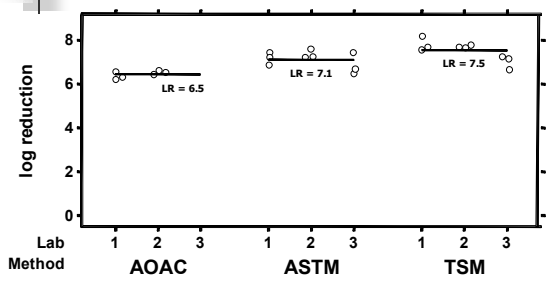
## Recoverable, viable spores per control carrier (log10 scale); red line is the mean



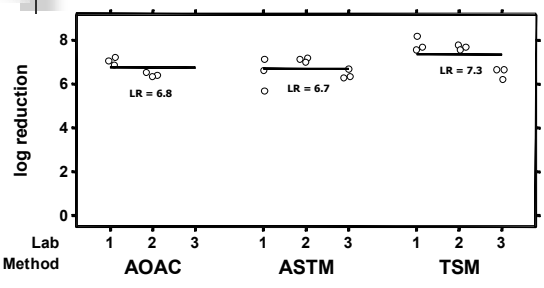

## AOAC Method - Collaborative Highlights

| Treatment | Comments |
|---|---|
| Bleach 3000ppm pH adj | No. positive ranged from 16 to 56 |
| Peracetic acid/hyd.per. | No. positive ranged from 5 to 60 |
| Bleach 3000ppm unadj | 60 out of 60 positives in 4 of 6 tests |
| Bleach 6000ppm pH adj | 0 out of 20 positives in 4 of 6 tests |

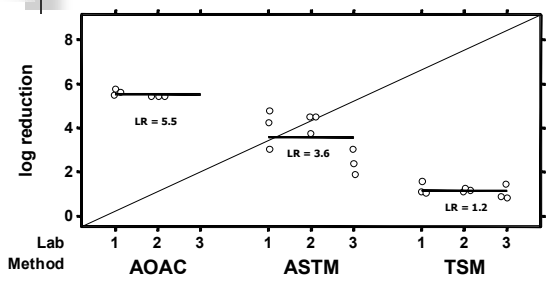
## Bleach 3000 ppm, pH adjusted (each point is a test; red line indicates the mean)



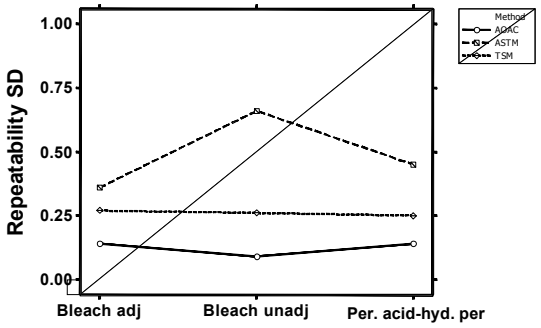

## Peracetic acid/hydrogen peroxide (each point is a test; red line indicates the mean)



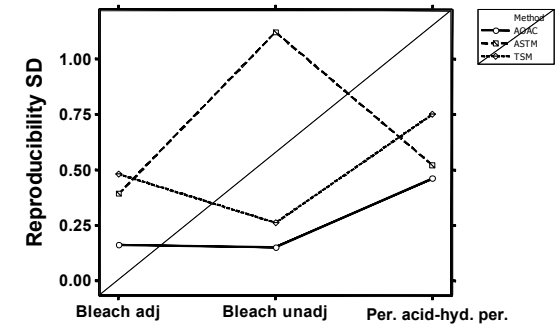
## Bleach 3000 ppm, pH unadjusted (each point is a test; red line indicates the mean)




## Repeatability SD is acceptably small (less than 0.9) for all test methods




## Reproducibility SD is acceptably small (less than 1.3) for all testing methods




## Selecting a Method
### Additional Attributes

- Questionnaire Submitted to Analysts
  - The Protocols - their 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

## Timeline for Surrogate Studies and Validation of a Quantitative Test

- Submit manuscript to AOAC on the 2004 test method collaborative – May, 2005
- Initiate surrogate studies with TSM - April 18th
- Complete surrogate studies - May 27th
- Surrogate analysis and report – July 1st
- TSM and 2-3 surrogates will be subjected to an AOAC multi-lab validation study in September
- Prepare summary report on TSM validation - December


## Acknowledgements

- Dr. Marty Hamilton for Statistical Support and Guidance on Test Design
- FDA and ECBC Staff
- EPA OPP Lab Staff
- EPA's ORD – Safe Buildings Program

# Crisis Exemptions for Products Intended to Inactivate *Bacillus anthracis*

***Presented at***

**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**

*Jeff Kempter, Senior Advisor*
*Office of Pesticide Programs*
*Environmental Protection Agency*
*February 23, 2005*

1

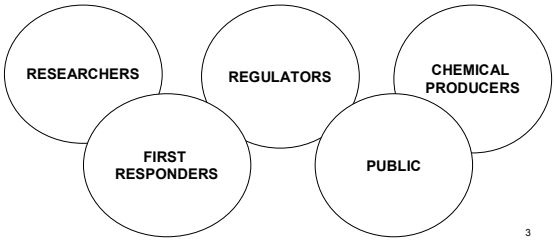
## OUTLINE

- Background to Crisis Exemptions
- Evaluating and Selecting Sporicides
- Issues That Demand Attention
- Are We There Yet?

2

## INTRODUCTION

- Evaluation, selection and use of chemicals to inactivate *B. anthracis* and other biological agents involves several groups:

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## BACKGROUND

- **In the U.S., decontamination chemicals are required to be registered or exempted by EPA prior to sale or distribution**
- **When anthrax attacks occurred in October, 2001, no products were approved specifically for use against *B. anthracis***
- **Accordingly, crisis exemptions had to be issued for each decon chemical at each contaminated site**

4

## CRISIS EXEMPTIONS

- **Of 63 requests for crisis exemptions, EPA approved 28 and rejected 35.**
- **Federal agencies and private companies could make requests**
- **Fumigation requests had to include**
  - **Remediation Action Plans**
  - **Sampling & Analysis Plans**
  - **Ambient Air Monitoring Plans**

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## EVALUATING AND SELECTING SPORICIDES FOR *B. anthracis*

- Safety Issues
- Efficacy Issues
- Liquids
- Gases/Vapors

6

## SAFETY ISSUES

- Containment of contaminated area
- Fumigant toxicity & human exposure
- Fumigant generation method
- Negative air systems
- Post-treatment aeration & scrubbing
- System backups/tests
- Ambient air monitoring

7

## EFFICACY ISSUES

- Gas containment
- Fumigate all at once or in sections
- Distribution of gas; absorbers of gas
- Reaching/holding efficacy parameters
- Monitoring of parameters
- Biological indicators
- Clearance sampling

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## LIQUID SPORICIDES*

- Aqueous chlorine dioxide
- Hydrogen peroxide/peracetic acid
- Sodium hypochlorite
- Hydrogen peroxide/quaternary ammonium foam**

*Hard, non-porous surfaces only

**Exemptions withdrawn for DF-100

9

## LIQUID SPORICIDES

| CHEMICAL | EFFECTIVE CONC. & CONTACT TIME | MATERIALS COMPATIBILITY | OTHER USES |
|---|---|---|---|
| Aqueous chlorine dioxide | 500 ppm X 30 min. | No known problems based on pesticide uses | EPA registered as a sanitizer and disinfection for many uses |
| Hydrogen peroxide and peroxyacetic acid | Contact times vary by product (15 to 60 min.) | No known problems based on pesticide uses | EPA registered as sanitizer, disinfectant, and sterilants for many uses |
| Bleach | 5,000-6,000 ppm X 60 min. (pH = 7) | Corrosive to stainless steel and other metals | EPA registered as a sanitizer and disinfectant for many uses |
| Hydrogen peroxide and quaternary ammonium | DF-100 ineffective after 1 hour; DF-200 is effective after 4 hours | Unknown | DF-200 successfully tested by DOD against virulent *B. anthracis* and a surrogate |

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## GASES/VAPORS

- Gaseous chlorine dioxide (buildings)
- Vaporized hydrogen peroxide (buildings)
- Paraformaldehyde (equipment in tented enclosures)
- Methyl bromide (lab/field studies)
- Ethylene oxide (off-site sterilization of items)

11

## GASES/VAPORS

| CHEMICAL | GENERATION METHOD | TOXICITY | EXPOSURE LIMITS |
|---|---|---|---|
| Formaldehyde Gas | On-site heating of paraformaldehyde prills (flakes) | Acutely toxic, animal carcinogen, genotoxin | 0.75 ppm PEL<br>2 ppm STEL<br>20 ppm IDLH |
| Chlorine Dioxide Gas | On-site reaction of precursor materials (sodium chlorite) | Acutely toxic, respiratory and eye irritant, no cancer data | 0.1 ppm PEL<br>0.3 ppm STEL<br>5.0 ppm IDLH |
| Hydrogen Peroxide Vapor | On-site vaporization of liquid hydrogen peroxide | Acutely toxic, respiratory irritant, no cancer data | 1.0 ppm PEL<br>No STEL<br>75 ppm IDLH |
| Methyl Bromide Gas | On-site vaporization of liquid methyl bromide from cylinder | Acutely toxic, neurological effects, insufficient cancer data | 4.0 ppm TLV<br>20 ppm PEL<br>250 ppm IDLH |
| Ethylene Oxide Gas | Release of gas into sterilization chamber | Acutely toxic, reproductive toxin, genotoxin, animal carcinogen | 1.0 ppm PEL<br>5 ppm 15 min. "Excursion"<br>800 ppm IDLH |

12

## GASES/VAPORS

| CHEMICAL | MATERIALS COMPATIBILITY | PENETRATION | SPORICIDAL USES |
|---|---|---|---|
| Formaldehyde Gas | Relatively unreactive | Medium | Biosafety cabinets, clean rooms, mail bags, mail equipment, buildings |
| Chlorine Dioxide Gas | May affect metals (Al, Cu, brass), computer parts, carpets and low grade paper at high CT values | Medium | Medical equipment, buildings |
| Hydrogen Peroxide Vapor | Relatively unreactive | Low | Clean rooms, medical equipment, buildings |
| Methyl Bromide Gas | May affect animal fur, leather, natural latex, and sulfur-containing articles | High | Experimental (efficacy studies on *B. anthracis* & spore strips) |
| Ethylene Oxide Gas | Relatively unreactive | High | Medical equipment, critical items |

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## DECONTAMATION REQUIRES EXTENSIVE COLLABORATION

- ✓ Interagency technical working group (TWG) directly supports Incident Commander
- ✓ Environmental clearance committee independently judges effectiveness of remediation
- ✓ National Response Team (NRT) Issued a Technical Assistance Document for *B. anthracis*

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## WHAT ISSUES DEMAND OUR ATTENTION?

- Regulatory
- Research
- Preparedness

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## REGULATORY ISSUES

- ❖EPA needs to establish efficacy test methods for *B. anthracis* spores
- ❖EPA's registration requirements need to be rigorous but reasonable
- ❖Need an answer to the question "How Clean is Safe?"

16

## INTERAGENCY EXPERT PANEL FOR EFFICACY TEST METHODS AND SURROGATES

- – EPA is conducting collaborative research with FDA, ECBC and AFRL on available test methods and surrogates
- – The Expert Panel is sharing draft test protocols for decon research across several federal agencies
- – The Expert Panel is providing knowledgeable input to EPA on many issues

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## COLLABORATIVE SPORICIDAL TESTING

- ❑ Collaborative testing of AOAC Sporicidal Test, QCT-1 and ECBC "three step" method (TSM)
  - – Phase 1: Compare performance of the quantitative methods to the AOAC method
  - – Phase 2: Selected quantitative method will be used to conduct surrogate studies
  - – Phase 3: Selected surrogates and quantitative method will be validated

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## SPORICIDE DATA AND LABELING REQUIREMENTS

- Test Data
  - Product Chemistry, Acute Toxicity--standard
  - Efficacy Data
    - AOAC Sporicidal Activity Test (B. subtilis & C. sporogenes)
    - Test against virulent agent or surrogate acceptable to EPA
    - Simulated use test for gases & vapors
- Labeling
  - EPA may classify these products for Restricted Use Only or somehow limit sale/use to trained personnel
  - Label must bear safety precautions and complete use directions (i.e., technical manual)
  - Products that pass efficacy tests are called "sterilants" and may list specific microorganisms tested

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## "HOW CLEAN IS SAFE?"

**The National Research Council of the National Academies of Science is conducting a study due out this Spring that will address:**

- **Anthrax spores and maybe plague, smallpox**
- **Infectious dose**
- **Risk assessment methods**
- **Natural vs. residual exposure**
- **Past cleanup efforts**
- **Enclosed and semi-enclosed facilities**

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## RESEARCH ISSUES

- ✓ **Improved and harmonized efficacy test methods**
- ✓ **Materials compatibility**
- ✓ **Parameters for optimal fumigant effectiveness**
- ✓ **Real-time monitoring methods**

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## RESEARCH ISSUES (cont'd.)

- ✓ **Scrubbing/removal technology**
- ✓ **Field-testing and test bed(s)**
- ✓ **Develop effective decon methods for outdoor or semi-open sites**
- ✓ **Coordinate research across agencies**

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## PREPAREDNESS ISSUES

- ❑ **Develop faster, safer, more cost-effective decon methods**
- ❑ **Have equipment and resources available and on stand-by**
- ❑ **Provide more guidance private industry on preparedness planning for bio-terrorism**
- ❑ **Increase interagency coordination, sharing & leveraging**

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## ARE WE THERE YET?

- **YES:**
  - **Certain decon methods are safe and effective for use on structures & objects**
  - **Some personnel and equipment can likely be initially mobilized quickly in emergencies**
  - **Crisis exemptions can be issued quickly for known decon methods**
- **NO:**
  - **Decon methods are still expensive and slow**
  - **Equipment and trained personnel are very limited**
  - **Many areas need research**
  - **Research and regulation need to be coordinated**
  - **Preparedness plans are needed for critical sites**

24

## Sampling & Clearance

Lessons Learned

Mark Durno, U.S. EPA
Tony Intrepido, U.S. Army CHPPM

February 23, 2005

## Discussion Topics

- Introductions
- Sampling Basics
  - U.S. Capitol, USPS, Boca Building
- Sampling Issues
  - TAD Workshop Findings
  - Verification Needs
    - Sampling Efficacy
    - Sampling / Spore Strip Approach
    - Aggressive Air Sampling (Large Building)

## *Anthrax Technical Assistance Document*

- National Response Team
  - National Coordination Council
- Chapter 6 lays out sampling approach for any biological contamination event.
- www.nrt.org
  - Click on "NRT publications"
  - Scroll until you find it

## *Pre Remediation Sampling*

- Considerations
- Objectives
- Approach
- Methods
- Analytical
- Transportation
- Coordination
- Interpretation

## *Sampling Considerations*

- Goal
  - Risk, characterize, extent, support, verify
- Data objectives
  - Develop your hypothesis
- No current standards
  - Lessons learned
- Plan development

## *Sampling Objectives*

- Develop in consultation with professionals:
  - Medical
  - Environmental
  - Public health
  - Industrial hygiene
  - Laboratory
  - Building experts
  - Local, state, federal agencies

## *Sampling Objectives*

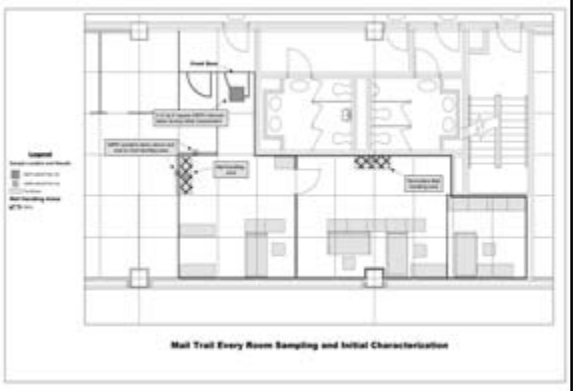
- Real-time monitoring
- Screening
- Bulk material
- Questionable article
- Extent of contamination
- Effectiveness of decontamination
- Clearance for re-occupancy
- Transitional
- Crime scene / forensic

## *Sampling Approach*

- Logical and systematic
- Scheduled
- Risk-based
- Targeted
- Statistical

## *Targeted Sampling Approach*

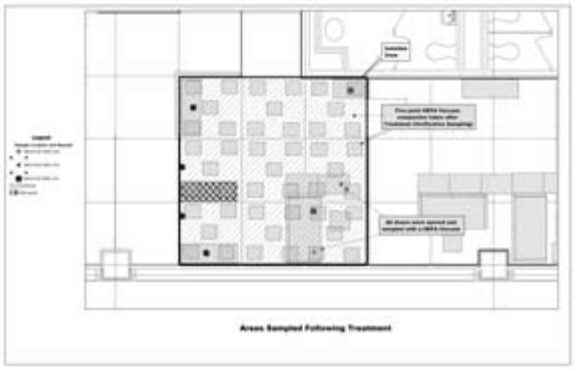
- Known sources
- Logical tracking
  - Air movement
  - Cross contamination
- Work toward or away from source





## *Statistical Sampling Approach*

- Need
  - Source not identified
  - Highly dispersed
- Considerations
  - Maximize the probability of a positive result
  - Assurance that a negative means absence
- Currently, no conclusive approach
  - Lab and sampling inefficiencies



## Detection / Sampling Breakout Session

NRT Civilian / Military Anthrax Workshop

Washington D.C.

April 14, 2004

## Open Discussion

- Subjects:
  - (1) General issues related to NRT / TAD.
  - (2) Hazard Identification
  - (3) Field Detection
  - (4) Sampling Guidance / Efficacy
  - (5) Analytical Capabilities
  - (6) Post Decon

## Hazard Identification

- Threat Assessment
  - Evaluate credibility of event
  - Determine hazard and physical characteristics of questionable substances.
  - If Biological contamination cannot be conclusively "ruled-out", and the situation is considered credible, confirmation sampling should be conducted.
    - For public health response – use culture plate.

## Field Detection

- What's out there and widely used?
  - Hand-held assays.
  - Infrared / Hazmat ID (rule-out).
  - Haz-tech system w/microscope & camera.
  - Rapid PCR.
- Technologies are "acceptable science" but need validated for field applications:
  - Some studies planned

## Sampling Guidance / Efficacy

- References available:
  - NRT TAD*
  - CDC sampling guidance for anthrax*
  - CDC BioWatch technical guidelines (sensitive)
  - OSHA e-tool for anthrax response
  - OSHA DFU and HEPA sampling methods
  - GSA guidelines for anthrax response
  - www.bt.cdc.gov

## Sampling Guidance / Efficacy

- Studies:
  - NIOSH: Sampling effectiveness (Sanderson)
  - NIOSH: Validation for air sampling method
  - USPS: Bert-Price statistical study
  - NCID: USPS DCBS 17 re-aerosolization (Dull)
  - Weis/Intrepido: Daschle re-aerosolization.
  - Canadian / DOJ ??

## Sampling Guidance / Efficacy

- Needs:
  - Further studies of sampling efficacy to answer the question: What is the detection limit of accepted sampling methods?
    - Dugway Proving Grounds (surface / air efficacy)
    - NIOSH / Sandia (surface efficacy)
    - RDECOM (Leahy letter)
    - CDC (Arduino – swab sampling)

## Analytical Capabilities

- LRN / DOD could become overwhelmed with multiple large scale events (limited reagents).
- CDC is attempting to standardize analytical methods through the LRN for environmental samples (wipe / sock being worked on currently).
- DOD is attempting to "harmonize" environmental analytical methods with LRN.
- Using non-LRN, non-DOD labs (ag labs, private labs) may raise consistency issues if used on a response.

## Post Decon / Verification

- Verification sampling has been exhaustive on past responses.
- The "ECC" concept is the best approach to insure adequate protection of public health through highly qualified professional debate.

## NRT / TAD Needs

- Better guidance for First Responders.
- Develop a matrix for acceptable sampling type in given situations.
- Encourage the use of Occupation Health Professionals at the local level.
- National Academy of Sciences: "How Clean is clean" study.
- Update links to all recent specific guidance and studies.
- Crossing the nomenclature barrier (ASM standards)

## NRT / TAD Needs

- Chapter 6:
  - Update to include more specifics in certain sections:
    - Use of statistical analysis
    - Sampling methods (add / remove)
    - Emphasis on total discipline coordination
    - More efficient verification approach

National Homeland Security Research Center Decontamination Workshop 23-25 February 2005

# The Use of the Trace Atmospheric Gas Analyzer (TAGA) to Qualitatively and Quantitatively Monitor Ambient Air For Chemical Warfare Agents and Decontamination Agents in Real Time at Parts Per Trillion by Volume Levels or Below

David B. Mickunas, US EPA/ERT

## ACKNOWLEDGEMENTS

Nancy H. Adams, Ph.D.
Safe Buildings Program Director
National Homeland Security Research Center

Mr. Eric N. Koglin
Contracting Officer Representative
National Homeland Security Research Center

Raj Mangaraj
Donald Kenny
Anne Gregg
Battelle Memorial Institute

## AMBIENT AIR MOBILE MONITORING FOR CHEMICAL WARFARE AGENTS

## TASKS

1. **Develop Spectra and Calibration Curves for the CWAs**
2. **Develop Chemical Ionization Capabilities to Maximize Sensitivity for the CWAs**
3. **Determine and Verify Detection and Quantitation Limits for Each CWA**
4. **Determine Dynamic Linear Range for CWAs**
5. **Establish Surrogate Relative Response Factors**
6. **Determine if Other Materials Interfere with CWA Response**
7. **Establish/Demonstrate Sample Air Flow Operating System and Conditions to Ensure that No Less Than 85% of Material at the CWAs Quantitation Limit**

**Task 1. Develop Spectra and Calibration Curves for the CWAs**

- All experiments performed with the Perkin Elmer-SCIEX (PE-SCIEX) API-365.
- The CWAs to be used are GA, GB, GD, GF, VX, HD, HN-1, HN-2, and HN-3.

**Task 2. Develop Chemical Ionization Capabilities to Maximize Sensitivity for the CWAs**

- The proton affinity of the G- and V-series CWAs are sufficiently higher than that of water to allow proton transfer from the $H_3O^+$ and $H_3O(H_2O)_n^+$ reagent ions generated in the APCI source of the API-365. Therefore, ambient air APCI conditions in the positive ion mode will be used for ionization of all G- and V-series of agents for this study.
- The protonated water and associated water clusters under ambient air APCI conditions are not efficient for the ionization of sulfur mustard (HD). The sensitivity for HD is enhanced by the addition of a small amount (approx 0.03%) of benzene to the APCI inlet.

**Task 3. Determine and Verify Detection and Quantitation Limits for Each CWA**

•The detection limit for each agent will be determined as three times the standard deviation of the ion pair's signal in the background (either room air or room air spiked with blank hexane) divided by the ion pair's response factor.

•The quantitation limit for a compound will be determined as ten times the standard deviation of the ion pair's signal in the background divided by the ion pair's response factor.

•In order to verify the accuracy of the gas phase agent concentrations, the concentration of the standard solutions used to generate the agents in the gas phase will be verified via a gas chromatographic method.

**Task 4. Determine Dynamic Linear Range for CWAs**

•The dynamic range of calibration for each agent will be determined by observing the signals obtained from the detection limit to the ion current at which the signal is no longer linear (i.e., saturation of the reagent ions).

•The dynamic range will be explored by varying the solution concentration and/or the rate of introduction via the syringe drive during the generation of calibration curves.

**Task 5. Establish Surrogate Relative Response Factors**

•Spectra and calibration curves for the surrogate compounds will be obtained using the same procedures described above.

•Both native diisopropyl methyl phosphonate (DIMP) and deuterated diisopropyl methylphosphonate ($d_{14}$-DIMP) will be used as surrogates for all of the G- and V-series agents.

•Chloroethylethylsulfide (CEES, halfmustard) will be used as the surrogate for the mustard agents.

•The relative response factors will be established by comparison of the response of the surrogate compound(s) to the response of the chemical warfare agents.

**Task 6. Determine if Other Materials Interfere with CWA Response**

•Evaluate the effect of two potential interferences (vehicle exhaust and bleach) at two interferent concentrations to be determined during testing.

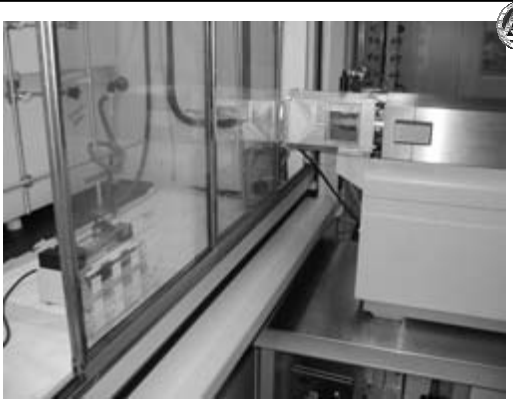
•Room temperature and humidity will not be controlled beyond the normal operation of the HVAC system.

•Interferent test concentrations will be obtained by diluting a concentrated feed with air. Depending on the interferent, the concentrated feed will be provided by one of two methods.

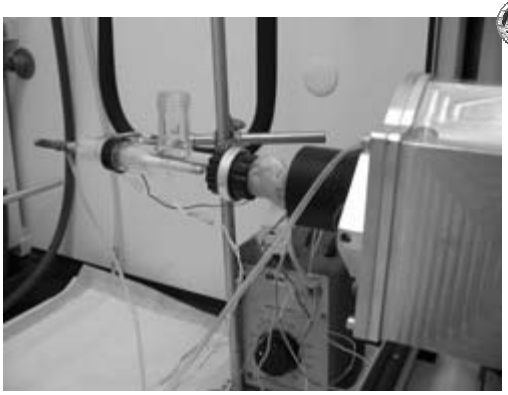
•This procedure will test two agent concentrations at two interferent concentrations. A false positive test will also be performed in the same manner without the introduction of the CWA.

**Task 7. Establish/Demonstrate Sample Air Flow Operating System and Conditions to Ensure that No Less Than 85% of Material at the CWAs Quantitation Limit Passes Through the System**

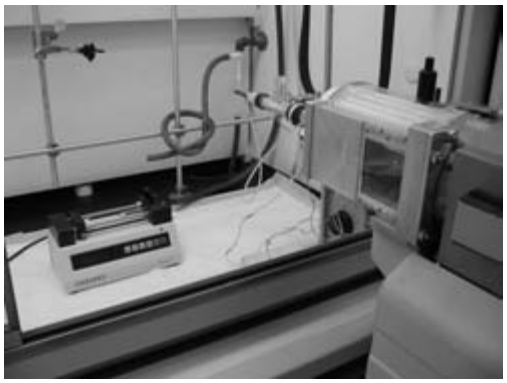
•A double-walled glass tube will extend out of the hood and into the ion source of the API-365. This tube is approximately three feet in length. In order to demonstrate an 85% transmission of the CWAs through the sampling line, initially a three-foot section will be used to obtain the baseline transmission and then add an additional three foot length to the sampling line (within the hood). The agents will be vaporized into the glass tubing as in previous tests at a known concentration and the percent transmission through the three- versus six-foot sampling lines will be compared.



**Experimental Chamber**



**Vaporizer Unit**

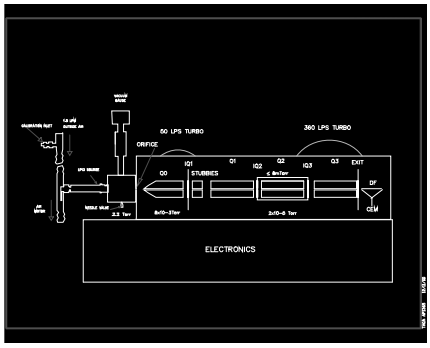


**Calibration Unit**

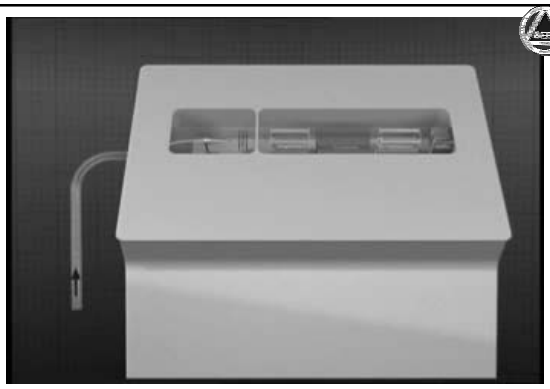
**Trace Atmospheric Gas Analyzer Mobile Laboratory**

**Trace Atmospheric Gas Analyzer (TAGA)**

**Atmospheric Pressure Chemical Ionization (APCI) Source**




**TAGA Schematics**



**TAGA Operational Process**

## Chemical Agents Investigated

**GA – Ethyl *N*-dimethylphosphoramidocyanidate**

**GB – Isopropyl methylphosphonofluoridate**

**GD – Pinacolyl methylphosphonofluoridate**

**GF – Cyclohexyl methylphosphonofluoridate**

**VX – *O*-Ethyl-S-[2-(diisopropylamino)ethyl] methyl phosphonothioate**

**HD – 2,2′-Di(chloroethyl)sulfide**

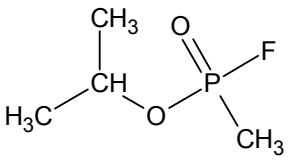
**HN1 - N-Ethyl-2,2′-di(chloroethyl)amine**

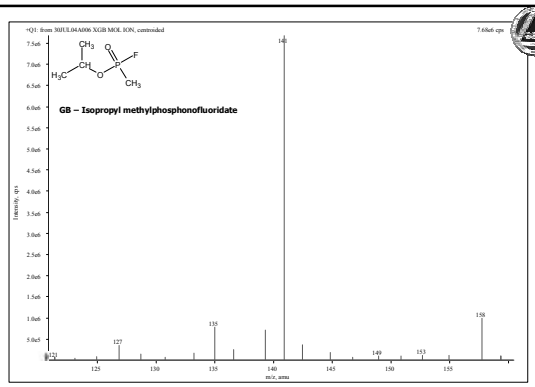
**HN2 - N-Methyl-2,2′-di(chloroethyl)amine**

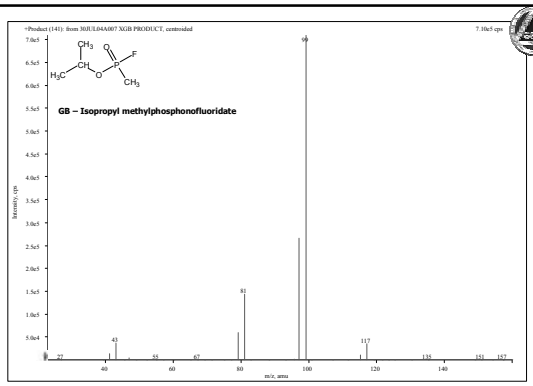
**HN3 – 2,2′,2′′-Tri(chloroethyl)amine**

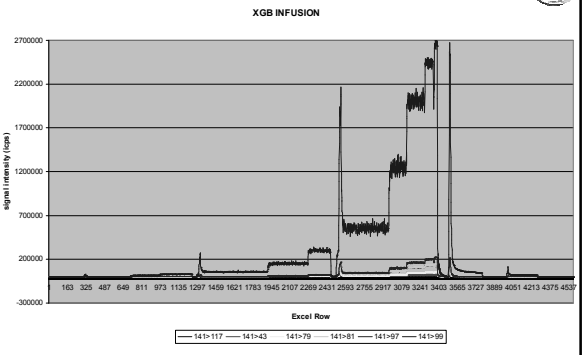
## GB – Isopropyl methylphosphonofluoridate

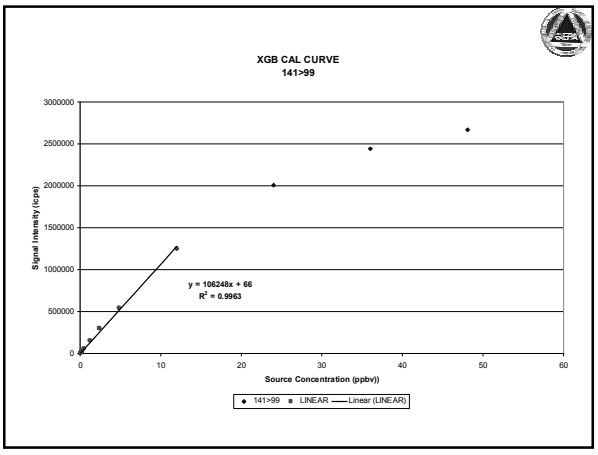
Molecular Weight – 140
Parent Ion – 141
Daughter Ions – 117, 99, 97, 81, 79, 43



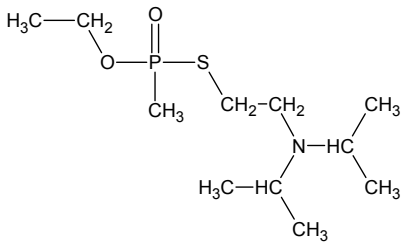



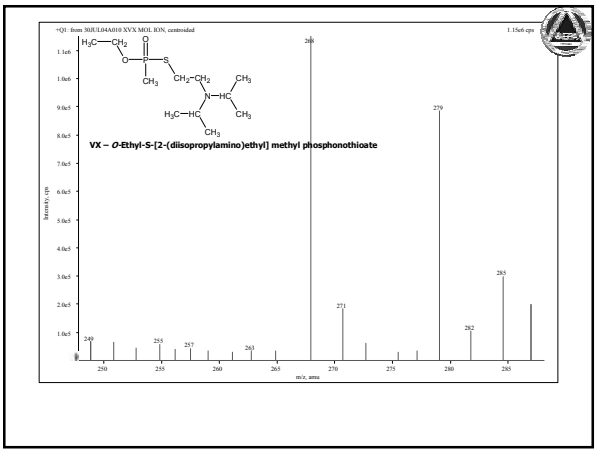



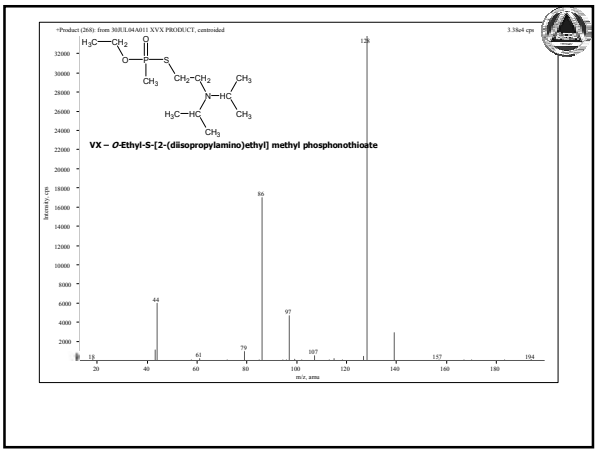


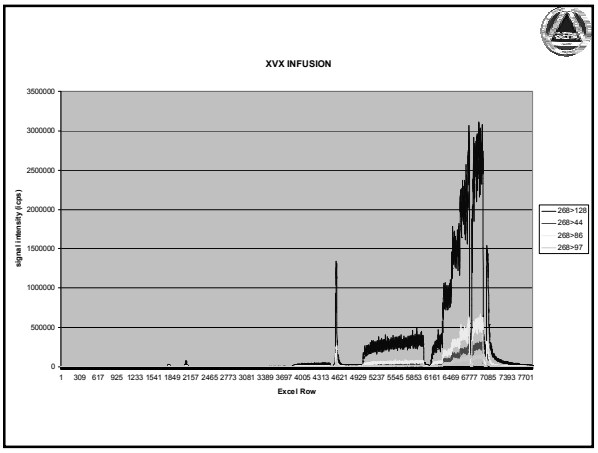

## VX – *O*-Ethyl-S-[2-(diisopropylamino)ethyl] methyl phosphonothioate

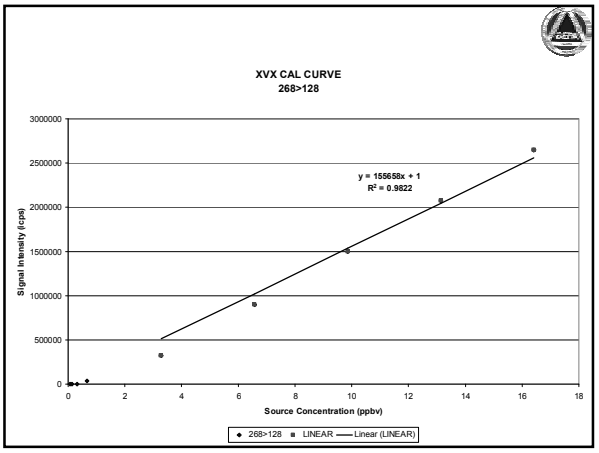
Molecular Weight – 267
Parent Ion – 268
Daughter Ions – 128, 97, 86, 44





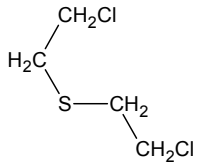



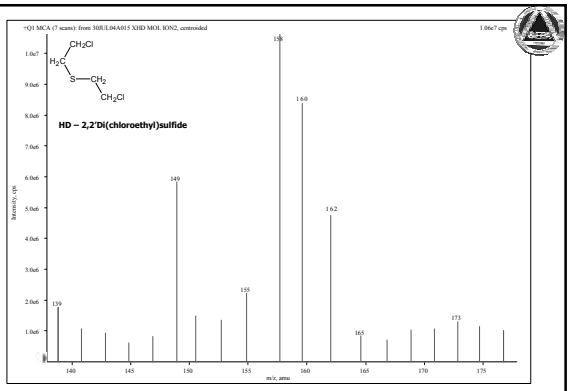



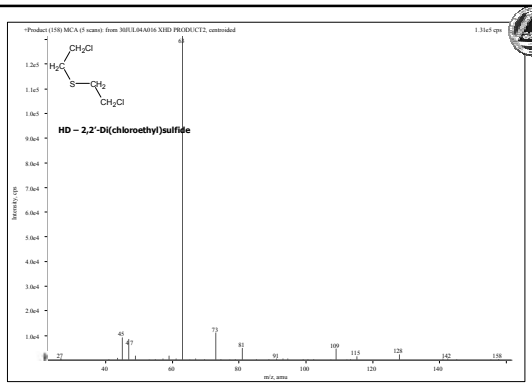



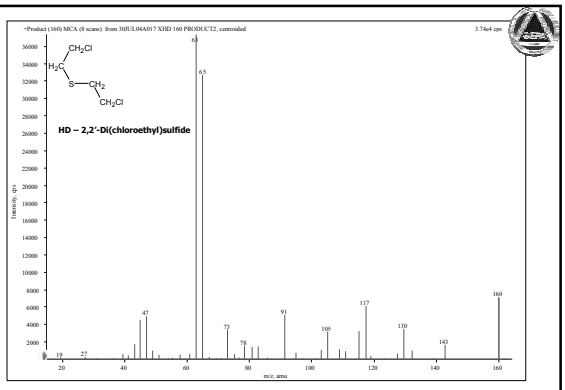
## HD – 2,2′-Di(chloroethyl)sulfide

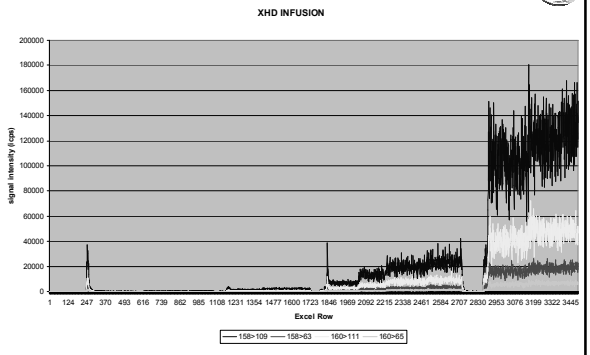
Molecular Weight – 158
Parent Ion – 158
Daughter Ions – 63, 109

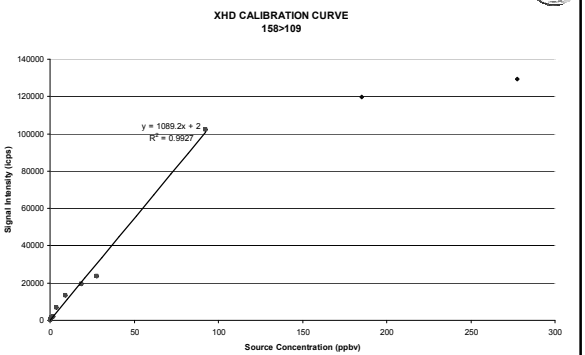


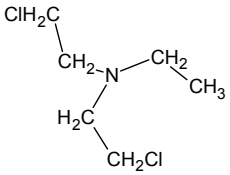



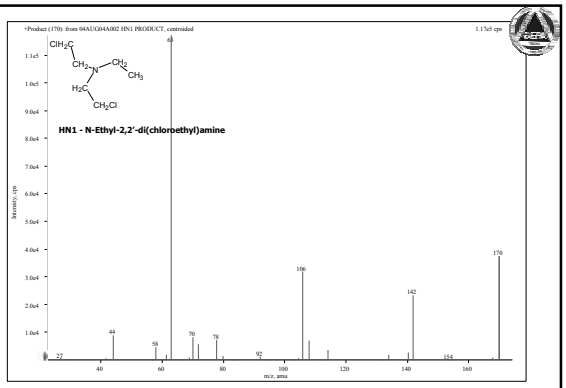



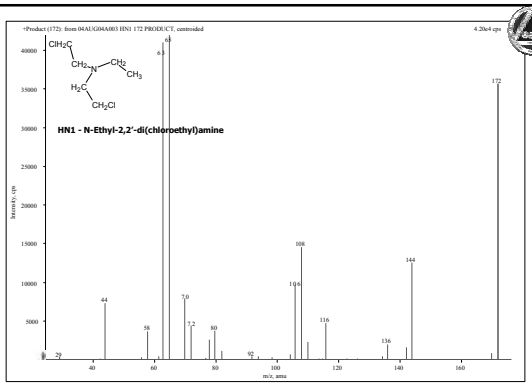



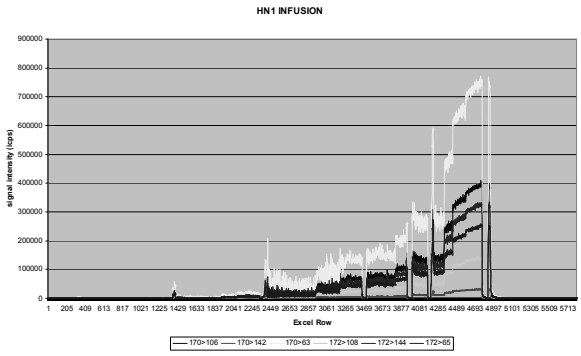
## NH1 - N-Ethyl-2,2'-di(chloroethyl)amine

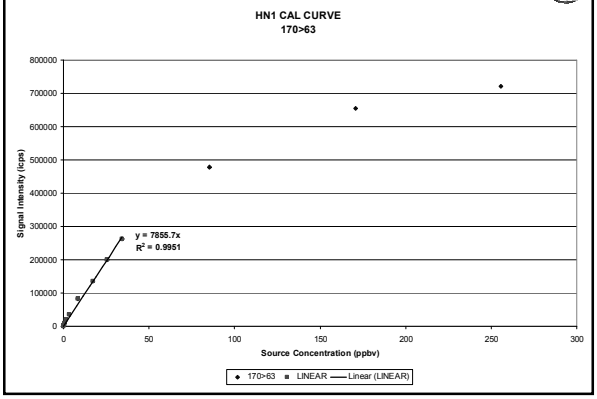
Molecular Weight – 169
Parent Ion – 170
Daughter Ions – 63, 106, 142



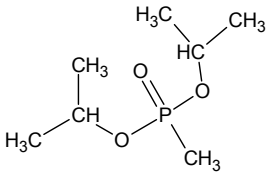



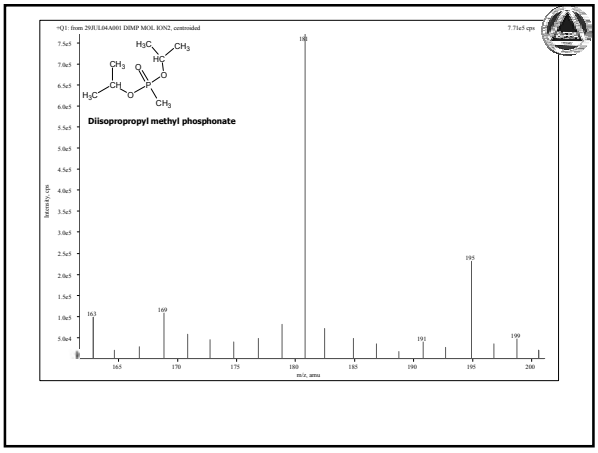



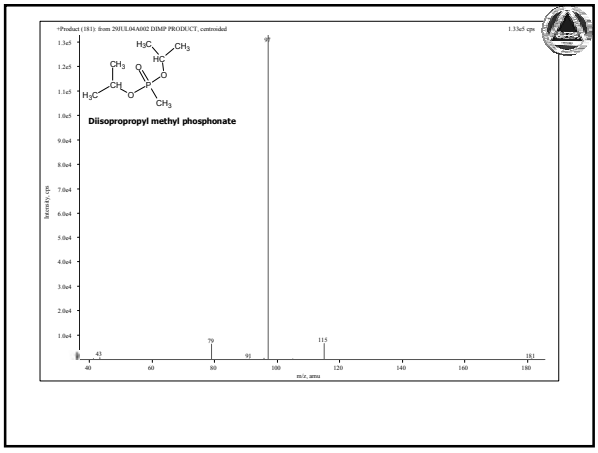



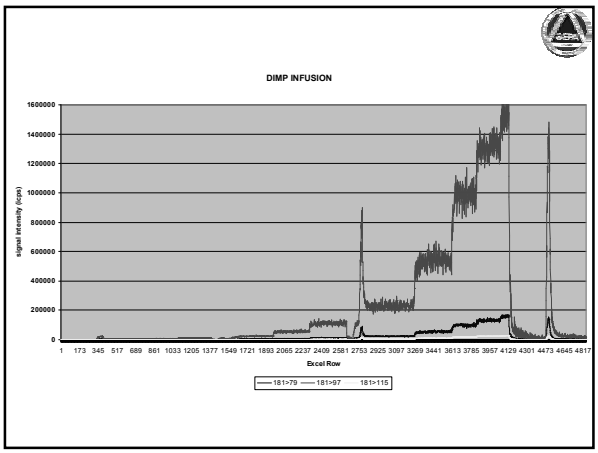

## Diisopropropyl methyl phosphonate

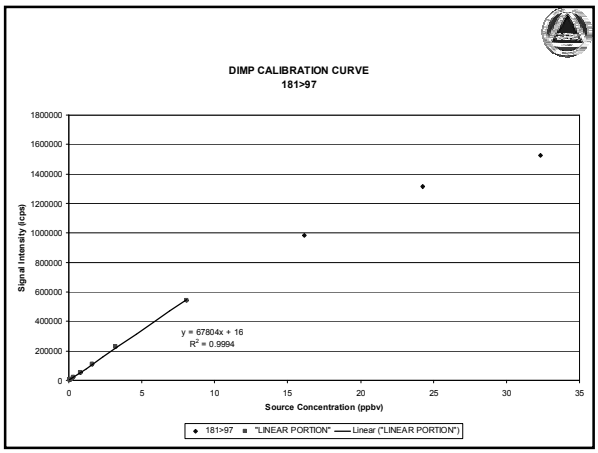
Molecular Weight – 180
Parent Ion – 181
Daughter Ions – 79, 97, 115





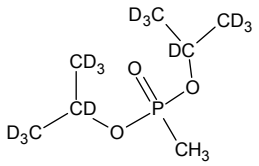



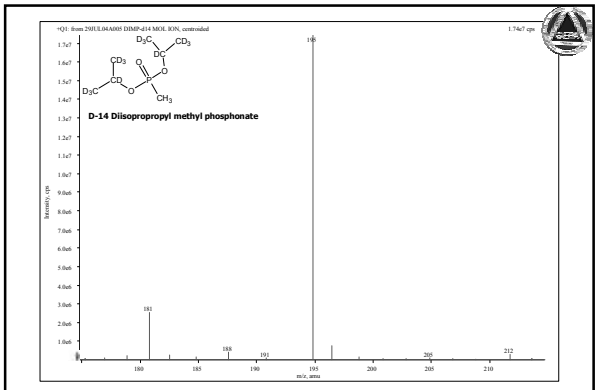



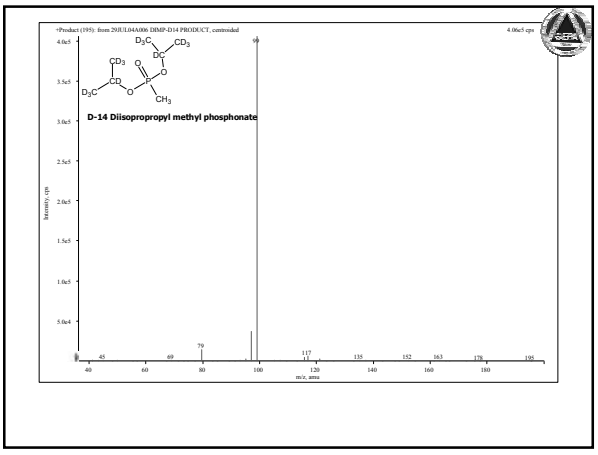



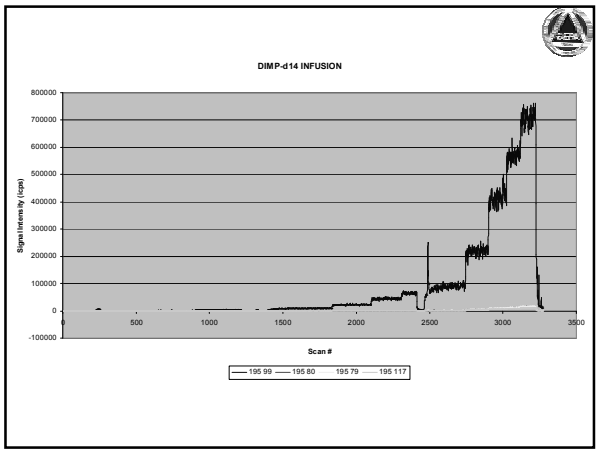

## D-14 Diisopropropyl methyl phosphonate

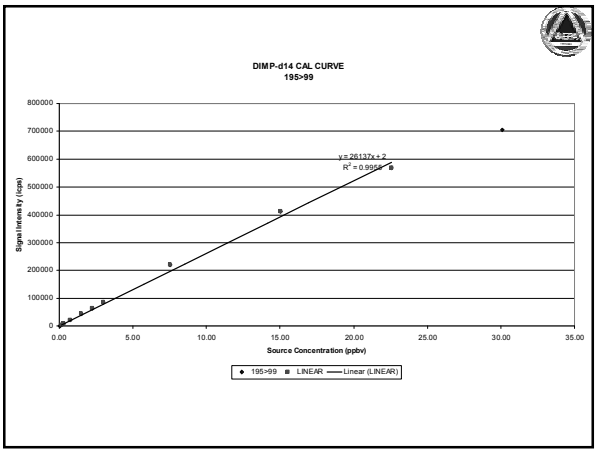
Molecular Weight – 194
Parent Ion – 195
Daughter Ions – 79, 80, 99, 117





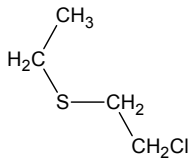


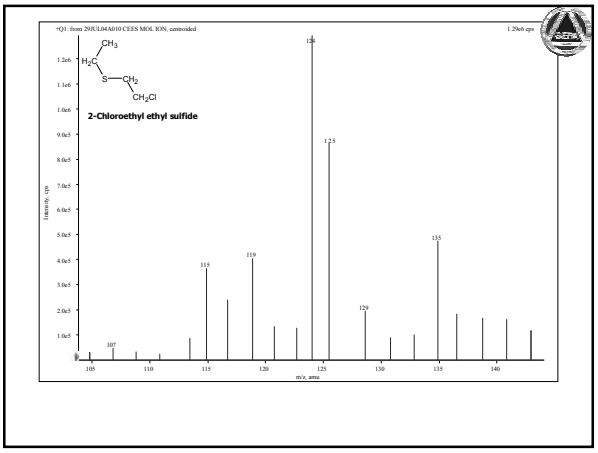



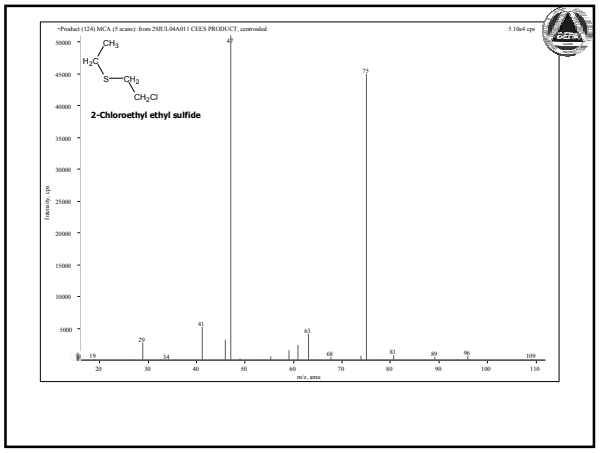



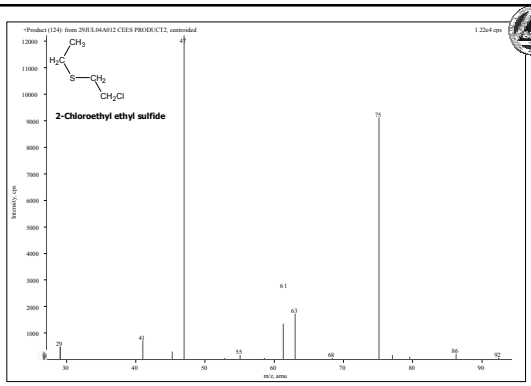

## CEES - 2-Chloroethyl ethyl sulfide

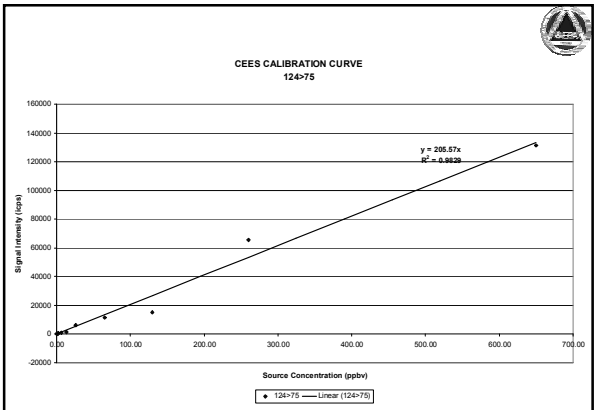
Molecular Weight – 124
Parent Ion – 124
Daughter Ions – 47, 75








| Acronym | Percutaneous Vapor Toxcity (pptv) | Immediately Dangerous to Life and Health (pptv) | Molecular Weight | Specific Gravity @ 25 °C | Vapor Density | Boiling Point (°C) | Melting Point (°C) | Vapor Pressure mm Hg @ 25 °C | Volatility @ 25 °C (pptv) | TWSA Method Detection Limit (pptv) |
|---|---|---|---|---|---|---|---|---|---|---|
| GA | 407500 | 15093 | 162.3 | 1.073 | 5.63 | 246 | -49 | 0.07 | 9.21E+07 | 0.52 |
| GB | 261964 | 17464 | 140.1 | 1.0087 | 4.86 | 147 | -56 | 2.9 | 3.82E+09 | 0.85 |
| GD | 50378 | 6717 | 182.18 | 1.022 | 6.33 | 167 | -80 | 0.4 | 5.26E+08 | 14.19 |
| GF | 50938 | 6792 | 180.14 | 1.133[a] | 9.2 | ----- | -12 | 0.068 | 8.94E+07 | 0.36 |
| VX | 27472 | 916 | 267.36 | 1.0083 | 6.2 | 300 | -20 | 0.007 | 9.21E+05 | 0.07 |
| HN1* | n.a. | 289349 | 170.08 | 1.09 | 5.9 | 85 | -34 | 0.25 | 3.29E+08 | 0.44 |
| HN2* | n.a. | 315484 | 156.07 | 1.15 | 5.4 | 75 | -60 | 0.427 | 5.62E+08 | 0.31 |
| HN3* | n.a. | 240887 | 204.54 | 1.24 | 6.9 | 138 | -4 | 0.0109 | 1.43E+07 | 0.97 |
| DIMP | n.a. | n.a. | 180.21 | 0.976 | n.a. | 121.05[b] | n.a. | 0.28 | 3.64E+08 | 0.83 |
| d-14 - DIMP | n.a. | n.a. | n.a. | n.a. | n.a. | n.a. | n.a. | n.a. | n.a. | 0.76 |
| HD | n.a. | 309494 | 159.08 | 1.27 | 5.4 | 228 | 14.4 | 0.112 | 1.47E+08 | 17.04 |
| CEES | n.a. | n.a. | 124.63 | 1.0663[a] | 4.27 | 156 | n.a. | 3.4 | 3.25E+06 | 126 |

* = Based on HD values
n.a. = Not Available
nd = Not Determined
[a] temp=20 °C
[b] 10 mm Hg

| Acronym | Primary Ion Transition | Method Detection Limit (pptv) | Method Quantitation Limit (ppvt) | Limits of Linearity (ppbv) | Analyte Response Factor (icps/pptv) | Surrogate | Surrogate Response Factor (icps/pptv) | Relative Response Factor |
|---|---|---|---|---|---|---|---|---|
| GA | 163>117 | 0.52 | 1.72 | 20.76 | 145 | DIMP | 68 | 0.47 |
| GB | 141>97 | 0.85 | 2.82 | 12.01 | 106 | DIMP | 68 | 0.64 |
| GD | 183>43 | 14.19 | 47.31 | 27.28 | 8 | DIMP | 68 | 8.50 |
| GF | 181>97 | 0.36 | 1.2 | 19.5 | 94 | DIMP | 68 | 0.72 |
| VX | 268>86 | 0.07 | 0.23 | nd | 156 | DIMP | 68 | 0.44 |
| HN1 | 170>106 | 0.44 | 1.48 | 34.1 | 8 | DIMP | 68 | 8.50 |
| HN2 | 158>65 | 0.31 | 1.04 | 9.77 | 14 | DIMP | 68 | 4.86 |
| HN3 | 204>63 | 0.97 | 3.24 | 7.13 | 24 | DIMP | 68 | 2.83 |
| DIMP | 181>79 | 0.83 | 2.78 | 8.1 | 68 | DIMP | 68 | 1.00 |
| $d_{14}$ - DIMP | 195>79 | 0.76 | 2.53 | 22.5 | 26.1 | DIMP | 68 | 2.61 |
| HD | 158>109 | 17.04 | 56.81 | 92.54 | 1 | CEES | 0.2 | 0.20 |
| CEES | 124>75 | 126 | 419 | nd | 0.2 | CEES | 0.2 | 1.00 |

| Acronym | Percutaneous Vapor Toxcity (pptv) | Immediately Dangerous to Life and Health (pptv) | Less than Acute Exposure Guideline Limit (pptv) | | | | | Method Detection Limit (pptv) | Method Quantitation Limit (ppvt) | Limits of Linearity (ppbv) |
|---|---|---|---|---|---|---|---|---|---|---|
| | | | 10 Minute | 30 Minute | 60 Minute | 240 Minute | 480 Minute | | | |
| GA | 407500 | 15093 | 1041 | 604 | 423 | 211 | 151 | 0.52 | 1.72 | 20.76 |
| GB | 261964 | 17464 | 1205 | 699 | 489 | 245 | 175 | 0.85 | 2.82 | 12.01 |
| GD | 50378 | 6717 | 470 | 269 | 188 | 94 | 67 | 14.19 | 47.31 | 27.28 |
| GF | 50938 | 6792 | 475 | 272 | 190 | 95 | 68 | 0.36 | 1.2 | 19.5 |
| VX | 27472 | 916 | 52 | 30 | 16 | 9 | 7 | 0.07 | 0.23 | nd |
| HN1* | n.a. | 289349 | 57870 | 18808 | 9693 | 2459 | 1201 | 0.44 | 1.48 | 34.1 |
| HN2* | n.a. | 315484 | 63097 | 20506 | 10569 | 2682 | 1309 | 0.31 | 1.04 | 9.77 |
| HN3* | n.a. | 240887 | 48177 | 15658 | 8070 | 2048 | 1000 | 0.97 | 3.24 | 7.13 |
| DIMP | n.a. | n.a. | n.a. | n.a. | n.a. | n.a. | n.a. | 0.83 | 2.78 | 8.1 |
| d-14 - DIMP | n.a. | n.a. | n.a. | n.a. | n.a. | n.a. | n.a. | 0.76 | 2.53 | 22.5 |
| HD | n.a. | 309494 | 61899 | 20117 | 10368 | 2631 | 1284 | 17.04 | 56.81 | 92.54 |
| CEES | n.a. | n.a. | n.a. | n.a. | n.a. | n.a. | n.a. | 126 | 419 | nd |

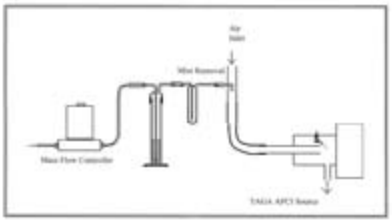
*** = Used HD Values**
**n.a. = Not Available**

# AMBIENT AIR MOBILE MONITORING FOR DECONTAMINATION AGENTS

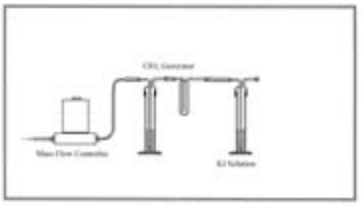
# TARGET COMPOUNDS

**Chlorine Dioxide**
**Chlorine**

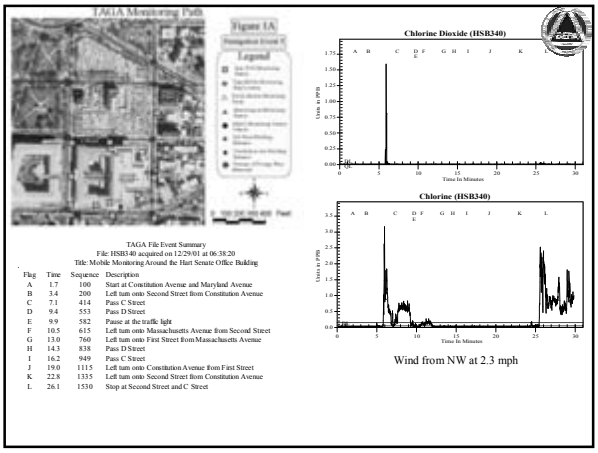
| Compounds | Parent/Daughter Masses |
|---|---|
| Chlorine Dioxide | 67/51 |
| Chlorine Dioxide | 69/53 |
| Chlorine | 70/35 |
| Chlorine | 72/37 |
| Chlorine | 72/35 |



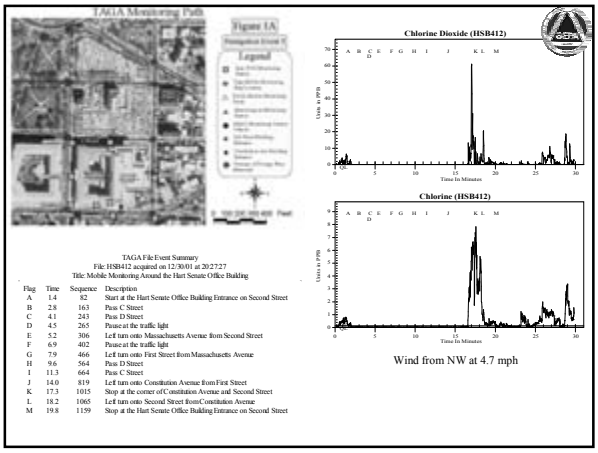
**Chlorine Dioxide Generator for TAGA Calibration**



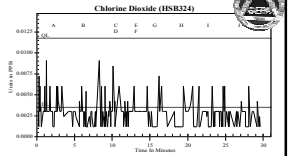
**Configuration for Calibration of Chlorine Dioxide Generation**

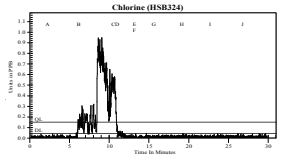



Wind from NW at 2.3 mph




Wind from NW at 4.7 mph

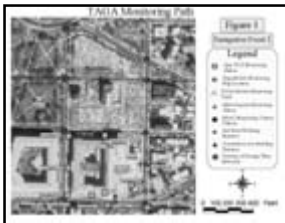


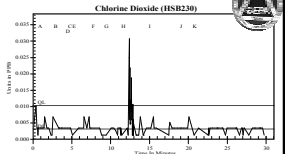



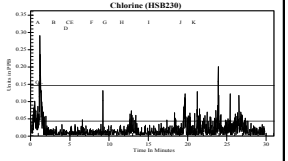

TAGA File Event Summary
File: HSB324 acquired on 12/28/01 at 22:01:58
Title: Mobile Monitoring Around the Hart Senate Office Building

| Flag | Time | Sequence | Description |
|---|---|---|---|
| A | 1.9 | 114 | Start at the Veterans of Foreign Wars Building Flagpole |
| B | 5.9 | 347 | Pass C Street |
| C | 10.3 | 601 | Pass D Street |
| D | 10.7 | 630 | Left turn onto Massachusetts Avenue from Second Street |
| E | 12.9 | 758 | Pause at the traffic light |
| F | 13.4 | 783 | Left turn onto First Street from Massachusetts Avenue |
| G | 15.3 | 899 | Pass D Street |
| H | 18.9 | 1106 | Pass C Street |
| I | 22.5 | 1320 | Left turn onto Constitution Avenue from First Street |
| J | 26.7 | 1562 | Left turn onto Second Street from Constitution Avenue |

Wind from S at 2.7mph






TAGA File Event Summary
File: HSB230 acquired on 12/16/01 at 21:22:06
Title: Mobile Monitoring Around the Hart Senate Office Building

| Flag | Time | Sequence | Description |
|---|---|---|---|
| A | 0.7 | 39 | Start at Hart Senate Office Building Entrance on Second Street |
| B | 2.7 | 158 | Pass C Street |
| C | 4.5 | 264 | Pass D Street |
| D | 4.8 | 279 | Pause at the traffic light |
| E | 5.1 | 297 | Left turn onto Massachusetts Avenue from Second Street |
| F | 7.6 | 443 | Left turn onto First Street from Massachusetts Avenue |
| G | 9.2 | 539 | Pass D Street |
| H | 11.4 | 667 | Pass C Street |
| I | 14.9 | 873 | Left turn onto Constitution Avenue from First Street |
| J | 18.9 | 1110 | Left turn onto Second Street from Constitution Avenue |
| K | 20.5 | 1203 | Stop at the Hart Senate Office Building Entrance on Second Street |

Wind from E at 4.4 mph

For additional information concerning the capabilities and applications of the TAGA, call or e-mail me at 732 906 6913 or Mickunas.Dave@epa.gov.

# INSURANCE
# AND
# INDEMNITY ISSUES

*Presented by Gerald J. Robinson*

## Insurance and Indemnity Issues

**Overview**

- **Postal Service Anthrax experience**
- **Indemnity language adopted and insurance purchased**
- **Problems with approach used**
- **Starting point for resolution**

## Insurance and Indemnity Issues

**Postal Service Anthrax Experience**

- **October 2001 – Brentwood and Trenton contaminated by letter mail filled with anthrax**
- **Need to decontaminate facilities to remove hazard and return facilities to service**
- **Contractors fumigate with chlorine dioxide gas**

## Insurance and Indemnity Issues

- **Contractors refuse to provide service without protection from risks inherent in decontamination service**
- **Risks**
  - **Harm to workers**
  - **Harm to community**
  - **Damage to facility**
  - **Possibility that process fails to work**
  - **Regulatory Risks**

## Insurance and Indemnity Issues

- **Solution to extraordinary risk problem**
- **Postal Service indemnifies contractors and assumes risks**
- **Postal Service purchases insurance to mitigate risk assumed**

## Insurance and Indemnity Issues

- **Broad indemnity granted**
- **Postal Service indemnified contractors for all claims caused by, arising out of, or in any way related to the decontamination project**

## Insurance and Indemnity Issues

- Exceptions
  - Claims caused by actions unrelated to the decontamination project
  - Claims caused by a violation of law unrelated to the project
  - Claims caused by willful misconduct or gross negligence

## Insurance and Indemnity Issues

- Project Insurance Purchased
  - General Liability Insurance
  - Environmental Liability
  - Professional Errors and Omissions Liability
  - Aggregate Limit of $100 million

## Insurance and Indemnity Issues

- Problems with this approach
  - Cost
  - Many Agencies may lack authority to indemnify
  - Time involved negotiating indemnification and obtaining insurance
  - Doesn't provide a standby solution

## Insurance and Indemnity Issues

- **Suggested approach**
- **Contractors obtain SAFETY act designation and certification for their technologies**

## Insurance and Indemnity Issues

- Support anti-terrorism by Fostering Effective Technologies Act of 2002 (commonly called the SAFETY Act)
- Creates a system of Litigation Management and Risk Management for qualified anti-terrorism technologies

## Insurance and Indemnity Issues

Litigation Management

- No punitive damages
- Non-economic damages only available when plaintiff suffers physical damage
- Actions only in federal court and only against sellers
- Government contractor defense (no liability)

## Insurance and Indemnity Issues

**Risk Management**

- **Liability is limited to the extent of liability limits of insurance policy**
- **Insurance must be purchased**

## Insurance and Indemnity Issues

- **Decontamination technologies are within the class of technologies covered by the SAFETY act**

## Insurance and Indemnity Issues

- Technologies that "would be effective in facilitating the defense against acts of terrorism, including technologies that prevent, defeat or respond to such acts" Section 863, (b) (7)
  - Decontamination services responds to a terrorist act by removing the possibility of further infection or harm to the public
  - Also, services may be anti-terrorism technologies – Section 865 (1)

## Insurance and Indemnity Issues

**How SAFETY Act Helps**

- Agencies that cannot indemnify contractors may use decontamination service
- Contractors have no liability or liability limited to the extent of insurance purchased
- Contractors immediately available to perform decontamination service

## Insurance and Indemnity Issues

**SAFETY Act Problems**

- Contractor may be unwilling to spend money to obtain insurance before event and contract
- Contractor must spend money and time to obtain SAFETY Act certification and designation
- SAFETY Act benefits may not be enforced

# Introduction to the Government Decontamination Service

**Robert Bettley-Smith, FRICS**
**GDS Project Director**

Department for Environment, Food and Rural Affairs (Defra)

## The Context

- Uncertainty surrounding global security
- Cross-Government effort to ensure UK is prepared for a range of emergencies
- CBRN Resilience Programme led by Home Office

## 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 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

## GDS Concept (1)

- Responsible authorities already obliged to prepare for CBRN events, including clean up
- Decontamination is a specialist area
- Expertise available in private sector
- Government recognises a central brigading of expertise would be more efficient than RAs each carrying out the same work

## GDS Concept (2)

- GDS will determine which companies could successfully decontaminate buildings and the open environment, and
- Make sure that responsible authorities can call on their services when necessary

## GDS Functions

- **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

**GDS Services – advice & guidance**

- Strategic National Guidance
- *Ad hoc* advice
- Case studies
- Participation in exercises

**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

**GDS will not …**

- **Assume** responsibility for decontamination
- **Fund** decontamination
- **Deal with** humans, animals or their remains

**GDS Administrative matters**

- Creation in summer 2005
- A Defra agency, but a *Government* service
- At a site in the Midlands
- About 20 staff
- Chief Executive being recruited

gds@defra.gsi.gov.uk

## *Laboratory Capacity Issues*

DECON-WORKSHOP

Rob Rothman
February 23, 2005

## *Homeland Security Presidential Directives*

**Federal agencies be prepared to respond to chemical, biological, and radiological (CBR) attacks.**

## *TICs vs. CBR Agents*
### *CAPABILITY/CAPACITY ISSUES*

- **Validated sample methods for priority agents**
- **Expertise related to CWAs**
- **Laboratory capacity to process potential sample demand**

## *Standardized Analytical Methods (SAM) Rev 1 September 2004*

**GOAL: To assure consistant/proficient sample analyses when called upon to respond to a national emergency:**

- **Identifies ~109 Priority agents**
- **Identifies specific methods for analysis in four environmental media:**
  - * **gas**
  - * **solid**
  - * **oily solid**
  - * **aqueous**

## *SAM Rev 2*

- **Update methods**
- **Add CWA degradation products**
- **Methods for drinking water**
- **Add 4 radionuclides:**
  - * **Strontium 90**
  - * **Cesium**
  - * **Iridium**
  - * **Cobalt 60**

## *Chemical Warfare Agents*

- **Nerve (sarin), Blister (lewisite), Blood (cyanogans), choking (phosgene)**
- **Chemical Weapons Convention**
- **Chemical Surety**
  - **Army Regulations 50-6**
  - **Personnel Reliability Program (PRP)**
  - **Dilute Agents vs. Neat**

## CWA DILUTE LIMITS

| AGENT | MAXIMUM QUANTITY | MAXIMUM CONCENTRATION |
|---|---|---|
| GA,GB GD,GF | 2O mg | 2.0 mg/ml |
| VX | 10 mg | 1.0 mg/ml |
| H,HD | 100 mg | 10 mg/ml |
| L, HL | 50 mg | 5.0 mg/ml |

## CWA Methods

**Joint Method(US/Finland**
- **Nerve, Blister, and Degradation**
- **All environmental media**

**OPCW Methods**

**VERIFIN Blue Books**

**Wiley Encyclopedia of Analytical Chemistry**

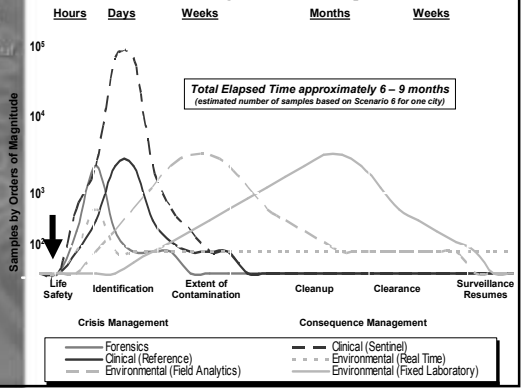
## Neat Labs

- **Alion Science and Technology**
  **Chicago, IL**
- **Calspan_UB Research Center**
  **Buffalo, NY**
- **Geomet Technologies**
  **Gaithersburg, MD**
- **Southwest Research Institute**
  **San Antonio, TX**
- **Battelle**
  **Columbus, OH**
- **Midwest Research Institute**
  **Kansas City, MO**
- **Edgewood Chemical and Biological Center (ECBC)**
  **Aberdeen Proving Grounds, MD**

## Dilute Labs

- **Argonne National Lab**
  **Argonne, IL**
- **QuickSilver Analytics, Inc.**
  **Abingdon, MD**
- **O.I. Analytical**
  **Pelham, AL**
- **Oak Ridge National Lab**
  **Oak Ridge, TN**
- **Lawrence Livermore National Lab**
  **Livermore, CA**

## Anatomy of Response

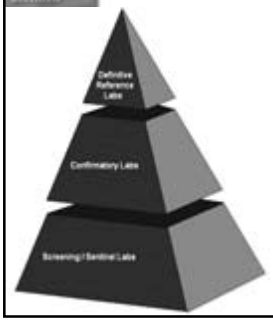



## Environmental Laboratory Response Network (eLRN)

**EPA, WITH CDC, DEVELOPED A JOINT PROPOSAL TO EXPAND THE LRN TO ADDRESS ENVIRONMENTAL SAMPLE LAB CAPACITY/RESPONSE ISSUES**

- **CDCs ROLE WILL REMAIN FOCUSED ON CLINICAL SAMPLES, WHILE EPA WILL ESTABLISH AN ENVIRONMENTAL SAMPLE COMPONENT**
- **EPA WILL MODEL THE ENVIRONMENTAL NETWORK COMPONENT AFTER THE EXISTING CDC CLINICAL LAB NETWORK**

## LRN: Roles and Responsibilities




**Definitive Reference Labs**
- **-Role:** Network Support & Attribution
- **-Responsibilities:**
  1) Definitive identification, 2) Methods development & sampling guidance, 3) QA and sampling procedures

**Confirmatory Labs**
- **-Role:** Confirmatory Analysis
- **-Responsibilities:**
  1) Coordination with sentinels & first responders, 2) Method validation

**Screening/Sentinel Labs**
- **-Role:** Screening & Surge Analysis
- **-Responsibilities:** Routine monitoring to identify potential incidents

## eLRN


## Optimal Characteristics

- **"All-Hazards**
- **Threat based, focused on specific agents and locations**
- **Rapid sentinel screening**
- **High confidence in methods and staff**
  - **"Gold Standard" confirmatory methods**
  - **Ongoing training and audits**
- **Sufficient surge capacity to address alerts and response**
- **Add "real-time" technology when supported by research**

## Near-Term EPA Reference Labs Activities

- **EPA ORD Labs in Las Vegas and Cincinnati**
  - *** Las Vegas focus on Chemical**
  - *** Cincinnati focus on Biological**
- **SAM- ID analytical methods for priority agents of concern**
  - *** Identify validated preferred methods for analysis – all environmental media**
- **Develop CWA Capacity**
  - *** Establish validated methods for primary agents and degradation products**
- **Expand Cincinnati lab BSL-3 capability**
- **Develop QA/PT Program for eLRN**
- **Implement a National TRIAGE Program**

## THANK YOU


- Rob Rothman
- Rothman.rob@epa.gov
- 513-569-7187

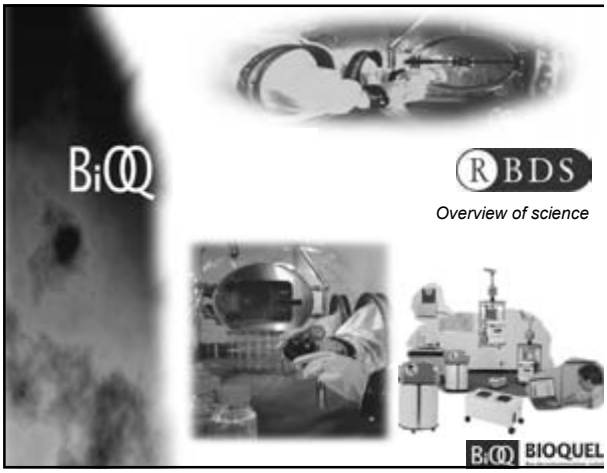
BIOQUELL
Bio-decontamination solutions

**Hydrogen peroxide vapor ("HPV")**
**for room / building decontamination**
**following chemical or biological agent attack**

**Overview of efficacy and practical issues**

**Mike Herd**
Vice President
BIOQUELL Inc.

February 2005




## Hydrogen peroxide vapour - an overview

**Gas**

$2H_2O_{2(g)}$ —*Catalytic conversion*→ $2H_2O$ + $O_2$

Hydrogen peroxide vapour — Excellent biocide

Water + Oxygen — "residue-free"

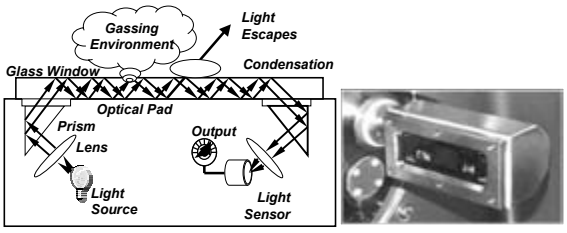
**RBDS – Room Bio-Decontamination Service**

- using hydrogen peroxide vapor technology, BIOQUELL provide an "infinitely scalable" room / building bio-decon service
- Tyvek pouched 6log *Geobacillus stearothermophilus* spores used as biological indicators to verify bio-decontamination

⇨ ***Applications in the healthcare, bio-defence, pharmaceutical and environmental sectors***

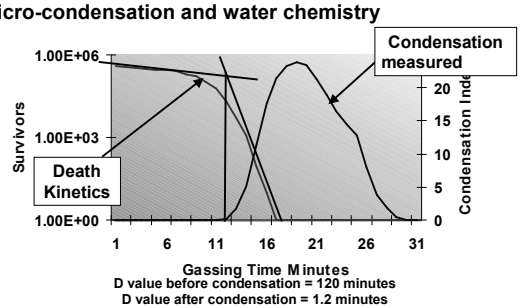
## Condensation monitor

**How it works:**




⇨ ***Use of optics to detect onset of micro-condensation***

## Micro-condensation and water chemistry




⇨ ***Micro-condensation critical for fast kill - D values go from 2 hours (pre dewpoint) to <2 minutes (post dewpoint)***

⇨ ***NB micro-condensation - often not visible; condensate layer < 1 micron***

## BIOQUELL's dewpoint model

**Detailed analysis of the physical chemistry**

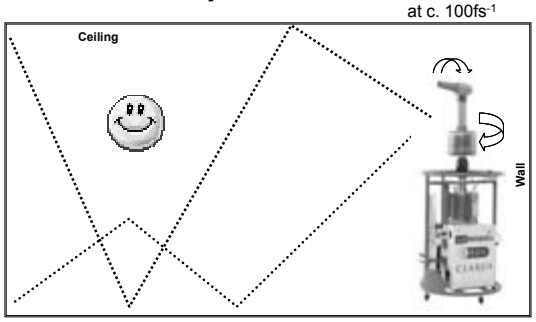
- results published in the PDA Journal of Science & Technology (November 2002)
- won the 2002 Fredrick D. Simon Award for best paper published in the PDA journal

| Inputs | | Outputs |
|---|---|---|
| ▪ volume of room<br>▪ adjustment for equipment (eg: chairs)<br>▪ starting temperature<br>▪ starting RH<br>▪ concentration of peroxide liquid<br>▪ airflow rates | Model | ▪ point micro-condensation starts<br>▪ gas concentration trend line<br>▪ relative humidity trend line<br>▪ max. gas rate injection<br>▪ mass of condensate<br>▪ cycle parameter prediction |

⇨ ***Good correlation between theoretical (model) and practical (experimental) results***

## Gas distribution is key

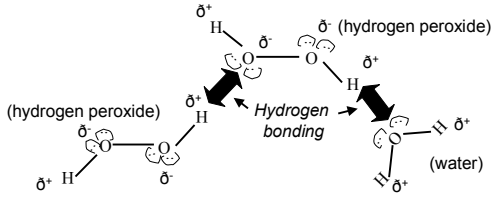
Vapour exits generator at c. 100fs$^{-1}$




Gas effectively "bounces" off hard surfaces in room ensuring good gas distribution – and hence good kill, even in challenge sites

BIOQUELL

## Hydrogen bonding – between $H_2O_2$ and $H_2O$

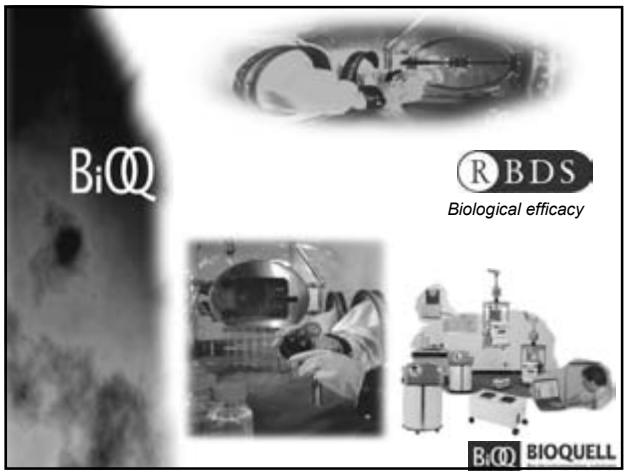



⇨ ***Strong hydrogen bonding between molecules***

⇨ ***Hence high kinetic energy is needed to disperse the gas...***

⇨ ***...but this can help practically, making BIOQUELL's technolo safe with (eg) rooms with a common false ceiling***

BIO




## Material Compatibility

Industrial-grade carpet (IC)

Bare wood (pine lumber) (BWD)

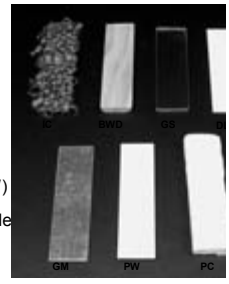
Glass (GS)

Decorative laminate (DL)

Galvanized metal ductwork (GM)

Painted (latex, flat) wallboard paper (PW)

Painted (latex, semi-gloss) concrete cinde block (PC).




BIO

## Anthrax bio-deactivation work with US EPA / ETV

| | | |
|---|---|---|
| Non-porous | Glass | 7.92 log kill (complete bio-deactivation) |
| | Decorative laminate | 7.85 log kill (complete bio-deactivation) |
| | Painted wallboard | 6.92 log kill (complete bio-deactivation) |
| | Galvanised metal ductwork | 7.54 log kill (complete bio-deactivation) |
| Porous | Painted concrete | 6.36 log kill |
| | Bare wood | 3.70 log kill |
| | Carpet | 3.01 log kill |

⇨ ***Note short cycle: 20 minutes gassing; 20 minutes dwell (plus issues with limits of detection)***

⇨ ***Bacillus anthracis Ames bio-deactivation data – report available on EPA website (ETV program)***

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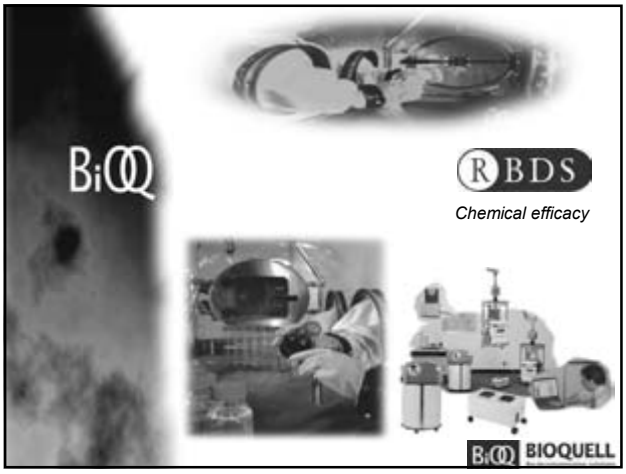
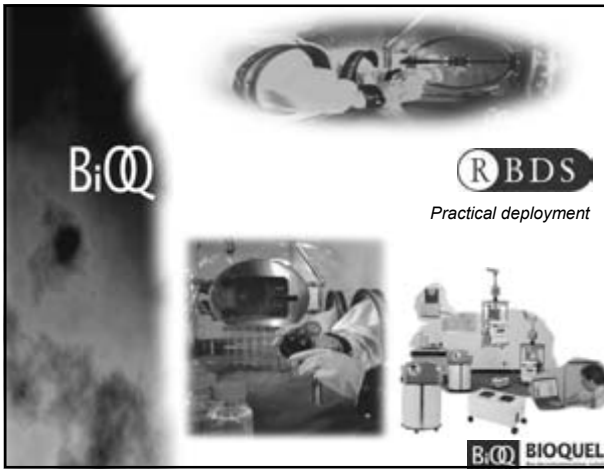
## Further efficacy data

| | | |
|---|---|---|
| Bacterial endospores | | *C. difficile** |
| | | *G. stearothermophilus* |
| | | *B. subtilis* |
| | | *B. Anthracis* |
| Vegetative bacteria | G+ve | MRSA* |
| | | VRE* |
| | G–ve Ent. | *Klebsiella** |
| | | *Serratia** |
| | G–ve Non-f. | *Acinetobacter** |
| | | *Pseudomonas** |

* typical nosocor pathogens found hospitals

BIO




**Case study: Acinetobacter in Hôpital Henri-Mondor**

- MDR-Acinetobacter in adult ICU
- crisis situation (following outbreak in Northern France)
- total of 7 mortalities (3 patients colonized when BIOQUELL arrived)
- 5-bed ICU comprising a 800m$^3$ (2,625ft$^3$) suite of rooms
- extensive bio-burden present before RBDS (including Acinetobacter) – and none after RBDS

BIOQUELL

**Case study: Acinetobacter in Hôpital Henri-Mondor**

- adjacent ward and public areas monitored for HPV – no leakage
- no further patient acquisition following RBDS
- RBDS has been re-deployed twice by the same hospital to combat a similar problem in other ICUs
- hospital intends to publish their experience and associated data

BIOQUEL

**Case study: MRSA at Lewisham Hospital, London**

- 10 patients were infected / colonised with MRSA - it appeared cross transmission had occurred
- 20-bed surgical ward, “Nightingale” design
- 35.7% of 28 surfaces and 27.7% of 18 air samples were found to be contaminated with MRSA
- ward emptied and cleaned manually for 4 days using bleach
- re-sampled and MRSA recovered from 16% of 65 surfaces

BIOQUELL

**Case study: MRSA at Lewisham Hospital, London**

- BIOQUELL asked to bio-decontaminate the ward using RBDS
- adjacent ward and public areas monitored for HPV – no leakage
- RBDS completed in 12 hours
- ward available for re-occupation immediately after RBDS
- no new acquisition of MRSA following RBDS

BIOQUEL

### Case study: Serratia - Royal Hallamshire, Sheffield

**Serratia is a problematic nosocomial pathogen, which can persist in the environment during outbreaks (Sarvikivi, 2004, ICHE)**

**BIOQUELL was contacted by a special care baby unit with an outbreak of Serratia (marcescens)**

- cleaning had failed to remove the organism from the environment
- infection acquisition was continuing (including mortality)

BIOQUELL

### Case study: Serratia - Royal Hallamshire, Sheffield

- BIOQUELL's RBDS technology was deployed
- Serratia and S. aureus cultured before RBDS and no environmental contamination detected after RBDS
- infection acquisition ceased – the 'acid test' of a successful bio-decontamination

BIO

### Solution: Clarus R


- weight: 20kg (44lbs)
- 500m$^3$ (Euro) / 250m$^3$ (US) bio-decontamination volume (17,700 / 9,000 cubic ft capability)
- high kinetic energy of vapour (exit velocity 100fs$^{-1}$)
- 2 axis vapour distribution system
- own $H_2O_2$ container
- infinitely scalable ("daisy chain" together)
- easily fits in back of vehicle
- easy to transport upstairs...
- ...and into awkward places
- self-sanitising

BIOQUELL

### Solution: Clarus R2

- weight of top: 8kg (18lbs)
- weight of filter / catalytic converter: 2( (44lbs)
- dual use re. bio-agent and chem age building remediation - effectively an N filter
- filter disposable – can be bagged rea incineration
- airflow: 450m$^3$/h (16,000ft$^3$/hr)
- top self-sanitising

⇨ ***Rapid catalytic conversion***

⇨ ***HEPA filtration will filter out any remaining bacteria – activated ca will filter chemical agents***

BIO

### Instrumentation module

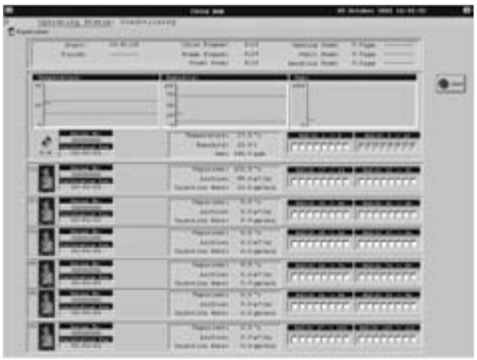
**Measures:**

- temperature
- gas concentration
- relative humidity

⇨ ***Monitor key environmental conditions in room which effect when dewpoint reached***

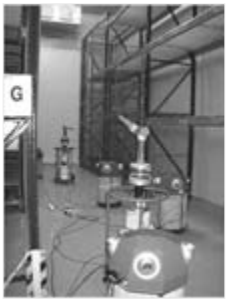
BIOQUELL

### Software controls



BIO

## "Scalable"



⇨ ***Clarus R and R2 units networked together***

## RBDS – material compatibility

**Excellent material compatibility results – eg:**

- computers
- electronics
- furniture

**RBDS site survey designed to identify potential problems, including for example:**

- soft, absorbent materials which will absorb hydrogen peroxide vapour – and typically desorb (out-gas) slowly

**BIOQUELL able to give detailed responses on material compatibility and/or carry out a trial on specific materials at BIOQUELL's facilities**

⇨ ***BIOQUELL has bio-decontaminated >10 hospital intensive care units (ICU) with no adverse effects – hence "real world" comfort of excellent material compatibility***

## Other practical issues encountered

**HVAC**

- largest problem area by far
- HVAC drawings almost always wrong / lost
- HVAC zones often problematic but BIOQUELL has developed a range of techniques
- HVAC can be dirty / have high levels of organic matter

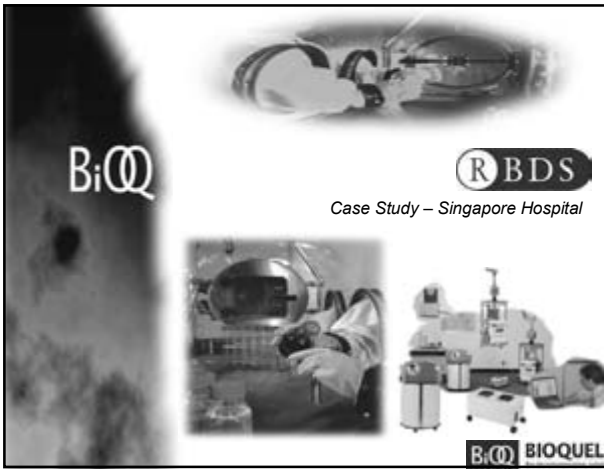
**Clients**

- tend to create further issues

**Lesser issues (all manageable but watch out for them)**

- alarm systems
- absorption of soft materials – hence longer gassing cycles
- availability of power

⇨ ***Do not underestimate the advantages of experience – BIOQUELL has bio-decontaminated >1,000 rooms / buildings***




## Singapore hospital – SARS case study

**3 Hospitals**

- 8 partially occupied wards
- 88 rooms – total volume 6,700m$^3$

**Client's requirements**

The SARS epidemic in Singapore was worsening; 87% of new infections were hospital acquired

Rapid, residue-free, bio-decontamination was sought - with no holes to be drilled in the facilities, no patients to be disturbed or placed at risk

A large volume of equipment (including delicate ICU Equipment) needed bio-decontamination

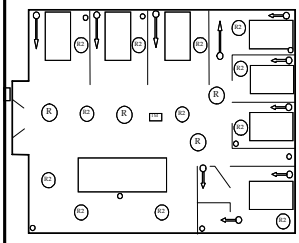
⇨ ***Urgent requirement to deploy equipment in Singapore. And fast.***

## The RBDS

**Results**

**Using RBDS, BIOQUELL was able to safely bio-decontaminate the required 88 rooms in 16 days, remaining flexible and sensitive to patients needs throughout**

**An example: East Shore Hospital ICU**



⇨ ***Ability to deploy around hospital staff / patients was critical***

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**Singapore ICU RBDS 4 hours from vacation to occupation**

BIOQUELL

**RBDS – Hospital Equipment Compatibility**

**Gambro Dialysis Machines**

**Siemens Servo 300C Ventilator**

**Tyco Puritan Bennett 800 Ventilator**

**Siemens Servo 900C Ventilator**

**Dinamap NIBP**

**Philips Defibrillators**

**Siemens Patient Monitor Systems**

⇨ ***Excellent material compatibility characteristics of BIOQUELL's technology***

BIOQUELL


BIOQUELL
Bio-decontamination solutions

**Hydrogen peroxide vapor ("HPV") for room / building decontamination following chemical or biological agent attack**

**Overview of efficacy and practical issues**

**Mike Herd**
Vice President
BIOQUELL Inc.

February 2005

## Whole-Structure Decontamination of Bacterial Spores by Methyl Bromide Fumigation

**Rudolf H. Scheffrahn**

UNIVERSITY OF FLORIDA IFAS

**Mark J. Weinberg**

HAMMERHEAD TERMITE CONTROL



**What is needed for *B. anthracis* spore cleanup?**

- Rapid decontamination
- No sensitive equip. damage
- Portability
- Cost effectiveness
- Safety

UF

**Structural remediation alternatives:**

- Foam/liquid disinfection
- HEPA vacuum/vaccine
- Fumigation

UF

**Methyl Bromide**

$(CH_3Br)$

METH-O-GAS® Q
COMMODITY FUMIGANT
FOR QUARANTINE/REGULATORY USE ONLY
SUPERVISION BY REGULATORY AGENT REQUIRED
ACTIVE INGREDIENTS: Methyl bromide.....100%
This product weighs 14.4 pounds per gallon.
DANGER • PELIGRO • POISON
KEEP OUT OF REACH OF CHILDREN

- Registered food/structural fumigant
- Stable up to 500°F
- Packaged in cylinders
- Non-corrosive alkylating agent
- TLV = 5 ppm
- Analysis by simple detection equip.
- Deep diffusion of porous materials
- Part of existing fumigation industry
- No volume or humidity limitations

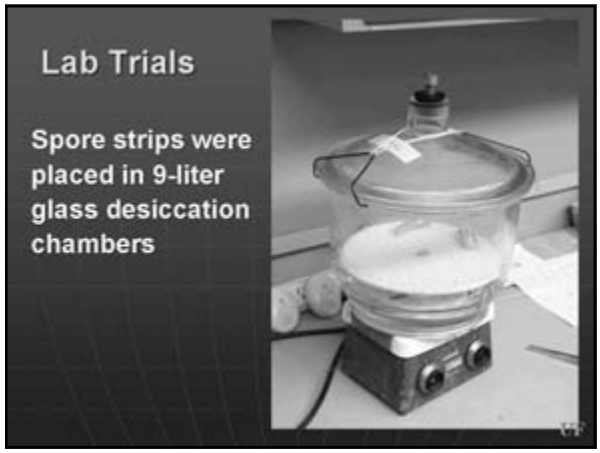
**Label: Meth-O-Gas® Commodity Fumigant-Great Lakes Chemical Co.**
**EPA Registration No. 5785-41**

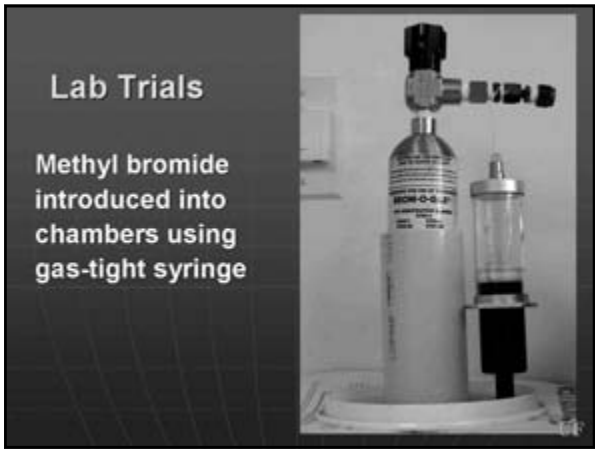
TABLE III METH-O-GAS Q
APPLICATION SUMMARY FOR STRUCTURES OR VEHICLES ASSOCIATED WITH RAW OR PROCESSED COMMODITIES(1)

| TREATMENT SITE | PESTS | RATE (lb/1000 ft3) | EXPOSURE TIME (hrs) |
|---|---|---|---|
| Warehouse, Shipboard, Railroad Car, Truck, Air and Sea Containers, Grain Elevator, Poultry Houses, Food Processing Plant, Restaurants, Feed Room, Grain Bin | cockroaches, confused flour beetle, rice weevil, granary weevil, saw toothed grain beetle, rusty grain beetle, lesser grain borer, cadelle, khapra beetle, drugstore beetle, larder beetle, carpet beetle, copra beetle, coffee bean weevil, etc. | **1 - 9** | **10 - 72** |
| | rats, mice and brown tree snakes (*Boiga irregularis*) | 0.2 - 0.4 | 8 - 16 |
| | fungi and some bacteria (e.g., *Solmonella* spp.) | 3 - 4 | 24 - 36 |

(1)At temperatures below 60°F, increase the dosage by 1/2 lb per 1,000 cu. ft. for every 10°F drop in temperature or use an approved procedure to heat the fumigant. No additional fumigant is required for rats and mice. Do not fumigate fungi and some bacteria when inside temperatures are less than 70°F.

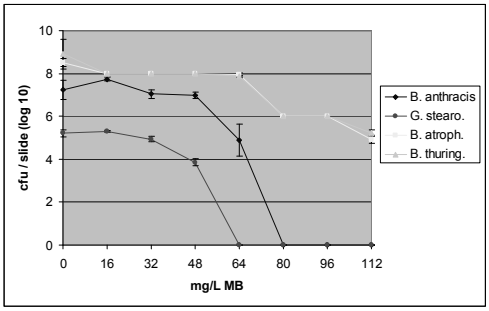
UF




## Spore count vs. methyl bromide conc. at 37°C for 48-hour fumigation




UF

CFU/slide *B. anthracis* spores after 48-hour exposure to methyl bromide at 0 or 80 mg/L and 37°C, with and without bioburden.

| *B. a.* strain | bioburden | 0 mg MB /L | 80 mg MB/L |
|---|---|---|---|
| ATCC 10 | N | 2.40E+04 | 0.00E+00 |
| ATCC 10 | Y | 3.90E+04 | 0.00E+00 |
| ATCC 937 | N | 2.70E+05 | 0.00E+00 |
| ATCC 937 | Y | 4.40E+04 | 0.00E+00 |
| ATCC 4728 | N | 6.90E+04 | 0.00E+00 |
| ATCC 4728 | Y | 3.90E+04 | 0.00E+00 |
| ATCC 9660 | N | 0.00E+00 | 0.00E+00 |
| ATCC 9660 | Y | 0.00E+00 | 0.00E+00 |
| ATCC 11966 | N | 1.80E+03 | 0.00E+00 |
| ATCC 11966 | Y | 1.50E+03 | 0.00E+00 |
| AMES-RIID | N | 4.89E+07 | 1.00E+02 |
| AMES-RIID | Y | 2.98E+07 | 0.00E+00 |
| ANR-1 | N | 6.70E+07 | 0.00E+00 |
| ANR-1 | Y | 8.01E+07 | 0.00E+00 |
| STERNE | N | 2.15E+07 | 0.00E+00 |
| STERNE | Y | 1.57E+07 | 0.00E+00 |
| ATCC 14187 | N | 8.40E+07 | 0.00E+00 |
| ATCC 14187 | Y | 2.19E+08 | 0.00E+00 |
| AMES-1-RIID | N | 1.92E+08 | 0.00E+00 |
| AMES-1-RIID | Y | 1.50E+08 | 0.00E+00 |

UF

CFU/slide of *B. anthracis* spores after 48-hour exposure to methyl bromide at 0 or 120 mg/L and 27°C.

| *B. a.* strain | 0 mg MB/L | 120 mg MB/L |
|---|---|---|
| ATCC 10 | 2.17E+04 | 0.00E+00 |
| ATCC 937 | 3.82E+05 | 6.60E+01 |
| ATCC 4728 | 1.02E+06 | 0.00E+00 |
| ATCC 9660 | 0.00E+00 | 0.00E+00 |
| ATCC 11966 | 4.34E+02 | 0.00E+00 |
| ATCC 14187 | 3.45E+07 | 2.40E+04 |
| AMES-1-RIID | 5.56E+07 | 2.70E+05 |
| AMES-RIID | 8.53E+07 | 2.19E+05 |
| ANR-1 | 5.06E+08 | 6.50E+03 |
| STERNE | 2.70E+07 | 8.00E+02 |

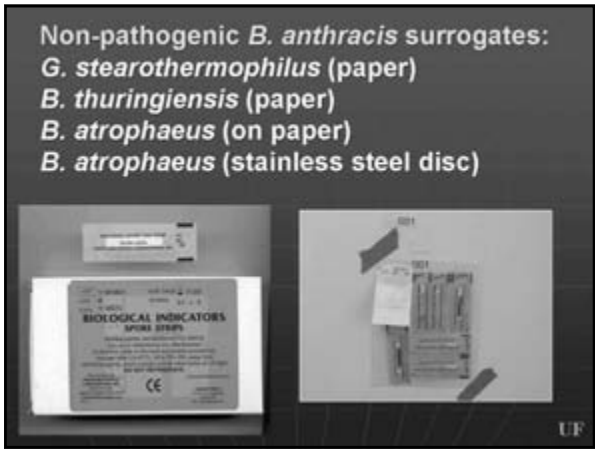
UF

## 2004 Field Trial, Big Pine Key, Florida

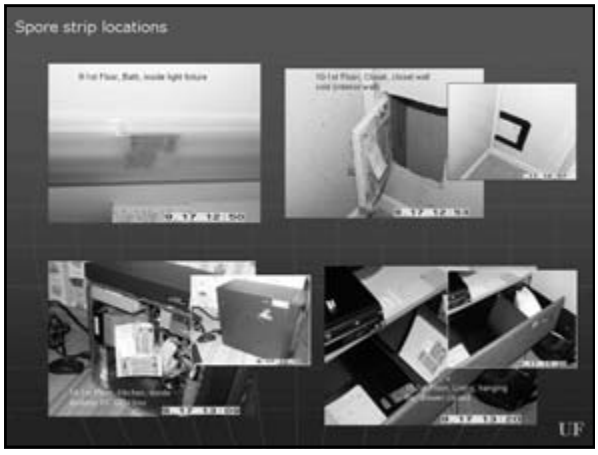

UF

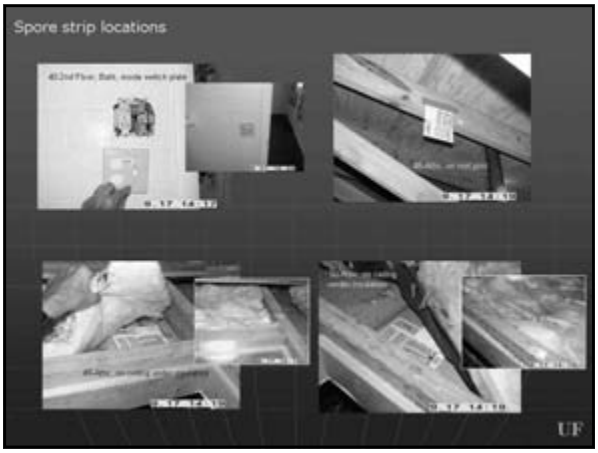

UF


UF


Non-pathogenic B. anthracis surrogates:
G. stearothermophilus (paper)
B. thuringiensis (paper)
B. atrophaeus (on paper)
B. atrophaeus (stainless steel disc)
BIOLOGICAL INDICATORS
SPORE STRIPS
UF


Spore strip locations
UF


Spore strip locations
UF


**Field site conditions:**

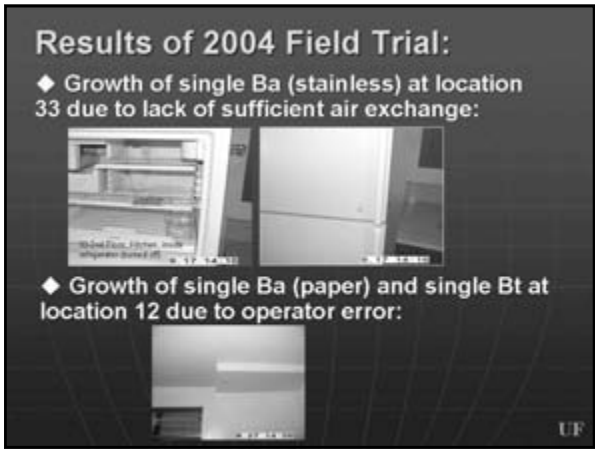
**312 mg MB/L mean conc.**
**48-hour exposure time**
**35°C mean temperature**




## Results of 2004 Field Trial:

- 48 Spore strip locations: no growth of any spore species (Gs, Bt, Ba (paper), or Ba (stainless steel), from both contract laboratories [IITRI quantitative Bt and Ba (paper) or Raven labs (Gs and Ba stainless]
- Growth on all controls (n=10/species)

UF





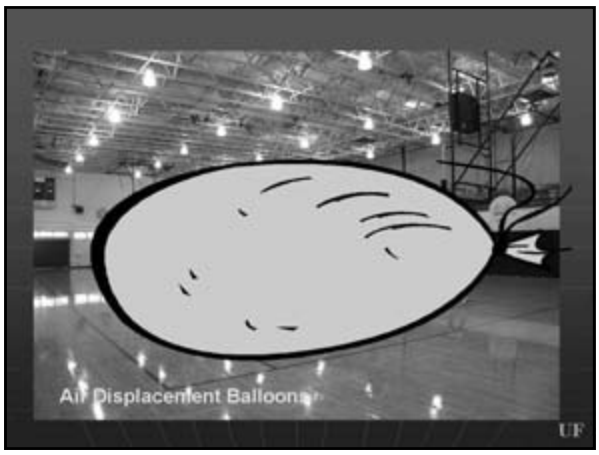
## Advantages of methyl bromide for *B. anthracis* decontamination:

- Low cost: $150/1,000 ft$^3$
- Rapid turnover: ± 200 hours
- All porous materials, voids, HVAC, etc. decontaminated – no secondary procedures needed
- No collateral damage
- No modification of ambient humidity

UF

**Technology for future MB fumigations:**

- Real-time IR MB detectors
- Air displacement balloons
- Multilayer or laminated tarpaulins
- Silicone ground seal
- MB Scrubbing




## Commercial fumigation structures:

- Single-family houses
- Multi-unit complexes
- Large commercial structures
- Government facilities
- Boats & ships
- Trucks and containers
- Military hardware

UF






M1A1 "Abrams" Tank
Spore Decontamination
Using Methyl Bromide
Volume 3,072 ft3
MeBr Required 14 oz (interior)
Set-up Time* 2 hrs
Exposure Time 48 hrs
Aeration Time 24 hrs
* 2 person taskforce
Equipment needed (cost $2.5K):
40'x60' tarp
80' snake
50 clamps
Fumiscope
heat exchanger
thermometer
shooting hose
2.8 amp fan
Kitagawa tubes
tube pump
Replacement cost $4.3M
UF


10.9 10:55 UF


10.9 11:01 UF


10.9 11:05 UF


10.9 11:07 UF


10.9 11:08 UF


10.9 11:11 UF


10.9 11:14 UF


10.9 11:18 UF


10.9 11:34 UF

## DF-200 Decontamination of CBW Agents, other Biological Pathogens and Toxic Industrial Chemicals

**Presented at**
**EPA Workshop on Decontamination, Cleanup, and Associated Issues for Sites Contaminated with Chemical, Biological, or Radiological Materials**
**Washington D.C.**

**February 24, 2005**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505-284-4160



Sandia is a multiprogram laboratory operated by Sandia Corporation, a Lockheed Martin Company, for the United States Department of Energy's National Nuclear Security Administration under contract DE-AC04-94AL85000.

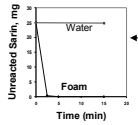

## DF-200
### Presentation Outline

- ✓Introduction
- ✓Sandia Decon Formulation (DF-200) Test Results
  - Neutralization of Chemical Warfare Agents
  - Kill of Biological Agents
  - Kill of Other Biological Pathogens
  - Neutralization of Toxic Industrial Chemicals
  - Aerosolized CBW Cloud Knockdown
- ✓Summary

## Sandia CBW Decon Formulations

http://www.sandia.gov/SandiaDecon/

Neutralization of CW Agents




Rapid and complete coverage

**Sandia Decon Foam**

Validated Kill & Neutralization of CBW Warfare Agents

As received

Sandia Foam
Contact Time: 1 Hour
Complete kill of anthrax spores

Commercial Licensees with EPA Approved Products

medec Inc.
ENVIROFOAM

## Sandia Decon Foam
### Corrosion Comparisons

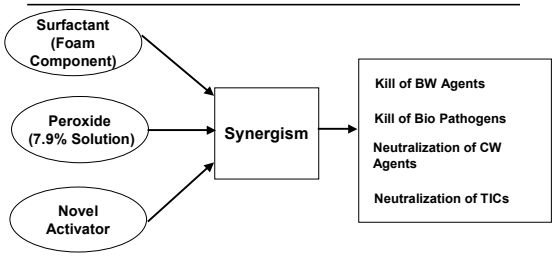
**Steel Coupons**

Deionized Water - 24 Hour Exposure

Sandia Decon Foam - 24 Hour Exposure

Bleach - 24 Hour Exposure

## Sandia DF-200
### How Does it Work?




Final concentration of hydrogen peroxide in standard DF-200 formulation is ~3.5%

## Decontamination of CW Agents

| Decon-taminant | GD | | | VX | | | HD | | |
|---|---|---|---|---|---|---|---|---|---|
| | 1 Min. | 30 Min. | 60 Min. | 1 Min. | 30 Min. | 60 Min. | 1 Min. | 30 Min. | 60 Min. |
| DS2 | **100** | **-** | **100** | **100** | **-** | **100** | **100** | **-** | **100** |
| DF-200 | **100** | **100** | **100** | **99** | **100** | **100** | **97** | **100** | **100** |

**Percent decontamination of live agents in reactor studies at the Edgewood Chemical and Biological Center (ECBC). Challenge ratio was 50:1.**

## DF-200 Performance

**Neutralization of CW Agents and TICs**

| Agent | Contact Time (Minutes) | Byproducts |
|---|---|---|
| Nerve Agents (G) | 1-10 | Nucleophilic Attack |
| Nerve Agents (V) | 10-15 | Nucleophilic Attack |
| Vesicants (HD) | 15-30 | Oxidation |
| Sodium Cyanide | 1-15 | Oxidation |
| Phosgene | 1-15 | Hydrolysis |
| Carbon Disulfide | 1-15 | Oxidation |

**Rapid neutralization of CW agents and TICs**

## Sandia Decon Foam

**Kill of BW Agents in DF-200**

| | *B. Anthracis* - Ames-RIID | | *B. anthracis* – ANR-1 | | *Y. pestis* – (ATCC 11953) | |
|---|---|---|---|---|---|---|
| | Average CFU/ml | Log Reduction | Average CFU/ml | Log Reduction | Average CFU/ml | Log Reduction |
| Control | **1.21 x $10^7$** | **0** | **6.42 x $10^7$** | **0** | **6.42 x $10^7$** | **0** |
| 15 Minute Contact | **No Growth** | **7** | **No Growth** | **7** | **No Growth** | **7** |
| 30 Minute Contact | **No Growth** | **7** | **No Growth** | **7** | **No Growth** | **7** |
| 60 Minute Contact | **No Growth** | **7** | **No Growth** | **7** | **No Growth** | **7** |

**Results of kill tests conducted against BW agents in DF200 solution.**

## Decontamination of CW and BW Agents Additional Testing

### CW Testing

- Commercial DF200 foam deployed on CARC surfaces using Intelegard's Merlin system. Challenge ratio of 120:1

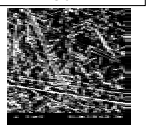
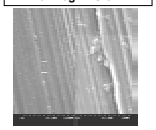
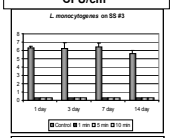
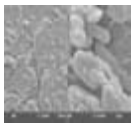
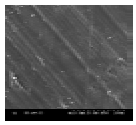
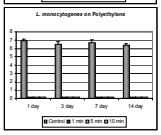
### BW Testing

- Three strains of anthrax, anthrax surrogate and Ricin toxin tested on CARC and in suspension
- Commercial DF200, High Test Hypochlorite, and Super Tropical Bleach

All results demonstrate high efficacy of DF200

Contact: Mr. Vic Murphy, murphyva@mcsc.usmc.mil, (703) 432-3193

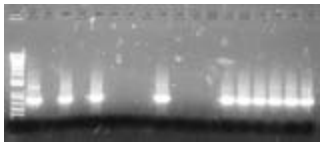
## Effectiveness of DF-200 vs. Biofilms

| | **Control Samples: Prior to treatment with DF-200. Average adhesion = 6-7 log CFU/cm²** | **Treated Samples: After 1 min treatment with DF-200. Average reduction = 6-7 log CFU/cm²** | **Data shown for recovered *L. monocytogenes*, Log CFU/cm²** |
|---|---|---|---|
| SS #3 |  |  |  |
| Poly-ethylene |  |  |  |

Work performed by Jill Bieker-Hawkinson, KSU

## Influenza A (H1N1) Inactivation Studies

**Results: RT-PCR conducted with forward and reverse N1 primers:**

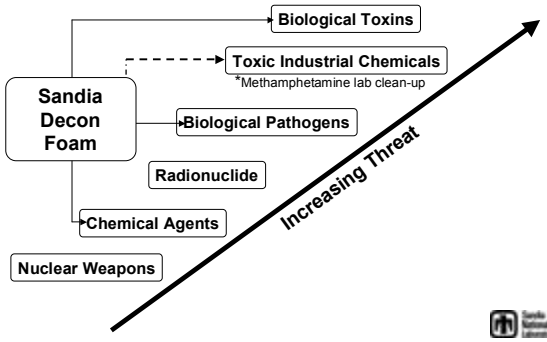



| Concentration Effect | Exposure Effect |
|---|---|
| **1:** 1kb RNA ladder | **11:** 12.5% DF-200D 30 min |
| **2:** pos clin sample | **12:** 12.5% DF-200D 15 min |
| **3:** neg clin sample | **13:** 12.5% DF-200D 1 min |
| **4:** trt with 0.1M PBS | **14:** 1% bleach 30 min |
| **5:** 10% bleach 1min | **15:** 1% bleach 15 min |
| **6:** 1% bleach 1min | **16:** 1% bleach 1 min |
| **7:** 50% DF-200D 1 min | **17:** 35% EtOH 30 min |
| **8:** 25% DF-200D 1 min | **18:** 35% EtOH 15min |
| **9:** 12.5% DF-200D 1 min | **19:** 35% EtOH 1 min |
| **10:** 70% EtOH | |

**All treatments with Sandia DF-200D resulted in complete loss of infectivity and complete loss of viral RNA integrity.**

Work performed by Jill Bieker-Hawkinson, KSU

## FBI WMD Threat List



## Challenges & Mechanisms of TIC Decontamination Chemistry

TIC

Water Insoluble — Water Soluble

### Attack Mechanisms

Nucleophilic Attack | Oxidation | Reduction | Buffering

**Limitations: toxic metals, strong acids/bases**

## DF200 Neutralization of TICs
**Solution and Headspace Gas Analysis**

| TIC | Challenge Ratio, Solution:TIC | % Decontaminated in solution/ % Decontaminated in headspace | | |
|---|---|---|---|---|
| | | 1 minute | 15 minutes | 60 minutes |
| Hydrogen Cyanide (gas) | 250:1 | 59 | 83 | >99/>99 |
| Hydrogen Cyanide (gas) | 1:1 | 96 | 95 | 48/96 |
| Sodium Cyanide (solid) | 200:1 | 93 | 98 | >99/>99 |
| Phosgene (gas) | 200:1 | 98 | >99 | >99 |
| Carbon Disulfide (liquid) | 200:1 | >99 | >99 | >99 |
| Malathion (liquid) | 200:1 | 89 | 95 | Below detection |
| Capsaicin (liquid) | 200:1 | >99 | Below detection | Below detection |

## CBW Cloud Knockdown & Neutralization
**Problem**

- ✓ One mechanism of the dispersal of CBW agents would be to create a "cloud" of active material that would drift and affect the intended target areas.
- ✓ The objectives of this project are
  - ➢ to explore methods of CBW cloud knockdown and neutralization.
  - ➢ If feasible, recommend conceptual deployment design
- ✓ **Success** will result in
  - ➢ protecting lives, minimizing impact to infrastructure and post-event decontamination efforts, and
  - ➢ facilitating timely restoration of operations.

The focus is on determining the feasibility of knocking down and neutralizing an aerosol cloud – not systems development

## CBW Cloud Knockdown & Neutralization
**Large Aerosol Chamber Design**

Large Chamber
- 8 foot high by 8 foot wide by 8 foot deep
- Static Free PVC
- Inflow from aerosol source with filtered exhaust
- Multiple Aerosol sampling ports
- Mixing Fans
- Internal Decon Spray System

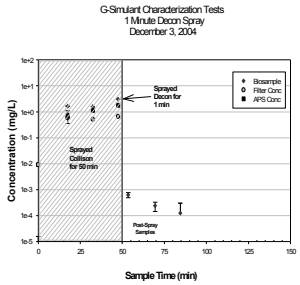
➢New Larger Chamber, Spring 2005

## CBW Cloud Knockdown & Neutralization
**Modeling and Transport Physics of CBW Cloud Conditions**

- Use CBW cloud scenarios defined by DoD Guardian program
  - Determined peak plume concentrations, duration, and exposure

NOTE: At a decon:agent ratio of ~800:1, DARPA Immune Building Program demonstrated an effective interior knockdown and decon
- 8-log knockdown and decon of anthrax simulant
- HD simulant concentration reduced by two orders of magnitude

## Recent Data
### DF200 Knockdown & Neutralization Spray

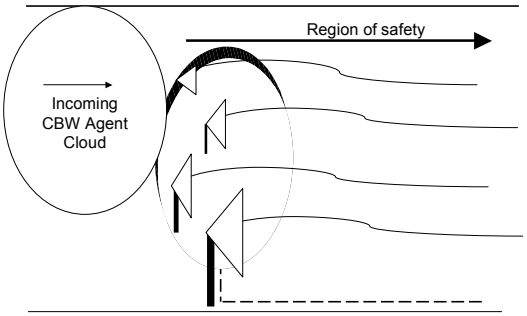



- **"Optimized" spray system**
- **3.2 g/m³ G-agent simulant**
- **138 g/m³ DF200 Spray density**
- **Immediate decrease of nearly 4 orders of magnitude**
- **~90,000 gallons of DF200 required for 50m x 50m x 1000m spray curtain**
- **Knockdown/neutralization proof of concept**
- **Various simulant and spray densities are being evaluated**

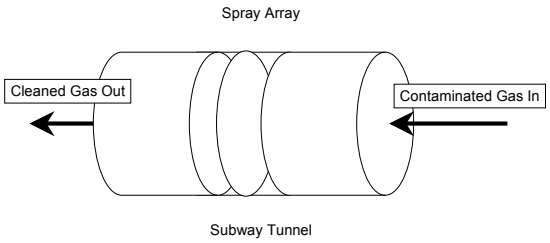
## CBW Cloud Knockdown & Neutralization
### Comments

- Many applications for fundamental capability; Technologies developed are also applicable to hazmat and civilian incident responses
  - Chemical plants
  - Chemical D-mil
  - Subways
  - Nuclear plants
  - High-profile buildings

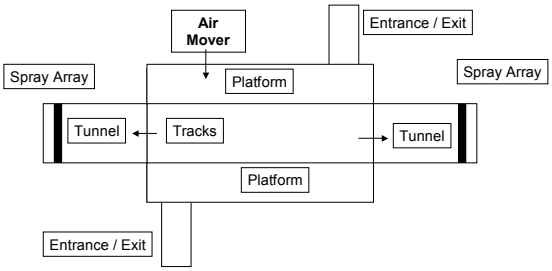
## CBW Cloud Knockdown and Neutralization
### Conceptual Design




## CBW Cloud Knockdown & Neutralization
### Subway Tunnel




## CBW Cloud Knockdown & Neutralization
### Subway Station




## Sandia Decontamination Technologies

**Sandia has developed unique decontamination formulations and application/delivery concepts to enable rapid and safe neutralization CBW agents, biological toxins and toxic industrial chemicals.**

**Hazmat Response**
Intentional/Accidental
Liquid, Solid, Gaseous
Indoor/Outdoor

## DF-200 Summary

- **DF-200 is available for use by the U.S. Military and the nation's first responders in the event of a chemical or biological incident**
- **EPA registration for use as a disinfectant granted in November 2004**
- **Many opportunities exist to utilize the fundamental DF-200 chemistry for other applications**

**Effective against chemical and biological agents, other biological pathogens and TICs**

## Sandia Decon Foam (DF-200)






**DF-200 is considered to be the best available decontamination technology by the US Military**

## Sandia Decon Formulation (DF-200)

**Project Team**

**Mark Tucker**
**Rita Betty**
**Gary Brown**
**Wayne Einfeld**
**Pauline Ho**
**Caroline Souza**
**Mollye Wilson**
**Kristine Muroya**
**Jonathan Leonard**
**Linda Johnson**
**Jill Bieker-Hawkinson**
**Bruce Kelley**

**Sandia Decon Foam Demonstration for President George W. Bush; July 22, 2002**

**Website**

http://www.sandia.gov/SandiaDecon

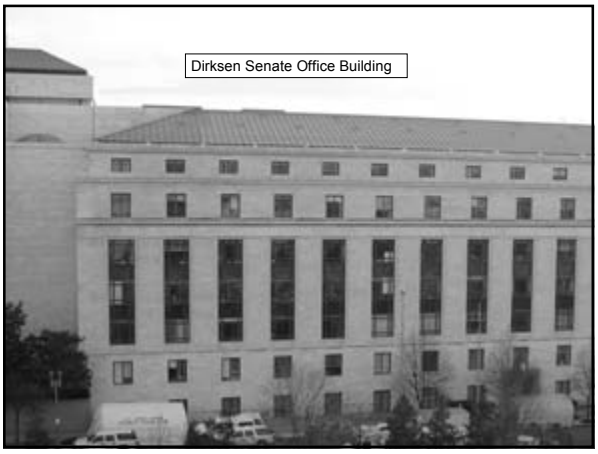
# Capitol Hill Ricin Incident : Decontamination Dilemmas (or …"Can't we just throw it away?")

Steve Jarvela and Jack Kelly
EPA Decontamination Technology Workshop
Washington D.C.
February 23-25, 2005

*Special thanks to Dr. Robert Bull and his staff at NMRC whose assistance during this incident went well beyond what could be expected*

## *Capitol Hill Ricin Incident – Presentation Outline*

- Incident Occurrence and EPA's Arrival
- EPA Activities in Incident Command
- Some Ricin Facts
- Decontamination of Affected Building Areas/Post-Decontamination Sampling
- The "Decon Team"
- Decontaminating Clothing, Mail and Miscellaneous Items Offsite





## *Incident Occurrence and EPA's Activities*

- February 2, 2004 – suspicious powder found on the mail slitter in mail room (Room 464) attached to Senator Frist's office in Dirksen Building
- Preliminary field samples and follow-up laboratory analyses by FBI/USCP confirm ricin
- Several Region III OSCs arrive at Capitol Hill per assistance request from House Sergeant at Arms
- EPA instilled into Incident Command Structure essentially within Operations Section

*……before going into our activities, some ricin facts*

## *Ricin*

- Protein toxin from the beans of the castor plant
- Fairly easy to produce the toxin and plants are found worldwide (grows as weed in southwest U.S. and commonly grown as U.S. ornamental plant)
- > 1 million tons of castor beans processed annually in production of castor oil (mainly India, China, Brazil)
- Castor beans are 35-55% oil by weight, process waste mash is 5% ricin by weight (lots of ricin out there!)
- Castor oil production ceased in U.S. in 1970s due to health and safety issues and low profit

## *Ricin*

- Very toxic to cells/inhibits protein synthesis
- Ricin actually made up of two toxins, each with a polypeptide chain (A and B), that work together to cause damage
- Toxic by inhalation, ingestion and injection. Not as toxic as botulinum
- Acute inhalation and oral toxicity well beyond the established "extremely toxic" classification (ricin LD50s are in **ug**/kg range) *…..proverbial bad stuff.*
- No vaccine as yet, no prophylactic antitoxin

## *Ricin – History as Bioweapon and Some Incidents*

- WW1 and WW2 ricin weapon development
- 1978 - assassination of Bulgarian dissident by injection with ricin-loaded umbrella pellet
- 1993 - white supremacist traveling through U.S. found to have ~130 grams of ricin in vehicle
- 1994-95 - Minnesota Patriots Council found with ~1 gram of ricin threatening to injure law enforcement
- 2003 - ricin found in threatening letter at South Carolina postal facility (NIOSH involved)
- 2004 - Washington State man found to be making ricin in garage (EPA Region 10 involved)

## *Castor Plant*

Photo credit: JBurstein and A Carbone, Harvard School of Public Health

## *Castor Plant as "Weed"*

Photo credit: JBurstein and A Carbone, Harvard School of Public Health

## *Castor Beans*


Photo credit: DOD Bio Agent Training Course

## *Simulated Crude Ricin Production*


Photo credit: DOD Bio Agent Training Course

## *EPA's Activities*

- EPA tasked to:
  - receive, inventory and store/secure unopened mail from several buildings until action determined
  - conduct additional characterization sampling*
  - perform decon of affected rooms and post-decon "clearance" sampling
  - decon potentially contaminated and contaminated clothing, mail and miscellaneous equipment

* sampling earlier performed by FBI and USCP; USCP continued to sample to augment EPA sampling

## *EPA's Activities*

- by February 8, approximately 80 drums of unopened mail removed from various buildings
- clothing from 32 potentially exposed individuals stored for disposition
- at least 670 samples had been collected by FBI, USCP and EPA (possibly many more) from three known Dirksen Bldg affected rooms, hallways, common areas and personnel "quarantine" room (Room 106)
- 19 positives found – all confined to wipes or HEPA vac samples collected within Room 464 or in the collection bag of the room 464-specific vacuum cleaner

## *Storage of drummed mail*

## Storage in Parking Lot

## Various Storage/Disposal Containers Used

## Personnel Decon after Sampling

## *EPA's Activities……by February 8*

- All air samples collected by USCP were negative
- office and personal items from Room 464 were "bagged and tagged". Large hard surface items left in place
- Sampling ongoing to return "high priority" items to congressional staff

Issue: How to Decon Affected Rooms?

## *Decision to Decon Dirksen Rooms*

- EPA tasked to come up with a decon plan (in a few hours of course) …we looked toward existing research data and experts
- Our primary document was the USAMRIID "Blue Book" for ricin decontamination:

" Ricin is stable under ambient conditions, but is detoxified by heat (80 degrees C for 10 min, or 50 degrees C for about an hour at pH 7.8)"

*….but we soon learned that dry ricin was a different animal than wet ricin*

……also…….

" Decontaminate with soap and water. Hypochlorite solutions (0.1 % sodium hypochlorite) can inactivate ricin."

## *Decision to Decon Dirksen Rooms*

- Initially, there was talk "from above" of using ClO2 gas (!?) in the rooms
- ….then there was discussion of heating up the rooms with propane heaters……

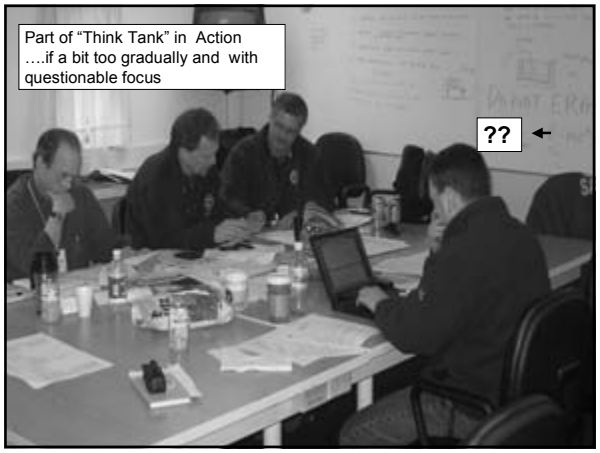
We prevailed that this would be overkill and time-consuming.

## *Decontamination of Rooms*

- Decision made to "decontaminate" Room 464 and adjacent rooms 463 and 465 as precaution. Large hard surface items and carpets deconned in place. (carpet in 464 removed and disposed)
- Room 106, where evacuees stationed, also addressed as precaution
- Common hallways, elevators, mail drop points addressed as precaution

## *Decision to Decon Dirksen Rooms*

- Final EPA recommendation:
  Use liquid 0.1 to 0.5% sodium hypochlorite solution on hard surfaces and steam vacuuming (with sodium hypochlorite added) on carpeted surfaces.
- Rationale:
  - relatively small size of the area;
  - what was known about ricin concentrations in Room 464 and non-detection in other building areas;
  - knowledge of ricin properties and what was known about ricin "carrier" powder;
  - research literature and input from EPA ERT, Army Edgewood, USAMRIID, USPHS, CDC, academia
  - input from inter-agency onsite Scientific Support Group (aka "The Think Tank") formed to recommend to lead OSC a decon approach, sampling plan, etc



## *Decontamination of Rooms*

Success!

- Rooms, hallways, etc. deconned on February 8 and Dirksen Building opened on Monday, February 9 !!(?)

(Only rooms 463, 464, and 465 remained closed for routine renovation)

## *EPA Tasked to Decon Clothing, Mail and Equipment, Office Items*

- Original set – 19 large bags of office items from Room 464 and 10 bags of clothing from quarantined personnel – materials not sampled for ricin
- Second Set – 12 large bags - miscellaneous paper items from Room 464, unopened mail, mail slitter and vacuum cleaner – limited sampling revealed contamination

## *EPA Tasked to Decon Clothing, Mail and Equipment, Office Items*

First Option Most Were Thinking ……but not to be.


## EPA Tasked to Decon Clothing, Mail and Equipment, Office Items

Knowing that clothing might be able to withstand soaking and dry cleaning … take the simple approach for clothing

## *EPA Tasked to Decon Clothing, Mail and Equipment, Office Items*

- Washing and dry cleaning not chosen for several reasons:
  - where to wash/dry? Could we be assured it would work? Sample afterward? (attempts at finding a federal facility with an autoclave were unsuccessful)
  - decon water disposal issue
  - mail/paper could not be washed. Some efficiency in doing all materials together if possible.
  - we were already going down the "heat will probably work" path based on discussions with researchers, DOD and others
  - saw an opportunity to advance the knowledge base for ricin decontamination

## *EPA Tasked to Decon Clothing, Mail and Equipment, Office Items*

- We formed a "Decon Team" to come up with a plan to decontaminate the materials
  - members from AFFRI, CDC/NIOSH, CDC Laboratory, EPA ERT, EPA III, Army Edgewood, Navy NMRC, and Academia
- Despite some skepticism, heat was to be used as the initial decon agent (research data suggested it would work)
- If heat not successful, Ethylene Oxide (EO) to be used as a second method based on its theoretical plausibility and availability (except on clothing due to off-gassing concerns)
- Chlorine Dioxide (ClO2) was to be a third option if time allowed - again, based on theoretical plausibility only

## *How/Where to Conduct Decon and Verify Effectiveness?*

- Past work during Capitol Hill Anthrax response proved helpful - EO sterilization facility in Richmond willing to assist
- Facility had ability to get temperature up to ~90 degrees C and relative humidity to ~85% for 24 hours or more
- If needed, ClO2 contractor working on AMI Anthrax project in Florida also willing to assist

*Decon Team efforts focused on how to package items, setting of sterilization specifications, effectiveness measurements, "how clean is clean?" opinions*

## *Big Issues for Decon Team – How Clean is Clean?*

- After decontamination, in order to make a recommendation on re-use of the items ("how clean is clean?"), how much did we know about:
  - contamination concentrations including sampling collection and extraction efficiencies
  - the location of contamination on clothing, mail, etc.
  - ricin powder processing characteristics (crude or purified?, "weapons-grade"?)
  - our trust in ricin toxicity values

## *How Clean is Clean?*

- EPA ORD did make an effort at coming up with criteria but cautioned due to many unknowns
- Essentially, we decided to proceed with the decontamination effort and worry about it later
- Given the unknowns and potential public health consequences, it was assumed we would need to get to close to 100% denaturation of ricin

## *Big Issues for Decon Team – How to Prove Effectiveness*

- Working with NMRC and Edgewood, we were able to obtain "live" crude and purified ricin as indicators of efficacy for each treatment run
- Indicators transported to and from NMRC/Edgewood, sterilization facility and laboratory….cleared through CDC Select Agent Transport regs
- This was a new and novel use of Region III vehicles …..but …whatever it takes to get the job done I suppose

## *Briefly…What was Done*

Original Set of Materials – 29 Tyvek bags of clothing and office items:

- Heat treatment #1 (3/11/04)
- 82-88°C, 80-85% RH, > 24 hours
- 28 crude and 28 purified ricin "tubes" interspersed within bags for later analyses
- temperature probes placed in bags

Original Set –
Heat Treatment #1 Lab Results-

(NMRC assay approach determines the remaining toxicity activity level of the ricin test samples….or…how much was the ricin deactivated?):

**Heat Treatment #1 - March 16, 2004 assay**

| packet | temperature (degrees C) | BDRD Sample # | APG# | (purified) BDRD Ricin Activity | (crude) APG Ricin Activity | (purified) BDRD % native ricin | (crude) APG% native ricin |
|---|---|---|---|---|---|---|---|
| 106-1/464-5 | 82 | 106-1 | 30 | - | + | 0 | 1.8 |
| 106-2/106-3 | 82 | 106-2 | 44 | - | + | 0 | 1.9 |
| 106-4/464-12 | 88 | 106-4 | 26 | - | ? | 0 | ? |
| 106-5/106-6 | 88 | 106-5 | 46 | - | + | 0.2 | 3.3 |
| 106-7/106-8 | 88 | 106-7 | 33 | - | + | 0 | 4.5 |
| 106-9/106-10 | 82 | 106-9 | 27 | ? | + | 0 | 5.3 |
| 464-1/464-2 | 82 | 464-1 | 42 | - | + | 0 | 1.4 |
| 464-3/464-4 | 82 | 464-3 | 35 | - | + | 0 | 0.9 |
| 464-6/464-7 | 88 | 464-6 | 31 | - | + | 0 | 0.6 |
| 464-8/464-9 | 88 | 464-8 | 32 | - | + | 0 | 2.1 |
| 464-10/464-11 | 82 | 464-10 | 28 | - | + | 0 | 0.7 |
| 464-13/464-14 | 82 | 464-13 | 37 | - | + | 0 | 1.4 |
| 464-15/464-16/464-19 | 82 | 464-15 | 29 | - | + | 0 | 2.3 |
| 464-17/464-18 | 88 | 464-17 | 34 | - | + | 0 | 1.3 |

*Results for Original Set Heat Treatment #1*

- 100% deactivation of 13 of the 14 *purified* ricin samples removed after treatment (14 of 28 removed)
- 14th sample at 99.8% deactivation
- 94.4 to 99.7 % deactivation of 14 of 28 *crude* ricin samples removed

*Point: Crude more difficult to deactivate than purified and we needed to get better efficacy*

*Original Set – Heat Treatment #2*

- Heat treatment #2 (3/26/04)
- Same temp, RH and time duration range
- Plan was to assay remaining 14 crude and purified ricin samples after undergoing second heat treatment
- Results:
  - 4 of 14 crude/ricin samples analyzed within days
  - 9 of 14 analyzed three weeks later *(one tube destroyed by a runaway forklift ….)*

*Original Set – Heat Treatment #2*

- 4 of 14 crude/purified (*assayed 3/29*):
  - 100% deactivation of *purified*
  - 99.8 – 99.99 % of *crude*
- 9 of 14 crude/purified (*assayed 4/21*):
  - > 99.9% deactivation of *crude*
  - 99.92 – 99.99% deactivation of *purified* (not 100% as above) ….*WHY? Believed to be the result of "protein refolding"*

*So what did we recommend to the USCP about the fate of the original set of materials?*

- Decon Team documentation memo merely kept to the facts, citing results and expressing "things to keep in mind"
- There was not unanimity on what the recommendation should be (but close)
- Recommendation letter was left up to the lead EPA Region III OSC

*Second Set of Materials*

- Provided to EPA relatively late (3/22) miscellaneous paper items, quarantined mail, Room 464 mail slitter and vacuum cleaner – some known to be contaminated
- What we did:
  - Exposed materials to heat treatment #1 (3/28) – knowing one heat treatment was insufficient we left 22 crude and 22 purified ricin samples in place/did not assay
  - Conducted an EO treatment pilot test (3/31) on store-bought items similar to the Second Set of Materials – utilized 4 crude and 4 purified ricin samples

*Second Set of Materials*

- pilot test results (EO treatment alone)
  - 98.9 - 99.9% deactivation for *purified*
  - 99.86 - 99.99% for *crude*
  - *….seemed that EO efficacy on ricin was more than just a theory*
- We decided to go with EO treatment on the Second Set of items already exposed to one heat treatment
- We obtained a new batch of crude and ricin samples to measure EO efficacy alone to compare with heat plus EO efficacy…..
  - …led to more Beltway drives with ricin

## *Second Set of Materials*

- The second set, already exposed to heat, was treated with EO
- EO operating parameters (we relied on the facility's expertise):
  - ~ 24 hour duration
  - avg EO concentration of 815 mg/l
  - RH of ~35%
  - Temp in 160 °F range
- 22 crude and 22 purified ricin samples –
  - -11 crude/purified exposed to heat and EO
  - -11 crude/purified exposed to EO alone

**EtO Treatment - May 12, 2004 assay (samples not exposed to heat treatment)**

| Packet | ETO INDICATOR* | HEAT INDICATOR** | APG # | BDRD Sample # | (crude ricin) APG Ricin Activity | (purified ricin) BDRD Ricin Activity | (crude ricin) APG% native ricin | (purified ricin) BDRD % native ricin |
|---|---|---|---|---|---|---|---|---|
| PO-1/PO-2 | - | ND | 9 | PO-1 | + | + | 0.009 | 0.004 |
| PO-3 | - | ND | 1 | PO-3 | + | + | 0.014 | 0.01 |
| PO-4 | - | ND | 10 | PO-4 | - | + | 0.009 | 0.008 |
| PO-5/PO-6 | - | ND | 5 | PO-5 | + | + | 0.015 | 0.02 |
| PO-7 PPE | ND | ND | 6 | PO-7 | + | + | 0.012 | 0.012 |
| PO-8 | - | ND | 2 | PO-8 | + | - | 0.017 | 0 |
| PO-9/PO-10 | - | ND | 4 & 3 | mixing | + | ND | 0.011, 0.016 | ND |
| PO-11/PO-12 | - | ND | 12 | PO-11 | + | - | 0.12 | 0.003 |
| PO-13 | - | ND | 15 | PO-13 | + | + | 0.063 | 0.008 |
| PO-14 | - | ND | 8 | PO-14 | + | + | 0.024 | 0.011 |
| PO-15 TRASH | - | ND | 11 | PO-15 | + | + | 0.081 | 0.0097 |

**no heat indicator utilized for EtO treatment but conducted at an average temp of 140 degrees Fahrenheit

**EtO and Heat Treatment - May 12, 2004 assay (samples exposed to both heat and EtO)**

| Packet | ETO INDICATOR* | HEAT TREATMENT INDICATOR (degrees C) | APG # | BDRD Sample # | (crude ricin) APG Ricin Activity | (purified ricin) BDRD Ricin Activity | (crude ricin) APG% native ricin | (purified ricin) BDRD % native ricin |
|---|---|---|---|---|---|---|---|---|
| PO-1/PO-2 | ND | 85 | 6 | PO-1 | + | ND | 0.005 | 0 |
| PO-3 | ND | 88 | 7 | PO-3 | - | ND | 0.005 | 0 |
| PO-4 | ND | 88 | 23 | PO-4 | ND | ND | 0 | 0 |
| PO-5/PO-6 | ND | ND | 7 | PO-5 | ND | ND | 0 | 0 |
| PO-7 PPE | ND | 88 | 25 | PO-7 | ND | ND | 0 | 0 |
| PO-8 | ND | 82 | 1 | PO-8 | ND | ND | 0 | 0 |
| PO-9/PO-10 | ND | 88 | 3 | PO-9 | ND | ND | 0 | 0 |
| PO-11/PO-12 | ND | 88 | 11 | PO-11 | ND | ND | 0 | 0 |
| PO-13 | ND | 88 | 43 | PO-13 | ND | ND | 0 | 0 |
| PO-14 | ND | 88 | 13 | PO-14 | ND | ND | 0 | 0 |
| PO-15 TRASH | ND | 88 | 5 | PO-15 | ND | ND | 0 | 0 |

*EtO indicators not utilized or data not available

**Initial Ricin Concentrations: purified ricin = 40 micrograms, crude ricin = 400 micrograms**
BDRD = Biological Defense Research Directorate (NMRC)
APG = Aberdeen Proving Ground (Edgewood)
ND = equals no ricin toxicity activity detected

## *Second Set of Materials*

- EO treatment alone:
  - *11 Crude* = 99.939 – 99.999% deactivation
  - *11 Purified* = 99.978 – 99.997%
- Heat plus EO:
  - *11 Crude* = 9 with 100% deactivation
    2 with 99.995 – 99.997 %
  - *11 Purified* = all 11 with 100% deactivation

## *Second Set of Materials*

- Again, Decon Team memo merely provided a synopsis of results with items to consider (i.e. for added "protection", some items had been surface cleaned with bleach solution prior to heat and EO treatment)
- Lead OSC provided recommendation to USCP

## Conclusions/Lessons Learned

- Capitol Hill responses are always a little….er… "different"
- An interagency, onsite Scientific Support Group during a response may have a place but we need to work the kinks out (need quicker turnaround and decisions primarily)
- The offsite Decon Team interagency group worked surprisingly well but delays can be expected the larger and more widespread the group's size

## Conclusions/Lessons Learned

- Without the participation of the DOD or DOD-related agencies on the Decon Team, NMRC, AFFRI and Army Edgewood, this work could not have occurred (NMRC's assistance went beyond what we could have hoped). This collaboration should serve Region 3 well in the future.
- We appreciated the opportunity to add to the ricin decon knowledge base but, in a future incident, it may be more efficient to take the simple, run-of-the-mill approach (e.g. dumpsters, washing machines and/or wash basins)

## References


- Grow, R.M., Johns Hopkins Center for Civilian Biodefense Strategies, *Ricin Toxin: Bioweapon,* April 2003, PP presentation.
- Center for Disease Control and Prevention, *Investigation of a Ricin-Containing Envelope at a Postal Facility- South Carolina 2003*, Morbidity and Mortality Weekly Report, November 21, 2003, 52 (46); 1129-11131.
- USAMRIID, *Ricin* in Medical Management of Biological Casualties Handbook, 4th ed, February 2001, pp 130-137.


## Photo Credits

- Burstein, JL and Carbone, A., Harvard Center for Public Health Preparedness-Harvard School of Public Health. *Ricin as a Biological Weapon.* PP Presentation, Date not known.
- Department of Defense (DOD) Bio-Agent Training Course
- Nick Brescia, EPA Region III OSC.

# Restoration from Decon

## *USPS Experience*

Presented by:

**Richard Orlusky**

richard.c.orlusky@usps.gov

February 2005

UNITED STATES POSTAL SERVICE

## Timeline USPS Trenton facility

- October 2001 - USPS Trenton P&DC closed
- April 2003 – Commenced construction fumigation system
- October 2003 - Building fumigated with Chlorine dioxide gas
- February 2004 - Decision on Re-occupancy issued by ECC
  - begin removing fumigation equipment from inside the building and limited site restoration work such as HVAC cleaning.
  - restoration contractors meeting with subcontractors onsite to review building systems, develop scope of work and cost estimates to restore the facility
- March 2004 - USPS Maintenance teams begin restoring mail machinery
- May 2004 - Decontamination contractors demobilize and building restoration contractors commence work
- February 2005 - Restoration contractors demobilize from site
- March 2005 - Building scheduled to commence operations

## Pre- Fumigation Factors Impacting Building Restoration

- Age of building, type of equipment and current state of maintenance.
- Surface cleaning with bleach solution effective but destroys equipment. Also damages flooring materials. Alternate products with less contact time might limit damage and reduce restoration costs.
- Typically building control systems are inoperable or shutdown after the building is evacuated. Interior subject to high temperatures (90 degree F and 90% humidity) especially after being sealed. This adds to building degradation especially over time.
- Building systems especially mail processing machinery receive daily preventative maintenance. The machinery degrades without its normal routine maintenance.
- Building Preparation Activities – removing porous material, moving fumigation equipment into the building, sealing the exterior can damages floors, doorways and walls.

## Restoration Considerations

- Direct impacts from "Decon" activities
- Cost of inspecting and servicing components vs. replacement
- Useful service life of existing building equipment
- Needed building upgrades
- Building aesthetics – employee and customer relations

## Our Experience

- Mail Machinery/Electronics - USPS Trenton mail machinery rebuilt. It was learned from the USPS Curseen-Morris fumigation that the equipment operational with overhaul but the availability was impacted.
- Electrical Wiring/Circuit Breaker Panels/ Motor Control Centers/Transformers – need to be thoroughly inspected especially small contact points (Life Safety Issues). Replace vs. repair determinations.
- Flooring – overlay performed on work room floor tiles. Damaged due to bleach cleaning, foot traffic and fumigation preparation activities. Carpeting in administrative areas replaced.
- Building Systems (HVAC, Boilers, Chillers)– motors, actuators and pumps replaced.
- Replaced employee lockers, lobby lock boxes, door fixtures. Painted interior surfaces. Employee and customer relations.

## Closing Thoughts on Building Restoration

- Age of structure, maintenance status, and type of equipment inside is a major determinate in cost, restoration time, and scope of work.
- Complete and current set of as-builts should be kept outside of building along with maintenance records and equipment specifications. Emergency response planning.
- Bring restoration contractor team in early before building is fumigated in order to begin planning a comprehensive scope of work.
- More testing of Chlorine dioxide and other decon agents for efficacy at lower concentrations and contact time may be helpful.
- Use surface cleaning agents (i.e. bleach) cautiously if fumigation is to be "decon" remedy.
- Restore building environmental controls as quickly as possible to maintain temperature and relative humidity control.
- If possible, perform equipment maintenance (even if building is closed).
- Down time after fumigation seems to be a factor. Reducing implementation of Sampling and Analysis Plan timeline might help improve equipment rehabilitation.
- Don't forget to cost in "Industrial Hygiene" services for sampling and HASP training, emergency response, evacuation planning, and site security.

# Another Look at Chlorine Dioxide Fumigation: Concentration-Times, Efficacy Tests and Biological Indicators

February 24, 2005
EPA Decontamination Workshop

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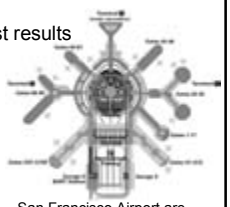
Lawrence Livermore National Laboratory
**Chemical & Biological Nonproliferation Program**

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.UCRL-pres-201161
Researchers reserve the right to publish data provided in this presentation.

## Presentation Outline

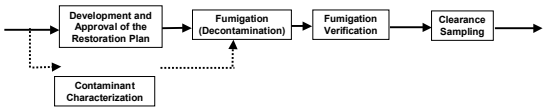
- Project Background
  - ✓ Decontamination & Restoration for a Major Transportation Facility DDAP
  - ✓ Deliverable: develop & test a rapid efficacy test
- Chlorine dioxide fumigation field-test results
  - ✓ $ClO_2$ concentration time curve
  - ✓ Efficacy tests
  - ✓ Biological indicators



San Francisco Airport are partners in the DDAP

## Sandia National Laboratory and Lawrence Livermore National Laboratory are collaborating on a Restoration DDAP

The primary objective of the Restoration Domestic Demonstration & Application Program (DDAP) is to develop and demonstrate a set of procedures, plans and technologies for the *rapid restoration* of major transportation nodes




✓Improve the fumigation verification step
- use of rapid viability determination methods for spore strips/discs

✓Improve the clearance sampling step
- use of rapid viability determination methods for environmental samples

## Large facilities require thousands of biological indicators to insure the fumigant is adequately dispersed

- Brentwood Post Office fumigation verification included 8,000 spore strips
  - Analysis of all the spore strips at Brentwood took approximately 30 days
- Capitol Hill used 1,556 spore strip verification samples

## Our field-test for rapid fumigation verification included scientific and operational objectives

**Operational goals**
- Demonstrate ~1000 BI overnight processing capability
- Demonstrate sample tracking/data analysis tools

**Scientific goals**
- Comparison of Rapid viability test protocol (RVTP) with standard culture method for biological indicators (BIs)
  - Determine accuracy of RVTP relative to standard culture method
- Perform rigorous QC analysis
  - Evaluate potential for cross-contamination
  - Determine accuracy of RVTP to detect blind positive samples
  - Determine assay sensitivity

## Test design

| Analytical Method | Spore conc. | $ClO_2$ exposure Time (hrs) Cntl 0 | 1 | 2 | 4 | 6 | 8 | 10 | 12 | Number of discs |
|---|---|---|---|---|---|---|---|---|---|---|
| Approx. CT (ppmv) | | 0 | 750 | 1500 | 3000 | 4500 | 6000 | 7500 | 9000 | |
| RVTP | $10^6$ | 50 | 50 | 50 | 50 | 50 | 50 | 50 | 50 | 400 |
| Method | $10^4$ | 10 | 10 | 10 | 10 | 10 | 10 | 10 | 10 | 80 |
| Standard | $10^6$ | 50 | 50 | 50 | 50 | 50 | 50 | 50 | 50 | 400 |
| Method | $10^4$ | 10 | 10 | 10 | 10 | 10 | 10 | 10 | 10 | 80 |
| **Subtotal** | | 120 | 120 | 120 | 120 | 120 | 120 | 120 | 120 | **960** |

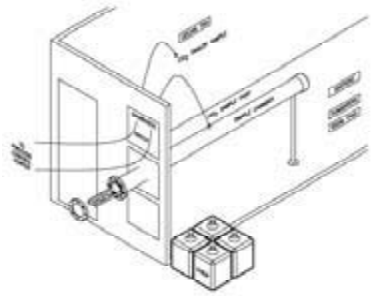
- Total BI number was 1094
- Half of the samples were analyzed by culture methods and half by RVTP
- Hundreds of samples were exposed to a non-lethal $ClO_2$ conc.
- Additional 50 BIs exposed for 12 hours for inhibition studies
- Each PCR plate had > 10% positive and >10% negative controls

## Fumigant Generation

1. **$ClO_2$ generation combines sodium hypochlorite with hydrochloric acid to produce chlorine, intermediate precursor**
2. **Sodium chlorite is added to produce chlorine dioxide gas**
3. **The gas is dissolved in water and the chlorine dioxide moves into the process stream, $ClO_2$ (emitters) stripper removes $ClO_2$ from water phase to gas phase**

**Chemical plant**
- **Sodium chlorite**
- **Hydrochloric acid**
- **Sodium hypochlorite**

## Test facility drawing



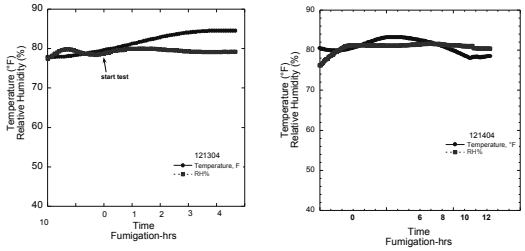
- **Airflow in the chamber was 3.31 $ft^3$/min**

**Sabre Technologies's MCAD 24 ft. test trailer**

**Chamber sample tray**

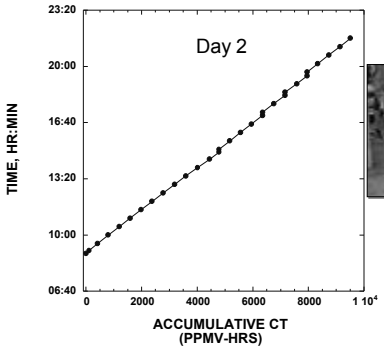
## Temperature and relative humidity in the chamber was monitored throughout the test

We averaged 79-85 °F and 78-81% RH




Day 1 Day 2

## Chlorine dioxide concentration was carefully controlled during testing




$ClO_2$ assayed by a modified Standard Methods APHA-AWWA-WPCF-4500. $ClO_2$ releases free iodine from an acidified KI solution. The liberated iodine is titrated with sodium thiosulfate.

## Every other sample was analyzed by RVTP

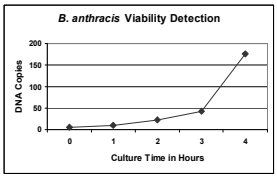
| | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| X | X | X | X | X | X | X | X | X | X |
| X | X | X | X | X | X | X | X | X | X |
| X | X | X | X | X | X | X | X | X | X |
| X | X | X | X | X | X | X | X | X | X |
| X | X | X | X | X | X | X | X | X | X |
| X | X | X | X | X | X | X | X | X | X |
| X | X | X | X | X | X | X | X | X | X |
| X | X | X | X | X | X | X | X | X | X |
| X | X | X | X | X | X | X | X | X | X |
| X | X | X | X | X | X | X | X | X | X |
| O | O | O | O | O | O | O | O | O | O |
| O | O | O | O | O | O | O | O | O | O |

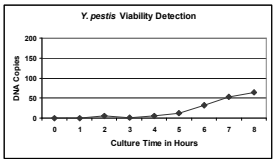
For all exposure levels, red X or O was cultured, black X or O was analyzed by RVTP, X = $10^6$ spores on BI
O = $10^4$ spores on BI

✓ All samples were barcoded with the location information and followed through each process of analysis using the methods establish by the National BASIS/BioWatch programs.

## Rapid viability test protocol was developed for biothreat agents

**There is a rapid increase in DNA copy number during growth**




**Graphs shows increasing copies of DNA indicating cell growth and therefore viability; initial inoculums were below detection**

**K. Smith, S. Kane, P. Coker, K. Montgomery, P. Imbro, P. Fitch, 2002, ROI pending**

## Efficacy test protocols

RVTP

1. Place BI in 96 well plate
2. Add tryptic soy broth (TSB) to each well
3. Transfer time 0 sample to 96 well PCR plate
4. Lyse cells
5. Transfer aliquot of lysate to second PCR plate
6. Analyze by real-time PCR
7. Continue to incubate culture plate at 37°C with shaking
8. Repeat steps 3-5 for 14 hr sample (endpoint)

Standard Culture

1. Place BI in 10 mL TSB in culture tube
2. Incubate @ 30-35°C, statically for 7 days
3. Determine positives by visual turbidity

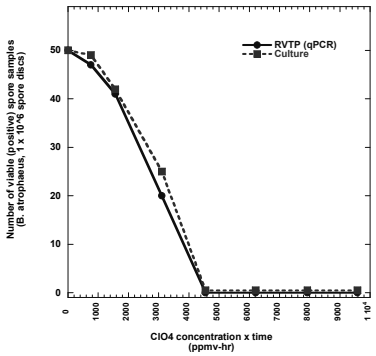
## Results

- ✓ Chlorine dioxide concentration-time curves
- ✓ Efficacy tests
- ✓ BI comparison

BioMek and BioRad Icyclers

Test chamber

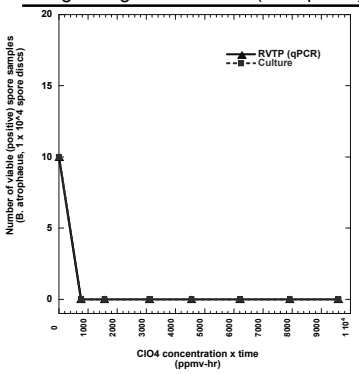
## Results: RVTP versus culture method using Biological indicators ($10^6$ spores/disc)




✓ **An exposure of 750 ppmv for a 6 hr resulted in no viable growth**

✓ **There was no significant difference between the RVTP results and the standard culture results (student T test for mean differences, *P*>0.05)**

## Results: RVTP versus standard culture method using biological indicators ($10^4$ spores)




✓**There was no significant difference between the RVTP results and the standard culture results, *P*>0.05**

## False-positive occurrence

| Exposure time (hr) | False positive rate (%) RVTP | Culture |
|---|---|---|
| 0 | 0 | 0 |
| 1 | 0 | 0 |
| 2 | 0 | 0 |
| 4 | 0 | 4 |
| 6 | 0 | 0 |
| 8 | 0 | 0 |
| 10 | 0 | 4 |
| 12 | 0 | 4 |

Standard culture methods resulted in 1.5% false positives
- False positives for culture samples determined by RVTP (qPCR)

No false negatives observed for RVTP
- False positive rate for RVTP defined as percent difference between positive result for 14 hr RVTP and visible growth in well

RVTP results are numeric, standard culturing are visual

## Calculated $\log_{10}$(CFU) survivors exposed to $ClO_2$ fumigation

| DPG[1] 730 ppmv, 90% RH, BAA | | LLNL 750 ppmv, 80%RH, B.*atrophaeus* | |
|---|---|---|---|
| Time (hrs) | Log(CFU)[2] | Time (hrs) | Log(CFU) |
| 0 | 8.2 | 0 | 8.2 |
| 1 | 4.8 | 1 | 2.1 |
| 2 | 2.1 | 2 | 1.9 |
| 4 | 0 | 4 | 1.4 |
| 6 | 0 | 6 | 0 |
| 8 | 0 | 8 | 0 |
| 12 | 0 | 10 | 0 |
| | | 12 | 0 |

[1] With permission "Laboratory Validation of Chlorine Dioxide Gas Decontamination(Anthrax Spores)" Bruce Harper, Lloyd Larsen US Army Dugway Proving Ground, Peter Steverson,EPA region 8 Emergency Response 2002 Joint Service Chemical and Biological Decontamination Conference, San Diego

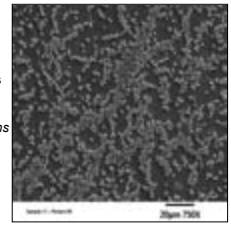
[2]All values represent the sum total of spores present on the 50 discs exposed at each time period.

## Comparison of biological indicators- discs and strips respond to non-lethal CTs was different

| $ClO_2$ Exposure ppmv-hrs | Positives/total sample # Apex disc | SGM strip |
|---|---|---|
| 0 | 10/10 | 10/10 |
| 780 | 3/10 | 9/10 |
| 1580 | 2/10 | 10/10 |
| 3140 | 0/10 | 10/10 |

SGM Biotech Strip- *B. subtilis var. Niger*, $10^6$ spores
APEX spore discs- *B. atrophaeus*, $10^6$ discs

*P <0.05, significantly different results between means*



Spores on stainless steel discs

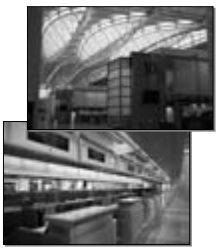
## Growth performance is different between the two type of biological indicators

- Biological indicators may differs in several qualities:
  - Hard versus porous surface material
  - Sleeve porosity and adsorptive capacity
  - Spore viability
  - Purity of spore preparations
  - Spore piling

## Summary

**The Restoration DDAP is developing rapid methods for restoration of a transportation facility following a biological attack**

- We met our objective of decreasing the analysis time for biological indicators from 7 d to 15 hr
- RVTP showed the same sensitivity as the culture technique and was highly accurate
- There are significant differences between biological indicators
- The EPA's $ClO_2$ fumigation recommendation of 750 ppm for 12 hr resulted in 'no viable spores' in this test



We have 2 field tests planned for '05; 1) test RVTP in a high-throughput automation mode, and 2) analyze hundreds of environmental samples (wipes, socks, filters) by RVTP and culturing methods


## Acknowledgements

LLNL
Paris Althouse
Tina Legler
Gloria Murphy
Tracy Letain
Mark Wagner
Tina Carlsen

Sabre Technologies, Inc
Dave Skodack
Darrell Dechant
Kevin Wade
Bob Summerville
Buddy Britton

Apex Laboratories, Inc.
Joseph Dalmasso

Funded by the Department of Homeland Security

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# Systematic Decontamination Project

**Homeland Security: Verification of Chem/Bio Decon Technologies**

**Philip Koga, Ph.D.**
US Army Edgewood Chemical Biological Center
Aberdeen Proving Ground, MD

**Presented at the USEPA-Sponsored Workshop on Decontamination, Cleanup, and Associated Issues for Sites Contaminated with CBR Materials**
**February 23-25, 2005**
**Washington, DC**

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## Background

**How do we clean up anthrax-contaminated buildings?**

- **Surface treatment vs. fumigation**
- **Efficacy data**
- **Impact on building materials and contents**

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## Systematic Decontamination Project

- **Joint effort between USEPA NHSRC and ECBC**
- **Systematic study on the performance of two to three commercial fumigant technologies**
  - **chlorine dioxide ($ClO_2$)**
  - **vaporized hydrogen peroxide (VHP™)**

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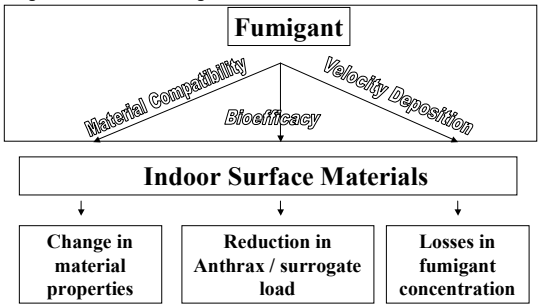


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## Bioefficacy - Objectives

1. **CT Range Finding:**
   - **series of CT (concentration x time) studies**
   - **six types of material coupons**
   - **Avirulent and virulent *B. anthracis***
   - **calculate D values**
2. **Parametric Study:**
   - **sub-optimal temperature and RH at optimal CT**
   - **one porous and one non-porous material**
   - **selected surrogates**

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## Bioefficacy – Target Microorganisms

1. ***Bacillus anthracis*** **(Ames or other suitable strain)**
2. ***B. anthracis*** **(NNR1Δ1, plasmid-free)**
3. ***Geobacillus stearothermophilus*** **(ATCC 7953)**
4. ***B. subtilis*** **(ATCC 19659)**
5. ***B. atrophaeus*** **(*B. subtilis* var. niger ATCC 49337)**
6. ***Yersinia ruckerii*** **(ATCC 29473)**

**BI - *Geobacillus stearothermophilus* (STERIS)**

**BI - *B. atrophaeus* (Apex Laboratories, Inc.)**

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## Test Materials

| Material | Source - Manufacturer |
|---|---|
| Unpainted concrete | York Building – Armstrong |
| Painted steel (I beam)[1] | Specialized Metals |
| Structural Pine Wood | Home Depot - Bowater |
| Ceiling tile | Home Depot – Armstrong |
| Carpet | Home Depot - Queen Shaw |
| Painted wall board[2] | Home Depot - US Gypsum |

1- Painted with TT-P-636 Red Oxide Primer (Coronado paint)
2- Painted with latex paint

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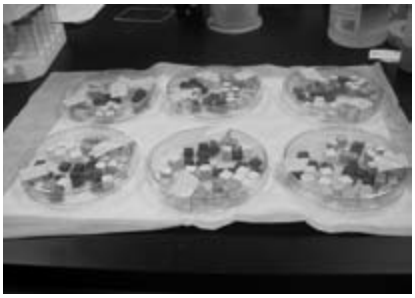
## 1.3 x 1.3 cm Test Coupons in Petri-plates



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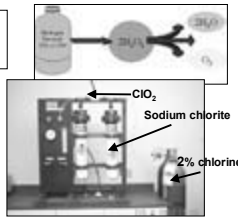
## Bioefficacy – Test Fumigants

**STERIS VHP™**
$H_2O_2$ → 2 OH · (free radical)




**ClorDiSys, Inc. (CSI)**
$2NaClO_2 + Cl_2 \rightarrow 2ClO_2 + 2NaCl$

**SABRE Oxi. Tech. (SOT)**
$2NaClO_2$ (25%) + HCl (15%) + NaOCl (12.5%) → $2ClO_2 + 2NaCl$

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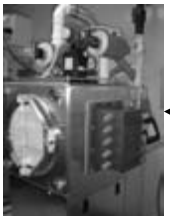
The Cloridox – GMP Generator & Test Chamber

Sampling Ante-chamber



Fumigation Chamber – 8 cu-ft

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## Bioefficacy – Test Chamber

- 8 cubic feet (2 ft x 2 ft x 2 ft)
- Constructed by ChlorDiSys, Inc. using 316 SS
- Contains a circulation fan and sensors for measuring temperature, RH, pressure, $ClO_2$, and $H_2O_2$
- Five antechambers for easy access and removal of coupons (inner and outer airlock doors)
- Separate fumigant feed ports

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## Bioefficacy – Study Design

1. CT Range-Finding Study (range of CT for 6 log kill)
   - A. Avirulent anthrax ($10^7$ spores in 50 μL inoculum)
     - Six test materials and two biological indicators
     - One VHP fumigant and two $ClO_2$ fumigants
     - Five replicates at five exposure times for each of three concentrations plus controls
     - CT range = 220 to 1800 ppm-hr for VHP
     - CT range = 2000 to 18000 ppm-hr for $ClO_2$

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## Bioefficacy – Study Design

1. CT Range-Finding Study

B. Virulent anthrax ($10^7$ spores in 50 μL inoculum)

- Two test materials (wood and steel) and two biological indicators
- One VHP fumigant and two $ClO_2$ fumigants
- Five replicates at five exposure times for each of two concentrations plus controls
- CT range dependent on results with avirulent BA


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## Bioefficacy – Study Design

2. Parametric study at varying temperature and RH

- Four surrogates ($10^7$ in 50 μL inoculum)
- Two test materials (wood and steel) and two biological indicators
- One VHP fumigant and one $ClO_2$ fumigant
- Five replicates at one exposure time and one concentration for each of two temperatures and two RH plus controls
- CT selected from preceding results


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## Bioefficacy – Study Execution

1. Preparation of building material coupons

- Autoclave using dry cycle
- Test 2 coupons per cycle for sterility
- Prepare spore suspension in 0.5% BSA
- Inoculate with $10^7$ cfu in 50 μL
- Air dry one hour in the biosafety cabinet
- Use within one week (one hour for *Y. ruckerii*)


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## Bioefficacy – Study Execution

2. Spore recovery and enumeration

- Immerse carrier in spore recovery medium
- Sonicate 10 minutes then vortex 2 minutes
- Prepare five 10-fold serial dilutions
- Spread plate 0.1 mL of selected dilutions in triplicate
- If no recovery observed with spread plates, repeat with pour plates


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## Bioefficacy – Study Execution

3. Exposure of coupons to fumigant

- Use cycle parameters recommended by vendor
- Dehumidification (<30% RH) for VHP
- Humidification (>75% RH) for $ClO_2$
- Conditioning phase (typically 2-10 minutes)
- Introduce coupons at start of sterilization phase
- Remove coupons at pre-selected times and immediately begin spore recovery process


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## Bioefficacy – Study Execution

4. Measurement of fumigant concentration

- VHP: Dräger electrochemical sensor in chamber
- VHP independently verified by chemical titration ($H_2O_2$ + KI + ammonium molybdate → triiodide which is titrated with thiosulfate)
- $ClO_2$: spectrophotometric gas sensor in chamber
- $ClO_2$ independently verified using Hach kits
- Hach kits validated using amperometric titration method


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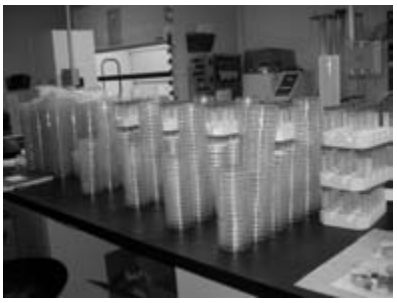
## Experimental Set up per CT Measurement



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## Bioefficacy – Schedule

| Fumigant | CT Range-Finding | Parametric |
|---|---|---|
| ChlorDiSys | Underway | 2QCY05 |
| STERIS | Start early March | 2QCY05 |
| Sabre | Need generator NLT March 20, 2005 | |

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## Deposition Velocity/Material Compatibility

1. Deposition Velocity Objective
   - Lab-scale measurement of the effects of six building materials on concentration / titer of $ClO_2$ and VHP
2. Material Compatibility Objective
   - Measure the effects $ClO_2$ and VHP may have on the integrity of the six building materials
   - Test for residual fumigant

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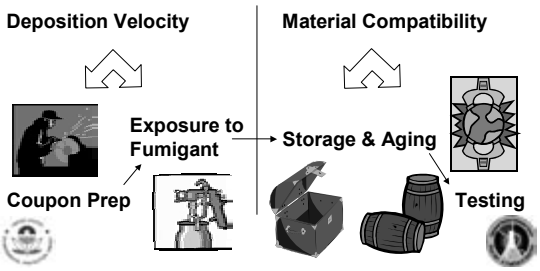
## Deposition Velocity/Material Compatibility

Related projects spanning a continuum of activity

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## Deposition Velocity Testing

- Same six test materials used for Bioefficacy study
  - Unpainted concrete
  - Structural Pine wood
  - Painted wall board
  - Painted steel
  - Ceiling tile
  - Carpet
- Two test fumigants
  - VHP™ (STERIS)
  - $ClO_2$ (CDG)

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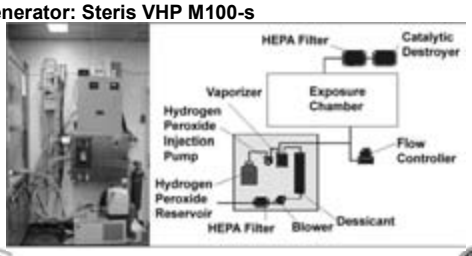
## Vaporized Hydrogen Peroxide Setup

Generator: Steris VHP M100-s



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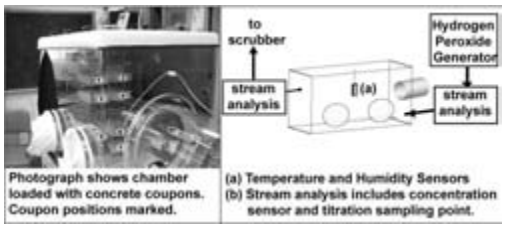
## VHP Exposure Chamber




Exposure Chamber: Plas-Labs compact glove box

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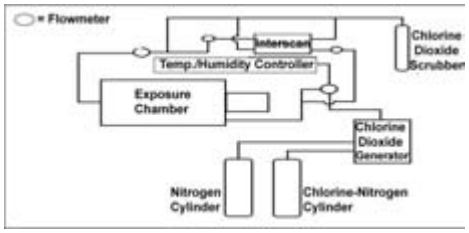
## Chlorine Dioxide Setup




Generator: CDG Technology bench-scale chlorine dioxide generator, Model "Micro"

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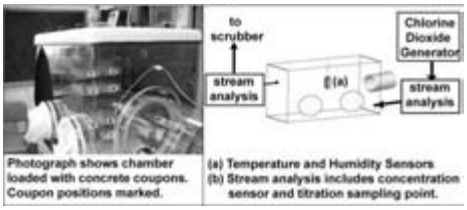
## Chlorine Dioxide Exposure Chamber




Exposure Chamber: Plas-Labs compact glove box

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## Deposition Velocity Testing

Experimental Conditions

| Test Run | Fumigant | Coupon | Comment |
|---|---|---|---|
| 1 | - | + | Mat. Compat. Controls |
| 2 | + | - | Baseline |
| 3 | + | + | Full Concentration |
| 4 | + | + | ½ Concentration same CT as Run 3 |

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## Deposition Velocity Testing

Experimental Conditions

| Test Parameter | VHP | $ClO_2$ |
|---|---|---|
| Temperature | >30°C | >24°C |
| Relative humidity, initial | <30% | >75% |
| Concentration 1 (ppm) | 250-300 | 2000-2500 |
| Exposure time 1 (hours) | 4 | 6 |
| Concentration 2 (ppm) | 125-150 | 1000-1250 |
| Exposure time 2 (hours) | 8 | 12 |
| Flow rate (cfm) | 0.2 | 3.0 |

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## Material Compatibility Testing

Test Materials
- Residential circuit breakers added
- Follow same exposure regimen as other materials

Coupon Aging
- Store exposed coupons in open containers for ~90 days at room temperature and ambient RH

Compatibility Testing
- Record visual changes at day 0 and day 90
- Test exposed coupons after day 90

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## Material Compatibility Testing

| Material | Test |
|---|---|
| Ceiling tile | ASTM C367-99: Strength Properties of Prefabricated Architectural Acoustical Tile or Lay-In Ceiling Panels, sections 5.1, 22-28 |
| Carpet | ASTM D1335-03: Tuft Bind of Pile Yarn Floor Coverings |
| Wallboard | ASTM C473-03: Physical Testing of Gypsum Panel Products |

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## Material Compatibility Testing

| Material | Test |
|---|---|
| Wood | ASTM D4761-02a: Mechanical Properties of Lumber and Wood-Based Structural Material |
| Steel | ASTM A370-03a: Mechanical Testing of Steel Products |
| Concrete | ASTM C140-03: Sampling and Testing Concrete Masonry Units and Related Units |
| | |

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## Material Compatibility Testing

| Material | Test |
|---|---|
| Wood | FTIR: changes in cellulose and other polymers |
| Metal | Ion chromatography: chloride, chlorite, chlorate, and perchlorate anions |
| Circuit Breakers | Store under load<br>UL Test Method 1077 |
| | |

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## Velocity Deposition/Materials Compatibility

**Schedule**

Deposition Velocity: Initiated

Materials Compatibility: 2QCY05

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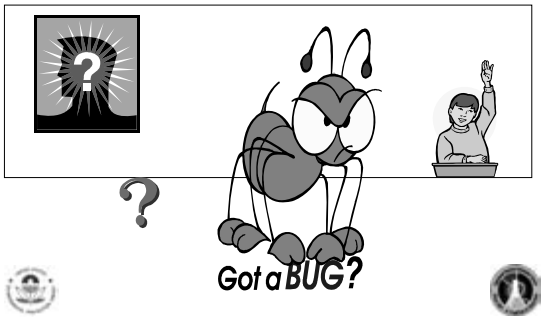
## Systematic Decontamination



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## Verification of Commercial Decontamination Technologies in Bench-Scale Studies Using *Bacillus anthracis* Spores

*M.L. Taylor, J.V. Rogers, Y.W. Choi, W.R. Richter, K.R. Riggs, C.L. Sabourin*
Battelle Memorial Institute, Columbus and Cincinnati, Ohio

*J.C.S. Chang*
Environmental Protection Agency, Research Triangle Park, North Carolina

## Outline

- Purpose of Testing
- Technologies Tested
- Test Apparatus
- Test Materials & Organisms
- Parameters Evaluated
- Generalized Test Procedures
- BIOQUELL, Inc. – Hydrogen Peroxide Gas Testing
- CERTEK, Inc. – Formaldehyde Gas Testing
- CDG Technology, Inc. – Chlorine Dioxide Testing
- Acknowledgements

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## Purpose of Testing

- EPA ETV Program – Battelle, Testing Contractor
  - Verify the performance characteristics of environmental technologies and report objective information to permitters, buyers and prospective users
  - Testing performed as stipulated in test/quality assurance plans developed with the participation of technical experts, stakeholders and vendors
- Focus of Initial Tests
  - Verify performance of fumigant-type technologies for decontaminating indoor surfaces inoculated with *B. anthracis* (Ames) and surrogates

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## Technologies Tested

| Technology | Vendor |
|---|---|
| Hydrogen Peroxide Gas | BIOQUELL, Inc. |
| Formaldehyde Gas | CERTEK, Inc. |
| Chlorine Dioxide Gas | CDG Research Corporation |

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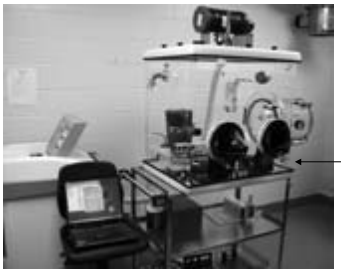
## Configuration of Testing Apparatus

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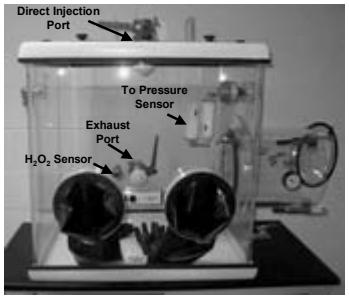
## Test Chamber

**Plas-Labs Compact Glove Box**

modified per vendor's request (BIOQUELL configuration shown)

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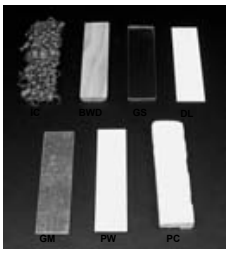
## Test Materials

- Industrial-grade carpet (IC)
- Bare wood (pine lumber) (BWD)
- Glass (GS)
- Decorative laminate (DL)
- Galvanized metal ductwork (GM)
- Painted (latex, flat) wallboard paper (PW)
- Painted (latex, semi-gloss) concrete cinder block (PC).

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## Organisms

- *Bacillus anthracis* Ames
- *Bacillus subtilis* (ATCC 19659)
- *Geobacillus stearothermophilus* (ATCC 12980)

Biological Indicator

- Biological Indicators
  - *Bacillus subtilis* (ATCC 19659)
  - *Geobacillus stearothermophilus* (ATCC 12980)
- Spore Strips
  - *Bacillus atrophaeus* (ATCC 9372)

Spore Strip

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## Parameters Evaluated

- Biological Efficacy Test
  - Log Reduction in viable spores on test materials
    - Quantitative
  - Positive/Negative bacterial growth at 1 and 7 days
    - Biological indicators/Spore strips; qualitative
- Coupon Damage
  - Changes in appearance, color, texture, etc.

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## Generalized Test Procedure

- Couple decontamination technology to test chamber
- Prepare coupons of test materials, inoculate
- Place into test chamber
- Implement decontamination technology
- Remove coupons from test chamber
- Analyze

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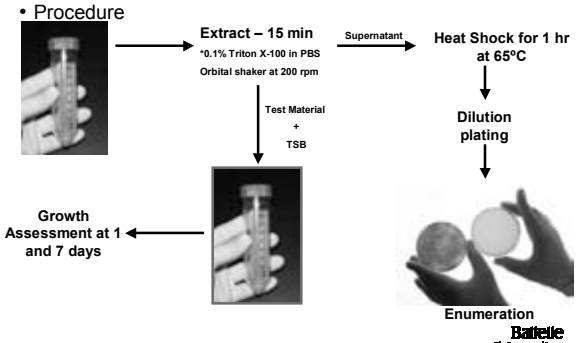
## Analysis Procedure for *B. anthracis* Ames

- Procedure

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## Data Analysis

- Efficacy (E) Calculation

  E = log(N'/N)

  N' = total viable spores recovered from control samples (no decon)

  N = total viable spores recovered from decontaminated samples

- Data (total spores; percent recovery)
- Expressed as Mean ± SD

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## Statistical Analysis

- Two-way analysis of variance (ANOVA) model
- Compared each mean to zero
- Compared each simulant to *B. anthracis* (within material)
- Compared each simulant to *B. anthracis* for porous and non-porous materials
- SAS® (Version 8.2) GLM procedure

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## BIOQUELL, Inc. – Hydrogen Peroxide

**Cycle Parameters**
**(Provided by Vendor)**

| | |
|---|---|
| •Cycle pressure: | 20 Pascals |
| •Conditioning time: | 10 min |
| •Gassing time: | 20 min |
| •Gassing dwell: | 20 min |
| •$H_2O_2$ injection rate: | 2.0 g/min |
| •$H_2O_2$ dwell rate: | 0.5 g/min |
| •$H_2O_2$ concentration during dwell: | ≥1000 ppm |
| •Aeration time: | set for 9999 min |


CLARUS™ C Unit

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## BIOQUELL, Inc. – Hydrogen Peroxide

Microcondensation during Dwell Phase

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## BIOQUELL, Inc. – Hydrogen Peroxide Results

**Mean Efficacy for Spores**

| Material[a] | | *B. anthracis*[b] | *B. subtilis*[b] | *G. stearothermophilus*[b] |
|---|---|---|---|---|
| Porous | Industrial-grade Carpet | 3.01 (2.62-3.55)[c] | 1.63 (1.46-1.76)[c, d] | 0.81 (0.69-0.89)[d] |
| | Painted Concrete | 6.36 (3.92-7.58)[c] | 6.09 (5.58-7.10)[c] | 4.09 (3.09-5.15)[c, d] |
| | Bare Wood | 3.70 (3.20-4.46)[c] | 2.18 (1.81-2.75)[c, d] | 4.09 (3.80-4.61)[c] |
| Non-porous | Glass | ≥7.92 (7.92)[c] | ≥7.57 (7.57)[c] | 4.68 (4.27-5.11)[c, d] |
| | Decorative Laminate | ≥7.85 (7.85)[c] | ≥7.66 (7.66)[c] | 3.75 (2.20-4.77)[c, d] |
| | Painted Wallboard Paper | ≥6.92 (6.92)[c] | ≥7.52 (7.52)[c] | 5.98 (5.47-6.99)[c] |
| | Galvanized Metal Ductwork | ≥7.54 (7.54)[c] | 6.44 (5.73-7.56)[c] | 1.97 (1.90-2.04)[c, d] |

[a] Three replicates were used for each test material for each organism.
[b] Log reduction in spores with range in parentheses.
[c] Mean significantly different from 0 (P≤0.05).
[d] Surrogates significantly different from *B. anthracis* for specified material (P≤0.05).

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## BIOQUELL, Inc. – Hydrogen Peroxide Statistical Analysis

| Material | | *B. anthracis* | *B. subtilis* | *G. stearothermophilus* |
|---|---|---|---|---|
| Porous | Industrial-grade Carpet | 3.01 | 1.63 | 0.81 |
| | Painted Concrete | 6.36 | 6.09 | 4.09 |
| | Bare Wood | 3.70 | 2.18 | 4.09 |
| Non-porous | Glass | 7.92 | 7.57 | 4.68 |
| | Decorative Laminate | 7.85 | 7.66 | 3.75 |
| | Painted Wallboard Paper | 6.92 | 7.52 | 5.98 |
| | Galvanized Metal Ductwork | 7.54 | 6.44 | 1.97 |

**All values are significantly different than zero (P≤0.05) except** ☐

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## BIOQUELL, Inc. – Hydrogen Peroxide Statistical Analysis

| Material | | *B. anthracis* | *B. subtilis* | *G. stearothermophilus* |
|---|---|---|---|---|
| Porous | Industrial-grade Carpet | 3.01 | 1.63 | 0.81 |
| | Painted Concrete | 6.36 | 6.09 | 4.09 |
| | Bare Wood | 3.70 | 2.18 | 4.09 |
| Non-porous | Glass | 7.92 | 7.57 | 4.68 |
| | Decorative Laminate | 7.85 | 7.66 | 3.75 |
| | Painted Wallboard Paper | 6.92 | 7.52 | 5.98 |
| | Galvanized Metal Ductwork | 7.54 | 6.44 | 1.97 |

☐ **Mean value is significantly different than *B. anthracis* (P=0.05)**

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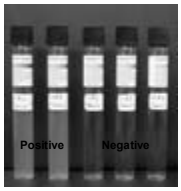
## BIOQUELL, Inc. – Hydrogen Peroxide Growth Indicators

| Indicator (Organism) | | Day 1 | | | Day 7 | | |
|---|---|---|---|---|---|---|---|
| | | S1 | S2 | S3 | S1 | S2 | S3 |
| Biological Indicator (*B. subtilis* ATCC 19659) | Control | + | + | + | + | + | + |
| Biological Indicator (*G. stearothermophilus* ATCC 12980) | Control | + | + | + | + | + | + |
| Spore Strip (*B. atrophaeus* ATCC 9372) | Control | + | + | + | + | + | + |
| Biological Indicator (*B. subtilis* ATCC 19659) | Decontaminated | - | - | - | - | - | - |
| Biological Indicator (*G. stearothermophilus* ATCC 12980) | Decontaminated | - | - | - | - | - | - |
| Spore Strip (*B. atrophaeus* ATCC 9372) | Decontaminated | - | - | - | - | - | - |




For all tests, control biological indicators and spore strips displayed positive growth while those decontaminated showed negative growth.

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## CERTEK, Inc. – Formaldehyde

### Cycle Parameters
**(Provided by Vendor)**

- Cycle pressure: ambient
- Conditioning time: 1 hour (ramp-up of formaldehyde concentration)
- Dwell time: 10 hours
- Formaldehyde concentration: theoretical – 8600 ppm; actual – 1,100 ppm
- Relative humidity: 75%
- Neutralization: 1 hour (ammonium carbonate)
- Total run time: 16-18 hours

CERTEK, Inc. Unit

Battelle

## CERTEK, Inc. – Formaldehyde Results

**Mean Efficacy for Spores**

| Material[a] | | *B. anthracis*[b] | *B. subtilis*[b] | *G. stearothermophilus*[b] |
|---|---|---|---|---|
| Porous | Industrial-grade Carpet | ≥7.00 (7.00)[c] | ≥8.04 (8.04)[c] | 5.68 (4.81-7.18)[c, d] |
| | Painted Concrete | 7.15 (5.93-7.76)[c] | 6.02 (5.61-6.22)[c] | 6.20 (4.03-7.29)[c] |
| | Bare Wood | ≥7.61 (7.61)[c] | 6.58 (5.57-7.08)[c] | ≥6.82 (6.82)[c] |
| Non-porous | Glass | ≥7.71 (7.71)[c] | ≥7.79 (7.79)[c] | ≥7.24 (7.24)[c] |
| | Decorative Laminate | 6.47 (5.61-7.66)[c] | 7.29 (6.38-7.74)[c] | ≥7.12 (7.12)[c] |
| | Painted Wallboard Paper | ≥5.17 (5.17)[c] | ≥7.68 (7.68)[c, d] | ≥7.19 (7.19)[c, d] |
| | Galvanized Metal Ductwork | ≥7.86 (7.86)[c] | 6.24 (5.39-7.87)[c, d] | ≥7.64 (7.64)[c] |

[a] Three replicates were used for each test material for each organism.
[b] Log reduction in spores with range in parentheses.
[c] Mean significantly different from 0 (P≤0.05).
[d] Surrogates significantly different from *B. anthracis* for specified material (P≤0.05).

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## CERTEK, Inc. – Formaldehyde Statistical Analysis

| Material | | *B. anthracis* | *B. subtilis* | *G. stearothermophilus* |
|---|---|---|---|---|
| Porous | Industrial-grade Carpet | ≥7.00 | ≥8.04 | 5.68 |
| | Painted Concrete | 7.15 | 6.02 | 6.20 |
| | Bare Wood | ≥7.61 | 6.58 | ≥6.82 |
| Non-porous | Glass | ≥7.71 | ≥7.79 | ≥7.24 |
| | Decorative Laminate | 6.47 | 7.29 | ≥7.12 |
| | Painted Wallboard Paper | ≥5.17 | ≥7.68 | ≥7.19 |
| | Galvanized Metal Ductwork | ≥7.86 | 6.24 | ≥7.64 |

**All values are significantly different than zero ($P \leq 0.05$) except** ☐

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## CERTEK, Inc. – Formaldehyde Statistical Analysis

| Material | | *B. anthracis* | *B. subtilis* | *G. stearothermophilus* |
|---|---|---|---|---|
| Porous | Industrial-grade Carpet | ≥7.00 | ≥8.04 | 5.68 |
| | Painted Concrete | 7.15 | 6.02 | 6.20 |
| | Bare Wood | ≥7.61 | 6.58 | ≥6.82 |
| Non-porous | Glass | ≥7.71 | ≥7.79 | ≥7.24 |
| | Decorative Laminate | 6.47 | 7.29 | ≥7.12 |
| | Painted Wallboard Paper | ≥5.17 | ≥7.68 | ≥7.19 |
| | Galvanized Metal Ductwork | ≥7.86 | 6.24 | ≥7.64 |

☐ **Mean value is significantly different than *B. anthracis* (P=0.05)**

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## CDG Research Corporation – Chlorine Dioxide

### Cycle Parameters
**(Provided by Vendor)**

- Cycle pressure: ambient
- Conditioning time: N/A
- Dwell time: 6 hours
- Chlorine Dioxide concentration: 2000 ppm
- Relative humidity: 70-80%
- Temperature: 23-27ºC
- Neutralization: 30-60 min followed by overnight aeration (10% NaOH, 10% $NaS_2O_4$ in water)
- Total run time: 16-18 hours

CDG Unit

Battelle

## CDG Research Corporation – Chlorine Dioxide Results

**Mean Efficacy for Spores**

| Material[a] | | *B. anthracis*[b] | *B. subtilis*[b] | *G. stearothermophilus*[b] |
|---|---|---|---|---|
| Porous | Industrial-grade Carpet | 4.62 (4.11-5.50) | 4.44 (4.28-4.62) | 3.22 (3.17-3.28)[c] |
| | Painted Concrete | 7.25 (6.24-7.76) | 4.74 (4.44-4.93)[c] | 5.79 (5.08-6.90)[c] |
| | Bare Wood | 4.33 (4.10-4.48) | 4.48 (4.14-4.79) | 3.79 (3.70-3.87) |
| Non-porous | Glass | 5.70 (5.35-6.06) | 5.23 (4.89-5.49) | 3.87 (3.64-4.20)[c] |
| | Decorative Laminate | 4.57 (4.19-4.85) | 5.14 (4.83-5.34) | 4.44 (4.29-4.59) |
| | Painted Wallboard Paper | ≥7.68 (7.68) | 4.62 (3.24-5.47)[c] | 5.62 (4.65-6.87)[c] |
| | Galvanized Metal Ductwork | ≥7.79 (7.79) | 5.57 (5.55-5.63)[c] | 3.43 (3.33-3.56)[c] |

[a] Three replicates were used for each test material for each organism.
[b] Log reduction in spores with range in parentheses.
[c] Surrogates significantly different from *B. antrhacis* for specified material (P≤0.05).

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## CDG Research Corporation – Chlorine Dioxide Statistical Analysis

| Material | | *B. anthracis* | *B. subtilis* | *G. stearothermophilus* |
|---|---|---|---|---|
| Porous | Industrial-grade Carpet | 4.62 | 4.44 | 3.22 |
| | Painted Concrete | 7.25 | 4.74 | 5.79 |
| | Bare Wood | 4.33 | 4.48 | 3.79 |
| Non-porous | Glass | 5.70 | 5.23 | 3.87 |
| | Decorative Laminate | 4.57 | 5.14 | 4.44 |
| | Painted Wallboard Paper | ≥7.68 | 4.62 | 5.62 |
| | Galvanized Metal Ductwork | ≥7.79 | 5.57 | 3.43 |

**All values are significantly different than zero (P≤0.05) except** ☐

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## CDG Research Corporation – Chlorine Dioxide Statistical Analysis

| Material | | *B. anthracis* | *B. subtilis* | *G. stearothermophilus* |
|---|---|---|---|---|
| Porous | Industrial-grade Carpet | 4.62 | 4.44 | 3.22 |
| | Painted Concrete | 7.25 | 4.74 | 5.79 |
| | Bare Wood | 4.33 | 4.48 | 3.79 |
| Non-porous | Glass | 5.70 | 5.23 | 3.87 |
| | Decorative Laminate | 4.57 | 5.14 | 4.44 |
| | Painted Wallboard Paper | ≥7.68 | 4.62 | 5.62 |
| | Galvanized Metal Ductwork | ≥7.79 | 5.57 | 3.43 |

☐ **Mean value is significantly different than *B. anthracis* (P=0.05)**

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## Acknowledgements


**Battelle**
Dr. James Estep – Battelle MREF Manager
Dr. Carol Sabourin – Verification Testing Coordinator
Dr. James Rogers – Study Director
Dr. Michael Taylor – BDT Center Director
Ms. Karen Riggs – BDT Center Manager
Dr. Harry Stone – Senior Reviewer
Mr. Young Choi – Lead Technician
Mr. Will Richter – Technician
Ms. Denise Rudnicki – Technician
Mr. Rick Tuttle – Technician
Ms. Nicole Caudill – Quality Assurance

**U.S. EPA**
Dr. John Chang – BDT Center Manager
Dr. Dorothy Canter, Reviewer
Mr. Jeff Kempter, Reviewer
Ms. Shirley Wasson, Quality Assurance
Mr. Bruce Henschel, Reviewer

**External Reviewers**
Dr. Phil Koga – U.S. Army Research Development & Engineering Command
Dr. Barry Pyle – Montana State University
Ms. Susan Springthorpe – University of Ottawa
Dr. Lloyd Larson – U.S. Army Dugway Proving Ground
Mr. John Kyme – Defense Group, Inc.
Dr. Greg Knudson, U.S. Central Intelligence Agency


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## New EPA Program: Technology Testing and Evaluation Program (TTEP)

TTEP established in July 2004 by the EPA National Homeland Security Research Center (NHSRC)

EPA Project Officer - Eric Koglin

Battelle Project Manager - Karen Riggs

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## Decontamination Technology Evaluation Tasks in Progress

Three Task Orders for evaluating building decontamination technologies were received September 2004

- "Decontamination Technology Testing and Evaluation"
  - EPA Task Order Project Officer, Dr. John Chang
    - Battelle Task Order Leader, Dr. Mike Taylor
- "Systematic Evaluation of Developmental and Commercially Available Methods for Biological Agent Decontamination"
  - EPA Task Order Project Officer, Dr. Shawn Ryan
    - Battelle Task Order Leader, Dr. Harry Stone
- "Systematic Evaluation of Developmental and Commercially Available Methods for Chemical Agent Decontamination"
  - EPA Task Order Project Officer, Dr. Shawn Ryan
    - Battelle Task Order Leader, Dr. Mike Taylor

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## *"DIRTY BOMBS" (RDDs) AND CLEANUP*

Fred B. Holbrook

DECON WORKSHOP
February 25, 2005


## *Terrorism and RDDs*


1. **Terrorism**
2. **RDDs**
3. **Radiological components**
4. **RDDs versus INDs**

## *Terrorism*

The calculated use of violence to inculcate fear; intended to coerce or intimidate governments or societies, in the pursuit of goals that are generally political, religious, or ideological. (DOD)

## *RDDs*

- RDDs are radiological dispersion devices or "dirty bombs".
- Physical effect: contamination
- Overall aim: psychological and economical
- Uses conventional explosives to disperse radioactive material.

## *Radiological components*

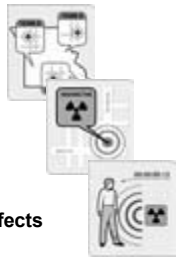
| | |
|---|---|
| ➢ Cesium-137 | 30 yrs (half-life) |
| ➢ Cobalt-60 | 5.25 yrs |
| ➢ Iridium-192 | 74 days |
| ➢ Strontium-90 | 29 years |
| ➢ Radium-226 | 1620 years |
| ➢ Plutonium-238 | 88 years |
| ➢ Americium-241 | 432 years |
| ➢ Californium-252 | 2.7 yrs |

## *RDDs versus INDs*

- Radiological Dispersion Devices can generate terror but cause few fatalities.
- Improvised Nuclear Device is a crude nuclear device and causes bldg. to come down near instantly with high doses radiation, heat & fires, and lost lives (depending on yield). Fission: force, electromagnetic waves, and fallout.
- 1300 to 2100 metric tons enriched uranium in world with questionable controls.

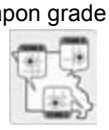
## *Radiological Considerations*

- **Availability**
- **Radiation**
- **Biological Effects**



## *Availability*

- Specialized materials – weapon grade U or Pu.
  - Government control



Radioactive materials
- Uses: academic, industrial, agricultural, and medical
- Problem: 1 lost source every day/NRC

## *Availability continued*

- Cs-137: gauges, well logging, cancer treatment, irradiators
- Co-60: gauges, radiotherapy, sterilization, radiography
- Ir-192: radiography, radiotherapy
- Am-241: medical diag, research, gauges, distance, smoke detector
- Cf-252: radiography, well logging, moisture/density, cancer treatment
- Problem: little security worldwide

## *Radiation*

- Alpha – helium nucleus
  shielding – paper or skin
  travel – few centimeters
  Problem – inhalation and ingestion
- Beta – electron
  shielding – Al foil or human skin
  travel – few feet
  Problem – deep and serious burns; internal

## *Radiation continued*

- Gamma – electromagnetic energy
  high energy short wavelength photon, pure energy, no charge
  shielding – lead
  travel – go thru many cm. lead
  Problem – severe damage internally

- Strength – how many nuclei decay per second; specific activity, Ci/gram

## *Biological effects*

- Dosage of ionizing radiation
- 25-50 rem - <white blood cells
- 100-200 rem – vomiting
- 300 rem – hair loss
- 400-500 – considered lethal to half people w/out treatment
- Statistics lacking for low level doses

## *Ominous Examples*

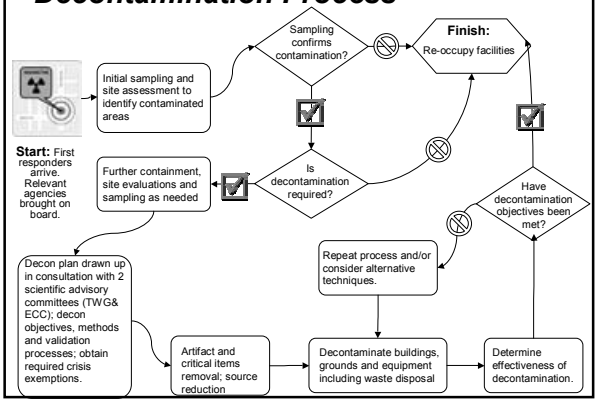
- **Chukotka**
- **Gamma Kolos**
- **Goiania, Brazil**
- **Considerations**

## *Scenarios*

- **Example 1 – Cesium**
- **Example 2 – Cobalt**
- **Example 3 – Americium**

## *Decontamination Techniques*

## *Decontamination Process*




## *Decontamination Techniques*

- Acids – dissolution of contaminates on substrates

- Chelants – dissolution chelation bond multivalent rad. for excretion
- $CO_2$ Blasting – abrasive removal/sublimation

## Decontamination Techniques

•Concrete Eating Bacteria – thiobacillus thiooxidans corrosion

•Dry Blasting – mechanical eroding of substrate

•Electro-kinetic Concrete Cleaning – electrical field induced migration of ionic contaminates

## Decontamination Techniques

•Foams – contaminant-specific extraction and encapsulation

•Gels – absorbent polymer gel fixes re-suspended rad. in engineered nanoparticles

•HEPA Vacuuming – vacuum filtration

## Decontamination Techniques

•Light Ablation – thermal vaporization

•Oxidizers – dissolution and erosion of substrate

•Manual Wiping – abrasive Removal

•Polymers – extraction filtration technology

## Decontamination Techniques

• Power Brushing mechanical erosion of contaminate substrate

• Pressure Washing – mechanical flushing

• Scabbling – mechanical eroding of contaminant

• Shaving – diamond tipped rotary cutting head surface removal

• Spalling – mechanical impact of contaminated surface

## Decontamination Techniques

• Sponge-jet Blasting – abrasive removal

• Strippable Coatings – chemical bonding to surface contaminates

• Vibratory Processing – high frequency removal in liquid media

• Hydrogen Peroxide – dissolution of materials on surface

• Geobacter Sulfurreducens – bacterial reduction of rad. producing precipitation

## EPA Homeland Security Research Program

# UK approach to RDD clean-up

**Dr Malcolm Wakerley**

Department for Environment, Food and Rural Affairs (Defra)

Washington, 25 February 2005

## Lessons to learn from

- Spain, US B-52 bomber nuclear weapons accident $10^3$t soil – US, 12,000m$^3$ vegetation waste
- Ukraine, Chernobyl reactor accident $^{137}$Cs fallout across most of Europe
- Brazil, Goiania, cancer therapy unit, $^{137}$Cs chloride, 3,000m$^3$ waste

## Consequences in UK

- Creation of Radiation Incident Monitoring Network, RIMNET, 92 gamma detectors about 30km apart and network of approved labs supplying data to London
- Need for large area monitoring – Airborne Gamma Survey
- 1996 review of decontamination and clean-up techniques for use in UK following radioactive accidents
  - National Radiation Protection Board
  - Rolls Royce Nuclear Engineering
  - Atomic Weapon Establishment

## 1996 Review

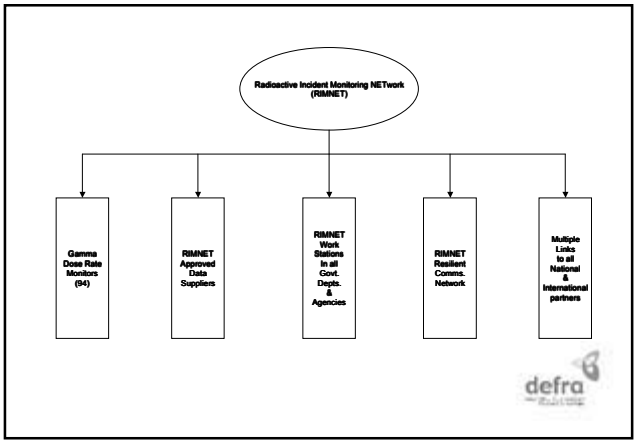
- Simple logic diagram and 22 tables on decontamination techniques, clean-up rates, resources required, costs incurred and wastes requiring disposal.
- Covers:-
  - metalled surfaces
  - large grass areas
  - gardens
  - trees and bushes
  - roofs
  - walls and windows
  - internal surfaces

## 1996 Review (cont)

- Worked example of a UK town, Gateshead and surroundings
  - 55 square miles
  - 200,000 population
  - 550 miles of roads
- Looked at inventory of mechanical equipment available within area and UK wide
- Used EXPURT (Exposure from Urban Radionuclide Transfer) Model

## Responses to 9/11

- Production of a Recovery Handbook for Radiation Incidents
- Production of a Recovery Handbook for CB Incidents
- Ability to feed Airborne Gamma Survey results to RIMNET
- Examination of modelling




## Radioactive Incident Monitoring Network (RIMNET)

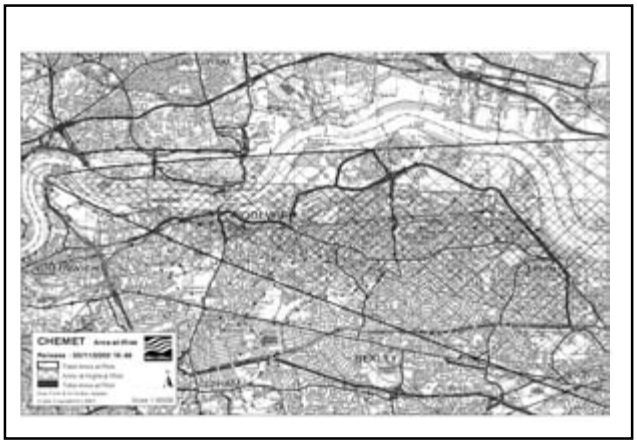
94 fixed monitoring locations across United Kingdom

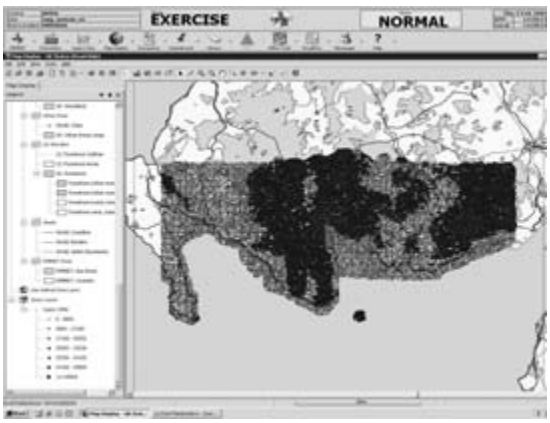
- Measuring ambient gamma dose rate
- Measuring Range: 50 nSv/h – 3 mSv/h
- Sensitivity: 15cps/uSv/h
- Temperature Range: -20oC - +40oC
- Energy Response: 60KeV – 1.25MeV, (normalised to caesium-137)


## Radioactive Incident Monitoring Network (RIMNET)

Access to modelling capability of UK Met. Office

- Short Range – Area of Impact (Chemet, PACRAM)
- Medium (Mesoscale) – Local effects (ADMS)
- Long Range (Lagrangian diffusion) – Transboundary impacts (NAME)



## Radiological Handbook

"To guide decision-makers through the available recovery options following a radioactive dispersal event"

Covers radionuclides that could be used by terrorists.

| | | | | |
|---|---|---|---|---|
| $^{60}Co$ | $^{75}Se$ | $^{90}Sr+^{90}Y$ | $^{95}Zr$ | $^{95}Nb$ |
| $^{99}Mo+^{99m}Tc$ | $^{103}Ru$ | $^{106}Ru$ | $^{131}I$ | $^{132}Te$ |
| $^{134}Cs$ | $^{136}Cs$ | $^{137}Cs$ | $^{140}Ba$ | $^{140}La$ |
| $^{144}Ce$ | $^{169}Yb$ | $^{192}Ir$ | $^{226}Ra+$ | $^{235}U+$ |
| $^{238}Pu$ | $^{239}Pu$ | $^{241}Am$ | | |

## Radiological Handbook (cont)

- Compilation of reliable, consistent and comprehensive information to help users identify issues and evaluate options
  - Recovery and Radiation Protection
  - Agricultural Food Production
  - Domestic Food Production and Free Food
  - Inhabited Areas
  - Drinking Water
- 570 pages and interactive CD format
- Being made available to US via Quad
- Being expanded to cover crops, climate in rest of Europe

## Radiological Handbook (cont)

| | |
|---|---|
| **Step 1** | Determine type of incident & scope radionuclides involved; scope extent & scale of contamination |
| **Step 2** | Determine extent of existing countermeasures eg precautionary advice/order, sheltering & evacuation |
| **Step 3** | Prioritise contaminated area into broad bands based on urgency of need for decisions. For each band: |
| **Step 4** | Determine land uses |
| **Step 5** | Divide contaminated area into broadly similar regions & into topic areas based on information obtained |

## Radiological Handbook (cont)

| | |
|---|---|
| **Step 6** | Prioritise regions &/or topic areas. Develop and implement monitoring strategy |
| **Step 7** | Consider options for each region and/or topic area |
| **Step 8** | Assess options for each region &/or topic area |
| **Step 9** | Choose options for each region &/or topic area |
| **Step 10** | Implement options Monitor & review effectiveness & impact of chosen options |

## Radiological Handbook (cont)


## Radiological Handbook (cont)

1 Introduction
2 Specific criteria for recovery in inhabited areas
3 Framework for making decisions
4 Determining the nature and extent of the incident and characterising the contamination
5 Estimating doses in inhabited areas
6 Considering appropriate recovery options
7 Assess consequences of implementing recovery options
8 Choice of a strategy
9 Pre-planning

United States
Environmental Protection
Agency



Office of Research and Development
National Homeland Security Research Center
Cincinnati, OH 45268

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EPA/600/R-05/083
October 2005