Medical Toxicology and Public Health—Update on Research and Activities at the Centers for Disease Control and Prevention and the Agency for Toxic Substances and Disease Registry

Curtis P. Snook, MD^a, John Cardarelli, PhD^a, R. Leroy Mickelsen, MS^a, Dino Mattorano, MS^a, Michael Nalipinski^b

^aNational Decontamination Team, U.S. Environmental Protection Agency

^bRegion 1, U.S. Environmental Protection Agency

The following is an update on activities in which medical toxicologists are actively involved at the EPA. The *Journal of Medical Toxicology* periodically will highlight some of these activities to illustrate the growing relationship between clinical toxicology and public health.

NATIONAL DECONTAMINATION TEAM, U.S. ENVIRONMENTAL PROTECTION AGENCY (EPA)

The National Decontamination Team (NDT) is responsible for providing scientific and technical expertise to local and regional EPA responders tasked with cleanup operations after incidents of environmental contamination involving chemical, biological, or radiological (CBR) agents. The NDT employs personnel with a wide variety of educational backgrounds and professional training including an analytical chemist; heating, ventilating and air-conditioning (HVAC) and other engineers; health physicists; industrial hygienists; a medical toxicologist; toxicologists; specialists in transportation and disposal of hazardous waste; and other environmental scientists and specialists. This wide range of expertise is necessary to address the broad scope of potential agents and activities needed for appropriate remediation of environmental contamination incidents. In addition to response activities, NDT scientists participate in the training of regional and local responders in the nature of CBR agents, responder health and safety, including proper personal protective equipment (PPE), environmental sampling and its phases along the

timeline of a response, decontamination technologies and strategies, risk assessment, and communication. An example of the type of events that the NDT has been involved in, and the toxicological issues associated with it, is the EPA response to the contamination of a shed, car, and house with naturally occurring *Bacillus anthracis* spores in Danbury, Connecticut, in 2007.

Bacillus anthracis Decontamination, Danbury, Connecticut, 2007

In August of 2007, a father and son in Danbury, Connecticut, developed skin lesions that proved to be cutaneous anthrax on culture. The cases were reported to the CDC and the FBI. The FBI and the Connecticut Department of Health sampled animal hides, originally from Africa, that had been handled by the father in making drums. The hides were found to be positive for *B. anthracis* spores. These spores were eventually determined to be naturally occurring and the event determined not to represent an act of bioterrorism.

In September of 2007, the Connecticut Departments of Environmental Protection and Public Health requested EPA's assistance in cleaning up the areas contaminated with *B. anthracis* spores. Available information indicated that the hides were processed into drums in a backyard shed and the father wore a respirator and protective outer clothing, which were reportedly removed before he entered the house. This explanation was consistent with the available sampling data. Samples were taken from inside the shed, a car used to transport the contaminated hides, a two-story house in which the two patients were living, and the yard. Most of the positive results were obtained from the shed.

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Approximately 20% of the samples taken from the house were positive. One of the samples taken from the car was positive and all samples taken from the yard were negative.

The EPA NDT received a request from an EPA Region 1 On-Scene Coordinator (OSC) for technical assistance with this incident. Decontamination and disposal were the primary concerns for which assistance was requested. Based on the successful prior use of amended bleach combined with high-efficiency particulate air (HEPA) vacuuming to decontaminate a New York City apartment, the OSC chose to use this decontamination strategy because it: 1) minimized hazards to applicators and the environment, 2) was easy to obtain and apply, 3) could achieve the necessary clearance criterion of no-growth, and 4) would quickly and efficiently allow reoccupancy by the family [1].

The shed and car were decontaminated using this approach through a series of steps including HEPA vacuuming, removal of contents, wetting surfaces with amended bleach, washing and brushing with soap and water, wetting and 60-minute contact time with amended bleach and rinsing with water. Copious amounts of amended bleach were applied within the shed, during which the applicators wore level-B personal protective equipment, which included full skin protection and a self-contained breathing apparatus. The shed doors were kept open to increase ventilation and reduce indoor airborne chlorine levels.

Post-remediation wipe and HEPA vacuum samples from the shed met the clearance criterion of no growth and supported the decision to allow reoccupancy. Similarly, wipe samples of the car resulted in no growth, which supported the decision to release it from impound. The portions of the house where positive samples were initially obtained were treated with HEPA vacuuming and bleach treatment. Post-treatment samples in those locations were negative; however, further sampling to characterize the extent of contamination within the house revealed additional contamination in locations not originally sampled.

During multiagency and multijurisdictional responses such as at Danbury, the EPA uses the Incident Command System (ICS) to coordinate the response. In this case, the ICS was followed and a Unified Command was established with representation from the City of Danbury, the Connecticut Department of Health (CDH), the Connecticut Department of Environmental Protection (CDEP), and the EPA. Assisting agencies included the FBI, CDC (including NIOSH), and the Red Cross.

The Unified Command made the decision to use a different decontamination technology for the house and porous personal items: fumigation with chlorine dioxide gas. This procedure was carried out with the help of a contractor procured with assistance from the NDT in December of 2007. The clearance criterion of no growth on post-decontamination samples was met after using this decontamination agent and procedure.

COMMENTARY

An extensive review of CDC epidemiological responses to human outbreaks of anthrax from occupational settings between the

years of 1950 and 2001 documented a variety of approaches to mitigation and decontamination [2]. These approaches included taking no action, burning contaminated materials, chlorinating water supplies, instituting administrative and engineering controls and PPE, vaccinating potentially exposed individuals, and in 2 instances, fumigating with formaldehyde vapor (now considered to be a human carcinogen). Secondary contamination of a worker's home was documented in 1 case, but not felt to be clinically significant to warrant any decontamination efforts. In response to the *B. anthracis* attacks in 2001, chlorine dioxide fumigation, vaporous hydrogen peroxide fumigation, and a combination of HEPA vacuuming, cleaning, and bleach application were all techniques used successfully to clean *B. anthracis* spore contamination.

Chlorine dioxide (ClO_2) is a yellow-green gas that is heavier than air and is used in a variety of industrial applications [3,4]. Many of these involve the use of its aqueous form. The bleaching of textiles and wood pulp for paper manufacturing is the most common use. Another frequent use is the purification of drinking water supplies. It is thought to be effective as a pesticide for *B. anthracis* because of its ability to oxidize proteins. Because it is not stable at high pressures, it cannot be stored or transported in high-pressure cylinders and must be generated on site. It is typically generated from chlorite (ClO_2^-) or chlorate (ClO_3^-) by a large number of different methods. Dry processes for its synthesis exist that rely on chlorine gas as a source material. However, this choice engenders the risks associated with accidental release of this gas either in transport or on site. A wet process can also be used in which the chlorine gas is generated on site using a reaction of hydrochloric acid with sodium hypochlorite. The chlorine gas, immediately on formation, is then reacted with a solution of sodium chlorite to generate the chlorine dioxide gas.

Chlorine dioxide is an irritant to airways, mucous membranes, and skin. It poses a risk of explosion at concentrations greater than 10% and is very reactive with some potential contaminants [5]. Structures to be fumigated with chlorine dioxide gas are covered with a tent to prevent environmental release during fumigation and perimeter air monitoring undertaken. Conditions of humidity and temperature are materially important to the success of fumigation and are monitored and controlled. Site security is important to prevent accidental exposure to unprotected bystanders. Spore strips are typically used as biological indicators during the fumigation process and constitute one measure of decontamination efficacy, as well as process parameter measurements such as chlorine dioxide concentration, temperature, and relative humidity. The final measure of decontamination efficacy and building clearance is post-decontamination environmental sampling. The currently accepted cleanup goal is no growth on all environmental samples.

Vaporous hydrogen peroxide (VHP) is another oxidizing fumigant with a long history of use as a disinfectant that is also used to decontaminate *B. anthracis* spores. It is generated by the controlled heating of a high concentration ($\geq 30\%$) aqueous solution of hydrogen peroxide in a sealed area under controlled conditions of relative humidity, which varies with the specific process

being used to generate the VHP [3]. Like chlorine dioxide, it decays over time and even more rapidly so that a continuous supply of fresh hydrogen peroxide is required to maintain the necessary sporocidal agent concentration.

HEPA vacuuming involves the use on surfaces of a vacuum cleaner that contains a HEPA filter. The HEPA filter cleans the vacuumed air of particulates at an efficiency of 99.97% for the most penetrating particle size (0.3 μ) and even greater efficiency for particles in the spore size range typical for naturally occurring *B. anthracis*. The spores are 2–6 μ in diameter and may be attached to one another or attached to other materials that would make filtration of the particles easier.

Amended bleach is a mixture of 1 part household bleach, 1 part vinegar, and 8 parts water. Household bleach is approximately 5% sodium hypochlorite. The amended bleach adjusts the pH to approximately 7 and the sodium hypochlorite concentration to approximately 0.5% or 5000 ppm. The amended bleach is more reactive than household bleach and has a shorter shelf life.

Role of a medical toxicologist on the EPA's National Decontamination Team

Subject matter expertise in medical toxicology in the NDT with the EPA is invaluable in a number of ways. One particularly relevant task was to prepare health and safety information for EPA responders to the recent incident involving the decay in orbit of a large US satellite that contained a large quantity of hydrazine. Another was to advise regional EPA and other federal and local responders on health and safety issues related to the occurrence of environmental contamination with ricin in Las Vegas, Nevada, and Salt Lake City, Utah.

Knowledge of medical toxicology has also proven useful in providing a medical perspective on the preparation of Provisional Advisory Levels (PALs) by the EPA's National Homeland Security Research Center (NHSRC). It became clear in the federal response to Hurricane Katrina that guidance in terms of relevant exposure limits was needed for time periods intermediate between those used for acute exposure (e.g., Acute Exposure Guideline Levels, or AEGs) and those used for chronic or lifetime exposures (Integrated Risk Information System, or IRIS values). Finally, an interesting role for a medical toxicologist in the EPA has been to serve as a liaison between responders and researchers working to

meet the informational needs of response. A taskforce was formed, the Taskforce on Research to Inform and Optimize (TRIO) chemical, biological, and radiological terrorist agent response, to innovate and improve cooperation and communication between these essential elements of readiness and response.

The EPA functions to protect human health and the environment. It has been presented with new challenges since the terrorist attacks on the United States in 2001. The NDT was created to help the Agency meet the challenges posed by responding to incidents involving chemical, biological, and radiological terrorism agents. A medical toxicologist has been an important and integral part of this new EPA resource.

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