Foam on the range

Geneviève Thouin and Konstantin Volchek of the Emergencies Science and Technology Division (ESTD), Environment Canada, discuss the challenges and outcomes of their chemical decontamination trial

A LARGE-SCALE decontamination technology demonstration was recently undertaken in Western Canada. This demonstration is part of a CBRN Research and Technology Initiative of Canada project CRTI-04-0019TD. The Chemical, Biological, Radiological, and Nuclear Research and Technology Initiative of Canada is the federal science community's response to providing science solutions to CBRN terrorist threats. It has been very successful, since its inception in 2002, in funding many science and technology projects and in building linkages among non-traditional partners. These new partnerships have increased knowledge and preparedness for countering CBRN threats by working together on a common mission.

The purpose of this demonstration project was to evaluate advanced decontamination technologies of buildings and structures. To date, chemical and biological trials have been completed and a similar radiological decontamination experiment is scheduled for early 2007.

This paper describes the chemical trial conducted in August 2006. Personnel from the Counter Terrorism Technology Centre, Defence Research and Development Canada in Suffield (DRDC Suffield), Environment Canada, Allen Vanguard Corporation, Science Applications International Corporation (SAIC Canada), and the US Environmental Protection Agency (US EPA) were all participants in this trial. The trial was carried out at DRDC Suffield, a designated Nato test site for such exercises.

To accommodate the chemical trial, a building was erected with three rooms that contained different combinations of the surface materials. Room A contained ceiling tiles, brick walls, and ceramic floor. Room B had ceiling tiles, drywall and carpet floor. Room C had ceiling tiles, wood wall panelling, and vinyl floor. The building was first contaminated with a mixture of the selected chemicals, diethyl malonate (DEM) and malathion, using spray dissemination. DEM was used to mimic the physical and chemical properties of nerve agents, while Malathion is representative of a large category of toxic industrial chemicals. The rooms were then

Table 1: Sequence of chemical demonstration major events (15 August 2006)

Time	Event
9:00	Equipment set-up
10:00	Decontamination line set-up and start of demonstration
10:43	First dissemination (Room C)
10:47	Malfunction with the spraying unit Preparation of alternate spraying device
11:37	Second dissemination (Rooms B and A)
11:45	Structure door closed
12:04	Collection of pre-decontami nation surface samples
12:10	Structure door opened
12:33	Structure door closed
12:38	Surface decontamination
13:08	Rinse
13:23	Defoaming
13:35	Collection of post-decontami nation surface samples
13:55	Structure door opened
14:03	Personnel decontamination and end of demonstration

decontaminated using the Surface Decontaminating Foam, also known as the Universal Containment System formulation. This product was developed by researchers of DRDC Suffield and is now marketed by Allen-Vanguard. The concentration of the target simulants on test surfaces and in the air was monitored prior to, during and after decontamination. A sequence of events is presented in Table 1.

Results of the trials were analysed, and the effectiveness of the decontamination technology was evaluated for different construction materials. Associated material and labour consumption is being assessed.

The exercise was a collaborative effort of several Canadian and US agencies, and was led by the Emergencies Science and Technology Division (ESTD) of Environment Canada. ESTD is responsible for chemical and oil spill research, development, training, and technology transfer. Its prime function is the development of knowledge and tools for oil and chemical spill preparedness. For almost 30 years the division has had a continuing national programme of research and development on spilled hazardous materials and spill countermeasures. Results of this research are regularly applied to real spill incidents, providing assistance to spill responders and feedback to the researchers on the direction of their work.

Technology transfer is an important component of the programme, and the group is active in providing operational guides, manuals and training, as well as some aspects of contingency planning. Additionally, the Division has an operational remote-sensing capability and also can provide specialised technical advice or analysis in support of real spill events. As the lead in this project, ESTD provided scientific, technological and analytical support, dissemination equipment, field analytical equipment, laboratory facilities and equipment for the analysis of surface, water and air samples, and qualified personnel in environmental emergency response, laboratory techniques, and analytical chemistry. Prior to conducting this decontamination demonstration, ESTD carried out major research funded by the CBRN Research and Technology Initiative to develop and evaluate surface decontamination technologies on a bench scale.

DRDC Suffield is one of Canada's main defence science and technology assets. It is located in southeast Alberta near Medicine Hat on one of the largest Nato military training facilities. Established in the early months of the Second World War, DRDC Suffield has long been active in the development of effective defensive countermeasures for chemical and biological weapons. DRDC Suffield has a chemical research group that is internationally renowned for both fundamental research and technology commercialisation.

The Counter Terrorism Technology Centre is part of DRDC Suffield. This centre is a key component of Canada's ability to respond to domestic and international chemical, biological and radiological, nuclear, and explosive (CBRNE) incidents. It uses highly specialised and safely equipped facilities to

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combat specific CBRNE threats. For the chemical trial, DRDC Suffield provided trial support, military detection equipment, detector paper witness cards and experimental expertise and personnel. The Counter Terrorism Technology Centre provided premises for test facilities, built the test structure, and provided personnel for support for contamination and decontamination tasks as well as an overall organisational support.

Allen-Vanguard is the leader in developing and marketing CBRNE decontamination equipment and technologies in Canada, the United States and the United Kingdom. The firm was assigned with the responsibility of decontamination for the chemical trial. For this demonstration, Allen-Vanguard tested the new Response Trike, developed during another project of the CBRN Research and Technology Initiative. This new system, which allows mixing and spray-application of the Surface Decontamination Foam ingredients, incorporates product improvements for enhanced material compatibility and cross-applications for other decontamination or hazmat scenarios.

SAIC Canada is a diversified high-technology research and engineering company focusing primarily in the market areas of environment, energy, and health. Its Environmental Emergencies Program, located in Environment Canada's Environmental Technology Centre in Ottawa, Ontario, focuses on research, development, and evaluation work related to the environmental emergency response. SAIC Canada provided personnel for logistics, sampling, and sample analysis.

The Environmental Response Team (ERT) is recognised as a vital link in the US EPA's continuing efforts to remediate and limit environmental damage to air, land, and water, and also in the evaluation of threats to human health. Established in 1978, the Environmental Response Team is comprised of a group of EPA technical professionals who provide experienced technical and logistical assistance in responding to environmental emergencies such as oil or hazardous materials spills, and the characterisation and clean up of hazardous waste sites. The ERT provides a full range of support for remediation of terrorist attacks, hazardous substance releases, and other complex emergency incidents. In such cases, the team can bring in special equipment with technically adept responders who provide experience and advice to the on-scene co-ordinator or lead responder. For the chemical field demonstration, the US EPA provided a team of experts as well as air analytical equipment, including a Trace Atmospheric Gas Analyzer (TAGA) bus.

Equipment Deployed

The demonstration was monitored by an array of sensors including about 100 sampling and monitoring instruments. These included portable Chemical Agent Monitors (CAMs), Chemical Agent Detection Systems (CADS II), AreaRAEs, TAGA, surface coupons, weather stations, etc.

Standard video and still photography were used in each room to obtain evidence of the spray pattern of the agent simulant mixture, mitigation properties of the Surface Decontamination Foam, and to provide a visual record of the trial. Witness cards comprised of three-way detector paper were used to obtain data on liquid agent droplet distribution and contamination density of the chemical simulants and their vapour presence were measured by portable Chemical Agent Monitors (CAMs), Chemical Agent Detection Systems (CADS II), and TAGA. All radio messages were recorded to provide an audio parallel to the video recordings.

The Canadian Forces use hand-held CAM sensors to detect chemical warfare agent vapour in air. This instrument is a portable ion-mobility spectrometer using a radioactive source to ionise substrates in sample air flows. It can be operated in either positive-ion mode (to detect G agents and VX) or negative mode (to sense vesicants such as mustard gas). DEM can trigger the positive detection mode. The CAMs were complemented with the CADS II, a real-time remote point source that can receive information from up to eight CAMs either by land line or by wireless radio frequency transmission, process, and record the signals.

An extensive air monitoring and sampling programme was undertaken in support of this project. Unique sampling ports were constructed and fastened to the building to permit monitoring and sampling of indoor air. In addition, several stations were positioned around the outside of the building. The data from one of those real-time air monitors is included in this report. The AreaRAE is a commercially available instrument with up to five gas detectors, including a photo-ionisation detector for parts-per-million measure-

Table 2: Surface Contamination Levels for DEM

Material	Location	Concentration (g/m^2)				Decontamination Rate (%)
		Before	St Dev	After	St Dev	
Ceiling tile	Rooms A, B, and C	3.08	3.51	0.17	4.16	94
Brick	Room A	5.00	3.55	0.00	0.00	100
Mortar	Room A	0.03	0.02	0.00	0.00	100
Ceramic tile	Room A	11.69	11.60	2.02	3.96	82
Grout	Room A	0.43	0.46	0.00	0.00	100
Drywall	Room B	6.63	3.21	0.00	0.01	100
Carpet	Room B	28.05	11.02	1.01	2.33	96
Wood panel	Room C	7.74	3.22	3.21	1.62	59
Vinyl tile	Room C	14.02	4.17	21.40	16.19	-53

Table 3: Surface Contamination Levels for malathion and malaoxon (in brackets)

Material	Location	Concentration (g/m^2)				Decontamination Rate (%)
		Before	St Dev	After	St Dev	
Ceiling tile	Rooms A, B, and C	3.83 (0.00)	4.28	2.30 (1.34)	3.60	40
Brick	Room A	2.79 (0.00)	1.99	0.25 (0.15)	0.22	91
Mortar	Room A	0.16 (0.00)	0.08	0.01 (0.00)	0.02	94
Ceramic tile	Room A	6.05 (0.00)	4.12	2.62 (0.31)	4.46	57
Grout	Room A	2.42 (0.00)	1.47	0.23 (0.00)	0.22	85
Drywall	Room B	3.03 (0.00)	1.62	0.70 (0.42)	0.63	77
Carpet	Room B	10.20 (0.00)	3.32	1.55 (0.57)	1.07	85

ment of volatile organic compounds (VOCs), a lower explosive limit (LEL), oxygen sensor as well as two electrochemical toxic sensors for measurement of specific toxic substances such as chlorine and sulphur dioxide. The field unit has an AC/DC power supply and is equipped with a wireless radio frequency modem which allows the unit to communicate and transmit readings and other information on a real-time basis with a remotely located base controller and computer.

TAGA is a triple quadrupole mass spectrometer, capable of monitoring with positive or negative ionisation using either a low pressure chemical ionisation source or an atmospheric pressure chemical ionisation source. To perform ambient air monitoring for the demonstration, the TAGA was used in positive ion mode to detect DEM.

Decontamination Results

In order to detect levels of contamination on building surfaces before and after decontamination, surface samples were extracted and analysed by GC/MS in the laboratory facilities of ESTD at the Environmental Technology Centre in Ottawa, Ontario.

In general, results for surface samples show an effective reduction in contamination levels after application of SDF. Not surprisingly, decontamination was better on non-porous surfaces than on porous surfaces, though the decontamination effectiveness on porous surfaces was higher than one would expect.

Table 2 shows concentration levels for DEM on the ceiling, walls, and the floor in each room, prior to and after decontamination. Relevant standard deviations and calculated decontamination rates are also presented. Table 3 shows similar results for malathion. It also shows, in brackets, numbers for malaoxon, a toxic degradation by-product of malathion.

A comparison of results in Tables 2 and 3 reveals a more effective destruction of DEM over malathion. This was not unexpected given the fact that DEM is relatively easily oxidised. The concentration of DEM was reduced on average by more than 90 per cent in Rooms A and B but far less in Room C. Room C was over-sprayed with a mixture of DEM and malathion as a result of a sprayer malfunctioning during the simulant dissemination phase. Much higher quantities of the simulant were released in Room C than it was called for in the test protocol. However, the amount of SDF used remained the same as was described in the protocol. Consequently, the quantity of SDF was not sufficient to react with the simulant in Room C. It was observed that the foam simply washed the simulant off the walls as opposed to reacting with it; simulant simply collected on the floor. Thus, the construction materials from the floor in Room C ended up with actual higher concentrations of simulant after decontamination. This resulted in a “negative” calculated decontamination rate. Similar trends are seen for the results for malathion in Table 3. According to Table 3, malaoxon formation was observed on some surfaces. This was likely the result of an incomplete oxidation of malathion.

In general, decontamination was quite effective considering the fact Allen-Vanguard used a highly diluted version of SDF for this trial. Doing this would allow them to gather important information on stoichiometry of a range of decontaminants for various substrates in a trial field setting. This is an important and valuable opportunity for any manufacturer.

Because of time constraints, decontamination was carried out only once, without being repeated. Prior to this field trial, a comprehensive two-year laboratory study at ESTD demonstrated that a higher strength SDF and repeated applications would result in practically 100 per cent destruction of malathion and virtually no malaoxon formed. Results of this trial suggest that a higher strength decontamination formulation and multiple applications will likely be required if the level of initial contamination is not known.

Along with surfaces samples, real-time air monitoring as well as air samples were collected throughout the trial. Responses increased during those times in which higher simulant vapour levels would be expected to be found (following application, downwind door opening, etc) and lower following decontamination. Despite the fact that CAMs are not designed to be used with DEM, the results generated by the CADS II during this demonstration have provided supporting data about the vapour levels of simulant present and the effect of applying decontaminant to the modules.

Real-time monitoring instruments were positioned outside the building. Tubing was used to connect the instruments to the sampling ports, thereby permitting air from inside the test structure to be examined. The data collected in room C – the first room that was contaminated and the last room downwind – by an instrument having a combination of combustible gas, toxic gas, and VOC sensors, From this data, additional information is collected. VOC peaks appear both with the dissemination of the simulants and the spraying of the decontamination agent, suggesting that both the agent mixture and decontamination agent contain VOCs. Chlorine peaks, however, only appear when the decontamination agent is applied, suggesting that chlorine may be evolved from the hypochlorite-based SDF. No concerns were associated with the oxygen levels, explosive vapour, or sulphur dioxide levels throughout the trial.

The TAGA was able to detect DEM levels as low as pptv in the downwind plume. As for the CAMs and AreaRAE, a good correlation between the events in the structure and the TAGA recordings was observed. Results from real-time air monitoring showed a reduction of over 90 per cent of the initial contamination levels after the decontamination formulation application. This illustrates the vapour suppression characteristic of SDF as well as its decontamination properties.

Conclusion

This exercise provided a unique opportunity to demonstrate large-scale decontamination of a building affected by chemical terrorism in a real field environment. It helped evaluate the performance of decontamination technologies by providing invaluable real-scenario information not always available in a laboratory setting. It proves that protocols and field trials are invaluable prior to finalising product development. It provided valuable scientific and technical information for future research and development as well as a more accurate estimate of resources required in terms of personnel, equipment, decontamination formulation, etc. It was also an opportunity to test and evaluate new monitoring instruments and equipment, as well as response procedures. This test will help in the development of equipment operator manuals, responder manuals, emergency procedures and guidelines.

This trial, along with the biological and radiological demonstrations, will also allow technological transfer, health and safety procedure sharing, and co-operation work between technology developers and users in the areas of emergency response and decontamination.