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Technical Report for the Demonstration of Wide Area Radiological Decontamination and Mitigation Technologies for Building Structures and Vehicles

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National Homeland Security Research Center
Office of Research and Development
U.S. Environmental Protection Agency
26 Martin Luther King Drive
Cincinnati, OH 45268

DISCLAIMER

The United States Environmental Protection Agency through its Office of Research and Development managed the research described here under Contract Number EP-C-11-038, Task Order 18. It has been subjected to the Agency's review and has been approved for publication. Note that approval does not signify that the contents necessarily reflect the views of the Agency. Mention of trade names, products, or services does not convey official EPA approval, endorsement, or recommendation.

Questions concerning this document or its application should be addressed to:

Sang Don Lee, Ph.D.
National Homeland Security Research Center
Office of Research and Development
U.S. Environmental Protection Agency
109 T.W. Alexander Drive
Research Triangle Park, NC 27711
Phone: 919-541-4531
E-mail: lee.Sangdon@epa.gov

Matthew Magnuson, Ph.D.
National Homeland Security Research Center
Office of Research and Development
U.S. Environmental Protection Agency
26 W. Martin Luther King Dr.
Cincinnati, OH 45268
Phone: 513-569-7321
E-mail: magnuson.matthew@epa.gov

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United States Environmental Protection Agency
Sang Don Lee
Matthew Magnuson
Ramona Sherman
Mario Ierardi
Scott Hudson
Terry Stilman
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Stephen Obsniuk

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Christanna Kendrot

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Garry E. McCormick
Michael Tobin
Larry Goff

EXECUTIVE SUMMARY

The U.S. Environmental Protection Agency in collaboration with the Department of Homeland Security conducted the "Wide-Area Urban Radiological Contaminant, Mitigation, and Cleanup Technology Demonstration" in Columbus, Ohio on June 22-25, 2015. Five wide-area radiological decontamination technologies (including strippable coatings, gels, and chemical foam technologies) were demonstrated on an urban building. Decontamination technologies were applied to remove the contaminants from the building's surfaces by physical, chemical, or other methods, which in practice could reduce the radiation exposure level. In addition, several radiological contaminant mitigation technologies were demonstrated, including building and vehicle wash technologies as well as several approaches to contain wash water and radioactive particles.

"Radiological contaminant mitigation" technologies are measures taken to reduce adverse impacts of radiological contamination on people and the environment and to facilitate such purposes as restoration of first responder services and critical infrastructure. Radiological contaminant mitigation technologies are designed for containing and removing radiological contamination on the surface in the first hours or days following a radiological event (early phase response). Such technologies include "radiological particle containment", which is designed to prevent the spread of particles that might result from vehicle or foot traffic. Radiological particle containment technologies are applicable for early phase response to contain the radionuclides and to reduce radiation dose to responders and the public. Radiological contaminant mitigation also includes "gross decontamination" technologies, which perform a type of decontamination that is conducted with the goal of reducing contamination levels. This reduction may not meet final cleanup levels but may be useful to mitigate some public hazard or contain contamination.

The purpose of the demonstrations was to educate potential end-users and stakeholders about a "Toolbox of Options" for radiological decontamination, as well as radiological contaminant mitigation. Both demonstrations were conducted using a 75-year old brick building and the surrounding area (including parking lots) in Columbus, OH. No radioactive contaminants were applied during either demonstration, as the objective was to duplicate and implement realistic operational conditions for these technologies. Surrogate contaminants such as particle tracers were used in several demonstrations. The decontamination technologies were used in a scaled-up setting with application to the building. Contaminant mitigation technologies were demonstrated on the building as well as on vehicles. Example technology application techniques/accessories included an articulating boom lift, repelling boatswain chair, stand-alone surface material structures, high-volume foam applicators, fire truck foam applicator, a vehicle wash tent for vehicles, particle tracers to simulate radiological contaminants, and liquid containment approaches of varying degrees of technological sophistication.

Example information that was obtained included decontamination rate, contaminant mitigation and containment capacity, user friendliness of each technology, the required utilities (electric, water, etc.) for each technology, skill level of workers required, and the cost. The condition (color, texture, integrity, etc.) of each building material present on the structure along with all structural components such as gutters, windows, doors, etc. was carefully examined and documented.

All demonstrations were open to individuals, organizations, and local, state, federal, tribal, and international governments who may be involved with implementing or planning radiological incident response. The demonstrations provided a unique opportunity to see more than 15 different technologies for decontamination and radiological contaminant mitigation (i.e., gross decontamination and containment). Five scalable technologies for wide-area radiological decontamination were demonstrated, including chemical foam solutions, strippable coatings, and gels. The gross decontamination technology demonstration included building and vehicle decontamination technologies and radioactive particle containment strategies. Wastewater treatment, a tool for waste management, was also demonstrated.

The demonstration also provided attendees a unique opportunity to participate in daily feedback sessions making the entire event an interactive training session pertaining to technology gap identification, inter-organizational communication of priorities and needs, and forward thinking about the planning required for proper preparation for a wide-area radiological event.

Whether for mitigation (i.e., gross decontamination and containment) or decontamination, decision-makers for all response groups need a variety of options since not every technology will be applicable to a specific incident or available at a specific site when needed. Certain technologies are more effective, but not widely available, while others are less effective, but more widely available. Other factors include resource availability and the ability to treat waste onsite without transport.

From all of the technology demonstrations, attendee feedback sessions, technical presentations, and other interactions, four themes emerged from the demonstration and are presented in the table below.

“Toolbox of Technologies” Emerging Themes
1. Full-scale testing of technologies is imperative for understanding function and efficacy.
2. “Systems approach” to a functional radiological response framework needs to be prioritized.
3. Communication amongst applicable agencies needs to be prioritized.
4. Fukushima response needs to be thoroughly studied, with application of lessons learned to develop a functional “systems based” framework for radiological response.

These themes are based on the observations of end-users and stakeholders of the demonstrated technologies applied specifically to the challenges of wide area radiological release, which can pose distinct challenges requiring specific solutions compared to other types of radiological releases such as nuclear warfare[18]. Integration of these themes into future research work and operational demonstrations may help develop and further systems, techniques, approaches, and processes to prepare the United States for possible future radiological incidents.

Acronyms

°C	degrees Celsius
ANL	Argonne National Laboratory
APR	Air-purifying respirator
CWCC	Columbus Window Cleaning Company
CASCAD	Canadian Aqueous System for Chemical/Biological Agent Decontamination
DeconGel	DeconGel™ 1128
DHS	U.S. Department of Homeland Security
EAI	Environmental Alternatives, Inc.
EC	Environment Canada
EPA	U.S. Environmental Protection Agency
FEMA	Federal Emergency Management Agency
HSRP	Homeland Security Research Program
INL	Idaho National Laboratory
IWATERS	Irreversible Wash Aid Treatment and Emergency Reuse System
kg	kilogram(s)
L	liter(s)
LLNL	Lawrence Livermore National Laboratory
Lpm	liters per minute
m	meter(s)
m^2	square meter(s)
min	minute(s)
mm	millimeter(s)
mph	miles per hour
MSDS	material safety data sheet
NGO	Non-governmental organization
NHSRC	National Homeland Security Research Center
PPE	personal protective equipment
psi	pound(s) per square inch
PVC	polyvinyl chloride
QAPP	Quality Assurance Project Plan
Rad	Radiation
SCBA	Self-contained breathing apparatus
SDF	Surface Decontamination Foam
Stripcoat	Stripcoat TLC Free ™
TSA	technical systems audit
UDF	Universal Decontamination Foam

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1.0 Introduction

The U.S. Environmental Protection Agency (EPA) has responsibility for protecting human health and the environment, including from accidental and intentional releases of radiological materials. In support of these responsibilities, the EPA National Homeland Security Research Center (NHSRC) has conducted performance evaluations for technologies aimed at the decontamination, gross decontamination, and prevention of the spread of radionuclides in urban settings.

In this report, "gross decontamination" is decontamination that is conducted with the goal of reducing contamination levels. This reduction may not meet final cleanup levels but may be useful to mitigate some public hazard or contain contamination. Preventing the spread of radionuclides in urban settings occurs through "radiological contaminant mitigation" technologies, which are measures taken to reduce adverse impacts of radiological contamination on people and the environment, and facilitate such purposes as restoration of first responder services and critical infrastructure.

The technology evaluations previously performed[1-17] have generated performance data at a small (e.g., laboratory) scale that can be used to support decisions concerning the selection and use of these technologies for urban surfaces contaminated with specific radiological agents. Quantitative measurements with live radiological materials (as well as complete technology descriptions) were performed in these performance evaluation studies[1-17]. Due to scale up concerns, additional information was needed regarding the suitability for deployment of these technologies in a wide-area scenario. Therefore, in June of 2015, EPA and the U.S. Department of Homeland Security (DHS) conducted a demonstration at Battelle in Columbus, OH. The demonstration had the objective of determining the practical and logistical realities in a wide-area decontamination scenario, such as applying decontamination technologies to tall buildings, washing vehicles, reducing spread of contamination from foot and vehicle traffic, and managing the resulting waste.

During this demonstration, no radiological material was used as a contaminant, and no quantitative measurement of removal was made. The demonstration included three main components: 1) each demonstrated technology was used (in the context of their use respective to building and vehicle application) and performance information pertaining to each technology was documented through observations by the technology operators, demonstration coordinators, video recording of the application procedures, and attendees viewing the technology application either in person (when safe) or via a live streaming video provided in a tent on the demonstration site, as well as online for those not able to attend in person; 2) during each day of the demonstration, the attendees were invited to provide feedback (how applicable to their organization, data gaps, etc.) about the technologies they had just seen demonstrated; and 3) one session of presentations that focused on the overall waste management response to a wide-area radiological incident. These latter considerations were summarized in a draft EPA report entitled, "Early Phase Waste Staging for Wide Area Radiological Releases." This report, available at http://www.epa.gov/hsresearch (last accessed January 28, 2016), should be referenced for additional inquiries regarding waste staging and generation.

Three major technology categories (all defined above) were included in the demonstration. While these categories are based on the different broad response phases during the incident timeline illustrated in Figure 1, all technologies may have a role in all phases, depending on site-specific conditions. The first major category, primarily applicable during early phase response, is for "gross decontamination" which, as defined above, may reduce contamination levels over a wide area, not to final cleanup levels, and may be useful to mitigate some public hazard to accomplish activities such as the ones listed in Figure 1. The second one was "scalable decontamination technologies" which could be used in the cleanup phase to meet final cleanup levels *and* for which their application can be scaled to match the amount of area contaminated.

The third category, radiological particle containment, can be important during both response phases because containment can enable both mitigation and decontamination activities. For example, radiological particle contaminant technologies are designed for containing and removing the radiological contamination on the surface in the first hours or days following a radiological event (early phase response) to prevent massive infrastructure (storm sewer, etc.) contamination during the first precipitation event or future well-intentioned response efforts. During all response phases, such containment may prevent the spread of radiological particles that might result from vehicle or foot traffic.

Figure 1 also includes potential technology users during the response timeline, as well as some of the types of activities that will also be occurring during these phases. (The users of the technologies during response will be incident-specific, so detailed discussion of "who" is beyond the scope of this document. However, a variety of responders may use these technologies, and many stakeholders have an interest in how the technologies are deployed.)

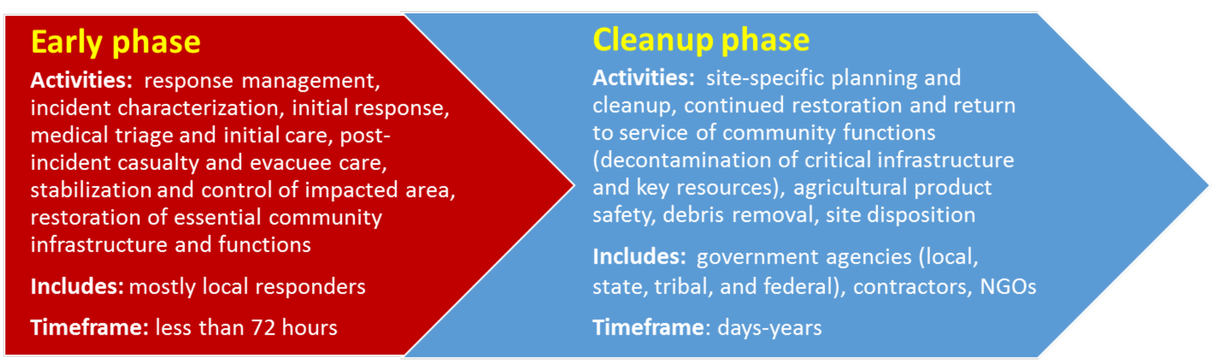


Figure 1. Incident timeline, including some potential activities and users during response phases. Other activities and users could be involved depending on site-specific conditions.

A building scheduled for demolition located in Columbus, Ohio was used as a test site for the demonstration. The building was constructed in 1940 and has four stories completely above ground (approximately 16 m) with an additional story (bottom) that is only half above ground. The building is mainly constructed of brick, but it has limestone sills beneath each of its numerous windows. The use of a structure destined for demolition provided the best case scenario for this technology demonstration as there is no concern for collateral damage.
Five "scalable decontamination technologies" were demonstrated on one side of the building, each over unique area of approximately 100 m^2 (16 meter (m) high x 6 m wide) for each

technology. The "gross decontamination" technologies were also applied to the other side of the building, as well as to vehicles. The waste water generated by these technologies were contained by liquid containment technologies of various levels of sophistication and, in the case of one technology, treated and reused. Two of these technologies were demonstrated in collaboration with the Columbus Division of Fire, as both involve additives to firefighting water or foam. One of the gross decontamination and liquid containment technology was composed of readily available, off-the-shelf components, and because it was designed and optimized to be a system, it perhaps represented the highest level of technology in this part of demonstration. In addition, two lower levels of technology for vehicle wash mitigation (and liquid containment) were demonstrated. They were also composed of commercially available, off-the-shelf components, used together but not optimized as a system.

To simulate and demonstrate radiological particle containment, fluorescent particles were applied to concrete pavers, and vehicles were driven over contaminated pavers that had been treated with particle containment technologies (test pavers) and those that had not (control). In addition, a person wearing cotton booties walked over test and control pavers. Afterward, a black light was applied to determine the relative extent of particle transport given the different technology types.

Table 1 gives the schedule of the demonstrations with each applicable technology, and Table 2 gives the general meteorological conditions during the demonstration. Overall, the weather for the demonstration could be described as warm, clear, and calm with temperatures between 22 and 34 degrees Celsius (°C) and relative humidity between 34% and 59% in the afternoon (81% and 92% in the mornings) with minimal winds. The outdoor conditions may have impacted the performance of some of the technologies (specifically the strippable coatings). However, additional experimental work would be required to confirm this. This report summarizes the demonstrations in the order in which they were performed.

Table 1. Demonstration Schedule

Day	Time	Activity	Vendor/Performer
Monday June 22	10:30 a.m.	Environmental Alternatives, Inc. (EAI) SuperGel	Battelle/EAI
	10:30 a.m.	CBI Polymers DeconGel™ application	Battelle/Idaho National Laboratory (INL)/Portage
	1 p.m.	Bartlett Stripcoat TLC Free ™ (Stripcoat) application	Battelle/INL/Portage
	3 p.m.	Demonstration Debrief and Feedback	NA
Tuesday June 23	9 a.m.	DeconGel removal (attempted)	INL/Portage
	10 a.m.	EAI Rad-Release II	Battelle/EAI
	11 a.m.	Stripcoat removal (attempted)	Battelle/INL/Portage
	1 p.m.	Environment Canada (EC) Universal Decontamination Foam	EC/Portage
	2 p.m.	DeconGel and Stripcoat application to a variety of surface materials	INL/Portage

	3 p.m.	Demonstration Debrief and Feedback	NA
Wednesday June 24	1 p.m.	Irreversible Wash-Aid, Treatment, and Emergency Reuse System: Building and Vehicle Wash; Separmatic Treatment	Argonne National Laboratory (ANL), HESCO, Separmatic, Columbus Division of Fire
	2 p.m.	EC Mitigation Formulation Building and Vehicle Wash	Columbus Division of Fire
	3 p.m.	Bosun chair application of decontamination technologies	Columbus Window Cleaning Company
	4 p.m.	Decontamination of a variety of surface materials	EC/INL/Portage
	5 p.m.	Demonstration Debrief and Feedback	NA
Thursday June 25	8:30 a.m.	Technical presentations	NA
	11 a.m.	Particle containment	Battelle and Lawrence Livermore National Laboratory (LLNL)
	1 p.m.	Other vehicle wash and liquid containment	Battelle/LLNL/Portage
	1:30 p.m.	Separmatic water barrel treatment	ANL/Separmatic
	2 p.m.	Demonstration Debrief and Feedback	NA

Table 2. Meteorological Conditions

Day/Time	Temperature [°C]	% Relative Humidity	Wind Velocity miles per hour (mph)
June 22/ 9 a.m.	24.2	81	0.3
June 22/ noon	30.5	59	3.2
June 22/ 4 p.m.	32.2	54	1.4
June 23/ 8 a.m.	22.7	92	2.2
June 23/ 1 p.m.	31.8	58	1.6
June 23/ 3 p.m.	34.1	49	2.0
June 24/ 1 p.m.	26.4	53	1.1
June 24/ 3 p.m.	33.5	34	0.9

The technology demonstration was conducted under the guidance of a Quality Assurance Project Plan (QAPP) entitled "Quality Assurance Project Plan for Demonstration of Non-Destructive Scalable Methods for Radiological Decontamination of Building Structures (Version 1.0 2/17/15)". The QAPP described each step of the demonstration to ensure that the technology demonstration was performed in a way that accurately reflected the purpose of the technologies and in a way that end users could understand the benefits and limitations of the technologies that were included. The QAPP also included the aspects of the demonstration that would be recorded for complete documentation of the technology demonstration and the vendor-provided procedures. The QAPP was prepared following the EPA Requirements for QAPPs (EPA QA/R-5, EPA/240/B-01/003). The Battelle QA Officer performed a technical systems audit (TSA) on June 23-25, 2015, to confirm compliance with the QAPP. Also present at the demonstration were EPA QA Officers on June 22-24, 2015. A TSA checklist was prepared and used to document the audit. No major findings were observed during the TSA.

For each of the technologies described below, a table is included that provides information applicable to the demonstration of each technology. Because the data in these tables are a mix of observation, collected data, and procedural information, Table 3 is given as an example of those tables describing the source and type of data for each table category. Note that cost is not included. Costs include materials, equipment, labor, waste disposal, liabilities, etc. and should be balanced against benefits as part of an overall analysis during planning and implementation.

Table 3. Example Technology Information from Demonstration

Surfaces	Surface description
Technology preparation	Description of steps required for technology preparation
Amount of material applied and collected as waste	Actual amount of material applied during demonstration (and collected as waste)
Time Required	Time required for application during demonstration
Application Method and Equipment Used	Equipment required for application during demonstration
Removal method	Vendor instructions for technology removal
Personal Protective Equipment (PPE)	PPE required for demonstration after review of Material Safety Data Sheets (MSDS)
Required Containment	Tools used to control spread of contamination due to application of each technology
Demonstration Observations	Observations of results of demonstration
Links	Links to EPA reporting site and/or demonstration video

2.0 Scalable Decontamination Technologies


Figure 2. Battelle Building A (East Wing) in Columbus, OH.

EPA has conducted extensive laboratory testing on decontamination technologies, [1-17] designed to determine efficacy or decontamination factors, at usually at a scale of 0.1 m^2 or less. This demonstration scaled up the application of the technologies to approximately 100 m^2 using an actual building under realistic outdoor conditions to observe operational factors at that scale. A building scheduled for demolition on Battelle's main campus located in Columbus, Ohio, was selected as the site where five scalable decontamination technologies were applied during the demonstration. Figure 2 shows the west face of the East Wing of Building A (hereafter referred to as "the building"), which is scheduled for demolition in late 2015. The use of a structure that will be demolished provides the best scenario for this technology demonstration as there is no concern about the possibility of slight damage to the property taking place. The building was constructed in 1940 and has four stories completely above ground (approximately 16 m) with an additional story (bottom) that is only half above ground. The building is constructed mainly of brick, but it has limestone sills beneath each of its numerous windows.

For the scalable decontamination technologies, the wall of the building was partitioned into five zones with equal surface areas of approximately 100 m^2 (approximately 16 m high and 6 m wide) (Figure 3). The surface conditions were dry upon application. There had been over 3 centimeters of rainfall two days before the start of the demonstration, but no rainfall occurred during the 24 hours preceding demonstration of any of the technologies applied to the building wall. On each day of the demonstration, the temperature, relative humidity, and wind velocity were measured at the demonstration site. The five decontamination technologies selected for the demonstration were CBI Polymer's DeconGel™ 1128 (DeconGel), Stripcoat TLC Free™ (Stripcoat), Environmental Alternatives, Inc., SuperGel and Rad-Release II, and Environmental Canada's (EC) Universal Decontamination Foam (UDF). Detailed descriptions of the technologies and corresponding application and removal procedures are presented in the following sections. These procedures were employed using a 20 m boom lift (Model 660SJ, JLG, Inc., McConnellsburg, PA) to reach the higher floors safely (Figure 4). There also was a sixth partition for application of the technologies using a bosun chair instead of the boom lift (see Figure 5).

A 20 m boom lift was the primary approach used during the demonstration to reach heights above 2 m because for buildings of 10 stories or less, boom lifts are commonly used for tasks like window washing and siding repair (and would likely be employed for decontamination if it were necessary). In addition, prior to the demonstration, all of the demonstration technology operators had previously completed the fall protection training required for work on a boom lift (thus, a very common skill). For buildings taller than 10 stories, bosun chairs are often used for similar tasks and, therefore, would be a plausible approach for decontamination if that were necessary. Because of the specialized training required for use of a bosun chair, Columbus Window Cleaning Company (CWCC) performed setup of the bosun chair using a portable rooftop rigging. For the gels and strippable coating, CWCC applied the decontamination material, and in the case of the liquids and foams, CWCC applied water to mimic application. This approach kept CWCC from needing to wear PPE required only for the liquids and foams that they were unaccustomed to wearing when working at heights. During an incident, PPE requirements would be determined from the site-specific health and safety plan.

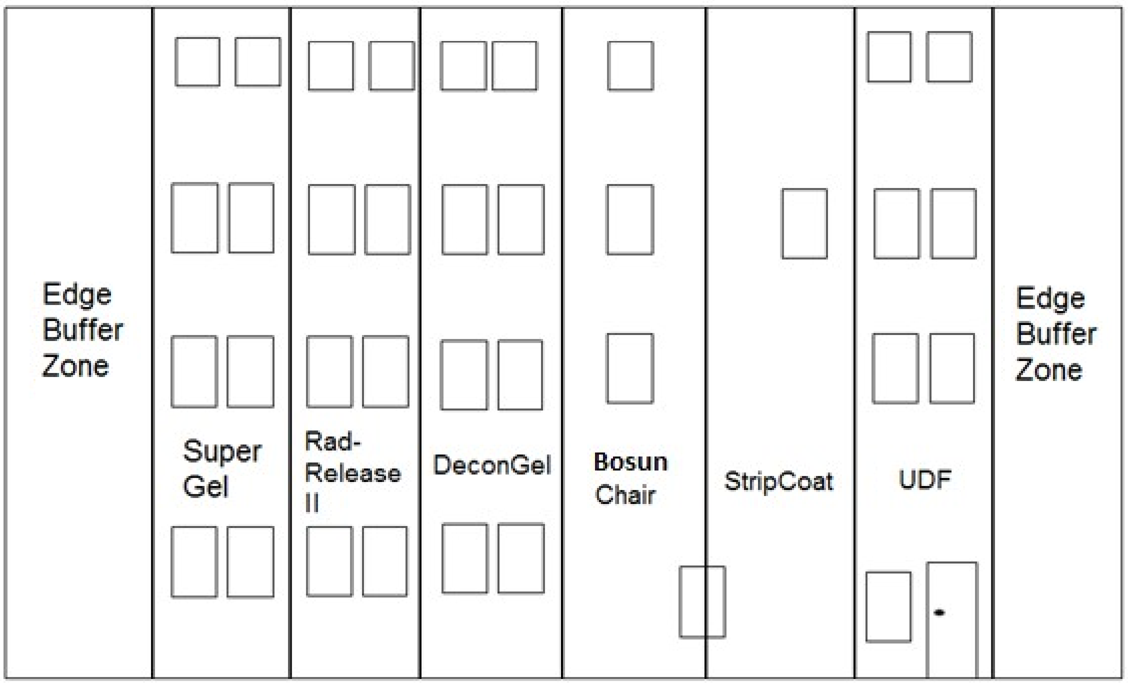


Figure 3. Labeled sketch of the west face of the building where demonstration of five scalable technologies took place, along with zones where technologies were applied. The sketch shows edge buffer zones where no products were applied. All of the scalable technologies were applied to small sections of the "Bosun chair" area.

Figure 4. Twenty-meter boom lift that was used to reach the higher elevations safely during the scalability demonstrations.

Figure 5. Bosun chair (left) and deployment from building roof (right).

2.1 DeconGel 1128 (CBI Polymers, Inc.)

DeconGel is one of several formulations by CBI Polymers, Inc., of a strippable coating designed for safely removing radioactive contamination from surfaces (decontamination application) or as a covering to contain contamination (mitigation application). DeconGel is sold as a water-based, paint-like (hydrogel) formulation that can be applied to horizontal, vertical, or inverted surfaces, including bare, coated and painted concrete, aluminum, steel, lead, rubber, plexiglass, herculite, wood, porcelain, tile grout, and vinyl, ceramic, and linoleum floor tiles. DeconGel is designed then to be peeled off, taking the contaminants with it, and according to the manufacturer and some of the EPA studies referenced above in this report, has successfully been peeled off many of the surfaces listed above.

Application and removal procedure. DeconGel was usable out of the container and required no mixing or diluting prior to application. The technology was applied to the building wall using an industrial electric airless sprayer (Magnum X7, Graco, Inc., Minneapolis, MN) with the spraying capability of 4 liters per minute (Lpm) (Figure 6). As described above, a 20 m boom lift was used to reach the higher elevations of the building. The application required that the sprayer tip have an orifice of 0.48 millimeters (mm). The manufacturer suggested that two coats would be adequate for coverage and successful removal. However, after applying two coats, the DeconGel did not peel from the brick as expected, so a third coat of DeconGel was applied on the first day.

After an overnight cure time, the DeconGel film was going to be peeled off by hand or in conjunction with a scraping tool to start the peel, but the film was too thin to peel off the wall easily. Therefore, three additional coats were added on the second day. However, after an additional overnight dry time, the coating was still unable to be peeled off the wall in pieces larger than a few square inches (Figure 6), having become entrapped in the mortar joints. Most of the DeconGel was not removed during the demonstration and was left to remain on the wall (which is scheduled for demolition). The DeconGel was able to be removed in large sheets from the window glass after an overnight curing time (Figure 6). In the small areas where DeconGel was removed from the wall, there did not appear to be any residual damage to the surface. It is not clear if the lack of ability to peel the DeconGel from the brick and mortar was solely due to thickness of the layer of DeconGel or if surface characteristics or some other variable (humidity or exposure to sunlight) played a role. The observations and details during the application of DeconGel are summarized in Table 4.

Figure 6. Application of DeconGel (left), attempted removal of cured DeconGel (which is non-hazardous) from brick and mortar (middle), successful removal from window glass (right).

Table 4. Summary of DeconGel Application

Surfaces	Brick and mortar, window glass, limestone window ledges, aluminum gutter, sod square
Technology preparation	Technology was ready to use out of the bucket
Amount of material applied and collected as waste	100 liters (approximately 91 kilograms (kg) wet weight) of DeconGel was applied to the wall in six coats. Dried coating was left on the wall.
Time Required	Spray application took place at a rate of 3 m^2/minute (min) for each coat (approximately 20 minutes for each coat). Vendor recommended additional coats could be added when previous coats were sticky (but not still running) to touch. An overnight curing time before peeling was recommended.
Application Method and Equipment Used	Graco Magnum^{TM} X7; 0.48 mm spray orifice and 1 Lpm flow rate (application by INL and Portage)
Removal method	Hand removal of dried film/coating
PPE (required by Battelle Health and Safety after review of MSDS)	• Tyvek coveralls • Nitrile gloves • Safety glasses • Face shield • Dust mask • Fall protection harness • Safety-toed boots
Required Containment	DeconGel did not drip or run appreciably during application. Use of drop cloths or plastic below application area was adequate for protecting surfaces below application area.
Demonstration Observations	**Brick/Mortar/Limestone:** Tried to hand peel DeconGel after three coats, but the film seemed to be too thin. Three more coats were added. However, even with additional thickness, the DeconGel could not be peeled off easily. **Window glass:** After three coats and an overnight curing, the DeconGel could easily be peeled off the window glass. **Aluminum gutter:** After three coats and an overnight curing, the DeconGel could easily be peeled off the aluminum gutter. **Sod:** DeconGel was applied to sod, but it fell right to the roots, not available for removal
Links	EPA RAD Removal Technical Brief (Last accessed January 21, 2016) EPA NHSRC Radiological Decontamination Reports (Last accessed January 21, 2016) Click on below image to play embedded video.  DeconGel 1128

2.2 Stripcoat TLC Free (Bartlett Nuclear, Inc.)

Bartlett's Stripcoat is a strippable coating designed for safely removing and preventing the spread of radioactive contamination. Stripcoat is sold as a paint-like formulation, and application options include use of a brush, roller, or sprayer. While curing, Stripcoat mechanically entraps contamination. Following application, the coating, according to the manufacturer, requires 4-10 hours to cure prior to removal. The dried coating containing the encapsulated contamination can then be peeled off the surface and disposed. According to the manufacturer, Stripcoat can also serve as a pre-contamination barrier to prevent contamination from attaching to a surface or as a covering to contain contamination, both contaminant mitigation applications.

Application and removal procedure. Prior to and during the application, Stripcoat was thoroughly mixed and applied using an industrial airless paint sprayer (Nova^{TM} 390 PC Airless Sprayer, Graco, Inc., Minneapolis, MN) (Figure 7). Typically, the coating can be removed after four hours of curing at normal room temperature, but during this demonstration, an overnight curing period was allowed before stripping. After an overnight cure time, the Stripcoat film was going to be peeled off by hand or in conjunction with a scraping tool to start the peel, but the film was too thin to peel off the wall easily (Figure 8). Therefore, two additional coats were added on the second day. After applying five coats of Stripcoat, the sprayer clogged and could not be repaired. After a second overnight drying period, the coating was still not able to be peeled off the side of the building, except in small pieces, as it appeared the coating became entrapped in the mortar joints. In the small areas where Stripcoat was removed from the wall, there did not appear to be any residual damage to the surface. Most of the Stripcoat was not removed during the demonstration. It is not clear if the lack of ability to peel was solely due to thickness of the layers of Stripcoat or if surface characteristics or some other variable (humidity or exposure to sunlight) played a role. The observations recorded by the technical staff during the application of Stripcoat are summarized in Table 5.

Figure 7. Stripcoat application via sprayer.

Figure 8. Removing Stripcoat by hand, peeling it off of the wall (cured material is non-hazardous).

Table 5. Summary of Stripcoat Application

Surfaces	Brick and mortar, window glass, limestone window ledges, aluminum gutter, sod square
Technology preparation	Technology was ready to use out of the bucket
Amount of material applied and collected as waste	100 L of Stripcoat (approximately 91 kg wet weight) were applied in five coats. Attempted to remove dried Stripcoat from wall. Technology was left on the wall.
Time Required	Spray application took place at a rate of 3 m^2/min (approximately 20 min total) for each coat. Recommended additional coats could be added when previous coats were sticky (but not still running) to touch. An overnight curing time before peeling was recommended.
Application Method and Equipment Used	Nova™ 390 PC Airless Sprayer, 0.48 mm spray orifice and 1 Lpm flow rate. (application by INL and Portage)
Removal method	Hand removal of dried film/coating
PPE (required by Battelle Health and Safety after review of MSDS)	• Tyvek coveralls • Nitrile gloves • Safety glasses • Face shield • Full Face Respirator or Half Face Respirator • Fall protection harness • Safety-toed boots
Required Containment	Stripcoat did not drip or run appreciably during application. Use of drop cloths or plastic below application area was adequate for protecting surfaces below application area.
Demonstration Observations	**Brick/Mortar/Limestone:** Tried to hand peel Stripcoat after three coats, but the film seem to be too thin. Two more coats were added. However, even with additional thickness, the Stripcoat could not be peeled off easily.

	Window glass: After three coats and an overnight curing, the Stripcoat could still not be peeled off the window glass as large pieces could not be peeled at a time, only very small (few cm^2) areas could be removed **Aluminum gutter:** After three coats and an overnight curing, the Stripcoat could not be peeled off the aluminum gutter for the same reasons as the window glass **Sod:** Stripcoat was applied to sod, but it fell right to the roots, not available for removal
Links	EPA RAD Removal Technical Brief (Last accessed, January 21, 2016) EPA NHSRC Radiological Decontamination Reports (Last accessed January 21, 2016) Click on below image to play embedded video. Stripcoat

2.3. SuperGel (Environmental Alternatives, Inc.)

SuperGel from Environmental Alternatives, Inc. (EAI) is a system of super absorbing polymers containing solid sequestering agents dissolved in a nonhazardous ionic wash solution. The resulting hydrogel is applied to a contaminated surface and provides exchangeable ions to the substrate which promotes desorption of radioactive cesium and other radionuclides. According to the manufacturer, the solid sequestering agent provides strong sorption of the target radionuclides within the gel. After removing the radionuclide-loaded hydrogel, the hydrogel can be dehydrated or possibly incinerated (depending on activity level) to minimize waste volume without loss of volatilized contaminants.

Application and removal procedure. SuperGel was prepared by combining two dry powders with water and mixing until a homogeneous mixture ('gel') was attained. SuperGel was to be applied by the vendor using their custom application equipment. The gel was applied to the surface by EAI staff with an industrial drywall texture sprayer (TexSpray™ RTX 1500, Graco, Inc., Minneapolis, MN) (Figure 9) and was left on the surface for 90 minutes. Removal was attempted by use of an industrial wet/dry vacuum (970C, Shop-Vac Corp., Williamsport, PA) (Figure 10) equipped with a 2-inch vacuum hose that continued to clog. For the demonstration, EAI had elected to use a vacuum provided by Battelle. Upon experiencing clogging, EAI noted that they would generally use a higher capacity vacuum to facilitate removal. As a result, a water rinse was applied to the wall surface to remove the SuperGel. The rinse water was collected using an aluminum gutter located at the base of the building to contain the SuperGel and water rinse. The residual material was collected by inserting a vacuum hose at the downhill side of the gutter (Figure 11). Water rinsing requires that the SuperGel (and contamination) be rinsed down the side of the building to reach the removal point, which is less preferable than vacuum removal at the contamination location. After SuperGel application and removal, there were white grainy particles that remained on the surface. However, two months after the demonstration, those residual particles were no longer visible. It is unclear whether the materials observed on the surface were removed by precipitation, wind, or denatured in place. The observations recorded by the technical staff during the application of SuperGel are summarized in Table 6.

Figure 9. SuperGel Application via sprayer.

Figure 10. Attempting to vacuum SuperGel. Vacuum hose kept clogging.

Figure 11. Applying a water rinse for SuperGel removal (left) and an aluminum gutter system at base of building for SuperGel and rinse water containment and collection using a vacuum (right).

Table 6. Summary of SuperGel Application

Surfaces	Brick and mortar, window glass, limestone window ledges, aluminum gutter, sod square
Technology preparation	Combination of two dry powders with water and then mixing
Amount of material applied and collected as waste	88 L of SuperGel applied and 220 L gallons of rinse water used for application to 100 m^2
Time Required	Spray application to the 100 m^2 area took place at a rate of 4 m^2/min (23 min). During non-demonstration conditions, a 90 min dwell time would be required, but that was not done. Initial vacuum step provided limited success in removal. Water rinse and final vacuum step took 52 min (2 m^2/min). For spray application and rinse removal, total decontamination rate was approximately 1.5 m^2/min.
Application Method and Equipment Used	Graco Drywall Texture Sprayer TexSpray™ RTX 1500; vendor applied
Removal method	Vacuum SuperGel off wall, rinse wall with water, vacuum rinse water
PPE (required by Battelle Health and Safety after review of MSDS)	• Tyvek coveralls • Nitrile gloves • Safety glasses • Face shield • Dust mask • Fall protection harness • Safety-toed boots
Required Containment	Aluminum gutter attached to base of building used in conjunction with vacuum waste collection at downhill side of gutter.
Demonstration Observations	**Brick/Mortar/Limestone:** SuperGel was applied to these surfaces as described above. Vacuum removal was attempted, but clogging necessitated water rinse removal. Small amounts of particle residue remained after removal; that residue was not present two months later. **Window glass:** SuperGel was applied and rinsed completely off the glass.

	Aluminum gutter: SuperGel was applied and rinsed completely off the gutter. **Sod:** Stripcoat was applied to sod, most was observed to sit on top of the sod and was observed to be mostly vacuumed off.
Links	EPA RAD Removal Technical Brief (Last accessed January 21, 2016) EPA NHSRC Radiological Decontamination Reports (Last accessed January 21, 2016) Click on below image to play embedded video.  SuperGel

2.4. Rad-Release II (Environmental Alternatives, Inc.)

The Rad-Release II decontamination technology from EAI is a chemical process that involves the sequential surface application of two solutions. The technology extracts radionuclides, including transuranics, from nearly all substrates. According to the manufacturer, the technology can be deployed on various geometries including walls, ceilings, equipment, structural beams, internal piping, and highly irregular surfaces. This process was developed to be used in sequence to synergistically remove the contaminants via the migration pathways, pores, and capillaries of the contaminated material.

Application and removal procedure. Both Rad-Release II solutions (i.e., Solution 1 and Solution 2) were usable out of the container and required no preparation prior to application. Rad-Release II was be applied and removed by the vendor using their custom application equipment. Each solution was applied to the building wall by EAI staff using an industrial foamer (Figure 12). Solution 1 was applied first using the foamer along with a light scrubbing (Figure 13) to ensure good contact with the contaminated surface. Typically, the solution would be left on the surface for 30 minutes, but in the case of this demonstration, the solution was left for only eight minutes. After eight minutes, the foam was rinsed off using water (Figure 14). The steps used for the application of Solution 1 were then repeated for Solution 2. After the final Rad-Release II water rinse, the surface was vacuumed (Figure 15). Following removal, the brick surface took on a white chalky look that was rinsed two additional times the following week. The additional rinses did not seem to help, as the staining of the surface did not seem to have diminished over the course of two months following the demonstration (Figure 16). The observations recorded by the technical staff during the application of Rad-Release II are summarized in Table 7.

Figure 12. Application of Rad-Release II Solution 1 from the ground (left) and lift (right).

Figure 13. A battery powered rotating scrub brush was used after application of Rad-Release II Solution 1 and Solution 2.

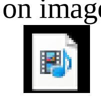
Figure 14. Water Rinse of Rad-Release II Solution 1.

Figure 15. After water rinse was applied, the Rad-Release II was vacuumed.

Figure 16. Brick took on a white "chalky" look after water rinse and vacuum removal steps of Rad-Release II. Image on left was taken a few days after demonstration, and image at right was taken two months after demonstration. Staining is evident as brick between windows in right image remained untreated while that to the left of the vertical line is clearly still stained (different shade of overall brick color is due to the lighting when the picture was taken).

Table 7. Summary of Rad-Release II Application

Surfaces	Brick and mortar, window glass, limestone window ledges, aluminum gutter
Technology preparation	Both Solution 1 and Solution 2 were usable out of the container
Amount of material applied and collected as waste	48 L of Solution 1 and two foams. Used 32 L of rinse water each for a total of 160 L liquid waste.
Time Required	Application, rinse, and vacuum removal of Solution 1 took 43 min total. Application, rinse, and vacuum removal of Solution 2 took 36 min total. Overall rate of 1.3 m^2/min.
Application Method and Equipment Used	Foamer to apply Solutions 1 and 2. A long handled, power-operated scrub brush; vendor applied
Removal method	Rinse and vacuum
PPE (required by Battelle Health and Safety after review of MSDS)	• Tyvek coveralls • Nitrile gloves • Safety glasses • Face shield • Dust mask • Fall protection harness • Safety-toed boots
Required containment	Containment and collection of 160 L at the base of the building was done with plastic sheeting taped to wall and sand bags creating small berm from which to vacuum rinse water.
Demonstration Observations	**Brick/Mortar/Limestone:** Rad-Release II left a white stain on the surface of the brick and limestone that was visible upon drying. Two additional water rinses were attempted in the week following the demonstration, but the staining remained. The stain was still evident two months following the demonstration.

	Window glass: Rad-Release II left some white streaks on the window glass, but most of it rinsed off cleanly. Appeared to remove some paint from window frames, which, if there is lead in the paint, would create a mixed waste situation. **Aluminum gutter:** Rad-Release II rinsed cleanly off the aluminum gutter.
Links	EPA RAD Removal Technical Brief (Last accessed January 21, 2016) EPA NHSRC Radiological Decontamination Reports (Last accessed January 21, 2016) Click on image below to play embedded video.  Rad Release II

2.5. Universal Decontamination Foam (Environment Canada)

Environment Canada's UDF was developed to enhance the radiological decontamination performance of Allen-Vanguard's existing commercial product called Surface Decontamination Foam (SDF). SDF is an aqueous foam decontaminant that is a derivative product of the Canadian Aqueous System for Chemical/Biological Agent Decontamination (CASCAD). SDF was originally developed primarily as a decontaminant for chemical and biological response and was not intended for radiological decontamination. The development of UDF was funded by the Chemical, Biological, Radiological-Nuclear and Explosives Research and Technology Initiative, Defense R&D Canada. National Homeland Security Research Center (NHSRC) was included in the development plan for the purpose of radiological efficacy determination and also contributed project funding for this purpose. In comparison to SDF, UDF contains radionuclide-sequestering agents. However, the UDF retains the chemical and the biological decontamination capability of SDF. When used for radiological decontamination, the foam can be rinsed off as soon as possible. For chemical and biological application, the foam is left on the surface for 30 minutes prior to rinsing.

Application and removal procedure. As shown in Figure 17, an industrial foamer (Air Foam Dolly System™, Allen-Vanguard, Ottawa, ON,) was used to apply the UDF to the building wall. Before application, the foamer was loaded with liquid foam and pressurized to 80 pounds per square inch (psi) with compressed air using a 4500 psi carbon wrapped 89 cubic foot Self-Contained Breathing Apparatus (SCBA) cylinders with CGA 347 fittings. The foam was then applied to the surface and rinsed immediately with water. No residue or surface damage was visible on the brick wall after application and removal. UDF has an oxidizer needed for chemical and biological decontamination. The oxidizer generates a chlorine odor (intensity varies with the degree of ventilation). As chemical and biological decontamination was not required for purposes of this demonstration, tests on the large surface area were done using UDF without an oxidizer. For control purposes, the oxidizer-containing formulation was applied to a small area on the wall using a handheld pump (Figure 18) and then rinsed. No residual or wall damage or discoloration was observed. The foams were removed by rinsing with water, and collection of foam was accomplished with a 4 m x 12 m x 0.3 m portable berm (12' x 36' x 1' Stinger™ Snap-Foam Berm, Container Corporation, Temecula, CA) composed of rugged, resistant fabric material with a capacity of 12,800 L (Figure 19). A conventional wet/dry vacuum was used to transfer the waste into drums. A defoaming agent was used to reduce the volume of foam collected and to prevent the vacuum hose from clogging. The observations recorded by the technical staff during the application of UDF are summarized in Table 8.

Figure 17. Air Foam Dolly System (left) used for UDF application (right).

Figure 18. UDF containing the oxidizer was applied to a small area using a handheld sprayer.

Figure 19. A water rinse was applied to remove UDF.

Table 8. Summary of UDF Application

Surfaces	Brick and mortar, window glass, limestone window ledges, aluminum gutter, sod square
Technology preparation	Environment Canada prepared foam additives in laboratory setting (because reagents are not packaged commercially in a pre-weighed fashion) in advance of demonstration.
Amount of material applied and collected as waste	140 L of foam was applied to 100 m^2 of building, 120 L of water was used to rinse as well. Approximately 1 L defoamer was added to waste stream. Portage performed application.
Time Required	Less than one minute to apply. Water rinse took between 2-3 minutes.
Application Method and Equipment Used	Air Foam Dolly System, Allen-Vanguard
Removal method	Water rinse using Air Foam Dolly System as water sprayer.
PPE (required by Battelle Health and Safety after review of MSDS)	• Tyvek coveralls • Nitrile gloves • Safety glasses • Face shield • Full Face Respirator or Half Face Respirator • Fall protection harness • Safety-toed boots

Required containment	Portable berm system extending 4 m from wall, 12 m wide, and 0.3 m deep. Foam was vacuumed into drum for disposal.
Demonstration Observations	The spray direction was impacted by the breeze occurring during application to building. The impact of wind should be taken into account to minimize overspray and to better contain the foam. **Brick/Mortar/Limestone:** UDF foam rinsed cleanly from building surfaces with no apparent residue. **Window glass:** UDF foam rinsed cleanly from window with no apparent residue. **Aluminum gutter:** UDF foam rinsed cleanly from gutter. **Sod:** UDF was applied to sod, and upon rinsing it washed to the roots, not available for additional removal.
Links	EPA RAD Removal Technical Brief (Last accessed January 21, 2016) EPA NHSRC Radiological Decontamination Reports (Last accessed January 21, 2016) Click on image below to play embedded video.  UDF

2.6 Summary of Impact of Technologies on Surface Appearance

The five technologies caused changes to the condition of the brick wall to varying degrees, as mentioned in Sections 2.1-2.5. In Figure 20, the top left photo shows the condition of the brick before the demonstration. After the UDF application and water rinse, the condition of the brick appeared to be identical to the pre-demonstration conditions. In the small areas that the Stripcoat and DeconGel were able to be removed from the brick and mortar, the brick surfaces appear to be unchanged from before application. The remaining two technologies caused the appearance of the brick to change after application. More specifically, SuperGel left white, grainy particles on the brick and the Rad-Release II cause discoloration of the bricks. Figure 21 shows a zoomed out image of the wall two months after the demonstration was completed. From a distance, it is difficult to notice any particles on the brick from the SuperGel. However, the Rad-Release II discoloration is very noticeable.

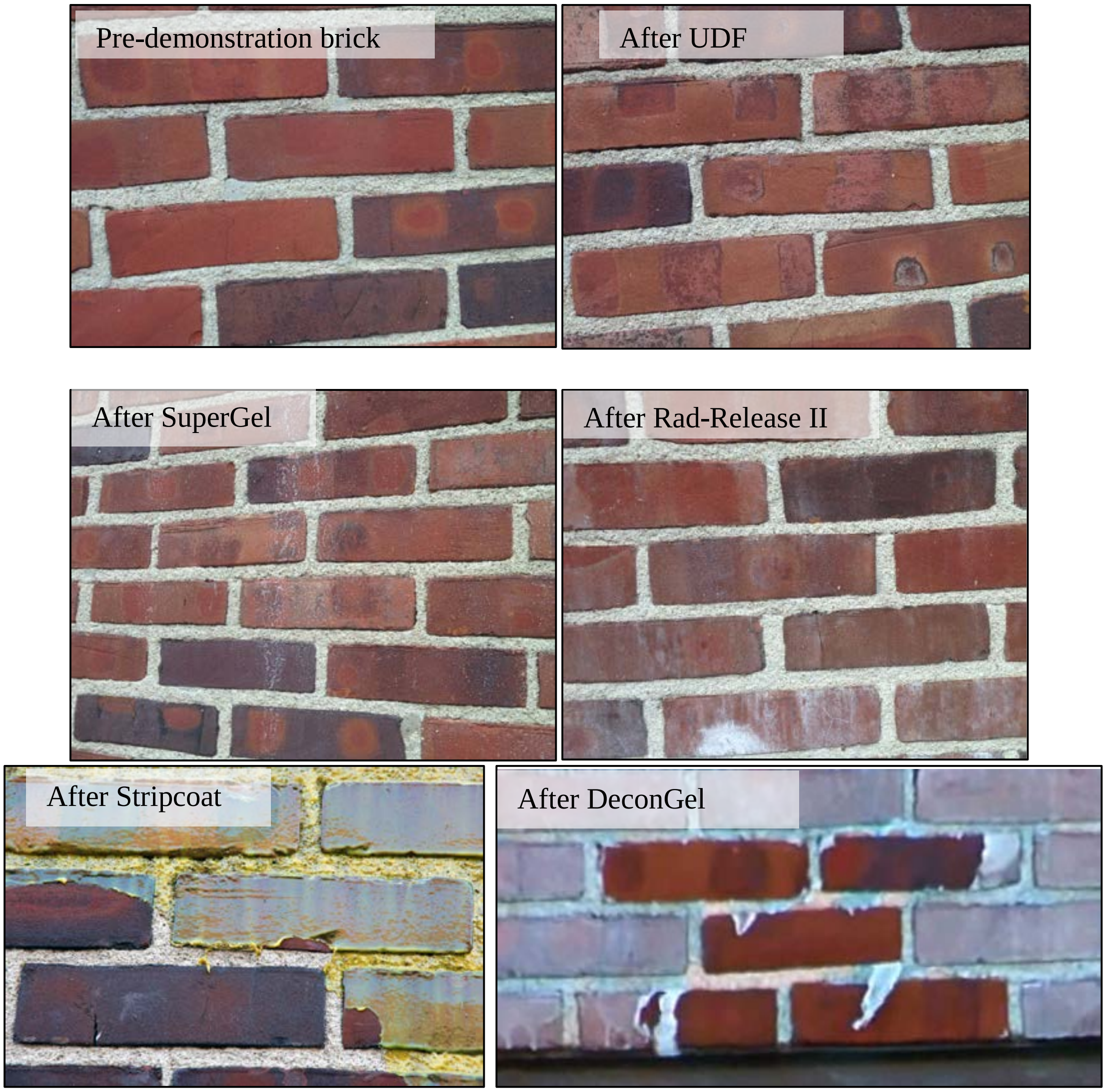


Figure 20. As seen in the images above, the condition of the brick after the application of UDF was unchanged from the pre-demonstration brick. After the application of SuperGel, small particles were seen on the brick. The condition of the brick was altered after Rad- Release II application, and a white "chalky" discoloration was observed. The strippable coatings (Stripcoat and DeconGel) were unable to be removed from the wall easily but were removed as intended from the window glass. In the small areas where the Stripcoat and DeconGel were able to be removed from the brick, the surface appears to be unchanged.

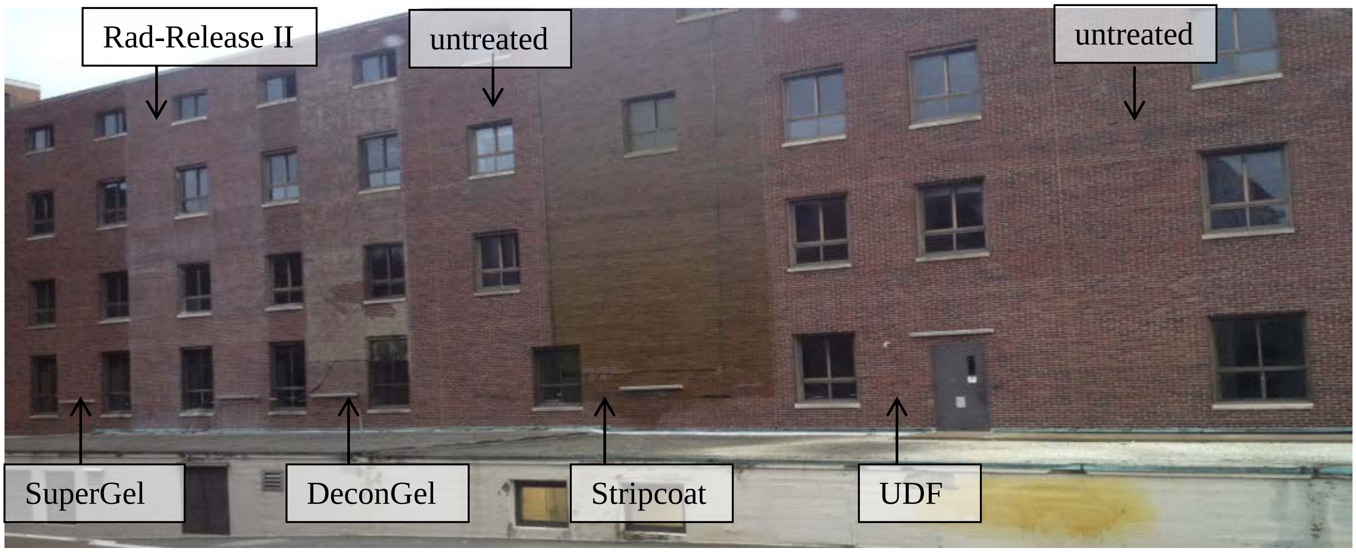


Figure 21. Labeled diagram of the west face of the building, two months after the demonstration occurred, showing the application locations of each of the five technologies. Rad-Release II discolored the bricks. DeconGel and Stripcoat were not able to be peeled off the wall easily, as intended. Other portions of the wall appear unaffected.

2.7. Bosun Chair Application

The bosun chair (Figure 4, left) is a common tool used by window washers. The chair closely resembles a swing and is comprised of a plank (or board) for the operator to sit on and straps, which connect to a rope. All the tools needed for the job are attached to the operator to prevent accidental drops. The simplistic design, versatility, and current widespread availability in the window washing industry make the bosun chair an obvious candidate for applying radiological decontamination technologies in an urban setting with high-rise buildings. Figure 4 (right) shows how the bosun chair was deployed off the side of a high-rise building. The operator started at the top of the building and slowly lowered the chair to progress downward. The chair was attached to an anchor point located on the roof of the building, and the operator wore a safety harness.

Application and removal procedure. Because the bosun chair was demonstrated only for the purpose of "proof of concept" during this demonstration, the application of each of the five scalable decontamination technologies was conducted on a smaller scale. An area of about 0.6 m by 1 m was targeted for each technology. DeconGel, Stripcoat, and SuperGel were applied with a paint brush (Figure 22). Because the bosun chair operator was not accustomed to working with chemicals, water was used to simulate the Rad-Release II and UDF technologies. During an actual incident, operator PPE requirements will be determined from the site-specific health and safety plan.

Applications were simulated using hand sprayers (Figure 23). The SuperGel was removed from the wall with a water rinse from a hand sprayer (Figure 24). Removal of the Stripcoat and DeconGel was attempted a week later as heavy rain occurred on the scheduled day of removal. However, neither DeconGel nor Stripcoat was able to be removed easily (similar to for the rest of the wall). A summary of the observations made regarding the bosun chair application is shown in Table 9.

Figure 22. Bosun chair application of DeconGel (left), Stripcoat (middle) and SuperGel (right) using a paint brush.

Figure 23. Bosun chair application of water simulation of Rad-Release II with a hand sprayer, followed by hand scrubbing.

Figure 24. SuperGel was removed from the wall using a water rinse from a hand held sprayer.

Table 9. Summary of Bosun Chair Application

Surfaces	Brick and mortar
Technology preparation	Same preparation steps taken as listed in above sections for each technology
Amount of material applied and collected as waste	Less than 4 L of each technology
Time Required	Application was completed on the afternoon of June 24, 2015. Because of the very small surface area (~1 m^2) that was covered to achieve the proof of concept of use of the bosun chair, the amount of time required to apply each technology was minimal.
Application Method and Equipment Used	DeconGel, Stripcoat, and SuperGel were applied with a paint brush. Because the bosun chair operator was not accustomed to working with chemicals, water was used to simulate the Rad-Release II and UDF technologies. Applications were simulated using hand sprayers.
Removal method	Rinse water was applied with hand sprayers for SuperGel, Rad-Release II, and UDF. The removal of the two strippable coatings was attempted but was not successful (as for the rest of the wall). The inability to remove the coatings was observed to be independent of the use of a bosun chair.
PPE (required by Battelle Health and Safety after review of MSDS)	• Tyvek coveralls • Nitrile gloves • Safety glasses • Fall protection harness • Safety-toed boots
Demonstration Observations	Columbus Window Cleaning Company (CWCC) was used to perform bosun chair work. Bosun chair operation requires anchors to be mounted to building roof (provided by CWCC). While technologies were observed to be able to be applied while using bosun chair, it appears that the surface area for which it would be practical for would be limited.
Links	Click on below image to play embedded video. Bosan Chair

2.8 Application to the Stand-Alone Surfaces

To test the decontamination technologies on additional building materials not found on or in the building, large slabs of common urban building materials (granite, quartz, marble, and limestone that were sealed and polished as standard countertops) were used. The slabs were divided into four sections, and one piece of each material was glued together to create one slab (2 m wide x 1.3 m tall) for each of the five technologies. The material slab(s) were located at ground level to allow for easier application of the technologies and easier visual comparison across different materials. The slabs were supported on metal racks with casters (OSA7247 A-Frame, Abaco Machines, Paramount, CA), and the racks with slabs were set up inside a 5 m wide x 5 m long x 0.3 m high containment berm (Model #4816-BK-SU, ENPAC Corp., Eastlake, OH). The application of the technologies was conducted on a smaller scale for the stand-alone application (Figure 25). Less than one liter of technology was applied to each slab. DeconGel and Stripcoat were poured into paint trays and applied with a paint roller. Rad-Release II and UDF were applied with a hand sprayer. SuperGel was applied with a hand trowel. There were no difficulties in application of any of the five technologies. Unlike the building application, the DeconGel and Stripcoat were easily removed from the materials in relatively large sheets of dried coating (after application of just two coats of material and an overnight curing time. (Figure 26). SuperGel, Rad-Release II and UDF foam were all rinsed from the surfaces without problem. The use of the Stripcoat, DeconGel, UDF and SuperGel did not result in any change in the physical appearance of the multi-material slabs. The Rad-Release II impacted the surface finish of the granite and limestone (Figure 27) by leaving a residue behind. Click the icon to view the demonstration video.

Stand Alone Surface Application

Figure 25. Stand-alone application of technologies. UDF (top), SuperGel (bottom left), Rad-Release II (bottom right).

Figure 26. Removal of technologies from stand-alone surfaces. DeconGel (top left), Stripcoat (top right), UDF (middle left), Rad-Release II (middle right), SuperGel (bottom).

Figure 27. As seen in the images above, the condition of the granite and limestone changed after the application of Rad-Release II. The granite had a wet, streaky appearance, and the limestone showed white "chalky" residue. The appearance of the marble and quartz did not appear to be altered.

3.0 Radiological Contaminant Mitigation Technologies

Radiological mitigation technologies are designed for containing and removing the radiological contamination on the surface in the first hours or days following a radiological event (early phase response) to prevent massive infrastructure (storm sewer, etc.) contamination during the first precipitation event or future well-intentioned response efforts. Below are descriptions of several mitigation technologies included in the demonstration, which collectively encompass approaches for water based washing, containment of the resulting aqueous waste, and on-site waste treatment. An additional aspect of the overall demonstration was to illustrate the importance of appropriate vehicle washing to avoid radiological particle movement by vehicle traffic.

3.1 Environment Canada Foam Building and Vehicle Application

Using a firefighting foam additive from Environment Canada, a prescribed 100 m^2 section of the east face of the east wing of the building and a vehicle were coated with foam and rinsed off to demonstrate the use of this product.

Building application. The Environment Canada additives (proprietary reagents for radiological mitigation) were prepared from purchased chemicals by weighing them into plastic bottles in a Battelle laboratory. A laboratory balance and weighing boats were required for preparation. The additives were then added to the firefighting foam concentrate (both Class A and Class B separately) connected to a foam eductor provided by the Columbus Division of Fire. The eductor required a water pressure of 200 psi and 380 Lpm of flow. Initially, the hose was connected to the foam eductor system, and the water was turned on under the conditions described above that were adequate for function of the foam eductor when the nozzle was directed towards the bottom right portion of the area to be treated. A firefighter applied the foam from the ground level (approximately 7-10 m from the wall) upward to the top of the building and then back and forth down the wall until the entire area was treated (Figure 28).

Immediately following the application, a water rinse was applied from the ground level to remove the foam (Figure 29). Treating the entire area took approximately 20 to 30 seconds per foam and rinse application and generated a total of approximately 800 L of liquid waste. This process was demonstrated separately for both Class A and B firefighting foams. There was no visible surface damage or residual material left on any of the surfaces after rinse removal of either foam. A summary of the observations made regarding the Environment Canada application to the building is shown in Table 10.

Figure 28. Application of Environment Canada foam via a fire truck.

Figure 29. Water rinse to remove Environment Canada foam.

Liquid Containment for Building Wash. Containment used for the building application was a 4 m x 12 m x 0.3 m portable berm (12’ x 36’ x 1’ Stinger Snap-Foam Berm, Container Corporation, Temecula, CA) composed of rugged, resistant fabric material with a capacity of 12,800 L (Figure 30). A tarp was secured to the wall of the building using tape as a way to direct liquids off of the wall into the containment. The foam and water were collected inside the berm. Defoamer was added to the wash water to diminish the foam prior to collection by vacuum into waste drums.

Figure 30. Building containment berms.

Table 10. Environment Canada Foam Building Application Summary

Surfaces applied	Brick and mortar, window glass, limestone window ledges
Technology preparation	Laboratory preparation of additives required before combining with firefighting foam concentrate; Columbus Division of Fire performed wash.
Amount of material applied and collected as waste	Approximately 800 L total of foam and water rinse across Class A and B foams
Time Required	Less than five minutes total
Application Method and Equipment Used	Firefighting foam eductor and fire engine
Removal method	Water rinse from fire engine
PPE	• Full Firefighter PPE (PPE is to mimic a real life situation and not driven by chemical hazards) • Full Face Air-Purifying Respirator (APR) with particulate and chemical filters
Demonstration Observations	Berms were relatively easy to set up, but required at least two people to move. The Gorilla Tape affixing the tarp to the brick wall would not stick for long periods of time, so strips of wood were fastened to the wall to secure the tarp to the wall for the duration of the foam application, preventing water from seeping behind the containment. None of the surfaces were changed by application of the foam.
Links	Click on below image to play embedded video. Env CA Foam Additive

Vehicle Application. A truck (F350™ Pickup Truck, Ford Motor Company, Dearborn, MI) provided by the Columbus Division of Fire was driven into the center of the handmade berm system (see more details about berm in Section 3.3). A portable firefighting foamer (PRO/pak™, Task Force Tips, Valparaiso, IN) that functions like the foamer used for the building only at much lower flow (48 Lpm) and pressure (35 psi) was used to wash the vehicle with foam containing the EC additives (Figure 31). The PRO/pak (containing first Type A foam with the EC additives and then Type B foam with the EC additives) was connected to the fire engine hose and the hose nozzle was directed at the hood of the vehicle and continued towards the bed of the truck until the entire vehicle was coated. The firefighter applying the foam had to move around the vehicle to ensure coverage. To move around the vehicle, the firefighter stepped in what would potentially be contaminated foam, but this likely could have been avoided by lofting the foam at a higher angle. The application of the foam to the vehicle took approximately 1 min and generated approximately 48 L of foam. The foam was applied gently to avoid splashing the foam beyond the containment area. The vehicle was then rinsed with approximately 48 L of water to remove the foam (Figure 32). The foam and water were collected inside the berm. Approximately 1 liter of defoamer was added to the wash water, and then the liquid waste was collected using a wet vacuum. The process was conducted for both Class A and B foams. By observation, both foams operated as expected and showed no change in performance due to the presence of the EC additives. A summary of the observations made regarding the Environment Canada foam application to the vehicle is shown in Table 11.

Figure 31. Environment Canada vehicle wash with foam.

Figure 32. Water rinse to remove Environment Canada foam.

Table 11. Environment Canada Foam Vehicle Application Summary

Condition of surface prior to application	F350 Pickup Truck from Columbus Division of Fire
Technology preparation	Laboratory preparation of additives required before combining with firefighting foam concentrate in PRO/pak; Columbus Division of Fire performed wash.
Amount of material applied and collected as waste	96 L of foam, 96 L of rinse water, and 2 L of defoamer.
Time Required	Less than 5 minutes total.
Application Method and Equipment Used	Pro/pak and fire engine
Removal method	Water rinse from firetruck
PPE	Full Firefighter PPE (PPE is to mimic a real life situation and not driven by chemical hazards)
Demonstration Observations	Type B foam generated a much more frothy foam than Type A. No surface changes were observed following the application and removal of the foams.
Links	Click on below image to play embedded video containing both the building and vehicle washing. Env CA Foam Additive

3.2 Irreversible Wash-Aid, Treatment, and Emergency Reuse System (IWATERS) for Building and Vehicle Application

The Irreversible Wash-Aid, Treatment, and Emergency Reuse System (IWATERS) describes a system of disseminating, collecting, and processing a decontamination wash water. The wash water is an aqueous solution of salts developed for radiological decontamination and is intended for eduction into a fire hose in a way very similar to the Environment Canada foam. For the purposes of this demonstration (summarized in Table 12), the salts in the wash were substituted by tap water for easier handling of waste. The tap water was added to an empty firefighting foam container and connected to the standard firefighting foam eductor provided by Columbus Division of Fire. A 100 m^2 section of the identified building and a vehicle were sprayed with water from the fire hose at a pressure of 200 psi and a flow rate of 380 Lpm (minimum pressure and flow settings for proper function of the eduction system). The water was contained using a HESCO Portable Berm System (described below) set up at the base of the building and on the parking lot for the building and vehicle containment demonstrations, respectively. The application to the building took less than 2 minutes and approximately 800 L of water were collected (corresponding to a coverage rate of approximately 6 L/m^2). However, the containment system was filled with approximately 16,000 L of water (directly from the fire hydrant) to demonstrate its ability to contain large volumes of water and to generate a depth of water adequate for demonstration of the Separmatic Treatment System (described below).

Building application. Using a firehose, the building was washed starting at the top and sweeping horizontally across the surface (Figure 33) until reaching the level of the containment.

Figure 33. Application of water via a fire truck to simulate the IWATERS.

Wash Water Containment. The containment technology used to contain the decontamination wash waters was a HESCO® JACKBOX™ barrier system (Alexandria, VA) that was set up at the base of the building and on the parking lot for the purpose of containing liquids generated during the building and vehicle washes (Figure 34). The berm was used to collect water off the east side of the building from the fire truck application. The vehicle collection portion was used to rinse a pickup truck (same as described above for the Environment Canada foam) with water from the fire truck. The HESCO® berm next to the building was approximately 13 m length and 3 m wide (Figure 35) and consisted of 1 m by 1 m HESCO® units. The section for the vehicle was made of 0.6 m by 0.6 m units and had an interior of 3 m by 8 m. Vermiculite clay was added to the floor of the building containment berm, but not for the vehicle section. To fill each HESCO® barrier system unit, 1 m^3 of sand was required for the large units and 0.02 m^3 for the smaller units. An earthen drive-over berm was constructed for the vehicle to enter the section on the parking lot (Figure 36).

As seen in Figure 36, a ground liner was laid out so that the liner covered a portion of the wall, covered the base of the wall and extended out towards the parking lot. Next, the HESCO® JACKBOX™ barriers were unpacked from the pallets that they arrived in and were assembled first along the wall so that the rear of the container met the wall in tight contact. The barrier system units along the wall were filled with sand, and then additional barrier system units were assembled to create a rectangular-shaped containment berm at the base of the building. The remaining baskets were also filled with sand via the skid steer loader. The HESCO® vehicle containment was assembled in a similar way.

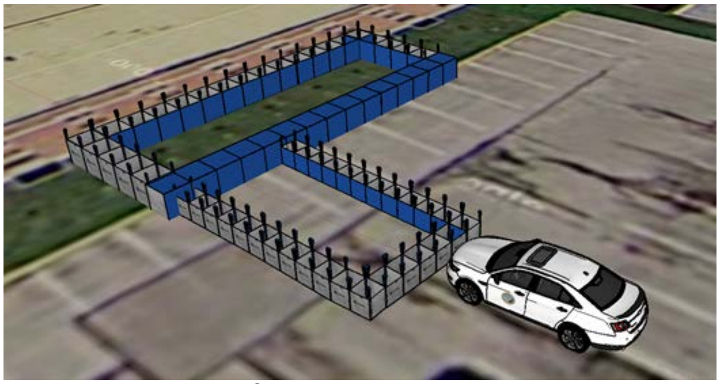


Figure 34. Concept sketch of the HESCO® berm layout. Source: Aaron Ackley, HESCO®

Figure 35. Images show the floor of the HESCO® berm for the building containment. Each unit was filled with sand and then covered with a tarp.

Figure 36. As seen in the images above, a ground liner was laid out, and then the HESCO® barrier units were assembled on top of the liner (top left). A skid steer loader was used to build the earthen berm for driving into the containment (top right) as well as to load sand into the assembled baskets (center). The HESCO® barrier units continued to be assembled and filled to create a containment berm (bottom two photos).

On-site Wash Water Treatment and Reuse System. Using the Separmatic Systems (Menomonee Falls, WI) treatment technology (Figure 37), the waste water from the IWATERS demonstration was treated and reused. The water residing in the HESCO® berm system at the base of the building was pumped to the separation system. The Separmatic system is designed to treat the water to permit reuse and was operated according to the manufacturer's instructions. The water was discharged into a draft tank where the water was drafted by the Columbus Division of Fire for re-application to the side of the building.

Figure 37. Separmatic System

Vehicle Application. A pickup truck from the Columbus Division of Fire was driven onto the ramp of earth into the HESCO® berm (Figure 38). A firetruck hose was used to wash the vehicle with water to simulate the decontamination wash water used in the IWATERS. The hose nozzle was directed at the hood of the vehicle and continued towards the bed of the truck until the entire vehicle was coated. The firefighter applying the water had to move around the vehicle to ensure coverage. The application of the water to the vehicle took less than five minutes. The water was applied gently to avoid splashing beyond the containment area. The vehicle was driven out of the containment area. The water was collected inside the HESCO® containment berm.

Figure 38. Vehicle wash occurring in HESCO® berm to simulate IWATERS application.

Table 12. IWATERS for Building and Vehicle Wash Summary

Surfaces Applied	Brick and mortar, window glass, limestone window ledges; F350 Pickup Truck from Columbus Division of Fire
Technology preparation	Orient firetruck appropriately and hook up hose. Columbus Division of Fire performed wash.
Amount of material applied and collected as waste	Approximately 16,000 L of water, 90 tons of sand and 21 tons of gravel for building of HESCO® barrier system
Time Required	Less than 5 minutes for washing, but HESCO® berm was filled with extra water to demonstrate ability to contain and for adequate depth for use with Separmatic intake.
Application Method and Equipment Used	Fire engine hose, HESCO® JACKBOX™ barrier system, Separmatic Water Treatment
Removal method	No removal required
PPE	• Full Firefighter PPE (PPE is to mimic a real life situation and not driven by chemical hazards) • Full Face APR with particulate and chemical filters
Demonstration Observations	HESCO® barrier system was very time consuming to set up and to tear down. A large amount of heavy earthen material was required including the system itself, the vermiculite and the sand. Heavy machinery was needed to set up and tear down the system. There seemed to be some leakage of water where the vehicle containment area met the building containment.
Links	EPA NHSRC Radiological Decontamination Reports (Last Accessed January 21, 2016) Click on below image to play embedded video.  IWATERS

3.3 Other Commercially Available Water Containment and Vehicle Wash

For this demonstration (summarized in Table 13), a vehicle 2015 Equinox™, Chevrolet, Detroit, MI, was washed with water using a standard pressure washer (GX390, BE Pressure Supply, Abbotsford, BC). The containment technology used in this experiment was a commercially-available heavy duty car wash mat composed of PVC material (ACC_M2, Chemical Guys, Los Angeles, CA) (Figure 39). The material was flat plastic sheeting with four-inch channels filled with air around the edges. The mat was free standing and had fast setup and teardown. The dimensions of the mat were 3.3 m x 6.7 m.

Figure 39. Other commercially available containment berm.

In addition to demonstrating the washing and water containment approaches, an additional aspect of this demonstration was to illustrate the importance of appropriate vehicle washing to avoid radiological particle movement by vehicle traffic. For this purpose, the first step of this demonstration was to apply a solution of fluorescent particles (PDT-06, Risk Reactor, Santa Ana, CA) mixed in a 1:1 water:isopropyl alcohol solution as a surrogate for radioactive dust to a vehicle using a handheld sprayer (56HD, Flo-Master, Lowell, MI). The solution evaporated overnight, leaving only the simulated contamination that was illuminated under a handheld black light (Model #16466, General Electric, Fairfield, CT), as seen in Figure 40.

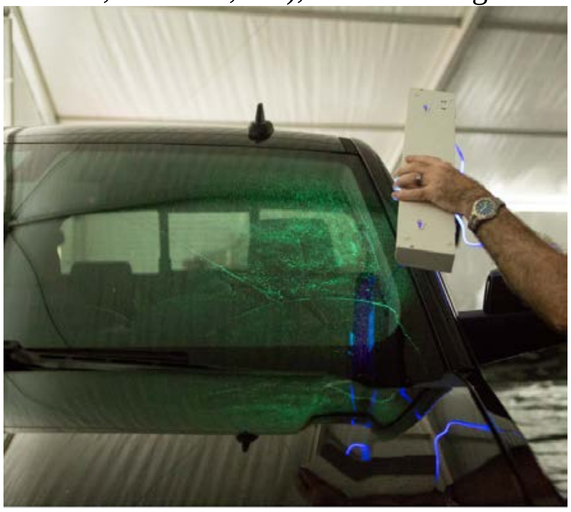


Figure 40. PDT-06 Simulation residue on the vehicle before the vehicle was washed.

The next day, the vehicle was driven onto the containment berm. The pressure washer was used to rinse the vehicle (water only) with the goal of removing fluorescent particles (Figure 41). During the demonstration, only one wall of the tent was opened to reduce overspray. After the first wash, the vehicle was driven out of the containment berm and into another tent for fluorescence measurement. The black light was waved over the vehicle to determine if any fluorescent particles remained.

The vehicle that underwent the pressure washer exhibited fewer remaining particles (determined by visual inspection) than the vehicle being washed with a garden hose (see section 3.4). By inference, even washed vehicles represent a route via which radiological contaminants could be transported to uncontaminated areas. Optimization of vehicle wash techniques could help reduce this concern. (Note that fluorescent particles were not utilized in the IWATERS or Environment Canada Foam demonstrations of vehicle wash because doing so would have been repetitive with this demonstration and logistically more complex to detect fluorescent particles. Namely, it would have involved retaining the Columbus Fire Department vehicle overnight, during which time it might have been needed for fire service purposes.)

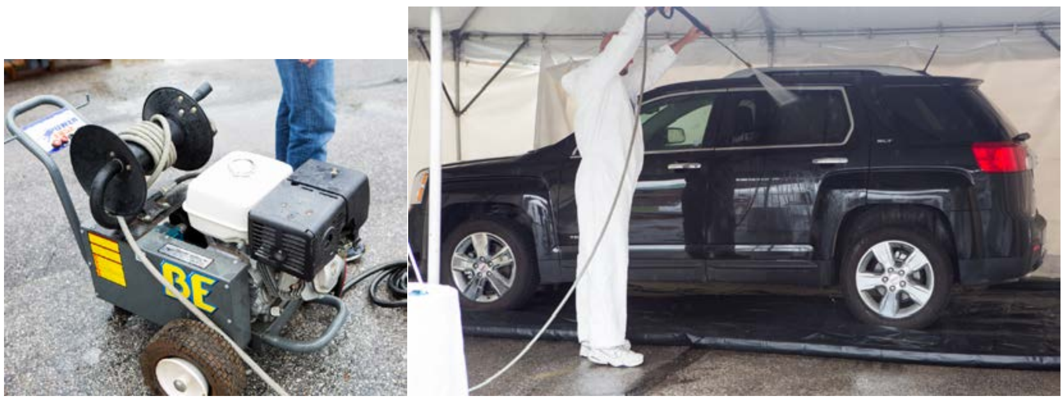


Figure 41. Image of the pressure washer (left) and vehicle wash (right).

The vehicle still had fluorescent particles remaining on the windshield and the door frame (visible only when the door was open) after the first wash (Figure 42). The vehicle was driven back to the containment berm and washed a second time. The second wash yielded better results, and it appeared that more (but not all) fluorescent particles had been removed. As noted, the vehicle that underwent the pressure washer exhibited fewer remaining particles removed than the vehicle being washed with a garden hose in Section 3.4.

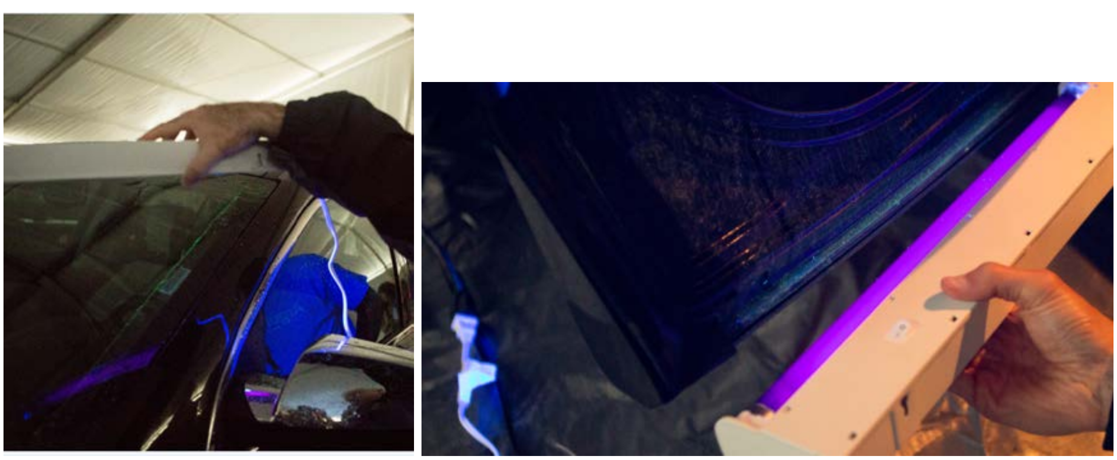
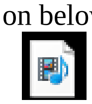


Figure 42. After the pressure washer wash, the vehicle remained contaminated with fluorescent particles on the windshield (left) and the inside the door frame (right).

Table 13. Other Commercially Available Water Containment and Vehicle Wash Summary

Surface Applied	2015 Chevrolet Equinox™, black. Windshield, hood of vehicle, and driver's side door were hand sprayed with fluorescent surrogate contamination solution.
Water Wash Containment Method	Water containment via a commercially-available heavy duty car wash mat composed of PVC material. Demonstration technicians performed the vehicle wash.
Amount of wash water applied and collected as waste	Approximately 8-12 L wash water sprayed onto vehicle and collected via the water containment.
Time Required	Overnight dry time for contamination solution. Approximately one minute for vehicle wash.
Removal method	Pressure washer
PPE	• Tyvek coveralls • Safety glasses • Safety-toed boots
Demonstration Observations	First wash did not effectively remove all fluorescent particles. Second wash performed better, but some particles were still evident. Difficult to visualize fluorescent particles during the day as light was intruding into the tent
Links	Click on below image to play embedded video.  Vehicle Wash

3.4 Handmade Water Containment and Vehicle Wash

For the handmade containment demonstration (summarized in Table 14), a vehicle (2015 Silverado™, Chevrolet, Detroit, MI) was washed with water using a garden hose. The objective of the handmade containment technology was to find commercially available materials that could be fashioned together to create a containment berm quickly. The handmade containment was used during the vehicle wash of Environment Canada foam and for the garden hose vehicle wash. The handmade containment used in this study was composed of cinder blocks, corrugated PVC piping, a tarp and bungee cords (Figure 43). The footprint of the berm was approximately 8 m x 5 m with three sides being cinder blocks and the fourth side consisting of PVC piping. The piping was affixed to the cinder blocks with bungee cords in a way that allowed the piping to be moved easily to allow a vehicle inside the berm. The cinder blocks and piping were covered with a 6.7 m x 10 m tarp (Extreme Duty PVC Tarp Item #31184, Weather Guard, Northern Too, Burnsville, MN) that was secured to the cinder blocks with bungee cords.

Figure 43. Image of the readily constructible containment berm.

Similar to the study in the previous section, the first step of the handmade containment demonstration was to apply a surrogate radioactive dust solution (same as for the medium containment) to a vehicle using a handheld sprayer. The solution evaporated overnight, leaving only the simulated contamination as seen in Figure 39.

The next day, after the surrogate contamination solution had evaporated, the vehicle was driven and centered on the containment berm. A 33 m garden hose with a spray nozzle (Model #1HLW3, Westward, Grainger, Lake Forest, IL) was used to apply water to the vehicle with the goal of removing fluorescent particles (Figure 44). After the first wash, the vehicle was driven out of the containment berm and into the tent for fluorescence measurement. A handheld black light (same as described above) was used to examine the vehicle to determine if any fluorescent particles remained.

Figure 44. Vehicle wash with garden hose sprayer

The vehicle still had fluorescent particles remaining on the door and windshield and hood after the first wash (Figure 46). The vehicle was driven back to the containment berm and washed a second time. The second wash completed removal of most of the particles. However, the vehicle that underwent the pressure washer (details in Section 3.3) showed higher particle removal than the vehicle being washed with a garden hose. Using a wet vacuum, the wash waste was pumped from the containment area to storage containers for proper disposal after the demonstration (Figure 45).

Figure 45. Wash water collection.

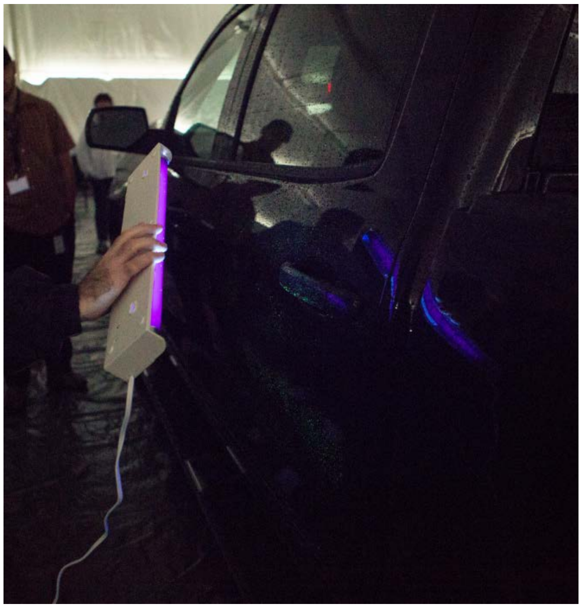


Figure 46. After being washed one time with a garden hose, the vehicle remained contaminated with fluorescent particles.

Table 14. Handmade Water Containment and Vehicle Wash Summary

Surface Applied	2015 Chevrolet Silverado™, black. Windshield, hood of vehicle, and driver's side door were hand sprayed with fluorescent surrogate contamination solution.
Water Wash Containment Method	Water containment handmade as described in the text. Portage performed the vehicle wash.
Amount of wash water applied and collected as waste	Approximately 32 L wash water sprayed onto vehicle and collected via the water containment for each wash.
Time Required	Overnight dry time for contamination solution. Approximately one minute for vehicle wash
Removal method	Garden hose with spray nozzle
PPE	• Tyvek coveralls • Safety glasses • Safety-toed boots
Demonstration Observations	• First wash did not effectively remove all fluorescent particles. The second wash performed better, but some particles were still evident. • Difficult to visualize fluorescent particles during the day as light was intruding into the tent. • Handmade containment took two-three hours to assemble the supplies and set up as each cinder block had to be individually placed. Once containment was set up, it was very easy and convenient to use.
Links	Click on below image to play embedded video. Containment

3.5 Separmatic Water Barrel Treatment

An aluminum gutter with end caps was installed on the brick wall at a height of approximately 3.3 m. The gutter had a downspout that was attached to the corrugated piping that leads into the water barrel (Figure 47) that could serve as a rainwater collection treatment system or a system in which water from other containment systems could be passed to reduce radiological contamination prior to disposal. Treatment is accomplished through mechanical filtration and adsorption of radioactive materials using media such as earth, clay, and/or sand. For the demonstration, a garden hose delivered water into the gutter, and water was collected in a pail post-filtration. The water barrel contained a bottom layer of sand to filter solid particles and the top layer of pulverized soil to sequester the radioactive ions. The treated water exited the barrel through a port located at the bottom of the barrel. Click on the icon to view the demonstration video.

Water Barrel Treatment

Figure 47. Separmatic water barrel treatment setup

4.0 Particle Containment

After an intentional radiological release or nuclear power plant accident, contamination is likely to spread across a large urban area. Resuspension and tracking of particulate contamination during mitigation and decontamination activities may further exacerbate remediation activities. There is a need for stabilization technologies and/or methodologies to reduce resuspension and tracking of contaminants to minimize the effect on human health and the environment. Traditional containment technologies such as fixatives have been widely tested but are typically not available in the quantities needed within the first 72 hours after a radiological release. Non-traditional radiological stabilization technologies such as fire retardants and dust suppression technologies (e.g., wetting agents other than water and chloride salts typically used in road and mining facility dust suppression) may provide rapid availability on a larger scale than traditional, specialized nuclear stabilization technologies. This demonstration showed the effectiveness of surface containment technologies at reducing the spread of contamination. The particle containment technologies demonstrated two methods of surface disturbance, driving and walking over the 0.3 m x 0.3 m concrete pavers covered with simulated radioactive dust (same as used for vehicles above in Section 3).

4.1 Application of Surrogate and Containment Technologies to Pavers

Surrogate radiological dust (same as for the water containment and vehicle demonstration) was applied to 24 of the pavers using a small hand-held sprayer (same as for previous application). The pavers were allowed to dry overnight and the alcohol evaporated, leaving only the dust particles and simulated contamination. Surrogate contamination was performed in advance of the demonstration event and kept indoors to prevent surface disturbance.

Three containment technologies were demonstrated:1) Fire retardant 2) Wetting agent and 3) Chloride salts. Before the demonstration event took place, the containment technologies were prepared. The fire retardant was a mixture of 100 g of fire retardant (MVP-F, Phos-Chek, Rancho Cucamonga, CA) added to 200 mL of water to make a gel/slurry. The wetting agent was a combination of 5 grams of a dust suppression product (Soil$_2$O^{TM}, GelTech Solutions, Jupiter, FL) and 1.7 L of water. The chloride salts were created with 100 grams of calcium chloride flakes dissolved in 1.6 L of water. The containment technologies were mixed and then were applied to the contaminated pavers using hand-held sprayers (six pavers with chloride salts) or paint rollers (six pavers with wetting agents and six pavers with fire retardant). The application of the containment technology was conducted on a tarp in case over-spraying occurred (Figure 48). The pavers were allowed to dry/cure indoors overnight. They were transferred to the demonstration location in a single layer in a covered truck to prevent any surface disturbance. Pavers were placed on a tarp-covered floor inside a tent for the demonstration.

Figure 48. Application of containment technologies to pavers.

4.2 Vehicle Particle Containment

Four black vehicles were arranged inside the tent, all facing the same direction. Pavers were spaced so that the tires contacted nine pavers such that one revolution of the exposed tire would contact the clean pavers. For the control, one vehicle was driven over the positive control pavers (the first three pavers being contaminated with PDT-06 and the last six being clean pavers) to qualitatively determine the portion of tracer particles transferred to a car tire and clean pavers without the application of stabilization material (Figure 49). Subsequently, cars were driven over the three containment technology treated pavers (Figure 50) and then, similar to the control, the final six pavers were clean. The control was tested first, followed by the wetting agent, chloride salts and fire retardant (Figure 50). The vehicles were driven very slowly (<5 miles per hour) over the pavers. In an actual emergency situation, emergency vehicles will be traveling at a much higher rate of speed, so the element of air movement and displacement by a moving vehicle, as well as the increased speed of the tires on the surface, are other variables to be considered.

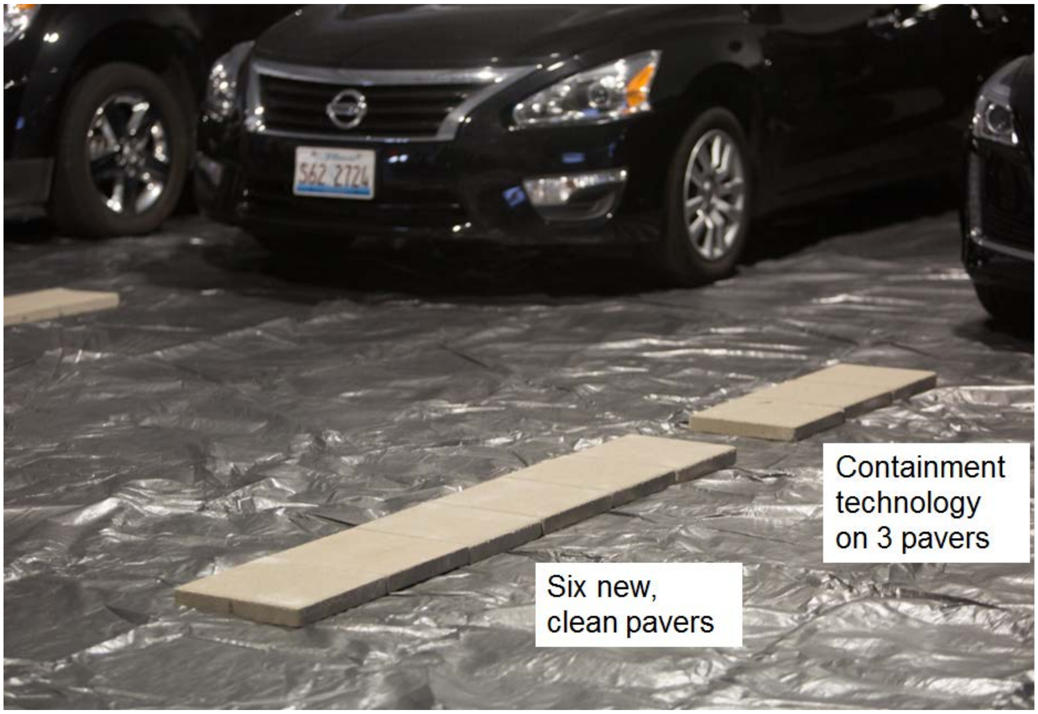


Figure 49. Depiction of vehicle particle containment setup.

Figure 50. Vehicle orientation and associated containment technology for particle containment study.

4.3 Pedestrian Particle Containment

A similar demonstration was performed using "bootie" shoe covers and walking on four sets of pavers that were set up inside the tent for the pedestrian particle containment. For the control, one person with disposable shoe covers on walked over five total pavers, the first three being contaminated with the surrogate radiological dust and the last two being clean pavers (Figure 51). For the containment technology scenarios, the first three pavers were contaminated with the surrogate radiological dust and then containment technologies were applied. Similar to the control, the final two pavers were clean. Click on the icon to view the demonstration video.

Particle Containment

Figure 51. Pedestrian particle containment. The fire retardant is pictured here. The same approach was used for the other two containment technologies.

4.4 Demonstration data and results

After the vehicles were driven over the pavers, the presence of fluorescent particles on the vehicle tires and the clean pavers was revealed by use of a handheld black light. After the pedestrians walked over the pavers, their disposable shoe covers were removed and the prevalence of fluorescent particles was observed under a black light. The concrete pavers contained relatively large particles that were either fluorescent or reflective. However, they were visible under the black light but easily distinguishable from the surrogate radiological dust because of the obvious size and color difference. These background particles can be observed in Figures 51 and 52 as the whiter and larger particles than the smaller more yellow particles indicative of the surrogate radiological dust.

For all four scenarios (control and three containment technologies), in both the walking and driving experiments, particle transport occurred. Figure 52 summarizes the results observed from the driving experiment, and Figure 53 shows the results of the walking experiment for the control scenario. The control experiments (without any containment technology) appeared to have the most particle transfer, and the fire suppressant technology appeared to have the least particle transfer. The wetting agent and chloride salt technologies fell between and had less particle transfer than the control but more than fire suppressant.

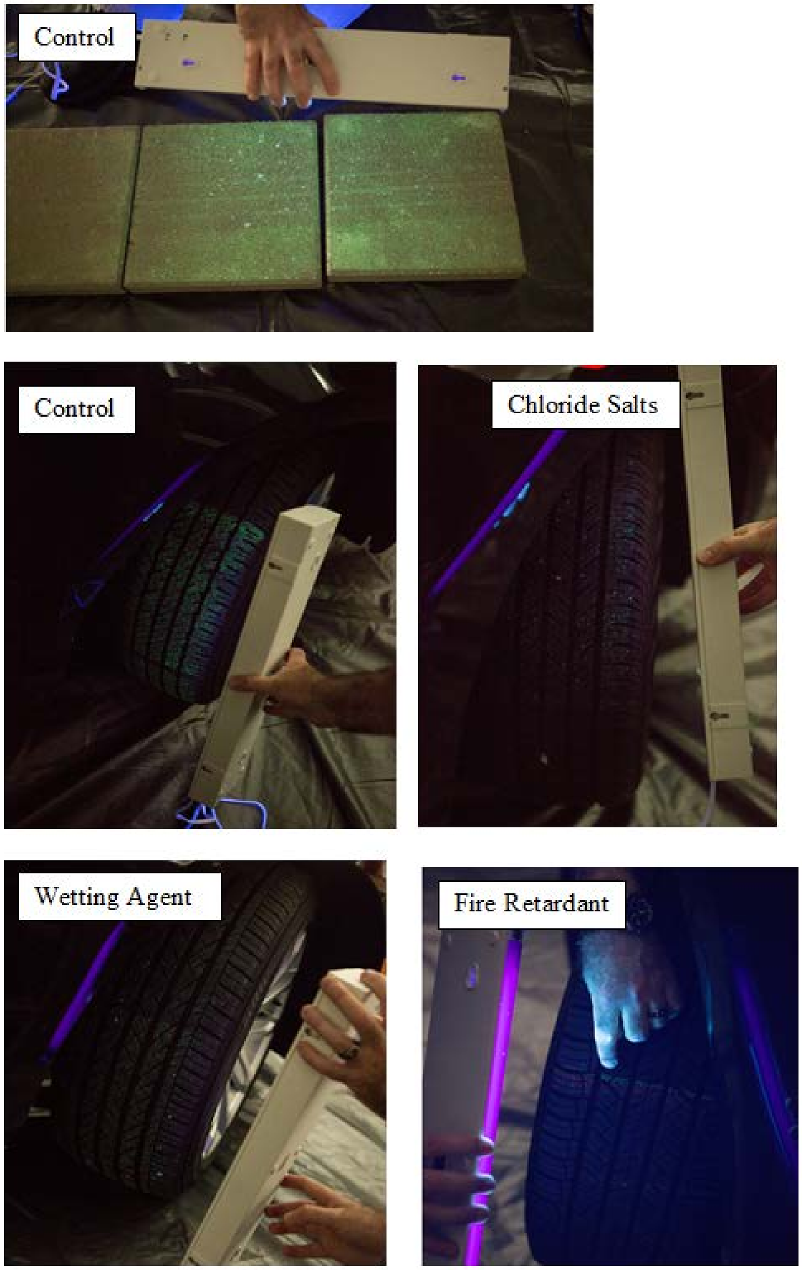


Figure 52. Results of the vehicle particle containment demonstration. Top image shows the control pavers after the vehicle had driven across. The control vehicle tires picked up the most particles (middle left), followed by the chloride salts. Wetting agents picked up a moderate number of particles (middle right and bottom left). The fire retardant scenario had the least amount of particle transfer (bottom right), but notice the narrow line of particles that was present when the tire contacted the edge of the paver, not covered by fire retardant.

Figure 53. The image on the left shows control pavers and, as seen, the level of fluorescent particles on the pavers containing tracer is much greater than the pavers without tracer. The image on the right shows the booties worn in the control scenario after the demonstration was completed.

5.0 Summary of Technical Presentations and Attendee Feedback

The demonstration included multiple opportunities, through written comments, panel discussions, and presentations, for ideas and feedback to be shared. Each morning there was a pre-demonstration briefing that reviewed the activities of the previous day and previewed the plan for the upcoming day. Each afternoon, there was a demonstration debrief to discuss the demonstrations that had just been observed, and on Wednesday, several dignitaries were given the opportunity to talk about the importance of this demonstration and the work that DHS and EPA are doing in the area of radiological decontamination. Those speakers included Lek Kadeli, Assistant Administrator of EPA's Office of Research and Development, Ben Stevenson of the DHS National Urban Security Technology Laboratory, James Sferra, Assistant Chief of the Ohio EPA, Zach Klein, Columbus City Council, and Matthew Magnuson and Sang Don Lee of EPA NHSRC. On Thursday morning, there was a technical session pertaining to the overall response to a radiological event. This section of the report summarizes the technical presentations and attendee feedback provided throughout the demonstration.

5.1 Technical Demonstrations

On the final morning of the demonstration, there was a session of presentations that focused on the overall response to a wide area radiological incident. Ben Stevenson of the DHS National Urban Security Technology Laboratory, who leads DHS's program for early radiological responders, talked about DHS's priority of providing first responders tools for radiological response. His talk focused on three goals: 1) Improving responder ability to save lives during the initial response operations of a radiological incident. 2) Increasing capability at all levels of government to manage and characterize complex and catastrophic incidents, and 3) Minimizing impact to community and economy through improved methods of incident stabilization, radiological cleanup, and recovery. In addition, he focused on the three areas where DHS and EPA are teaming most closely and the focus of the demonstration: containment of contamination, gross mitigation of hazard, and initial waste management.

Paul Lemieux, a researcher with EPA's National Homeland Security Research Center and internationally recognized expert on waste management, gave a presentation about the importance of the implications of early-phase waste handling during wide area radiological events. He described anticipated waste types, possible temporary storage facilities that may be available, and other staging considerations such as required agreements and permits that would be helpful to have ahead of time.

The last speaker of the session was John Cardarelli, a health physicist on assignment to the EPA Office of Emergency Management/ CBRN Consequence Management Advisory Division, spoke about a radiological decontamination decision support tool to assist first responders in selection of decontamination technology and method. This decision support tool is in the midst of development and uses the United Kingdom's handbook as a source of relevant radiological decontamination information as a potential tool for first responders to use in identifying a response to a radiological event. John Cardarelli noted that this tool was not "reinventing the wheel" but just packaging information in a more useful way. John Cardarelli indicated that several offices in EPA will have the opportunity in the near future to review the tool as it progresses in development.

5.2 Feedback on Demonstrated Technologies

At the close of each day of the demonstration, there was a "Demonstration Debrief and Feedback" time that allowed the attendees to discuss the technologies they had just observed and provide feedback on various topics surrounding radiological decontamination technologies and how they are applicable to the attendee's job responsibilities. Attendees included EPA and the United Kingdom Government Decontamination Service staff responsible for decontamination and mitigation research, waste management following a wide area radiological event, and other related work such as radiological detection and decontamination of drinking water infrastructure. Other attendees included the Navajo Nation EPA which is responsible for abandoned uranium mine cleanup efforts in New Mexico, first responders such as firefighters from the United States and Canada who are interested in the most effective mitigation techniques that can be deployed in an emergency response. Also in attendance were people from various State of Ohio departments and the New York City Department of Environmental Protection who are responsible for coordination of local, state, and federal assets in the event of a wide area radiological event. Feedback forms that included questions about the roles of the various agencies that were represented, as well as questions about specific technologies, were distributed each day of the demonstration. Table 15 summarizes feedback received about the various technologies. The feedback in Table 15 represents the opinions of the individuals who expressed them. The opinions are largely raw feedback from the forms and have not necessarily been verified for accuracy and completeness, although the authors of this report have added some text in brackets for context. The content of Table 15, like the rest of this report, is subject to the disclaimer statement at the beginning of this report. Further, because the people providing feedback were from a variety of organizations, the contents of Table 15 may be relevant to their organization or specific responsibilities, or to specific sites/scenarios they envisioned. For example, fire/hazmat department personnel may have tended to prefer technologies which they could immediately implement during an incident, whereas state or federal planners may have commented more on technologies that could be useful if they made appropriate plans prior to an incident.

Table 15. Feedback on Specifc Technologies. *The feedback represents the opinions of the individuals who expressed them and are largely raw feedback from the forms. While this report's authors have added some text in brackets for context, the contents of this table have not necessarily been verified for accuracy and completeness, and they are subject to the disclaimer statement at the beginning of this report.*

Technology	Feedback Received
DeconGel	• Seemingly not suitable for aged brick and mortar; better for smooth surfaces with no exposure to the sun [due to removal difficulties on brick and mortar, compared to other surfaces illustrated. Consult manufacturer for effects of sun exposure.] • Solid waste is easier to manage than liquid (if the DeconGel could be removed)

	• Removal without destruction of surface (if the DeconGel could be removed [e.g. from the smooth surfaces]) • Might be good for decon of portable monitors or meters • Perhaps it can be used for contamination prevention or as a fixative • Slow process when considering true “wide area” contamination or for first responder use [wide area contamination involves large areas and first responders may not carry out other activities] • Easy to determine coverage [due to blue color additive] • Possibly useful for biological decontamination [because biological decontamination may involve particle removal, just like radiological decontamination] • Can it be left in place for weeks and months with various weather conditions while higher priorities are accomplished? • Use on porous surfaces seems suspect [this is similar to comment above about its application to brick and mortar] • Not being able to remove coating [from brick and mortar] is a major drawback; need to increase strength of dried coating to facilitate removal • Required proximity to surface could increase dose to worker
SuperGel	• Technology could be improved with less use of water [perhaps refers to making the water wash step quicker and therefore using less water] • Use of electricity for application tools is a limitation [this comment may apply to other decontamination technologies, as well] • Addition of a color would aid in determination of surface coverage • Extensive equipment needed for application a limitation [this comment may apply to other decontamination technologies, as well] • Hard to imagine scaling up for use on skyscrapers [this comment may apply to other decontamination technologies, as well]Removal appeared difficult and collection equipment could become a hazard for concentrated radioactive dose [this comment may apply to other decontamination technologies, as well] • Fast application • Slow process when considering true “wide area” contamination or for first responder use [this comment may apply to other decontamination technologies, as well] • Vacuum removal was difficult today so still an open question [on the brick and mortar surfaces in particular] • Established contractor capability is a benefit [this comment may apply to other decontamination technologies, as well] • Low hazard material • Use of water would be a major issue in waste collection [this comment may apply to other decontamination technologies, as well] • Removal would have to be redesigned for speed of removal [similar to “wide area” comment above] • Required proximity to surface could increase dose to worker [this comment may apply to other decontamination technologies, as well]
Stripcoat	• Seemingly not suitable for aged brick and mortar; better for smooth surfaces with no exposure to the sun [due to removal difficulties on brick and mortar, compared to other surfaces illustrated. Consult manufacturer for effects of sun exposure.]

	• Extensive equipment needed for application a limitation [this comment may apply to other decontamination technologies, as well] • Removal without destruction of surface (if Stripcoat could be removed [e.g. from the smooth surfaces]) • Slow process when considering true “wide area” contamination or for first responder use [this comment may apply to other decontamination technologies, as well] • Overspray risk • Perhaps it can be used as a contamination prevention or fixative • Not being able to remove coating [from brick and mortar] is a major drawback; need to increase strength of dried coating to facilitate removal • Seemed to work well on the smooth stand-alone surfaces • Required proximity to surface could increase dose to worker [this comment may apply to other decontamination technologies, as well]
Rad-Release II	• Multi-step process inherently is a drawback • Labor intensive application process • Spray-on good for rough surfaces • Full process seemed to discolor the brick • Water collection is big drawback [this comment may apply to other decontamination technologies, as well] • Hard to be consistent with scrubbing; would like to see how important scrubbing is for removal
EC UDF	• Risk of overspray using air dolly as in this demo • Fast application and can be applied from a distance, minimizing dose [to workers applying it] • Need to control secondary waste • Less labor intensive than other technologies • Wastewater must be collected and disposed [this comment may apply to other decontamination technologies, as well] • Uses ammonia and takes relatively large amount of rinse water
Environment CA Foam Additive	• Easily deployed by first responders as it uses existing equipment and recycles water [the additive does not recycle water – comment is perhaps referring to IWATERS system below] • Make available to commercial market [additives are all commercially available] • Would consider stockpiling this for scalable use by first responders • It would assist in getting first responder equipment back in service • Allow testing at various fire departments • Better technology for first responders; easy to use with our equipment • Higher than five floors may offer unique application problems [this comment may apply to other technologies, as well] • Adhesion was good for brick media [presumably the foam rolled down the vertical surface at an acceptable rate] • Is it applicable for multiple radionuclides? [data will be in technical report by Environment Canada] • Relatively low logistical effort behind application and removal, ease of transfer of knowledge from regular firefighting foam
IWATERS /Separmatic	• Probably the most immediately useful tool for first response as it used existing equipment and recycles water

	• Availability for first responder use is a benefit, but significant use of water is a drawback [perhaps if used without water recycling] • Containment/collection/treatment is very complicated and would require efficacy testing [this testing appears in technical reports summarized in reference 18] • Fast application with water treatment of waste • Use of water a limitation [as it generates waste water if not recycled] • Containment is required; HESCO® used here [other containment systems may be used; HESCO® utilized here for reasons discussed in text.
Bosun Chair Application	• Could be used for residual hot-spot treatment • Very slow and labor intensive over large areas • Dependent on availability of operators [with required training] • Effective at high elevations [e.g. on tall buildings]
Other Commercially Available and Handmade Water Containment and Vehicle Wash	• Very good application for wash on/wash off decon technologies

5.2 Summary of Daily Feedback Sessions

Monday, June 22. The first feedback session touched on a number of topics focused mainly on the three technologies that had been demonstrated that day (DeconGel, SuperGel, and Stripcoat). The application of these products at Fukushima was discussed, with each vendor summarizing their level of involvement with the situation in Japan. EAI has been involved with introducing their products to the Japanese. The Japanese have not been quick to begin using new products in the aftermath of Fukushima. Sang Don Lee, an EPA research scientist (with EPA's National Homeland Security Research Center) and the US Embassy Science Fellow following the Fukushima disaster, mentioned that the wide area nuclear power plant incident can contaminate various areas including urban, rural, forest, river, and ocean. The remediation strategies may be different for different areas of contamination and the expected removal efficacy of various technologies may change over time depending on the impacted areas because of weather conditions and type of surfaces. Therefore, the selection of appropriate tools for removal will need to consider the fate and transport potential of the contaminant.

The scalability and supply chain for DeconGel and the EAI products were discussed. For both companies, it seems that some inventory is available, but their feeling is that the lead time for mass orders would be significant. Funding/demand does not seem to be available for that initiative, so vendors can just produce it and then sit on significant inventory, as it is not feasible from a financial standpoint. On the topic of available workers, EAI did note that one approach in an emergency situation would be to use military responders until civilian responders could be trained adequately.

Tuesday, June 23. The discussion focused mainly on the technologies demonstrated that day (inability to remove strippable coatings, EC UDF). A number of factors such as the weather (heat especially was discussed because of how warm that day was), lift operator proficiency, and effectiveness of accessories used for containment (e.g., duct tape) can impact the time required for decontamination technology application. For that day's demonstration, the operators had used ice vests to keep cool and focused on staying hydrated by drinking plenty of water. Generic gray duct tape was not effective for taping the tarp to the brick, but a stronger tape (Gorilla Tape, Gorilla Glue Company, Cincinnati, OH) had been effective. The application time of the technologies was observed to decrease when a more proficient lift operator was used.

Secondary waste was also a key discussion topic of the day. The question was asked whether these technologies could be put down the storm water drains, and Battelle explained that it would depend on local requirements. Battelle and the City of Columbus have a very conservative approach to use of storm water drains, so almost nothing other than storm water is allowed to be intentionally and knowingly allowed to go down the storm water drain. Also discussed was that some of these technologies have been used in nuclear power plants and Navy ships, where operators are proficient in disposal; however, there has been limited involvement of commercial disposal avenues.

Also mentioned was that UDF is not currently commercially available, so waste guidance is somewhat limited. In addition, there was discussion of the toxicity of UDF and the observed containment during the demonstration. The EC staff noted that the hazard is similar to using household hypochlorite bleach. [The UDF formulation normally contains such bleach to deactivate pathogens and degrade chemicals. Note that bleach was not added for the demonstration to avoid safety concerns; the absence of bleach is not expected to affect the properties of the foam or its radiological decontamination capabilities.]

Wednesday, June 24. The overarching topic of the day was the approach to planning and coordination of response to a possible large scale radiological event. William ('Bill') Steuteville, EPA's Region 3 Homeland Security Coordinator and the Region 3 On-Scene Coordinator who helped coordinate the Liberty RadEx exercise that simulated wide area urban clean-up, noted that containment of the contamination was the real concern and that technologies from Fukushima needed to be tested here in the United States. Some of the first responders commented that their focus is always saving lives first and then comes cleanup and waste containment. Their observation was that some of the technologies they had seen this week were just too labor-intensive to be practical for first responders. This observation brought up a discussion of how different localities might obtain operators for the technologies.

There was a question about the shelf life and cold weather use of all of the demonstrated products. Tom Layton of CBI Polymers answered that the shelf life is seven years, and the product has been used in temperatures down to 32 ^{o}F with success. EC staff noted that the additives and foam could be applied at low temperatures. This issue is one that needs to be considered for all of the products.

Sang Don Lee commented that seasonal variation in activity levels (and applicability of some decontamination approaches) have been observed following the Fukushima disaster with key variables being the soil frost line and availability of leaves and soil in the summer months, possibly increasing dose.

Mario Ierardi with EPA's Office of Resource Conservation and Recovery (EPA's Office that deals with solid waste issues to ensure responsible national management of such wastes) noted that we need a systems and whole of community approach to solve this problem. We need to answer the questions: "What are we going to do with the waste?" in the case of a truly wide area event like Fukushima. He commented that we need a "framework", not just a demonstration. That framework needs to address urban environments and include tactics, strategies, and constraints. He challenged the group present on whether or not we were "thinking big enough," especially in the context of what Japan is dealing with right now and how we would have handled a similar event. Sang Don Lee noted that demonstration feedback would be in the report and that information gaps would be improved by participation in ongoing research projects. He summarized that waste needs to be considered ahead of time and that good data need to be provided to decision makers.

Charlotte Fire Department noted the need for first responders to be trained in crime scene preservation even while performing mitigation efforts so the perpetrators can be caught.

Sang Don Lee noted that a radiological response would be led by DHS in the US. A current need is to identify those who want to weigh in on priority technologies, in particular for an urban incident and used the example of how in Japan the first responders were out responding to first earthquake/events and then the meltdown occurred, putting them at a disadvantage to respond given their initial activities.

Zack Clayton, radiological coordinator for Ohio EPA, summarized a recent RAD tabletop exercise in Columbus where an incident at Crew Stadium cause evacuation of two counties north of Columbus due to no water and sewage facilities. He was making the point of the extreme nature of the planning that would be required.

Paul Lemieux, a researcher with EPA's National Homeland Security Research Center and internationally recognized expert on waste management, clarified the term decontamination by stating that decontamination refers to restoration of radioactivity levels that are safe for rehabitation or site disposition, and mitigation refers to early decontamination to prevent massive infrastructure contamination during first precipitation event and contamination of storm sewers, etc. Sang Don Lee clarified that mitigation during early phase response may prevent the negative impact of future activities that may cause secondary contamination (driving around contaminated fire equipment). Decontamination is cleanup to a specified level of activity, and remediation is to minimize human exposure and dose throughout the entire response. Matthew Magnuson, a research scientist with EPA's National Homeland Security Research Center added that mitigation decreases future contamination, minimizing the possible worsening of the situation through response efforts, even those performed with good intentions.

Mario Ierardi suggested that we need to start with DHS scenarios and develop a "framework" for addressing each of the scenarios. Bill Steuteville said that scientists should tell us what works, firefighters can tell us what works, and EPA can tell us what works. Ben Stevenson of the DHS

National Urban Security Technology Laboratory, who leads DHS's program for early radiological responders said that the Federal Emergency Management Agency (FEMA) is the coordinating agency and that a "spreadable waste" framework is needed to address low contamination and high contamination scenarios.

Thursday, June 24. The final debrief of the demonstration included additional discussion of future planning. Sang Don Lee relayed observations he had made on his recent trips to Japan as part of EPAs official engagement with the government of Japan. For instance, he noted that if a similar incident happens in the US, we need to work as a team and communicate effectively. He specifically detailed concerns about particle contamination in various locations in Japanese vehicles (air filters, ducts, etc.) and the need to address that issue. Also, the issue of cleaning items within a hot zone can be problematic. A variety of issues become involved, including the upset of fixed cesium in the future, the exposure of mechanics, and the proper disposal of used parts (and other personal property that may become contaminated). In addition, motor oils have been found to become contaminated and will need to be disposed.

Sang Don Lee also emphasized the need for temporary waste storage locations and the need to coordinate those locations ahead of time. For instance in Japan, they have a tremendous amount of material that needs to be disposed of, and the locations and methods of transportation are not clear (and expensive). Sang Don Lee noted that a "systems approach" and "communication" will be the key for our planning and possible response to a future event. He used the example of Florida bouncing back from storms because they are organized at the county level with prearranged agreements. Paul Lemieux said that the transportation cost for waste will be high, as will the cost of people not returning to their previous cities and homes.

The debrief concluded with a brief discussion of the effect of weather on decontamination efforts (acid rain, high temperatures aiding evaporation, etc.) as well as river and ocean water contamination.

6.0 Demonstration Summary and Outcomes

This demonstration provided a unique opportunity to see more than 15 different radiological decontamination, mitigation, and containment technologies applied to the practical and logistical realities in a wide-area decontamination scenario, such as applying decontamination technologies to tall buildings, washing vehicles, reducing spread of contamination from foot and vehicle traffic, and managing the resulting waste. The demonstration also provided attendees a unique opportunity to participate in daily feedback sessions making the entire event an interactive training session pertaining to technology gap identification, inter-organizational communication of priorities and needs, and forward thinking about the planning required for proper preparation for a wide-area radiological event.

Whether for mitigation or decontamination, decision-makers for all response groups need a variety of options since not every technology will be applicable to a specific incident or available at a specific site when needed. Certain technologies are more effective but not widely available, while others are less effective but more widely available. Table 16 provides a summary of the performance of each of the technologies demonstrated along with a link to a technical brief that includes experimental efficacy data for most of the demonstrated technologies.

Table 16. Performance Summary of Demonstrated Technologies

Technology	Performance Summary
DeconGel[1]	• Previous EPA testing has used DeconGel 1108 applied with a brush and DeconGel was successfully removed from all surfaces it was tested on (concrete, granite, marble, limestone) • During the demonstration, DeconGel 1128 was applied with a sprayer to aged brick and mortar, and it could not be removed after multiple coats had been applied • Solid waste disposal would offer advantages over liquid waste disposal if the coating could be removed from surfaces • DeconGel 1108 was applied to smooth surfaces using a brush during the demonstration, and the dried coating could be removed • Required proximity to the surface could increase dose to worker
SuperGel[1]	• No visible impact on surface after application • Vacuum clogging caused need to water-rinse entire wall. • Vacuum collection equipment could become a hazard for a concentrated radioactive dose • Required proximity to surface could increase dose to worker
Stripcoat[1]	• Previous EPA testing has used Stripcoat applied with a sprayer (indoors) and the Stripcoat was successfully removed from concrete • During the demonstration, Stripcoat was applied with a sprayer to aged brick and mortar (outdoors) and Stripcoat could not be removed after multiple coats were applied. • Solid waste disposal would offer advantages over liquid waste if the coating could be removed from surfaces • Stripcoat was applied to smooth surfaces using a brush during the demonstration and the dried coating could be removed

	• Required proximity to surface could increase dose to worker
Rad-Release II[1]	• Spray application good for uneven and rough surfaces • Multi-step process inherently is a drawback as it increases time and labor • Distinct discoloration of the brick occurred as result of the decontamination process • Scrubbing step was observed to be difficult to be consistent with • Liquid application and removal a waste and containment concern
EC UDF[1]	• Fast application and can be applied from a distance, minimizing dose • No visible residual impact to surfaces • Water rinse creates need for waste water containment • High risk of overspray using air dolly as used during this demonstration • Less labor intensive than other technologies
Environment CA Foam Additive	• Easily deployed by first responders as it uses existing firefighting equipment • Not currently available commercially, making implementation more difficult • Foam application/water rinse creates need for waste water containment • Application equipment inherently generates large volumes of waste water
IWATERS /Separmatic	• Easily deployed by first responders as it uses existing firefighting equipment • Use in concert with Sepramatic water recycling for ongoing mitigation efforts is beneficial • Significant use of water is a drawback • HESCO® containment used during this demonstration; a large amount of heavy earthen material was required; heavy machinery was needed to set up and tear down the system; even with complexity, some leakage of water occurred • Other commercially available and handmade water containment and vehicle washing technologies were promising for potential "self-help" applications
Bosun Chair Application of Technologies	• Very slow and labor intensive over large areas, making actual use unlikely • Dependent on availability of trained operators • Provides access to surfaces higher than 10 stories
Particle Containment Technologies	• Demonstration showed promising results from containment technologies used for vehicle and foot traffic containment • Demonstration approach was rudimentary; realism of dusty, dirty environments needs to be added to evaluate true effectiveness

[1]Quantitative efficacy data available in EPA RAD Removal Technical Brief (last accessed January 26, 2015) located on EPA's website.

For more information about this demonstration or the results in this report, contact Sang Don Lee (Lee.Sangdon@epa.gov) or Matthew Magnuson (Magnuson.Matthew@epa.gov) of the US EPA National Homeland Security Research Center.

As this report has described, the gross decontamination technology demonstration included building and vehicle decontamination technologies, and radioactive particle containment strategies. Five scalable technologies for wide-area radiological decontamination technologies were also demonstrated, including chemical foam solutions, strippable coatings, and gels. Wastewater treatment, a tool for waste management, was also demonstrated.

From all of the technology demonstrations, attendee feedback sessions, technical presentations, and other interactions, four themes emerged from the demonstration and are given in Table 17 below. These themes are based on the observations of end-users and stakeholders of the demonstrated technologies applied specifically to the challenges of wide area radiological release, which can pose distinct challenges requiring specific solutions compared to other types of radiological releases, such as nuclear warfare[18]. The third theme (Table 17) reflects general feedback (i.e. compared to the specific technical feedback in Section 5.2) regarding the value of having all types of personnel potentially involved in early and cleanup phase activities gathered in one place, to better advance solutions to the responsibilities of all. In some respects, the third theme is a "systems approach" for interactions between personnel, in some sense analogous to the technical "system approach" summarized in Theme 2. Integration of these themes into future research work and operational demonstrations may help develop and further systems, techniques, approaches, and processes to prepare the United States for possible future radiological incidents.

Table 17. Themes Emerging from Technology Demonstration

"Toolbox of Technologies" Emerging Themes
1. Full-scale testing of technologies is imperative for understanding function and efficacy
2. "Systems approach" to a functional radiological response framework needs to be prioritized
3. Communication amongst applicable agencies needs to be prioritized
4. Fukushima response needs to be thoroughly studied and apply lessons learned to develop a functional "systems based" framework for radiological response

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