Demonstration of Wide Area Radiological Decontamination and Mitigation Technologies for Building Structures and Vehicles-16508

Ryan James, Sang Don Lee**, Matthew Magnuson***
*Battelle Memorial Institute
**EPA National Homeland Security Research Center

ABSTRACT

Researchers at the U.S. Environmental Protection Agency in collaboration with the Department of Homeland Security conducted the “Wide-Area Urban Radiological Contaminant, Mitigation, and Clean-Up Technology Demonstration” in Columbus, Ohio on June 22-25, 2015. EPA’s National Homeland Security Research Center (NHSRC) demonstrated five wide-area radiological decontamination technologies (including strippable coatings, gels, and chemical foam technologies) 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 radiation exposure level.

In addition, NHSRC teamed with the Department of Homeland Security (DHS) to demonstrate several radiologifcal contaminant mitigation technologies 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 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 design to prevent the spread of particles which 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. 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 of this technology 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 high- and low-technology liquid containment approaches.

Results and stakeholder observations from the demonstration are now publically in a report entitled “Technical Report for the Demonstration of Radiological Decontamination and Mitigation Technologies for Building Structures and Vehicles” available at http://www.epa.gov/hsresearch 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 of worker 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. were 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.

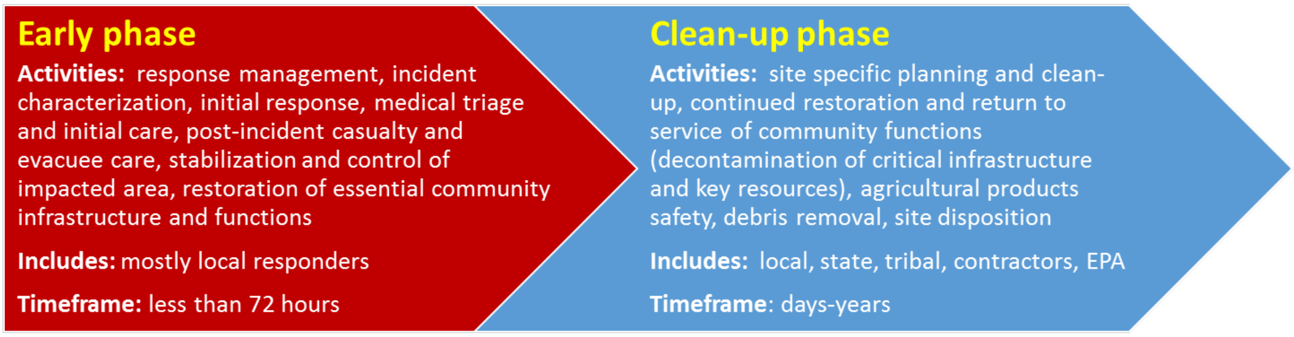
INTRODUCTION

The U.S. Environmental Protection Agency (EPA) has responsibility for protecting human health and the environment 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 preventing the spread of radionuclides in urban settings. “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.

These evaluations 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 the 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 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 decontaminations 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 contamination, 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 summarized a draft EPA report entitled, “Early Phase Waste Staging for Wide Area Radiological Releases.” This report, available at http://www.epa.gov/hsresarch, should be referenced for additional inquiry regarding waste staging and generation.

Three major technology categories were included in the demonstration. The first two were for gross decontamination and decontamination, and are primarily applicable during the early and clean-up response phases, respectively, as illustrated in Figure 1. The third category, radiological particle containment, can be important during both response phases, because it can enable both mitigation and decontamination activities. (Note all these categories are defined in the abstract.) 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, it is recognized that a variety of responders may use these, and there are many stakeholders that have an interest in how they are deployed.)



Early phase

Activities: response management, incident characterization, initial response, medical triage and initial care, post-incident casualty and evacuee care, stabilization and control of impacted area, restoration of essential community infrastructure and functions

Includes: mostly local responders

Timeframe: less than 72 hours

Clean-up phase

Activities: site specific planning and clean-up, continued restoration and return to service of community functions (decontamination of critical infrastructure and key resources), agricultural products safety, debris removal, site disposition

Includes: local, state, tribal, contractors, EPA

Timeframe: days-years

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.

DEMONSTRATION DESCRIPTION

Summary

A building scheduled for demolition on Battelle's main campus located in Columbus, Ohio was used as a test site for demonstrating five scalable decontamination activities. 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. Figure 2 shows the west face of the East Wing of Building A (hereafter, referred to as "the building"), which was subsequently demolished two months later. 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.

Scalable decontamination technologies are designed for deployment months or years following a radiological incident (late phase response). Five of these technologies were demonstrated on the other side of the building over unique area of approximately 100 m^2 (16 meter (m) high x 6 m wide) for each technology.

Each of these "gross decontamination" technologies was also applied to the building and vehicles and 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. 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 represented the highest level of technology in the demonstration. In addition, two lower levels of technology for vehicle wash mitigation (and liquid containment) were demonstrated. They were also composed of 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.

Scalable Radiological Decontamination Technologies

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 2). The surface conditions appeared dry upon application. There had been over 3 centimeters (cm) of rainfall 2 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 include CBI Polymer's DeconGel^{TM} 1128 (DeconGel), Stripcoat TLC Free^{TM} (Stripcoat), Environmental Alternatives Inc. SuperGel and Rad-Release II, and Environmental Canada's (EC) Universal Decontamination Foam (UDF). 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) in order to safely reach the higher floors (Figure 3). There also was a sixth partition for application of the technologies using a bosan chair instead of the boom lift (see Figure 4).

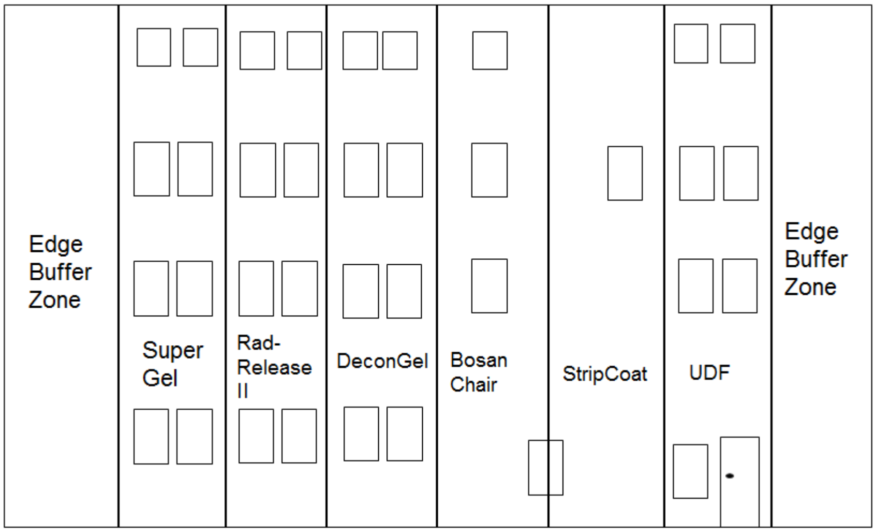


Figure 2. Labeled sketch of the west face of the building where demonstration of five scalable technologies took place, along with zones where technologies were applied. The sketch shows edge buffer zones where no products were applied. All of the scalable technologies were applied to small sections of the "Bosan chair" area.

Figure 3. 20 m-boom lift that was used to safely reach the higher elevations during the scalability demonstrations.

Figure 4. Bosan chair (left) and deployment from building roof (right).

The technology demonstration was conducted under the guidance of a Quality Assurance Project Plan (QAPP). 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 that end users could understand the benefits and limitations of the applied technologies. 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.

For each of the technologies demonstrated, Table 1 shows the type of information to be discussed including information applicable to the demonstration of each technology. This information is a mix of observational, collected data, and procedural information.

Table I. *Example Technology Information from Demonstration*

Surfaces	Surface description
Technology preparation	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
Cost of application	Cost of application per unit area (for demonstration)
PPE	PPE required for demonstration per MSDS
Required Containment	Tools used to control spread of contamination due to application of each technology.
Demonstration Observations	Observations of results of demonstration

Gross Decontamination Technologies

In addition to the scalable decontamination technologies, two gross decontamination (as defined in the abstract) technologies were demonstrated on the building and vehicles. One was a firefighter foam additive from Environment Canada, and the other was the Irreversible Wash-Aid, Treatment, and Emergency Reuse System (IWATERS) developed by EPA, Technical Support Working Group, and Argonne National Laboratory. Both of these technologies were used in conjunction with a foam eductor provided by Columbus Division of Fire (IWATERS was demonstrated using only a water eduction). The eductor required a water pressure of 200 pounds per square inch (psi) and 380 liters per minute (Lpm) of flow. Initially, the hose was connected to the foam eductor system and water turned on at the conditions described above that were adequate for the operation of the foam eductor with the nozzle directed towards the bottom right portion of the area to be treated.

Building Application

A firefighter applied the spray stream 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 covered (Figure 5 shows the foam application and the IWATERS reuse system, which is similar except the spray is clear). Immediately following the application, a water rinse was applied from the ground level to remove the foam, while the IWATERS system was a one pass rinse. 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. There was no visible surface damage or residual material left on any of the surfaces after rinse removal of either foam.

Liquid waste containment systems were employed to accommodate the runoff. For the Environment Canada foam, the containment was plastic polyethylene sheeting attached to the bottom of the building. Containment in the IWATERS system is through a rapidly-deployable berm of a type routinely used for flood control. Additionally, the IWATERS system includes an onsite treatment system that was demonstrated by allowing the firefighters to immediately reuse the rinse water, which may be desirable if large urban areas are to be treated.

Figure 5. Application of Environment Canada foam via a fire truck (left). Water reuse system of IWATERS (right).

Figure 6. Environment Canada vehicle wash with foam.

Vehicle Application

The IWATERS system is utilized for vehicles by constructing a berm for wash wash containment and then spraying the vehicle with the fire hose nozzle, similar to spraying the building. While the Environment Canada foam could be utilized for vehicles with the fire hose eductor pictured in Figure 5, in the demonstration, it was applied as shown in Figure 6 to the vehicle using the Pro-Pak foam dispensing system, a system that many fire department use. This application system allows more precise control of the application and hence minimization of the amount of foam used and waste generated.

Washing of vehicles was also demonstrated using a standard pressure washer (GX390, BE Pressure Supply, Abbotsford, BC) and a garden hose because while the components for both IWATERS and Environment Canada foam are available within a city or region, garden hoses and pressure washers are even more readily available.

Containment of the wastes from vehicle washing was integrated into the demonstration. Wash water in the IWATERS system is an integral part of its design, as described for building application, with the difference that the berm is configured differently. Multiple vehicles could be driven in and out of the berm for washing via a ramp (a similar application as for flood control). The IWATERS system also enables reuse of water from vehicle washes.

Two other systems to contain wash water were demonstration. The first was a commercially available, heavy-duty car wash mat composed of PVC material (ACC_M2, Chemical Guys, Los Angeles, CA). The mat consisted of plastic sheeting with 4-inch channels filled with air around the edges. It was free standing and had 30 minute setup and teardown. The dimensions of the mat were 3.3 m x 6.7 m.

A second wash water containment approach was composed of cinder blocks, corrugated polyvinyl chloride (PVC) piping, a tarp and bungee cords (shown in part in Figure 6 above). 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 easily be moved 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.While the other containment approach is composed of commercially available component, the components for this onemay be the most readily available of any described above.

Particle Containment Technologies

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 evacuation, response, mitigation and decontamination activities may create containment issues and further exacerbate remediation activities.

Such resuspension and tracking may occur via foot and vehicle traffic. During the demonstration, this was illustrated by applying a solution of fluorescent particles (PDT-06, Risk Reactor, Santa Ana, CA) mixed in a 1:1 water and isopropyl alcohol solution as a surrogate for radioactive dust to a vehicle using a hand-held sprayer (56HD, Flo-Master, Lowell, MI) . The solution was allowed to evaporate overnight, leaving only the simulated contamination that illuminated under a handheld black light (Model #16466, General Electric, Fairfield, CT) as seen in Figure 7.

Figure 7. PDT-06 Simulation residue on the vehicle before being washed.

The next day, the washed, as described above with (water only) with the goal of removing fluorescent particles. The black light was utilized by waving it over the vehicle to determine if any fluorescent particles remained. Figure 8 shows the particles remaining on the windshield and the door frame (visible only when the door was open). The vehicle that underwent the pressure washer exhibited fewer remaining particles (determined by visual inspection) than the vehicle being washed with a garden hose. 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.

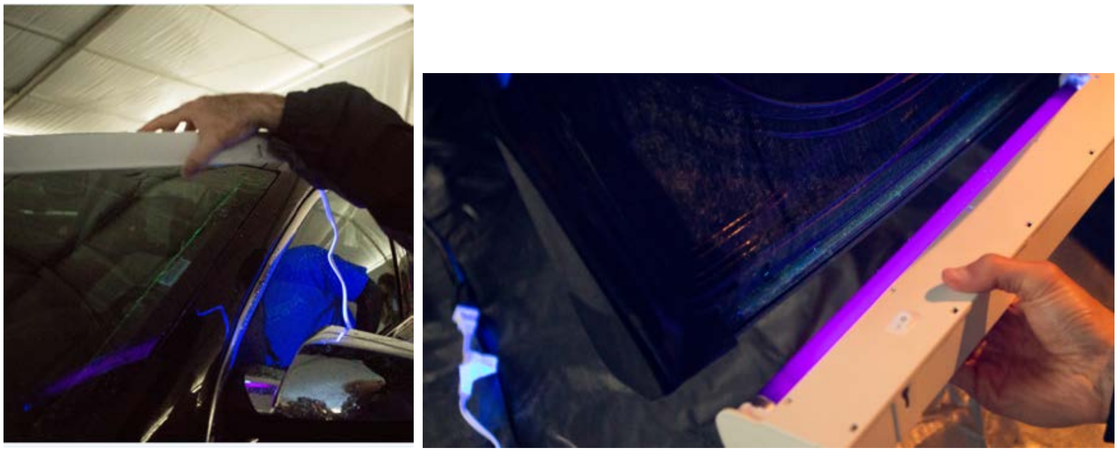


Figure 8. After washing, the vehicle remained contaminated with fluorescent particles on the windshield (left) and the inside of the door frame (right).

To reduce other means of particle tracking and resuspension, non-traditional radiological stabilization technologies such as fire retardants and dust suppression technologies (e.g., wetting agents (other than water), 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. Three particle containment technologies were demonstrated with 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).

Surrogate radiological dust (the fluorescent material described above resulting in Figures 7 and 8) was applied to 24 of the pavers using a small hand-held sprayer (Figure 9). The pavers were allowed to dry overnight; the alcohol evaporated, leaving only the dust particles and simulated contamination.

There were three containment technologies demonstrated: 1) fire retardant, 2) wetting agent, and 3) chloride salts. Before the demonstration took place, the containment technologies were prepared. The fire retardant was a mixture of a fire retardant (MVP-F, Phos-Chek, Rancho Cucamonga, CA) added to water to make a gel/slurry. The wetting agent was a combination of a dust suppression product (Soil2OTM, GelTech Solutions, Jupiter, FL) and water. The chloride salts were made by adding calcium chloride flakes and water. The containment technologies were mixed and then were applied to the contaminated pavers using hand-held sprayers

(6 pavers with chloride salts) or paint rollers (6 pavers with wetting agents and 6 pavers fire retardant).

Figure 9. Application of containment technologies to pavers.

Four vehicles were arranged inside the tent all facing the same direction. Pavers were spaced such that the tires contacted nine pavers, and such that one revolution of 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 10). Subsequently, cars were driven over the three containment technology treated pavers and then, similar to the control, the final 6 pavers were clean. The control was tested first, followed by the wetting agent, chloride salts and fire retardant (Figure 11). The vehicles driven very slowly (<5 miles per hour) over the pavers. In an actual emergency situation, emergency vehicles will be travelling 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.

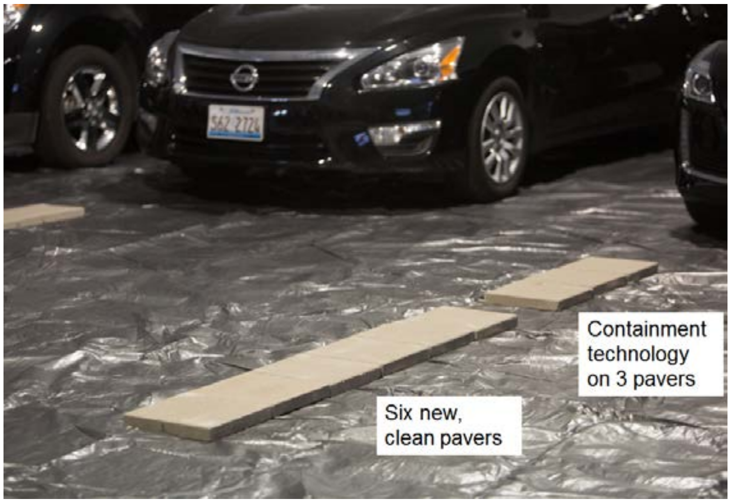


Figure 10. Depiction of vehicle particle containment setup.

Figure 11. Vehicle orientation and associated containment technology for particle containment study.

A similar demonstration was performed using “bootie” shoe covers and walking on four sets of pavers that were setup inside the tent for the pedestrian particle containment. For the control, one person, with disposable shoe covers on, walked over 5 total pavers, the first three being contaminated with the surrogate radiological dust and the last two being clean pavers (Figure 12). 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.

Figure 12. Foot traffic particle containment. The fire retardant is pictured here. The same approach was used for the other two containment technologies.

For all four scenarios (control and three containment technologies), in both the foot traffic and vehicle experiments, particle transport occurred. Figure 13 summarizes the results observed from the driving experiment. 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 salts technologies fell in between and had less particle transfer than the control, but more than fire suppressant.

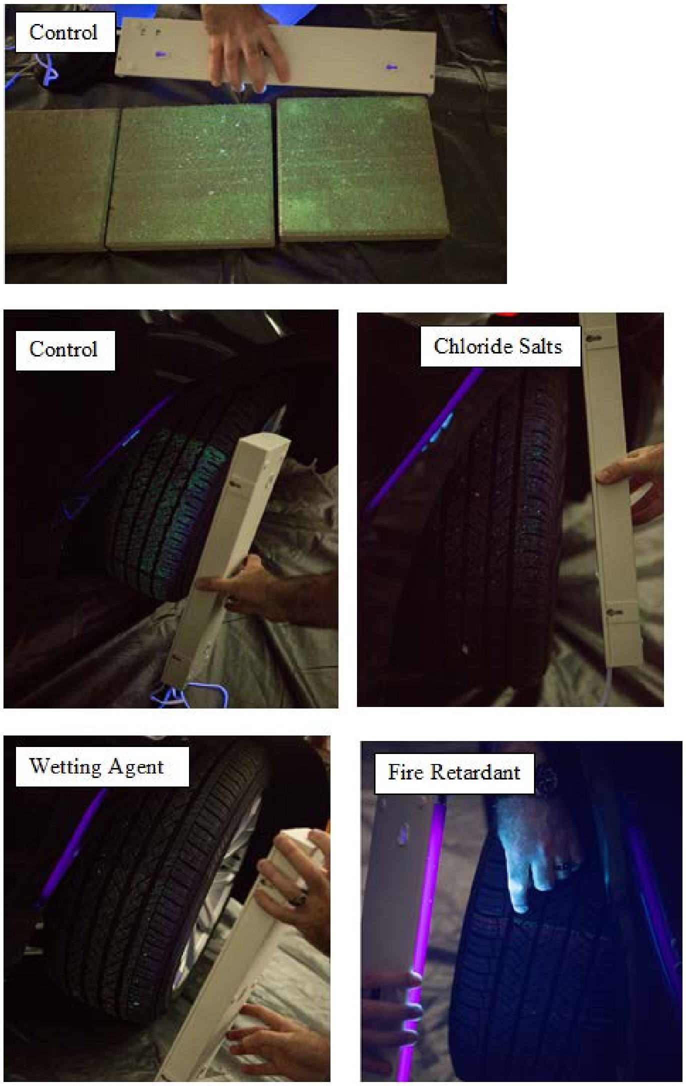


Figure 13. Results of the vehicle particle containment demonstration. Top image shows the control pavers. Control vehicle tires picked up the most particles, followed by the chloride salts. Wetting agents picked up a moderate amount of particles. The fire retardant scenario had the least amount of particle transfer, but notice the narrow line of particles that were present when the tire contacts the edge of the paver, not covered by fire retardant.

CONCLUSIONS

This demonstration provided a unique opportunity to see more than 15 different radiological gross decontamination, decontamination, and containment technologies demonstrated. It 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 onsite without transport.

As described above and also in an upcoming report (available at www.epa.gov/hsresearch), 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 II 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]. 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 II. 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 framework

DISCLAIMER

The U.S. Environmental Protection Agency through its Office of Research and Development partially funded and collaborated in the research described here. 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.

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