Evaluation of Chemical-Based Technologies for Removal of Radiological Contamination from Building Material Surfaces

Background

Because of their potential for deployment as a terrorist weapon in an urban setting, an improvised nuclear device (IND) or radiological dispersion device (RDD, or "dirty bomb") is a very real and significant danger. Cesium-137, Cobalt-60, Strontium-85 or Americium-243 are some of the many radioactive isotopes with the potential to be employed in an IND or RDD. The National Response Framework, the federal document that details how the nation responds to such threats, identifies the U.S. Environmental Protection Agency (EPA) as a lead federal agency for decontamination following such a radiological incident. This response could include the decontamination of buildings, equipment, and outdoor areas. In support of this role, EPA's Homeland Security Research Program (HSRP) evaluated the performance of fourteen chemical-based decontamination technologies for their ability to remove various radionuclides from the surface of unpainted building materials. In addition, HSRP evaluated various deployment-related characteristics of the products.

This work, completed in 2013, is described in a series of reports. *These peer-reviewed reports provide rigorous evaluations of the efficacy of fourteen commercially-available surface cleaning technologies of the type that could be employed to decontaminate concrete surfaces following an RDD incident releasing radioactive Cesium, Cobalt, Strontium, or Americium. Results may be applicable to contamination resulting from INDs and Nuclear Power Plant (NPP) accidents.* These reports, which can be accessed via the HSRP website (www2.epa.gov/homeland-security-research), provide information that emergency responders and their support personnel can use in recommending or selecting appropriate technologies for use during cleanup operations. This information can also be used

As part of U. S. EPA's Office of Research and Development, the Homelands Security Research Program (HSRP) provides products and expertise to improve our nation's ability to respond to environmental contamination caused by terrorist attacks on our nation's water infrastructure, buildings and outdoor areas.

HSRP conducts research related to:

- Detecting and containing contamination from chemical, biological, and radiological agents
- Assessing and mitigating exposure to contamination
- Understanding the health effects of contamination
- Developing risk-based exposure advisories
- Decontaminating and disposing of contaminated materials.

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to assist federal, state, and local emergency management authorities and emergency response planners to prepare for radiological homeland security events.

Results

A summary of the decontamination efficacy results is presented in Tables 1-4. Unpainted concrete, limestone, granite, and marble coupons were contaminated with Cs-137, Co-60, Sr-85, or Am-243 and the amount of contamination (radiological activity) deposited on each coupon was measured. Each coupon was then treated with the decontamination technology under investigation and the amount of contamination remaining was measured. Like all other building materials, concrete was contaminated and decontaminated within two weeks or decontaminated after one year ("Concrete-1Y" material in Tables 1-4). The efficacy of the decontamination technology is expressed in terms of percent of contamination removed (%R). These efficacy measures are determined based on the following relationship:

$$\%R = (1-A_f/A_o) \times 100\%$$

$\%R$ = percent of contamination removed

A_o = radiological activity from the surface of the coupon before decontamination

A_f = radiological activity from the surface of the coupon after decontamination

Decontamination results are tabulated per radionuclide (Table 1 for Cs-137; Table 2 for Co-60; Table 3 for Sr-85; Table 4 for Am-243 and ordered per tested decontamination product. Not all surface types were included for all fourteen decontamination technologies and four radionuclides.

Operational-related characteristics are presented in Table 5.

Table 1. Efficacy of Decontamination Products for Removal of Cs-137

Product	Application Type	Reference	Material	Decontamination Efficacy %R
EAI Rad-Release II	Liquid Spray/Rinse/Vacuum	1,2	Concrete	80 ± 8
		2	Concrete-1Y	50 ± 17
		3	Limestone	38 ± 13
		3	Granite	72 ± 3
		3	Marble	89 ± 5
EAI SuperGel*	Gel/Vacuum	2,4	Concrete	73 ± 6
		2	Concrete-1Y	46 ± 6
		3	Limestone	15 ± 6
		3	Granite	50 ± 3
		3	Marble	71 ± 3
CBI DeconGel 1108	Strippable Coating	5	Concrete	67 ± 9
		3	Limestone	35 ± 13
		3	Granite	72 ± 4
		3	Marble	93 ± 1
Intek LH-21	Liquid Spray/Rinse/Vacuum	3	Concrete	45 ± 16
		3	Limestone	39 ± 10
		3	Granite	56 ± 5
		3	Marble	91 ± 6
SDF	Foam Spray/Vacuum/Rinse	2	Concrete	51 ± 4
		2	Concrete-1Y	29 ± 10
UDF	Foam Spray/Vacuum/Rinse	2	Concrete	62 ± 9
		2	Concrete-1Y	37 ± 10
CBI DeconGel 1101	Strippable Coating	5	Concrete	45 ± 8
EAI Rad-Release I	Liquid Spray/Rinse/Vacuum	1	Concrete	71 ± 13
INTEK ND-75	Liquid Spray/Rinse/Vacuum	6	Concrete	47 ± 6
INTEK ND-600	Liquid Spray/Rinse/Vacuum	6	Concrete	52 ± 12
RDS Liquid	Liquid Spray/Wipe	7	Concrete	53 ± 7
RDS Foam	Foam Spray/Wipe	7	Concrete	51 ± 8
RDS 2000	Liquid Spray/Rinse/Vacuum	3	Concrete	11 ± 4

%R, percent of contamination removed

*: EAI SuperGel, developed by Argonne National Laboratories; previously tested as Argonne Supergel

Table 2. Efficacy of Decontamination Products for Removal of Co-60

Product	Application Type	Reference	Material	Decontamination Efficacy
				%R
EAI Rad-Release II	Liquid Spray/Rinse/Vacuum	8	Concrete	79 ± 6
		8	Granite	64 ± 10
EAI SuperGel*	Gel/Vacuum	8	Concrete	62 ± 5
		8	Granite	48 ± 14
CBI DeconGel 1108	Strippable Coating	3	Concrete	85 ± 2
RDS 2000	Liquid Spray/Rinse/Vacuum	3	Concrete	51 ± 3

%R, percent of contamination removed

*: EAI SuperGel, developed by Argonne National Laboratories; previously tested as Argonne Supergel

Table 3. Efficacy of Decontamination Products for removal of Sr-85

Product	Application Type	Reference	Material	Decontamination Efficacy
				%R
EAI Rad-Release II	Liquid Spray/Rinse/Vacuum	8	Concrete	70 ± 6
		8	Granite	44 ± 4
EAI SuperGel*	Gel/Vacuum	8	Concrete	40 ± 7
		8	Granite	32 ± 2
CBI DeconGel 1108	Strippable Coating	3	Concrete	64 ± 6
RDS 2000	Liquid Spray/Rinse/Vacuum	3	Concrete	43 ± 11

%R, percent of contamination removed

*: EAI SuperGel, developed by Argonne National Laboratories; previously tested as Argonne Supergel

Table 4. Efficacy of Decontamination Products for removal of Am-243

Product	Application Type	Reference	Material	Decontamination Efficacy
				%R
EAI Rad-Release II	Liquid Spray/Rinse/Vacuum	9	Concrete	88 ± 5
		9	Granite	51 ± 3
EAI SuperGel*	Gel/Vacuum	9	Concrete	67 ± 9
		9	Granite	34 ± 2
CBI DeconGel 1108	Strippable Coating	10	Concrete	84 ± 6
RDS 2000	Liquid Spray/Rinse/Vacuum	3	Concrete	69 ± 10
Intek LH-21	Liquid Spray/Rinse/Vacuum	3	Concrete	87 ± 7
Bartlett Stripcoat	Strippable Coating	11	Concrete	46 ± 5

%R, percent of contamination removed

*: EAI SuperGel, developed by Argonne National Laboratories; previously tested as Argonne Supergel

Table 5. Operational Characteristics

Parameter	Description
Decontamination Rate	• EAI Rad-Release I and Rad-Release II: Applied using spray bottles in just seconds. Rad-Release I is a single step process requiring approximately 30 minutes dwell time. Rad-Release II is two-step process requiring a total of 60 minutes dwell time. Scale-up would require spray or foam generating equipment, but dwell time would be the same. • EAI SuperGel: Applied by trowel (paint scraper), scale-up would require spray equipment (similar to airless paint sprayer) or roller. Requires 1-2 hour dwell time. • DeconGel 1101 and 1108: Applied with paint brush, scale-up would require spray equipment or roller. Requires overnight drying before stripping dry coating. Curing of DeconGel 1108 is faster at elevated temperatures and dry conditions; when applied to wet surfaces curing may be delayed beyond 24 h [12,13]. • INTEK LH-21, ND-75 and ND-600: Applied using spray bottles in just seconds. LH-21 requires six 10-minute application cycles. ND-75 requires three 15-minute application cycles. ND-600 requires three 30-minute application cycles. Scale-up would require spray equipment, but dwell times would be the same. • Allen-Vanguard Surface Decontamination Foam (SDF) and Decontamination Formulation (UDF): Applied using a foamer in approximately one minute followed by a 30 minute dwell time; vacuumed and reapplied foam for another 30 minutes. For UDF, additional reagent was sprayed with 30 minutes dwell time. Scale-up would require spray or foam generating equipment, but dwell time would be the same. • RDS Liquid and Foam: Applied using spray/foam bottles in seconds. Requires six cycles of application with two solutions and wiping with towels. Required 3-6 minutes for each 225 cm^2 concrete coupon. • Kärcher-Futuretech RDS 2000: Applied using hand pressurized sprayer in seconds. Requires three application cycles with 5 minutes dwell times each. • Bartlett Services Stripcoat TLC-Free™: Two coatings applied two hours apart with paint brush; scale-up would require spray equipment or roller. Requires overnight drying before stripping the dry coating. Curing of Stripcoat TLC Free™ is consistently 4 h and appears independent of environmental conditions {5-40 °C; 20-80% RH) [12,13].
Applicability to irregular surfaces	All technologies were judged to be applicable to irregular surfaces, but those requiring vacuum removal (EAI products, INTEK products, SDF, UDF, and RDS 2000) may prove to be more difficult depending on the surface and available vacuum attachments.
Skilled labor requirement	As evaluated, a brief training session is adequate. Scale-up would require somewhat more complex equipment and/or contractor support with corresponding training requirements for equipment operation.
Utilities required	110 V for vacuum; scale-up would require more complex equipment such as sprayers.
Extent of portability	Very portable; limited by need for utilities for vacuum and possible scaled-up application tools.
Setup time	Less than 15 minutes for all technologies as tested. Scaled-up application would require increased setup time consistent with commercial spraying equipment.

Parameter	Description
Secondary waste management	• EAI Rad-Release I and Rad-Release II: Approximately 3-8 L/m^2 liquid collected by wet vacuum; less for porous materials. • EAI SuperGel: 5-10 L/ m^2 gel waste collected in wet vacuum. • DeconGel 1101 and 1108: 200 g/m^2 of dried coating. • INTEK: Approximately 3-5 L/m^2 liquid collected by the wet vacuum; less for porous materials. • SDF and UDF: 25 L/m^2 of foam and 15 L/m^2 rinse water. • RDS Liquid and Foam: 5 L/m^2 mostly collected by the towels used to wipe the surface; 2000-3000 cm^3 of towels used during this evaluation. Capacity of the wipe material was not evaluated and may not scale linearly for a large scale scenario. • RDS 2000: Approximately 10 L/m^2 liquid collected by wet vacuum; less for porous materials. • Stripcoat TLC-Free™: 400 g/m^2 of dried coating.
Surface damage	None of the technologies caused visible surface damage.
Cost (material only; does not include labor, equipment, or waste management)	• EAI Rad-Release I and Rad-Release II: Approximately \$33-55/m^2 • EAI SuperGel: Approximately \$1.50-3.00/m^2 • DeconGel 1101 and 1108: Approximately \$50-125/m^2 (both 1101 and 1108) • INTEK: Approximately \$1/m^2 for ND-75; \$2/m^2 for ND-600; and \$4/m^2 for LH-21 • SDF and UDF: \$8.25/m^2 for SDF; \$12/m^2 for UDF • RDS Liquid and Foam: Approximately \$250/m^2 • RDS 2000: Approximately \$75/m^2 • Bartlett Stripcoat: Approximately \$33/m^2

Technology Evaluation Reports Referenced

1. U.S. EPA, Office of Research and Development, Environmental Alternatives, Inc. Rad-Release I and II for Radiological Decontamination. U.S. Environmental Protection Agency, Washington, DC, EPA/600/R-11/083, 2011.
2. U.S. EPA, Office of Research and Development, *Decontamination of Concrete with Aged and Recent Cesium Contamination*. U.S. Environmental Protection Agency, Washington, DC, EPA/600/R-13/001, 2013.
3. U.S. EPA, Office of Research and Development, *Decontamination of Cesium, Cobalt, Strontium, and Americium from Porous Surfaces*. U.S. Environmental Protection Agency, Washington, DC, EPA/600/R-13/232, 2013.
4. U.S. EPA, Office of Research and Development, *Argonne National Laboratory Argonne SuperGel for Radiological Decontamination*. U.S. Environmental Protection Agency, Washington, DC, EPA/600/R-11/081, 2011.
5. U.S. EPA, Office of Research and Development, *CBI PolymersDeconGel® 1101 and 1108 for Radiological Decontamination*. U.S. Environmental Protection Agency, Washington, DC, EPA/600/R-11/084, 2011.
6. U.S. EPA, Office of Research and Development, *INTEK Technologies ND-75 and ND-600 for Radiological Decontamination*. U.S. Environmental Protection Agency, Washington, DC, EPA/600/R-11/085, 2011.

7. U.S. EPA, Office of Research and Development, *Radiation Decontamination Solutions, LLC "Quick Decon" Solutions for Radiological Decontamination*. U.S. Environmental Protection Agency, Washington, DC, EPA/600/R-11/086, 2011.
8. U.S. EPA, Office of Research and Development, *Decontamination of Concrete and Granite Contaminated with Cobalt-60 and Strontium-85*. U.S. Environmental Protection Agency, Washington, DC, EPA/600/R-11/086, 2011.
9. U.S. EPA, Office of Research and Development, *Decontamination of Concrete and Granite Contaminated with Americium-243*. U.S. Environmental Protection Agency, Washington, DC, EPA/600/R-13/204, 2013.
10. U.S. EPA, Office of Research and Development, *CBI Polymers DeconGel® 1108 for Radiological Decontamination of Americium*. U.S. Environmental Protection Agency, Washington, DC, EPA/600/R-12/067, 2013.
11. U.S. EPA, Office of Research and Development, *Bartlett Services, Inc.Stripcoat TLC FreeTMRadiological Decontamination of Americium*. U.S. Environmental Protection Agency, Washington, DC, EPA/600/R-13/005, 2013.
12. U.S. EPA, Office of Research and Development, *Evaluation of the Curing Times of Strippable Coatings and Gels as used for Radiological Decontamination.* U.S. Environmental Protection Agency, Washington, DC, EPA/600/R-14/238, 2014.
13. U.S. EPA, Office of Research and Development, *Impact of Stagnant Air Flow Conditions on the Curing Times of Strippable Coatings and Gels as used for Radiological Decontamination.* U.S. Environmental Protection Agency, Washington, DC, EPA/600/R-15/171, 2015.

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