EPA 600/R-11/083 | August 2011 | www.epa.gov/ord

United States
Environmental Protection
Agency

Technology Evaluation Report

Environmental Alternatives, Inc. Rad-Release I and II for Radiological Decontamination

Office of Research and Development
National Homeland Security Research Center

Disclaimer

The U.S. Environmental Protection Agency (EPA), through its Office of Research and Development's National Homeland Security Research Center, funded and managed this technology evaluation through a Blanket Purchase Agreement under General Services Administration contract number GS23F0011L-3 with Battelle. This report has been peer and administratively reviewed and has been approved for publication as an EPA document. Mention of trade names or commercial products does not constitute endorsement or recommendation for use of a specific product.

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

John Drake
National Homeland Security Research Center
Office of Research and Development
U.S. Environmental Protection Agency
26 West Martin Luther King Dr.
Cincinnati, OH 45268
513-569-7164
drake.john@epa.gov

Foreword

The Environmental Protection Agency (EPA) holds responsibilities associated with homeland security events: EPA is the primary federal agency responsible for decontamination following a chemical, biological, and/or radiological (CBR) attack. The National Homeland Security Research Center (NHSRC) was established to conduct research and deliver scientific products that improve the capability of the Agency to carry out these responsibilities.

An important goal of NHSRC's research is to develop and deliver information on decontamination methods and technologies to clean up CBR contamination. When directing such a recovery operation, EPA and other stakeholders must identify and implement decontamination technologies that are appropriate for the given situation. The NHSRC has created the Technology Testing and Evaluation Program (TTEP) in an effort to provide reliable information regarding the performance of homeland security related technologies. Through TTEP, NHSRC provides independent, quality assured performance information that is useful to decision makers in purchasing or applying the tested technologies. TTEP provides potential users with unbiased, third-party information that can supplement vendor-provided information. Stakeholder involvement ensures that user needs and perspectives are incorporated into the test design so that useful performance information is produced for each of the tested technologies. The technology categories of interest include detection and monitoring, water treatment, air purification, decontamination, and computer modeling tools for use by those responsible for protecting buildings, drinking water supplies and infrastructure, and for decontaminating structures and the outdoor environment. Additionally, environmental persistence information is also important for containment and decontamination decisions.

NHSRC is pleased to make this publication available to assist the response community to prepare for and recover from disasters involving CBR contamination. This research is intended to move EPA one step closer to achieving its homeland security goals and its overall mission of protecting human health and the environment while providing sustainable solutions to our environmental problems.

Jonathan G. Herrmann, Director
National Homeland Security Research Center

Acknowledgments

Contributions of the following individuals and organizations to the development of this document are gratefully acknowledged.

United States Environmental Protection Agency (EPA)
John Drake
Emily Snyder
Sang Don Lee
Eletha Brady-Roberts
Scott Hudson
Alyssa Hughes

University of Tennessee
Dr. Howard Hall

United States Department of Energy's Idaho National Laboratories

Battelle Memorial Institute

Contents

Figures

Tables

Abbreviations/Acronyms

ANSI	American National Standards Institute
ASTM	ASTM International
BQ	Becquerel
CBRNIAC	Chemical, Biological, Radiological, Nuclear Defense Information Analysis Center
°C	degrees Celsius
CC	cross-contamination
CFR	Code of Federal Regulations
Cs	cesium
cm	centimeter
cm^2	square centimeter
DARPA	Defense Advanced Research Projects Agency
DF	decontamination factor
DHS	U.S. Department of Homeland Security
DOD	Department of Defense
EAI	Environmental Alternatives, Inc.
EPA	U.S. Environmental Protection Agency
Eu	Europium
°F	degrees Fahrenheit
IEEE	Institute of Electrical and Electronics Engineers
INL	Idaho National Laboratory
keV	kilo electron volts
mL	milliliter(s)
L	liter
m	meter
m^2	square meter
µCi	microCurie
NHSRC	National Homeland Security Research Center
NIST	National Institute of Standards and Technology
ORD	Office of Research and Development
PE	performance evaluation
PPE	personal protective equipment
%R	percent removal
QA	quality assurance
QC	quality control
QMP	quality management plan
RDD	radiological dispersion device
RH	relative humidity
RML	Radiological Measurement Laboratory
RSD	relative standard deviation
TCLP	Toxicity Characteristic Leaching Procedure
Th	thorium
TSA	technical systems audit
TTEP	Technology Testing and Evaluation Program

Executive Summary

The U.S. Environmental Protection Agency's (EPA) National Homeland Security Research Center (NHSRC) is helping to protect human health and the environment from adverse impacts resulting from acts of terror by carrying out performance tests on homeland security technologies. Through its Technology Testing and Evaluation Program (TTEP), NHSRC evaluated the Environmental Alternatives Inc. (EAI) Rad-Release I and Rad-Release II and their ability to remove radioactive cesium (Cs)-137 from the surface of unpainted concrete.

Experimental Procedures. The Rad-Release I decontamination technology is a chemical process that involves the topical application of a single decontamination solution to treat various substrates bearing radiological contamination. Rad-Release II is a similar chemical process that involves the topical application of two solutions. Eight 15 centimeter (cm) × 15 cm unpainted concrete coupons were contaminated with approximately 1 microCurie (µCi) of Cs-137 per coupon. The amount of contamination deposited on each coupon was measured using gamma spectroscopy. The eight contaminated coupons were placed in a test stand (along with one uncontaminated blank coupon) that was designed to hold nine concrete coupons in a vertical orientation to simulate the wall of a building. Four coupons were decontaminated with Rad-Release I and four with Rad-Release II. The one-step Rad-Release I included application of a spray, a 30 minute dwell time, rinse, and removal. Rad-Release II included two formulations which followed the same procedure as Rad-Release I. The decontamination efficacy was determined by calculating both a decontamination factor (DF) and percent removal (%R). Important deployment and operational factors were also documented and reported.

Results. The decontamination efficacy (in terms of %R) attained for Rad-Release I and Rad-Release II was evaluated for each concrete coupon used during the evaluation. When the decontamination efficacy metrics (%R and DF) of the four contaminated coupons decontaminated by each were averaged together, the average %R for Rad-Release I was 71% ± 13% and the average DF was 3.9 ± 1.5. The average %R for Rad-Release II was 85% ± 2% and the average DF was 7.0 ± 1.1.

The application of Rad-Release I and Rad-Release II was performed using plastic spray bottles. For Rad-Release I, the concrete coupons were thoroughly wetted with Rad-Release I with 3-4 sprays. Then, the solution was worked into the surface of the coupon by scrubbing the entire surface of the coupon once with a scouring pad. During this evaluation, the initial application of Rad-Release I took only 10-15 seconds for each coupon. The next step was a 30 minute dwell time for the Rad-Release I to reside on the surfaces of the concrete coupons. After 30 minutes, the surface of the concrete coupons were thoroughly wetted with a deionized water/10% nitric acid rinse solution using another spray bottle and then the sprayed material was removed with a wet vacuum

(vacuuming took about one minute per coupon). Rad-Release II was used in the same way but there were two formulations that went through the process described above. Therefore, the Rad-Release I application took approximately 37 minutes and the Rad-Release II application took approximately 65 minutes because the dwell times were the major factor in the application time.

The waste generated through use of Rad-Release I and Rad-Release II was estimated to be approximately 7 liters (L)/ square meter (m^2). As used for this evaluation, only the wet vacuum required electricity. Scaled up applications in remote locations may require additional utilities to provide means for sprayer or foamer application and vacuum removal. Minimal training would be required for technicians using Rad-Release I and Rad-Release II, and the surface of the concrete was not visibly damaged during use.

1.0 Introduction

The U.S. Environmental Protection Agency's (EPA) National Homeland Security Research Center (NHSRC) is helping to protect human health and the environment from adverse effects resulting from acts of terror. NHSRC is emphasizing decontamination and consequence management, water infrastructure protection, and threat and consequence assessment. In doing so, NHRSC is working to develop tools and information that will improve the ability of operational personnel to detect the intentional introduction of chemical, biological, or radiological contaminants on or into buildings or water systems, to contain or mitigate these contaminants, to decontaminate affected buildings and/or water systems, and to dispose of contaminated materials resulting from clean-ups.

NHSRC's Technology Testing and Evaluation Program (TTEP) works in partnership with recognized testing organizations; stakeholder groups consisting of buyers, vendor organizations, and permitters; and through the participation of individual technology developers in carrying out performance tests on homeland security technologies. The program evaluates the performance of homeland security technologies by developing evaluation plans that are responsive to the needs of stakeholders, conducting tests, collecting and analyzing data, and preparing peer-reviewed reports. All evaluations are conducted in accordance with rigorous quality assurance (QA) protocols to ensure that data of known and high quality are generated and that the results are defensible. Through TTEP, NHSRC provides high-quality information that is useful to decision makers in purchasing or applying the evaluated technologies, and in planning cleanup operations. The evaluations generated through TTEP provide potential users with unbiased, third-party information that can supplement vendor-provided information. Stakeholder involvement ensures that user needs and perspectives are incorporated into the evaluation design so that useful performance information is produced for each of the evaluated technologies.

Under TTEP, NHSRC evaluated the performance of two technologies from Environmental Alternatives, Inc. (EAI) (Keene, NH), Rad-Release I and Rad-Release II, in removing radioactive isotope cesium (Cs)-137 from unpainted concrete. A peer-reviewed test/QA plan was followed, entitled "The Performance of Selected Radiological Decontamination Processes on Urban Substrates", Version 1.0, Amendment 1 dated July 14, 2010. This document will be referred to as the test/QA plan and was developed according to the requirements of the Quality Management Plan (QMP) for the Technology Testing and Evaluation Program, Version 3.0 dated January 2008. The evaluation generated the following performance information:

- Decontamination efficacy, defined as the extent of radionuclide removal following use of Rad-Release I and Rad-Release II, and the possibility of cross-contamination (CC)

- Deployment and operational factors, including the approximate rate of surface area decontamination, applicability to irregular surfaces, skilled labor requirement, utility requirements, portability, secondary waste management, and technology cost.

The evaluation of Rad-Release I and Rad-Release II took place October 27, 2010, with the pre-evaluation activity measurements occurring in September 2010 and the post-evaluation activity measurements occurring in early November 2010. All of the experimental work took place in a radiological contamination area at the U.S. Department of Energy's Idaho National Laboratory (INL). This report describes the quantitative results and qualitative observations gathered during the evaluation of the Rad-Release I and Rad-Release II. The contractor and EPA were responsible for QA oversight. A technical systems audit (TSA) was conducted during the evaluation as well as a data quality audit of the evaluation data.

2.0 Technology Description

This technology evaluation report provides results on the performance of Rad-Release I and Rad-Release II under laboratory conditions. The following description of Rad-Release I and Rad-Release II is based on information provided by the vendor and was not verified during this evaluation.

The Rad-Release I decontamination technology is a chemical process that involves the topical application of a single decontamination solution to treat various substrates bearing radiological contamination. Rad-Release II is a similar chemical process that involves the sequential topical application of two solutions (applied in the order directed by EAI). Both Rad-Release technologies extract radionuclides, including transuranics, from nearly all substrates. 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.

Rad-Release I and II are effective for both loose surface and fixed subsurface contamination and situations in which the contamination is a mixture of pure elements, oxides, and related compounds with varying solubility indices. Substrates for which Rad-Release I and II can be used include those that are both porous and seemingly nonporous. Both technologies can be deployed on various geometries including walls, ceilings, equipment, structural beams, internal piping and highly irregular surfaces.

To maximize the efficacy of the extraction process, the chemistry and application are tailored to the specific substrate, targeted contaminant(s), and surface interferences. The Rad-Release I solution contains salts to promote ion exchange and surfactants to remove dirt, oil, grease, and other surface interferences. Broad-target and target-specific chelants are blended into the solution to sequester and encapsulate the contaminants, keeping them in suspension until they are removed by the subsequent rinse. Rad-Release II includes one solution that is chemically similar to Rad-Release I and serves the same purpose in decontamination (although it is not the same solution). Rad-Release II includes a second solution designed as a caustic solution containing salts to promote ion exchange, ionic and nonionic surfactants, and additional sequestering agents, also utilized to encapsulate the contaminants and keep them in suspension until they are removed by the subsequent rinse.

Both Rad-Release I and Rad-Release II are applied in low volumes, as either an atomized spray or foam. Foam deployment of the solution is most appropriate for large scale applications while the spray application (as used during this evaluation) is beneficial for smaller applications and applications where waste minimization is a critical factor. After the decontamination solution is applied, light mechanical action (e.g., a light scrubbing or brushing with a scouring pad) is applied to ensure good contact with the contaminated surface. The solution is then left to reside for 30 minutes followed by a rinse and removal.

Several options are available to facilitate the removal step (e.g., vacuuming, simple wiping with absorbent laboratory wipes or rags for small surfaces, use of a clay overlay technique to wick out the Rad-Release and contamination over time and then remove the clay at a later date, or use of an absorbent polymer that is sprayed over the chemically treated surface to leach or wick out the contaminant laden solutions and bind them up). The sequence of application, dwell, rinse, and removal of the decontamination solution constitutes a single iteration. This procedure may be repeated, as needed, until the desired residual contaminant levels are achieved.

The blended solution contains no hazardous components regarding flammability or reactivity (as per Title 40 of the Code of Federal Regulations Section 261 (40CFR 261)) and has no components that would be classified as hazardous for disposal under Toxicity Characteristic Leaching Procedure (TCLP) testing. As a result, the waste stream from a project can be characterized based on the contaminants that were removed. Liquid waste volumes are usually 400 mL/square meter (m^2) to 4000 mL/m^2 of contaminated substrate. Depending on the matrix and the amount of rinse applied, the liquid waste stream may have a resultant pH of less than 2. A pH neutral waste can be attained by stoichiometrically adding sodium bicarbonate or another neutralizing agent. Waste may be handled by solidification, incineration, discharged to liquid effluent treatment systems, and/or evaporation. More information is available at www.eai-inc.com.

Figure 2-1. Rad-Release container (right) and spray bottle applicator (left).

3.0 Experimental Details

3.1 Experiment Preparation

3.1.1 Concrete Coupons

The concrete coupons were prepared from a single batch of concrete made from Type II Portland cement. The ready-mix company (Burns Brothers Redi-Mix, Idaho Falls, ID) that supplied the concrete for this evaluation provided the data which describe the cement clinker used in the concrete mix. For Type II Portland cement, the ASTM International (ASTM) Standard C 150-7[1] specifies that tricalcium aluminate accounts for less than 8% of the overall cement clinker (by weight). The cement clinker used for the concrete coupons was 4.5% tricalcium aluminate (Table 3-1). For Type I Portland cement the tricalcium aluminate content should be less than 15%. Because Type I and II Portland cements differ only in tricalcium aluminate content, the cement used during this evaluation meets the specifications for both Type I and II Portland cements. The apparent porosity of the concrete from the prepared coupons ranged from 15-30%.

Table 3-1. Characteristics of Portland Cement Clinker Used to Make Concrete Coupons

Cement Constituent	Percent of Mixture
Tricalcium Silicate	57.6
Dicalcium Silicate	21.1
Tricalcium Aluminate	4.5
Tetracalcium Aluminoferrite	8.7
Minor Constituents	8.1

The concrete was representative of exterior concrete commonly found in urban environments in the United States as shown by INL under a previous project entitled, "Radionuclide Detection and Decontamination Program. Broad Agency Announcement 03-013" sponsored by the U.S. Department of Defense (DOD), Defense Advanced Research Projects Agency (DARPA) and U.S. Department of Homeland Security (DHS). The wet concrete was poured into 0.9 meter (m) square plywood forms with the exposed surface "floated" to allow the smaller aggregate and cement paste to float to the top, and the concrete was then cured for 21 days. Following curing, the squares were cut to the desired size with a laser-guided rock saw. For this evaluation, the "floated" surface of the concrete coupons was used. The coupons were approximately 4 centimeters (cm) thick, 15 cm × 15 cm square, and had a surface finish that was consistent across all the coupons. No further weathering, conditioning, or treatment was performed on these concrete coupons.

3.1.2 Coupon Contamination

Eight coupons were contaminated by spiking individually with 2.5 milliliters (mL) of aqueous solution that contained 0.4 microCurie (μCi)/mL Cs-137 as a solution of cesium chloride, corresponding to an activity level of approximately 1 μCi over the 225 square centimeters (cm^2) surface. Application of the Cs-137 in an aqueous solution was justified because even if Cs-137 were dispersed in a particle form following a radiological dispersion device (RDD) or "dirty bomb" event, morning dew or rainfall would likely occur before the surfaces could be decontaminated. In addition, from an experimental standpoint, it is much easier to apply liquids, rather than particles, homogeneously across the surface of the concrete coupons. The liquid spike was delivered to each coupon using an aerosolization technique developed by INL (under a DARPA/DHS project).

The aerosol delivery device was constructed of two syringes. The plunger and needle were removed from the first syringe and discarded. Then a compressed air line was attached to the rear of the syringe. The second syringe contained the contaminant solution and was equipped with a 27 gauge needle, which penetrated through the plastic housing near the tip of the first syringe. Compressed air flowing at a rate of approximately 1 - 2 liter (L) per minute created a turbulent flow through the first syringe. When the contaminant solution in the second syringe was introduced, it became nebulized by the turbulent air flow. A fine aerosol was ejected from the tip of the first syringe, creating a controlled and uniform spray of fine liquid droplets onto the coupon surface. The contaminant spray was applied all the way to the edges of the coupon, which were taped (after having previously been sealed with polyester resin) to ensure that the contaminant was applied only to the surfaces of the coupons. The photographs in Figure 3-1 show this procedure being performed using a nonradioactive, nonhazardous aqueous dye to demonstrate that the 2.5 mL of contaminant solution is effectively distributed across the surface of the coupon.

Figure 3-1. Demonstration of contaminant application technique.

3.1.3 Measurement of Activity on Coupon Surface

Gamma radiation from the surface of each concrete coupon was measured to quantify contamination levels both before and after evaluation of Rad-Release I and Rad-Release II. These measurements were made using an intrinsic, high purity germanium detector (Canberra LEGe Model GL 2825R/S, Meriden, CT). After being placed in the detector, each coupon was measured until the average activity level of Cs-137 from the surface stabilized to a relative standard deviation (RSD) of less than 2%. Gamma-ray spectra acquired from Cs-137 contaminated coupons were analyzed using INL Radiological Measurement Laboratory (RML) data acquisition and spectral analysis programs. Radionuclide activities on coupons were calculated based on efficiency, emission probability, and half-life values. Decay corrections were made based on the date and the duration of the counting period. Full RML gamma counting QA/quality control (QC), as described in the test/QA plan, was employed and certified results were provided.

3.1.4 Surface Construction Using Test Stand

To evaluate the decontamination technologies on vertical surfaces (simulating walls), a stainless steel test stand that held three rows of three concrete coupons was used. The test stand, approximately 2.7 m × 2.7 m, was erected within a containment tent. The concrete coupons were placed into holders so their surfaces extended just beyond the surface of the stainless steel face of the test stand. Eight of the nine coupons placed in the test stand were contaminated with Cs-137, which has a half-life of 30 years. One uncontaminated coupon was placed in the bottom row of the test stand (position 8) and decontaminated in the same way as the other coupons. This coupon, referred to as the CC blank, was placed there to observe possible CC caused by the decontamination higher on the wall. Figure 3-2 shows the containment tent and the test stand loaded with the concrete coupons.

Figure 3-2. Containment tent: outer view (left) and inner view with test stand containing contaminated coupons with numbered coupon positions (right).

3.2 Evaluation Procedures

The nine concrete coupons in the test stand which had been contaminated approximately one month before were decontaminated using Rad-Release I and Rad-Release II. Rad-Release I was applied to the coupons in positions 3, 5, 6, 8 (blank coupon), and 9 while Rad-Release II was used on the coupons in positions 1, 2, 4, and 7. Both Rad-Release I and Rad-Release II were applied in the order given above to simulate an approach that would likely be taken in an actual decontamination event, where higher wall surfaces would be decontaminated first because of the possibility of secondary contamination lower on the wall.

The application of Rad-Release I and Rad-Release II was performed using plastic spray bottles (32 oz. Heavy Duty Spray Bottle, Rubbermaid Professional, Atlanta, GA). For Rad-Release I, the concrete coupons were thoroughly wetted with Rad-Release I with 3 - 4 sprays. Then, the solution was worked into the surface of the coupon by scrubbing the entire surface of the coupon once with a scouring pad (Heavy Duty Scouring Pad, 3M Scotch-Brite, St. Paul, MN). During this evaluation, the initial application of Rad-Release I took only 10-15 seconds for each coupon. The next step was a 30 minute dwell time for the Rad-Release I to reside on the surfaces of the concrete coupons. The coupon surfaces were kept damp with 1-2 sprays of additional Rad-Release I approximately every five minutes. The additional 1-2 sprays of the Rad-Release solutions was performed to simulate foam collapse, i.e. the reintroduction of fresh Rad-Release solutions to the contaminated matrix, as would be observed when deployed as a foam for larger scale real-world applications. After 30 minutes, the surface of the concrete coupons were thoroughly wetted with a deionized water/10% nitric acid rinse solution using another spray bottle and then the solution sprayed on the surface was removed with a wet vacuum (12 gallon, 4.5 horsepower, QSP® Quiet Deluxe, Shop-Vac Corporation, Williamsport, VA) which took about one minute per coupon. The overall decontamination method for Rad-Release I included:

1. Apply Rad-Release I with spray bottle
2. Scrub surface with scouring pad
3. Wait 30 minutes, during which the surface is kept wet with additional sprays every 5 minutes (to simulate foam collapse)
4. Thoroughly wet with deionized water/10% nitric acid rinse solution
5. Remove with wet vacuum by moving over the surface one time with the open end of a 1 ¼ inch hose flat against the surface without an attachment.

The application of Rad-Release II was a two-step application done using the same steps as described above for Rad-Release I. The above procedure was followed for Rad-Release II, Solution 1. Then, the same procedure was repeated for Rad-Release II, Solution 2. Therefore, the Rad-Release I procedure took approximately 37 minutes to complete while the Rad-Release II procedure took approximately 65 minutes.

The temperature and relative humidity (RH) were recorded at the start and finish. The temperature was 21 °C (70 °F) at the start and 19 °C (66 °F) at the end and the RH was 20% in both instances. According to the vendor, these conditions were acceptable for use of the Rad-Release solutions.

4.0 Quality Assurance/Quality Control

QA/QC procedures were performed in accordance with the program QMP and the test/QA plan for this evaluation.

4.1 Intrinsic Germanium Detector

The germanium detector was calibrated weekly during the overall project. The calibration was performed in accordance with standardized procedures from the American National Standards Institute (ANSI) and the Institute of Electrical and Electronics Engineers (IEEE)[2]. In brief, detector energy was calibrated using thorium (Th)-228 daughter gamma rays at 238.6, 583.2, 860.6, 1620.7, and 2614.5 kilo electron volts (keV). Table 4-1 gives the calibration results across the duration of the project. Each row gives the difference between the known energy levels and those measured following calibration (rolling average across the six most recent calibrations). Pre-contamination measurements were performed in late September and the post-contamination results were measured in late November. Each row represents a six week rolling average of calibration results. In addition, the energies were compared to the previous 30 calibrations to confirm that the results were within three standard deviations of the previous calibration results. All the calibrations fell within this requirement.

Table 4-1. Calibration Results – Difference from Th-228 Calibration Energies

	Calibration Energy Levels (keV)				
Date Range (2010)	**Energy 1 238.632**	**Energy 2 583.191**	**Energy 3 860.564**	**Energy 4 1620.735**	**Energy 5 2614.533**
9-27 to 11-2	-0.003	0.010	-0.039	-0.121	0.017
10-5 to 11-8	-0.003	0.011	-0.029	-0.206	0.023
10-12 to 11-16	-0.004	0.015	-0.040	-0.245	0.031
10-19 to 11-24	-0.005	0.014	-0.001	-0.320	0.043

Gamma ray counting was continued on each coupon until the activity level of Cs-137 on the surface had an RSD of less than 2%. This RSD was achieved during the first hour of counting for all the coupons measured during this evaluation. The final activity assigned to each coupon was a compilation of information obtained from all components of the electronic assemblage that comprises the "gamma counter," including the raw data and the spectral analysis described in Section 3.1.3. Final spectra and all data that comprise the spectra were sent to a data analyst who independently confirmed the "activity" number arrived at by the spectroscopist. When both the spectroscopist and an expert data analyst independently arrived at the same value the data were considered certified. This process defines the full gamma counting QA process for certified results.

The background activity of the concrete coupons was determined by analyzing four arbitrarily selected coupons from the stock of concrete coupons used for this evaluation. The ambient activity level of these coupons was measured for at least two hours. No activity was detected above the minimum detectable level of 2×10^{-4} µCi on these coupons. Because the background activity was not detectable (and the detectable level was more than 2,500 times lower than the post-decontamination activity levels), no background subtraction was required.

Throughout the evaluation, a second measurement was taken on five coupons in order to provide duplicate measurements to evaluate the repeatability of the instrument. Three of the duplicate measurements were performed after contamination prior to application of the decontamination technology and two were performed after decontamination. All five of the duplicate pairs showed difference in activity levels of 2% or less, within the acceptable difference of 5%.

4.2 Audits

4.2.1 Performance Evaluation Audit

RML performed regular checks of the accuracy of the Th-228 daughter calibration standards (during the time when the detector was in use) by measuring the activity of a National Institute of Standards and Technology (NIST)-traceable europium (Eu)-152 standard (in units of Becquerel, BQ) and comparing it to the accepted NIST value. Results within 7% of the NIST value are considered (according to RML internal quality control procedures) to be within acceptable limits. The Eu-152 activity comparison is a routine QC activity performed by INL, but for the purposes of this evaluation serves as the performance evaluation (PE) audit. This audit confirms the accuracy of the calibration of the germanium detector critical to the results of the evaluation. Table 4-2 gives the results of each of the audits applicable to the duration of the evaluation including the pre-decontamination measurements performed in late September. All results are below the acceptable difference of 7%.

Table 4-2. NIST-Traceable Eu-152 Activity Standard Check

Date	NIST Activity (BQ)	INL RML Result (BQ)	Relative Percent Difference
9-15-2010	124,600	122,000	2%
10-13-2010	124,600	123,100	1%
11-10-2010	124,600	121,600	2%

4.2.2 Technical Systems Audit

A TSA was conducted during testing at INL to ensure that the evaluation was performed in accordance with the test/QA plan. As part of the audit, the actual evaluation procedures were compared with those specified in the test/QA plan and the data acquisition and handling procedures were reviewed. No significant adverse findings were noted in this audit. The records concerning the TSA are stored indefinitely with the Contractor QA Manager.

4.2.3 Data Quality Audit

At least 10% of the raw data acquired during the evaluation and transcribed into spreadsheets for use in the final report was verified by the QA manager. The data were traced from the initial raw data collection, through reduction and statistical analysis, to final reporting, to ensure the integrity of the reported results.

4.3 QA/QC Reporting

Each assessment and audit was documented in accordance with the test/QA plan. Draft assessment reports were prepared and sent to the Test Coordinator and Program Manager for review and approval. Final assessment reports were then sent to the EPA QA Manager and contractor staff.

5.0 Evaluation Results

5.1 Decontamination Efficacy

The decontamination efficacy of the Rad-Release I and Rad-Release II was measured for each contaminated coupon in terms of percent removal (%R) and decontamination factor (DF). Both of these parameters provide a means of representing the extent of decontamination accomplished by a technology. The %R gives the extent as a percent relative to the activity and the DF is the ratio of the initial activity to the final activity or the factor by which the activity was decreased. These terms are defined by the following equations:

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

$$DF = A_o/A_f$$

where, A_o is the radiological activity from the surface of the coupon before application of Rad-Release I and Rad-Release II and A_f is radiological activity from the surface of the coupon after treatment. While the DFs are reported, the narrative describing the results focuses on the %R.

Tables 5-1 and 5-2 give the %R and DF for Rad-Release I and Rad-Release II, respectively. All coupons were oriented vertically. The target activity for each of the contaminated coupons (pre-decontamination) was within the acceptable range of 1 µCi ± 0.5 µCi. The overall average (plus or minus one standard deviation) of the contaminated coupons was 1.11 µCi ± 0.041 µCi and 1.0 µCi ± 0.08 µCi for the coupons used for Rad-Release I and Rad-Release II, respectively. The post-decontamination coupon activities were less than the pre-decontamination activities showing an overall reduction in activity for both technologies. For Rad-Release I, the %R averaged 71% ± 13% and the DF averaged 3.9 ± 1.5. Overall, the %R ranged from 53% to 82% and the DF ranged from 2.1 to 5.5. For Rad-Release II, the %R averaged 85 ± 2% and the DF averaged 7.0 ± 1.1. Overall, the %R ranged from 83% to 88% and the DF ranged from 5.7 to 8.5. A t-test was performed on the two data sets in order to determine the likelihood of generating the observed %R data if the data sets were not different. The probability of generating these data sets if the data sets were not significantly different was 0.133 so at a 95% confidence interval, the Rad-Release I and Rad-Release II were not considered significantly different from one another.

Table 5-1. Decontamination Efficacy Results for Rad-Release I

Coupon Location in Test Stand	Pre-Decon Activity (µCi / Coupon)	Post-Decon Activity (µCi / Coupon)	%R	DF
Top right	1.08	0.51	53%	2.1
Center middle	1.17	0.36	70%	3.3
Center right	1.09	0.20	82%	5.5
Bottom right	1.10	0.23	79%	4.8
Average	**1.11**	**0.32**	**71%**	**3.9**
Std. Dev	**0.041**	**0.14**	**13%**	**1.5**

Table 5-2. Decontamination Efficacy Results for Rad-Release II

Coupon Location in Test Stand	Pre-Decon Activity (µCi / Coupon)	Post-Decon Activity (µCi / Coupon)	%R	DF
Top left	0.97	0.14	85%	6.9
Top middle	1.04	0.12	88%	8.5
Center left	1.12	0.20	83%	5.7
Bottom left	0.96	0.14	85%	6.8
Average	**1.0**	**0.15**	**85%**	**7.0**
Std. Dev	**0.08**	**0.03**	**2%**	**1.1**

As described in Section 3.1, the CC blank was included in the test stand to evaluate the potential for CC due to application of Rad-Release I and Rad-Release II on wall locations above the placement of the uncontaminated coupon. In the case of this evaluation, Rad-Release I was applied to the contaminated coupon in the center middle position. Upon application of the Rad-Release I to the contaminated center middle coupon, some Rad-Release I ran down the wall onto the uncontaminated coupon in the bottom middle position. Rad-Release I was then applied to the CC blank using the same method as for the other coupons. After decontamination, the activity of the CC blank was found to be 0.0218 µCi. This value was 10 times greater than the minimum detectable level, but more than 5 times less than the post-decontamination activities of the contaminated coupons. Therefore, this result suggested that cross-contamination resulting from the application of Rad-Release I and Rad-Release II on coupons located above the CC blank was detectable, but minimal. Assuming that the Rad-Release I attained a 71%R on the CC blank, this residual activity of 0.0218 µCi would correspond to a pre-decontamination activity of 0.1 µCi, consistent with approximately 10% of the activity from the coupon located above. The liquid nature of the decontamination solutions facilitates flow of contamination down the side of the test stand. However, it is likely that Rad-Release I and Rad-Release II would not flow as easily down the side of an actual concrete wall as was the case for the stainless steel test stand, which would tend to reduce cross-contamination.

5.2 Deployment and Operational Factors

A number of operational factors were documented by the technician that performed the testing with the Rad-Release I and Rad-Release II. One of the factors was the degree of difficulty in application. The application of Rad-Release I and Rad-Release II was described in Section 3.2 and included use of a plastic spray bottle. Application of the Rad-Release I and Rad-Release II solutions to each coupon took 10-15 seconds in addition to the recommended dwell time of 30 minutes for each solution. For Rad-Release I, there was only one solution so there was only one 30 minute dwell time prior to rinsing by spraying with the deionized water/10% nitric acid solution and wet vacuum removal (approximately 1 minute per coupon). The total time elapsed for the five coupons decontaminated with Rad-Release I was approximately 37 minutes. For Rad-Release II, there were two solutions that were applied using the identical procedure that included a 30 minute dwell time for each. The total elapsed time for the four coupons decontaminated with Rad-Release II was approximately 65 minutes. These application and removal times are applicable only to the experimental scenario including these rather small concrete coupons. According to EAI, if Rad-Release I and Rad-Release II were applied to larger surfaces, larger application tools such as larger sprayers or foamers would likely be used which would impact the application rate. In addition, larger vacuum heads would be used for removal.

Rad-Release I and Rad-Release II behaved very similarly during application and removal. Both the Rad-Release I and Rad-Release II, Solution 1 reacted with the surface of the concrete to create a thin foam of bubbles upon application. EAI indicated that this was likely a release of carbon dioxide due to acid-base chemistry occurring at the surface of the concrete. Neither Rad-Release I nor Rad-Release II caused any immediate visible damage to the surface of the coupons, however long term surface changes were not evaluated. The Rad-Release II coupons did not dry as quickly as the Rad-Release I coupons. Following use of Rad-Release I, the coupons could be removed from the test stand almost immediately and be dry to touch, while the Rad-Release II coupons were left in the test stand overnight before removing them from the test stand and were still somewhat damp. Figure 5-1 shows a photograph of the rinse and vacuuming step of the Rad-Release procedure. The personal protective equipment (PPE) used by the technician in the picture was required because the work was performed in a radiological contamination area using Cs-137 on the concrete coupon surfaces. Whenever radioactive contaminated material is handled, anti-contamination PPE will be required and any waste will be considered low level radioactive waste (and will need to be disposed of accordingly). The required PPE was not driven by the use of the Rad-Release solutions (which are not hazardous), rather the interaction with surfaces contaminated with Cs-137.

Figure 5-1. Rinsing and vacuuming Rad-Release from concrete coupon.

Table 5-3 summarizes qualitative and quantitative practical information gained by the operator during the evaluation of Rad-Release I and Rad-Release II. All of the operational information was gathered during use of Rad-Release I and Rad-Release II on the concrete coupons inserted into the test stand. Some of the information given in Table 5-3 could differ if the Rad-Release I and Rad-Release II were applied to a larger surface or to a surface that was smoother or more rough and jagged than the concrete coupons used during this evaluation.

Table 5-3. Operational Factors Gathered from the Evaluation

Parameter	Description/Information
Decontamination rate	Technology Preparation: Rad-Release I and Rad-Release II are provided ready to use. The solutions were transferred into spray bottles and applied. Application: The limiting factor of decontamination rate is the surface area covered before the 30 minute dwell times. Larger surfaces would likely utilize sprayer or foamer application. During this experimental design, the initial application to the concrete coupons took only seconds and then the coupons were kept damp (to simulate the ongoing presence of a foam during a large-scale application) with reapplication during the dwell time. Rinsing and vacuuming took approximately one minute per coupon. In all, the application and removal took seven minutes in addition to the 30 minute dwell time for Rad-Release I (for a total elapsed time of 37 minutes) and five minutes in addition to the 60 minute wait time for Rad-Release II. Aside from the wait times, this corresponds to a decontamination rate of approximately 1 m^2/hr for both Rad-Release I and II. Estimated volumes used included 330 mL of Rad-Release I and Rad-Release II Solution 1, 380 mL Rad-Release II Solution 2, and 440 mL of the rinse solution.
Applicability to irregular surfaces	Application to irregular surfaces would not seem to be problematic as Rad-Release I and Rad-Release II are sprayed into hard to reach locations. Removal may be difficult if vacuuming jagged edges or gaps is required.
Skilled labor requirement	Adequate training would likely include a few minutes of orientation so the technician is familiar with the application technique including dwell times and requirement of keeping surface wet. Larger surfaces may require more complex equipment such as spray or foam application.
Utilities requirement	Electricity for the wet vacuum.
Extent of portability	At a scale similar to that used for this evaluation, vacuum removal would be the only portability factor. However, for larger scale applications, limiting factors would include the ability to apply the Rad-Release I and Rad-Release II at an adequate scale and then rinse and remove with a vacuum. Portable electrical generation or vacuum capability may be required.
Secondary waste management	1.5 L of liquid was applied to the concrete coupons used during this evaluation. That volume corresponds to a waste generation rate of approximately 7 L/m^2 depending on how much of the solutions absorb to the surfaces. Because Cs-137 was used for this testing, all waste (in vacuum) was solidified and disposed of as low level radioactive waste.
Surface damage	Concrete surfaces appeared undamaged.
Cost (material)	Rad-Release solutions are not sold as a stand-alone product. EAI, Inc. offers decontamination services which employ the Rad-Release products for which the cost varies greatly from project to project. Typical project costs have been approximately \$33-\$55/m^2.

6.0 Performance Summary

This section presents the findings from the evaluation of the Rad-Release I and Rad-Release II for each performance parameter evaluated.

6.1 Decontamination Efficacy

The decontamination efficacy (in terms of %R) attained for Rad-Release I and Rad-Release II was evaluated for each concrete coupon used during the evaluation. When the decontamination efficacy metrics (%R and DF) of the four contaminated coupons decontaminated with each Rad-Release were averaged together, the average %R for Rad-Release I was 71% ± 13% and the average DF was 3.9 ± 1.5. The average %R for Rad-Release II was 85% ± 2% and the average DF was 7.0 ± 1.1.

6.2 Deployment and Operational Factors

The application of Rad-Release I and Rad-Release II was performed using a plastic spray bottles. For Rad-Release I, the concrete coupons were thoroughly wetted with Rad-Release I with 3-4 sprays. Then, the solution was worked into the surface of the coupon by scrubbing the entire surface of the coupon once with a scouring pad. During this evaluation, the initial application of Rad-Release I took only 10-15 seconds for each coupon. The next step was a 30 minute dwell time for the Rad-Release I to reside on the surfaces of the concrete coupons. After 30 minutes, the surface of the concrete coupons were thoroughly wetted with a deionized water/10% nitric acid rinse solution using another spray bottle and then removed with a wet vacuum (vacuuming took about one minute per coupon). Rad-Release II was used in the same way but there were two formulations that went through the process described above. Therefore, the Rad-Release I application took approximately 37 minutes and the Rad-Release II application took approximately 65 minutes because the dwell times were the major factor in the application time.

The waste generated through use of Rad-Release I and Rad-Release II was estimated to be approximately 7 L/m^2. When Rad-Release I and Rad-Release II are used on surfaces that are radioactively contaminated, the waste generated will need to be disposed as radioactive waste. As used for this evaluation, only the wet vacuum required electricity. Scaled up applications in remote locations may require additional utilities to provide means for sprayer or foamer application and vacuum removal. Minimal training would be required for technicians using Rad-Release I and Rad-Release II, and the surface of the concrete was not visibly damaged during use. Rad-Release solutions are not sold as a stand-alone product but along with the decontamination service for which the cost varies greatly from project to project. Typical projects cost approximately corresponds to \$33-\$55/m^2.

7.0 References

1. ASTM Standard C 150-07, "Standard Specification for Portland Cement." ASTM International, West Conshohocken, PA, www.astm.org, 2007.

2. Calibration and Use of Germanium Spectrometers for the Measurement of Gamma Emission Rates of Radionuclides. American National Standards Institute. ANSI N42.14-1999. IEEE New York, NY (Rev. 2004).

SCIENCE

EPA
United States
Environmental Protection
Agency

PRESORTED STANDARD
POSTAGE & FEES PAID
EPA
PERMIT NO. G-35

Office of Research and Development (8101R)
Washington, DC 20460

Official Business
Penalty for Private Use
$300