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Technology Evaluation Report

CBI Polymers DeconGel® 1101 and 1108 for Radiological Decontamination

Office of Research and Development
National Homeland Security Research Center

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Disclaimer

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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. NHSRC, through TTEP, 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

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Abbreviations/Acronyms

ANSI	American National Standards Institute
ASTM	ASTM International
BQ	Becquerel
°C	degrees Celsius
CBRNIAC	Chemical, Biological, Radiological and Nuclear Defense Information Analysis Center
CC	cross-contamination
Cs	cesium
cm	centimeter
cm^2	square centimeter
cm^3	cubic centimeter
DARPA	Defense Advanced Research Projects Agency
DG	DeconGel®
DF	decontamination factor
DHS	U.S. Department of Homeland Security
DOD	Department of Defense
EPA	U.S. Environmental Protection Agency
Eu	Europium
°F	degrees Fahrenheit
g	gram
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
Th	thorium
TSA	technical systems audit
TTEP	Technology Testing and Evaluation Program

Executive Summary

The U.S. Environmental Protection Agency's (EPA's) 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 recently evaluated the performance of DeconGel® (DG) 1101 and DG 1108 strippable coatings from CBI Polymers (Honolulu, HI). The objective of evaluating DG 1101 and DG 1108 was to test their ability to remove radioactive cesium (Cs)-137 from the surface of unpainted concrete.

Experimental Procedures. DG 1101 and DG 1108 were applied as paint-like coatings and then cured in order to bind the Cs-137 so the cured coating containing CS-137 could be removed from the surface causing little or no surface damage. Prior to the evaluation, eight 15 centimeter (cm) × 15 cm unpainted concrete coupons were contaminated with Cs-137 at a level of approximately 1 microcurie (µCi, measured by 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. Following manufacturer's recommendations, both DG 1101 and DG 1108 coatings were applied and removed twice for each coupon (four coupons total for each technology) before the residual activity of the contaminated coupons was measured. 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 percent removal and decontamination factor attained by the DG 1101 and DG 1108 was evaluated for each concrete coupon used during the evaluation. When the decontamination efficacy metrics (%R and DF) of the four contaminated coupons were averaged together, the average %R for DG 1101 was 45 ± 7% and the average DF was 1.9 ± 0.24. The average %R for DG 1108 was 67 ± 9% and the average DF was 3.2 ± 0.87.

Both the DG 1101 and DG 1108 were painted onto the concrete coupons with a 4 inch paint brush. The time required to apply each coating to a coupon was an average of 30 seconds for each coat that was applied. During this evaluation, two coats were applied to each coupon and then the coupons were allowed to dry overnight and the coatings were removed. That cycle was repeated once.

The dry coatings were removed by first scoring the surface of the coupons (covered with dried coatings) into four sections with a utility knife and using the tip of the knife to free corners of the dried coating so they could be pulled off the surface by hand. The dry coatings were removed from each coupon in an average of 1 minute 24 seconds. The technician who did the removal became more adept at the removal task during the second removal as the average time required to remove the dry coatings from one coupon decreased between the first and second removals. These application and removal times are specific to the experimental scenario used during this evaluation. If these coatings were applied to larger surfaces, larger paint application tools such as rollers or sprayers may be used which would likely impact the application rate. In addition, larger sections of dry coating could likely be removed in a similar amount of time as for the small coupons. No utilities were required for use of DG 1101 and DG 1108 making them decontamination options that are amenable to use in remote settings. The only limitation on the portability of DG 1101 and DG 1108 is the ability to transport an adequate amount of the wet material to the contaminated site. Minimal training would be required for technicians using DG1101 and DG 1108, and the surface of the concrete was not damaged during application and removal of the DG 1101 and DG 1108.

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 cleanups.

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 CBI Polymers, LLC (Honolulu, HI), DeconGel® 1101 and 1108 (hereafter referred to as DG 1101 or DG 1108) 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 DG 1101 and DG 1108, 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 DG 1101 and DG 1108 took place October 25-27, 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 DG 1101 and DG 1108. 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 DG 1101 and DG 1108 under laboratory conditions. The following is a description of DG 1101 and DG 1108, based on unverified information provided by CBI Polymers.

DG 1101 and DG 1108 are strippable coatings designed for safely removing radioactive contamination or as a covering to contain contamination. DG 1101 and DG 1108 are sold as a paint-like formulation. Application options include use of a paint brush, roller, or sprayer. The water-based wet coating (hydrogel) can be applied to horizontal, vertical or inverted surfaces and can be applied to most surfaces including bare, coated and painted concrete, aluminum, steel, lead, rubber, plexiglas, herculite, wood, porcelain, tile grout, and vinyl, ceramic and linoleum floor tiles. Following application, the coating requires approximately 12 hours to cure prior to removal. When dry, the product binds the contaminants into a polymer matrix. The dried coating containing the encapsulated contamination can then be peeled off the surface and disposed of. More information is available at www.decongel.com.

Figure 2-1. DeconGel® 1101 and DeconGel® 1108

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.

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, which corresponded 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, the contaminant solution 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 DG 1101 and DG 1108. 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 eight concrete coupons in the test stand which had been contaminated approximately one month before were decontaminated using DG 1101 and DG 1108. DG 1101 was applied to the coupons in positions 1, 2, 4, and 7 while DG 1108 was used on the coupons in positions 3, 5, 6, 8 (blank coupon), and 9. Both DG 1101 and DG 1108 were applied to the coupons 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 DG 1101 and DG 1108 was performed in the same way using a standard four inch paint brush.

The specifications of the paint brush were not critical as a perfectly smooth application was not required. The paint brush was loaded with the wet coatings by dipping the brush into a plastic bucket containing the wet coatings and then the wet coatings were applied generously until the entire surface of the coupon was covered. The paint brush was then used to work the wet coatings into the surfaces. Then the brush was used to smooth the applied wet DG 1101 and DG 1108 on each concrete coupon. If there were areas of the coupons that were not covered completely, additional wet DG 1101 or DG 1108 was added. The first coat of the DG 1101 or DG 1108 was allowed to set for 2 hours and a second coat was added on top of the initial coat following the same method. The coupons with the wet DG 1101 and DG 1108 were allowed to dry overnight.

The dry coatings were removed by first scoring the surface of the coupons (now covered with dried coatings) into four sections with a utility knife and using the tip of the knife to free corners of the dried coating so they could be pulled off the surface by hand. This process was repeated once. The overall decontamination method for DG 1101 and DG 1108 included:

1. Apply wet coating followed by two hour drying time and apply a second coat
2. Dry overnight
3. Remove dried coatings
4. Apply wet coating followed by two hour drying time and apply a second coat
5. Dry overnight
6. Remove final dried coatings.

The temperature and relative humidity (RH) were recorded at the application and removal times. The temperature in all four instances was between 19 °C (66 °F) and 21 °C (70 °F) and the RH was always between 20% and 22%. Because the room in which the evaluation was performed was climate-controlled, these conditions did not vary significantly throughout the evaluation. According to the vendor, these conditions were acceptable for use of the DG 1101 and DG 1108.

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 comprise 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 DG 1101 and DG 1108 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 DG 1101 or DG 1108 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 DG 1101 and DG 1108, 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 1.10 µCi ± 0.03 µCi and 1.07 µCi ± 0.02 µCi for the coupons used for DG 1101 and DG 1108, respectively. The post-decontamination coupon activities were less than the pre-decontamination activities showing an overall reduction in activity for both technologies. For DG 1101, the %R averaged 45 ± 7% and the DF averaged 1.9 ± 0.24. Overall, the %R ranged from 35% to 52% and the DF ranged from 1.5 to 2.1. For DG 1108, the %R averaged 67 ± 9% and the DF averaged 3.2 ± 0.87. Overall, the %R ranged from 57% to 75% and the DF ranged from 2.3 to 4.0. 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 0.045 so at a 95% confidence interval, the DG 1101 and DG 1108 were considered significantly different from one another.

Table 5-1. Decontamination Efficacy Results for DG-1101

Coupon Location in Test Stand	Pre-Decon Activity (µCi / Coupon)	Post-Decon Activity (µCi / Coupon)	%R	DF
Top left	1.10	0.72	35%	1.5
Top middle	1.07	0.51	52%	2.1
Center left	1.13	0.61	46%	1.8
Bottom left	1.08	0.56	48%	1.9
Average	**1.10**	**0.60**	**45%**	**1.9**
Std. Dev	**0.026**	**0.09**	**7%**	**0.24**

Table 5-2. Decontamination Efficacy Results for DG-1108

Coupon Location in Test Stand	Pre-Decon Activity (µCi / Coupon)	Post-Decon Activity (µCi / Coupon)	%R	DF
Top right	1.07	0.28	74%	3.8
Center middle	1.09	0.27	75%	4.0
Center right	1.04	0.45	57%	2.3
Bottom right	1.08	0.42	61%	2.6
Average	**1.07**	**0.36**	**67%**	**3.2**
Std. Dev	**0.022**	**0.09**	**9%**	**0.87**

As described above in Section 3.1, the CC blank was included in the test stand to evaluate the potential for CC due to application of DG 1101 and DG 1108 on wall locations above the placement of the uncontaminated coupon. DG 1101 was applied to the contaminated coupon in the top middle position and DG 1108 was applied to the contaminated coupon in the center middle position. Upon application of the DG 1108 to the contaminated center middle coupon, there was a small amount of wet DG 1108 that dripped onto the uncontaminated coupon in the bottom middle position. DG-1108 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 0.0076 µCi. This value was five times greater than the minimum detectable level, but more than 50 times less than the post-decontamination activities of the contaminated coupons. Therefore, this detectable result suggested that cross-contamination resulting from the application/removal of DG 1101 and 1108 on coupons located above the CC blank is possible, but that the extent of CC observed here was minimal.

5.2 Deployment and Operational Factors

A number of operational factors were documented by the technician who performed the testing with the DG 1101 and DG 1108. One of the factors was the degree of difficulty in application and removal. The application of both technologies was described in Section 3.2. Both the DG 1101 and DG 1108 technologies were painted onto the concrete coupons with a four inch paint brush. The time required to apply each coating to a coupon was an average of 30 seconds for each coat that was applied. The overall time required to remove the coatings from each coupon was an average of 1 minute and 24 seconds. However, it was clear that the technician who did the removal became more adept at the removal task during the second removal as the average time required to remove the dry coatings from the concrete from one coupon dropped from 1 minute 51 seconds for the first removal to just 57 seconds for the second removal. These application and removal times are applicable only to the experimental scenario including these rather small concrete coupons. If these coatings were applied to larger surfaces, larger paint application tools such as rollers or sprayers may be used which would likely impact the application rate. In addition, larger sections of dry coating could likely be removed in a similar amount of time as the small coupons.

DG 1101 and DG 1108 coatings behaved very similarly during application and removal. The DG 1101 was a rather viscous gel when wet and therefore tended to stay on the coupon very well upon application. Removal of the DG 1101 was very easy as it was easily pulled from the concrete surface once a corner was freed by a knife.

The DG 1108 was less viscous and tended to run down the coupon upon application with some of the wet DG 1108 running off of the coupon, leaving what appeared to be a thin layer of wet coating. While DG 1108 may have been less viscous than DG 1101 when wet, the DG 1108 was removed in a fashion similar to DG 1101 after drying. While the removal method was practically similar, the DG 1108 required some additional effort to remove the dry coating from the surface of the concrete as the DG 1108 seemed to be adsorbed more strongly.

Figure 5-1 shows a photograph of an uncontaminated coupon during removal of the DG 1101 during a dry run outside the radiological containment tent. In this instance, the dry coating was able to be removed as one large piece. When using the DG 1101 and DG 1108 within the test stand, the technician scored the coupons into four sections and removed each section separately. The coupon surfaces were left undamaged by the DG 1101 and DG 1108. The personal protective equipment (PPE) used by the technicians (including respirators and full anti-contaminatino PPE) 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 (from removal of DG 1101 and DG1108) will be considered low level radioactive waste (and will need to be deposed of accordingly). The PPE was not driven by the use of DG 1101 and DG 1108 (which are not hazardous), rather the interaction with surfaces contaminated with Cs-137.

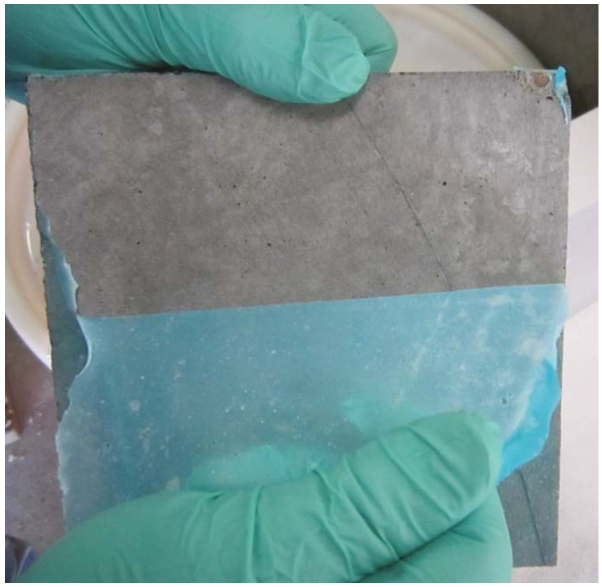

Figure 5-1. Concrete coupon during coating removal.

Table 5-3 summarizes qualitative and quantitative practical information gained by the technician during the evaluation of DG 1101 and DG 1108. All of the operational information was gathered during use of DG 1101 and DG 1108 on the concrete coupons inserted into the test stand. Some of the information given in Table 5-3 could differ if the DG 1101 and DG 1108 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: No preparation was required as wet DG 1101 and DG 1108 was poured out of a bottle ready to use. Application: Average of 30 seconds to apply each coat of wet coating to each coupon for both DG 1101 and DG 1108. Two hours were allowed to elapse and then a second coat was added. Then an overnight drying time was required before removal of the dry coating. The limiting factor of decontamination rate is the surface area covered before the overnight drying time. Larger surfaces would require larger roller brushes or paint sprayer application. Approximately 125 mL total of each wet coating was used for each application to the concrete coupons. That volume corresponds to approximately 25-30 mL per coupon for a loading of 1.2 L/square meter (m^2).
Applicability to irregular surfaces	Application to irregular surfaces would not seem to be problematic as the wet coatings can be painted or sprayed into hard to reach locations. Removal of the dry coating may take longer if the dry coating fractures on jagged edges or gaps in surfaces.
Skilled labor requirement	Adequate training would likely include a few minutes of orientation so the technician is familiar with the application technique and the required drying time.
Utilities requirement	No utilities were required to complete the experimental plan described in this report. If sprayer was used to apply DG 1101 or DG 1108, applicable power would be required.
Extent of portability	The limiting factors of portability for the DG 1101 and DG 1108 would include the ability to transport adequate wet coating and application tools to the job location.
Secondary waste management	Amount of secondary waste generated was based on the dried coating from coating applied to an uncontaminated coupon. The coating from one coupon weighed 3.6 grams (g). Therefore, the dried coatings from all nine coupons for two application and removal cycles would correspond to 65 g of waste with a volume of approximately 51 cubic centimeters (cm^3). Assuming two applications of two coats and two corresponding removals, this procedure corresponds to a waste generation of 319 g/m^2 and a volumetric waste generation of 252 cm^3/m^2 of surface. Because Cs-137 was used for this testing, all waste (liquid and solid gel) was disposed of as low level radioactive waste.
Surface damage	Concrete surfaces appeared undamaged.
Cost (material)	The material cost is $40/L for DG 1101 and $40/L for DG 1108 which corresponds to approximately $40/m² if used in a similar way as used during this evaluation. Labor costs were not calculated.

6.0 Performance Summary

This section presents the findings from the evaluation of the DG 1101 and DG 1108 for each performance parameter evaluated.

6.1 Decontamination Efficacy

The decontamination efficacy (in terms of %R) attained by the DG 1101 and DG 1108 was evaluated for each concrete coupon used during the evaluation. When the decontamination efficacy metrics (%R and DF) of the four contaminated coupons were averaged together the average %R for DG 1101 was 45 ± 7% and the average DF was 1.9 ± 0.24. The average %R for DG 1108 was 67 ± 9% and the average DF was 3.2 ± 0.87. These results were determined to not be significantly different from one another.

6.2 Deployment and Operational Factors

Both the DG 1101 and DG 1108 were painted onto the concrete coupons with a 4 inch paint brush. The time required to apply each coating to a coupon was an average of 30 seconds for each coat that was applied. Overall, 125 mL of each coating was used for each coat applied to the coupons used during this evaluation. This value corresponded to a coverage rate of 0.83 m^2/L. During this evaluation, two coats were applied to each coupon and then the coupons were allowed to dry overnight and the coatings were removed. That cycle was repeated once.

The dry coatings were removed by first scoring the surface of the coupons (now covered with dried coatings) into four sections with a utility knife and using the tip of the knife to free corners of the dried coating so they could be pulled off the surface by hand. The dry coatings were removed from each coupon in an average of 1 minute 24 seconds. The technician who did the removal became more adept at the removal task during the second removal as the average time required to remove the dry coatings from one coupon dropped from 1 minute 51 seconds for the first removal to just 57 seconds for the second removal. These application and removal times are specific to the experimental scenario used during this evaluation. If these coatings were applied to larger surfaces, larger paint application tools such as rollers or sprayers may be used which would likely impact the application rate. In addition, larger sections of the coating could likely be removed in an amount of time similar to the time required for removal of coating from small coupons.

The waste generated through use of DG1101 and DG 1108 was estimated to be approximately 319 grams (g)/m^2 and a volumetric waste generation of 252 cubic centimeters (cm^3)/m^2 of surface. Because this technology evaluation included Cs-137, all the waste was disposed as low level radioactive waste. No utilities were required for use of DG 1101 and DG 1108 making them decontamination options that are amenable to use in remote settings. If a sprayer was used to apply DG 1101 or DG 1108, applicable power would be required. The only limitation on the portability of DG 1101 and DG 1108 is the ability to transport an adequate amount of the wet material to the job site. Minimal training would be required for technicians using DG1101 and DG 1108, and the surface of the concrete was not damaged during application and removal of the DG 1101 and DG 1108. The material cost is $40 per L for DG 1101 or DG 1108 which corresponds to approximately $40/m^2 if used in a similar way as used during this evaluation. Labor and waste management costs would be dependent on the particular physical characteristics of the area being decontaminated and so were not calculated.

7.0 References

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

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