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Bartlett Services Inc. Stripcoat TLC Free™ Radiological Decontamination Strippable Coating

TECHNOLOGY EVALUATION REPORT

Office of Research and Development
National Homeland Security Research Center

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Technology Evaluation Report

Bartlett Services Inc. Stripcoat TLC Free™ Radiological Decontamination Strippable Coating

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Notice

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Preface

The U.S. Environmental Protection Agency (EPA) is charged by Congress with protecting the nation's air, water, and land resources. Under a mandate of national environmental laws, the Agency strives to formulate and implement actions leading to a compatible balance between human activities and the ability of natural systems to support and nurture life. To meet this mandate, EPA's Office of Research and Development (ORD) provides data and science support that can be used to solve environmental problems, to build the scientific knowledge base needed to manage our ecological resources wisely, to understand how pollutants affect our health, and to prevent or reduce environmental risks.

In September 2002, EPA announced the formation of the National Homeland Security Research Center (NHSRC). The NHSRC is part of the ORD; it manages, coordinates, supports, and conducts a variety of research and technical assistance efforts. These efforts are designed to provide appropriate, affordable, effective, and validated technologies and methods for addressing risks posed by chemical, biological, and radiological terrorist attacks. Research focuses on enhancing our ability to detect, contain, and decontaminate in the event of such attacks.

NHSRC's team of world renowned scientists and engineers is dedicated to understanding the terrorist threat, communicating the risks, and mitigating the results of attacks. Guided by the roadmap set forth in EPA's Strategic Plan for Homeland Security, NHSRC ensures rapid production and distribution of security-related products.

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. 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. In addition, environmental persistence information is important for containment and decontamination decisions.

The evaluation reported herein was conducted by Battelle as part of the TTEP program. Information on NHSRC and TTEP can be found at http://www.epa.gov/nhsrc.

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Contents

Figures

Tables

Abbreviations/Acronyms

BQ	Bequerel
Cs	cesium
C	centigrade
cm	centimeters
D&D	decontamination and decommissioning
DARPA	Defense Advanced Research Projects Agency
DF	decontamination factor
DHS	U.S. Department of Homeland Security
DoD	Department of Defense
EPA	U.S. Environmental Protection Agency
Eu	Europium
g	gram
INL	Idaho National Laboratory
keV	kilo electron volts
kg	kilogram
mg	milligram
mL	milliliter
L	liter
m	meter
µCi	microcuries
NHSRC	National Homeland Security Research Center
ORD	Office of Research and Development
%R	percent removal
PE	Performance evaluation
psi	pounds per square inch
Stripcoat	Bartlett Services, Inc. Stripcoat TLC™ Free strippable coating
QA	quality assurance
QC	quality control
QMP	quality management plan
RDD	radiological dispersion device
RML	Radiological Measurement Laboratory
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) Technology Testing and Evaluation Program (TTEP) 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. Under TTEP, Battelle recently evaluated the performance of Stripcoat TLC™ Free strippable coating (Stripcoat) from Bartlett Services, Inc. (Plymouth, Massachusetts). The objective of evaluating Stripcoat was to test its ability to remove radioactive cesium (Cs)-137 from the surface of unpainted concrete.

Stripcoat is applied as a paint-like coating and is then cured in order to bind the Cs-137 physically so the cured coating can be removed from the surface causing little or no surface damage. Prior to the evaluation of Stripcoat, 15 cm × 15 cm unpainted concrete coupons were contaminated with Cs-137 at a level of approximately 53 microcuries (µCi, measured by gamma spectroscopy), then several of these contaminated coupons were used within horizontal and vertical surfaces constructed with 24 coupons.

Following manufacturer's recommendations, Stripcoat was applied and removed three successive times before the residual activity of the contaminated coupons was measured. In addition, an evaluation of the decontamination efficacy of Stripcoat was performed both 7 and 30 days following application of the contaminant to the coupons. Results include decontamination efficacies, a comparison of the decontamination efficacy between the vertical and horizontal surfaces, and a comparison between the 7-day and 30-day results. Important deployment and operational factors were also documented and reported. A summary of the evaluation results for Stripcoat is presented below for each performance parameter. Discussion of the observed performance can be found in Section 5 of this report.

Decontamination Efficacy: The decontamination efficacy expressed as percent removal, %R, attained by Stripcoat was evaluated on separate concrete surfaces after both 7 days and 30 days following the contamination of the coupons. Overall, Stripcoat decontaminated the concrete coupons with an average %R of 32.0 ± 9.9. The %Rs from the vertical and horizontal surfaces were determined to be not significantly different from one another. In addition, the %Rs between the 7-day and 30- day tests and between coupons placed on the edge and within the other coupons were also determined to be not significantly different from one another. Upon successive Stripcoat application and removal cycles, 51% – 65% of the Cs-137 removed during all three application cycles occurred during the first application cycle.

Deployment and Operational Factors: Stripcoat is supplied ready for use as a coating with a consistency similar to wall paint. Stripcoat was applied, following manufacturer's recommendation, to the surfaces with an airless paint sprayer. The horizontal and vertical surfaces used during this evaluation totaled 1.1 m^2 and each complete application took approximately 5 minutes. The objective was to attain a layer of paint-like coating approximately 40 mils thick. However, because a measurement of coating thickness was not performed, a qualitative guideline was followed. The coating was applied thick enough to cover the surface, but not so thick that the coating ran down the wall. Following application, the coating dried overnight and was removed using a paint scraper. First, coupon edges were scored and the coating was pulled from the surface. In most cases, Stripcoat was removed in large pieces across the borders between coupons. The Stripcoat removal rate was 4.9 m^2 per hour, the rate of waste generation (removed coating) was 0.26 kg/m^2, and the volume of the waste was, on average, 0.145 g/cm^3. Cured Stripcoat was elastic and could be pressed together into a sphere for disposal. In addition, Stripcoat was well suited for rough or jagged surfaces. The cured coating was easily removed across the borders of coupons (a distance of 0.3–0.7 cm). A limited evaluation of cross-contamination was performed, and the results confirmed that cross-contamination did occur. Any damage to the surface of the concrete caused by Stripcoat was not visible to the naked eye.

Conclusion: Stripcoat removed approximately 32% of the Cs-137 from the unpainted concrete coupons placed together to form concrete surfaces with both horizontal and vertical orientations. The Stripcoat worked the same in either orientation and after 7 and 30 days following the application of Cs-137 to the concrete coupons. Stripcoat can be applied to irregular surfaces.The coating was elastic and easily removed across the borders of the coupons.

1.0 Introduction

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 effects resulting from intentional acts of terror. With an emphasis on decontamination and consequence management, water infrastructure protection, and threat and consequence assessment, NHSRC is working to develop tools and information that will help detect the intentional introduction of chemical or biological contaminants in buildings or water systems, the containment of these contaminants, the decontamination of buildings and/or water systems, and the disposal of material resulting from cleanups.

NHSRC's Technology Testing and Evaluation Program (TTEP) works in partnership with recognized testing organizations; with stakeholder groups consisting of buyers, vendor organizations, and permitters; and with the participation of individual technology developers in carrying out performance tests on homeland security technologies. The program evaluates the performance of innovative 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. TTEP provides high-quality information that is useful to decision makers in purchasing or applying the evaluated 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 evaluation design so that useful performance information is produced for each of the evaluated technologies.

Under TTEP, Battelle recently evaluated the performance of the Bartlett Services, Inc. Stripcoat TLC™ Free strippable coating (Stripcoat) in decontaminating the radioactive isotope Cs-137 from unpainted concrete. This evaluation was conducted according to a peer-reviewed test/QA plan[1] that was developed according to the requirements of the quality management plan (QMP) for TTEP[2]. The following performance characteristics of Stripcoat were evaluated:

- Decontamination efficacy defined as the extent of radionuclide removal following application and removal of Stripcoat.
- Deployment and operational data, including rate of surface area decontamination; applicability to irregular surfaces; skilled labor requirement; utilities requirements; extent of portability; shelf life of media; secondary waste management, including the estimated amount and characteristics of the spent media; the possibility of cross-contamination; and the cost of using Stripcoat.

This evaluation took place from December 10, 2007 until January 21, 2008. All of the experimental work took place at U.S. Department of Energy's Idaho National Laboratory (INL). This report describes the quantitative results and qualitative observations gathered during this evaluation of Stripcoat. Quality Assurance oversight of this evaluation was provided by Battelle, INL, and EPA. Under the direction of the Battelle QA Manager, INL QA staff conducted a technical systems audit (TSA) during the evaluation. The Battelle QA Manager conducted a data quality audit of all evaluation data.

2.0
Technology Description

This technology evaluation report provides results on the performance of Stripcoat TLC™ Free (Stripcoat) under laboratory conditions. Following is a description of Stripcoat, based on unverified information provided Bartlett Services, Inc. (Plymouth, Massachusetts).

Stripcoat is a non-hazardous, non-toxic strippable coating designed for safely removing radioactive contamination or as a covering to contain contamination. Stripcoat is sold as a paint-like formulation, therefore, use of a brush, roller, or sprayer are all application options. The target thickness during application was 40 mils. While curing, Stripcoat mechanically entraps contamination. Following application, the coating requires 4–10 hours to cure prior to removal. After curing, the coating strips off along with surface contamination. The manufacturer advises that Stripcoat can also serve as a barrier to prevent contamination.

The below pictures are from the current evaluation. The photo shown at the left of Figure 2-1 is the paint-like formulation. The middle photo in Figure 2-1 shows the application of Stripcoat to the concrete coupon surfaces. The coating is then removed (Figure 2-1, right).

Figure 2-1. Preparation (left), Application (middle), and Removal of Stripcoat (right)

3.0
Experimental Details

3.1 Experimental Preparation

3.1.1 Concrete Coupons

The concrete coupons were prepared from a single batch of concrete made from Type II Portland cement[3]. Table 3-1 lists data provided by the ready-mix vendor about the cement clinker used in the concrete mix. The ASTM C150[3] requirement for Type II Portland cement specifies that tricalcium aluminate be less than 8% of the overall cement clinker. As shown in Table 3-1, the cement clinker used for the concrete coupons was 4.5% tricalcium aluminate. The maximum allowable tricalcium aluminum content for Type I is 15%, so the cement used during this evaluation mets the specifications for both Type I and II Portland cements.

Table 3-1. Characteristics of the Portland Cement Clinker

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 wet concrete was poured into 0.9 meter (m) square plywood forms with the surface exposed. The concrete surface was “floated” to get the smaller aggregate and cement paste to float to the top, and 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 square, and had a surface finish that was consistent across all the coupons and representative of exterior concrete commonly found in urban environments in the United States as shown by INL under a U.S. Department of Defense, Defense Advanced Research Projects Agency (DARPA) and U.S. Department of Homeland Security (DHS) project[4].

3.1.2 Coupon Contamination

Each contaminated coupon was spiked with 2.5 milliliters (mL) of unbuffered, slightly acidic aqueous solution containing 137 milligrams (mg)/ liter (L) Cs-137 corresponding to an activity level of approximately 53 µCi over the 225 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 an RDD event, morning dew or rainfall would likely occur before the surfaces could be decontaminated. In addition, the ability to apply liquids homogeneously across the surface of the concrete coupons greatly exceeds that for particles. The liquid spike was delivered to each coupon using an aerosolization technique developed by INL under the DARPA/DHS project[4]. The aerosol delivery device is constructed of two syringes. The first syringe had the plunger removed and a nitrogen gas line was attached to the rear of the syringe. The second syringe contained the contaminant spiking solution and was equipped with a 27 gauge needle which penetrated through the plastic housing near the tip of the first syringe. Nitrogen gas was turned on at a flow of approximately 1–2 liters per minute, creating a turbulent flow through the first syringe. The liquid spike in the second syringe was introduced and then nebulized by the turbulent gas 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. Coupon edges were taped and sealed with epoxy to ensure that the contaminant was applied only to the surfaces. Contaminant was sprayed to the edges of the coupons.

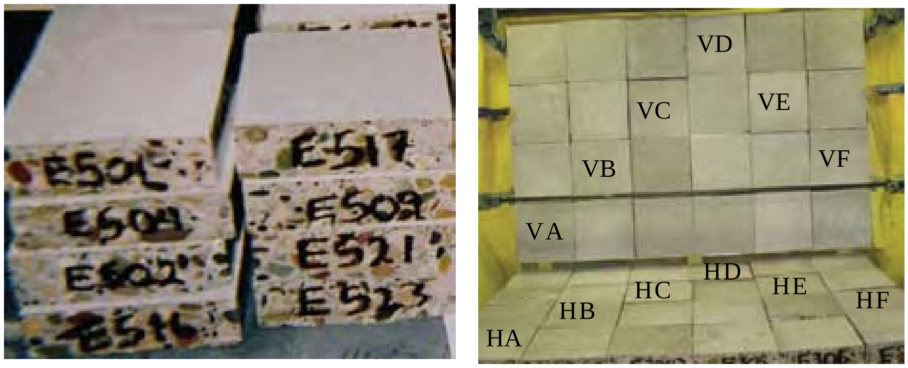
3.1.3 Measurement of Activity on Coupon Surface

Measurement of gamma radiation from the surface of concrete coupons was used to quantify contamination levels before and after application of the strippable coating. These measurements were made using one of three identical intrinsic, high purity germanium detectors following contamination and after application of Stripcoat. After being placed into the detector, each coupon was measured until the average activity level of Cs-137 from the surface stabilized to a relative standard deviation of less than 2%. Gamma-ray spectra acquired from Cs-137 spiked coupons were analyzed using the INL Radiological Measurement Laboratory (RML) data acquisition and spectral analysis programs. Radionuclide activities on coupons were calculated based on the efficiency, emission probability, and half-life values. Decay corrections were made based on reference time and 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) as well as horizontal surfaces (simulating sidewalks and drives), a test stand was fabricated that held four rows of six concrete coupons to create surfaces that were approximately 90 cm wide × 60 cm deep (horizontal) or tall (vertical). Six of the 24 coupons used to construct each surface were contaminated with Cs-137. Figure 3-1 shows a picture of several concrete coupons and a test stand loaded with the concrete coupons. After the coupons were contaminated with Cs-137, some were allowed to age for 7 days and some for 30 days prior to their placement in the test stand for application and removal of Stripcoat. The two different time frames were used to

Figure 3-1. Concrete Coupons (left) and Test Stand With the Contaminated Coupons Labeled "V" for Vertical and "H" for Horizontal (right)



evaluate the effectiveness of decontamination technologies within one week of a radiological incident and within one month. Within the surfaces on the test stand, the six contaminated coupons were arranged so that one coupon was on each side edge, one was on the top edge, and several were not on an edge at all. Figure 3-1 shows the pattern of contaminated coupons on each surface. The coupon codes indicate the orientation of each coupon (H for horizontal and V for vertical) as well as the location within the surface (positions A–E). The top surfaces of the coupons were not labeled during the evaluation.

3.2 Evaluation of Stripcoat

3.2.1 Application of Stripcoat

The decontamination process was begun 7 days (7-day test) following the application of the Cs-137 to the concrete coupons. Three application and removal cycles were completed before the final measurement of residual activity was made. To summarize the timeline, the 7-day coupons were contaminated on December 3 and then included in the construction of the vertical and horizontal surfaces. The first application of Stripcoat was made to the surfaces on December 10 and allowed to dry overnight, the first removal of Stripcoat was performed on December 11, the second application/removal cycle was performed on December 11 and 12, and the final application/removal cycle was performed on December 12 and 13. Therefore, the final removal of Stripcoat was performed 10 days following application of the Cs-137 to the coupons. In a similar way, the 30-day coupons were contaminated on December 17 and the first of three applications of Stripcoat was performed on January 16 and completed over the next several days. Following the final removal of Stripcoat, the contaminated coupons were removed from the surfaces and residual activity was measured.

The temperature and relative humidity were recorded during both the 7-day and 30-day tests. These conditions did not vary significantly in the laboratory where the coupons were stored and the evaluation was performed. Over the duration of testing, the temperature was always within the range of 23–26°C and the relative humidity was always within the range of 11–17%.

3.2.2 Progressive Decontamination Efficacy With Each Application of Stripcoat

The focus of this evaluation was determining the overall decontamination efficacy of Stripcoat following three separate applications. The test plan called for the Stripcoat to be applied and removed three times before measurement of the residual activity. However, as a side experiment during the evaluation, a few coupons were measured following each application and removal of Stripcoat to determine the degree of decontamination that occurred with each application and removal. The progressive decontamination efficacy was determined using two and three coupons for the 7- and 30-day tests, respectively. Only two coupons were analyzed for the 7-day test because of the limited availability of contaminated coupons. These coupons had been contaminated as extras in case of an accidental breakage. These coupons were set in a horizontal orientation to the side of the test stand and the Stripcoat was applied and removed as for the rest of the coupons on the test stand. These coupons were transported to the RML for activity measurement four times, once upon application of Cs-137 and once following each of three applications and removals of Stripcoat.

4.0 Quality Assurance/Quality Control

QA/quality control (QC) procedures were performed in accordance with the program QMP[2] and the test/QA plan[1] for this evaluation.

4.1 Intrinsic Germanium Detector

Calibrations of intrinsic, high purity germanium detectors were established using standardized procedures from American National Standards Institute and the Institute of Electrical and Electronics Engineers[5]. 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). This calibration was performed weekly and documented by the RML. Table 4-1 shows the results of the calibrations by giving the difference between the known energy levels and those measured following calibration. The calibrations are shown for each of the three detectors used during this evaluation. The energies were compared to the previous 30 calibrations. The operator alerted if the results exceeded three standard deviations of the other calibration results. The calibrations are shown for each of the three detectors used during this evaluation. None of these calibrations exceeded that threshold.

For each measurement of activity on each coupon, gamma ray counting continued until the activity level of Cs-137 on the surface had a relative standard deviation of less than 2%. The final activity assigned to that coupon was a compilation of information obtained from all components of the electronic assemblage, which comprised the "gamma counter," including the raw data and the spectral analysis conducted by the spectroscopist using an INL data analysis program. Final spectra and all data which comprised the spectra were sent to a data analyst who independently confirmed the "activity" number determined by the spectroscopist. When both the spectroscopist and an expert data analyst independently arrived at the same number, then the data were certified. This entire process defines the full gamma counting QA process for certified results.

The background activity of the concrete coupons was determined by the analysis of ten arbitrarily selected coupons from the stock of concrete coupons. The ambient activity level of these coupons was measured for two hours and the activity for all of the coupons was determined to be below the minimum detectable level of 2×10^{-4} µCi. Because the background activity was not detectable, and the detectable level was more than 5,000 times lower than the post-decontamination activity levels, no background subtraction was required.

Throughout the evaluation, 12 contaminated coupons were measured as duplicates. Four duplicate analyses each were completed for three sample sets including coupons that had been contaminated, coupons decontaminated during the 7-day test, and coupons decontaminated during the 30-day test. Three of the duplicate samples showed no difference from the original measurement, while the average percent

Table 4-1. Calibration Results – Difference (keV) From Th-228 Calibration Energies

		Calibration Energy Levels in keV				
Date	Detector	Energy 1 238.632	Energy 2 583.191	Energy 3 860.564	Energy 4 1620.735	Energy 5 2614.511
11-6-2007	1	-0.002	0.008	-0.004	-0.206	0.022
	4	-0.004	0.022	-0.119	-0.028	0.013
	5	-0.002	0.007	-0.006	-0.193	0.019
12-3-2007	1	0.000	0.002	-0.025	0.028	-0.001
	4	-0.006	0.022	-0.076	-0.170	0.034
12-11-2007	1	-0.002	0.008	-0.040	-0.108	0.011
	4	-0.004	0.014	-0.041	-0.194	0.025
12-18-2007	1	-0.003	0.012	-0.026	-0.273	0.028
	4	-0.003	0.013	-0.063	-0.135	0.018
1-15-2008	1	-0.003	0.012	-0.042	-0.190	0.022
	4	-0.004	0.018	-0.069	-0.211	0.024
1-22-2008	1	-0.006	0.022	-0.022	-0.390	0.055
	4	-0.003	0.011	-0.032	-0.169	0.021

difference between the original and duplicate measurements was 0.71%, within the acceptable difference of 3%.

4.2 Audits

4.2.1 Performance Evaluation Audit

RML performs monthly checks of the accuracy of the Th-228 daughter calibration standards by measuring the activity of a NIST-traceable Eu-152 standard (in units of Bequerel, BQ) and comparing it to the accepted NIST value. Results within 7% of the NIST value are considered to be within acceptable limits. The Eu-152 activity comparison is a routine quality control activity performed by INL. For the purposes of this evaluation, the calibration serves as the performance evaluation (PE) audit that confirms the accuracy of the calibration standards used for the instrumentation critical to the results of our evaluation. Table 4-2 gives the results of each of these audits for each detector that was used during this evaluation. All results are within the acceptable difference of 7%.

4.2.2 Technical Systems Audit

A technical systems audit was conducted during testing at INL to ensure that the evaluation was performed in accordance with the test/QA plan[1] and the TTEP QMP[2]. As part of the audit, the actual evaluation procedures were compared with those specified in the test/QA plan[1]. In addition, 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 Battelle Quality Assurance Manager.

One test/QA plan deviation occurred during this evaluation. Instead of a 0.25 mL volume of Cs-137 spiking solution as was stated in the test/QA plan, a 2.5 mL volume was used in order to attain a more homogeneous coverage across each coupon. The evaluation was not negatively impacted.

4.2.3 Data Quality Audit

At least 10% of the data acquired during the evaluation were audited. The Battelle Quality Assurance Manager traced the data from the initial acquisition, through reduction and statistical analysis, to final reporting, to ensure the integrity of the reported results. All calculations performed on the data undergoing the audit were checked.

4.3 QA/QC Reporting

Each assessment and audit was documented in accordance with the test/QA plan[1] and the QMP.[2] Once the assessment report was prepared by the Battelle Quality Assurance Manager, it was routed to the Test Coordinator and Battelle TTEP Program Manager for review and approval. The Battelle Quality Assurance Manager then distributed the final assessment report to the EPA Quality Manager and Battelle staff.

There was one deviation from the test/QA plan during this evaluation. Instead of a 0.25 mL volume of Cs-137 spiking solution as was stated in the test/QA plan, a 2.5 mL volume was used in order to attain a more homogeneous coverage across each coupon. There was no negative impact to the evaluation.

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

Date	Detector	NIST Activity (BQ)	INL RMLResult (BQ)	Difference
11-11-2007	4	124,600	130,300	5%
11-13-2007	1	124,600	122,900	1%
	5	124,600	124,700	0%
12-11-2007	1	124,600	122,400	2%
	4	124,600	128,900	3%
1-15-2008	1	124,600	122,000	2%
	4	124,600	129,300	4%

5.0 Evaluation Results

5.1 Decontamination Efficacy

The decontamination efficacy was determined for each contaminated coupon in terms of percent removal (%R) and decontamination factor (DF) as defined by the following equations:

$$\%R = (1-A_f/A_o) \times 100\% \text{ and } DF = A_o/A_f$$

where A_o is the radiological activity from the surface of the coupon before application of Stripcoat and A_f is the radiological activity from the surface of the coupon after removal of the strippable coating. The DFs are reported in the following data tables, but for the sake of brevity, the narrative describing the results will focus on the %R. The following sections describe the performance of Stripcoat 7 and 30 days after contaminant application and on horizontal and vertical surfaces. Throughout the evaluation, Microsoft® Excel was used to perform paired t-tests in order to determine if significant differences existed within the data set. In all cases, the t-tests were two-tailed and were conducted at the 95% confidence interval.

5.1.1 7-Day Decontamination Efficacy Results

Table 5-1 gives the %R and DF for Stripcoat after a 7-day time period between coupon contamination and use of Stripcoat. The coupon codes indicate the orientation of each coupon (H for horizontal and V for vertical) as well as the location within the surface (position A–E) as shown in Figure 3-1. The target activity for each of the contaminated coupons (pre-decontamination) was within the acceptable range of 53 µCi ± 5.3 µCi. The overall average (plus or minus one standard deviation) of the contaminated coupons was 56.8 µCi ± 1.7 µCi for the horizontal surface, 53.5 µCi ± 1.7 µCi for the vertical surface, and 55.2 µCi ± 2.4 µCi across all the coupons in both surfaces, a variability of 4%. Evaluating Stripcoat for its effectiveness in the horizontal and the vertical orientations was an important objective for this evaluation. Because Stripcoat is applied as a liquid, this evaluation sought to find out if the coating adhered adequately to the wall to accomplish decontamination with similar efficacies as in the horizontal orientation. The post-decontamination coupon activities were significantly less than the pre-decontamination activities. For the horizontal

Table 5-1. 7-Day Decontamination Efficacy Results

	Coupon Code	Pre-Decon Activity µCi / Coupon	Post-Decon Activity µCi / Coupon	%R	DF
Horizontal	HA	57.7	42.9	25.6	1.3
	HB	57.9	42.4	26.8	1.4
	HC	53.8	41.7	22.5	1.3
	HD	55.8	33.8	39.4	1.7
	HE	57.8	35.5	38.6	1.6
	HF	57.9	33.5	42.1	1.7
	Avg	56.8	38.3	32.5	1.5
	SD	1.7	4.5	8.5	0.2
Vertical	VA	56.3	38.9	30.9	1.4
	VB	52.2	27.9	46.6	1.9
	VC	52.6	39.7	24.5	1.3
	VD	51.7	41.3	20.1	1.3
	VE	53.5	41.5	22.4	1.3
	VF	54.6	41.8	23.4	1.3
	Avg	53.5	38.5	28.0	1.4
	SD	1.7	5.3	9.8	0.2
Overall	**Avg**	**55.2**	**38.4**	**30.3**	**1.5**
	SD	**2.4**	**4.7**	**9.0**	**0.2**

and vertical surfaces, the %Rs (defined in Section 5.1) were 32.5 ± 8.5 and 28.0 ± 9.8. These %Rs were determined to be not significantly different by a paired t-test analysis (p=0.52), indicating that the decontamination efficacy of Stripcoat in the horizontal and vertical orientations was similar. The overall average %R for the 7-day test was 30.3 ± 9.0.

The contaminated coupons included in the surfaces were placed at various locations across the surface and various paired t-tests were performed to allow observation of whether or not location on the surface affected the decontamination efficacy. Within the 7-day coupons, those on the edge (horizontally and/or vertically) of the surfaces were compared with those not on the edges (horizontally and/or vertically) to see if significant differences existed. During the 7-day test, no such differences were identified, therefore, Stripcoat performed equally on the vertical and horizontal surfaces whether the coupons were located on an edge or not.

5.1.2 30-Day Decontamination Efficacy Results

Table 5-2 gives the %R and DF for Stripcoat after a 30-day time period between contaminant application and use of Stripcoat. As with the 7-day results, the target activity for each of the contaminated coupons (pre-decontamination) was within the acceptable range of 53 µCi ± 5.3 µCi. The overall average (plus or minus one standard deviation) of the contaminated coupons was 53.2 µCi ± 3.0 µCi for the horizontal surface, 55.6 µCi ± 1.4 µCi for the vertical surface, and 54.4 µCi ± 2.6 µCi across all the coupons on both surfaces, a variability of 5%.

The post-decontamination coupon activities were significantly less than the pre-decontamination activities. For the horizontal and vertical surfaces respectively, the %Rs (defined in Section 5.1) were 35.8 ± 8.7 and 31.9 ± 13.0. These were determined to be not significantly different by a paired t-test analysis (p=0.56), indicating that the decontamination efficacy of Stripcoat in the horizontal and vertical orientations was similar. The overall average %R for the 30-day test was 33.8 ± 10.7.

As with the 7-day coupons, the contaminated coupons included on the surfaces were placed at various locations across the surface and various paired t-tests were performed to determine if location within the surface affected the decontamination efficacy. As for the 7-day test, no differences were identified in decontamination efficacy during the 30-day test; therefore, Stripcoat performed equally on the vertical and horizontal surfaces and when the coupons were located on the edge or not.

Table 5-2. 30-Day Decontamination Efficacy Results

	Coupon Code	Pre-Decon Activity µCi / Coupon	Post-Decon Activity µCi / Coupon	%R	DF
Horizontal	HA	55.6	41.7	25.0	1.3
	HB	55.2	39.9	27.7	1.4
	HC	50.8	29.8	41.3	1.7
	HD	48.7	31.9	34.5	1.5
	HE	52.6	27.0	48.7	1.9
	HF	56.2	35.2	37.4	1.6
	Avg	53.2	34.3	35.8	1.6
	SD	3.0	5.8	8.7	0.2
Vertical	VA	54.8	33.1	39.6	1.7
	VB	54.3	48.1	11.4	1.1
	VC	57.1	43.7	23.5	1.3
	VD	56.3	29.0	48.5	1.9
	VE	54.1	36.6	32.3	1.5
	VF	57.0	36.4	36.1	1.6
	Avg	55.6	37.8	31.9	1.5
	SD	1.4	7.0	13.0	0.3
Overall	**Avg**	**54.4**	**36.0**	**33.8**	**1.5**
	SD	**2.6**	**6.4**	**10.7**	**0.2**

5.1.3 Comparison of 7-Day and 30-Day Decontamination Efficacy

Given there were no significant differences determined between the horizontal and vertical surfaces during the 7-day or 30-day tests, the overall average %Rs can be compared to determine if Stripcoat performed differently during the two sets of experiments. The overall average %Rs for the 7-day and 30-day tests were 30.3 ± 9.0 and 33.8 ± 10.7, respectively, suggesting that the increased time of the contaminant binding to the concrete surface caused a slightly decreased %R. However, a paired t-test determined that these two averages were not significantly different from one another at the 95% confidence interval ($p=0.45$). This difference is not significant because the standard deviations of the post-decontamination activity measurements across several coupons increased significantly compared with the pre-decontamination measurement of activity across the same coupons. This increase indicated the somewhat variable efficacy of the Stripcoat in removing Cs-137 from the surface of the concrete.

In addition to the comparison of overall average, various paired t-tests were performed, including data from both the 7-day and 30-day tests to allow observation of whether or not location within the surface impacted the decontamination efficacy. The increased number of data points improved statistical power in determining significant differences in the data. Thus, all of the vertical and horizontal coupons, edge and non-edge, from both tests were compared to determine if significant differences existed. However, out of these analyses, no comparisons generated a significant difference from the rest of the data set. Therefore, Stripcoat performed statistically similar during the 7- and 30-day tests when the coupons were in the vertical and horizontal orientations and whether or not they were among other coupons within the surfaces or on the edge of the surfaces.

5.1.4 Progressive Decontamination Efficacy With Each Application of Stripcoat

As described previously, three application cycles were completed for each test. Therefore, a few coupons were measured after each application/removal cycle to determine the level of decontamination with each cycle. Table 5-3 shows the results from each measurement of activity starting with the initial measurement prior to the first application and removal of Stripcoat through three successive applications and removals of Stripcoat. Table 5-3 also shows the total %R (additive across applications), the %R attributed to each successive application, and the percent of the total removal attributable to each application cycle. For example, of the 16.6 %R that was attained for the first 7-day coupon, 10.1% was attained with the first application. Overall, the first application corresponded to 61.2% of the total removal from that coupon.

The results indicated that most of the decontamination occurs with the first application and removal cycle of Stripcoat. While only five coupons were tested in this fashion, the results were consistent. More than half of the decontamination occurred with the first application cycle. Thereafter, about half of the remaining removal occurred during each of the two final application and removal cycles.

The percent of total removal with the first cycle ranged from 51 to 65%, from 16% to 26% for the second cycle, and from 12% to 34% for the third and final cycle of application and removal of Stripcoat. An experimental design more focused on this aspect of Stripcoat's performance would be required to draw additional conclusions.

5.2 Deployment and Operational Factors

5.2.1 Description of Application

The yellow Stripcoat had a paint-like consistency and was provided in a five-gallon bucket ready to apply without further preparation. Prior to the application of Stripcoat, a Graco Nova™ 390 sprayer with a Graco 519 tip was primed with the wet Stripcoat as directed by the manufacturer's instructions. The sprayer was provided by Bartlett Services, Inc. for this evaluation. Any commercially available, airless paint sprayer with similar specifications could be used. The sprayer manufacturer's operating instructions should be followed.

Thereafter, Stripcoat was applied to the surfaces. There was no calibrated pressure indicator. The maximum pressure of this sprayer was 3,300 pounds per square inch (psi) and the spray pattern that produced an even, covering coating with no significant runs occurred when the pressure was adjusted to the maximum and then the knob turned back approximately one-quarter of a turn.

The Stripcoat was applied in a single coat with the objective of attaining a wet thickness of 40 mils. Because coating thickness was not measured, a qualitative guideline was followed. The coating was applied thick enough to cover the surface, but not so thick that the coating ran down the wall. Spray application to the horizontal and vertical surfaces took approximately five minutes. An average of 0.9 L of wet Stripcoat was applied with each application to the surfaces which had an area of 1.1 m^2. Figure 5-1 shows a picture of Stripcoat freshly applied to the vertical surface and, then again, following the overnight drying time.

During the third Stripcoat application of the 7-day test, the sprayer pump plugged and had to be re-primed before the application could be successfully completed. Other than that instance, the 7-day test application was completed without

Table 5-3. Decontamination Efficacy With Each Application of Stripcoat™ TLC

Test	Stripcoat Application	Activity µCi / Coupon	Total %R	%R Each Application	% of Total Removal
7-Day	Pre-decon	59.2	NA[a]	NA	NA
	#1	53.2	10.1	10.1	61.2%
	#2	51.5	13.0	2.9	17.3%
	#3	49.4	16.6	3.5	21.4%
	Pre-decon	59.9	NA	NA	NA
	#1	45.5	24.0	24.0	61.8%
	#2	39.50	34.1	10.0	25.8%
	#3	36.60	38.9	4.8	12.4%
30-Day	Pre-decon	58.2	NA	NA	NA
	#1	47.0	19.2	19.2	54.6%
	#2	44.6	23.4	4.1	11.7%
	#3	37.7	35.2	11.9	33.7%
	Pre-decon	56.3	NA	NA	NA
	#1	41.0	27.2	27.2	51.0%
	#2	34.5	38.7	11.5	21.7%
	#3	26.3	53.3	14.6	27.3%
	Pre-decon	54.6	NA	NA	NA
	#1	37.4	31.5	31.5	65.4%
	#2	33.1	39.4	7.9	16.3%
	#3	28.3	48.2	8.8	18.3%

[a] Not applicable as this was the initial measurement of activity.

difficulty. Prior to the 7-day test, the paint sprayer pump, gun, and hoses were new. Following the 7-day application, the hoses and pump were rinsed with water as recommended by Bartlett Services, Inc. and the five-gallon bucket containing the Stripcoat was sealed. These items were stored in the laboratory.

Between the 7-day and 30-day applications, two problems emerged. First, on the day the 30-day tests were to begin, the technicians removed the lid of the bucket to find that the Stripcoat had solidified. This was unexpected because conditions in the laboratory had not changed significantly during the elapsed time. The paint apparently solidified because the bucket had not been properly sealed when the lid was placed back on for storage. Bartlett Services, Inc. provided additional Stripcoat to complete the test.

When the additional Stripcoat arrived, the technicians began priming the sprayer pump as had been done for the 7-day application. First, the pump was primed with water to ensure function of the pump and sprayer and then the pump was primed with Stripcoat. When the fresh Stripcoat came into contact with the pump and tubing, the pump bypass valve and filter body became plugged with residue apparently left over from the previous use. Apparently, the pump had not been adequately cleaned after the last application of the 7-day test. The pump had to be disassembled and then rinsed thoroughly with water before the coating could be sprayed.

Following the first coating removal of the 30-day test, the sprayer equipment was rinsed with water and the second application was completed. During the third application, the sprayer and tubing again clogged as they had during the third application of the 7-day test. The pump was again disassembled and rinsed with water before it would function properly. Following these occurrences, Bartlett Services, Inc. informed the technicians that a water rinse, as the company

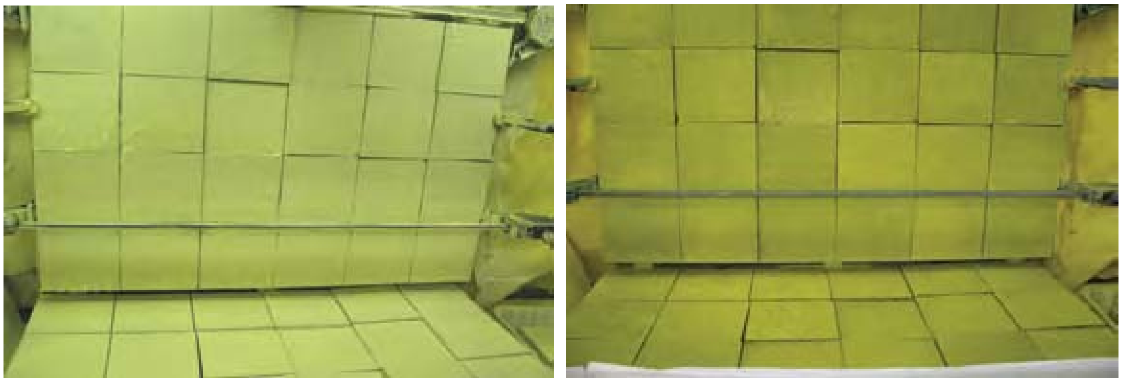


Figure 5-1. Stripcoat After Application (left) and After Drying Overnight (right)

had originally suggested, was not adequate for cleaning the pump and tubing. A mineral spirits wash was necessary to remove the residue from the walls of the pump and tubing. Clearly, not doing this wash resulted in the plugging of the pump and tubing and led to delays in coating application.

5.2.2 Description of Removal

The removal of Stripcoat was done following the overnight drying, which cured Stripcoat into a solid coating that, upon removal, was elastic. After scoring the Stripcoat at the edge of a coupon, the coating could, for the most part, be pulled in large pieces off the surface across the border of coupons. The first application of the 30-day test was somewhat thinner than the other applications, so the Stripcoat tore at the borders of the coupons. However, for the other five applications, the coating was thick enough so that the cured coating could be easily removed across the borders of the coupons which had, at times, rather jagged edges. Figure 5-2 shows the removal process.

The dried coating removed from the surface was collected in a tared bag and weighed. For the six removal cycles, the average weight of dried coating was 276 g ± 42.5 g. The time to remove Stripcoat from the two surfaces totaling 1.1 m^2 ranged from 10–24 minutes for an average rate of removal of 4.9 m^2/hour.

5.2.3 Miscellaneous Operational Information and Data

Table 5-4 includes important operational parameters such as the time required to apply and remove the coating, required skill level of the operator, the portability of the technology, estimated cost, required utilities, and cross contamination concerns. All of the operational information gathered during this evaluation was obtained from use of Stripcoat on relatively small surfaces (1.1 m^2) that were built with concrete coupons. Therefore, some of the information given in Table 5-4 could differ if Stripcoat was applied to a larger surface or a surface that was more smooth or more rough and jagged.

Data describing the rate of decontamination is given in Table 5-4. Assuming that users of Stripcoat will be using paint sprayers that had been cleaned with mineral spirits prior to its application, the average rate of application of Stripcoat

Figure 5-2. Stripcoat Removal

probably will not be the limiting rate step because use of a paint sprayer is generally efficient. However, a thorough paint sprayer cleaning between uses is critical, given the experiences described in Section 5.2.1. Application using a paint sprayer will allow use on a wide variety of surfaces, even irregularly shaped surfaces. Stripcoat was well-suited to the irregular surfaces used during this evaluation. Horizontal gaps of several millimeters existed between some of the concrete coupons and the Stripcoat was removed across those boundaries. Also, some of the coupons were of slightly different heights and the Stripcoat was able to be removed across those boundaries.

Cross-contamination of radionuclides during application and removal of Stripcoat is an operational aspect that was considered to a minimal extent during this evaluation. As has been described, six coupons from each surface had been contaminated prior to the construction of the surfaces. The other coupons had not been contaminated and, upon placement into the test stand, indicated extremely low background levels of activity when measured with a qualitative gamma counter. When all of the coupons were removed from the test stand following the three application and removal cycles of Stripcoat for both the 7-day and 30-day tests, the non-contaminated coupons indicated an activity level (again using the qualitative gamma counter) that was higher than background.

While the study of cross-contamination was not a focus of the evaluation, the activity from a few of the non-contaminated coupons was quantitatively measured. Of the coupons that were selected for measurement, the coupon that was located just to the right of the “VA” coupon and below the “VB” coupon during the 7-day test had an activity of 0.86 µCi, approximately 1.6% of the amount applied to any one of the six contaminated coupons within each surface. However, the

Table 5-4. Operational Factors Gathered From the Evaluation

Parameter	Description/Information
Factors affecting decontamination rate	Coating Preparation: Provided ready for use; 20 minutes to prime pump Application: Approximately 5 minutes and average of 0.78 L for 1.1 m^2 Drying time: overnight Removal time: 4.9 m^2/hour
Applicability to irregular surfaces	Application to more irregular surfaces than those encountered during this evaluation would not seem to be much of a problem because a sprayer is able to reach most types of surfaces. Stripcoat cures into an elastic coating that could be used on the surfaces made from concrete coupons used during this evaluation. In most cases, Stripcoat could be removed across the borders of coupons even when separated by several millimeters horizontally or vertically.
Skilled labor requirement	After a brief training session and time to acclimate to using a paint sprayer, most able-bodied people could successfully perform both the application and removal procedures.
Utilities requirement	A paint sprayer generally requires 110 volt power. However, Stripcoat can also be applied with a roller or brush, eliminating the need for a separate power source.
Extent of portability	With the exception of extreme cold, which would prevent the application of Stripcoat (which is water-based), its portability seems limitless.
Shelf life of media	Shelf life is advertised as one year, but a five-gallon bucket of Stripcoat solidified between the 7-day and 30-day tests. The paint apparently solidified because the bucket had not been properly sealed when the lid was placed back on for storage.
Secondary waste management	Solid waste production: ~0.26 kg/m^2 Solid waste density: ~0.145 g/cm^3 Cured Stripcoat is extremely elastic. Each coating removal resulted in approximately 2 L of waste material. Thorough mineral spirit cleaning of paint sprayer is required between uses or the sprayer will likely clog.
Surface damage	No damage was visible to the eye; some loose particles could be seen to be stuck to the coating.
Cost	\$23.50/L corresponding to \$16.66/m^2 for one application; Bartlett Services, Inc. suggests three applications so that would correspond to \$50.00/m^2; that does not include the cost of a paint sprayer.

rest of the coupons that were measured quantitatively had much lower activities. Over the 7-day and 30-day tests, the residual activity of nine other non-contaminated coupons ranged from 0.0018 µCi – 0.05 µCi and had an average activity of 0.015µCi ± 0.014 µCi. These coupons included the coupon in the same position (during the 30-day test) as the 0.86 µCi coupon mentioned above. This coupon had an activity of 0.0097 µCi, 0.0018% of the contaminated coupons. The widely varying activity on a coupon in the same position suggested that the cross-contamination was not specific to that location within the surfaces. As cross-contamination was not a focus of the evaluation, the proper controls were not in place to thoroughly investigate the observed cross-contamination. The possibility exists that cross-contamination occurred during the construction of the surfaces on the test stand and might be independent of the Stripcoat.

6.0 Performance Summary

Summary results from evaluation of Stripcoat are presented below for each performance parameter evaluated. Discussion of the observed performance can be found in Section 5 of this report.

6.1 Decontamination Efficacy

The decontamination efficacy attained by Stripcoat was evaluated on separate test stands after both 7 days and 30 days following the contamination of the coupons. Overall, Stripcoat decontaminated the concrete coupons with an average %R of 32.0 ± 9.9. The %Rs from the vertical and horizontal surfaces were determined to be not significantly different from one another. In addition, the %Rs between the 7-day and 30- day tests and between coupons placed on the edge and within the other coupons were also determined to be not significantly different from one another. Upon successive Stripcoat application and removal cycles, 51%–65% of the Cs-137 removed in total during all three application cycles occurred during the first application cycle.

6.2 Deployment and Operational Factors

Stripcoat is supplied as a ready for use coating with a consistency similar to wall paint. Stripcoat was applied, following manufacturer's recommendation, to the surfaces with an airless paint sprayer. The horizontal and vertical surfaces used during this evaluation totaled 1.1 m^2 and each complete application took approximately 5 minutes. The objective of application was to attain a layer of paint-like coating approximately 40 mils thick. However, because a measurement of coating thickness was not performed, a qualitative guideline was followed. The coating was applied to a thickness that was enough to cover the surface by visual inspection, but not so thick that the coating ran down the wall. Following application, the coating was allowed to dry overnight and then removed using a paint scraper to score the edge of the coupons. The coating was pulled from the surface. In most cases, Stripcoat was removed in large pieces across the borders between coupons. The Stripcoat removal rate was 4.9 m^2 per hour; the rate of waste generation (removed coating) was 0.26 kg/m^2; and the volume of the waste was, on average, 0.145 g/cm^3. In addition, Stripcoat was well suited for rough or jagged surfaces because the cured coating was easily removed across the borders of coupons (a distance of approximately 0.3–0.7 cm), which created an irregular surface. A limited evaluation of cross-contamination was performed, and the results confirmed that cross-contamination did occur. Any damage to the surface of the concrete caused by Stripcoat was not visible to the naked eye.

6.3 Conclusion

Stripcoat removed approximately 32% of the Cs-137 from the unpainted concrete coupons placed together to form concrete surfaces with both horizontal and vertical orientations. Stripcoat worked the same in either orientation and after 7 and 30 days following the application of Cs-137 to the concrete coupons. Stripcoat could be applied to irregular surfaces. The coating was elastic and easily removed across the border of the coupons.

7.0 References

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