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Technology Evaluation Report

Argonne National Laboratory Argonne SuperGel 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. Through TTEP, NHSRC provides independent, quality assured performance information that is useful to decision makers in purchasing or applying the tested technologies. TTEP provides potential users with unbiased, third-party information that can supplement vendor-provided information. Stakeholder involvement ensures that user needs and perspectives are incorporated into the test design so that useful performance information is produced for each of the tested technologies. The technology categories of interest include detection and monitoring, water treatment, air purification, decontamination, and computer modeling tools for use by those responsible for protecting buildings, drinking water supplies and infrastructure, and for decontaminating structures and the outdoor environment. Additionally, environmental persistence information is also important for containment and decontamination decisions.

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

Jonathan G. Herrmann, Director
National Homeland Security Research Center

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Abbreviations/Acronyms

ANSI	American National Standards Institute
ANL	Argonne National Laboratory
ASG	Argonne SuperGel
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
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
°F	degrees Fahrenheit
hr	hour
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) 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 the Technology Testing and Evaluation Program (TTEP), NHSRC evaluated the Argonne National Laboratory (ANL) SuperGel (hereafter referred to as ASG) and its ability to remove radioactive cesium (Cs)-137 from the surface of unpainted concrete.

Experimental Procedures. The ASG is a system of superabsorbing polymers containing solid sequestering agents dissolved in a nonhazardous ionic wash solution. The resulting hydrogel is applied to a contaminated surface and provides exchangeable ions to the substrate to promote the desorption of radioactive cesium and other radionuclides. Eight 15 centimeter (cm) × 15 cm unpainted concrete coupons were contaminated with approximately 1 microCurie (μCi) of Cs-137 per coupon. The amount of contamination deposited on each coupon was measured using gamma spectroscopy. The eight contaminated coupons were placed in a test stand (along with one uncontaminated blank coupon) that was designed to hold nine concrete coupons in a vertical orientation to simulate the wall of a building. Each coupon was decontaminated with ASG and the decontamination efficacy was determined by calculating both a decontamination factor (DF) and percent removal (%R). Important deployment and operational factors were also documented and reported.

Results. The decontamination efficacy (in terms of %R) attained for decontamination with ASG was evaluated for each concrete coupon used during the evaluation. When the decontamination efficacy metrics (%R and DF) of the eight contaminated coupons were averaged together, the average %R for the ASG was 71% ± 4% and the average DF was 3.6 ± 0.62.

The ASG had to be prepared from two powders combined with water. When fully mixed, the mixture had the look of cooked oatmeal, but was very "slippery" as it tended to slide off tools that were used to get the ASG onto the concrete coupons. The ASG was applied to the concrete coupons using a paint brush to transport the ASG and a spackling knife to smooth the ASG across the surface. After a 90 minute dwell time, a wet vacuum was used to remove the ASG. Use of the ASG was very straight forward. Minimal training would be required for technicians using the ASG, and the surface of the concrete was not visibly damaged during decontamination with the ASG.

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.

Through TTEP, NHSRC evaluated the performance of Argonne SuperGel (hereafter referred to as ASG) from Argonne National Laboratory (Argonne, IL), 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 the ASG, 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 the ASG took place November 2, 2010, with the pre-evaluation activity measurements occurring in September 2010 and the post-evaluation activity measurements also occurring in November 2010. All of the experimental work took place in a radiological contamination area at the U.S. Department of Energy's Idaho National Laboratory (INL). This report describes the quantitative results and qualitative observations gathered during the evaluation of the ASG. 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 ASG under laboratory conditions. The following description of the ASG is based on information provided by the vendor and was not verified during this evaluation.

The ASG is a system of super absorbing polymers containing solid sequestering agents dissolved in a nonhazardous ionic wash solution. The resulting hydrogel is applied to a contaminated surface and provides exchangeable ions to the substrate to promote the desorption of radioactive cesium and other radionuclides. The solid sequestering agent provides strong sorption of the target radionuclides within the gel. After removing the radionuclide-loaded hydrogel by conventional wet-vacuum, the hydrogel can be dehydrated or incinerated to minimize waste volume without loss of volatilized contaminants. To summarize, the goals of this approach are:

- In situ dissolution of bound contaminants without dissolving or corroding contaminated structural components.
- Controlled extraction of water and dissolved radionuclides from the surface and pore/microcrack structures into a super-absorbing hydrogel.
- Rapid stabilization of the solubilized radionuclides with high-affinity and high-specificity sequestering agents immobilized in the hydrogel layer.
- Low toxicity reagents and low volume radioactive waste.

The superabsorbing polymers consist of an anionic mixture of polyacrylamide and polyacrylate in both linear and cross-linked form. The solid sequestering agent is mixed into the dry polymer (10% by mass). The ionic wash solution is composed of a single component salt at 1 mole/liter (L) concentration (no strong acid or base is used). The reconstituted hydrogel (19-20 gram ionic wash solution per gram of dry polymer mix) is applied by hand for small applications or sprayed on for larger applications. The hydrogel is allowed to react with the contaminated surface for at least 30-60 minutes to maximize the ionic exchange of radionuclides and diffusion/absorption into the hydrogel. The hydrogel is designed to adhere to vertical surfaces without slipping and maintain hydration in direct sunlight for more than an hour. Because no component of the hydrogel is hazardous, there are no special precautions required to deal with hazardous materials. The hydrogel is also compliant with disposal as low-level radioactive waste.

Conventional wet-vacuum technology is sufficient to remove the hydrogel from the contaminated surface. For small-scale applications, the head of a standard wet vacuum is adequate, while for larger scale applications, a squeegee attachment is recommended.

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 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 the ASG. 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 the ASG. The ASG was applied from top to bottom 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 ASG was prepared by mixing two dry powders with water as directed by the vendor. The mixture was then stirred with a drill equipped with a mixing tool until the mixture was homogeneous. The ASG was applied to the concrete coupons using a four-inch paint brush to transport the ASG and a spackling knife to smooth the ASG across the surface. The specifications of the paint brush were not critical as a perfectly smooth application was not required. Altogether, the application of the ASG took approximately 45 seconds per coupon, the ASG was allowed to be on the surface for 90 minutes, and then the ASG was removed with a wet vacuum (12 gallon, 4.5 horsepower, QSP® Quiet Deluxe, Shop-Vac Corporation, Williamsport, VA) which required approximately one minute per concrete coupon. The temperature and relative humidity (RH) were recorded at the start and finish. The temperature and RH were 21°C (70 °F) and 22% at the start and 22°C (72 °F) and 22% at the finish. According to the vendor, these conditions were acceptable for use of the ASG.

The overall decontamination method for the ASG included:

1. Apply gel with paint brush and smoothing with spackling knife
2. Wait 90 minutes
3. Remove with wet vacuum by moving over the surface one time with a 4 inch flat vacuum attachment against the surface.

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).[3] 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 shows 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 11-6	-0.004	0.015	-0.040	-0.245	0.031
10-19 to 11-24	-0.005	0.014	-0.001	-0.320	0.043

Gamma ray counting was continued on each coupon until the activity level of Cs-137 on the surface had an RSD of less than 2%. This RSD was achieved during the first hour of counting for all the coupons measured during this evaluation. The final activity assigned to each coupon was a compilation of information obtained from all components of the electronic assemblage that comprises the "gamma counter," including the raw data and the spectral analysis described in Section 3.1.3. Final spectra and all data that comprise the spectra were sent to a data analyst who independently confirmed the "activity" number determined 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 shows 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 ASG was measured for each contaminated coupon in terms of percent removal (%R) and decontamination factor (DF). Both of these measurements 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 ASG 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.

Table 5-1 shows the %R and DF for ASG. 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 1.06 µCi ± 0.053 µCi. The post-decontamination coupon activities were less than the pre-decontamination activities showing an overall reduction in activity. The %R averaged 71% ± 4% and the DF averaged 3.6 ± 0.62. Overall, the %R ranged from 66% to 79% and the DF ranged from 3.0 to 4.8.

Table 5-1. Decontamination Efficacy Results for Argonne SuperGel

Coupon Location in Test Stand	Pre-Decon Activity (µCi / Coupon)	Post-Decon Activity (µCi / Coupon)	%R	DF
Top left	1.12	0.38	66%	3.0
Top middle	1.16	0.29	75%	4.0
Top right	1.04	0.32	70%	3.3
Center left	1.03	0.33	68%	3.2
Center middle	1.01	0.32	69%	3.2
Center right	1.02	0.21	79%	4.8
Bottom left	1.07	0.32	70%	3.3
Bottom right	1.03	0.27	74%	3.8
Average	**1.06**	**0.30**	**71%**	**3.6**
Std. Dev	**0.053**	**0.05**	**4%**	**0.62**

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 ASG on wall locations above the placement of the uncontaminated coupon. ASG was 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 0.00216 µCi. This value was three times greater than the minimum detectable level, but more than 100 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 the ASG 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 ASG. One of the factors was the degree of difficulty in application. Once fully mixed, the ASG had the look of cooked oatmeal but was very "slippery" and tended to slide off any plastic tools (which is why the paint brush was used) that were used to get the ASG onto the concrete coupons. However, once on the concrete, the ASG adhered rather well. Altogether, the application of the ASG took approximately 45 seconds per coupon and removal with a wet vacuum took approximately one minute per concrete coupon. The ASG caused no visible damage to the surface of the coupons. Figure 5-1 shows a photograph of ASG in the container prior to application, ASG on a concrete coupon and the vacuum removal of the ASG. The personal protective equipment (PPE) used by the technician in the picture was required because the work was performed in a radiological contamination area using Cs-137 on the concrete coupon surfaces. Whenever radioactive contaminated material is handled, anti-contamination PPE will be required. The required PPE was not driven by the use of ASG (which is non-toxic), rather the interaction with surfaces contaminated with Cs-137.

Figure 5-1. ASG in container prior to application (top left), after application to concrete coupon (bottom left), and during vacuum removal (right).

Table 5-2 summarizes qualitative and quantitative practical information gained by the technician during the evaluation of the ASG. All of the operational information was gathered during use of the ASG on the concrete coupons inserted into the test stand. Some of the information given in Table 5-2 could differ if the ASG was 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. For example, large scale mixing of ASG for application to a city block could be performed using cement mixing trucks and application made using viscous sprayers mounted on the mixing trucks.

Table 5-2. Operational Factors Gathered from the Evaluation

Parameter	Description/Information
Decontamination rate	Technology Preparation: 15 minutes to measure and mix powder with water. The ASG is able to be used for several days after mixing as long as the ASG is kept moist as it will dry out if left exposed to air for several days. Application: ASG was applied with a paint brush to each concrete coupon in approximately 45 seconds (1.9 square meters (m^2)/hour (hr)). After a 90 minute dwell time, the ASG was removed with a wet vacuum and the surface was wiped with a paper towel at a rate of approximately 1.25 minutes per coupon (1.1 m^2/hr). Aside from the wait time (which is independent of the surface area), the application and removal rate was approximately 0.7 m^2/hr for hand application and corresponding removal. Estimated volumes used across all the concrete coupons included 1-2 L of ASG. Overall that volume corresponds to a loading of 5-10 L/m^2.
Applicability to irregular surfaces	Application to irregular surfaces may be problematic as the ASG could slide off jagged edges and be hard to apply to hard to reach locations.
Skilled labor requirement	Adequate training would likely include a few minutes of orientation so the technician is familiar with the application technique. Larger surfaces may require more complex equipment such as sprayer application.
Utilities requirement	As evaluated here, electricity was required to operate the wet vacuum.
Extent of portability	At a scale similar to that used for this evaluation, the only limitation on portability would be the ability to provide vacuum removal in remote locations. However, for larger scale applications, limiting factors would include the ability to apply the ASG at scale applicable to an urban contamination (area of city blocks or square miles).
Secondary waste management	1-2 L of ASG was applied to the concrete coupons used during this evaluation. That volume corresponds to a waste generation rate of approximately 5 - 10L/m^2. The ASG was collected entirely by the wet vacuum. Because Cs-137 was used for this testing, all waste (in vacuum and paper towels) was disposed of as low level radioactive waste.
Surface damage	Concrete surfaces appeared undamaged.
Cost (material)	The material cost is approximately $0.30/L for the ASG (depending on source material costs). This cost corresponds to approximately $2/$m^2$ 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 ASG for each performance parameter evaluated.

6.1 Decontamination Efficacy

The decontamination efficacy (in terms of %R) attained for decontamination with ASG was evaluated for each concrete coupon used during the evaluation. When the decontamination efficacy metrics (%R and DF) of the eight contaminated coupons were averaged together, the average %R for the ASG was 71% ± 4% and the average DF was 3.6 ± 0.62.

6.2 Deployment and Operational Factors

The ASG had to be prepared from two powders combined with water. The mixture was then stirred with a drill and mixing tool until well mixed. When fully mixed, the mixture had the look of cooked oatmeal, but was very "slippery" as it tended to slide off tools that were used to get the ASG onto the concrete coupons. The ASG was applied to the concrete coupons using a paint brush and a spackling knife to smooth the ASG across the surface. Altogether, the application of the ASG took approximately 45 seconds per 225 cm^2 coupon and removal with a wet vacuum took approximately one minute per concrete coupon.

The waste generated through use of the ASG was estimated to be approximately 5-10 L/m^2. As used for this evaluation, electricity was used to operate the wet vacuum. Scaled up applications in remote locations may require additional utilities to provide means for sprayer and larger scale vacuum removal. Minimal training would be required for technicians using the ASG, and the surface of the concrete was not visibly damaged during use of the ASG. The material cost for ASG is approximately \$0.30/L. This corresponds to \$2/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.
2. Calibration and Use of Germanium Spectrometers for the Measurement of Gamma Emission Rates of Radionuclides. American National Standards Institute. ANSI N42.14-1999. IEEE New York, NY (Rev. 2004).

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