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Evaluation of Simple Green® Commercial Cleaner for Radiological Decontamination on Indoor Surfaces

Office of Research and Development
National Homeland Security Research Center

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U.S. ENVIRONMENTAL PROTECTION AGENCY
CINCINNATI, OH 45268

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Disclaimer

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

John Drake

National Homeland Security Research Center

Office of Research and Development

U.S. Environmental Protection Agency

26 West Martin Luther King Dr.

Cincinnati, OH 45268

513-569-7164

drake.john@epa.gov

If you have difficulty accessing this PDF document, please contact Kathy Nickel (Nickel.Kathy@epa.gov) or Amelia McCall (McCall.Amelia@epa.gov) for assistance.

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. In certain situations following an accidental or intentional release of radiological materials (including terrorist incidents such as a radiological dispersal device (RDD) or "dirty bomb"), off-the-shelf, household cleaners may provide the clean up that is needed. This document provides information on ability of the first such household cleaner we examined to decontaminate indoor surfaces in a residential setting.

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.

Gregory Sayles, Ph.D., Acting Director
National Homeland Security Research Center

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. In this investigation, NHSRC selected the commercial cleaner Simple Green® and evaluated its ability to remove radioactive cesium (Cs-137) from the surface of multiple building materials found regularly in homes. These materials include: wood finished with polyurethane, vinyl flooring, painted wallboard, plastic laminate, and polished granite.

Experimental Procedures. Simple Green® is a concentrated multipurpose cleaner sold commercially. The manufacturer recommends that a 1:10 dilution (described as medium strength) of the Simple Green® concentrate be used for "everyday" household use. Because this is a strength likely to be already prepared for normal household use, this concentration was selected for use during this evaluation. For each surface material, six 15 centimeter (cm) x 15 cm 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. Three coupons (in a horizontal orientation) of each surface material were decontaminated with 1:10 Simple Green® and three were decontaminated with water. The diluted Simple Green® (DSG) or water was sprayed onto the coupon surface and the entire surface was then scrubbed with a brush in a circular motion. The surfaces were then wiped with a cloth dampened with water and then dried with a clean dry disposable towel.

Results. The percent removal (%R) and decontamination factor (DF) were calculated for each surface coupon material. The decontamination of two of the surface materials, plastic laminate and vinyl flooring, resulted in a %R of more than 93% for both DSG and water. The decontamination of wood coated with polyurethane resulted in %R values of approximately 65% for both DSG and water. The decontamination of granite and painted wallboard resulted in average %R values between 7% and 14%. Of these surface materials, only plastic laminate exhibited a statistically significant difference between the %R for DSG and that for water.

The similarity between the %R produced by DSG and water was somewhat unexpected because the presence of the DSG would be expected to increase the effectiveness of the cleaning compared to the cleaning performed with only water. In general, the less porous materials (plastic laminate and vinyl flooring) were decontaminated more effectively than the more porous materials (wood and painted wallboard). The decontamination effectiveness was more dependent on the porosity of the surfaces as opposed to the use of DSG or not. In addition, the surfaces used during this evaluation were all cleaned prior to contamination. The results might be different if the surfaces were dirty or grimy. In these cases, the cleaning properties of Simple Green® may be more effective in mobilizing radionuclide contamination than water. Some additional decontamination experiments were performed with granite coupons from different sources. Data from these experiments suggested that the removal of cesium from the granite was dependent on the surface characteristics of the granite.

Deployment and Operational Factors. During this evaluation, the DSG was applied at a rate consistent with the manufacturer's recommendation for general use of the product, which equated to approximately 15 seconds per coupon, or 5 m2/hour. Because Simple Green® is a household cleaner, no skills or specialized training were required, and the only required tools were a spray bottle, brush, and disposable towels, making the method very portable. Two disposable towels were used for each surface coupon. The disposable towels made up the entirety of the secondary waste as all the liquid was absorbed into the towels. The health physicist overseeing the health and safety aspects of this evaluation collected wipe samples from the gloves of the person performing decontamination with the DSG and water once during the evaluation of each surface material to determine the likelihood of worker contamination when using this decontamination approach. In all instances, there was no measurable activity on the gloves, indicating that the gloves had not become contaminated even though in some cases most of the CS-137 had been removed from the coupons. Personal contamination was apparently prevented because the gloves did not come into contact with the surface of the coupons. The technician was using the brush and towels at all times to remain protected from contamination. Lastly, a one-liter container of Simple Green® concentrate costs approximately \$10. Following the method used during this evaluation, a one-liter container costing approximately \$10 would correspond to a material only cost of approximately \$0.06/m^2 to use DSG as a decontamination agent.

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John Drake

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Abbreviations/Acronyms

ANSI	American National Standards Institute
ASTM	ASTM International
BG	background
BQ	Becquerel
°C	degrees Celsius
CBRNIAC	Chemical, Biological, Radiological, Nuclear Defense Information Analysis Center
Cs	cesium
cm	centimeters
DARPA	Defense Advanced Research Projects Agency
DF	decontamination factor
DHS	Department of Homeland Security
DOD	Department of Defense
DSG	diluted Simple Green®
EPA	U.S. Environmental Protection Agency
Eu	europium
HPGe	high purity germanium
IEEE	Institute of Electrical and Electronics Engineers
INL	Idaho National Laboratory
keV	kiloelectron volt(s)
L	liter
µCi	microCurie
mg	milligrams
mL	milliliters
mR	millirem
NHSRC	National Homeland Security Research Center
NIST	National Institute of Standards and Technology
ORD	Office of Research and Development
QA	quality assurance
QC	quality control
QMP	Quality Management Plan
%R	percent removal
RCT	radiological control technician(s)
RH	relative humidity
RML	Radiological Measurement Laboratory
TSA	technical systems audit

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, NHSRC is working to develop tools and information that will improve the ability of operational personnel to detect the intentional introduction of chemical, biological, or radiological contaminants on or into buildings or water systems, to contain or mitigate these contaminants, to decontaminate affected buildings and/or water systems, and to dispose of contaminated materials resulting from clean-ups.

NHSRC is looking at a range of issues which would need to be addressed in the aftermath of terrorist use of a radiological dispersal device in an urban area. In the early phase of response to such an event evacuation zones would have been established based on predictions of contamination levels in affected areas, requiring members of the public to vacate their homes and businesses. As contamination levels became better understood, based on surveys and characterization efforts, some previously restricted areas would be released, allowing residents to return to homes and businesses previously off-limits. Returning residents may be concerned about the possibility of small amounts of contamination having been brought into their homes, for instance by being tracked in on shoes or brought in on clothing and personal items, and may wish to perform some cleaning activities themselves. In this study, NHSRC sought to examine the merits of using common commercially available cleaning agents for decontamination of surfaces inside a residence which might be only very slightly contaminated. In this study NHSRC examined a range of possible cleaning products and selected one product for the initial evaluation. Criteria considered in the selection process included (1) wide availability through commercial suppliers (major retail chain stores, grocery stores, pharmacies, department stores, hardware stores), (2) likelihood of the availability of significant quantities, (3) consistent formulation across suppliers and geographic regions, (4) applicability to multiple surface types, and (5) cost. Based on a survey of available products, one of the products which seemed to best meet these criteria was selected for the initial evaluation. The product selected was Simple Green®. The study concentrated primarily on evaluating the ability of Simple Green® for removal of radioactive cesium isotope (Cs-137) from several common indoor surfaces. A peer-reviewed test/QA plan[1] was developed and followed to generate the following performance information:

- Decontamination efficacy, defined as the extent of radionuclide removal following use of Simple Green®.
- Deployment and operational factors, including the approximate rate of surface area decontamination, applicability to irregular surfaces, skilled labor requirement, portability, secondary waste management, and cost associated with use of Simple Green®.

This evaluation was conducted throughout May and June of 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 Simple Green®. Battelle and EPA were responsible for QA oversight. The Battelle QA Manager conducted a technical systems audit (TSA) during the evaluation as well as a data quality audit of the evaluation data.

2.0
Technology Description

Simple Green® is a commercially available multi-purpose cleaner that was evaluated for its ability to decontaminate radiological contamination. The cleaner is sold as a concentrate and is typically diluted prior to cleaning multiple surfaces and contaminants. The dilution level of one part Simple Green® concentrate to nine parts ASTM International (ASTM) Type I [2] water (hereafter referred to as simply water) for a 1:10 dilution factor was used for this evaluation. The manufacturer recommends that a 1:10 dilution of the Simple Green® concentrate be used for "everyday" household use. Because this dilution level is likely to be prepared already for normal household use, this dilution level was selected for use during this evaluation. This dilution level corresponds to the "medium everyday strength" on the Simple Green® "Quick-Mix Guide" from the Simple Green® website (www.simplegreen.com) and will be referred to throughout this report as diluted Simple Green® (DSG).

Figure 2-1. Bottle of Simple Green® concentrate.

3.0 Experimental Details

3.1 Pre-evaluation Preparation

3.1.1 Surface Coupon Preparation

The surface coupons used for the evaluation were composed of common surface materials that would likely be decontaminated in a residential setting. The selection of coupon materials involved consideration of likely pathways for radiological contamination to present a personal health hazard. It was decided that coupon materials should represent those commonly found in food preparation and personal hygiene areas, and are listed below. In addition to the five materials listed, stainless steel was used as a baseline or control material for comparison. The materials were obtained from home improvement or lumber stores. The outline of the coupons was measured and marked onto the surface of the material and the material was cut using a material-appropriate saw and blade. The various materials were cut into approximately 15 centimeters (cm) × 15 cm coupons and had surface finishes representative of the surface finish that would typically be found in a residential setting (e.g. countertops, tabletops, flooring, walls, etc.). Some of these materials were rather thin so they were mounted to a plywood support using an epoxy resin so the coupons could be measured using the existing detector geometry set up for coupons that are approximately 4 cm thick. Seven coupons of each surface material were prepared for testing.

These surface coupons were made from:

- Wood finished with polyurethane – wood cut from the middle of doors of a bathroom vanity (American Classics, Medium Oak Model KB36-MO cabinet, Haddonfield, NJ) stained with two coats of polyurethane
- Vinyl flooring (Armstrong, Model 26295061,The Home Depot, Idaho Falls, ID)
- Painted wall board (SHEETROCK® Brand FIRECODE® C Core Gypsum Panels, Lowes®, Idaho Falls, ID) with 2 coats of Pastel Base Behr Premium Plus Semi-Gloss Enamel paint (The Home Depot, Idaho Falls, ID)
- Plastic laminate – Wilsonart® 4728K-350-52 (The Systemcenter Inc., Honolulu, HI)
- Polished granite – India granite (Biscuit Brown, Mickelson Marble, Idaho Falls, ID)

The wood, painted wallboard, and granite represent porous surfaces while the vinyl flooring and plastic laminate represent nonporous surfaces. Prior to contaminant application, the coupon surfaces were visually examined for obvious cracks or abnormalities and, if none were found, the coupon surfaces were cleaned with a soft nylon brush and water and allowed to air dry for approximately 24 hours. The side of each coupon was marked with an identifying number using a permanent marker. The edges of the coupons were sealed with epoxy prior to contaminant application to protect against the possibility of any contaminant solution seeping into the coupons through the edges and to ensure that Cs-137 was applied only to the surface of the coupons.

3.1.2 Coupon Contamination

Coupons were contaminated by spiking individually with 2.5 milliliters (mL) of aqueous solution that contained 0.26 milligrams (mg)/liter (L) Cs-137 as a solution of cesium chloride, corresponding to an activity level of approximately 1 microCurie (µCi) over the 225 square centimeter (cm^2) surface. Application of the Cs-137 in an aqueous solution was justified because even if Cs-137 were dispersed in particle form following a radiological dispersion device or "dirty bomb" event, cesium chloride can take up moisture from the air and go fully or partially into solution before the surfaces could be decontaminated. In addition, from an experimental standpoint, it is much easier to apply liquids, rather than dry particles, homogeneously across the surface of the coupons. The liquid spike was delivered to each coupon using an aerosolization technique developed by INL under a Defense Advanced Research Projects Agency (DARPA) and a U.S. Department of Homeland Security (DHS) project[3].

The aerosol delivery device was constructed of two syringes. The plunger and needle were removed from the first syringe and discarded. Then a compressed nitrogen gas 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 nitrogen 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, this solution became 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. The contaminant spray was applied all the way to the edges of the coupon, which were taped (after having previously been sealed with epoxy) 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 a coupon.

Because the gamma radiation from each coupon was measured before and after application of DSG and water, differences in contaminant load between coupons is also not critical. However, the acceptable upper and lower limits for the target amount of gamma radiation applied to each coupon prior to application of the DSG or water was set at 0.5 to 1.5 µCi.

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. The measurement of gamma radiation from the coupon surfaces is not a destructive measurement technique; therefore, the same coupons that were spiked with Cs-137 and had the gamma radiation measured were used for application of the DSG or water.

3.2 Evaluation Procedures

Prior to the start of testing, a "dry run" of the experimental design was performed to determine the exact approach to using DSG and ASTM water as surface decontamination agents. The resulting approach included the decontamination of one coupon at a time positioned horizontally within a secondary container and the decontamination procedure was the same for the DSG and water. The steps included: 1) application of the DSG or water across the surface of each coupon by squeezing the trigger of a spray bottle (Plastic Spray Bottle, Wal-Mart, Idaho Falls, Idaho) three times, 2) a hand brush was used to scrub the surface using a circular motion, 3) the surface was wiped with a disposable towel (Wypall X60, Kimberly Clark, Neenah, WI) moistened with 10 mL of water, and 4) a clean dry towel was used to dry the surface completely. Figure 3-2 shows a picture of the decontamination approach being performed. The temperature and relative humidity (RH) were recorded throughout the two-day evaluation (TMH-360 Digital Thermometer, EAI Education, Oakland, NJ).

The temperature in the laboratory was consistently within the range of 22.8 degrees Celsius (°C) to 23.9 °C and the RH was between 18% and 21%.

Figure 3-1. Demonstration of contaminant application technique.

3.1.3 Measurement of Activity on Coupon Surface

Each contaminated coupon was allowed to air dry until the surface no longer appeared wet and then was transported to the INL Radiological Measurement Laboratory (RML) for measurement of the Cs-137 gamma radiation from the surface of each coupon. Gamma radiation from the surface of each concrete coupon was measured to quantify contamination levels both before and after decontamination with DSG or water. 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 of less than 2%. The low activity coupons (less than 2 millirem (mR)/hour as qualitatively surveyed by the radiological control technicians [RCTs]) were counted for approximately one hour while the more highly contaminated coupons (more than 2 mR/hour) were counted for approximately 20 minutes. Gamma-ray spectra acquired from Cs-137-contaminated coupons were analyzed using RML data acquisition and spectral analysis programs.

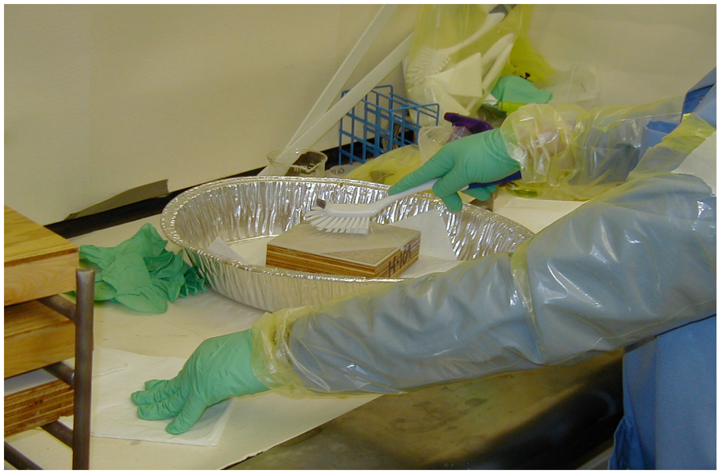

Figure 3-2. Laminate coupon being scrubbed with brush after DSG application.

Table 3-1 presents the experimental design that was completed during this evaluation. For each surface material, six coupons were contaminated with Cs-137. Three of the coupons were decontaminated with DSG and three with water. Both DSG and water were used to determine if the DSG has a decontamination efficacy beyond that of water. One coupon of each surface material was left uncontaminated and decontaminated with DSG to serve as a method blank. These control coupons were stored along with the rest of the coupons from the time of preparation through the completion of the evaluation to evaluate the possibility of cross contamination. In addition, on each day of testing, one stainless steel coupon (Multipurpose Stainless Steel, Model 9085K41, McMaster-Carr, Princeton, NJ), contaminated with Cs-137, was decontaminated with both DSG and water. The contaminated stainless steel coupons were included as an extremely smooth, nonporous control to demonstrate that a surface can be decontaminated successfully. Throughout the evaluation, three coupons of each surface material that were not contaminated were measured for background (BG) gamma radiation.

Table 3-1. Replicates of Coupons of Various Materials

Material	Blank, No Decontamination	Blank, Decontaminated with Simple Green	Contaminated, Decontaminated with Water	Contaminated, Decontaminated with Simple Green
Wood (polyurethane)	3	1 per day	3	3
Vinyl	3	1 per day	3	3
Painted wall board	3	1 per day	3	3
Plastic laminate	3	1 per day	3	3
Polished granite	3	1 per day	2†	3
Stainless steel control	3	none	1 per day	1 per day

†Two granite coupons were used because of limited coupon availability.

4.0 Quality Assurance / Quality Control

QA/QC procedures were performed in accordance with the test/QA plan[1] for this evaluation.

4.1 Intrinsic Germanium Detector

The germanium detector was calibrated three times during the Simple Green® evaluation. 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).[4] 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 kiloelectron volts (keV). Table 4-1 gives the difference between the known energy levels and those measured following calibration. 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

Date	Calibration Energy Levels (keV)				
	Energy 1 238.632	Energy 2 583.191	Energy 3 860.564	Energy 4 1620.735	Energy 5 2614.533
5-18-2010	-0.004	0.015	-0.030	-0.330	0.033
6-10-2010	-0.002	0.008	-0.016	-0.154	0.019
6-14-2010	-0.004	0.010	-0.005	-0.180	0.029

Gamma ray counting was continued on each coupon until the activity level of Cs-137 on the surface had a relative standard deviation (RSD) of less than 2%. As mentioned in Section 3.1.3, the low activity coupons were counted for approximately one hour while the more highly contaminated coupons were counted for approximately 20 minutes. 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 coupons was determined by analyzing three coupons from each type of surface material used for this evaluation. The ambient activity level of these coupons was measured for one hour. No activity (attributable to Cs-137) was detected above the minimum detectable level of 2×10^{-4} µCi on these coupons. Because the background activity was not detectable, no background subtraction was required.

Throughout the evaluation, duplicate measurements were taken in 12 instances to evaluate the repeatability of the activity measurement with the different surface materials. Following coupon contamination, six coupons were measured twice. Following the decontamination of those six coupons using DSG or water, those same coupons were measured twice again. Six of the 12 duplicate pairs exhibited a difference in activity levels between the two measurements of less than 1%, while the other six duplicate pairs had a difference of less than 4% between the two measurements, within the acceptable difference of 5%.

4.2 Audits

4.2.1 Performance Evaluation Audit

The INL 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 to be within acceptable limits. The Eu-152 activity comparison is a routine QC activity performed by the INL RML, but for the purposes of this evaluation serves as the performance evaluation (PE) audit, an audit that confirms the accuracy of the calibration standards used for the instrumentation critical to the results of an evaluation. Table 4-2 gives the results of each of the audits applicable to the duration of the evaluation. All results are below the acceptable difference of 7%.

4.2.4 Data Quality Audit

The Battelle QA Manager verified all of the raw data acquired during the evaluation and transcribed into spreadsheets for use in the final report. 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.

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

Date	NIST Activity (BQ)	INL RML Result (BQ)	Relative Percent Difference
April 2010	125,000	121,600	2.76%
May 2010	125,000	120,600	3.58%
June 2010	125,000	121,100	3.17%

4.2.2 Technical Systems Audit

The Battelle QA Manager conducted a TSA during testing at INL to ensure that the evaluation was performed in accordance with the test/QA plan.[1]

As part of the audit, the actual evaluation procedures were compared with those specified in the test/QA plan[1] 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 Battelle QA Manager.

4.2.3 Test/QA Plan Deviations

Throughout testing few deviations to the test/QA plan were documented. These deviations as well as the impact on the evaluation are shown below:

- Clarification of the decontamination procedure used for DSG and water (as already described in Section 3.2) – no impact to the evaluation as this deviation provided additional detail about the decontamination method following the “dry run”
- Use of DSG rather than water for method blanks – positive impact to the evaluation as use of DSG provided for a more thorough evaluation of possible cross contamination
- Clarification of the source of wood used for wood coupons – no impact to the evaluation
- Clarification of the source of granite used for coupons – no impact to the evaluation
- Two granite coupons were decontaminated with water instead of three – the impact to the evaluation is the collection of slightly less repeatability data for granite decontaminated with water

4.3 QA/QC Reporting

Each assessment and audit was documented in accordance with the test/QA plan.[1] The Battelle QA Manager prepared the draft assessment report and sent it to the Test Coordinator and Battelle Program Manager for review and approval. The Battelle QA Manager then sent the final assessment report to the EPA and Battelle staff.

5.0
Evaluation Results

5.1 Decontamination Efficacy

The decontamination efficacy of DSG was determined for each contaminated coupon in terms of percent removal (%R) and decontamination factor (DF). Both terms provide a means of representing the extent of decontamination accomplished by a technology. The %R presents efficacy as a percent relative to the initial 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 Equation 1 below:

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

where:

A_o = the radiological activity of the coupon before application of DSG or water

A_f is radiological activity from the surface of the coupon after treatment.

Table 5-1 gives the activity level of each surface coupon after contamination with Cs-137, the activity level following decontamination with either DSG or water, and the %R and DF for DSG and water for each surface coupon. 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 1.17 µCi ± 0.14 µCi, a variability of 12%. For all surface coupons, the post-decontamination coupon activities were less than the pre-decontamination activities showing an overall reduction in activity. However, the magnitude of decrease between the surface coupon materials varied widely.

A paired t-test was performed on the data resulting from decontamination due to DSG and water. The probabilities (p) associated with these paired t-tests provide the probability that the %R and DF values from DSG and water come from data sets that are the same. Therefore, probabilities of less than 0.05 indicate significant differences between the two data sets at the 95% confidence interval.

For plastic laminate, the average %R for decontamination using DSG and water was 97.6%R ± 0.2%R and 93.4%R ± 1.1%R, respectively. The DF values for DSG and water were 41.3 ± 3.8 and 15.4 ± 2.3, respectively. The paired t-test revealed a significant difference (p=0.021) between the %R produced by decontamination using DSG and the %R produced by decontamination using water as well as between the DF resulting from each decontamination approach (p=0.0077).

The average %R for DSG was higher than for water. This result indicates that for plastic laminate, albeit slightly, DSG removed Cs-137 more effectively than water.

The decontamination of vinyl flooring with DSG (96.8%R ± 0.3%R,) and water (96.0%R ± 0.7%R) resulted in average %R values of greater than 95% and DF values of 31.0 ± 3.2 for DSG decontamination and 25.5%R ± 4.8%R for water. Even though the uncertainty around these values was rather small (<1% in the case of %R), the mean values were very similar resulting in a paired t-test (%R p=0.30, DF p=0.31) that indicated that there was no significant difference at the 95% confidence interval between the decontamination of the vinyl flooring using DSG and that using water.

For the coupons made of wood coated with polyurethane, the degree of decontamination was considerably less than for the previous two surface materials. The average %R for DSG and water was 67.2%R ± 3.5%R and 68.1%R ± 6.7%R, respectively, while the average DF values were 3.1 ± 0.3 and 3.2 ± 0.6, respectively. The results from each decontamination approach were very similar, which was confirmed with a paired t-test (%R p=0.89, DF p=0.82) meaning that no statistical difference between the performance of DSG and that for water was observed.

The granite and painted wallboard coupons were decontaminated to a much lesser extent than the previously discussed surface materials. For the granite coupons, the average %R values for DSG and water were 13.9%R ± 1.6%R and 11.7%R ± 3.3%R, respectively, while the average DF values were 1.2 ± 0.0 and 1.1 ± 0.0 for DSG and water, respectively. Three granite coupons were decontaminated with DSG. However, because only five identical granite coupons could be obtained at the time of testing, only two granite coupons were decontaminated with water. For the painted wallboard coupons, the average %R for DSG and water was 9.5%R ± 1.7%R and 7.3%R ± 3.5%R, respectively, while the average DF values were 1.1 ± 0.0 for DSG and water. As was the case with the vinyl flooring and the wood, a paired t-test showed that for granite (%R p=0.73, DF p=0.74) and painted wallboard (%R p=0.42, DF p=0.42)

Table 5-1. Decontamination Efficacy Results

Coupon Type–Decon Agent	Predecon (µCi)	Postdecon (µCi)	%R	Avg %R±SD	DF	Avg DF±SD
Plastic laminate - DSG	0.93	0.0224	97.6	97.6 ± 0.2	41.5	41.3 ± 3.8
	1.16	0.0310	97.3		37.4	
	1.06	0.0236	97.8		44.9	
Plastic laminate – Water	0.96	0.075	92.2	93.4 ± 1.1	12.8	15.4 ± 2.3
	1.14	0.071	93.8		16.1	
	1.18	0.068	94.2		17.4	
Vinyl Flooring - DSG	1.35	0.044	96.7	96.8 ± 0.3	30.7	31.0 ± 3.2
	1.37	0.049	96.4		28.0	
	1.27	0.037	97.1		34.3	
Vinyl Flooring – Water	1.35	0.064	95.3	96.0 ± 0.7	21.1	25.5 ± 4.8
	1.38	0.045	96.7		30.7	
	1.43	0.058	95.9		24.7	
Wood - DSG	1.35	0.49	63.7	67.2 ± 3.5	2.8	3.1 ± 0.3
	1.23	0.36	70.7		3.4	
	1.19	0.39	67.2		3.1	
Wood – Water	1.15	0.3	73.9	68.1 ± 6.7	3.8	3.2 ± 0.6
	1.07	0.42	60.7		2.5	
	1.15	0.35	69.6		3.3	
Painted Wallboard - DSG	0.93	0.86	7.5	9.5 ± 1.7	1.1	1.1 ± 0.0
	1.22	1.09	10.7		1.1	
	1.18	1.06	10.2		1.1	
Painted Wallboard – Water	1.08	1.00	7.4	7.3 ± 3.5	1.1	1.1 ± 0.0
	1.02	0.91	10.8		1.1	
	1.05	1.01	3.8		1.0	
Granite - DSG	1.17	1.00	14.5	13.9 ± 1.6	1.2	1.2 ± 0.0
	1.16	1.02	12.1		1.1	
	1.13	0.96	15.1		1.2	
Granite – Water†	1.17	1.06	9.4	11.7 ± 3.3	1.1	1.1 ± 0.0
	1.12	0.96	14.0		1.2	
Stainless steel control DSG	0.92	0.0234	97.5	96.9 ± 0.8	39.3	33.3± 8.5
	1.12	0.04	96.3		27.3	
Stainless steel control Water	1.14	0.059	94.8	95.2 ± 0.6	19.3	21.2 ± 2.7
	1.20	0.05	95.7		23.1	

†Two granite coupons were decontaminated with water.

there was no significant difference between the %R or DF values for DSG or water. An appendix provides some additional data from coupons prepared from seven different sources of polished granite.

All of the surface coupons for each of the five surface types were collected from the same source and were essentially identical. For each of those surface materials, the method used for decontaminating with DSG and water was shown to be reproducible. With the exception of granite and painted wallboard, the materials that exhibited the lowest average %R, the standard deviation of the replicate %R values were less than 10% of the average %R. In addition, plastic laminate and vinyl flooring exhibited reproducibility of within less than 1%. Even for granite and painted wallboard, the standard deviations generated were less than 5%R.

Data for the stainless steel control coupons are also listed in Table 5-1. Once during each day of testing a contaminated stainless steel coupon was decontaminated to show that a nonporous surface such as stainless steel could be effectively decontaminated. For both DSG and water, these coupons exhibited removals of greater than 95%R. In addition, for each coupon material, noncontaminated coupons were treated with the same decontamination procedure with DSG and water to determine whether or not cross-contamination was taking place during the evaluation. No detectable activity was measured on any of these method blank coupons.

Based on the data in Table 5-1 the performance of the DSG and water was nearly identical. The two nonporous surfaces, plastic laminate and vinyl flooring, as well as the nonporous stainless steel controls were decontaminated by more than 90%. The porous surfaces of wood, painted wallboard, and granite were decontaminated to a much lesser extent. Since DSG is a product intended to provide enhanced cleaning performance over simply using water, the fact that there was generally no significant difference between using DSG and water was unexpected. However, one possible reason for the similar performance is that the coupon surfaces were cleaned prior to contamination and were free from dirt and grime. If dirty coupons had been used it is possible that the DSG would have been a more effective decontamination agent.

5.2 Deployment and Operational Factors

Table 5-2 summarizes qualitative and quantitative practical information gained by the operator during the evaluation of Simple Green®. All of the operational information was gathered during use of DSG on a variety of types of coupons positioned horizontally in a laboratory hood. Some of the information given in Table 5-2 could differ if DSG were applied to a larger surface or to surfaces that were not evaluated during this evaluation.

Table 5-2. Operational Factors Gathered from the Evaluation

Parameter	Description/Information
Decontamination rate	Approximately 15 seconds per coupon to accomplish routine of three sprays, scrub with a brush, wipe with a damp towel, and dry with another clean, dry towel. Corresponds to approximately 5 m^2/hour.
Applicability to irregular surfaces	Wiping off irregular or rough surfaces is not likely to function well. This decontamination technique seems best suited for smooth surfaces, as were exclusively used during this evaluation.
Skilled labor requirement	Simple Green® is a household cleaner. No skill or specialized training was required.
Extent of portability	The only required tools are a spray bottle of DSG (spray bottle would need to be purchased separately as Simple Green® is purchased as a concentrate), a brush, and disposable towels. These can be carried most places.
Secondary waste management	Two disposable towels were used for each surface coupon, corresponding to approximately 4,000 cm^3 of disposable towel waste per square meter of surface decontaminated. There was no excess liquid waste as all the liquid was absorbed into the disposable towels. Also, one brush was used and disposed of for each coupon. However, this detail was an artifact of the experimental design. It is likely that one brush could be used for most decontamination jobs.
Personal contamination	The health physicist overseeing the health and safety aspects of this evaluation collected wipe samples from the gloves of the person performing decontamination with the DSG and water once during the evaluation of each surface material. In all instances, there was no measurable activity, indicating that the gloves had not become contaminated even though in some cases most of the Cs-137 had been removed from the coupons. Apparently, personal contamination was prevented because the gloves did not come into contact with the surface of the coupons. At all times, the technician was using the brush and towels to remain protected from contamination.
Surface damage	No surface damage was visible.
Cost	A 1 liter container of Simple Green® concentrate costs approximately $10. Following the methodology used during this evaluation, a cost of $10 for a liter of concentrate would correspond to approximately $0.06/$m^2$ (material only).

6.0 Performance Summary

This section summarizes Battelle's results from the evaluation of Simple Green®.

6.1 Decontamination Efficacy

The percent removal (%R) and decontamination factor (DF) were calculated for each surface coupon material. The decontamination of two of the surface materials, plastic laminate and vinyl flooring, resulted in %R values of more than 93% for both DSG and water. The decontamination of wood coated with polyurethane resulted in %R values of approximately 65% for both DSG and water. The decontamination of granite and painted wallboard resulted in average %R values between 7% and 14%. Of these surface materials, only plastic laminate exhibited a statistically significant difference between the %R for DSG and that for water.

Simple Green® is a product intended to provide enhanced cleaning performance over simply using water. The fact that there was generally no significant difference between using DSG and water was unexpected. However, one possible reason for the similar performance is that the coupon surfaces were cleaned prior to contamination and were free from dirt and grime. If dirty coupons had been used it is possible that the DSG would have been a more effective decontamination agent. In general, the less porous materials (plastic laminate and vinyl flooring) were decontaminated more effectively than the more porous materials (wood and painted wallboard). The decontamination effectiveness was more dependent on the porosity of the surfaces as opposed to the use of DSG or not.

Some additional decontamination experiments were performed with granite coupons from different sources. Data from these experiments suggested that the removal of cesium from granite was dependent on the surface characteristics of the granite.

6.2 Deployment and Operational Factors

Approximately 15 seconds per coupon were required to accomplish the decontamination method used during this evaluation which was consistent with the instructions for use suggested by the manufacturer, corresponding to a decontamination rate of approximately 5 m^2/hour. Because Simple Green® is a household cleaner, no skills or specialized training were required, and the only required tools were a spray bottle, brush, and disposable towels making the method very portable.

Two disposable towels were used for each surface coupon. The two disposable towels made up the entirety of the secondary waste as all the liquid was absorbed into the towels. The health physicist overseeing the health and safety aspects of this evaluation collected wipe samples from the gloves of the person performing decontamination with the DSG and water once during the evaluation of each surface material to determine the likelihood of worker contamination when using this decontamination approach. In all instances, there was no measurable activity, indicating that the gloves had not become contaminated even though in some cases most of the CS-137 had been removed from the coupons. Apparently, personal contamination was prevented because the gloves did not come into contact with the surface of the coupons. At all times, the technician was using the brush and towels to remain protected from contamination. Lastly, a one liter container of Simple Green® concentrate costs approximately \$10. Following the method used during this evaluation, a cost of \$10 for a one-liter container would correspond to a material only cost of approximately \$0.06/m^2 to use DSG as a decontamination agent.

7.0 References

1. "Test/QA Plan for the Performance of Selected Radiological Decontamination Processes on Urban Substrates," Version 1.0. Battelle, Columbus, Ohio, March 2009.
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3. Radionuclide Detection and Decontamination Program. Broad Agency Announcement 03-013, U.S. Department of Defense (DOD) Defense Advanced Research Projects Agency (DARPA) and the U.S. Department of Homeland Security, classified program.
4. "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).

Appendix
Additional Granite Results

Table A. Additional Granite Decontamination Efficacy Results

Coupon Type–Decon Agent	Pre-decon (µCi)	Post-decon (µCi)	%R	DF
Granite - DSG†	1.21A	0.88	27.3	1.4
	1.16B	0.49	57.8*	2.4
	1.21C	1.1	9.1	1.1
Granite – Water†	1.24D	1.14	8.1	1.1
	1.2E	1.09	9.2	1.1
	1.02F	0.96	5.9	1.1
	1.17G	1.10	6.0	1.1
	1.05G	0.96	8.2	1.1

† Letters in first data column are for reference to the granite descriptions in Table B.

*DSG applied twice because brushing step omitted the first time.

The coupons described by the data in Table A were unique compared to the rest of the surface materials because seven of the eight coupons came from unique sources of polished granite with slightly different colors and surface characteristics. Because the decontamination method was shown to be reproducible for the other surface coupons (see main body of report), it is likely that differences between the %R values for the polished granite coupons are due to differences in surface characteristics across the coupons rather than measurement variability. For the polished granite decontaminated with water, none of the coupons exhibited %R values exceeding 10% regardless of the surface characteristics. For the DSG decontaminated coupons, there was a broad range of %R (9.1%R to 57.8%R). However, the coupon with the highest removal had DSG application and towel wiping routine performed twice because the brushing step had been omitted following the first DSG application. The technician then repeated the DSG application and towel wiping routine, but this time included the brushing step. Because the surface coupons were not from the same source material and the application methods were not identical, it is not possible to determine if there were significant differences between the DSG and water decontamination. Because of the variability in %R, it seems likely that the DSG decontamination is highly dependent on the surface characteristics of the polished granite. Table B provides descriptions (including the grain size, or size of stones making up the appearance of the granite, and color) of the seven sources of polished granite coupons.

Table B. Description of Granite Coupons

Coupon*	Grain Size (inch)	Color
A	1 to 2	Black
B	1 and ¼	Larger orange and gray grains mixed with smaller black grains
C	1/8 to ¼	Mixture of brown and black
D	1/8 to ¼	Orange grains
E	1/8 to ¼	Red with black grains
F	1 and ¼	Large orange grains with smaller black grains
G	1/8 to ¼	Black

*Letters are referenced to coupons in Table A.

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