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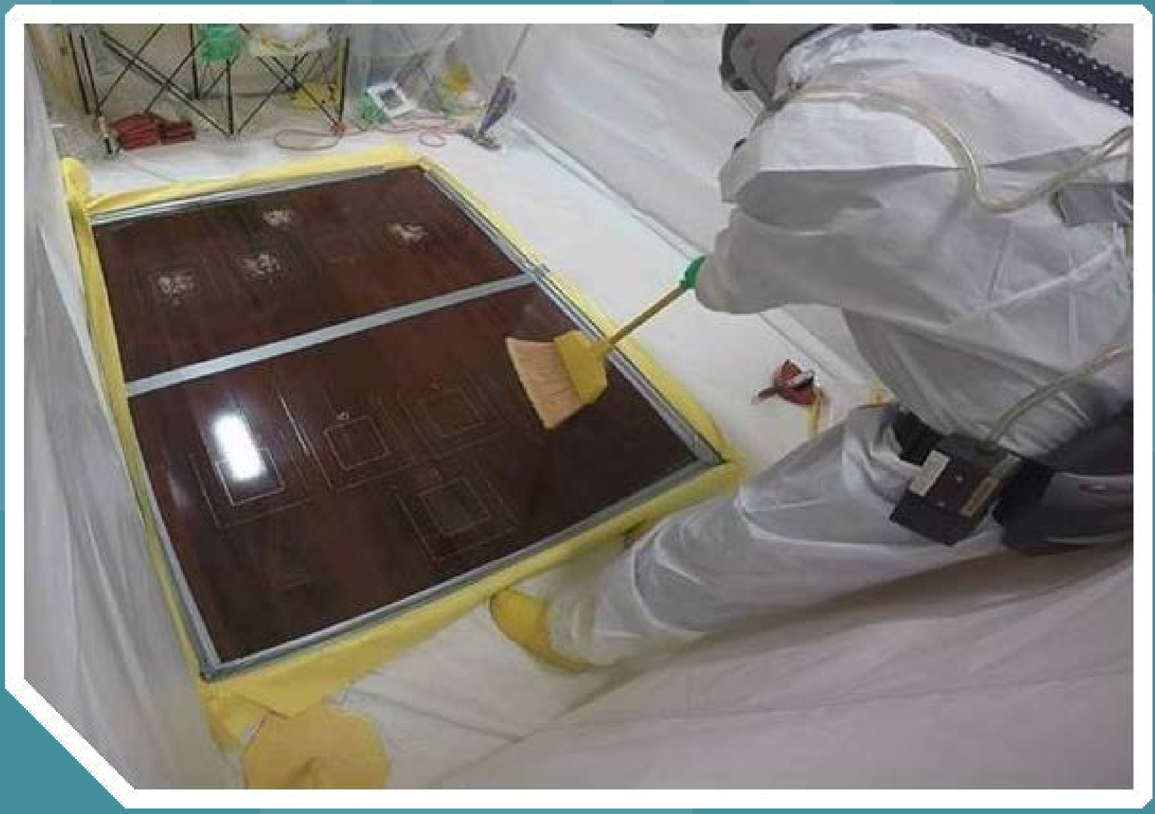
Evaluation of Low-Tech Indoor Remediation Methods Following Wide Area Radiological/Nuclear Incidents



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Technology Evaluation Report

Evaluation of Low-Tech Indoor Remediation Methods Following Wide Area Radiological/Nuclear Incidents

U.S. Environmental Protection
Agency Cincinnati, OH 45268

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Disclaimer

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Abbreviations/Acronyms

%R	percent(s) removal
ASFM	aqueous simulated fallout material
ARD	Arizona Road Dust
CBRN	chemical, biological, radioactive, and nuclear
cm	centimeter(s)
Cs	cesium
DAC	derived air concentration
EPA	U.S. Environmental Protection Agency
ft	feet
g	gram(s)
HEPA	high efficiency particle air
HSRP	Homeland Security Research Program
kg	kilogram(s)
mg	milligram(s)
mL	milliliter(s)
m	meter(s)
µm	micron(s)
µCi	microcurie
PPE	personal protective equipment
QA	quality assurance
QC	quality control
Rad/Nuc	radiological or nuclear
Rb	rubidium
RPD	relative percent difference
SFM	simulated fallout material
STREAMS	Scientific, Technical, Research, Engineering and Modeling Support

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Executive Summary

The U.S. Environmental Protection Agency's (EPA's) Homeland Security Research Program (HSRP) is helping to protect human health and the environment from adverse impacts resulting from intentional or unintentional releases of chemical, biological, radiological and nuclear (CBRN) contamination. One way the HSRP helps to protect human health and the environment is by performance testing technologies for remediating CBRN contamination from various locations. The objective of the work described here is to collect information and experimental data needed for technical experts to provide simple and useful guidance for residents of the effects of using low-tech remediation options available in the United States.

Initially, literature containing pertinent information related to common housekeeping activities within the United States was compiled into a summary compendium including relevant information about multiple low-tech cleaning methods from the literature search results. Through discussion and prioritization, an EPA project team, made up of several EPA scientists and emergency responders, gathered the information into a list of 14 housekeeping activities for decontamination evaluation testing. These types of activities are collectively referred to as "low-tech" remediation methods because of the comparative simple tools, equipment, and operations involved. Similarly, eight common indoor surfaces were chosen that were contaminated using three different contamination conditions. These indoor surfaces were selected because of their prevalence in personal residences and commercial office buildings and of the inconvenience associated with removing and replacing relatively expensive items (compared to curtains, bedding, etc.). The low-tech remediation methods were selected based on availability and ease of use for the homeowners and potentially contractors hired by the homeowners. These methods would also be applicable for the remediation of commercial services that are critical to everyday life. Thirty-three combinations of methods and surfaces were chosen for testing under three contamination conditions for a total of 99 decontamination experiments. This report contains a technical video (no sound) and photographs that show the experimental approaches used in this study. The video and photographs are attached to Appendix B.

This method of evaluation included use of multiple common household surfaces (countertops [0.6 m^2], pieces of furniture, flooring [1.4 m^2], etc.) at a pilot scale for decontamination testing. Testing included deposition (heavy particle, light particle, and aqueous loadings) and measurement of the radioactive contaminant on the surface; application of the decontamination method; and subsequent measurement of residual contamination to determine a quantitative decontamination efficacy (i.e., effectiveness of radionuclide removal) attained by each method. Semi-quantitative and quantitative information pertaining to each method was collected. This type of information included number of wipes/sponge pads used, relative level of contamination on the wipes/sponge pads, and level of contamination on the components of a remediation tool (e.g., handle, support end, and sponge end).

A summary of the evaluation results for these low-tech remediation methods is presented below while a discussion of the observed performance can be found in Section 4 of this report.

Decontamination Efficacy: As summarized below, the decontamination efficacy attained by the low-tech remediation methods on various surfaces and three contamination methods was evaluated following contamination of the flooring and non-flooring surfaces:

- 83% of heavy particle loading experiments (across both particle sizes) exhibited contaminant removal greater than 90%
- For the heavy particle loading experiments, contaminant removal was not dependent on particle size
- 88% of the light particle loading experiments exhibited contaminant removal greater than 97%
- 16% of the aqueous contaminant application experiments exhibited contaminant removal greater than 90%
- 28% of the aqueous contaminant application experiments exhibited contaminant removal less than 10% (all either wood furniture, wood trim, or granite countertops)
- Of the three contamination methods, the aqueous contaminant application experiments had the lowest removal efficacy

Deployment and Operational Factors: Section 4 provides an operational summary of the various low-tech remediation methods that were employed during testing by presenting observations made by the operators using each low-tech remediation method. In addition, it provides the fate of the simulated fallout material (containing radiological activity) following decontamination. This was done by performing a qualitative radiological survey of the tools used for decontamination. For example, this survey revealed that minimal contaminant ended up on the gloves or other personal protective equipment of the decontamination technician, but that in general, most of the contaminant (and therefore most of the radiological activity) ended up on the part of the tools that had most contact with the contaminant during removal.

Based on the results of the decontamination experiments described above, the amount (and types) of radiological waste that would be generated from the decontamination of a typical house (using the most effective remediation methods) was estimated. For this example, a two-story house assumed to be 186 square meters (2,000 square feet) was used . The total solid waste generated was estimated to be 49 kilograms (kg). The level of activity in this waste will be dependent on the initial contamination levels, which will then, in turn, affect waste management activities.

Several air samplers were positioned throughout the testing to measure the potential inhalation dose to the decontamination worker. The air sampler filters never exceeded 0.2% of the derived air concentration, which is the average atmospheric concentration of the radionuclide that would lead to the annual occupational limit of intake of the radionuclide if working in that environment for a 2,000 hour working year.

Also, after every decontamination experiment, the operators were surveyed from head to toe to determine if they had received any contamination on their personal protective equipment (PPE). None of those surveys resulted in activity measurements above background levels. This is consistent with the little or no contamination found on the decontamination workers' gloves and the high activity found on the low-tech remediation tools. Almost all of the activity was isolated on the item that was in contact with the surface being decontaminated.

The results indicated that the aqueous contaminant that was allowed to dry was much more difficult to remove than the dried dust contaminant, and particles size was not a factor in dry contaminant removal. In particular, the granite countertop and wood trim exhibited extremely low removal percentages for the aqueous contaminant. Most of the removal for the dry contaminant were greater than 95%, although dry vacuum on carpet, wet vacuum on laminate, and electrostatic pad on wood furniture stand out as least effective for the simulated fallout material. The amount of waste is driven by the surface density of the fallout material as well as the weight of the tools used. The data from this project show that tools such as wet and dry vacuums are not the most effective and they are heavy and bulky to dispose of. Wipes and cloths were rather effective, can be conveniently transported between sites (in new packaging), and can possibly be disposed of at each site more efficiently that attempting to transport powered equipment that would have become contaminated.

1.0 Introduction

The U.S. Environmental Protection Agency (EPA) is responsible for environmental cleanup after the release of chemical, biological, radioactive, and nuclear (CBRN) contaminants. EPA's Homeland Security Research Program (HSRP) is tasked to perform scientific studies and develop strategies and guidance for this cleanup. For wide area radiological or nuclear (Rad/Nuc) incidents (e.g., nuclear power plant accident, discharge of a radiological dispersal device or improvised nuclear device), there may be indoor areas such as personal residences, office buildings, or critical infrastructure (such as firehouses and hospital emergency rooms) that may be contaminated with Rad/Nuc material (requiring cleanup), but the radiation may not be high enough to warrant the evacuation of residents. Therefore, homeowners, office workers, or fire fighters/hospital workers may want or need to take action themselves to reduce potential radioactive dose to those living or working in these areas. This research is focused on evaluating low-tech remediation methods that can be performed by tenants or contractors hired by tenants to reduce exposure.

Following the Fukushima Nuclear Power Plant incident, the Japanese national government developed guidance[1] for decontamination strategies specifically focused on residential structures. This guidance outlined which areas required decontamination, which technologies were applicable for the affected areas, and in what order these areas should be decontaminated. The document also provided guidance for on-site waste management.

The objective of this study is to begin gathering information needed to inform residents of what is available and its effectiveness as a low-tech remediation within the United States. This study identified, collected, evaluated, and summarized available articles, reports, guidance documents, and other pertinent information related to common housekeeping activities within the United States. This resulted in a summary compendium including relevant information about multiple low-tech cleaning methods from the literature search results. Through discussion and prioritization, an EPA project team, made up of several EPA scientists and emergency responders, focused the information into a list of 14 housekeeping activities for decontamination evaluation testing. These types of activities are collectively referred to as "low-tech" remediation methods because of the comparatively simple tools, equipment, and operations involved. Similarly, eight common household surfaces were chosen that were contaminated using three different contamination conditions. Thirty-three combinations of methods and surfaces were chosen for testing under the three contamination conditions for a total of 99 tests.

This method evaluation included use of multiple common household surfaces (countertops [0.6 squared meter (m^2)], pieces of furniture [0.4 m^2], flooring [1.4 m^2], etc.) at a pilot scale for decontamination testing. Testing included deposition and measurement of the radioactive contaminant on the surface; application of the decontamination method; and subsequent measurement of residual contamination to determine a quantitative decontamination efficacy (i.e., effectiveness of radionuclide removal) attained by each method. Semi-quantitative and quantitative information pertaining to each method was collected. This type of information included number of wipes/sponge pads used, relative level of contamination on the wipes/sponge pads, and level of contamination on the components of a low-tech remediation tool (e.g., handle, support end, and sponge end). Qualitative information on operational ease and appearance of the surfaces after decontamination was also collected.

This evaluation took place from May 10, 2016 through July 20, 2016 at Battelle's West Jefferson Campus, in West Jefferson, Ohio. Quality assurance (QA) oversight of this evaluation was performed in accordance with EPA Quality Assurance Program for this evaluation. Per quality requirements, two audits were conducted: a technical systems audit and an audit of data quality on the results from the evaluation.

2.0 Experimental Details

This report was a technology evaluation that included use of low-tech remediation methods on horizontal surfaces common to an indoor residential environment and included evaluating the decontamination efficacy, method constraints, safety concerns, feasibility, waste generation, potential exposure, and cost. This evaluation included the radiological contaminants cesium (Cs)-137, with a half-life of 30 years, added to Arizona Road Dust (ARD) with particle size greater than 250 micrometer (µm) and rubidium (Rb)-86 added to ARD particles between 1 and 10 µm to generate simulated fallout material (SFM) as dry deposition. Rubidium, with a half-life of 19 days, was chosen as a shorter-lived surrogate for cesium, but also possesses similar chemical properties to cesium[2].

The dry deposition of particles was conducted using a heavy and a light loading onto the surfaces for two distinct contamination conditions. During heavy loading, high activity material was applied to individual test squares and low activity material was applied to the remainder of the surface. During light loading, fine grained material was applied to only the test squares. An aqueous solution of Cs-137 (as cesium chloride) was applied to each surface to simulate a contamination event where initially SFM had been wet due to precipitation or some other source of water and then dried. This contamination approach will hereafter be referred to as aqueous SFM (ASFM). For each surface sample, the SFM or ASFM was deposited on the surface, a pre-decontamination measurement of activity was performed, the low-tech remediation method was applied, and lastly a post-decontamination measurement of activity was conducted. All of the radiological work was conducted in a 4 m × 2.6 m contamination control tent located in a high bay area. A technical video (no sound) and photographs in Appendix B show the experimental approaches used in this study.

2.1 Experimental Preparation

2.1.1 Surfaces

This technology evaluation included use of low-tech remediation methods on surfaces found within a home or other indoor building where people live or work. Surface types chosen for this evaluation included a variety of materials used in homes for flooring, countertops, furniture, and fixtures. The materials were large enough to be considered at pilot scale, i.e., a scale large enough to simulate use in a home and relatively inconvenient and expensive to remove and replace. The surfaces were divided into two surface classes: flooring surfaces and non-flooring surfaces. The surfaces (including dimensions) used are summarized in Table 2-1.

Table 2-1. Description of Surface Materials

Surface	Material Type	Source Information (Manufacturer; Model/Size; Location)	Description/ Approximate Surface Area
Flooring	Sealed Hardwood Flooring	Home Legend; High Gloss Santos Mahogany, 12 cm wide planks, Click Lock Exotic Hardwood Flooring; Adairsville, GA	1.5 m × 0.9 m = 1.4 m^2
	Laminate Flooring	TrafficMASTER; Eagle Peak Hickory, Laminate Flooring, Shaw Industries; Dalton, GA	
	Carpet	TrafficMASTER; Thoroughbred II-Color Chestnut Texture Carpet, PureColor solution-dyed BCF Polyester texture, Shaw Industries; Dalton, GA	
Non-Flooring	Painted Wood Trim	Finished Elegance; MDF Molding Board; Fruitland, ID	0.2 m × 2.4 m = 0.5 m^2
	Sealed Granite Countertop	Discount Granite; Luna Pearl Granite Island; Columbus, OH	0.1 m × 1 m = 0.6 m^2
	Laminate Countertop	Wilsonart; Jeweled Coral Quarry Laminate Countertop; Temple, TX	
	Toilet Tank Cover	Kohler; Toilet Tank Cover in White, porcelain (vitreous china); Kohler, WI	0.2 m × 0.5 m × 4 covers = 0.4 m^2
	Wood Furniture	Shipyard Sofa Table; American Signature Furniture, wood finish, sealed with nutmeg color; Columbus, OH	1.2 m × 0.5 m = 0.4 m^2

m = meter, cm=centimeter

The size of the surfaces used in the evaluation depended on the typical placement within the home and whether cleaned by hand or using a handled device, such as a broom or vacuum. For surfaces and furniture/fixture items that are typically cleaned by hand, the size was approximately 0.5 m^2 or a common size of the item itself. For flooring options, the size was approximately 1.5 m^2. These options are larger because they are typically cleaned using tools such as brooms and vacuums which are operated with a person standing up holding onto a handle that is approximately 1 m in length or a vacuum that is pushed with a handle. All surfaces were purchased new so the surfaces were clean and undamaged. Newly purchased surfaces were staged and put through the evaluation steps in an indoor location containing a radiological containment tent, minimizing differences in conditions during use of the various methods over the course of the evaluation testing. Older surfaces in homes may not present the same results. Figures 2-1 and 2-2 are pictures of the flooring and non-flooring surfaces, respectively.

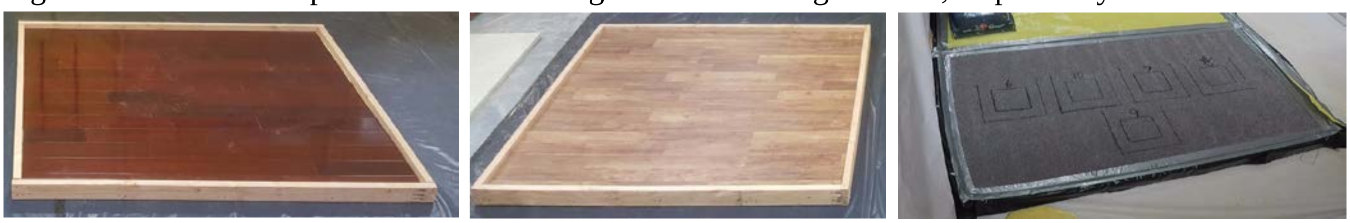


Figure 2-1. Hardwood, laminate, and carpet (from left) flooring surfaces.

Figure 2-2. Toilet tank, laminate, granite, wood furniture, and painted wood trim non-flooring surfaces.

All of the radiological work was conducted in the tent shown in Figure 2-3 (Dual Chamber Tent, LANCS Industries, Kirkland, WA) which was located in an indoor high bay area (Building JS-23 in West Jefferson, OH). The evaluation tent measured approximately 4 m × 2.6 m with separate rooms for donning PPE and performing the experiments. Decontamination technicians wore respiratory protection while performing the experimental procedures. The tent was connected to a high efficiency particle air (HEPA) filtration system which pulled air throughout the tent, but did not allow particles past the HEPA filter.

Figure 2-3. Containment tent used for pilot scale experiments.

2.1.2 Surface Contamination

Three contaminant deposition approaches (heavy SFM loading, light SFM loading, and ASFM) were used to evaluate the decontamination methods. In an actual fallout event, the level of SFM loading would vary greatly depending on the height of a possible explosion, ground characteristics below a possible explosion, distance from radiological release, meteorological conditions, ventilation of residences or offices, etc. Previous fallout remediation research [3-5] (mostly outdoor) has used surface densities of approximately 20 mg/cm^2 so we used this as the heavy SFM loading. This relatively high level served as a worst case scenario for decontamination, possible worker contamination, and waste handling. We then used a SFM density of 2 mg/cm^2 as a light SFM loading to simulate a less heavy loading which may be more representative of more actual scenarios. Regardless of approach, each flooring and non-flooring surface was marked with numbered squares using permanent marker. The squares were 15 cm × 15 cm and used to define the areas of quantitative decontamination evaluation and to ensure the pre- and post-decontamination gamma measurements were taken from the same locations.

Heavy SFM loading. The first contaminant deposition approach included a heavy SFM loading consisting of ARD at two particle size ranges. This approach has been used during previous EPA radiological decontamination technology evaluations[5-6]. Cs-137 was tagged to ARD particles that were greater than 250 µm in diameter (12203-250 Test Dust, Powder Technology, Inc., Arden Hills, MN) at an activity concentration level of 1 microcurie (µCi)/gram (g) and Rb-86 was tagged to ARD particles that ranged from 1 to 10 µm (ISO 12103-1 A1 Ultrafine Test Dust, Powder Technology, Inc., Arden Hills, MN) at an activity concentration level of 10 µCi/g. The Cs-137 (#8137, Eckert & Ziegler Analytics, Atlanta, GA) used for tagging was obtained as 5 milliliter (mL) volumes of 20 µCi/mL in 0.1 molar aqueous hydrochloric acid, and the Rb-86 (N9300145, Perkin Elmer, Waltham, MA) was obtained as 1 millicurie in microliter volumes. For both particle types, SFM was made by adding dilute aqueous radionuclide to a fixed amount of the substrate, mixed to be thoroughly damp, and then allowed to dry. Approximately 2 g of each particle size was measured into a salt shaker (166A Tablecraft, Shenzhen, China) and rotated to mix well. For particle application, one shaker was emptied onto each surface square corresponding to 10 milligram (mg)/cm^2 of each SFM for a total particle density of 20 mg/cm^2 and 2 µCi of Cs-137 and 20 µCi of Rb-86 on each square. The remaining surface was then covered at the same particle density and size, but with a lower activity (0.1 µCi/g Cs-137 and 1 µCi/g Rb-86) particle mixture (for purposes of personal exposure/dose estimation).

Light SFM loading. The second deposition method consisted of a lighter particle load and included only 1 to 10 µm ARD tagged with Cs-137 at an activity concentration level of 8 µCi/g. Only 0.5 g of these particles were added to each square for an extremely light loading, but still a total of 2 µCi of Cs-137 on each square. The SFM was prepared in a similar manner, adjusting the amount of Cs-137 and mass of particles accordingly.

Aqueous Contamination. The third application included 2.5 mL of an aqueous mist of Cs-137 at a concentration of 0.8 µCi/mL (diluted from the source standard with deionized water) for a total addition of 2 µCi per square. A similar contamination approach has been used during several EPA radiological decontamination studies[7-14]. The ASFM mist was delivered to each surface using a calibrated sprayer (11 pumps corresponds to approximately 2.5 mL). Exact calibration of this sprayer was not required as the gamma radiation measurement for each surface before decontamination, and not the volume of radionuclide applied, is the critical measurement for determination of applied radionuclide. A small amount of pooling on the surface being contaminated occurred as expected during the application of the liquid aerosol, so the surface was air dried prior to gamma radiation measurement. Solution on the surface was covered as uniform as possible with the evaluation staff's visual inspection while application. Table 2-2 and Figure 2-4 summarize the three different experimental conditions used for contaminating the surfaces.

Table 2-2. Summary of Contamination Experimental Conditions

Deposition Approach	Contaminant	Loading on Surface
Heavy SFM Loading	Cs-137 tagged to >250 µm ARD	4 g 1:1 high activity particle size mixture on testing square (20 mg/cm^2)
	Rb-86 tagged to 1-10 µm ARD	20 mg/cm^2 1:1 low activity particle size mixture on remaining surface
Light SFM Loading	Cs-137 tagged to 1-10 µm ARD	0.5 grams ARD deposited on each square
Aqueous SFM	Cs-137 in deionized water	Sprayed on testing squares and allowed to dry

Figure 2-4. Contamination of laminate flooring surface with a heavy SFM loading on and around squares (left). Light SFM loading laminate flooring surface on testing squares (center), and ASFM applicator (right).

2.1.3 Measurement of Activity on Coupon Surface

Following surface contamination, the Cs-137 and/or Rb-86 gamma radiation was measured by placing the spectrometer above the contaminated square on the surface. Initially, the activity measurements were made using a Micro-Detective HPGe gamma spectrometer (Ortec®, Oak Ridge, TN) shown in Figure 2-5. The cooling unit on the instrument failed during the course of the test and was replaced with a InSpector™ 1000 Digital Hand-Held MCA (Canberra Industries, Inc., Meriden, CT). Regardless of the instrument, the pre-decontamination measurements were collected over a 100 second measurement period and the post-decontamination measurements were taken over a 300-second (five-minute) measurement period.

The measurement of gamma radiation from the surfaces is a non-destructive measurement technique; surfaces that had been contaminated with SFM or ASFM and have had the gamma radiation measured were then decontaminated using the low-tech method. Following application of the decontamination method, the residual activity on the surface was measured again to calculate the percent removal (%R). Careful positioning of the gamma spectrometer above the contaminated squares was performed to allay concerns over differences in geometry of the surfaces confounding the gamma measurements. Reproducible positioning was done by attaching a support stand around the detector face. The support stand allowed the detector to be set down on top of each square in a location that was labeled ahead of time with a permanent marker. This feature facilitated repeatable geometry due to the consistent position of the detector face with respect to the surface and repeatable location because of the ease of positioning onto the pre-marked surface.

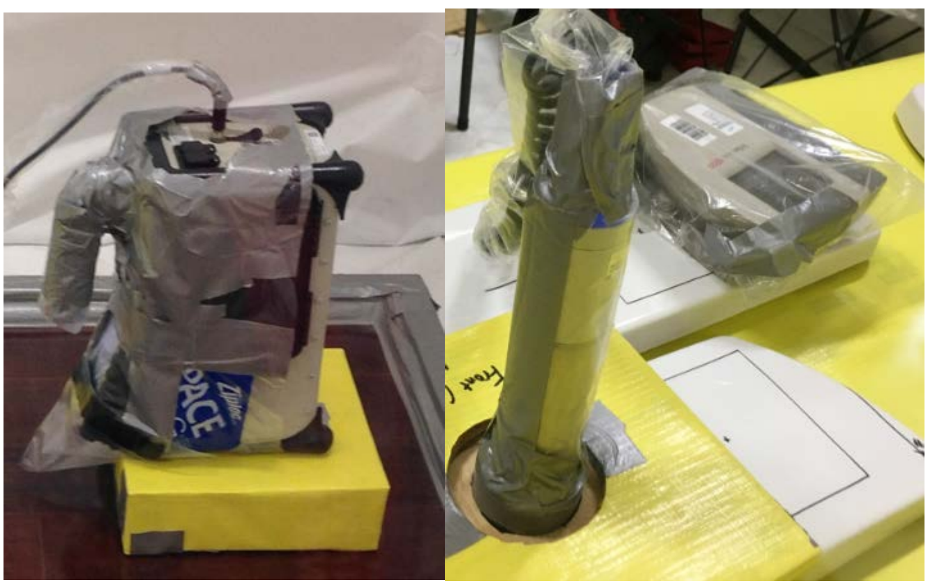


Figure 2-5. Ortec® Micro-Detective Gamma Spectrometer (left) and the InSpector™ 1000, Digital Hand-Held MCA (right) with support to facilitate repeatable geometry.

2.2 Decontamination Methods

Throughout the course of this evaluation, the evaluation tent was staged separately with the contaminated surfaces given in Table 2-1 (a total of 33 separate staging) with various surfaces for application of the decontamination methods evaluated. Four replicate surface measurements were included for each surface. Once contaminated with a heavy SFM loading, an initial pass in a single direction or standard “sweeping action” where particles were collected at one end of the surface was performed. Then, the decontamination method was applied to the staged surface in a way that two complete passes over the entire surface occurred as presented in Figure 2-6. The first pass took place in one direction, implementing a "Z" pattern (or back and forth) across the surface, covering the entire surface, then a second pass (using the same pattern) occurred in the perpendicular direction, so the entire surface had been treated a second time. The low-tech methods used in this evaluation are presented in Table 2-3.

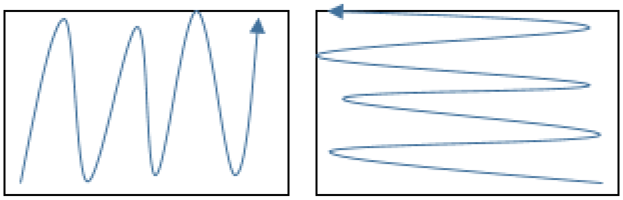


Figure 2-6. Pass 1 pattern (left) and Pass 2 pattern (right) with decontamination approaches.

In addition to the evaluation of the decontamination method efficacy, the potential for resuspension of radiological material during application of each method, was also measured using two approaches. First, post-decontamination measurement of one area on each surface that was not contaminated provided indication of the extent of cross-contamination due to the low-tech method. Second, particle resuspension was measured using low volume particle samplers positioned 0.25 m and 0.5 m from the surfaces during application of each low-tech method. Radiological air sampling and analysis was performed daily (per a Battelle standard operating procedure) to collect suspended particles and to measure potential dose during the method evaluation. Particle air samples were collected inside and outside the radiological containment area as well as from within the breathing zone of the decontamination technicians. Air sampling pumps operating at 2-3 liters per minute were connected to holders containing round quartz fiber filters (60 millimeters in diameter) and operated for the duration of the time that the decontamination technicians were working within the radiological containment area. The activity on the filters were counted daily to document air concentrations.

Potential exposure to users of low-tech remediation methods was monitored by conducting qualitative radiological surveys of the workers' PPE after decontamination activities. The focus was on the hands (covered by PPE) and other areas (e.g. elbows, knees, and feet) that were likely to have been exposed to the SFM or ASFM. All gloves used by the workers were collected and surveyed together using a qualitative survey instrument and the locations of contamination were documented on a data collection form. In addition, other items such as wipes and towels were counted and surveyed to determine the approximate amounts of activity and magnitude of waste streams generated by use of these decontamination methods.

Table 2-3. Low-Tech Remediation Methods Used for the Evaluation

Surface Application	Decontamination Method	Source	Method Comments
Flooring (built into frame)	Pre-wet Disposable Pads on Swiffer® Mop	Swiffer® Sweeper®, Sweeper® Wet Mopping Cloths, Procter & Gamble, Cincinnati, OH	None.
	Spray Agent with Swiffer® Mop	Swiffer® Wet Jet, Procter & Gamble, Cincinnati, OH	Sprayed on top of the deposited SFM or ASFM.
	Water with sponge mop	PVA Blue Sponge Mop, Rubbermaid, Atlanta, GA	Wet sponge prior to decontamination.
	Dry Swiffer®	Swiffer® Sweeper®, Swiffer® Sweeper® Disposable Refill Cloths, Procter & Gamble, Cincinnati, OH	None.
	Broom with dust pan	Standard Broom, Rubbermaid, Atlanta, GA	Went over surfaces multiples times with minimal visible improvement after first 2 passes.
	Dry Vacuum	Shark®, NV352 Navigator Lift-Away Pro Bagless Upright Vacuum, SharkNinja, China	None.
	Wet Vacuum	Hoover® Commercial SteamVac Spotter/Carpet Cleaner, Techtronic Industries, Hong Kong, China	None.
		Hoover® SteamVac SpinScrub Carpet Cleaner with Clean Surge, Techtronic Industries, Hong Kong, China	
Non-Flooring (placed 0.9 m above floor)	Water with Paper Towel	Brawny®, Georgia-Pacific Consume Products, Atlanta, GA	Wet paper towel by spraying before wiping.
	Formula 409® with Paper Towel	Formula 409®, Clorox® Company, Oakland, CA	Wet paper towel by spraying before wiping.
	Pre-wet Disposable Wipe	Disinfecting Wipes, Clorox® Company, Oakland, CA	None.
	Dry Paper Towel	Brawny®, Georgia-Pacific Consume Products, Atlanta, GA	None.
	Dry Cloth	HDX, Model 7-660, Home Depot, Atlanta, GA	None.
	Electrostatic Pad	Swiffer® Dusters Kit, Procter & Gamble, Cincinnati, OH	None.
	Polish Oil	SAS Dutch Glow®, 12 oz. Amish Wood Milk Furniture, Tarrytown, NY	Sprayed lightly on top of ASFM and SFM.

2.3 Decontamination Conditions

The evaluation was performed over the course of approximately 2 months from May 10 to July 20, 2016. During the evaluation the temperature in the tent averaged 23.9 ± 1.6 degrees Celsius and the average relative humidity averaged 63% ± 5%. Tables 2-4 and 2-5 present the 33 combinations of decontamination methods and surfaces tested during this study. All three contamination conditions were used with these test combinations for a total of 99 tests with four replicates for a total of 396 determinations of removal.

Table 2-4. Test Matrix of Decontamination Methods for Flooring Surfaces

	Decontamination Methods						
Surfaces	**Pre-wet Disposable Pads on Swiffer® Mop**	**Spray Agent with Swiffer® Mop**	**Water with sponge Mop**	**Dry Swiffer**	**Broom**	**Dry Vacuum**	**Wet Vacuum**
Sealed Hardwood Flooring	×	×	×	×	×		
Laminate Flooring	×	×	×	×	×	×	×
Carpet						×	×

Table 2-5. Test Matrix of Decontamination Methods and for Non-flooring Surfaces

	Decontamination Methods						
Surfaces	**Water w/ Paper Towel**	**Formula 409® with Paper Towel**	**Pre-wet Disposable Wipe**	**Dry Paper Towel**	**Dry Cloth**	**Electrostatic Pad**	**Polish Oil**
Granite Countertop	×	×	×				
Laminate Countertop	×	×	×				
Toilet Tank Top			×	×	×	×	
Painted Wood Trim			×	×	×	×	
Wood furniture			×	×	×	×	×

3.0 Quality Assurance/Quality Control

Quality Assurance (QA)/quality control (QC) procedures were performed in accordance with the EPA Quality Assurance Program for this evaluation. Before contaminating each surface, the background activities of the surfaces were determined by a 5-minute acquisition. The background measurements fluctuated daily due to the contents in the tent at the time of gamma measurement. The measurement results were normalized for the background levels measured on the respective testing days. Typical background activity levels were approximately 3% of the pre-decontamination activity levels. The regions of interest (ROI) were set up around the strongest emitting energies for the two contaminant of interest (661 keV for Cs-137 and 1,076 keV for Rb-86). ROIs were determined through data analysis of Cs-137 and Rb-86 sources, setting the ROI so the full emission peak was counted. These ROI parameters were used for all the measurements collected throughout the testing. The software automatically corrected for the background instrument noise providing net counts for each counting period. Spectra were collected from each surface before contaminant application, after contaminant deposition, and after decontamination. Section 4.1 of the report describes how the percent removal was calculated using these counts.

3.1 Ortec® Micro-Detective

The Ortec® Micro-Detective was used for the first few weeks of testing and then malfunctioned due to a failed cooling unit. The quality of the data collected by this instrument was verified with seven daily comparisons of contaminant deposition measurements. The day-to-day relative percent differences (RPDs) ranged from 1% to 12%. Measurements were not able to be made after the cooler failed, so the problem was immediately apparent, and the replacement instrument was put into service. Throughout the evaluation, a duplicate measurement was taken on one of the replicate contaminated squares from each experiment to provide duplicate measurements to further evaluate the repeatability of the instrument. The average and standard deviation for the RPDs determined for this instrument were 1% ± 1% (N=16). The requirement for duplicate results was 25% or less.

3.2 InSpector™ 1000

The InSpector™ 1000 was set up to monitor for Cs-137 and Rb-86. A positive control coupon was contaminated with the ASFM Cs-137 and allowed to dry. This coupon was measured at the beginning and end of each testing day using a 100-second acquisition to ensure the instrument was performing consistently throughout the day. The RPD was calculated for 21 positive control measurements and ranged from 0% to 13%, with all but three of the measurements between 0% and 3% RPD. In addition, the raw gamma counts collected daily throughout the course of 6 weeks of operation had a relative standard deviation of 6%, indicating very consistent instrument performance. A duplicate measurement was taken on one of the replicate contaminated squares from each experiment to provide duplicate measurements to further evaluate the repeatability of the instrument. The average and standard deviation for the RPDs determined for this instrument were 2% ± 2% (N=87). The requirement for duplicate results was 25% or less.

3.3 Audits

3.3.1 Technical System Audit

A technical systems audit was performed on July 15, 2016 to confirm compliance with project quality requirements. The audit report was completed and no findings or observations were reported.

3.3.2 Data Quality Audit

At least 10% of the data acquired during the evaluation were audited. The QA officer 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 audited data were checked for accuracy. The audit revealed a %R formula error that was corrected in the report and data spreadsheets.

3.4 QA/QC Reporting

Each assessment and audit were documented in accordance with project quality requirements. Once the assessment report was prepared by the QA officer, the report was routed to the task order leader and Scientific, Technical, Research, Engineering and Modeling Support (STREAMS II) contract manager for review and approval.

4.0 Evaluation Results and Performance Summary

4.1 Decontamination Efficacy

The decontamination efficacy was determined for each contaminated coupon in terms of %R:

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

where A_o is the radiological activity from the surface of the coupon before application of the decontamination technologies, A_f is the radiological activity from the surface of the coupon after decontamination, and BG is the background before contamination. As discussed in Section 2.1.2, approximately 2 µCi of Cs-137 and 20 µCi of Rb-86 was added to each heavy loading SFM square, approximately 2 µCi of Cs-137 to the light loading SFM square, and approximately 2 µCi of Cs-137 to each ASFM square. Because of the variability in particle application geometry and because of the time it would take to perform an instrument calibration regularly, the raw counts were used to calculate %R. The background activity before subtraction was, on average, 3% of the pre-decontamination activity.

Table 4-1 gives the average %R for each low-tech remediation method and each of the three contaminant deposition techniques. Each %R is given with the standard deviation over four replicates. If the %R is reported with a 'greater than' sign (>), it means that the average %R exceeded 100% and is reported as having a %R greater than the lower limit of the average minus the standard deviation.

Observations about the heavy loading SFM flooring surface decontamination efficacy data include:

- Efficacy of each particles size was not significantly different from one another
- In only five of 27 instances (across both particles sizes) were the average %R less than 90%
- In 16 of 27 instances, the average %R was 95% or above
- The largest standard deviation was 12%
- Use of the wet-vacuum on laminate floor provided the lowest average %R, 46% and 34% for the large and small particles sizes, respectively. Dry vacuum on carpet was the next lowest average %R with 83% and 85%, for the large and small particles sizes, respectively.

Observations about the light loading SFM flooring surface decontamination efficacy data include:

- 12 out of 14 average %R were 97% and above; dry and wet vacuum on carpet were the two outliers, exhibiting %R of 87% and 93%, respectively.

Observations about the ASFM flooring surface decontamination efficacy data include:

- Only four of 13 instances had average %R exceeding 90%; one other instance exceeded 80%
- The dry vacuum on carpet and laminate floor had the lowest average %R of 22% and 14%, respectively.

- Laminate and sealed hardwood floor using wet Swiffers® had the highest average %R (92%-94%).

Table 4-1. Decontamination Efficacy for Flooring Surfaces

Method	Flooring Surface	% Removal for Each Contamination Deposition Approach: Cs-137, > 250 µm Heavy Loading SFM			Rb-86, <10 µm Heavy Loading SFM			Cs-137, <10 µm Light Loading SFM			Cs-137 ASFM		
Dry Broom	Laminate	100%	±	2%	>99%			98%	±	0%	40%	±	16%
	Sealed Hardwood	>99%			>99%			>99%			27%	±	6%
Swiffer® with dry pad	Laminate	93%	±	4%	93%	±	9%	99%	±	2%	59%	±	7%
	Sealed Hardwood	>99%			>96%			99%	±	1%	64%	±	8%
Sponge mop with water	Laminate	99%	±	0%	99%	±	1%	97%	±	1%	73%	±	3%
	Sealed Hardwood	98%	±	3%	96%	±	3%	98%	±	0%	86%	±	1%
Swiffer® spray mop	Laminate	97%	±	2%	97%	±	2%	99%	±	1%	92%	±	1%
	Sealed Hardwood	>99%			100%	±	2%	100%	±	0%	93%	±	1%
Swiffer® w/ pre-wet pad	Laminate	96%	±	6%	NA		NA	99%	±	1%	94%	±	1%
	Sealed Hardwood	92%	±	6%	93%	±	6%	100%	±	0%	92%	±	1%
Dry Vacuum	Carpet	82%	±	6%	85%	±	3%	87%	±	2%	22%	±	4%
	Laminate	97%	±	1%	98%	±	1%	98%	±	0%	14%	±	6%
Wet Vacuum	Carpet	92%	±	1%	88%	±	4%	93%	±	1%	53%	±	11%
	Laminate	46%	±	12%	34%	±	8%	100%	±	0%	NA		NA

Table 4-2 gives the average %R for each low-tech remediation method and each of the three contaminant deposition techniques.

Observations about the heavy loading SFM non-flooring surface decontamination efficacy data include:

- Efficacy of each particles size was not significantly different from one another
- In only six of 38 instances (across both particles sizes) were the average %R less than 90%
- In 25 of 38 instances, the average %R plus or minus the standard deviation included 100%
- The largest standard deviation was 7%
- Use of the electrostatic pad on the wood furniture provided the lowest average %R, 72% and 80% for the large and small particles sizes, respectively.

Table 4-2. Decontamination Efficacy for Non-Flooring Surfaces

Method	Non-Flooring Surface	% Removal for Each Contamination Deposition Approach			
		Cs-137, > 250 µm Heavy Loading SFM	Rb-86, <10 µm Heavy Loading SFM	Cs-137, <10 µm Light Loading SFM	Cs-137 ASFM
Dry Cloth	Wood furniture	>98%	>98%	100% ± 0%	42% ± 6%
	Toilet tank cover	88% ± 2%	89% ± 2%	98% ± 1%	83% ± 4%
	Wood trim	98% ± 4%	>97%	97% ± 2%	44% ± 17%
Dry paper towel	Wood furniture	>99%	>99%	100% ± 0%	8% ± 3%
	Toilet tank cover	99% ± 1%	98% ± 1%	100% ± 0%	71% ± 6%
	Wood trim	98% ± 4%	96% ± 4%	98% ± 4%	3% ± 13%
Electro-static pad	Wood furniture	72% ± 1%	80% ± 4%	100% ± 0%	61% ± 7%
	Toilet tank cover	>99%	98% ± 1%	99% ± 1%	39% ± 2%
	Wood trim	99% ± 2%	99% ± 2%	98% ± 3%	0% ± 18%
Paper towel w/ water	Granite countertop	95% ± 5%	91% ± 3%	99% ± 1%	8% ± 2%
	Laminate countertop	>99%	>99%	99% ± 0%	76% ± 7%
Spray Agent with Paper Towel	Granite countertop	100% ± 0%	100% ± 0%	100% ± 0%	14% ± 2%
	Laminate countertop	85% ± 1%	87% ± 3%	100% ± 0%	84% ± 6%
Pre-wet Clorox® Wipes	Wood furniture	99% ± 3%	96% ± 7%	99% ± 0%	69% ± 11%
	Granite countertop	94% ± 3%	91% ± 3%	99% ± 0%	0% ± 16%
	Laminate countertop	93% ± 3%	92% ± 6%	95% ± 1%	89% ± 3%
	Toilet tank cover	99% ± 1%	100% ± 0%	100% ± 0%	95% ± 3%
	Wood trim	98% ± 3%	>98%	99% ± 0%	NA ± NA
Polish Oil	Wood furniture	100% ± 0%	>99%	99% ± 1%	59% ± 6%

Observations about the light loading SFM non-flooring surface decontamination efficacy data include:

- All average %R were 95% and above, 17 out of 19 instances were 98% or above (apparently, the lesser loading and small particles size facilitated removal).

Observations about the ASFM non-flooring surface decontamination efficacy data include:

- Only one of 19 instances had average %R exceeding 90% (pre-wet Clorox® wipes on toilet tank covers) and only three instances exceeded 80%
- In five instances, the average %R did not exceed 10%; the surfaces were the wood furniture, painted wood trim, and the granite countertop
- Granite countertop had three average %R (0%, 14%, and 8%) below 20%R
- Laminate countertop and the toilet tank cover had the highest average %R
- Wood trim average %R were scattered, but the standard deviations were rather high for the wood trim results; this may suggest that the ASFMs transport into the pores of the surface, impacting the repeatability of the measurement.

Table 4-3 provides observations of the efficacy data by surface type.

Table 4-3. Efficacy Observations of Each Surface Type

Low-tech Method	Efficacy Summary
	Flooring Surfaces
Laminate floor	With exception of wet vacuum, SFM %R near 100%; ASFM %R were greater than 90% for wet Swiffer® methods, 73% for sponge mop with water, and 60% or less for dry methods
Wood floor	Polished surface. SFM %R near 100%; ASFM %R were greater than 90% for wet Swiffer® methods, 86% for sponge mop with water, and 69% or less for dry methods
Carpet	Highly fibrous surface. SFM %R between 82% and 92%; ASFM %R were 53% and 22% for wet and dry vacuum, respectively
	Non-flooring Surfaces
Wood furniture	Finished wood furniture with wood grooves in surface. Heavy loading SFM near 100% removal except for electrostatic pad. Light loading SFM near 100% removal. ASFM %R ranged from 8% to 61%.
Toilet Tank Cover	Porcelain surface. Except for dry cloth, SFM %R near 100%; ASFM %R ranged from 39% to 95%.
Wood trim	Painted wood surface. SFM %R near 100%; ASFM %R ranged from 0% to 44% (see comment on variability in text above).
Laminate countertop	SFM %R between 85% and 100% with light loading SFM near 100%; ASFM %R ranged from 76% to 89%, the highest ASFM %R.
Granite countertop	Polished surface. SFM %R between 91% and 100% with light loading SFM near 100%; ASFM %R ranged from 0% to 14%, the lowest ASFM %R, this result indicates the liquid application may have penetrated into the pores of the granite or strongly bonded to the granite surface.

4.2 Operational and Deployment Factors

Operator observations and remediation method waste stream. Table 4-4 provides an operational summary of the various low-tech remediation methods that were employed during testing by summarizing observations made by the operators using each low-tech remediation method. In addition, it provides the location of activity measured qualitatively as low-tech remediation tools were being placed in radiological waste.

Table 4-4. Operational Summary of Each Low-tech Remediation Method

Low-tech Method	Operational Summary	Waste Stream Summary
	Floor Surfaces	
Dry Broom	Repeated sweeping of the same surface did not improve the visible cleanliness	ASFM: Significant activity on the broom and dust pan broom; SFM: Minimal activity; activity goes with particles into waste as there was little activity on brooms or pans.
Swiffer® with dry pad	Sometimes the particles went over top of the Swiffer® pad because there were so many particles. Also, the pad would get loaded quickly, requiring frequent pad changes.	BG activity on gloves and handle, >99% on dry pads
Sponge mop with water	Flat sponges worked acceptably, but did not pick up the particles very well, just pushed the particles	BG activity on gloves and handle, >99% on sponges
Swiffer® spray mop	Sometimes left the flooring too wet for experimental setup as there was not enough room to continue to push/dry up the water. Easy to use and sprays evenly and easy.	BG activity on gloves and handle, >99% on pads
Swiffer® w/ pre-wet pad	Pad is good quality as it is quilted and the 15 cm mop face was a good size for the surfaces that were deconned. Light and easy to use, no electrical needs; all surfaces deconned to greater than 92%.	BG activity on gloves and handle, >99% on pads
Dry Vacuum	Nose of the vacuum was not that close to the surface and sat off the surface of the laminate floor, but on the carpet it seemed to work better.	BG activity on gloves and handle, >99% in canister
Wet Vacuum	Had to apply the correct amount of water. If too much water was added, a muddy puddle was created on the laminate flooring and would have to apply the vacuum to the floor more often to remove the water.	BG activity on gloves and handle, >99% in reservoir
	Non-floor Surfaces	
Dry Cloth	Did not draw particles into towel, tended to push the particles, making containment more difficult; notably more effective than dry paper towel on ASFM removal	BG activity on gloves, >99% on cloths
Dry paper towel	Paper towels seemed to work better than the dry cloth in collecting particles	BG activity on gloves, >99% on paper towels
Electrostatic pad	Clung to some of the particles, easier to contain the particles, easier to direct the particles into a pile than what was possible with the dry cloth; plastic handle did not allow much leverage; poor particle removal from furniture and ASFM from wood trim, furniture, and toilet tank cover	BG activity on gloves, >99% on pads
Paper towel w/ water	Dampened paper towel with 3-4 sprays of water before wiping surfaces. If the paper towel was too saturated, the paper towel did not move as freely across the surfaces	BG activity on gloves, >99% on paper towels
Formula 409® w/ paper towel	Dampened paper towel with 3-4 sprays of Formula 409® before wiping surfaces. Seemed to function well and was convenient to use.	Trace activity on gloves, >94% on paper towels
Pre-wet Clorox® Wipes	Wipe size made decontamination difficult, the wipes were always doubled up to decontaminate.	BG activity on gloves, >99% on wipes
Polish Oil	Polish was sprayed gently on top of SFM and then wiped clean; seemed to do a good job of allowing particles to be collected in rag	BG activity on gloves, >99% on polish rag

Waste stream from typical house. Based on the results of the decontamination experiments described above, Table 4-5 reports the number of low-tech remediation method accessories (wipes, brooms, pads, etc.) that were required to accomplish decontamination of the surfaces (using each type of deposition) within this project.

Table 4-5. Accessories for each Low-tech Remediation Method by Deposition Method

Low-tech Method	**Number of Accessories (wipes, pads, etc.)**		
	Heavy Loading	**Light Loading**	**ASFM**
	Floor Surfaces (1.4 m²)		
Dry Broom	Laminate:1 broom Wood:1 broom	Laminate:1 broom Wood:1 broom	Laminate:1 broom WOOD:1 broom
Swiffer® with dry pad	Laminate: 1 Swiffer® + 3 pads Wood: 1 Swiffer® + 3 pads	NA	Laminate: 1 Swiffer® + 1 pad Wood: 1 Swiffer® + 2 pads
Sponge mop with water	Laminate: 1 sponge mop Wood: 1 sponge mop	Laminate: 1 sponge mop Wood: 1 sponge mop	Laminate: 1 sponge mop Wood: 1 sponge mop
Swiffer® spray mop	Laminate: 1 Swiffer® + 3 pads Wood: 1 Swiffer® + 4 pads	Wood: 1 Swiffer® + 2 pads	Wood: 1 Swiffer® + 2 pads
Swiffer® w/ pre-wet pad	Laminate: 1 Swiffer® + 3 pads Wood: 1 Swiffer® + 4 pads	NA	Wood: 1 Swiffer® + 2 pads
Dry Vacuum	Laminate: 1 vacuum Carpet: 1 vacuum	Laminate: 1 vacuum Carpet: 1 vacuum	Laminate: 1 vacuum Carpet: 1 vacuum
Wet Vacuum	Laminate: 1 vacuum Carpet: 1 vacuum	Laminate: 1 vacuum Carpet: 1 vacuum	Laminate: 1 vacuum Carpet: 1 vacuum
Non-floor Surfaces (wood trim-0.5 m², countertops-0.6 m², 4 tank covers-0.4 m², wood furniture-0.6 m²)			
Dry Cloth	Wood furniture: 3 cloths Wood Trim: 2 cloths Toilet Cover: 5 cloths	Wood Trim: 2 cloths Toilet Cover: 2 cloths	Wood furniture: 3 cloths Wood Trim: 2 cloths Toilet Cover: 4 clothes
Dry paper towel	Wood furniture: 3 paper towels Wood Trim: 6 paper towels Toilet Cover: 5 paper towels	Wood Trim: 2 paper towels Toilet Cover:5 paper towels	Wood furniture: 3 paper towels Wood Trim: 2 paper towels Toilet Cover: 8 paper towels
Electrostatic pad	Wood furniture: 3 pads Wood Trim: 4 pads Toilet Cover: 5 pads	Wood furniture: pads Wood Trim: 2 pads Toilet Cover: 3 pads	Wood furniture: 3 pads Wood Trim: 2 pads Toilet Cover: 4 pads
Paper towel w/ water	Granite: 8 paper towels Laminate: 5 paper towels	Granite: 2 paper towels	Granite: 3 paper towels Laminate: 3 paper towels
Formula 409® w/ paper towel	Granite: 8 paper towels Laminate: 7 paper towels	Granite: 3 paper towels Laminate: 3 paper towels	Granite: 4 paper towels Laminate: 3 paper towels
Pre-wet Clorox® Wipes	Wood furniture: 5 wipes Wood Trim: 5 wipes Toilet Cover: 4wipes Granite: 12 wipes	Wood furniture: wipes Wood Trim: 2 wipes Toilet Cover: 3 wipes Granite: 2 wipes	Wood furniture: 3 wipes Wood Trim: 2 wipes Toilet Cover: 4 wipes Granite: 3 wipes
Polish Oil	Wood furniture: 3 cloths	Wood furniture: 1cloth	Wood furniture: 3 cloths

Table 4-6 through Table 4-8 expands on the accessory use data and provides an estimate of how much radiological waste (and what types, including the accessories mentioned above and SFM) would be generated from the decontamination of a typical two-story house under three types of depositions. This estimate was made by extrapolating the number of accessories and amount of SFM relative to the amount of surface area in the home. For this example, a two-story house is assumed to equal 186 square meters (2,000 square feet). As shown in Table 4-9, as estimated 49 kilograms (kg) of solid waste would be generated under heavy loading conditions and no liquid waste would be generated from the decontamination efforts. However, under ASFM conditions, 32 L of liquid and 13kg of solid waste would be generated. The number of items estimated in the tables (4-6 through 8) are extrapolated based on the area tested in this study.

Table 4-6. Estimated Waste from Decontamination of Typical House (Heavy SFM Loading)

Surface	Amount	Method	Number of items	Potential %R
Carpet	139 m^2	Dry vacuum	1 vacuum and SFM with 20 mg/cm^2	82%
Laminate floor	46 m^2			97%
Laminate counter	2 m^2	Formula 409® w/ paper towel	12 paper towels with 20 mg/cm^2 SFM	85%
Toilet Tank Covers	4 covers	Clorox® pre-wet wipes	12 wipes with 20 mg/cm^2 SFM	99%
Tub/shower	2	Formula 409® w/ paper towel	12 paper towels with 20 mg/cm^2 SFM	99%
Wood furniture	10 m^2	Polish oil	50 dry cloths	100%

Table 4-7. Estimated Waste from Decontamination of Typical House (Light SFM Loading)

Surface	Amount	Method	Number of items	Potential %R
Carpet	139 m^2	Dry vacuum	1 vacuum and SFM with 2 mg/cm^2	87%
Laminate floor	46 m^2			98%
Laminate counter	2 m^2	Formula 409® w/ paper towel	6 paper towels with 2 mg/cm^2 SFM	87%
Toilet Tank Covers	4 covers	Clorox® pre-wet wipes	8 wipes with 2 mg/cm^2 SFM	100%
Tub/shower	2	Formula 409® w/ paper towel	6 paper towels with 2 mg/cm^2 SFM	100%
Wood furniture	10 m^2	Polish oil	17 dry cloths	99%

Table 4-8. Estimated Waste Stream from Decontamination of Typical House (ASFM Loading)

Surface	Amount	Method	Number of items	Potential %R
Carpet	139 m^2	Wet vacuum	1 vacuum 32 L water	53%
Laminate floor	47 m^2	Pre-wet Swiffer	54 pre-wet pads	94%
Laminate counter	2 m^2	Formula 409® w/ paper towel	6 paper towels	84%
Toilet Tank Covers	4 covers	Clorox® pre-wet wipes	12 wipes	95%
Tub/shower	2	Formula 409® w/ paper towel	6 paper towels	95%
Wood furniture	10 m^2	Polish oil	50 dry cloths	59%

Table 4-9. Estimated Waste Stream as a Function of Deposition Method

Surface	Estimated Waste Volume: Heavy SFM Loading	Light SFM Loading	ASFM
Carpet	1 vacuum (6 kg), 37 kg SFM	1 vacuum (6 kg), 3.7 kg SFM	1 vacuum (10 kg), 32 kg wastewater
Laminate			162 g pre-wet pads
Laminate Counter	36 g in damp paper towels; 400 g SFM	18 g in damp paper towels; 40 g SFM	18 g in damp paper towels
Toilet Tank Covers	36 g in damp wipes; 180 g SFM	24 g in damp wipes; 18 g SFM	36 g in damp wipes
Tub/shower	36 g in damp paper towels; 400 g SFM	18 g in damp paper towels; 40 g SFM	18 g in damp paper towels
Wood Furniture	3 kg dry cloths and 2 kg SFM	2 kg dry cloths and 200 g SFM	3 kg dry cloths
Estimate of total mass, volume, and activity	49 kg into 0.2 m^3 bag (if initial fallout had activity of 0.5 µCi/g, then 19 mCi)	12 kg into 0.2 m^3 bag (if initial fallout had activity of 0.5 µCi/g, then 1.9 mCi)	45 kg into 0.2 m^3 bag (if initial activity of 0.01 mCi/m^2, then 1.9 mCi)

Potential operator exposure. Throughout the evaluation, technicians were required to use full anti-contamination PPE including positive air pressure respirators (with HEPA filters) because the work was performed in a radiological enclosure using unsealed radiological material of various particles sizes. However, in order to estimate the potential airborne exposure of the decontamination workers to radiological material, four sets of particle air filter samples were collected during each decontamination experiment. One of these air samplers was placed in the breathing zone of the decontamination worker and the sample collected only during surface decontamination. The other three air samplers were placed in the common area within the radiological containment tent. One was placed adjacent to the decontamination work area and the other two were placed near the outflow to the tent HEPA filtration system to capture the airflow of particles through the tent (even if they were being vented). During the 10 weeks of testing, the activity concentrations of the air sampler filters never exceeded 0.2% of the derived air concentration (DAC), The DAC is the average atmospheric concentration of the radionuclide that would lead to the annual occupational limit of intake of the radionuclide if working in that environment for a 2,000-hour work year. The low filter concentration suggests that the potential particle inhalation exposure and resulting dose due to the experimental conditions was minimal. Performance of these same low-tech remediation methods in a home setting may produce different results.

In addition to air sampling, the operators were surveyed from head to toe after every decontamination experiment to determine if they had received any contamination on their PPE. None of the surveys resulted in activity measurements above background levels. This is consistent with the waste stream results shown in Table 3-3, where even the decontamination worker’s gloves had little or no contamination and almost all of the activity was isolated on the item that was in contact with the surface being cleaned.

At any time, radiological material was handled, anti-contamination PPE was required. Additionally, any waste (e.g., from use of low-tech remediation methods and post-decontamination surfaces) was considered, at a minimum, as low level radioactive waste (unless surveyed for free release). The requirement for this level of PPE was not driven by the use of the low-tech remediation technologies (which only have the hazards described on their product labels), but rather by the presence of Cs-137.

4.3 Performance Summary

The primary objective was to determine the efficacy of low-tech remediation methods that would be readily available for people in personal residences and other indoor facilities such as offices and medical center to use in case of a radiological event causing radiological fallout to be present. Fourteen different low-tech remediation methods were evaluated on eight different surfaces (not all methods were used on every surface). In total, 33 different combinations of low-tech remediation methods and surfaces where evaluated using three different radiological contamination deposition methods (heavy loading, light loading, and ASFM) for a total of 99 different experiments. Overall the results indicated that the ASFM was much more difficult to remove than the SFM and particles size was not a factor in SFM removal. In particular, the granite countertop and wood trim exhibited extremely low %Rs for the ASFM. Most of the %Rs for the SFM were greater than 95% and above although dry vacuum on carpet, wet vacuum on laminate, and electrostatic pad on wood furniture stand out as least effective for SFM.

Secondary objectives included the observation of the likelihood of decontamination technician contamination while performing these low-tech remediation methods as well as estimating the waste stream following implementation of low-tech remediation. In order to accomplish these objectives, whole body surveys were completed after every decontamination test and multiple air samples were collected. None of these indicated technician contamination even during the heavy loading portions of the evaluation but it is still imperative to wear proper PPE prior to taking any maintenance or response activities in potentially contaminated area. The type, weight, and volume of the waste stream from a personal residence was estimated based on typical surface areas of various types as well as the amount of low-tech remediation accessories (wipes, pads, etc.) used during this evaluation on relatively smaller total surface area. Radiological activity was estimated based on what the starting activity of the fallout may have been. Overall, the amount of waste is driven by the surface density of the fallout material as well as the weight of the tools used. The data from this project show that tools such as wet and dry vacuums are not the most effective and they are heavy and bulky to dispose of. Wipes and cloths were rather effective, can be conveniently be transported between sites (in new packaging), and can possibly be disposed of at each site more efficiently that attempting to transport powered equipment that would have become contaminated. Additional research may require to obtain the impact of low-tech methods for other potential contamination situations such as outdoor. The current study results can help responders as well as local governments to develop remediation guidance for their stakeholders responding to a nuclear/radiological incident.

5.0 References

1. Decontamination Guidelines, 2nd Edition, Japanese Ministry of the Environment, 2013.
2. O. Paz Tal, R. Bar Ziv, R. Hakmon, E. J. C. Borojovich, A. Nikoloski, T. Ohaion, R. (Yanosh) Levi, I. Yaar, Study of Cleanup Procedures for Contaminated Areas: Examination of Rubidium as a Surrogate to Cesium, Conference of the Nuclear Societies in Israel; Dead Sea (Israel); 11-13 Feb 2014, p 27.
3. Wiltshire, L. L.; Owen, W. L. *Three Tests of Fire hosing Technique and Equipment for the Removal of Fallout from Asphalt Streets and Roofing Materials*; USNRDL-TR-1048; U.S. Naval Radiological Defense Laboratory: San Francisco, California, 1966.
4. Clark, D. E.; Cobbin, W. C. *Removal Effectiveness of Simulated Dry Fallout from Paved Areas by Motorized and Vacuumized Street Sweepers*; USNRDL-TR-746; U.S. Naval Radiological Defense Laboratory: San Francisco, California, 1963.
5. U.S. EPA. Technology Evaluation Report, Compressed Air and Vacuuming for Radiological Decontamination of Sensitive Equipment. U.S. Environmental Protection Agency, Washington, DC, 2014 (draft).
6. U.S. EPA. Technology Evaluation Report, River Technologies LLC 3-Way Decontamination System for Radiological Decontamination. U.S. Environmental Protection Agency, Washington, DC, EPA/600/R-11/015, 2011.
7. U.S. EPA. CS Unitec ETR180 Circular Sander for Radiological Decontamination. Technology Evaluation Report. Washington, D.C.: U.S. Environmental Protection Agency. EPA/600/R-11/018, 2011.
8. U.S. EPA. Empire Abrasive Blast N'Vac for Radiological Decontamination. Technology Evaluation Report. Washington, D.C.: U.S. Environmental Protection Agency. EPA/600/R-11/014, 2011.
9. U.S. EPA. Industrial Contractors Supplies, Inc. Surface Dust Guard with DiamondWheel for Radiological Decontamination. Technology Evaluation Report. Washington, D.C.: U.S. Environmental Protection Agency. EPA/600/R-11/013, 2011.
10. U.S. EPA. Industrial Contractors Supplies, Inc. Surface Dust Guard with Wire Brush for Radiological Decontamination. Technology Evaluation Report. Washington, D.C.: U.S. Environmental Protection Agency. EPA/600/R-11/016, 2011.
11. U.S. EPA. Decontamination of Concrete and Granite Contaminated with Cobalt-60 and Strontium-85. U.S. Environmental Protection Agency, Washington, DC, EPA/600/R-13/002, 2012.
12. U.S. EPA. Decontamination of Concrete with Aged and Recent Cesium Contamination. U.S. Environmental Protection Agency, Washington, DC, EPA/600/R-13/001, 2013.

13. U.S. EPA. Technology Evaluation Report Bartlett Services, Inc. Stripcoat TLC Free Radiological Decontamination of Americium. U.S. Environmental Protection Agency, Washington, DC, EPA/600/R-13/005, 2013.

14. U.S. EPA. Evaluation of Chemical-Based Technologies for Removal of Radiological Contamination from Building Material Surfaces. U.S. Environmental Protection Agency, Washington, DC, EPA/600/S-15/155, 2015.

Appendix A
Evaluation Results by Decontamination Method

Date	Decontamination Method	Surface	Cs-137, Rb-86, Cs-137 ASFM, Cs-137 Light	%R	Average	Standard Deviation
6/27/2016	Dry Broom	Laminate Floor	Cs-137	101%	100%	2%
6/27/2016	Dry Broom	Laminate Floor	Cs-137	100%		
6/27/2016	Dry Broom	Laminate Floor	Cs-137	97%		
6/27/2016	Dry Broom	Laminate Floor	Cs-137	102%		
6/27/2016	Dry Broom	Laminate Floor	Rb-86	101%	100%	1%
6/27/2016	Dry Broom	Laminate Floor	Rb-86	99%		
6/27/2016	Dry Broom	Laminate Floor	Rb-86	99%		
6/27/2016	Dry Broom	Laminate Floor	Rb-86	101%		
7/20/2016	Dry Broom	Laminate Floor	Cs-137 Lt	98%	98%	0%
7/20/2016	Dry Broom	Laminate Floor	Cs-137 Lt	99%		
7/20/2016	Dry Broom	Laminate Floor	Cs-137 Lt	99%		
7/20/2016	Dry Broom	Laminate Floor	Cs-137 Lt	98%		
5/17/2016	Dry Broom	Laminate Floor	Cs-137 ASFM	28%	40%	16%
5/17/2016	Dry Broom	Laminate Floor	Cs-137 ASFM	25%		
5/17/2016	Dry Broom	Laminate Floor	Cs-137 ASFM	51%		
5/17/2016	Dry Broom	Laminate Floor	Cs-137 ASFM	57%		
7/15/2016	Dry Broom	Wood Floor	Cs-137 Lt	101%	100%	1%
7/15/2016	Dry Broom	Wood Floor	Cs-137 Lt	100%		
7/15/2016	Dry Broom	Wood Floor	Cs-137 Lt	99%		
7/15/2016	Dry Broom	Wood Floor	Cs-137 Lt	99%		
6/28/2016	Dry Cloth	Wood furniture	Cs-137	98%	100%	2%
6/28/2016	Dry Cloth	Wood furniture	Cs-137	99%		
6/28/2016	Dry Cloth	Wood furniture	Cs-137	102%		
6/28/2016	Dry Cloth	Wood furniture	Cs-137	102%		
6/28/2016	Dry Cloth	Wood furniture	Rb-86	102%	102%	2%
6/28/2016	Dry Cloth	Wood furniture	Rb-86	99%		
6/28/2016	Dry Cloth	Wood furniture	Rb-86	104%		
6/28/2016	Dry Cloth	Wood furniture	Rb-86	101%		
7/22/2016	Dry Cloth	Wood furniture	Cs-137 Lt	100%	100%	0%
7/22/2016	Dry Cloth	Wood furniture	Cs-137 Lt	100%		
7/22/2016	Dry Cloth	Wood furniture	Cs-137 Lt	100%		
7/22/2016	Dry Cloth	Wood furniture	Cs-137 Lt	100%		
6/30/2016	Dry Cloth	Wood furniture	Cs-137 ASFM	44%	42%	6%
6/30/2016	Dry Cloth	Wood furniture	Cs-137 ASFM	38%		
6/30/2016	Dry Cloth	Wood furniture	Cs-137 ASFM	36%		
6/30/2016	Dry Cloth	Wood furniture	Cs-137 ASFM	49%		
5/31/2016	Dry Cloth	Toilet Tank Cover	Cs-137	87%	88%	2%
5/31/2016	Dry Cloth	Toilet Tank Cover	Cs-137	85%		
5/31/2016	Dry Cloth	Toilet Tank Cover	Cs-137	90%		
5/31/2016	Dry Cloth	Toilet Tank Cover	Cs-137	89%		

Date	Decontamination Method	Surface	Cs-137, Rb-86, Cs-137 ASFM, Cs-137 Light	%R	Average	Standard Deviation
5/31/2016	Dry Cloth	Toilet Tank Cover	Rb-86	86%	89%	2%
5/31/2016	Dry Cloth	Toilet Tank Cover	Rb-86	90%		
5/31/2016	Dry Cloth	Toilet Tank Cover	Rb-86	89%		
5/31/2016	Dry Cloth	Toilet Tank Cover	Rb-86	91%		
7/14/2016	Dry Cloth	Toilet Tank Cover	Cs-137 Lt	97%	98%	1%
7/14/2016	Dry Cloth	Toilet Tank Cover	Cs-137 Lt	99%		
7/14/2016	Dry Cloth	Toilet Tank Cover	Cs-137 Lt	96%		
7/14/2016	Dry Cloth	Toilet Tank Cover	Cs-137 Lt	98%		
6/28/2016	Dry Cloth	Toilet Tank Cover	Cs-137 ASFM	82%	83%	4%
6/28/2016	Dry Cloth	Toilet Tank Cover	Cs-137 ASFM	85%		
6/28/2016	Dry Cloth	Toilet Tank Cover	Cs-137 ASFM	77%		
6/28/2016	Dry Cloth	Toilet Tank Cover	Cs-137 ASFM	86%		
5/25/2016	Dry Cloth	Wood Trim	Cs-137	92%	98%	4%
5/25/2016	Dry Cloth	Wood Trim	Cs-137	98%		
5/25/2016	Dry Cloth	Wood Trim	Cs-137	101%		
5/25/2016	Dry Cloth	Wood Trim	Cs-137	101%		
5/25/2016	Dry Cloth	Wood Trim	Rb-86	97%	101%	4%
5/25/2016	Dry Cloth	Wood Trim	Rb-86	99%		
5/25/2016	Dry Cloth	Wood Trim	Rb-86	104%		
5/25/2016	Dry Cloth	Wood Trim	Rb-86	105%		
7/14/2016	Dry Cloth	Wood Trim	Cs-137 Lt	99%	97%	2%
7/14/2016	Dry Cloth	Wood Trim	Cs-137 Lt	98%		
7/14/2016	Dry Cloth	Wood Trim	Cs-137 Lt	96%		
7/14/2016	Dry Cloth	Wood Trim	Cs-137 Lt	94%		
6/15/2016	Dry Cloth	Wood Trim	Cs-137 ASFM	46%	44%	17%
6/15/2016	Dry Cloth	Wood Trim	Cs-137 ASFM	39%		
6/15/2016	Dry Cloth	Wood Trim	Cs-137 ASFM	26%		
6/15/2016	Dry Cloth	Wood Trim	Cs-137 ASFM	66%		
6/29/2016	Dry Paper Towel	Wood furniture	Cs-137	101%	101%	1%
6/29/2016	Dry Paper Towel	Wood furniture	Cs-137	101%		
6/29/2016	Dry Paper Towel	Wood furniture	Cs-137	101%		
6/29/2016	Dry Paper Towel	Wood furniture	Cs-137	100%		
6/29/2016	Dry Paper Towel	Wood furniture	Rb-86	102%	101%	1%
6/29/2016	Dry Paper Towel	Wood furniture	Rb-86	101%		
6/29/2016	Dry Paper Towel	Wood furniture	Rb-86	100%		
6/29/2016	Dry Paper Towel	Wood furniture	Rb-86	102%		
7/22/2016	Dry Paper Towel	Wood furniture	Cs-137 Lt	99%	100%	0%
7/22/2016	Dry Paper Towel	Wood furniture	Cs-137 Lt	100%		
7/22/2016	Dry Paper Towel	Wood furniture	Cs-137 Lt	100%		
7/22/2016	Dry Paper Towel	Wood furniture	Cs-137 Lt	100%		

Date	Decontamination Method	Surface	Cs-137, Rb-86, Cs-137 ASFM, Cs-137 Light	%R	Average	Standard Deviation
6/30/2016	Dry Paper Towel	Wood furniture	Cs-137 ASFM	8%	8%	3%
6/30/2016	Dry Paper Towel	Wood furniture	Cs-137 ASFM	6%		
6/30/2016	Dry Paper Towel	Wood furniture	Cs-137 ASFM	8%		
6/30/2016	Dry Paper Towel	Wood furniture	Cs-137 ASFM	12%		
5/23/2016	Dry Paper Towel	Toilet Tank Cover	Cs-137	98%	99%	1%
5/23/2016	Dry Paper Towel	Toilet Tank Cover	Cs-137	99%		
5/23/2016	Dry Paper Towel	Toilet Tank Cover	Cs-137	100%		
5/23/2016	Dry Paper Towel	Toilet Tank Cover	Cs-137	101%		
5/23/2016	Dry Paper Towel	Toilet Tank Cover	Rb-86	97%	98%	1%
5/23/2016	Dry Paper Towel	Toilet Tank Cover	Rb-86	98%		
5/23/2016	Dry Paper Towel	Toilet Tank Cover	Rb-86	99%		
5/23/2016	Dry Paper Towel	Toilet Tank Cover	Rb-86	99%		
7/25/2016	Dry Paper Towel	Toilet Tank Cover	Cs-137 Lt	100%	100%	0%
7/25/2016	Dry Paper Towel	Toilet Tank Cover	Cs-137 Lt	101%		
7/25/2016	Dry Paper Towel	Toilet Tank Cover	Cs-137 Lt	100%		
7/25/2016	Dry Paper Towel	Toilet Tank Cover	Cs-137 Lt	100%		
5/25/2016	Dry Paper Towel	Toilet Tank Cover	Cs-137 ASFM	77%	71%	6%
5/25/2016	Dry Paper Towel	Toilet Tank Cover	Cs-137 ASFM	74%		
5/25/2016	Dry Paper Towel	Toilet Tank Cover	Cs-137 ASFM	67%		
5/25/2016	Dry Paper Towel	Toilet Tank Cover	Cs-137 ASFM	65%		
5/24/2016	Dry Paper Towel	Wood Trim	Cs-137	93%	98%	4%
5/24/2016	Dry Paper Towel	Wood Trim	Cs-137	97%		
5/24/2016	Dry Paper Towel	Wood Trim	Cs-137	101%		
5/24/2016	Dry Paper Towel	Wood Trim	Cs-137	101%		
5/24/2016	Dry Paper Towel	Wood Trim	Rb-86	90%	96%	4%
5/24/2016	Dry Paper Towel	Wood Trim	Rb-86	94%		
5/24/2016	Dry Paper Towel	Wood Trim	Rb-86	99%		
5/24/2016	Dry Paper Towel	Wood Trim	Rb-86	100%		
7/14/2016	Dry Paper Towel	Wood Trim	Cs-137 Lt	93%	98%	4%
7/14/2016	Dry Paper Towel	Wood Trim	Cs-137 Lt	97%		
7/14/2016	Dry Paper Towel	Wood Trim	Cs-137 Lt	101%		
7/14/2016	Dry Paper Towel	Wood Trim	Cs-137 Lt	101%		
6/15/2016	Dry Paper Towel	Wood Trim	Cs-137 ASFM	3%	3%	13%
6/15/2016	Dry Paper Towel	Wood Trim	Cs-137 ASFM	-14%		
6/15/2016	Dry Paper Towel	Wood Trim	Cs-137 ASFM	7%		
6/15/2016	Dry Paper Towel	Wood Trim	Cs-137 ASFM	16%		
7/12/2016	Dry Vacuum	Carpet	Cs-137	74%	83%	6%
7/12/2016	Dry Vacuum	Carpet	Cs-137	87%		
7/12/2016	Dry Vacuum	Carpet	Cs-137	82%		
7/12/2016	Dry Vacuum	Carpet	Cs-137	87%		

Date	Decontamination Method	Surface	Cs-137, Rb-86, Cs-137 ASFM, Cs-137 Light	%R	Average	Standard Deviation
7/12/2016	Dry Vacuum	Carpet	Rb-86	82%	85%	3%
7/12/2016	Dry Vacuum	Carpet	Rb-86	83%		
7/12/2016	Dry Vacuum	Carpet	Rb-86	85%		
7/12/2016	Dry Vacuum	Carpet	Rb-86	89%		
7/21/2016	Dry Vacuum	Carpet	Cs-137 Lt	87%	87%	2%
7/21/2016	Dry Vacuum	Carpet	Cs-137 Lt	90%		
7/21/2016	Dry Vacuum	Carpet	Cs-137 Lt	88%		
7/21/2016	Dry Vacuum	Carpet	Cs-137 Lt	84%		
7/11/2016	Dry Vacuum	Carpet	Cs-137 ASFM	28%	23%	4%
7/11/2016	Dry Vacuum	Carpet	Cs-137 ASFM	26%		
7/11/2016	Dry Vacuum	Carpet	Cs-137 ASFM	18%		
7/11/2016	Dry Vacuum	Carpet	Cs-137 ASFM	21%		
7/5/2016	Dry Vacuum	Laminate Floor	Cs-137	95%	97%	1%
7/5/2016	Dry Vacuum	Laminate Floor	Cs-137	97%		
7/5/2016	Dry Vacuum	Laminate Floor	Cs-137	97%		
7/5/2016	Dry Vacuum	Laminate Floor	Cs-137	97%		
7/5/2016	Dry Vacuum	Laminate Floor	Rb-86	96%	98%	1%
7/5/2016	Dry Vacuum	Laminate Floor	Rb-86	99%		
7/5/2016	Dry Vacuum	Laminate Floor	Rb-86	98%		
7/5/2016	Dry Vacuum	Laminate Floor	Rb-86	97%		
7/20/2016	Dry Vacuum	Laminate Floor	Cs-137 Lt	98%	98%	0%
7/20/2016	Dry Vacuum	Laminate Floor	Cs-137 Lt	98%		
7/20/2016	Dry Vacuum	Laminate Floor	Cs-137 Lt	98%		
7/20/2016	Dry Vacuum	Laminate Floor	Cs-137 Lt	99%		
7/8/2016	Dry Vacuum	Laminate Floor	Cs-137 ASFM	23%	15%	6%
7/8/2016	Dry Vacuum	Laminate Floor	Cs-137 ASFM	11%		
7/8/2016	Dry Vacuum	Laminate Floor	Cs-137 ASFM	16%		
7/8/2016	Dry Vacuum	Laminate Floor	Cs-137 ASFM	10%		
6/29/2016	Electrostatic Pad	Wood furniture	Cs-137	73%	72%	1%
6/29/2016	Electrostatic Pad	Wood furniture	Cs-137	73%		
6/29/2016	Electrostatic Pad	Wood furniture	Cs-137	71%		
6/29/2016	Electrostatic Pad	Wood furniture	Cs-137	72%		
6/29/2016	Electrostatic Pad	Wood furniture	Rb-86	80%	80%	4%
6/29/2016	Electrostatic Pad	Wood furniture	Rb-86	75%		
6/29/2016	Electrostatic Pad	Wood furniture	Rb-86	80%		
6/29/2016	Electrostatic Pad	Wood furniture	Rb-86	86%		
7/22/2016	Electrostatic Pad	Wood furniture	Cs-137 Lt	100%	100%	0%
7/22/2016	Electrostatic Pad	Wood furniture	Cs-137 Lt	100%		
7/22/2016	Electrostatic Pad	Wood furniture	Cs-137 Lt	100%		
7/22/2016	Electrostatic Pad	Wood furniture	Cs-137 Lt	99%		

Date	Decontamination Method	Surface	Cs-137, Rb-86, Cs-137 ASFM, Cs-137 Light	%R	Average	Standard Deviation
7/7/2016	Electrostatic Pad	Wood furniture	Cs-137 ASFM	52%	61%	7%
7/7/2016	Electrostatic Pad	Wood furniture	Cs-137 ASFM	58%		
7/7/2016	Electrostatic Pad	Wood furniture	Cs-137 ASFM	66%		
7/7/2016	Electrostatic Pad	Wood furniture	Cs-137 ASFM	67%		
5/23/2016	Electrostatic Pad	Toilet Tank Cover	Cs-137	100%	100%	1%
5/23/2016	Electrostatic Pad	Toilet Tank Cover	Cs-137	99%		
5/23/2016	Electrostatic Pad	Toilet Tank Cover	Cs-137	101%		
5/23/2016	Electrostatic Pad	Toilet Tank Cover	Cs-137	101%		
5/23/2016	Electrostatic Pad	Toilet Tank Cover	Cs-137	99%	99%	1%
5/23/2016	Electrostatic Pad	Toilet Tank Cover	Cs-137	98%		
5/23/2016	Electrostatic Pad	Toilet Tank Cover	Cs-137	100%		
5/23/2016	Electrostatic Pad	Toilet Tank Cover	Cs-137	100%		
5/23/2016	Electrostatic Pad	Toilet Tank Cover	Rb-86	97%	98%	1%
5/23/2016	Electrostatic Pad	Toilet Tank Cover	Rb-86	99%		
5/23/2016	Electrostatic Pad	Toilet Tank Cover	Rb-86	99%		
5/23/2016	Electrostatic Pad	Toilet Tank Cover	Rb-86	99%		
5/23/2016	Electrostatic Pad	Toilet Tank Cover	Rb-86	97%	98%	1%
5/23/2016	Electrostatic Pad	Toilet Tank Cover	Rb-86	99%		
5/23/2016	Electrostatic Pad	Toilet Tank Cover	Rb-86	99%		
5/23/2016	Electrostatic Pad	Toilet Tank Cover	Rb-86	99%		
7/25/2016	Electrostatic Pad	Toilet Tank Cover	Cs-137 Lt	98%	99%	1%
7/25/2016	Electrostatic Pad	Toilet Tank Cover	Cs-137 Lt	99%		
7/25/2016	Electrostatic Pad	Toilet Tank Cover	Cs-137 Lt	99%		
7/25/2016	Electrostatic Pad	Toilet Tank Cover	Cs-137 Lt	100%		
5/25/2016	Electrostatic Pad	Toilet Tank Cover	Cs-137 ASFM	37%	39%	2%
5/25/2016	Electrostatic Pad	Toilet Tank Cover	Cs-137 ASFM	41%		
5/25/2016	Electrostatic Pad	Toilet Tank Cover	Cs-137 ASFM	39%		
5/25/2016	Electrostatic Pad	Toilet Tank Cover	Cs-137 ASFM	38%		
5/24/2016	Electrostatic Pad	Wood Trim	Cs-137	96%	99%	2%
5/24/2016	Electrostatic Pad	Wood Trim	Cs-137	98%		
5/24/2016	Electrostatic Pad	Wood Trim	Cs-137	100%		
5/24/2016	Electrostatic Pad	Wood Trim	Cs-137	99%		
5/24/2016	Electrostatic Pad	Wood Trim	Rb-86	101%	99%	2%
5/24/2016	Electrostatic Pad	Wood Trim	Rb-86	100%		
5/24/2016	Electrostatic Pad	Wood Trim	Rb-86	98%		
5/24/2016	Electrostatic Pad	Wood Trim	Rb-86	96%		
7/14/2016	Electrostatic Pad	Wood Trim	Cs-137 Lt	94%	98%	3%
7/14/2016	Electrostatic Pad	Wood Trim	Cs-137 Lt	97%		
7/14/2016	Electrostatic Pad	Wood Trim	Cs-137 Lt	100%		
7/14/2016	Electrostatic Pad	Wood Trim	Cs-137 Lt	101%		

Date	Decontamination Method	Surface	Cs-137, Rb-86, Cs-137 ASFM, Cs-137 Light	%R	Average	Standard Deviation
6/15/2016	Electrostatic Pad	Wood Trim	Cs-137 ASFM	-5%	-1%	18%
6/15/2016	Electrostatic Pad	Wood Trim	Cs-137 ASFM	-18%		
6/15/2016	Electrostatic Pad	Wood Trim	Cs-137 ASFM	-5%		
6/15/2016	Electrostatic Pad	Wood Trim	Cs-137 ASFM	24%		
6/1/2016	Paper Towel with Water	Granite Countertop	Cs-137	88%	95%	5%
6/1/2016	Paper Towel with Water	Granite Countertop	Cs-137	93%		
6/1/2016	Paper Towel with Water	Granite Countertop	Cs-137	97%		
6/1/2016	Paper Towel with Water	Granite Countertop	Cs-137	99%		
6/1/2016	Paper Towel with Water	Granite Countertop	Rb-86	87%	91%	3%
6/1/2016	Paper Towel with Water	Granite Countertop	Rb-86	90%		
6/1/2016	Paper Towel with Water	Granite Countertop	Rb-86	93%		
6/1/2016	Paper Towel with Water	Granite Countertop	Rb-86	94%		
7/14/2016	Paper Towel with Water	Granite Countertop	Cs-137 Lt	100%	99%	1%
7/14/2016	Paper Towel with Water	Granite Countertop	Cs-137 Lt	100%		
7/14/2016	Paper Towel with Water	Granite Countertop	Cs-137 Lt	100%		
7/14/2016	Paper Towel with Water	Granite Countertop	Cs-137 Lt	98%		
6/30/2016	Paper Towel with Water	Granite Countertop	Cs-137 ASFM	10%	8%	2%
6/30/2016	Paper Towel with Water	Granite Countertop	Cs-137 ASFM	7%		
6/30/2016	Paper Towel with Water	Granite Countertop	Cs-137 ASFM	7%		
6/30/2016	Paper Towel with Water	Granite Countertop	Cs-137 ASFM	6%		
7/7/2016	Paper Towel with Water	Laminate Countertop	Cs-137	100%	100%	1%
7/7/2016	Paper Towel with Water	Laminate Countertop	Cs-137	100%		
7/7/2016	Paper Towel with Water	Laminate Countertop	Cs-137	100%		
7/7/2016	Paper Towel with Water	Laminate Countertop	Cs-137	99%		
7/7/2016	Paper Towel with Water	Laminate Countertop	Rb-86	100%	100%	1%
7/7/2016	Paper Towel with Water	Laminate Countertop	Rb-86	100%		
7/7/2016	Paper Towel with Water	Laminate Countertop	Rb-86	100%		
7/7/2016	Paper Towel with Water	Laminate Countertop	Rb-86	101%		
7/13/2016	Paper Towel with Water	Laminate Countertop	Cs-137 Lt	98%	99%	0%
7/13/2016	Paper Towel with Water	Laminate Countertop	Cs-137 Lt	99%		
7/13/2016	Paper Towel with Water	Laminate Countertop	Cs-137 Lt	99%		
7/13/2016	Paper Towel with Water	Laminate Countertop	Cs-137 Lt	99%		
6/29/2016	Paper Towel with Water	Laminate Countertop	Cs-137 ASFM	80%	76%	7%
6/29/2016	Paper Towel with Water	Laminate Countertop	Cs-137 ASFM	84%		
6/29/2016	Paper Towel with Water	Laminate Countertop	Cs-137 ASFM	68%		
6/29/2016	Paper Towel with Water	Laminate Countertop	Cs-137 ASFM	71%		
7/6/2016	Polish Oil	Wood furniture	Cs-137	101%	101%	0%
7/6/2016	Polish Oil	Wood furniture	Cs-137	101%		
7/6/2016	Polish Oil	Wood furniture	Cs-137	101%		
7/6/2016	Polish Oil	Wood furniture	Cs-137	100%		

Date	Decontamination Method	Surface	Cs-137, Rb-86, Cs-137 ASFM, Cs-137 Light	%R	Average	Standard Deviation
7/6/2016	Polish Oil	Wood furniture	Rb-86	101%	101%	1%
7/6/2016	Polish Oil	Wood furniture	Rb-86	101%		
7/6/2016	Polish Oil	Wood furniture	Rb-86	100%		
7/6/2016	Polish Oil	Wood furniture	Rb-86	100%		
7/18/2016	Polish Oil	Wood furniture	Cs-137 Lt	99%	99%	1%
7/18/2016	Polish Oil	Wood furniture	Cs-137 Lt	99%		
7/18/2016	Polish Oil	Wood furniture	Cs-137 Lt	98%		
7/18/2016	Polish Oil	Wood furniture	Cs-137 Lt	99%		
7/7/2016	Polish Oil	Wood furniture	Cs-137 ASFM	67%	59%	6%
7/7/2016	Polish Oil	Wood furniture	Cs-137 ASFM	59%		
7/7/2016	Polish Oil	Wood furniture	Cs-137 ASFM	56%		
7/7/2016	Polish Oil	Wood furniture	Cs-137 ASFM	54%		
6/28/2016	Pre-wet Clorox® Wipes	Wood furniture	Cs-137	101%	99%	3%
6/28/2016	Pre-wet Clorox® Wipes	Wood furniture	Cs-137	101%		
6/28/2016	Pre-wet Clorox® Wipes	Wood furniture	Cs-137	99%		
6/28/2016	Pre-wet Clorox® Wipes	Wood furniture	Cs-137	95%		
6/28/2016	Pre-wet Clorox® Wipes	Wood furniture	Rb-86	101%	96%	7%
6/28/2016	Pre-wet Clorox® Wipes	Wood furniture	Rb-86	97%		
6/28/2016	Pre-wet Clorox® Wipes	Wood furniture	Rb-86	101%		
6/28/2016	Pre-wet Clorox® Wipes	Wood furniture	Rb-86	85%		
7/18/2016	Pre-wet Clorox® Wipes	Wood furniture	Cs-137 Lt	100%	99%	0%
7/18/2016	Pre-wet Clorox® Wipes	Wood furniture	Cs-137 Lt	99%		
7/18/2016	Pre-wet Clorox® Wipes	Wood furniture	Cs-137 Lt	99%		
7/18/2016	Pre-wet Clorox® Wipes	Wood furniture	Cs-137 Lt	99%		
6/29/2016	Pre-wet Clorox® Wipes	Wood furniture	Cs-137 ASFM	69%	69%	11%
6/29/2016	Pre-wet Clorox® Wipes	Wood furniture	Cs-137 ASFM	61%		
6/29/2016	Pre-wet Clorox® Wipes	Wood furniture	Cs-137 ASFM	63%		
6/29/2016	Pre-wet Clorox® Wipes	Wood furniture	Cs-137 ASFM	85%		
6/1/2016	Pre-wet Clorox® Wipes	Granite Countertop	Cs-137	92%	94%	3%
6/1/2016	Pre-wet Clorox® Wipes	Granite Countertop	Cs-137	92%		
6/1/2016	Pre-wet Clorox® Wipes	Granite Countertop	Cs-137	95%		
6/1/2016	Pre-wet Clorox® Wipes	Granite Countertop	Cs-137	98%		
6/1/2016	Pre-wet Clorox® Wipes	Granite Countertop	Rb-86	89%	91%	3%
6/1/2016	Pre-wet Clorox® Wipes	Granite Countertop	Rb-86	89%		
6/1/2016	Pre-wet Clorox® Wipes	Granite Countertop	Rb-86	92%		
6/1/2016	Pre-wet Clorox® Wipes	Granite Countertop	Rb-86	94%		
7/14/2016	Pre-wet Clorox® Wipes	Granite Countertop	Cs-137 Lt	99%	99%	0%
7/14/2016	Pre-wet Clorox® Wipes	Granite Countertop	Cs-137 Lt	99%		
7/14/2016	Pre-wet Clorox® Wipes	Granite Countertop	Cs-137 Lt	100%		
7/14/2016	Pre-wet Clorox® Wipes	Granite Countertop	Cs-137 Lt	99%		

Date	Decontamination Method	Surface	Cs-137, Rb-86, Cs-137 ASFM, Cs-137 Light	%R	Average	Standard Deviation
6/30/2016	Pre-wet Clorox® Wipes	Granite Countertop	Cs-137 ASFM	7%	-7%	16%
6/30/2016	Pre-wet Clorox® Wipes	Granite Countertop	Cs-137 ASFM	-20%		
6/30/2016	Pre-wet Clorox® Wipes	Granite Countertop	Cs-137 ASFM	7%		
6/30/2016	Pre-wet Clorox® Wipes	Granite Countertop	Cs-137 ASFM	-22%		
7/13/2016	Pre-wet Clorox® Wipes	Laminate Countertop	Cs-137 Lt	94%	95%	1%
7/13/2016	Pre-wet Clorox® Wipes	Laminate Countertop	Cs-137 Lt	96%		
7/13/2016	Pre-wet Clorox® Wipes	Laminate Countertop	Cs-137 Lt	97%		
7/13/2016	Pre-wet Clorox® Wipes	Laminate Countertop	Cs-137 Lt	94%		
5/31/2016	Pre-wet Clorox® Wipes	Toilet Tank Cover	Cs-137	100%	99%	1%
5/31/2016	Pre-wet Clorox® Wipes	Toilet Tank Cover	Cs-137	100%		
5/31/2016	Pre-wet Clorox® Wipes	Toilet Tank Cover	Cs-137	99%		
5/31/2016	Pre-wet Clorox® Wipes	Toilet Tank Cover	Cs-137	99%		
5/31/2016	Pre-wet Clorox® Wipes	Toilet Tank Cover	Rb-86	100%	100%	0%
5/31/2016	Pre-wet Clorox® Wipes	Toilet Tank Cover	Rb-86	100%		
5/31/2016	Pre-wet Clorox® Wipes	Toilet Tank Cover	Rb-86	100%		
5/31/2016	Pre-wet Clorox® Wipes	Toilet Tank Cover	Rb-86	99%		
7/25/2016	Pre-wet Clorox® Wipes	Toilet Tank Cover	Cs-137 Lt	100%	100%	0%
7/25/2016	Pre-wet Clorox® Wipes	Toilet Tank Cover	Cs-137 Lt	100%		
7/25/2016	Pre-wet Clorox® Wipes	Toilet Tank Cover	Cs-137 Lt	100%		
7/25/2016	Pre-wet Clorox® Wipes	Toilet Tank Cover	Cs-137 Lt	100%		
6/28/2016	Pre-wet Clorox® Wipes	Toilet Tank Cover	Cs-137 ASFM	98%	95%	3%
6/28/2016	Pre-wet Clorox® Wipes	Toilet Tank Cover	Cs-137 ASFM	97%		
6/28/2016	Pre-wet Clorox® Wipes	Toilet Tank Cover	Cs-137 ASFM	94%		
6/28/2016	Pre-wet Clorox® Wipes	Toilet Tank Cover	Cs-137 ASFM	92%		
5/25/2016	Pre-wet Clorox® Wipes	Wood Trim	Cs-137	95%	98%	3%
5/25/2016	Pre-wet Clorox® Wipes	Wood Trim	Cs-137	98%		
5/25/2016	Pre-wet Clorox® Wipes	Wood Trim	Cs-137	101%		
5/25/2016	Pre-wet Clorox® Wipes	Wood Trim	Cs-137	100%		
5/25/2016	Pre-wet Clorox® Wipes	Wood Trim	Rb-86	105%	103%	2%
5/25/2016	Pre-wet Clorox® Wipes	Wood Trim	Rb-86	105%		
5/25/2016	Pre-wet Clorox® Wipes	Wood Trim	Rb-86	102%		
5/25/2016	Pre-wet Clorox® Wipes	Wood Trim	Rb-86	101%		
7/14/2016	Pre-wet Clorox® Wipes	Wood Trim	Cs-137 Lt	99%	99%	0%
7/14/2016	Pre-wet Clorox® Wipes	Wood Trim	Cs-137 Lt	99%		
7/14/2016	Pre-wet Clorox® Wipes	Wood Trim	Cs-137 Lt	98%		
7/14/2016	Pre-wet Clorox® Wipes	Wood Trim	Cs-137 Lt	98%		
6/15/2016	Pre-wet Clorox® Wipes	Wood Trim	Cs-137 ASFM	116%	95%	19%
6/15/2016	Pre-wet Clorox® Wipes	Wood Trim	Cs-137 ASFM	70%		
6/15/2016	Pre-wet Clorox® Wipes	Wood Trim	Cs-137 ASFM	91%		
6/15/2016	Pre-wet Clorox® Wipes	Wood Trim	Cs-137 ASFM	101%		

Date	Decontamination Method	Surface	Cs-137, Rb-86, Cs-137 ASFM, Cs-137 Light	%R	Average	Standard Deviation
7/5/2016	Sponge Mop with Water	Laminate Floor	Cs-137	99%	99%	0%
7/5/2016	Sponge Mop with Water	Laminate Floor	Cs-137	99%		
7/5/2016	Sponge Mop with Water	Laminate Floor	Cs-137	100%		
7/5/2016	Sponge Mop with Water	Laminate Floor	Cs-137	99%		
7/5/2016	Sponge Mop with Water	Laminate Floor	Rb-86	100%	99%	1%
7/5/2016	Sponge Mop with Water	Laminate Floor	Rb-86	99%		
7/5/2016	Sponge Mop with Water	Laminate Floor	Rb-86	100%		
7/5/2016	Sponge Mop with Water	Laminate Floor	Rb-86	99%		
7/19/2016	Sponge Mop with Water	Laminate Floor	Cs-137 Lt	97%	97%	1%
7/19/2016	Sponge Mop with Water	Laminate Floor	Cs-137 Lt	96%		
7/19/2016	Sponge Mop with Water	Laminate Floor	Cs-137 Lt	97%		
7/19/2016	Sponge Mop with Water	Laminate Floor	Cs-137 Lt	97%		
7/8/2016	Sponge Mop with Water	Laminate Floor	Cs-137 ASFM	76%	74%	3%
7/8/2016	Sponge Mop with Water	Laminate Floor	Cs-137 ASFM	70%		
7/8/2016	Sponge Mop with Water	Laminate Floor	Cs-137 ASFM	73%		
7/8/2016	Sponge Mop with Water	Laminate Floor	Cs-137 ASFM	75%		
6/27/2016	Sponge Mop with Water	Wood Floor	Cs-137	94%	98%	3%
6/27/2016	Sponge Mop with Water	Wood Floor	Cs-137	98%		
6/27/2016	Sponge Mop with Water	Wood Floor	Cs-137	102%		
6/27/2016	Sponge Mop with Water	Wood Floor	Cs-137	96%		
6/27/2016	Sponge Mop with Water	Wood Floor	Rb-86	93%	96%	3%
6/27/2016	Sponge Mop with Water	Wood Floor	Rb-86	99%		
6/27/2016	Sponge Mop with Water	Wood Floor	Rb-86	99%		
6/27/2016	Sponge Mop with Water	Wood Floor	Rb-86	93%		
7/15/2016	Sponge Mop with Water	Wood Floor	Cs-137 Lt	97%	98%	0%
7/15/2016	Sponge Mop with Water	Wood Floor	Cs-137 Lt	98%		
7/15/2016	Sponge Mop with Water	Wood Floor	Cs-137 Lt	98%		
7/15/2016	Sponge Mop with Water	Wood Floor	Cs-137 Lt	98%		
5/20/2016	Sponge Mop with Water	Wood Floor	Cs-137 ASFM	84%	86%	1%
5/20/2016	Sponge Mop with Water	Wood Floor	Cs-137 ASFM	85%		
5/20/2016	Sponge Mop with Water	Wood Floor	Cs-137 ASFM	86%		
5/20/2016	Sponge Mop with Water	Wood Floor	Cs-137 ASFM	87%		
5/31/2016	Formula 409® w/ paper towel	Granite Countertop	Cs-137	101%	101%	0%
5/31/2016	Formula 409® w/ paper towel	Granite Countertop	Cs-137	101%		
5/31/2016	Formula 409® w/ paper towel	Granite Countertop	Cs-137	101%		
5/31/2016	Formula 409® w/ paper towel	Granite Countertop	Cs-137	101%		
5/31/2016	Formula 409® w/ paper towel	Granite Countertop	Rb-86	100%	100%	0%
5/31/2016	Formula 409® w/ paper towel	Granite Countertop	Rb-86	100%		
5/31/2016	Formula 409® w/ paper towel	Granite Countertop	Rb-86	100%		
5/31/2016	Formula 409® w/ paper towel	Granite Countertop	Rb-86	100%		

Date	Decontamination Method	Surface	Cs-137, Rb-86, Cs-137 ASFM, Cs-137 Light	%R	Average	Standard Deviation
7/13/2016	Formula 409® w/ paper towel	Granite Countertop	Cs-137 Lt	101%	100%	0%
7/13/2016	Formula 409® w/ paper towel	Granite Countertop	Cs-137 Lt	101%		
7/13/2016	Formula 409® w/ paper towel	Granite Countertop	Cs-137 Lt	100%		
7/13/2016	Formula 409® w/ paper towel	Granite Countertop	Cs-137 Lt	100%		
6/29/2016	Formula 409® w/ paper towel	Granite Countertop	Cs-137 ASFM	15%	14%	2%
6/29/2016	Formula 409® w/ paper towel	Granite Countertop	Cs-137 ASFM	16%		
6/29/2016	Formula 409® w/ paper towel	Granite Countertop	Cs-137 ASFM	12%		
6/29/2016	Formula 409® w/ paper towel	Granite Countertop	Cs-137 ASFM	12%		
5/31/2016	Formula 409® w/ paper towel	Laminate Countertop	Cs-137	85%	85%	1%
5/31/2016	Formula 409® w/ paper towel	Laminate Countertop	Cs-137	78%		
5/31/2016	Formula 409® w/ paper towel	Laminate Countertop	Cs-137	84%		
5/31/2016	Formula 409® w/ paper towel	Laminate Countertop	Cs-137	85%		
5/31/2016	Formula 409® w/ paper towel	Laminate Countertop	Rb-86	84%	87%	3%
5/31/2016	Formula 409® w/ paper towel	Laminate Countertop	Rb-86	85%		
5/31/2016	Formula 409® w/ paper towel	Laminate Countertop	Rb-86	87%		
5/31/2016	Formula 409® w/ paper towel	Laminate Countertop	Rb-86	91%		
7/13/2016	Formula 409® w/ paper towel	Laminate Countertop	Cs-137 Lt	99%	100%	0%
7/13/2016	Formula 409® w/ paper towel	Laminate Countertop	Cs-137 Lt	100%		
7/13/2016	Formula 409® w/ paper towel	Laminate Countertop	Cs-137 Lt	100%		
7/13/2016	Formula 409® w/ paper towel	Laminate Countertop	Cs-137 Lt	100%		
6/29/2016	Formula 409® w/ paper towel	Laminate Countertop	Cs-137 ASFM	88%	84%	6%
6/29/2016	Formula 409® w/ paper towel	Laminate Countertop	Cs-137 ASFM	89%		
6/29/2016	Formula 409® w/ paper towel	Laminate Countertop	Cs-137 ASFM	76%		
6/29/2016	Formula 409® w/ paper towel	Laminate Countertop	Cs-137 ASFM	83%		
6/28/2016	Swiffer® Spray Mop	Laminate Floor	Cs-137	95%	97%	2%
6/28/2016	Swiffer® Spray Mop	Laminate Floor	Cs-137	96%		
6/28/2016	Swiffer® Spray Mop	Laminate Floor	Cs-137	98%		
6/28/2016	Swiffer® Spray Mop	Laminate Floor	Cs-137	98%		
8/1/2016	Swiffer® Spray Mop	Laminate Floor	Cs-137	98%	96%	2%
8/1/2016	Swiffer® Spray Mop	Laminate Floor	Cs-137	98%		
8/1/2016	Swiffer® Spray Mop	Laminate Floor	Cs-137	97%		
8/1/2016	Swiffer® Spray Mop	Laminate Floor	Cs-137	94%		
6/28/2016	Swiffer® Spray Mop	Laminate Floor	Rb-86	95%	97%	2%
6/28/2016	Swiffer® Spray Mop	Laminate Floor	Rb-86	97%		
6/28/2016	Swiffer® Spray Mop	Laminate Floor	Rb-86	101%		
6/28/2016	Swiffer® Spray Mop	Laminate Floor	Rb-86	96%		
7/19/2016	Swiffer® Spray Mop	Laminate Floor	Cs-137 Lt	98%	99%	1%
7/19/2016	Swiffer® Spray Mop	Laminate Floor	Cs-137 Lt	99%		
7/19/2016	Swiffer® Spray Mop	Laminate Floor	Cs-137 Lt	99%		
7/19/2016	Swiffer® Spray Mop	Laminate Floor	Cs-137 Lt	99%		

Date	Decontamination Method	Surface	Cs-137, Rb-86, Cs-137 ASFM, Cs-137 Light	%R	Average	Standard Deviation
5/18/2016	Swiffer® Spray Mop	Laminate Floor	Cs-137 ASFM	91%	92%	1%
5/18/2016	Swiffer® Spray Mop	Laminate Floor	Cs-137 ASFM	92%		
5/18/2016	Swiffer® Spray Mop	Laminate Floor	Cs-137 ASFM	92%		
5/18/2016	Swiffer® Spray Mop	Laminate Floor	Cs-137 ASFM	93%		
6/16/2016	Swiffer® Spray Mop	Wood Floor	Cs-137	101%	100%	1%
6/16/2016	Swiffer® Spray Mop	Wood Floor	Cs-137	101%		
6/16/2016	Swiffer® Spray Mop	Wood Floor	Cs-137	100%		
6/16/2016	Swiffer® Spray Mop	Wood Floor	Cs-137	99%		
6/16/2016	Swiffer® Spray Mop	Wood Floor	Rb-86	102%	100%	2%
6/16/2016	Swiffer® Spray Mop	Wood Floor	Rb-86	101%		
6/16/2016	Swiffer® Spray Mop	Wood Floor	Rb-86	99%		
6/16/2016	Swiffer® Spray Mop	Wood Floor	Rb-86	99%		
7/15/2016	Swiffer® Spray Mop	Wood Floor	Cs-137 Lt	100%	100%	0%
7/15/2016	Swiffer® Spray Mop	Wood Floor	Cs-137 Lt	100%		
7/15/2016	Swiffer® Spray Mop	Wood Floor	Cs-137 Lt	100%		
7/15/2016	Swiffer® Spray Mop	Wood Floor	Cs-137 Lt	100%		
5/19/2016	Swiffer® Spray Mop	Wood Floor	Cs-137 ASFM	94%	93%	1%
5/19/2016	Swiffer® Spray Mop	Wood Floor	Cs-137 ASFM	92%		
5/19/2016	Swiffer® Spray Mop	Wood Floor	Cs-137 ASFM	94%		
5/19/2016	Swiffer® Spray Mop	Wood Floor	Cs-137 ASFM	93%		
7/29/2016	Swiffer® Spray Mop	Wood Floor	Cs-137 ASFM	90%	91%	3%
7/29/2016	Swiffer® Spray Mop	Wood Floor	Cs-137 ASFM	92%		
7/29/2016	Swiffer® Spray Mop	Wood Floor	Cs-137 ASFM	88%		
7/29/2016	Swiffer® Spray Mop	Wood Floor	Cs-137 ASFM	95%		
6/28/2016	Swiffer® with Pre-wet Pad	Laminate Floor	Cs-137	92%	83%	6%
6/28/2016	Swiffer® with Pre-wet Pad	Laminate Floor	Cs-137	84%		
6/28/2016	Swiffer® with Pre-wet Pad	Laminate Floor	Cs-137	78%		
6/28/2016	Swiffer® with Pre-wet Pad	Laminate Floor	Cs-137	79%		
8/1/2016	Swiffer® with Pre-wet Pad	Laminate Floor	Cs-137	99%	96%	6%
8/1/2016	Swiffer® with Pre-wet Pad	Laminate Floor	Cs-137	88%		
8/1/2016	Swiffer® with Pre-wet Pad	Laminate Floor	Cs-137	99%		
8/1/2016	Swiffer® with Pre-wet Pad	Laminate Floor	Cs-137	99%		
6/28/2016	Swiffer® with Pre-wet Pad	Laminate Floor	Rb-86	87%	78%	8%
6/28/2016	Swiffer® with Pre-wet Pad	Laminate Floor	Rb-86	83%		
6/28/2016	Swiffer® with Pre-wet Pad	Laminate Floor	Rb-86	74%		
6/28/2016	Swiffer® with Pre-wet Pad	Laminate Floor	Rb-86	69%		
7/19/2016	Swiffer® with Pre-wet Pad	Laminate Floor	Cs-137 Lt	100%	99%	1%
7/19/2016	Swiffer® with Pre-wet Pad	Laminate Floor	Cs-137 Lt	99%		
7/19/2016	Swiffer® with Pre-wet Pad	Laminate Floor	Cs-137 Lt	99%		
7/19/2016	Swiffer® with Pre-wet Pad	Laminate Floor	Cs-137 Lt	98%		

Date	Decontamination Method	Surface	Cs-137, Rb-86, Cs-137 ASFM, Cs-137 Light	%R	Average	Standard Deviation
5/18/2016	Swiffer® with Pre-wet Pad	Laminate Floor	Cs-137 ASFM	96%	94%	1%
5/18/2016	Swiffer® with Pre-wet Pad	Laminate Floor	Cs-137 ASFM	93%		
5/18/2016	Swiffer® with Pre-wet Pad	Laminate Floor	Cs-137 ASFM	94%		
5/18/2016	Swiffer® with Pre-wet Pad	Laminate Floor	Cs-137 ASFM	93%		
6/16/2016	Swiffer® with Pre-wet Pad	Wood Floor	Cs-137	84%	92%	6%
6/16/2016	Swiffer® with Pre-wet Pad	Wood Floor	Cs-137	91%		
6/16/2016	Swiffer® with Pre-wet Pad	Wood Floor	Cs-137	94%		
6/16/2016	Swiffer® with Pre-wet Pad	Wood Floor	Cs-137	99%		
6/16/2016	Swiffer® with Pre-wet Pad	Wood Floor	Rb-86	86%	93%	6%
6/16/2016	Swiffer® with Pre-wet Pad	Wood Floor	Rb-86	90%		
6/16/2016	Swiffer® with Pre-wet Pad	Wood Floor	Rb-86	97%		
6/16/2016	Swiffer® with Pre-wet Pad	Wood Floor	Rb-86	99%		
7/18/2016	Swiffer® with Pre-wet Pad	Wood Floor	Cs-137 Lt	100%	100%	0%
7/18/2016	Swiffer® with Pre-wet Pad	Wood Floor	Cs-137 Lt	100%		
7/18/2016	Swiffer® with Pre-wet Pad	Wood Floor	Cs-137 Lt	100%		
7/18/2016	Swiffer® with Pre-wet Pad	Wood Floor	Cs-137 Lt	100%		
5/19/2016	Swiffer® with Pre-wet Pad	Wood Floor	Cs-137 ASFM	92%	92%	1%
5/19/2016	Swiffer® with Pre-wet Pad	Wood Floor	Cs-137 ASFM	91%		
5/19/2016	Swiffer® with Pre-wet Pad	Wood Floor	Cs-137 ASFM	93%		
5/19/2016	Swiffer® with Pre-wet Pad	Wood Floor	Cs-137 ASFM	92%		
7/29/2016	Swiffer® with Pre-wet Pad	Wood Floor	Cs-137 ASFM	96%	94%	3%
7/29/2016	Swiffer® with Pre-wet Pad	Wood Floor	Cs-137 ASFM	90%		
7/29/2016	Swiffer® with Pre-wet Pad	Wood Floor	Cs-137 ASFM	98%		
7/29/2016	Swiffer® with Pre-wet Pad	Wood Floor	Cs-137 ASFM	94%		
6/27/2016	Swiffer® with Dry Pad	Laminate Floor	Cs-137	88%	93%	4%
6/27/2016	Swiffer® with Dry Pad	Laminate Floor	Cs-137	97%		
6/27/2016	Swiffer® with Dry Pad	Laminate Floor	Cs-137	97%		
6/27/2016	Swiffer® with Dry Pad	Laminate Floor	Cs-137	92%		
6/27/2016	Swiffer® with Dry Pad	Laminate Floor	Rb-86	83%	93%	9%
6/27/2016	Swiffer® with Dry Pad	Laminate Floor	Rb-86	96%		
6/27/2016	Swiffer® with Dry Pad	Laminate Floor	Rb-86	104%		
6/27/2016	Swiffer® with Dry Pad	Laminate Floor	Rb-86	87%		
7/19/2016	Swiffer® with Dry Pad	Laminate Floor	Cs-137 Lt	100%	99%	2%
7/19/2016	Swiffer® with Dry Pad	Laminate Floor	Cs-137 Lt	99%		
7/19/2016	Swiffer® with Dry Pad	Laminate Floor	Cs-137 Lt	99%		
7/19/2016	Swiffer® with Dry Pad	Laminate Floor	Cs-137 Lt	97%		
5/17/2016	Swiffer® with Dry Pad	Laminate Floor	Cs-137 ASFM	51%	59%	7%
5/17/2016	Swiffer® with Dry Pad	Laminate Floor	Cs-137 ASFM	57%		
5/17/2016	Swiffer® with Dry Pad	Laminate Floor	Cs-137 ASFM	64%		
5/17/2016	Swiffer® with Dry Pad	Laminate Floor	Cs-137 ASFM	65%		

Date	Decontamination Method	Surface	Cs-137, Rb-86, Cs-137 ASFM, Cs-137 Light	%R	Average	Standard Deviation
6/27/2016	Swiffer® with Dry Pad	Wood Floor	Cs-137	103%	101%	1%
6/27/2016	Swiffer® with Dry Pad	Wood Floor	Cs-137	101%		
6/27/2016	Swiffer® with Dry Pad	Wood Floor	Cs-137	99%		
6/27/2016	Swiffer® with Dry Pad	Wood Floor	Cs-137	102%		
6/27/2016	Swiffer® with Dry Pad	Wood Floor	Rb-86	111%	104%	4%
6/27/2016	Swiffer® with Dry Pad	Wood Floor	Rb-86	102%		
6/27/2016	Swiffer® with Dry Pad	Wood Floor	Rb-86	101%		
6/27/2016	Swiffer® with Dry Pad	Wood Floor	Rb-86	104%		
7/15/2016	Swiffer® with Dry Pad	Wood Floor	Cs-137 Lt	97%	99%	1%
7/15/2016	Swiffer® with Dry Pad	Wood Floor	Cs-137 Lt	100%		
7/15/2016	Swiffer® with Dry Pad	Wood Floor	Cs-137 Lt	100%		
7/15/2016	Swiffer® with Dry Pad	Wood Floor	Cs-137 Lt	100%		
5/20/2016	Swiffer® with Dry Pad	Wood Floor	Cs-137 ASFM	73%	64%	8%
5/20/2016	Swiffer® with Dry Pad	Wood Floor	Cs-137 ASFM	62%		
5/20/2016	Swiffer® with Dry Pad	Wood Floor	Cs-137 ASFM	68%		
5/20/2016	Swiffer® with Dry Pad	Wood Floor	Cs-137 ASFM	54%		
7/12/2016	Wet Vacuum	Carpet	Cs-137	90%	91%	1%
7/12/2016	Wet Vacuum	Carpet	Cs-137	91%		
7/12/2016	Wet Vacuum	Carpet	Cs-137	91%		
7/12/2016	Wet Vacuum	Carpet	Cs-137	91%		
7/12/2016	Wet Vacuum	Carpet	Rb-86	93%	92%	2%
7/12/2016	Wet Vacuum	Carpet	Rb-86	89%		
7/12/2016	Wet Vacuum	Carpet	Rb-86	92%		
7/12/2016	Wet Vacuum	Carpet	Rb-86	92%		
7/21/2016	Wet Vacuum	Carpet	Cs-137 Lt	94%	93%	1%
7/21/2016	Wet Vacuum	Carpet	Cs-137 Lt	92%		
7/21/2016	Wet Vacuum	Carpet	Cs-137 Lt	92%		
7/21/2016	Wet Vacuum	Carpet	Cs-137 Lt	94%		
7/11/2016	Wet Vacuum	Carpet	Cs-137 ASFM	66%	53%	11%
7/11/2016	Wet Vacuum	Carpet	Cs-137 ASFM	54%		
7/11/2016	Wet Vacuum	Carpet	Cs-137 ASFM	54%		
7/11/2016	Wet Vacuum	Carpet	Cs-137 ASFM	40%		
7/6/2016	Wet Vacuum	Laminate Floor	Cs-137	58%	46%	12%
7/6/2016	Wet Vacuum	Laminate Floor	Cs-137	55%		
7/6/2016	Wet Vacuum	Laminate Floor	Cs-137	36%		
7/6/2016	Wet Vacuum	Laminate Floor	Cs-137	35%		
7/6/2016	Wet Vacuum	Laminate Floor	Rb-86	37%	34%	8%
7/6/2016	Wet Vacuum	Laminate Floor	Rb-86	43%		
7/6/2016	Wet Vacuum	Laminate Floor	Rb-86	25%		
7/6/2016	Wet Vacuum	Laminate Floor	Rb-86	30%		

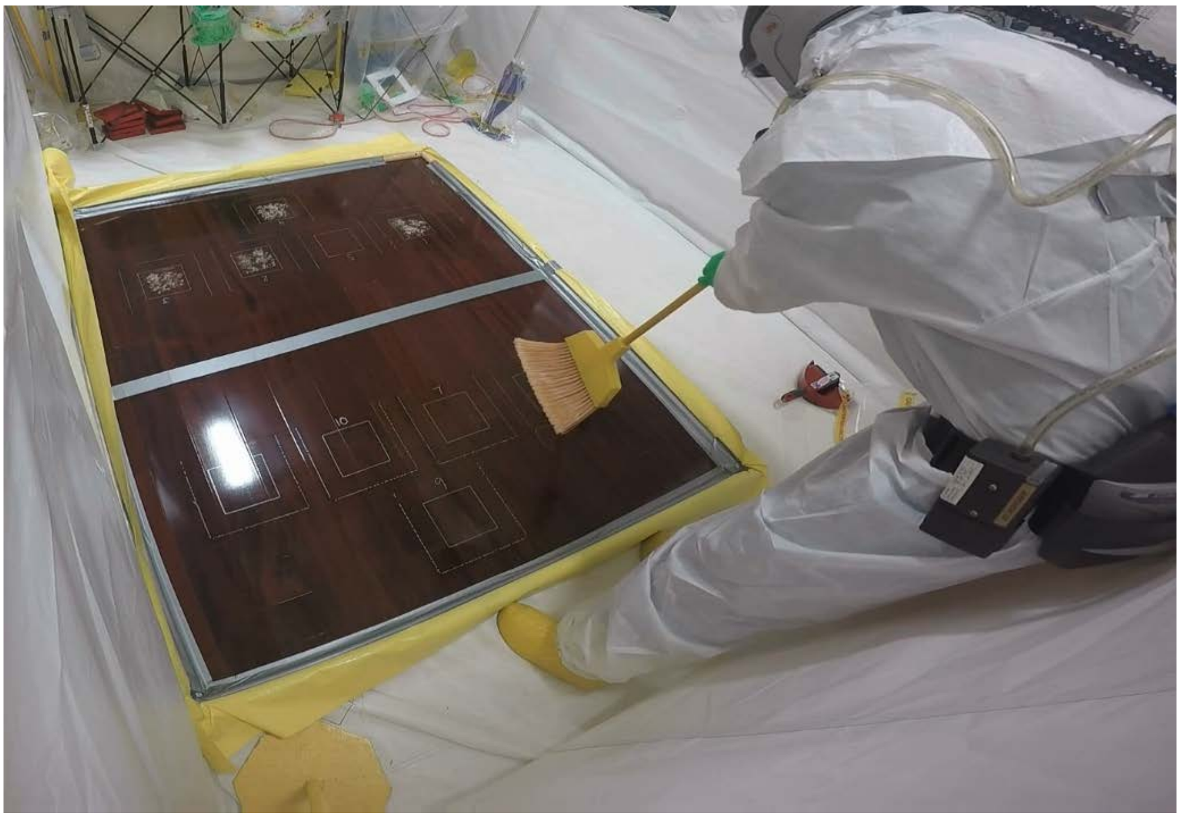
Date	Decontamination Method	Surface	Cs-137, Rb-86, Cs-137 ASFM, Cs-137 Light	%R	Average	Standard Deviation
7/20/2016	Wet Vacuum	Laminate Floor	Cs-137 Lt	100%	100%	0%
7/20/2016	Wet Vacuum	Laminate Floor	Cs-137 Lt	100%		
7/20/2016	Wet Vacuum	Laminate Floor	Cs-137 Lt	100%		
7/20/2016	Wet Vacuum	Laminate Floor	Cs-137 Lt	100%		

Appendix B
Photos of Decontamination Methods

Technical Video

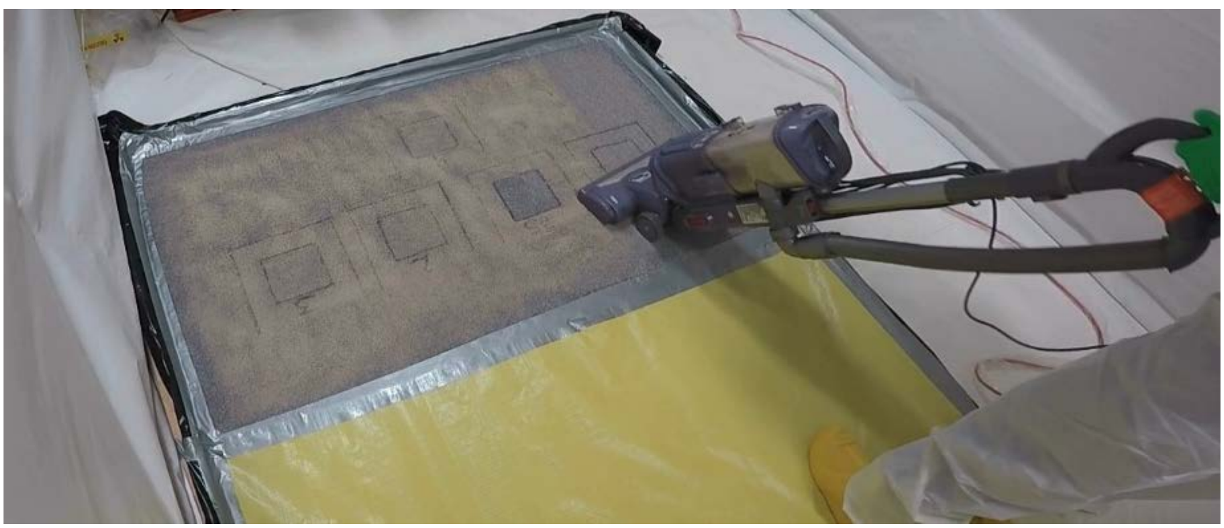
EPA Low-Tech RAD video_rev01_small.mp4

Decontamination Methods Used on Floor Surfaces



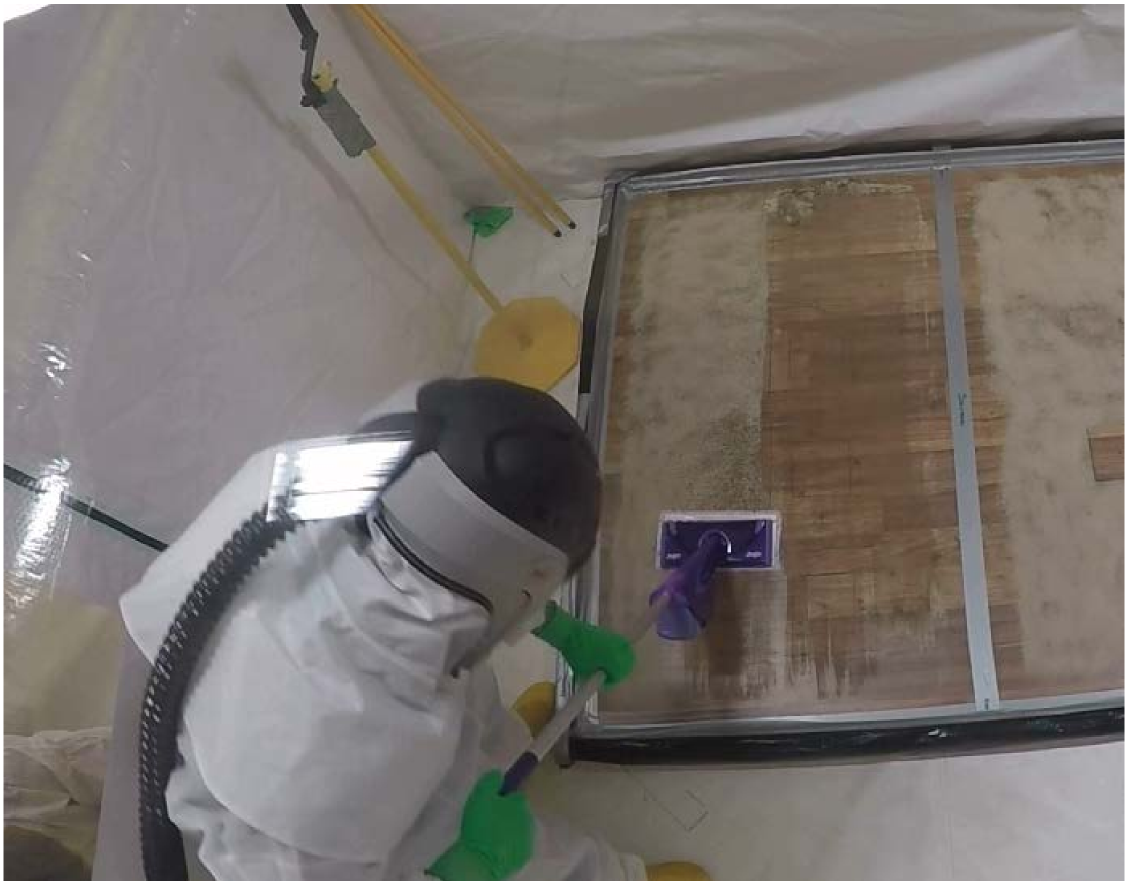
B.1. Dry broom on sealed hardwood flooring

B.2. Dry electrostatic pad (dry disposable pad with Swiffer® mop) on jointed laminate flooring



B.3. Dry vacuum on carpet

B.4. Pre-wet disposable pad with Swiffer® mop on laminate flooring



B.5. Spray agent with Swiffer® mop on jointed flooring

B.6. Wet vacuum on laminate flooring

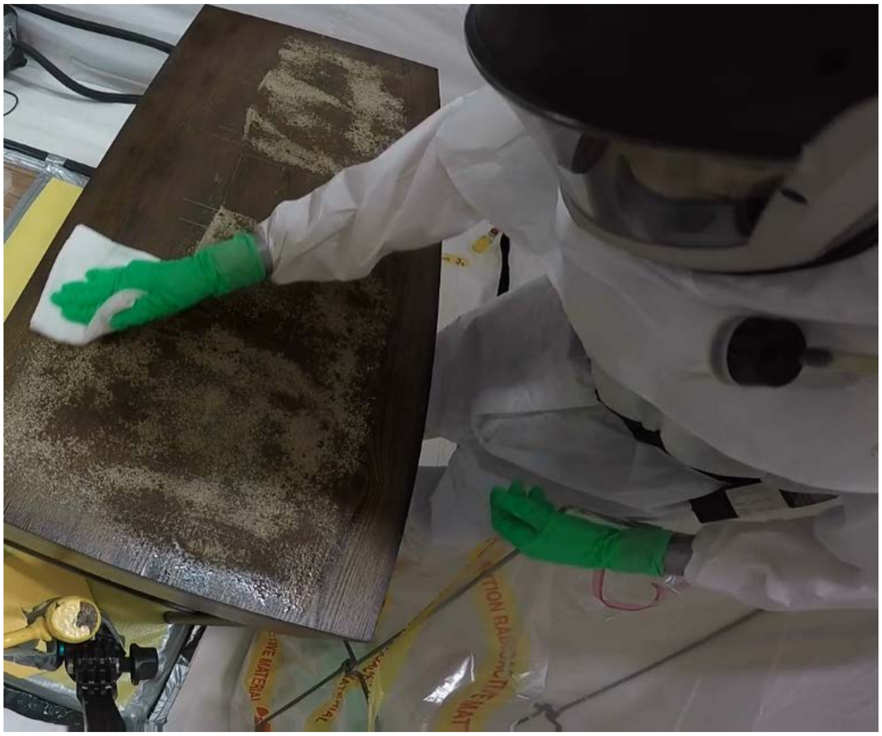
B.7. Water with sponge mop on laminate flooring

Decontamination Methods used on Non-Floor Surfaces

B.8. Dry cloth on toilet tank covers

B.9. Electrostatic pad on toilet tank covers

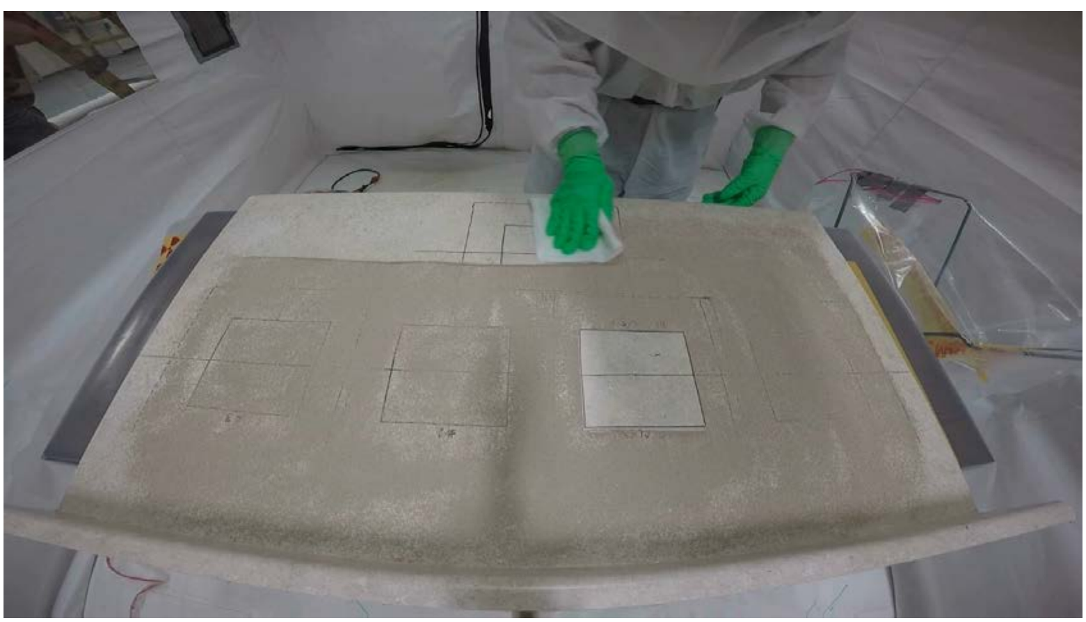
B.10. Dry paper towel on toilet tank covers



B.11. Polish oil and dry cloth on wood furniture

B.12. Pre-wet disposable Clorox® wipe on wood furniture

B.13. Formula 409® w/ paper towel on laminate counter (left) and contaminated granite countertop (right)



B.14. Water with paper towel on a laminate countertop

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