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Laboratory Demonstration of Radiological Decontamination Using Radpro®

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ABSTRACT

In the event of terrorist activity involving the explosive dispersion of radioactive materials (a "dirty" bomb), a number of different types of surfaces and substrates, including concrete, granite, brick, cinder block, tile, asphalt, wood, glass, plastic, iron, and steel, may become radiologically contaminated. Incident cleanup is assumed to involve decontamination of these surfaces.

Laboratory testing was conducted using samples of concrete, ferrous metal, steel, aluminum, lead, tin, glass, lexan, vinyl, asphalt shingle, wood, and rubber surfaces. The surfaces were sprayed with Cs-137 or Co-60 solutions to simulate contamination. The entire surface area of the samples was surveyed using a Ludlum Model 2360 scaler/ratemeter with Ludlum Model 43-93-2 100 cm^2 open area alpha/beta scintillation probe. The surfaces were then decontaminated using RadPro® chemical decontamination technology that is currently field proven and ready to deploy. The entire surface area of the samples was re-surveyed following decontamination.

The RadPro® chemical decontamination technology was able to remove virtually all of the removable contamination and over 90% of the fixed contamination from these surfaces during the laboratory testing.

INTRODUCTION

A terrorist activity involving radioactive materials (a "dirty" bomb) could result in a number of different types of surfaces and substrates, including concrete, granite, brick, cinder block, tile, asphalt, wood, glass, plastic, iron, and steel, becoming radiologically contaminated. Incident cleanup is assumed to involve decontamination of these surfaces [1]. Environmental Alternatives Inc. (EAI) has an existing process known as the TechXtract RadPro™ (RadPro®) chemical decontamination technology that is currently field proven and ready to deploy. The chemistry and the methods of application are patented under 5 U.S. Patents, as well as several foreign patents [2-6]. Previous applications of the RadPro® chemical decontamination technology include decontamination of glove boxes at the Rocky Flats facility [7] and demonstration for use on the hot cells in West Valley, New York [8], along with many successful projects throughout the nuclear industry.

The RadPro® chemical extraction process employs many components in three separate chemical formulations. 0300 and 0200 are surface preparation formulations, which contain complex blends of acids and other chemical agents to remove dirt, oil, grease, and other interferences from the surfaces. Each formulation has an important role on its own, but when 0200 is overlain on 0300, the resulting complex compounds have a powerful ability to put even the most insoluble inorganic oxides into solution. Formulation 0100 penetrates below the surface, moving horizontally and vertically through the microscopic pores. Chemical agents in the formulation bind to the contaminants and prevent them from re-contacting and re-contamination the material, keeping them in suspension until the contaminants can be removed in the rinse step. The formulations used possess no hazardous flammable or reactive components nor characteristics that would classify them as hazardous for disposal under Toxicity Characteristics Leaching Procedure (TCLP) testing. As a result, the waste stream from a project can be characterized based solely on the contaminants extracted.

This technology can be used to remove a wide variety of contaminants from porous surfaces and substrates and is made possible by tailoring of the chemistry and process for individual contaminants and other project-specific factors.

The chemical process has been successful in extracting a variety of radioactive contaminants for the Department of Energy. EAI currently has decontaminated concrete floors and walls, metal working equipment, tools, lead bricks/shielding, internal piping, evaporation basins, holding tanks, gloveboxes, spent fuel racks and entire buildings and structures.

The RadPro® solution can be applied to the surfaces using a light atomized spray or foam. Once the RadPro® chemical has been applied, the formulation is worked into the surface using light mechanical action such as a rotary scrubbing tool. After the prescribed dwell time, a light atomized rinsate of DI water is used followed by a high suction vacuum extraction using a nuclear grade wet/dry HEPA vacuum.

Because of the system's effectiveness in removing radiological contamination, RadPro® system could be utilized to address effects of a dirty-bomb. The system is "low-tech" making it ideal for first-responders and others with limited resources available to them at the time of attack. The system can be refined to the extent it can be packaged for military health and safety personnel, and the chemical formulation used is non-hazardous to health or the environment. Volumes of material can be shipped to each installation and stored in anticipation of resolving the after-effects of an attack. The wide range of radiological materials and surfaces already successfully decontaminated makes this system an ideal approach to restoring and maintaining operational pace.

To demonstrate that the RadPro® system could be useful for such decontamination efforts, bench-scale laboratory testing was conducted on a number of different surfaces that may require decontamination.

MATERIALS AND METHODS

The following materials and methods were employed during the bench-scale testing:

Cs-137 and Co-60 Stock Solutions

The Cs-137 and Co-60 stock solutions were obtained from Analytics, Atlanta, GA. The Cs-137 stock solutions contained roughly 3.71×10^6 disintegrations per second in 5 mL of 0.1M HCl. The Co-60 stock solutions contained roughly 1.11×10^6 disintegrations per second in 5 mL of 0.1N HCl.

Cs-137 and Co-60 Spiking Solutions

Spiking solutions were produced by diluting 1 mL of the Cs-137 or Co-60 stock solution to a volume of 100 mL with distilled, deionized water.

Material Surfaces

The material surfaces for the laboratory testing were chosen to reflect the types of building material and metal surfaces which may need decontamination in the event of a dirty bomb event. The aluminum surface utilized was from aircraft scrap. Asphalt shingles, bathroom ceramic tiles, vinyl flooring and wood were obtained from a local home improvement store in Knoxville, TN. The brake drum, car metal, lead and tin sheet metal were obtained from a salvage dealer. The concrete pieces utilized in the bench-scale decontamination study were air conditioner pads, obtained from a local pre-cast concrete facility in Knoxville, TN. The glass and lexan were obtained from a local glass window repair shop in Knoxville, TN. The Humvee metal surface was obtained from a military scrap yard. The surface size ranged from 500 cm^2 to over 4,000 cm^2. These surfaces were used "as is", with no precleaning or preparation.

Surface Spiking Methodology

The selected surface was placed inside of a containment tent prior to spiking (Figure 1). The containment tent only served to minimize the spread of spiking solution as it was sprayed onto the surface. The spiking solution was transferred to a spray bottle and misted onto the appropriate surface so that the surface was contaminated with approximately 50,000 to 150,000 disintegrations per minute per 100 square centimeters (dpm/100 cm^2). No attempt was made to ensure consistent coverage as that would not simulate natural dispersal of radioactivity. At the completion of spraying, the plastic cover sheeting of the containment tent was removed (Figure 1). The wetted surface was allowed to dry at least overnight.

Figure 1. View of Bench-Scale Radiological Decontamination Setup (Front of Containment Tent Opened to Promote Drying)

Radiological Monitoring Methodology

Radiological surveys of the Cs-137 or Co-60-contaminated surfaces were obtained pre- and post-decontamination using a Ludlum Model 2360 scaler/ratemeter with Ludlum Model 43-93-2 100 cm^2 open area alpha/beta scintillation probe. The monitor and probe combinations were calibrated prior to use to determine their efficiencies to Cs-137 and Co-60. For the limited areas decontaminated during the bench-scale testing, the total surface was measured by taking multiple field instrument counts across the entire surface. These values were averaged over no more than one square meter and high values will be limited to 100 cm^2. This approach is consistent with the standard [9] commonly used for radiological decommissioning in this country.

Background Surveys

Background surveys of each material type were conducted by counting for 60 seconds at a minimum of 3 survey locations. These surveys were conducted to determine the background radiation levels associated with these surfaces.

Pre-Decontamination Surveys

Pre-decontamination surveys were taken on the Cs-137 or Co-60-contaminated surfaces. Each surface to be surveyed was divided off into 100 cm^2 sections so that at least 95% of the total surface area could be surveyed. Counts at each survey locations were obtained for 30 to 60 seconds. These surveys established the extent of contamination prior to any decontamination efforts.

Decontamination

Following the pre-decontamination survey, the RadPro® extraction chemicals were applied onto the contaminated surfaces. The specific chemical solution employed was selected by EAI based on the properties of the specific surface and are proprietary to EAI. The chemical state of the chemical solutions varied from liquid to foam. The chemical solutions were allowed to stay ("dwell") on the surfaces for varying times from 10 to 30 minutes, then removed by a wet/dry vacuum.

The chemical application and removal/collection equipment (Figures 2 through 4) was provided and operated by EAI personnel. Most of this equipment was the same or similar to that which would be used for full-scale radiological decontamination of concrete, glass, and metal surfaces.

Figure 2. Wet/Dry HEPA vacuum for removal/collection of applied chemicals

Figure 3. Foam generator/applicator for adding chemicals as a foam to the surfaces

Figure 4. Steam generator for steam cleaning of surfaces

As necessary, EAI personnel applied multiple chemical solutions in the course of decontaminating a given surface. When the surface was considered decontaminated by EAI personnel, post-decontamination surveys were conducted.

Post-Decontamination Surveys

Post-decontamination surveys were taken on surfaces when the decontamination of the surface was complete. The same exact survey locations used for the pre-decontamination survey were used for the post-decontamination survey. This was specifically done to allow comparison of not only the average Cs-137 or Co-60 activity for the surface pre- and post-decontamination, but each survey location could be compared pre-and post-decontamination.

Calculation of Surface Activity

Radiological surveys of the Cs-137 or Co-60-contaminated surfaces were obtained pre- and post-decontamination to determine the counts associated with each 100 cm^2 area for the material surface. For example, a 100 cm^2 sampling location on a piece of Cs-contaminated concrete may have had 1,372 counts in 30 seconds during a post-cleaning survey. However, the activity on the surface needs to be calculated using these survey results. The surface activity is calculated using the efficiency of the radiation monitor and probe and is corrected for the background activity, using the following equation:

[Survey Results (cpm) – Background (cpm)]/ (Efficiency %/100) = Activity (dpm) (Eq. 1).

The efficiency is determined by the calibration of radiation monitor and the probe against source standards. The background counts per minute are determined by the background radiological survey (see above).

As an example, a 100 cm^2 sampling location on a piece of Cs-137-contaminated concrete was found to have 1,372 counts in 30 seconds during a post-decontamination survey. Concrete material used in the bench-scale testing was found to have had a background of 400 counts per minute. Calibration of the radiation monitor with the probe indicated that instrument had an efficiency of 19.98% with respect to Cs-137. The Cs-137 activity in dpm would be calculated using the following equation:

[(1,372 counts/30 sec * 60 sec/min) – 400 counts/min] / (19.98/100) = 11,730 dpm (Eq. 2)

RESULTS

Calibration of Radiation Survey Equipment

All of the scaler/ratemeter and probe combinations utilized during the bench-scale testing were calibrated against Cs-137 and Co-60 sources to determine their efficiencies (Table I) prior to their use during the bench-scale testing.

Table I. Efficiencies for the Radiation Survey Equipment

Ludlum Model 2360 Scaler/Ratemeter Serial Number	Ludlum Model 43-93-2 Alpha/Beta Scintillation Probe Serial Number	Efficiency (%)	
		Cs-137	Co-60
81685	PR221008	23.6	9.8
81686	PR230871	19.98	9.6
100044	PR221004	17.6	8.9

These efficiencies were used to calculate the surface activity from the survey results obtained during bench-scale testing.

Background Survey Results

Background survey testing was conducted on each of surfaces used in the bench scale testing. A minimum of 3 locations were counted for 60 seconds. Table II below has the background counts on the clean material surfaces. As can be seen from the counts per minute in Table II, all of the surfaces have a different level of background radiation. The background counts per minute for each surface was determined by using one less significant figure from the average counts per minute. These background counts per minutes for each material surface were used to correct the activities calculated from the post-decontamination surveys.

Table II. Background Survey Results

Material	Aircraft Aluminum	Asphalt Shingle	Brake Drum	Car Metal	Ceramic Tile	Concrete	Glass
Average Background (cpm)	310	300	320	320	350	400	350
Material	Humvee Metal	Lead	Lexan	Rubber	Sheet Metal	Vinyl Flooring	Wood
Average Background (cpm)	330	190	290	280	320	310	310

Decontamination Efficacy

Based on the pre- and post-decontamination surveys of the surfaces, the percent removal of the Cs-137 and Co-60 contamination could be determined for each surface. Any remaining radioactivity after decontamination would likely be assumed to be fixed.

Table III. RadPro® Removal Efficencies for the Various Surfaces

Material	Cs-137			Co-60		
	Initial Reading[1] (dpm/100 cm^2)	Final Reading[1] (dpm/100 cm^2)	Removal (%)	Initial Reading [1] (dpm/100 cm^2)	Final Reading[1] (dpm/100 cm^2)	Removal (%)
Aircraft Aluminum	90,740	70	>99	180,147	942	>99
Asphalt Shingle	48,300	1,730	96	73,137	2,732	96
Brake Drum	70,440	2,040	97	119,853	6,789	94
Car Metal	55,400	150	>99	135,853	47	>99
Ceramic Tile	31,780	3,980	87	95,569	3,579	96
Concrete	61,780	12,300	80	190,074	28,032	85
Glass	44,060	-70[2]	>99	5,337	-68	>99
Humvee Metal	73,880	-290	>99	178,695	5,342	97
Lead	65,000	1,490	98	89,126	921	99
Lexan	61,220	-30	>99	156,726	-121	>99
Rubber	123,800	1,070	99	108,253	2,542	98
Tin Sheet Metal	54,620	-170	>99	128,400	184	>99
Vinyl Flooring	70,540	-110	>99	261,021	-58	>99
Wood	83,220	11,160	87	160,821	15,579	90

[1]Average of all individual 100 cm^2 areas on the surface

[2] Final Reading that are less than zero indicate that the final reading (in cpm) was less than the background reading (in cpm) for the material

The less porous the surface, the more easily it was decontaminated by the RadPro® system. Most of the smooth, non-porous surfaces (aircraft aluminum, car metal, glass, lead, lexan, rubber, tin sheet metal, and vinyl) and semi-porous surfaces (asphalt shingle and brake drum) were easily decontaminated by the RadPro® system.

Porous surfaces (concrete, ceramic tile (not sealed), and wood) represent the hardest to decontaminate surface for the RadPro® system. The radiological contamination may move into the pores, increasing the effort required to remove the contamination. Multiple decontamination cycles would be required to further reduce the radiological contamination for the porous surfaces.

CONCLUSIONS

The RadPro® Technology, as applied by EAI, successfully decontaminated the types of surfaces that may be affected by a terrorist event involving a dirty bomb. For most of the surfaces, over 95% of the contamination was removed. Concrete and wood surfaces may pose a challenge for decontamination and multiple decontamination cycles may be required for these surfaces. Total survey of the surfaces prior to and post-decontamination verified the extent of decontamination.

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