# Side-by-Side Performance Comparison of Chemical-Based Decontamination Products for Dirty Bomb Cleanup – 11099

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## ABSTRACT

The U.S. Environmental Protection Agency's (EPA) National Homeland Security Research Center (NHSRC) is helping to protect human health and the environment from adverse impacts resulting from accidental and intentional releases of radiological materials, including terrorist incidents such as a radiological dispersal device (RDD) or "dirty bomb". In order to prepare for such an event, NHSRC is conducting performance evaluations of commercial, off-the-shelf radiological decontamination technologies, such as those originally developed for the nuclear power industry and the DOE complex. Desirable decontamination technologies must not only be effective in removing threat contaminants from typical building materials, but must do so without being destructive to building surfaces. Due to the large areas likely to be affected by such an event, the time required to perform effective decontamination and the cost of deployment are significant issues as well. An emphasis on "low-tech" methodologies led to the selection of simple, low cost, easy to use technologies which can be transported and deployed quickly, requiring only minimal support services or infrastructure. In FY2010, NHSRC tested the performance of nine chemical-based decontamination products for their effectiveness in the removal of radioactive cesium (Cs-137) from the surface of unpainted concrete. Six-inch square concrete coupons were contaminated at a level of approximately 1 microCurie (µCi) per coupon, measured by gamma spectroscopy. The coupons were placed in a test stand designed to hold them in a vertical orientation to simulate the wall of a building. The coupons were then decontaminated using the product according to the manufacturer's recommended procedure. The decontamination efficacy attained by the product was determined by calculating an average decontamination factor (DF) and an average percent removal (%R) for each product. Important deployment and operational factors, such as the rate at which each product could be used to decontaminate a vertical surface, the amount of secondary waste produced, and the degree of any surface degradation, were also documented and reported. This data will be presented and the various technologies will be discussed.

## INTRODUCTION

EPA has evaluated commercially available technologies for their ability to remove radioactive cesium-137 from the surface of concrete building material according to a test plan developed for this evaluation. The test procedure was designed to simulate a cleanup scenario that included decontamination of the outside of a concrete building contaminated as a result of a notional radiological dispersion device. The concrete used during the evaluation was standard Portland type building concrete positioned in a vertical orientation. The cesium-137 was applied to concrete coupons and measured to confirm an activity level of approximately 1 microCurie (µCi). The contaminated coupons were then positioned in a 9ft × 9ft test stand in a vertical orientation to simulate the wall of a building. This simulated wall was then decontaminated using one of the technologies selected for evaluation. The program evaluated nine different technologies (or products) from five different vendors. These methods were selected based on wide availability, applicability to radiological decontamination, and anticipated deployment cost and difficulty. Six technologies were sprays or foam washes, two were strippable coating technologies, and one was a decontamination gel. Following application of the decontamination technology, the residual activity on the coupons was measured. The decontamination efficacy was determined from the difference in activity before and after application of the decontamination technologies. In addition to decontamination efficacy, qualitative factors such as amount of secondary waste, cost, ease of application and removal, and health and safety issues were documented during the evaluation.

## EXPERIMENTAL METHODS

### *Concrete Coupons*

The concrete coupons were prepared in a single batch of concrete made from Type II Portland cement[1]. The concrete was poured into 0.9 m square plywood forms and the surface was "floated" to bring the smaller aggregate and cement paste to the top, and then cured for 21 days. Following curing, square coupons were cut to the desired size with a laser guided saw. For this evaluation, the "floated" surface was used as the working surface to minimize the possibility of chemical interferences due to mold release agents. The coupons were approximately 15 cm × 15 cm × 4 centimeters (cm) thick, with a surface finish that was consistent across all the coupons and that was representative of concrete structures typically found in an urban environment. The edges of the coupons were sealed with epoxy and masked with an impervious tape to ensure that the contaminant would be applied only to the working surface of the coupon. These coupons were used for both the contaminated samples as well as the clean, uncontaminated, control samples.

### *Coupon Contamination*

Each coupon selected for contamination was spiked with 2.5 milliliters of an unbuffered, slightly acidic aqueous solution containing 0.26 mg/L Cs-137, which corresponds to an activity level of approximately 53 $\mu Ci/m^2$, or about 1 µCi per coupon. The liquid spike was delivered to each coupon using an aerosolization technique. The aerosol delivery device was constructed of two syringes. The first syringe had the plunger removed and a pressurized air line attached to the rear of the syringe. The second syringe contained the aqueous contaminant solution and was equipped with a 27 gauge needle which penetrated through the plastic housing near the tip of the first syringe. Air was supplied at a flow rate of approximately 1 - 2 liters per minute creating a turbulent flow through the first syringe. The liquid spike in the second syringe was introduced and became nebulized by the turbulent gas flow. The result was a very fine aerosol ejected from the tip of the first syringe, creating a controlled and uniform spray of fine liquid droplets deposited over the entire coupon working surface.

***Measurement of Activity on Coupon Surface***

The level of gamma radiation emanating from the surface of the concrete coupons was measured both before and after application of the decontamination technologies to evaluate their decontamination efficacy. These measurements were made using an intrinsic, high purity germanium detector which was regularly calibrated over the course of testing using standard instrument calibration procedures[2].

***Test Stand***

In order to evaluate the performance of the decontamination technologies in an environment representative of an actual urban setting, a large vertical surface (simulating a building wall) was fabricated of stainless steel which held three rows of three concrete coupons embedded and evenly distributed across the surface. Figure 1 shows the concrete coupons mounted in the assembled test stand which was approximately 3 m × 3 m.

**Figure 1. Loaded Test Stand**

***Technology Descriptions and Application***

Nine different decontamination technologies from five different vendors were evaluated. Six technologies were sprays or foam washes. They include Rad-Release I and Rad-Release II from Environmental Alternatives, Inc. (EAI), a liquid and a foam from Radiological Decontamination Solutions (RDS), ND-75 and ND-600 from INTEK, DeconGel 1101 and DeconGel 1108 from CBI Polymers, and Argonne Gel (AG) from Argonne National Laboratory. The EAI and INTEK technologies were sprayed onto the concrete, rinsed with de-ionized water using a hand-held spray bottle, and removed using a wet vacuum. Both the liquid and the foam products from RDS technologies were sprayed on and then wiped off. The CBI DeconGel products were applied as a gel using a paint brush and after curing were manually peeled from the surfaces. The Argonne Gel was applied as a gel and removed using a wet vacuum. Prior to the actual test, each of the technologies was used in a “dry run” to determine appropriate application techniques and durations. Following the application of the technologies to both the contaminated and the control coupons, the coupons were removed from the test stand and the residual activity on the surfaces of the coupons was measured. Comparison of the activity level following use of the decontamination technologies to that measured prior to their application provided the means to calculate the decontamination efficacy.

### *Calculation of Decontamination Efficacy*

The decontamination efficacy calculated for each of the contaminated coupons is expressed in terms of percent removal (%R) and decontamination factor (DF) as defined by the following equations:

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

$$DF = A_o/A_f$$

where $A_o$ is the radiological activity measured on each coupon before application of the decontamination technology and $A_f$ is radiological activity of the coupon after application. The DF is reported in Table 1 followed by a narrative description of the results focused on %R.

## RESULTS AND DISCUSSION

### *Decontamination Efficacy*

Table 1 presents a summary of the results of the evaluation in terms of the activity levels on the coupons before decontamination and after application of the decontamination technologies, as well as the calculated %R and DF for each technology. Each cell in the table represents the average and standard deviation of eight replicate concrete coupons.

**Table 1. Decontamination Efficacy Results (Average ± Standard Deviation, N=4)**

| Decontamination Technology | Pre-Decon Activity µCi / Coupon | Post-Decon Activity µCi / Coupon | %R | DF |
|---|---|---|---|---|
| Argonne Gel | 1.03 ± 0.01 | 0.28 ± 0.05 | 73 ± 5 | 3.8 ± 0.7 |
| Decon Gel 1101 | 1.10 ± 0.03 | 0.60 ± 0.09 | 49 ± 7 | 1.9 ± 0.2 |
| Decon Gel 1108 | 1.07 ± 0.02 | 0.36 ± 0.09 | 67 ± 9 | 3.2 ± 0.9 |
| EAI Rad-Release I | 1.11 ± 0.04 | 0.34 ± 0.14 | 71 ± 13 | 3.9 ± 1.5 |
| EAI Rad-Release II | 1.02 ± 0.08 | 0.15 ± 0.03 | 85 ± 2 | 7.0 ± 1.1 |
| INTEK ND-75 | 1.12 ± 0.05 | 0.60 ± 0.04 | 47 ± 6 | 1.9 ± 0.2 |
| INTEK ND-600 | 1.08 ± 0.03 | 0.52 ± 0.12 | 52 ± 12 | 2.1 ± 0.4 |
| RDS Liquid | 1.10 ± 0.03 | 0.52 ± 0.09 | 53 ± 7 | 2.1 ± 0.3 |
| RDS Foam | 1.02 ± 0.11 | 0.49 ± 0.07 | 51 ± 8 | 2.1 ± 0.4 |

The results of this evaluation indicate that the five decontamination technologies tested produced a wide range of decontamination efficacies, ranging from nominally 85 %R to 50%R. Overall, the repeatability of the results was very good, as the standard deviations of the %R were relatively small with respect to the average %R. A paired t-test was performed to determine any significant differences between the data sets at a 95% confidence interval. The t-test analysis revealed that the Rad-Release II produced %Rs that were significantly higher than most of the other technologies, with the exception of Rad-Release I, where there was no statistically significant difference. The Argonne Gel and Decon Gel 1108 products generated statistically similar efficacies which were significantly higher than the remaining products. Decon Gel 1101, the INTEK technologies, and the RDS technologies were all statistically similar.

### *Operational Factors*

During the evaluation, detailed observations and measurements of several practical aspects of using these technologies were made. These deployment and operational factors included the time required to decontaminate the coupons (including application, removal, and any required dwell time), applicability to irregular surfaces, skilled labor requirements, utilities required, extent of portability, and secondary waste management (estimated amount and characteristics of effluent and/or spent media). Table 2 summarizes the operational information for the technologies by category. Certain parameters such as decontamination rate, set-up time, and secondary waste are highly dependent on scale of application. For this evaluation, the total area covered was limited to 0.2 $m^2$. Extrapolation to larger areas should not be assumed to be a direct multiplier.

## Table 2. Summary of Operational Factors

| Parameter | Description |
|---|---|
| **Decontamination rate** | Argonne SuperGel: Applied by trowel (paint scraper), scale up would require spray equipment (similar to airless paint sprayer) or roller. Requires 1-2 hour dwell time.<br><br>DeconGel 1101 and 1108: Applied with paint brush, scale up would require spray equipment or roller. Requires overnight drying before stripping dry coating.<br><br>EAI Rad-Release I and Rad-Release II: Applied using spray bottles in just seconds. Rad-Release I is a single step process requiring approximately 30 minute dwell time. Rad-Release II is two-step process requiring a total of 60 minutes dwell time. Scale-up would require spray or foam generating equipment, but dwell time would be the same.<br><br>INTEK ND-75 and ND-600: Applied using spray bottles in just seconds. ND-75 requires three 15 minute application cycles. ND-600 requires three 30 minute application cycles. Scale-up would require spray equipment, but dwell times would be the same.<br><br>RDS Liquid and Foam: Applied using spray/foam bottles in seconds. Requires six cycles of application with two solutions and wiping with towels. Required 3-6 minutes for each 225 $cm^2$ concrete coupon. |
| **Applicability to irregular surfaces** | All technologies were judged to be applicable to irregular surfaces, but those requiring vacuum removal (AG, EAI, INTEK) may prove to be more difficult depending on the surface and available vacuum attachments. |
| **Skilled labor requirement** | As evaluated, a brief training session is adequate. Scale up would require somewhat more complex equipment and/or contractor support with corresponding training requirements for equipment operation. |
| **Utilities required** | 110v for vacuum; scale up would require more complex equipment such as sprayers. |
| **Extent of portability** | Very portable; limited by need for utilities for vacuum and possible scaled-application tools. |
| **Set-up time** | Less than 15 minutes for all technologies as tested. Scaled up application would require increased set-up time consistent with commercial spraying equipment. |
| **Secondary waste management** | Argonne SuperGel: 5 L/ $m^2$ gel waste collected in wet vacuum.<br>DeconGel 1101 and 1108: 319 g/$m^2$ of dried coating and a volumetric waste generation of 252 $cm^3/m^2$.<br>EAI Rad-Release I and Rad-Release II: Approximately 1 L/$m^2$ collected by the wet vacuum<br>INTEK: Approximately 1 L/$m^2$ collected by the wet vacuum<br>RDS Liquid and Foam: 4 L/$m^2$ mostly collected by the towels used to wipe the surface; 2000-3000 $cm^3$ of towels used during this evaluation. The maximum effective collection capacity of the towels was not reached due to the relative size of the coupons, therefore the total secondary waste volume for a scaled up scenario is not a direct comparison. The capacity of the toweling material was not evaluated. |
| **Surface damage** | None of the technologies caused visible surface damage. |

## ACKNOWLEDGEMENTS

Contributions of the following individuals and organizations to the development of this document are gratefully acknowledged.

**United States Environmental Protection Agency (EPA)**
Emily Snyder
Dan Mackney
Scott Hudson

**Portage Incorporated**
Donald Jenkinson


## DISCLAIMER

The U.S. Environmental Protection Agency, through its Office of Research and Development, managed the research described here. It has been subjected to the Agency's review and has been approved for publication. Note that approval does not signify that the contents necessarily reflect the views of the Agency. Mention of trade names or commercial products does not constitute endorsement or recommendation for use of a specific product.

## References


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