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Technology Evaluation Report

INTEK Technologies ND-75 and ND-600 for Radiological Decontamination

Office of Research and Development
National Homeland Security Research Center

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INTEK Technologies
ND-75 and ND-600 for Radiological Decontamination

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Disclaimer

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Foreword

The Environmental Protection Agency (EPA) holds responsibilities associated with homeland security events: EPA is the primary federal agency responsible for decontamination following a chemical, biological, and/or radiological (CBR) attack. The National Homeland Security Research Center (NHSRC) was established to conduct research and deliver scientific products that improve the capability of the Agency to carry out these responsibilities.

An important goal of NHSRC's research is to develop and deliver information on decontamination methods and technologies to clean up CBR contamination. When directing such a recovery operation, EPA and other stakeholders must identify and implement decontamination technologies that are appropriate for the given situation. The NHSRC has created the Technology Testing and Evaluation Program (TTEP) in an effort to provide reliable information regarding the performance of homeland security related technologies. Through TTEP, NHSRC provides independent, quality assured performance information that is useful to decision makers in purchasing or applying the tested technologies. TTEP provides potential users with unbiased, third-party information that can supplement vendor-provided information. Stakeholder involvement ensures that user needs and perspectives are incorporated into the test design so that useful performance information is produced for each of the tested technologies. The technology categories of interest include detection and monitoring, water treatment, air purification, decontamination, and computer modeling tools for use by those responsible for protecting buildings, drinking water supplies and infrastructure, and for decontaminating structures and the outdoor environment. Additionally, environmental persistence information is also important for containment and decontamination decisions.

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

Jonathan G. Herrmann, Director
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Abbreviations/Acronyms

ANSI	American National Standards Institute
ASTM	ASTM International
BQ	Becquerel
CBRNIAC	Chemical, Biological, Radiological and Nuclear Defense Information Analysis Center
°C	degrees Celsius
CC	cross-contamination
Cs	Cesium
cm	centimeter
cm^2	square centimeter
DARPA	Defense Advanced Research Projects Agency
DF	decontamination factor
DHS	U.S. Department of Homeland Security
DOD	Department of Defense
EPA	U.S. Environmental Protection Agency
Eu	Europium
°F	degrees Fahrenheit
IEEE	Institute of Electrical and Electronics Engineers
INL	Idaho National Laboratory
keV	kilo electron volts
mL	milliliter(s)
L	liter
m	meter
m^2	square meter
µCi	microCurie
NHSRC	National Homeland Security Research Center
NIST	National Institute of Standards and Technology
ORD	Office of Research and Development
PE	performance evaluation
PPE	personal protective equipment
%R	percent removal
QA	quality assurance
QC	quality control
QMP	quality management plan
RDD	radiological dispersion device
RH	relative humidity
RML	Radiological Measurement Laboratory
RSD	relative standard deviation
Th	Thorium
TSA	technical systems audit
TTEP	Technology Testing and Evaluation Program

Executive Summary

The U.S. Environmental Protection Agency's (EPA) National Homeland Security Research Center (NHSRC) is helping to protect human health and the environment from adverse impacts resulting from acts of terror by carrying out performance tests on homeland security technologies. Through its Technology Testing and Evaluation Program (TTEP) NHSRC evaluated the INTEK Technologies ND-75 and ND-600 decontamination agents and their ability to remove radioactive cesium (Cs)-137 from the surface of unpainted concrete.

Experimental Procedures. ND-75 and ND-600 are aqueous based decontamination agents that function by forming complexes with metal ions and solubilizing them. Eight 15 centimeter (cm) × 15 cm unpainted concrete coupons were contaminated with approximately 1 microCurie (µCi) of Cs-137 per coupon. The amount of contamination deposited on each coupon was measured using gamma spectroscopy. The eight contaminated coupons were placed in a test stand (along with one uncontaminated blank coupon) that was designed to hold nine concrete coupons in a vertical orientation to simulate the wall of a building. Four contaminated coupons were decontaminated with ND-75 and the other four contaminated coupons were decontaminated with ND-600, and the decontamination efficacy was determined by calculating both a decontamination factor (DF) and percent removal (%R). Important deployment and operational factors were also documented and reported.

Results. The decontamination efficacy (in terms of %R) attained for ND-75 and ND-600 was evaluated for each concrete coupon used during the evaluation. When the decontamination efficacy metrics (%R and DF) of the four contaminated coupons decontaminated by each were averaged together, the average %R for ND-75 was 47% ± 6% and the average DF was 1.9 ± 0.22. The average %R for ND-600 was 52% ± 12% and the average DF was 2.1 ± 0.44.

The application of ND-75 and ND-600 included use of plastic spray bottles. Application of the ND-75 and ND-600 solutions to each coupon took very little time (just a few seconds) in relation to the recommended dwell time of 30 minutes and 15 minutes for ND-75 and ND-600, respectively. Following application, rinsing was performed by spraying with deionized water and wet vacuum removal (approximately 30 seconds per coupon). This procedure was repeated two additional times so the total time elapsed for the coupons decontaminated with ND-75 was just over 90 minutes and for the coupons decontaminated with ND-600, just over 45 minutes.

For this evaluation, electricity was used to operate the wet vacuum. Scaled up applications in remote locations may require additional utilities to provide means for sprayer and larger scale vacuum removal. Minimal training would be required for

technicians using the ND-75 and ND-600, and the surface of the concrete was not visibly damaged during use of the ND-75 or ND-600.

1.0 Introduction

The U.S. Environmental Protection Agency's (EPA) National Homeland Security Research Center (NHSRC) is helping to protect human health and the environment from adverse effects resulting from acts of terror. NHSRC is emphasizing decontamination and consequence management, water infrastructure protection, and threat and consequence assessment. In doing so, NHRSC is working to develop tools and information that will improve the ability of operational personnel to detect the intentional introduction of chemical, biological, or radiological contaminants on or into buildings or water systems, to contain or mitigate these contaminants, to decontaminate affected buildings and/or water systems, and to dispose of contaminated materials resulting from cleanups.

NHSRC's Technology Testing and Evaluation Program (TTEP) works in partnership with recognized testing organizations; stakeholder groups consisting of buyers, vendor organizations, and permitters; and through the participation of individual technology developers in carrying out performance tests on homeland security technologies. The program evaluates the performance of homeland security technologies by developing evaluation plans that are responsive to the needs of stakeholders, conducting tests, collecting and analyzing data, and preparing peer-reviewed reports. All evaluations are conducted in accordance with rigorous quality assurance (QA) protocols to ensure that data of known and high quality are generated and that the results are defensible. Through TTEP, NHSRC provides high-quality information that is useful to decision makers in purchasing or applying the evaluated technologies, and in planning cleanup operations. The evaluations generated through TTEP provide potential users with unbiased, third-party information that can supplement vendor-provided information. Stakeholder involvement ensures that user needs and perspectives are incorporated into the evaluation design so that useful performance information is produced for each of the evaluated technologies.

Through TTEP, NHSRC evaluated the performance of ND-75 and ND-600 from INTEK Technologies (Fairfax, VA), in removing radioactive isotope cesium (Cs)-137 from unpainted concrete. A peer-reviewed test/QA plan was followed, entitled "The Performance of Selected Radiological Decontamination Processes on Urban Substrates", Version 1.0, Amendment 1 dated July 14, 2010. This document will be referred to as the test/QA plan and was developed according to the requirements of the Quality Management Plan (QMP) for the Technology Testing and Evaluation Program, Version 3.0 dated January 2008. The evaluation generated the following performance information:

- Decontamination efficacy, defined as the extent of radionuclide removal following use of the ND-75 and ND-600, and the possibility of cross-contamination (CC)
- Deployment and operational

factors, including the approximate rate of surface area decontamination, applicability to irregular surfaces, skilled labor requirement, utility requirements, portability, secondary waste management, and technology cost.

The evaluation of the ND-75 and ND-600 took place November 3, 2010, with the pre-evaluation activity measurements occurring in September 2010 and the post-evaluation activity measurements also occurring in November 2010. All of the experimental work took place in a radiological contamination area at the U.S. Department of Energy's Idaho National Laboratory (INL). This report describes the quantitative results and qualitative observations gathered during the evaluation of the ND-75 and ND-600. The contractor and EPA were responsible for QA oversight. A technical systems audit (TSA) was conducted during the evaluation as well as a data quality audit of the evaluation data.

2.0 Technology Description

This technology evaluation report provides results on the performance of ND-75 and ND-600 under laboratory conditions. The following description of the ND-75 and ND-600 decontamination products is based on information provided by the vendor and was not verified during this evaluation.

ND-75 is an operationally friendly, aqueous based, near neutral pH solution, formulated around an organic polydentate chelating agent (ethylenediaminetetraacetyl hydrazide) that functions by forming coordination compounds with metal ions and solubilizing them. Specifically, the interaction between the chelating agent and radioactive metal compound weakens the structural integrity of the contaminant and causes it to break away from the substrate material. The chelating agent continues to solubilize these particles while they are suspended in the ND-75 solution.

Operationally, ND-600 is a similar decontamination agent. ND-600 functions by removing radioactive loose surface (smearable) deposits, including grime, soil, and light amounts of oil or grease that may entrap them, and emulsifying, dispersing and dissolving them. The chelating agents in ND-600 form coordination compounds with metal ions, thus solubilizing them. Both ND-75 and ND-600 function across a broad temperature range. This range can extend from below freezing (when used with an appropriate antifreeze) to 113 °C (235 °F) (in a pressurized system).

For both ND-75 and ND-600, decontamination is achieved by immersing or spraying the contaminated item, maintaining a wet surface for 15 or 30 minutes and then rinsing with fresh water. Agitation, flow, or scrubbing will enhance performance. Repeat application, using fresh ND-75 or ND-600, often helps achieve the decontamination factor desired. ND-75 and ND-600 may not be discharged to U.S. waters. After decontamination, the contaminated solution and rinse water may be mixed with a solidification agent for disposal as low-level radioactive waste. In the absence of radioactivity, ND-75 and ND-600 and their corresponding rinse waters may be destroyed by incineration or by chemical oxidation, using sodium hypochlorite, calcium hypochlorite, or alkaline permanganate. Figure 2-1 shows containers of both ND-75 and ND-600.

Figure 2-1. Containers of ND-75 (left) and ND-600 (right).

3.0 Experimental Details

3.1 Experiment Preparation

3.1.1 Concrete Coupons

The concrete coupons were prepared from a single batch of concrete made from Type II Portland cement. The ready-mix company (Burns Brothers Redi-Mix, Idaho Falls, ID) that supplied the concrete for this evaluation provided the data which describes the cement clinker used in the concrete mix. For Type II Portland cement, the ASTM International (ASTM) Standard C 150-7[1] specifies that tricalcium aluminate accounts for less than 8% of the overall cement clinker (by weight). The cement clinker used for the concrete coupons was 4.5% tricalcium aluminate (Table 3-1). For Type I Portland cement the tricalcium aluminate content should be less than 15%. Because Type I and II Portland cements differ only in tricalcium aluminate content, the cement used during this evaluation meets the specifications for both Type I and II Portland cements. The apparent porosity of the concrete from the prepared coupons ranged from 15-30%.

Table 3-1. Characteristics of Portland Cement Clinker Used to Make Concrete Coupons

Cement Constituent	Percent of Mixture
Tricalcium Silicate	57.6
Dicalcium Silicate	21.1
Tricalcium Aluminate	4.5
Tetracalcium Aluminoferrite	8.7
Minor Constituents	8.1

The concrete was representative of exterior concrete commonly found in urban environments in the United States as shown by INL under a previous project entitled, “Radionuclide Detection and Decontamination Program. Broad Agency Announcement 03-013” sponsored by the U.S. Department of Defense (DOD), Defense Advanced Research Projects Agency (DARPA) and U.S. Department of Homeland Security (DHS).The wet concrete was poured into 0.9 meter (m) square plywood forms with the exposed surface “floated” to allow the smaller aggregate and cement paste to float to the top, and the concrete was then cured for 21 days. Following curing, the squares were cut to the desired size with a laser-guided rock saw. For this evaluation, the “floated” surface of the concrete coupons was used. The coupons were approximately 4 centimeters (cm) thick, 15 cm × 15 cm square, and had a surface finish that was consistent across all the coupons.

3.1.2 Coupon Contamination

Eight coupons were contaminated by spiking individually with 2.5 milliliters (mL) of aqueous solution that contained 0.4 microCurie (µCi)/mL Cs-137 as a solution of cesium chloride, corresponding to an activity level of approximately 1 µCi over the 225 square centimeters (cm^2) surface. Application of the Cs-137 in an aqueous solution was justified because even if Cs-137 were dispersed in a particle form following a radiological dispersion device (RDD) or "dirty bomb" event, morning dew or rainfall would likely occur before the surfaces could be decontaminated. In addition, from an experimental standpoint, it is much easier to apply liquids, rather than particles, homogeneously across the surface of the concrete coupons. The liquid spike was delivered to each coupon using an aerosolization technique developed by INL (under a DARPA/DHS project).

The aerosol delivery device was constructed of two syringes. The plunger and needle were removed from the first syringe and discarded. Then a compressed air line was attached to the rear of the syringe. The second syringe contained the contaminant solution and was equipped with a 27 gauge needle, which penetrated through the plastic housing near the tip of the first syringe. Compressed air flowing at a rate of approximately 1 - 2 liter (L) per minute created a turbulent flow through the first syringe. When the contaminant solution in the second syringe was introduced, it became nebulized by the turbulent air flow. A fine aerosol was ejected from the tip of the first syringe, creating a controlled and uniform spray of fine liquid droplets onto the coupon surface. The contaminant spray was applied all the way to the edges of the coupon, which were taped (after having previously been sealed with polyester resin) to ensure that the contaminant was applied only to the surfaces of the coupons. The photographs in Figure 3-1 show this procedure being performed using a nonradioactive, nonhazardous aqueous dye to demonstrate that the 2.5 mL of contaminant solution is effectively distributed across the surface of the coupon.

Figure 3-1. Demonstration of contaminant application technique.

3.1.3 Measurement of Activity on Coupon Surface

Gamma radiation from the surface of each concrete coupon was measured to quantify contamination levels both before and after evaluation of ND-75 and ND-600. These measurements were made using an intrinsic high purity germanium detector (Canberra LEGe Model GL 2825R/S, Meriden, CT). After being placed in the detector, each coupon was measured until the average activity level of Cs-137 from the surface stabilized to a relative standard deviation (RSD) of less than 2%. Gamma-ray spectra acquired from Cs-137 contaminated coupons were analyzed using INL Radiological Measurement Laboratory (RML) data acquisition and spectral analysis programs.

Radionuclide activities on coupons were calculated based on efficiency, emission probability, and half-life values. Decay corrections were made based on the date and the duration of the counting period. Full RML gamma counting QA/quality control (QC), as described in the test/QA plan, was employed and certified results were provided.

3.1.4 Surface Construction Using Test Stand

To evaluate the decontamination technologies on vertical surfaces (simulating walls), a stainless steel test stand that held three rows of three concrete coupons was used. The test stand, approximately 2.7 m × 2.7 m, was erected within a containment tent. The concrete coupons were placed into holders so their surfaces extended just beyond the surface of the stainless steel face of the test stand. Eight of the nine coupons placed in the test stand were contaminated with Cs-137, which has a half-life of 30 years. One uncontaminated coupon was placed in the bottom row of the test stand (position 8) and decontaminated in the same way as the other coupons. This coupon, referred to as the CC blank, was placed there to observe possible CC caused by the decontamination higher on the wall. Figure 3-2 shows the containment tent and the test stand loaded with the concrete coupons.

Figure 3-2. Containment tent: outer view (left) and inner view with test stand containing contaminated coupons with numbered coupon positions (right).

3.2 Evaluation Procedures

The eight concrete coupons in the test stand which had been contaminated approximately one month before were decontaminated using either the ND-75 or ND-600. The ND-75 was applied to the coupons in positions 1, 2, 4, 7, and 8 (blank coupon) and simultaneously, ND-600 was used on the coupons in positions 3, 5, 6, and 9. The ND-75 and ND-600 were applied from top to bottom to simulate an approach that would likely be taken in an actual decontamination event, where higher wall surfaces would be decontaminated first because of the possibility of secondary contamination lower on the wall.

The ND-75 and ND-600 required no preparation as they were provided ready to use. The application of ND-75 and ND-600 was performed using plastic spray bottles (32 oz. Heavy Duty Spray

Bottle, Rubbermaid Professional, Atlanta, GA). During this evaluation, the initial application of ND-75 took only a few seconds with 3-4 sprays for each coupon. The next step was a 30 minute dwell time for the ND-75 to reside on the surface of the concrete coupons. The coupon surfaces were kept damp with 1-2 sprays of additional ND-75 approximately every five minutes. After 30 minutes, the surfaces of the concrete coupons were thoroughly wetted with deionized water using another spray bottle and then the water was removed with a wet vacuum (12 gallon, 4.5 horsepower, QSP® Quiet Deluxe, Shop-Vac Corporation, Williamsport, VA) that required about one minute per coupon. This procedure was repeated two additional times for a total elapsed time of just over 90 minutes.

The vendor approved application procedure for ND-600 was the same as for ND-75 with two exceptions. First, following spray application of the ND-600 to each concrete coupon, the solution was worked into the surface of the coupon by scrubbing the entire surface of the coupon once with a scouring pad (Heavy Duty Scouring Pad, 3M Scotch-Brite, St. Paul, MN). Then, instead of a 30 minute dwell time, the dwell time was 15 minutes. As for ND-75, the surfaces were kept damp with 1-2 sprays of additional ND-600 approximately every five minutes during the dwell time. The procedure was also performed a total of three times on each coupon for a total elapsed time of just over 45 minutes. The temperature and relative humidity (RH) were recorded at the start and finish. The temperature and RH were 18 °C (64 °F) and 25% during the evaluation, respectively. According to the vendor, these conditions were acceptable for use of the INTEK solutions.

The overall decontamination method for ND-75 and ND-600 included:

1. Apply decontamination solution (ND-75 or ND-600) with spray bottle
2. For ND-600 only, scrub the surface with a scouring pad after application
3. Allow for 30 minute dwell time for ND-75 and 15 minute dwell time for ND-600
4. Keep the surface damp by wetting the coupon every 5 minutes with additional 1-2 sprays of the respective technology
5. Thoroughly wet surface with deionized water
6. Remove liquid with a wet vacuum by moving over the surface one time with the open end of a 1 ¼ inch hose flat against the surface without an attachment
7. Repeat steps 1-6 two more times.

4.0 Quality Assurance/Quality Control

QA/QC procedures were performed in accordance with the program QMP and the test/QA plan for this evaluation.

4.1 Intrinsic Germanium Detector

The germanium detector was calibrated weekly during the overall project. The calibration was performed in accordance with standardized procedures from the American National Standards Institute (ANSI) and the Institute of Electrical and Electronics Engineers (IEEE).[2] In brief, detector energy was calibrated using thorium (Th)-228 daughter gamma rays at 238.6, 583.2, 860.6, 1620.7, and 2614.5 kilo electron volts (keV). Table 4-1 shows the calibration results across the duration of the project. Each row gives the difference between the known energy levels and those measured following calibration (rolling average across the six most recent calibrations). Pre-contamination measurements were performed in late September and the post-contamination results were measured in late November. Each row represents a six week rolling average of calibration results. In addition, the energies were compared to the previous 30 calibrations to confirm that the results were within three standard deviations of the previous calibration results. All the calibrations fell within this requirement.

Table 4-1. Calibration Results – Difference from Th-228 Calibration Energies

	Calibration Energy Levels (keV)				
Date Range (2010)	**Energy 1 238.632**	**Energy 2 583.191**	**Energy 3 860.564**	**Energy 4 1620.735**	**Energy 5 2614.533**
9-27 to 11-2	-0.003	0.010	-0.039	-0.121	0.017
10-5 to 11-8	-0.003	0.011	-0.029	-0.206	0.023
10-12 to 11-16	-0.004	0.015	-0.040	-0.245	0.031
10-19 to 11-24	-0.005	0.014	-0.001	-0.320	0.043

Gamma ray counting was continued on each coupon until the activity level of Cs-137 on the surface had a RSD of less than 2%. This RSD was achieved during the first hour of counting for all the coupons measured during this evaluation. The final activity assigned to each coupon was a compilation of information obtained from all components of the electronic assemblage that comprise the "gamma counter," including the raw data and the spectral analysis described in Section 3.1.3. Final spectra and all data that comprise the spectra were sent to a data analyst who independently confirmed the "activity" number arrived at by the spectroscopist. When both the spectroscopist and an expert data analyst independently arrived at the same value the data were considered certified. This process defines the full gamma counting QA process for certified results.

The background activity of the concrete coupons was determined by analyzing four arbitrarily selected coupons from the stock of concrete coupons used for this evaluation. The ambient activity level of these coupons was measured for at least two hours. No activity was detected above the minimum detectable level of 2×10^{-4} µCi on these coupons. Because the background activity was not detectable (and the detectable level was more than 2,500 times lower than the post-decontamination activity levels), no background subtraction was required.

Throughout the evaluation, a second measurement was taken on five coupons in order to provide duplicate measurements to evaluate the repeatability of the instrument. Three of the duplicate measurements were performed after contamination prior to application of the decontamination technology and two were performed after decontamination. All five of the duplicate pairs showed difference in activity levels of 2% or less, within the acceptable difference of 5%.

4.2 Audits

4.2.1 Performance Evaluation Audit

RML performed regular checks of the accuracy of the Th-228 daughter calibration standards (during the time when the detector was in use) by measuring the activity of a National Institute of Standards and Technology (NIST)-traceable europium (Eu)-152 standard (in units of Becquerel, BQ) and comparing it to the accepted NIST value. Results within 7% of the NIST value are considered (according to RML internal quality control procedures) to be within acceptable limits. The Eu-152 activity comparison is a routine QC activity performed by INL, but for the purposes of this evaluation serves as the performance evaluation (PE) audit. This audit confirms the accuracy of the calibration of the germanium detector instrumentation critical to the results of the evaluation. Table 4-2 gives the results of each of the audits applicable to the duration of the evaluation including the pre-decontamination measurements performed in late September. All results are below the acceptable difference of 7%.

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

Date	NIST Activity (BQ)	INL RML Result (BQ)	Relative Percent Difference
9-15-2010	124,600	122,000	2%
10-13-2010	124,600	123,100	1%
11-10-2010	124,600	121,600	2%

4.2.2 Technical Systems Audit

A TSA was conducted during testing at INL to ensure that the evaluation was performed in accordance with the test/QA plan. As part of the audit, the actual evaluation procedures were compared with those specified in the test/QA plan and the data acquisition and handling procedures were reviewed. No significant adverse findings were noted in this audit. The records concerning the TSA are stored indefinitely with the Contractor QA Manager.

4.2.3 Data Quality Audit

At least 10% of the raw data acquired during the evaluation and transcribed into spreadsheets for use in the final report was verified by the QA manager. The data were traced from the initial raw data collection, through reduction and statistical analysis, to final reporting, to ensure the integrity of the reported results.

4.3 QA/QC Reporting

Each assessment and audit was documented in accordance with the test/QA plan. Draft assessment reports were prepared and sent to the Test Coordinator and Program Manager for review and approval. Final assessment reports were then sent to the EPA QA Manager and contractor staff.

5.0 Evaluation Results

5.1 Decontamination Efficacy
The decontamination efficacy of the ND-75 and ND-600 was measured for each contaminated coupon in terms of percent removal (%R) and decontamination factor (DF). Both of these measurements provide a means of representing the extent of decontamination accomplished by a technology. The %R gives the extent as a percent relative to the activity and the DF is the ratio of the initial activity to the final activity or the factor by which the activity was decreased. These terms are defined by the following equations:

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

$$DF = A_o/A_f$$

where, A_o is the radiological activity from the surface of the coupon before application of ND-75 or ND-600 and A_f is radiological activity from the surface of the coupon after treatment. While the DFs are reported, the narrative describing the results focuses on the %R.

Tables 5-1 and 5-2 give the %R and DF for ND-75 and ND-600, respectively. All coupons were oriented vertically. The target activity for each of the contaminated coupons (pre-decontamination) was within the acceptable range of 1 µCi ± 0.5 µCi.

The overall average (plus or minus one standard deviation) of the contaminated coupons was 1.12 µCi ± 0.047 µCi and 1.08 µCi ± 0.035 µCi for the coupons used for ND-75 and ND-600, respectively. The post-decontamination coupon activities were less than the pre-decontamination activities showing an overall reduction in activity for both technologies. For ND-75, the %R averaged 47% ± 6% and the DF averaged 1.9 ± 0.22. Overall, the %R ranged from 41% to 54% and the DF ranged from 1.7 to 2.2. For ND-600, the %R averaged 52 ± 12% and the DF averaged 2.1 ± 0.44. Overall, the %R ranged from 35% to 61% and the DF ranged from 1.5 to 2.6. The four coupons decontaminated with ND-600 had one coupon (bottom right) that appeared to be a slight outlier compared to the other three coupons. There was no explanation for this result. A t-test was performed on the two data sets in order to determine the likelihood of generating the observed %R data if the data sets were not different. The probability of generating these data sets if the data sets were not significantly different was 0.295 so at a 95% confidence interval, the ND-75 and ND-600 were not considered significantly different from one another.

Table 5-1. Decontamination Efficacy Results for ND-75

Coupon Location in Test Stand	Pre-Decon Activity (µCi / Coupon)	Post-Decon Activity (µCi / Coupon)	%R	DF
Top left	1.17	0.53	54%	2.2
Top middle	1.14	0.59	48%	1.9
Center left	1.11	0.63	43%	1.8
Bottom left	1.06	0.63	41%	1.7
Average	**1.12**	**0.60**	**47%**	**1.9**
Std. Dev	**0.047**	**0.04**	**6%**	**0.22**

Table 5-2. Decontamination Efficacy Results for ND-600

Coupon Location in Test Stand	Pre-Decon Activity (µCi / Coupon)	Post-Decon Activity (µCi / Coupon)	%R	DF
Top right	1.13	0.44	61%	2.6
Center middle	1.05	0.48	55%	2.2
Center right	1.07	0.47	56%	2.3
Bottom right	1.07	0.70	35%	1.5
Average	**1.08**	**0.52**	**52%**	**2.1**
Std. Dev	**0.035**	**0.12**	**12%**	**0.44**

As described above in Section 3.1, the CC blank was included in the test stand to evaluate the potential for CC due to application of ND-75 and ND-600 on wall locations above the placement of the uncontaminated coupon. ND-75 was applied to the CC blank using the same method as for the other coupons. After decontamination, the activity of the CC blank was found to be 0.0224 µCi. This value was about 10 times greater than the minimum detectable level, but more than 25 times less than the post-decontamination activities of the contaminated coupons. Therefore, this result suggested that cross-contamination resulting from the application of the ND-75 and ND-600 was detectable, but to a minimal extent. Assuming that the ND-75 attained a 47 %R on the CC blank, this residual activity of 0.0224 µCi would correspond to a pre-decontamination activity of 0.048 µCi, consistent with approximately 5% of the activity from the coupon located above. The liquid nature of the decontamination solutions facilitates flow of contamination down the side of the test stand. However, it is likely that the ND-75 and ND-600 solutions would not flow as easily down the side of an actual concrete wall as was the case for the stainless steel test stand, mitigating concerns about cross-contamination.

5.2 Deployment and Operational Factors

A number of operational factors were documented by the technician who performed the testing with the ND-75 and ND-600. One of the factors was the degree of difficulty in application. The application of ND-75 and ND-600 was described in Section 3.2 and included use of plastic spray bottles. Figure 5-1 shows a photograph of the application of ND-75 or ND-600 to a concrete coupon and the corresponding vacuum removal. The personal protective equipment (PPE) used by the technician in the picture was required because the work was performed in a radiological contamination area using Cs-137 on the concrete coupon surfaces. Whenever radioactive contaminated material is handled, anti-contamination PPE will be required and any waste will be considered low level radioactive waste (and will need to be disposed of accordingly). The required PPE was not driven by the use of the INTEK solutions (which are not hazardous), rather the interaction with surfaces contaminated with Cs-137.

Figure 5-1. Application and removal of ND-75 or ND-600.

Table 5-3 summarizes qualitative and quantitative practical information gained by the technician during the evaluation of the ND-75 and ND-600. All of the operational information was gathered during use of the ND-75 and ND-600 on the concrete coupons inserted into the test stand. Some of the information given in Table 5-3 could differ if the ND-75 and ND-600 were applied to a larger surface or to a surface that was smoother or more rough and jagged than the concrete coupons used during this evaluation.

Table 5-3. Operational Factors Gathered from the Evaluation

Parameter	Description/Information
Decontamination rate	Technology Preparation: ND-75 and ND-600 were supplied ready to use. Application: ND-75 and ND-600 were applied to each concrete coupon using a plastic spray bottle (total applications time of just a few seconds). ND-75 required a 30 minute dwell time before rinse and wet vacuum removal. This procedure was performed three times for a total elapsed time of just over 90 minutes. For ND-600, the dwell time (following a brief scrubbing) was 15 minutes and the procedure was also performed three times for a total elapsed time of just over 45 minutes. Estimated volumes used across all the concrete coupons included 0.6 L of ND-75 and 0.3 L ND-600. Overall those volumes correspond to solution requirements of 3 L/square meter (m^2) for the ND-75 and 1.5 L/m^2 ND-600.
Applicability to irregular surfaces	Application to irregular surfaces would not seem to be problematic as ND-75 and ND-600 are sprayed into hard to reach locations. Removal may be difficult if vacuuming jagged edges or gaps is required.
Skilled labor requirement	Adequate training would likely include a few minutes of orientation so the technician is familiar with the application technique. Larger surfaces may required more complex equipment such as sprayer application and larger scale vacuum removal.
Utilities requirement	As evaluated here, electricity was required to operate the wet vacuum.
Extent of portability	At a scale similar to that used for this evaluation, vacuum removal would be the only portability factor. However, for larger scale applications, limiting factors would include the ability to apply the ND-75 and ND-600 at an adequate scale (including scrubbing surface for ND-600) and then rinse and remove with a vacuum. Portable electrical generation or vacuum capability may be required.
Secondary waste management	A total of 0.5 L of ND-75 and 0.5 L of ND-600 was applied to the concrete coupons used during this evaluation. That volume corresponds to a waste generation rate of approximately 5 L/m^2 depending on how much of the solutions absorb to the surfaces. Because Cs-137 was used for this testing, all waste (in vacuum) was disposed of as low level radioactive waste. In the absence of radioactivity, ND-75 and ND-600 may not be discharged to U.S. waters so require solidification and landfill disposal or chemical oxidation.
Surface damage	Concrete surfaces appeared undamaged.
Cost (material)	The material cost is \$0.33 per liter for the ND-75 and \$1.52 for the ND-600. Corresponds to approximately \$1/m^2 for ND-75 and \$2/m^2 ND-600. Labor and waste management costs were not calculated.

6.0 Performance Summary

This section presents the findings from the evaluation of the ND-75 and ND-600 for each performance parameter evaluated.

6.1 Decontamination Efficacy

The decontamination efficacy (in terms of %R) attained for the three applications, as recommended by the manufacturer, of ND-75 and ND-600 was evaluated for each concrete coupon used during the evaluation. When the decontamination efficacy metrics (%R and DF) of the four contaminated coupons for each decontamination were averaged together, the average %R for ND-75 was 47% ± 6% and the average DF was 1.9 ± 0.22. The average %R for ND-600 was 52% ± 12% and the average DF was 2.1 ± 0.44.

6.2 Deployment and Operational Factors

The application of ND-75 and ND-600 included use of plastic spray bottles. Application of the ND-75 solution to each coupon took very little time (just a few seconds) in relation to the recommended dwell time of 30 minutes prior to rinsing by spraying with the deionized water and wet vacuum removal (approximately 30 seconds per coupon). This procedure was repeated two additional times so the total time elapsed for the five coupons decontaminated with ND-75 was just over 90 minutes.

The application procedure for ND-600 was the same as for ND-75 with two exceptions. First, following spray application of the ND-600 to each concrete coupon, the solution was worked into the surface of the coupon by scrubbing the entire surface of the coupon once with a ScotchBrite pad. Then, instead of a 30 minute dwell time, the dwell time was 15 minutes. The procedure was also performed a total of three times on each coupon for a total elapsed time of just over 45 minutes.

The waste generated through use of the ND-75 and ND-600 was estimated to be approximately 5-10 L/m^{2}and because of the use of Cs-137 during this evaluation, was considered low level radioactive waste. As used for this evaluation, electricity was used to operate the wet vacuum. Scaled up applications in remote locations may require additional utilities to provide means for sprayer and larger scale vacuum removal. Minimal training would be required for technicians using the ND-75 and ND-600, and the surface of the concrete was not visibly damaged during use of the ND-75 and ND-600. The cost is $0.33 per liter for the ND-75 and $1.52 for the ND-600, which, corresponds to approximately $1/m^2 for ND-75 and $2/m^2 ND-600. Labor and waste management costs would be dependent on the particular physical characteristics of the area being decontaminated and so were not calculated.

7.0 References

1. ASTM Standard C 150-07, “Standard Specification for Portland Cement.” ASTM International, West Conshohocken, PA, www.astm.org, 2007.

2. Calibration and Use of Germanium Spectrometers for the Measurement of Gamma Emission Rates of Radionuclides. American National Standards Institute. ANSI N42.14-1999. IEEE New York, NY (Rev. 2004).

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