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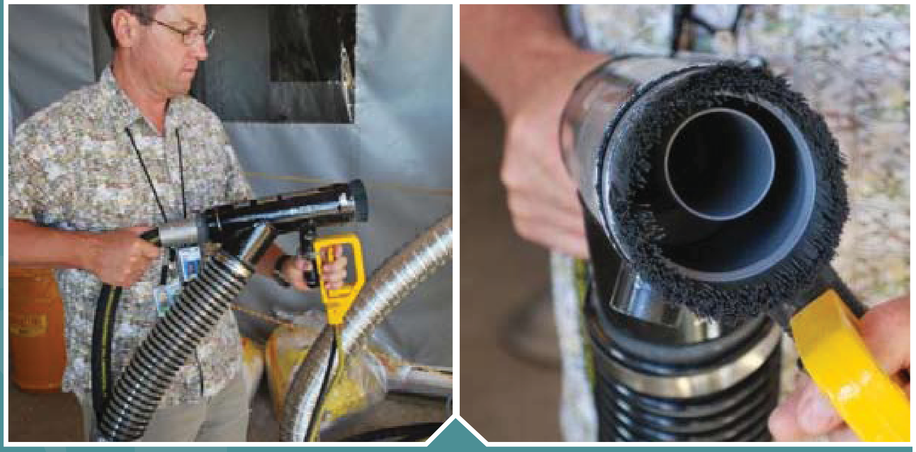
Empire Abrasive Blast N'Vac for Radiological Decontamination

TECHNOLOGY EVALUATION REPORT



Office of Research and Development
National Homeland Security Research Center

EPA 600-R-11-014
May 2011

Technology Evaluation Report

Empire Abrasive Blast N'Vac for Radiological Decontamination

United States Environmental Protection Agency
Cincinnati, OH 45268

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. TTEP 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
National Homeland Security Research Center

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Abbreviations/Acronyms

ANSI	American National Standards Institute
ASTM	American Society for Testing and Materials
BQ	Becquerel
Cs	cesium
cfm	cubic feet per minute
cm	centimeters
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
ft	feet
HEPA	High Efficiency Particle Air
IEEE	Institute of Electrical and Electronics Engineers
INL	Idaho National Laboratory
keV	kilo electron volts
mg	milligram
mL	milliliter
L	liter
m	meter
m^2	square meter
μCi	microCuries
NHSRC	National Homeland Security Research Center
NIST	National Institute of Standards and Technology
ORD	Office of Research and Development
%R	percent removal
PE	performance evaluation
psi	pounds per square inch
QA	quality assurance
QC	quality control
QMP	quality management plan
RDD	radiological dispersion device
RML	Radiological Measurement Laboratory
RSD	relative standard deviation
TSA	technical systems audit
TTEP	Technology Testing and Evaluation Program
Th	thorium

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 performance of the Empire Abrasive Blast N'Vac (hereafter referred to as the Blast N'Vac) and its ability to remove radioactive cesium (Cs)-137 from the surface of unpainted concrete.

Experimental Procedures. The Blast N'Vac is a heavy duty abrasive grit blasting technology that removes bound Cs from a surface by blasting away the concrete surface. Eight 15 centimeter (cm) × 15 cm unpainted concrete coupons were contaminated with approximately 1 microCurie (μCi) of Cs-137 per coupon and allowed to age for seven days. 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. Each coupon was treated with the Blast N'Vac, 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 attained by the Blast N'Vac was evaluated for each individual concrete coupon used during the evaluation. When the decontamination efficacy metrics (DF and %R) of the eight contaminated coupons were averaged together, the average %R for the Blast N'Vac was 97 ± 2% the average DF was 58 ± 52. Hypothesis testing was performed to determine if there were significant differences among the %R values determined for the coupons in each row (top, middle, and bottom) of the test stand. No differences were found.

Following the manufacturer's recommendations, the Blast N'Vac was used with size 24 aluminum oxide abrasive grit. The rate at which the Blast N'Vac was used to decontaminate a vertical surface was approximately 2.7 square meters (m^2) per hour, with significant visual surface destruction and some secondary waste. The texture of the concrete surface is not relevant to the efficacy of the Blast N'Vac and similar blasting technologies. Battelle observed that, because of the aggressiveness with which the abrasive grit removes concrete surfaces, irregularities within the surface would not impact the effectiveness of the technology. The Blast N'Vac required a source of compressed air that provided at least 400 cubic feet per minute (cfm) of air flow at a pressure of 120 pounds per square inch (psi). An Ingersoll-Rand 75902 diesel-powered air compressor was the only source of power required for the operation of the Blast N'Vac. Such a large air compressor is not a common piece of equipment. Therefore, the size and availability of the compressor required may limit the locations where the Blast N'Vac can be used.

A very limited evaluation of cross-contamination was performed. During an actual decontamination of a vertical surface, the higher elevation surfaces would likely be decontaminated first, possibly exposing the lower elevation surfaces to secondary contamination. To simulate an actual scenario, one uncontaminated coupon was placed in the bottom row of the test stand and decontaminated using the Blast N'Vac in the same way as the other coupons. Following decontamination using the Blast N'Vac, this uncontaminated coupon did not exhibit measurable activity, suggesting that cross contamination was minimal. It should be noted that very small amounts of blasting abrasive grit (individual grains) were found throughout the containment tent and there was some abrasive grit that collected at the base of the test stand.

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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 clean-ups.

NHSRC, through its 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. TTEP provides high-quality information that is useful to decision makers in purchasing or applying the evaluated technologies and in planning clean-up operations. 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 evaluation design so that useful performance information is produced for each of the evaluated technologies.

Under TTEP, NHSRC recently evaluated the performance of the Empire Abrasive Blast N'Vac (Langhorne, PA; hereafter referred to as the Blast N'Vac) in removing radioactive isotope Cs-137 from concrete. A peer-reviewed test/QA plan was developed according to the requirements of the quality management plan (QMP) for TTEP. The evaluation generated the following performance information:

- Decontamination efficacy, defined as the extent of radionuclide removal following use of the Blast N'Vac, and the possibility of cross-contamination.

- 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.

This evaluation took place from August 11, 2009 until October 13, 2009. 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 this evaluation of the Blast N'Vac. The contractor, Battelle, and EPA were responsible for QA oversight. The Battelle QA Manager conducted both a technical systems audit (TSA) and a data quality audit of the evaluation data.

2.0 Technology Description

The following description of the Blast N'Vac is based on information provided by the vendor and was not verified during this evaluation.

Blast N'Vac is a heavy duty abrasive grit blasting technology that also collects the spent abrasive grit by means of a blasting head surrounded with a vacuum collection shroud. During this evaluation, the Blast N'Vac was used with size 24 aluminum oxide abrasive grit. The Blast N'Vac was powered entirely by compressed air. An Ingersoll-Rand 75902 diesel-powered air compressor provided approximately 400 cubic feet per minute (cfm) of compressed air at approximately 120 pounds per square inch (psi). The Blast N'Vac is plumbed to provide not only an adequate amount of compressed air to perform the abrasive grit blasting but also adequate suction to perform the abrasive grit recovery. The air compressor was not provided by Empire Abrasive, but is considered a required utility for operation of the technology. In addition, while not tested as part of this evaluation, the Blast N'Vac came equipped with blasting heads shaped specifically for work in corners.

Figure 2-1 shows the Blast N'Vac blasting gun used during this evaluation. The photograph on the right clearly shows the inner blasting head and the vacuum shroud surrounding the blasting head. Figure 2-2 shows (from left to right) the abrasive grit reservoir, the high efficiency particle air (HEPA) filter, and the abrasive grit collection drum situated on a skid. The Blast N'Vac can also be equipped to recycle abrasive grit continuously, but that feature was not used during this evaluation in order to minimize the amount of equipment at risk of becoming contaminated with radiological material. Therefore, the abrasive grit was blasted and collected for disposal in the collection drum. All components in Figure 2-2 were successfully protected from contamination and were returned following the evaluation.

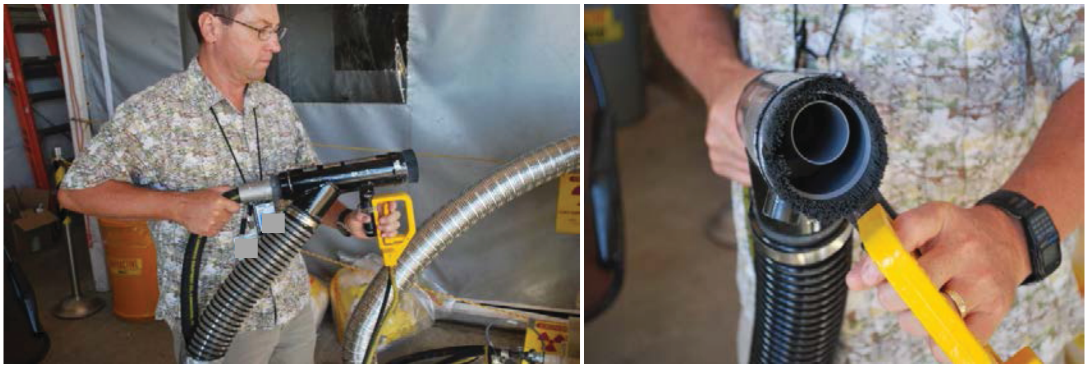

Figure 2-1. Blast N'Vac as assembled for testing (left). Close-up of Blast N'Vac vacuum head (right).

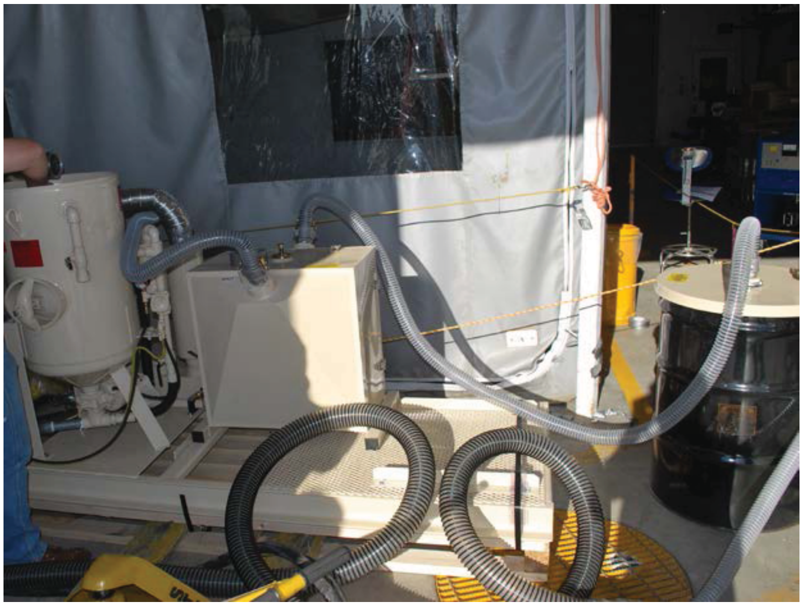

Figure 2-2. Blast N'Vac abrasive grit reservoir, HEPA filter, and collection drum.

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 describe the cement clinker used in the concrete mix. For Type II Portland cement, the American Society for Testing and Materials (ASTM) Standard C 150-7[1] specifies that tricalcium aluminate account 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.

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 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. The concrete was representative of exterior concrete commonly found in urban environments in the United States as shown by INL under a previous project sponsored by the U.S. Department of Defense (DOD), Defense Advanced Research Projects Agency (DARPA) and

U.S. Department of Homeland Security (DHS).[2]

3.1.2 Coupon Contamination

Eight coupons were contaminated by spiking individually with 2.5 milliliters (mL) of aqueous solution that contained 0.26 milligrams (mg)/liter (L) Cs-137 as a solution of cesium chloride, corresponding to an activity level of approximately 1 microCurie (µCi) over the 225 cm^2 surface. Application of the Cs in an aqueous solution was justified because even if Cs 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 dry 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[2]) and described in detail in the test/QA plan, and then allowed to age for seven days.

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 L per minute created a turbulent flow through the first syringe. When the contaminant solution in the second syringe was introduced, the solution 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.

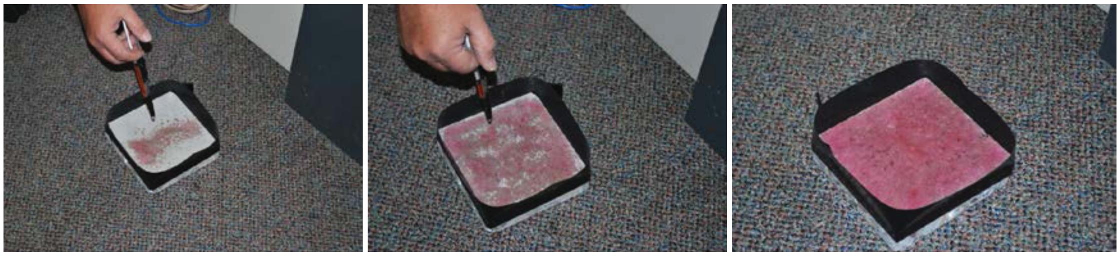

Figure 3-1. Demonstration of contaminant application technique.

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 the Blast N'Vac. These measurements were made using an intrinsic, high purity germanium detector (Canberra LEGe Model GL 2825R/S, Meriden, CT). After being placed in the detector, each coupon was measured until the average activity level of Cs-137 from the surface stabilized to a relative standard deviation of less than 2%. Gamma-ray spectra acquired from Cs-137 contaminated coupons were analyzed using INL Radiological Measurement Laboratory (RML) data acquisition and spectral analysis programs (PCGAP, Idaho National Engineering and Environmental Laboratory, Idaho Falls, ID; INEEL/EXT-2000-00908; http://www.inl.gov/technicalpublications/Documents/3318133.pdf). 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 was fabricated that held three rows of three concrete coupons. A test stand, approximately 9 feet (ft) × 9 ft, 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 and decontaminated using the Blast N'Vac in the same way as the other coupons. This coupon was placed there to observe possible secondary contamination caused by the decontamination higher on the wall. Figure 3-2 shows the containment tent and the test stand loaded with the concrete coupons.

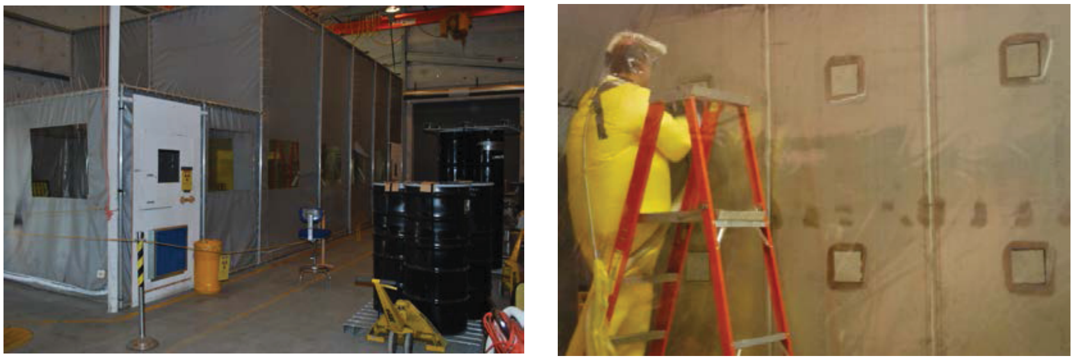

Figure 3-2. Containment tent: outer view (left) and inner view with test stand containing contaminated coupons (right).

3.2 Evaluation Procedures

The containment tent consisted of two rooms. One room contained the test stand to hold the contaminated coupons and the other room (the shorter part of the tent as shown in Figure 3-2) held the collection drum. The abrasive grit hoses (both blasting and vacuum) connected to the blasting head in the room with the test stand through a small opening in the tent wall between the two rooms. The abrasive grit reservoir and air compressor were located outside the containment tent. The positive pressure blasting hose was connected directly to the blasting head through a small opening in the outer tent wall, through the smaller room, and also through a small opening in the tent wall between the two rooms. The vacuum line was connected first to the collection drum and then to the collection shroud surrounding the blasting head, through the same openings in the tent. Each of the tent openings was taped closed around the hoses. Figure 3-3 shows the smaller diameter blasting hose and the larger diameter vacuum hose connecting to the blasting head as the operator applies the Blast N'Vac to a concrete coupon.

The nine concrete coupons in the test stand were blasted with the Blast N'Vac starting with the top row and working from left to right, then proceeding to the middle and bottom rows. The coupons were blasted in this manner 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 flow of abrasive grit was controlled by a trigger on the blasting head; the vacuum flow was controlled by an on/off valve near the abrasive grit reservoir. Therefore, the vacuum ran during the entire evaluation and the abrasive grit flow was easily turned on and off between coupons. Each coupon was blasted for approximately 30 seconds. However, the operator made certain he had covered the entire surface before progressing to the next coupon, so the actual times for eight out of nine coupons ranged from 22 to 35 seconds. One coupon had taken 80 seconds because of periodic diminished flow of abrasive grit. The pressure conditions during blasting were 66 psi on the blaster and 50 psi for the vacuum (as measured on the gauges near the abrasive grit reservoir). The temperature and relative humidity were recorded before and after the approximately one hour test. These conditions did not vary significantly in the room where the evaluation was performed. Over the duration of testing, the temperature was steady at 19.8 °C and the relative humidity was 36%.

Figure 3-3. Operator applying Blast N'Vac to concrete coupon.

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 once each week. 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).[3] 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). This calibration was performed three times throughout the evaluation and documented by the RML. Table 4-1 gives the difference between the known energy levels and those measured following calibration. The energies were compared to the previous 30 calibrations to confirm that the results were within three standard deviations of the previous calibration results. All the calibrations fell within this requirement.

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

	Calibration Energy Levels (keV)				
Date	**Energy 1 238.632**	**Energy 2 583.191**	**Energy 3 860.564**	**Energy 4 1620.735**	**Energy 5 2614.533**
8-25-2009	-0.005	0.014	-0.031	-0.199	0.031
9-21-2009	-0.003	0.009	-0.040	-0.125	0.015
10-13-2009	-0.003	0.008	-0.011	-0.180	0.020

Gamma ray counting was continued on each coupon until the activity level of Cs-137 on the surface had a relative standard deviation (RSD) of less than 2%. This RSD occurred within the initial 1 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 nine 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 150 times lower than the post-decontamination activity levels), no background subtraction was required.

Throughout the evaluation, a second measurement was taken on 10 coupons in order to provide duplicate measurements to evaluate the repeatability of the instrument. Half of the duplicate measurements were performed after contamination prior to application of the decontamination technology and half were performed after decontamination. Five of the duplicate pairs showed no difference in activity levels between the two measurements; the other five duplicate pairs had a difference of 2% between the two measurements, 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 to the accepted NIST value. Results within 7% of the NIST value are considered to be within acceptable limits. The Eu-152 activity comparison is a routine QC activity performed by INL, but for the purposes of this evaluation the activity comparison serves as the performance evaluation (PE) audit, an audit that confirms the accuracy of the calibration standards used for the instrumentation critical to the results of an evaluation. Table 4-2 gives the results of each of the audits applicable to the duration of the evaluation. All results are below the acceptable difference of 7%.

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

Date	NIST Activity (BQ)	INL RML Result (BQ)	Relative Percent Difference
8-18-2009	124,600	122,400	2%
9-10-2009	124,600	122,600	2%
10-12-2009	124,600	122,300	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 and the TTEP QMP. 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 Battelle QA Manager.

4.2.3 Data Quality Audit

The Battelle QA Manager verified all of the raw data acquired during the evaluation and transcribed into spreadsheets for use in the final report. The data were traced from the initial raw data collection, through reduction and statistical analysis, to final reporting, to ensure the integrity of the reported results.

4.3 QA/QC Reporting

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

5.0 Evaluation Results

5.1 Decontamination Efficacy

The decontamination efficacy of the Blast N' Vac was measured for contaminated coupons 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:

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

where A_o is the radiological activity from the surface of the coupon before application of the Blast N'Vac and A_f is radiological activity from the surface of the coupon after treatment. While the DFs are reported in Table 5-1, the narrative describing the results focuses on the %R.

Table 5-1 gives the %R and DF for the Blast N'Vac. 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 1.17 µCi ± 0.04 µCi, a variability of 3%. The post-decontamination coupon activities were less than the pre-decontamination activities showing an overall reduction in activity. The %R (calculated as described above) averaged 97% ± 2% and the DF averaged 58 ± 52. Overall, the %R ranged from 92% to 99% and the DF ranged from 12 to 178. The coupon with the DF of 178 was observed to have exhibited a relatively high DF as the rest of the coupons had DFs that were substantially lower. The very high DF was caused by the extremely low post-decontamination activity for that coupon. It is not clear why the coupon was decontaminated more extensively than the others.

Paired t-tests were performed to determine whether location (top, middle, or bottom) on the test stand affected the decontamination efficacy. No significant difference between any of the rows was found. The bottom middle coupon was not contaminated to test the possibility of cross-contamination. Activity of the uncontaminated coupon was measured after the Blast N'Vac had been applied to all nine coupons. No activity was detected on that coupon, suggesting that cross-contamination due to the application of the Blast N'Vac was minimal.

Table 5-1. Decontamination Efficacy Results

Coupon Location in Test Stand	Pre-Decon Activity µCi / Coupon	Post-Decon Activity µCi / Coupon	%R	DF
Top left	1.19	0.007	99	178
Top middle	1.19	0.026	98	46
Top right	1.15	0.028	98	41
Center left	1.14	0.094	92	12
Center middle	1.19	0.015	99	82
Center right	1.24	0.033	97	38
Bottom left	1.12	0.028	98	40
Bottom right	1.14	0.042	96	27
Average	**1.17**	**0.034**	**97**	**58**
Std. Dev	**0.04**	**0.026**	**2**	**52**

5.2 Deployment and Operational Factors

A number of operational factors were documented by the Blast N'Vac operator. One of the factors was damage to the surface of the concrete coupons. Figure 5-1 shows photographs of a coupon before and after blasting with the Blast N'Vac. The surface of the coupon at the right has been removed by the Blast N'Vac and the aggregate layer of concrete has been exposed. This is evidenced by the large pieces of gravel and sand that are visible. Because of the extensive surface removal, the effectiveness of the Blast N'Vac will have to be weighed against the amount of surface damage caused by the decontamination technology.

Figure 5-1. Test coupon surfaces before (left) and after (right) treatment with the Blast N'Vac.

Another important factor to consider is the personal protection of the technology operators. During this evaluation, the radiological control technicians required the operators to wear full anti-contamination personal protective equipment that included a full face respirator with supplied air. This level of personal protection was required by the INL RCTs because of the likelihood of airborne radiological contamination due to the act of blasting. However, each situation will need to be considered independently by local RCTs to determine the proper level of personal protection.

Table 5-2 summarizes qualitative and quantitative practical information gained by the operator during the evaluation of the Blast N’Vac. All of the operational information was gathered during use of Blast N’Vac on the concrete coupons inserted into the test stand. Some of the information given in Table 5-2 could differ if the Blast N’Vac were applied to a larger surface or surfaces made up of different types of concrete.

Table 5-2. Operational Factors Gathered from the Evaluation

Parameter	Description/Information
Decontamination rate	Technology Preparation: Upon initial receipt, it took 1.5 days to get the components assembled and the abrasive grit valve to function properly. Initially, we provided approximately 250 cfm of compressed air, however that flow rate did not allow the proper function of the abrasive grit valve. Once we provided approximately 400 cfm of compressed air at 120 psi the valve began to function well. Application: Approximately 30 seconds per concrete coupon for most coupons during this evaluation corresponds to an application rate of 2.7 m^2/hour; less or more time per coupon may result in different levels of radiological decontamination.
Applicability to irregular surfaces	Irregular surfaces will not be a problem for the Blast N'Vac as the abrasive grit blasting is an aggressive decontamination technique, thus removing the surface of the concrete and making the operation of the Blast N'Vac independent of the surface characteristics of the concrete. In addition, while coupon configurations other than a flat square were not tested as part of this evaluation, the Blast N'Vac came equipped with blasting heads shaped for work in corners and was designed to maintain the ability to recover the abrasive grit following blasting.
Skilled labor requirement	Adequate training would likely require approximately one hour. In addition to the assembly and operation of the Blast N'Vac, topics would need to include precautions unique to pressurized blasting, the theory of operation, and troubleshooting. The operator experienced a significant level of exertion as he completed the evaluation. The weight of the Blast N'Vac, in combination with the additional weight and awkwardness of the attached blasting and vacuum hoses, increased the level of effort required to use the Blast N'Vac. Depending on what row of the test stand is being used, the operator was required to bend over, stand on the floor, or stand on a ladder. These factors will exclude some people from operating the Blast N'Vac. However, most people who are used to performing physical labor should not have any problem operating the unit.
Utilities required	400 cfm compressed air at 120 psi is the sole utility requirement.
Extent of portability	The limiting factors of portability for the Blast N'Vac will include the availability of 400 cfm compressed air (longer hoses may require higher flow/pressure air and vacuum). In addition, the skid containing the abrasive reservoir and HEPA filter is approximately 3 ft by 8 ft and weighs several hundred pounds. Therefore, it is a factor that would have to be considered to allow for portability.
Amount of spent blasting media	Following blasting of nine coupons, approximately 20 pounds of abrasive grit was used and approximately 5 pounds of concrete waste was collected.
Secondary waste management	An estimated 95% of the abrasive grit was collected by the vacuum. There was very little dust visible during the evaluation. However, very small amounts of blasting abrasive grit (individual grains) were found throughout the containment tent including at the base of the test stand. This abrasive was vacuumed up at the close of the evaluation. The radiological control technicians overseeing the evaluation determined that there was no secondary-contamination due to this wide distribution of small amounts of abrasive grit. The activity of the grit and dust collected by the vacuum or vacuum filter was not measured quantitatively. However, given the effectiveness of the Blast N'Vac, presumably the waste had significant activity levels.
Surface damage	Surface removed and aggregate exposed. See description and photograph in text.
Cost	As evaluated, the price of the Blast N'Vac would be $11,840. This price includes the blasting equipment only and not the compressed air required for operation or the blasting grit.

6.0 Performance Summary

This section presents the findings from the evaluation of the Blast N'Vac for each performance parameter evaluated.

6.1 Decontamination Efficacy

The decontamination efficacy (in terms of %R) attained by the Blast N'Vac was evaluated for each individual concrete coupon used during the evaluation. When the decontamination efficacy metrics (DF and %R) of the eight contaminated coupons were averaged together, the average %R for the Blast N'Vac was 97 ± 2% the average DF was 58 ± 52. Hypothesis testing was performed to determine if there were significant differences among the %R values determined for the coupons in each row (top, middle, and bottom) of the test stand. No differences were found.

6.2 Deployment and Operational Factors

Following the manufacturer's recommendations, the Blast N'Vac was used with a size 24 aluminum oxide abrasive grit. The rate at which the Blast N'Vac was used to decontaminate a vertical surface was approximately 2.7 m^2 per hour, with significant visual surface destruction and some secondary waste. The texture of the concrete surface is not relevant to the efficacy of the Blast N'Vac and similar blasting technologies. Battelle observed that, because of the aggressiveness with which the abrasive grit removes concrete surfaces, irregularities within the surface would not impact the effectiveness of the technology. The Blast N'Vac required a source of compressed air that provided at least 400 cfm of air flow at a pressure of 120 psi. An Ingersoll-Rand 75902 diesel-powered air compressor was the only source of power required for the operation of the Blast N'Vac. Such a large air compressor is not a common piece of equipment. Therefore, the size and availability of the compressor may limit the locations where the Blast N'Vac can be used.

A very limited evaluation of cross-contamination was performed. During an actual decontamination of a vertical surface, the higher elevation surfaces would likely be decontaminated first, possibly exposing the lower surface to secondary contamination. To simulate an actual scenario, one uncontaminated coupon was placed in the bottom row of the test stand and decontaminated using the Blast N'Vac in the same way as the other coupons. Following decontamination, this uncontaminated coupon did not exhibit measurable activity suggesting that cross contamination was minimal. While cross-contamination on the test stand seemed to be minimal, very small amounts of blasting abrasive grit (individual grains) were found throughout the containment tent and there was some abrasive grit that collected at the base of the test stand.

7.0 References

1. ASTM Standard C 150-07, "Standard Specification for Portland Cement." ASTM International, West Conshohocken, PA, www.astm.org, 2007.
2. Radionuclide Detection and Decontamination Program. Broad Agency Announcement 03-013, U.S. Department of Defense (DOD) Defense Advanced Research Projects Agency (DARPA) and the U.S. Department of Homeland Security, classified program.
3. 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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