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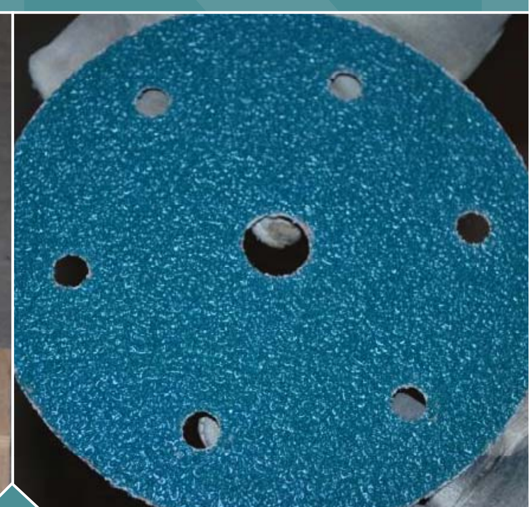
CS Unitec ETR180 Circular Sander for Radiological Decontamination

TECHNOLOGY EVALUATION REPORT



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National Homeland Security Research Center

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Technology Evaluation Report

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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. 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
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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
cm^2	square 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
ETR180	CS Unitec ETR180
Eu	europium
HEPA	High Efficiency Particle Air
IEEE	Institute of Electrical and Electronics Engineers
INL	Idaho National Laboratory
keV	kilo electron volts
kg	kilogram
mg	milligram
mL	milliliter
L	liter
m	meter
m^2	square meters
µCi	microCurie
NHSRC	National Homeland Security Research Center
NIST	National Institute of Standards and Technology
ORD	Office of Research and Development
%R	percent removal
RH	relative humidity
PE	performance evaluation
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
V	volt

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 CS Unitec ETR180 (hereafter referred to as the ETR180) and its ability to remove radioactive cesium (Cs)-137 from the surface of unpainted concrete.

Experimental Procedures. The ETR180 is a lightweight disk sander with a dust hood and configuration that allows sanding all the way to a wall edge. Bound Cs can be removed from a surface by sanding away the surface layer. 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 sanded with the ETR180, 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 ETR180 was evaluated for each concrete coupon used during the evaluation. When the decontamination efficacy metrics (%R and DF) of the eight contaminated coupons were averaged together, the average %R for the ETR180 was 54 ± 10% and the average DF was 2.3 ± 0.7. Hypothesis testing was performed to determine if there were significant differences between 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 ETR180 was used with 24 grit sanding disks. The ETR180 could decontaminate a vertical surface at a rate of approximately 1.4 square meters (m^2) per hour with minimal surface destruction and minimal secondary waste. The texture of the coupon surface may be important to the efficacy of the ETR180 and similar radiological decontamination technologies. It was observed that because sanding disks do not cut into concrete surfaces, uneven concrete surfaces may prevent the sanding disk from reaching some areas of the concrete surfaces.

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 ETR180 in the same way as the other coupons. Following decontamination, this uncontaminated coupon did not exhibit measurable activity, suggesting that cross contamination was minimal. Overall, the vacuum shroud was effective at containing the secondary waste. There was very little dust visible during the evaluation and very little remaining on the floor in front of the test stand following the evaluation. In addition, the radiological control technicians did not find any measurable airborne contamination through analysis of air filters sampled near the test stand. The dust collected by the vacuum was not analyzed for gamma radiation.

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 evaluated the performance of the CS Unitec (Norwalk, CT) ETR180 (hereafter referred to as the ETR180) in removing radioactive isotope cesium (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 ETR180, 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 the evaluation of the ETR180. The contractor, Battelle, and EPA were responsible for QA oversight. The Battelle QA Manager conducted a technical systems audit (TSA) during the evaluation as well as a data quality audit of the evaluation data.

2.0 Technology Description

The following description of the ETR180 is based on information provided by the vendor and was not verified during this evaluation.

ETR180 is a lightweight (3 kilogram, kg) circular sander with a variable speed motor, a dust shroud, and a configuration to allow sanding all the way to a wall edge. The ETR180 is powered by standard 110 volt (V) electricity; according to vendor specifications, it operates at approximately 1,450 revolutions per minute. The handle can be adjusted for right- and left-handed operators. The dust shroud allows dust extraction over the brush rim and through the punched sanding disk and base plate. The ETR180 comes with a centering tool for attaching the sanding disks, which are centered for balanced and smooth operation. The largest sanding disk the unit can use is 18 centimeters (cm) in diameter. During this evaluation, the ETR180 was used with 24 grit sanding disks provided by the vendor. Several different disks of varying coarseness (grit density) were evaluated during dry runs. A blue dye was applied to the coupon surface and allowed to dry, after which the ETR180 was used with each disk. The 24 grit disks were chosen as being aggressive enough to effectively clean the surface while being only minimally destructive. Figure 2-1 shows the ETR180 being applied to a coupon surface during the dry run using a 24 grit sanding disk.

In order to minimize the secondary waste produced during sanding, the ETR180 was connected to a high efficiency particulate air (HEPA) vacuum (C83985-01, Minuteman, Addison, IL) with a flow rate of 95 cubic feet per minute (cfm). CS Unitec did not provide the vacuum, but approved of its use during this evaluation.

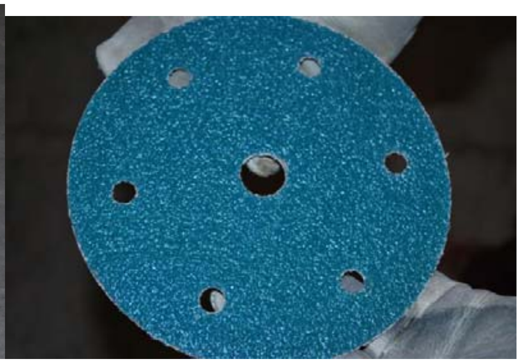

Figure 2-1. CS Unitec ETR180 (left) and sanding disk (right).

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 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 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.

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 cm thick, 15 cm $\times$ 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 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 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[4]) and described in detail in the test/QA plan. The coupons were 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 ETR180. 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. 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. The 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 ETR180 in the same way as the other coupons. This coupon was placed on the test stand to observe possible secondary contamination caused by the decontamination process being conducted 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; the other room (the shorter part of the tent as shown in Figure 3-2) held the vacuum. An opening in the tent wall between the two rooms was just large enough to allow the vacuum hose connected to the ETR180 to pass through. The tent opening was taped closed around the hose prior to the start of the evaluation.

The nine concrete coupons in the test stand were sanded using the ETR180 starting with the top row and working from left to right, then proceeding to the middle and bottom rows. The coupons were sanded 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 ETR180 was connected to the vacuum and used at full power for one minute on each coupon. The temperature and relative humidity (RH) were recorded before (21.1°C, 32% RH) and after (21.4°C, 32% RH) the approximately one hour test. These conditions did not vary significantly in the room where the evaluation was performed.

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 during the overall project 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 2,500 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 it 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 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 ETR180 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 of removal 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 ETR180 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.

Table 5-1 gives the %R and DF for the ETR180. 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 1.15 µCi ± 0.07 µCi, a variability of 6%. The post-decontamination coupon activities were less than the pre-decontamination activities showing an overall reduction in activity. The %R averaged 54 ± 10% and the DF averaged 2.3 ± 0.7. Overall, the %R ranged from 42% to 74% and the DF ranged from 1.7 to 3.9. The coupons with the %R values of 61% and 74% were notably higher than the %R values for the other six coupons, which all fell within the range of 42% to 53%. There was no obvious reason for these larger %R values.

Paired t-tests were performed at a 95% confidence interval to determine whether location (top, middle, or bottom) on the test stand affected the decontamination efficacy. While the average %R for the top row (47% ± 5%) of coupons was slightly lower than the middle (58% ± 14%) and bottom (57% ± 6%) rows, 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 ETR180 had been used on all nine coupons. No activity was detected on the uncontaminated coupon, suggesting that cross-contamination resulting from ETR180 sanding 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	1.12	0.53	53	2.1
Top middle	1.21	0.71	42	1.7
Top right	1.21	0.64	47	1.9
Center left	1.06	0.53	50	2.0
Center middle	1.12	0.57	50	2.0
Center right	1.13	0.29	74	3.9
Bottom left	1.09	0.52	52	2.1
Bottom right	1.25	0.48	61	2.6
Average	**1.15**	**0.53**	**54**	**2.3**
Std. Dev	**0.07**	**0.12**	**10**	**0.7**

5.2 Deployment and Operational Factors

A number of operational factors were documented by the ETR180 operator. One of the factors was damage to the surface of the concrete coupons. Figure 5-1 shows photographs of an uncontaminated coupon before and after sanding with the ETR180. The slight pink color is due to a dye that was applied to the surface of the noncontaminated coupon for illustrative purposes. The coupon on the right still has all of the obvious surface characteristics (discolorations, etc.) visible on the coupon on the left. However, a very thin layer of the surface (referred to as the “cream” of the concrete) has been removed as a result of sanding with the ETR180 making those characteristics more pronounced on the right coupon. The ETR180 operator referred to the condition of the right coupon as looking “polished.” It is clear from these photographs that a small amount of the surface was removed, but not enough to significantly change the look of the coupon.

Figure 5-1. Test coupons before (left) and after (right) sanding with the ETR180.

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 sanding. 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 ETR180. All of the operational information was gathered during use of ETR180 on the concrete coupons inserted into the test stand. Some of the information given in Table 5-2 could differ if the ETR180 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 5-2. Operational Factors Gathered from the Evaluation

Parameter	Description/Information
Decontamination rate	Technology Preparation: 15 minutes to attach sanding disk, vacuum shroud, and vacuum to the ETR180. Application: One minute per concrete coupon used during this evaluation corresponds to an application rate of 1.4 m^2/hour; less or more time per coupon may result in different levels of radiological decontamination.
Applicability to irregular surfaces	Application to irregular surfaces could be problematic for sanding disk technologies like the ETR180 because the rotating disk does not cut into the surface of the concrete: therefore, irregular coupon surfaces may prevent the sanding disk from reaching some areas of the coupons.
Skilled labor requirement	The rotating sanding disk is an extremely basic technology requiring minimal training. Adequate training would likely include a few minutes of orientation so the operator is familiar with the power switches on the vacuum and the ETR180. The ETR180 centering tool was helpful in attaching the sanding disks. The ETR180 weighs 3 kg. The operator during this evaluation experienced a significant level of exertion as he completed the evaluation. The weight of the ETR180, in combination with the additional weight and awkwardness of the attached HEPA vacuum hose, increased the level of effort required to use the ETR180 when standing on a ladder holding the ETR180 at a level equivalent to the operator's chest. These factors will exclude some people from operating the ETR180. However, most people who are used to performing physical labor should not have any problem operating the ETR180.
Utilities requirement	110V power for both the ETR180 and an applicable vacuum.
Extent of portability	The limiting factors of portability for the ETR180 will include the availability of power and the ability to connect to the vacuum by staying close enough to the vacuum or by having vacuum hosing of adequate length.
Sanding media	A new sanding disk was used after treating every 5 concrete coupons. The 24 grit surface became smoother after each successive sanding.
Secondary waste management	The vacuum shroud was effective at containing the secondary waste. There was very little dust visible during the evaluation and very little remaining on the floor in front of the test stand following the evaluation. In addition, the radiological control technicians did not find any measurable airborne contamination during the evaluation. The dust collected by the vacuum was not analyzed for gamma radiation, but given the decrease in activity on the coupons, the waste would have had measurable activity.
Surface damage	Operator described surface as being "polished." See description and photograph in text.
Cost	The cost of ETR 180 is $389 and replacement disks are less than $5 each.

6.0 Performance Summary

This section presents the findings from the evaluation of the ETR180 for each performance parameter evaluated.

6.1 Decontamination Efficacy

The decontamination efficacy (in terms of %R) attained by the ETR180 was evaluated for each concrete coupon used during the evaluation. When the decontamination efficacy metrics (%R and DF) of the eight contaminated coupons were averaged together, the average %R for the ETR180 was $54 \pm 10\%$ and the average DF was 2.3 ± 0.7. Hypothesis testing was performed to determine if there were significant differences between 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 ETR180 was used with 24 grit sanding disks. The ETR180 could decontaminate a vertical surface at a rate of approximately 1.4 m^2 per hour with minimal surface destruction and minimal secondary waste. The texture of the coupon surface may be important to the efficacy of the ETR180 and similar radiological decontamination technologies. Battelle observed that because sanding disks do not cut into concrete surfaces, uneven concrete surfaces may prevent the sanding disk from reaching some areas of the concrete surfaces.

A 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 ETR180 in the same way as the other coupons. Following decontamination, this uncontaminated coupon did not exhibit measurable activity, suggesting that cross contamination was minimal. Overall, the vacuum shroud was effective at containing the secondary waste. There was very little dust visible during the evaluation and very little remaining on the floor in front of the test stand following the evaluation. In addition, the radiological control technicians did not find any measurable airborne contamination through analysis of air filters sampled near the test stand. The dust collected by the vacuum was not analyzed for gamma radiation.

7.0 References

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