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Testing of Dry Decontamination Technologies for Chemical, Biological, Radiological, and Nuclear (CBRN) Response

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May 2023

Cold Regions Research
and Engineering Laboratory

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Abstract

This report provides a summary of the results obtained in laboratory-scale testing of dry-decontamination technologies. The purpose of the experiment is to assess nonaqueous technologies to determine the viability of a solution to mitigate chemical, biological, radiological, and nuclear (CBRN) defense, CBRN Response Enterprise, medical casualty care, and cold-weather operational gaps. The Cold Regions Research and Engineering Laboratory (CRREL) assessed the efficacy, via percentage reduction, of four nonaqueous technologies to decontaminate particulate contamination, at three operational temperatures, from three starting challenges. Testing was conducted by CRREL personnel according to protocols developed in conjunction with the Homeland Defense/Civil Support Office Maneuver Support Center of Excellence and the Armed Forces Radiobiology Research Institute (AFRRI) and approved by Joint Program Executive Office CBRN Protection. CRREL subsequently collected data and conducted statistical measures of significance and explored additional questions about the technology capabilities. CRREL personnel then deployed with AFRRI support to Arctic Eagle/Patriot 22 (AE/P-22) for field testing of the technologies and their evaluation from an operational perspective. AE/P-22 allowed for direct, full-scale testing of the technology in conditions approximating a use-case scenario. This report documents the culmination of analysis performed on CRREL- and AFRRI-collected test data results, operational factors, and user inputs.

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Preface

This study was conducted for the Joint Program Executive Office CBRN Protection, under MIPR 11743123.

The work was performed by the Engineering Resources Branch of the Research and Engineering Division, US Army Engineer Research and Development Center, Cold Regions Research and Engineering Laboratory (ERDC-CRREL). At the time of publication of this report, Dr. Melisa Nallar was branch chief; Dr. Caitlin A. Callaghan was division chief; and Mr. David Ringelberg was the technical director for Cold Regions Science and Engineering. The acting deputy director of ERDC-CRREL was Dr. Ivan P. Beckman, and the director was Dr. Joseph L. Corriveau.

COL Christian Patterson was the commander of ERDC, and Dr. David W. Pittman was the director.

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1 Introduction

1.1 Background

A situation where chemical, biological, radiological, or nuclear agents are released into the environment is considered a chemical, biological, radiological, and nuclear (CBRN) incident. Domestic and foreign threats and hazards range from an accidental or intentional release of hazardous particulates into the air during an industrial accident, a terrorist CBRN weapon, or adversary employment of a dusty chemical agent. CBRN incidents are a serious threat to the military forces and civilians in the operating environment. While defense and prevention are key, attention also needs to be given to treatment and decontamination methods to be used if or when an incident does occur.

Casualties or patients will have contamination on their skin and clothing, as well as conventional wounds. Removal of the contamination should be accomplished as soon as possible and before admission into a clean treatment area. Current CBRN decontamination technologies for patients or casualties predominantly involve contamination removed by water. These water-based methods are effective, but they require significant logistic resources for transporting water, tanks, equipment, or sources of water on-site. In regions that experience subfreezing temperatures, water-based decontamination technologies will render additional operational challenges such as maintaining the liquid phase of the water and preventing hypothermia for the casualties.

With advances in dry decontamination technologies, there is a potential to expand the range of temperatures at which decontamination can be safely and effectively conducted while reducing the amount of waste from the decontamination process. Companies have recently developed wipes, sprays, and vacuum systems that neutralize and remove contaminants. The adoption of a successful dry decontamination technology would reduce capability gaps in this area. Based on the known risk profile in cold conditions where dry decontamination methods are necessary, we are especially interested in the development of decontamination technologies for use with radiological particles and dry, dusty chemicals.

1.2 Objective

1.2.1 Overall

The personnel dry decontamination experiment assessed available technologies to determine the viability of nonaqueous capabilities for personnel decontamination of particles (i.e., radiological, dusty chemical, toxic industrial material) contamination. The results will provide future commanders the flexibility to make risk-informed decisions on the mitigation of residual CBRN contamination while reducing the logistical burden and increasing responsiveness. This project provides analytical data to the next-generation personnel decontamination in concert with the Defense Threat Reduction Agency and the US Army Combat Capabilities Development Command, Chemical Biological Center's conventional chemical warfare agent personnel dry decontamination capability development. Information leads to mass casualty/patient decontamination modernization with possible increased flow and output, reduced personnel and logistical burden, and provision of flexible contamination mitigation capability independent of hazards and environmental conditions.

The Cold Regions Research and Engineering Laboratory (CRREL) provides Joint Project Managers (JPM) CBRN Protection with independent performance data of nonaqueous decontamination technologies at a range of temperatures, with emphasis on cryosphere applications where wet decontamination technologies are not effective for use on humans, including both ambulatory and nonambulatory casualties. CRREL staff performed experiments to decontaminate simulated human flesh (dead-pig skin), contaminated with a radiological simulant (nonradioactive material simulating its adhesion to the skin), utilizing a range of customer-selected decontamination technologies. The final laboratory data were analyzed with the results used to select the decontamination technologies to be administered during the field operational assessment (Phase 3) performed by Uniformed Service Personnel but observed by CRREL at Arctic Eagle/Patriot 22 (AE/P-22) in Anchorage, Alaska.

1.2.2 Laboratory Analysis

The project team assessed the viability of four nonaqueous technologies to decontaminate particulate (i.e., radiological, toxic industrial materials, and dusty chemical agents) contamination, at three operational

temperatures, from three starting challenges, to determine the percent reduction of contamination.

CRREL tested four technologies (i.e., isopropyl wipe, FiberTect wipe, containment spray with high-efficiency particulate air [HEPA] vacuum, and another HEPA vacuum), at three operational temperatures (64°F, 35°F, and 5°F [average temperature of Alaska in the winter]), from three starting challenges (levels of potential contamination on pig skin) to determine percent reduction.

CRREL evaluated data from these tests and identified the best-performing technologies based on contamination removal and ease of use. Supplemental constant temperature tests were performed on the two technologies with the best performance metrics (FiberTect wipes and the existing HEPA vacuum). These tests included larger pig skins and an assessment of the contaminant's fate for each technology and provided additional data before AE/P-22.

1.2.3 Operational Assessment at Arctic Eagle/Patriot 22 (AE/P-22)

The project team assessed the technologies through hands-on utilization of established dry decontamination procedures for casualties with the user (i.e., operator and role players) feedback and operational analysis (e.g., ease of use; ability to perform tasks to standard; protection of victims and casualties from further contamination, exposure, or injury; logistical impact; the amount of waste produced; impact on personnel; and comparison to wet method) through observer.

At AE/P-22, CRREL collected operational data for evaluation to determine the feasibility of technologies to meet mission task standards and analyze user feedback to provide recommended revisions of procedures and equipment.

Reduction of contamination and decontamination of casualties within a set time are key performance standards during the mass casualty decontamination process. Nonambulatory casualties must have their

decontamination completed in 9 min* or fewer, and an ambulatory casualty performing self-decontamination must be able to finish in 3 min or fewer. A key objective of analysis from the output of this testing is to determine if these standards can be met by dry decontamination technologies. JPM CBRN Protection provided the test protocols because each product had an associated manufacturer-developed application method. A test plan was drafted to ensure JPM CBRN Protection's identified protocols were followed, and the plan was implemented and monitored by the Homeland Defense/Civil Support Office, Maneuver Support Center of Excellence, personnel for correct application. An additional protocol for the field tests was also developed under which the tests at AE/P-22 by uniformed service personnel were observed and monitored.

With data collection at AE/P-22, the primary objective was to assess operational factors. These included the ease of use of the test articles and the processing time required per role player subjected to simulated decontamination. The efficacy of the technologies for the full field trial was evaluated during the exercise, but only as a confirmatory measure. The laboratory testing for phase two was considered the primary statistical determinant. Operational factors were judged by timing throughput with the two technologies, operator assessments, and role-player assessments.

During operational testing, the standardized methods for using the technologies were not ubiquitously employed. Instead, the uniformed service personnel (both operators and role players) sought the best operational flow, improvised on patterns of use and configuration of materials for the technologies, and experimented with combinations of the two technologies being used together. CRREL and Armed Forces Radiobiology Research Institute (AFRRI) personnel collected data in careful coordination with uniform service personnel to guarantee that the data for each different configuration were separated so that the relative performance of the different schemes of use could be compared, within the limits of the data collected.

* For a full list of the spelled-out forms of the units of measure and unit conversions used in this document, please refer to *US Government Publishing Office Style Manual*, 31st ed. (Washington, DC: US Government Publishing Office 2016), 248–52 and 345–7, respectively. https://www.govinfo.gov/content/pkg/GPO-STYLEMANUAL-2016/pdf/GPO-STYLEMANUAL-2016.pdf.

After the completion of the field exercise, all collected data were postprocessed and analyzed. The final project outcome is the supporting conclusions and observations based on these tabulated results, provided in the conclusions section (Chapter 5 Conclusions) of this document. Phases 2 and 3, the laboratory and field exercise results, should be considered in combination when reviewing the final assessment of the technology and recommendations for the path forward in developing this capability; one does not supersede the other. The laboratory testing was more controlled while the field exercise focused more on demonstrating operational knowledge on the feasibility of employing these technologies in CBRN mass casualty decontamination.

1.3 Approach

This project provides an independent analysis of dry decontamination technologies being developed for Joint Program Executive Office CBRN Protection (JPEO-CBRND). It provides analytical data for the next-generation personnel decontamination to mitigate current operational gaps in support of casualty and patient decontamination of particulate contamination. The CRREL and the AFRRI supported the evaluation of these technologies with a laboratory experiment in Phase two (after initial bench-scale warm tests conducted elsewhere as Phase I), including analysis and writeup of results and the phase three field trials involving a joint CRREL-AFRRI team sent to AE/P-22 to observe and record performance of the equipment during the field training exercise. The outcome of testing at the CRREL laboratory during the initial phase, as well as supplemental follow-up testing based on observations from the first phase, is documented in Sections 3.2, 3.3, and 3.4. The final results from Phase 3 testing (exercise field trials), including considerations of efficacy but primarily focused on operational factors, are incorporated in Section 5.

Other organizations involved in the community of interest includes US Northern Command (USNORTHCOM), National Guard Bureau (NGB), National Guard New England Enhanced Response Force Package (CERF-P), US Army North (USARNORTH), US Army Nuclear and Countering Weapons of Mass Destruction Agency, Joint Task Force–Civil Support (JTF-CS), US Marine Corps Chemical Biological Incident Response Force (USMC CBIRF), US Army 95th CBRN Company, and the Department of Energy (DoE).

2 Review of Technologies

2.1 Chemical, Biological, Radiological (CBR) M2DCON Multipurpose Decontamination Wipe

This technology is an alcohol solution-based, nonwoven polymeric wipe produced by M2DCON, Inc (Brook Park, Ohio, USA). The company states the alcohol-based formula in the wipe contains components that enhance the contamination dissolution by the alcohol and allows for the removal of many contaminate types.

2.2 First-Line Technology FiberTect Wipe

This technology is a nonwoven, composite wipe with activated carbon produced by First Line Technology (Chantilly, Virginia, USA). The company states that the wipe has adsorbing and absorbing capabilities for removing several different types of contaminants. This wipe is normally used with the Dahlgren Deco spray applied to it immediately before use; however, performance without the spray was evaluated in the second phase of testing. This decision was based on results from Phase 2 laboratory testing and field logistics for acquiring Dahlgren Decon spray.

2.3 SX34 Waterless Decontamination Spray and Vacuum

This technology is a powder spray-on produced by Cristanini SpA (Veronese, Italy) and distributed by ITL Solutions (Hampton, Virginia, USA). According to the company, the SX34 extracts contaminants from a material's surface due to a solvent-cosolvent system in the spray that allows for easy removal by a brush or vacuum. Requires a brush or vacuum to remove spray from the surface

2.4 High-Efficiency Particulate Air (HEPA) Vacuum

This technology is a preexisting standard HEPA vacuum produced by NIKRO Industries, Inc. (Villa Park, Illinois, USA) being used for CBRN testing. The vacuum has the following specifications:

- Product Name: Back-Pak HEPA Vacuum (dry)
- Product Number: BP00288
- HEPA Filter 99.97% @ 0.3 μ
- 1.25 hp motor; 95 cfm; 88 in. waterlift

- 2.5 gal capacity
- Weight 16 lb

All technologies were tested in Phase 2. In Phase 3, only FiberTect wipes and HEPA vacuums were tested. The SX34 and chemical, biological, radiological (CBR) M2DCON were excluded before Phase 3 and not subjected to the operational evaluation. The reasons for this determination are discussed in Section 3, in addition with the decision to proceed with FiberTect testing without the associate Dahlgren Decon spray.

3 Laboratory Assessment

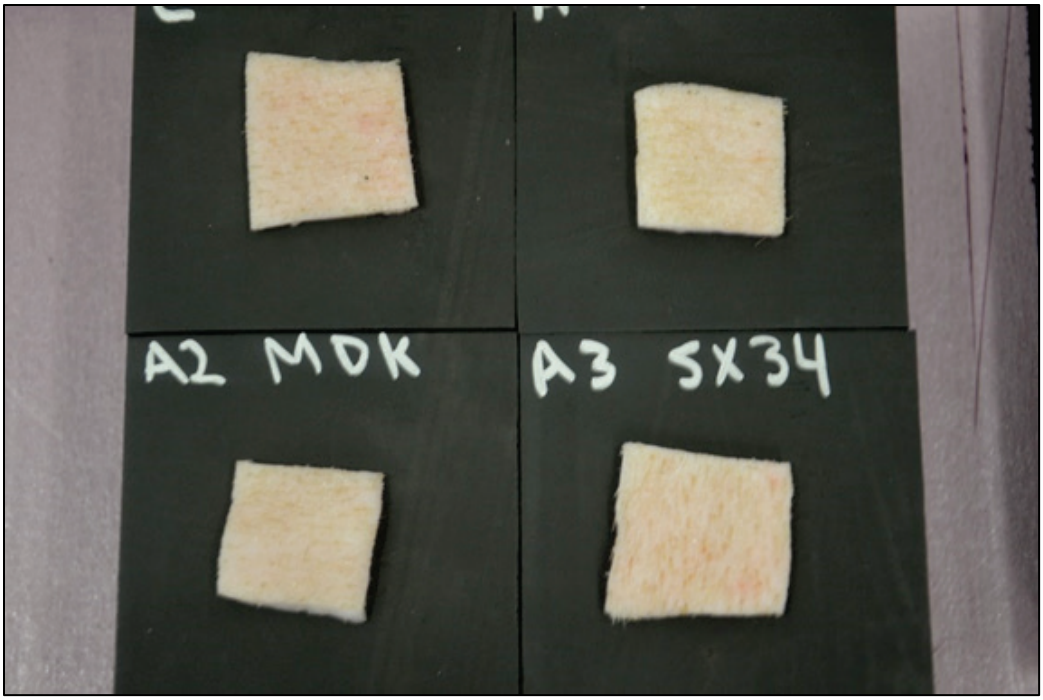
3.1 Test Plan—Laboratory Testing

3.1.1 Laboratory Assessment with 1 × 1 in. Pig Skins

The Phase 2 test plan was developed to provide actionable information for procurement decisions. Three temperatures were selected for analysis. These were a typical warm temperature, 64°F; the temperature which current recommendations treat as the threshold for wet decontamination, 35°F; and a temperature which represents the extreme cold for the northern contiguous United States regions and a typical winter temperature for Alaska and northern Canada, 5°F. Three concentrations of simulant were used, developed from literature sources and preliminary laboratory testing of the technologies in project Phase 1 (not discussed in this report). Simulant starting concentrations were 2, 5, and 10 g/m^2. Finally, particle characterization was used to determine the percent reduction of simulant to analyze the efficacy of the different technologies.

The stimulant used in this study was Fisher Scientific Silica Gel Desiccant 28–200 mesh, Grade 12 (Fisher Scientific, Pittsburgh, Pennsylvania, USA). The particle size distribution of the silica gel accurately represents expected radiological dust particles that may be encountered during a CBRN event. The 1 × 1 in. pigskins acquired from Lampire Biological Laboratory (Pipersville, Pennsylvania, USA) were used as the contamination medium, shown in Figure 1. Pig skins are a good surrogate for human skin because they are similar in moisture, oil, and hair content. A SciAps XRFS X-250 (Woburn, Massachusetts, USA) was used to detect the simulant on the skin and assess the performance of the decontamination technology. The X-ray fluorescence (XRF) analyzer can detect the silica in the silica gel and provide an accurate assessment of percent coverage. Photos of the postdecontamination skin were collected at 75× magnification using a camera mounted on a dissecting microscope. These photos were collected as a second layer of data but were not used in the analysis because the XRF analyzer was sufficient for the decontamination assessment. An analysis of particle size distribution of postdecontamination simulant was attempted but unsuccessful due to the small volume of stimulant used.

Figure 1. Image of 1 × 1 in. sample pig skin.



3.1.1.1 Measures of Merit

The following three measures of merit were used to evaluate the various decon technologies:

1. Temperature performance
   a. 64°F
   b. 35°F
   c. 5°F
2. Concentration of simulant
   a. 10 g/m^2
   b. 5 g/m^2
   c. 2 g/m^2
3. Particle characterization
   a. XRF analysis

3.1.1.2 Protocol

The following protocol was executed for the evaluation of each decon technology:

1. Thaw the frozen pig skin and test within the next 30 min.
2. Scan the pig skin with XRF to establish a baseline of silica.
3. Contaminate the pig skin with simulant at the desired concentration.
4. Scan the pig skin with XRF in three locations to establish predecontamination percentage silicon.
5. Decontaminate the pig skin with dry decontamination product following the manufacturer's procedure.
6. Scan the pig skin with XRF in three locations to determine the amount removed.
7. Collect three images of the pig skin using a camera on a microscope.

This protocol was used for all temperature conditions and simulant concentrations. For the subfreezing temperature conditions, the pig skins were kept at 64°F until ready for testing to keep them from freezing. The XRF analysis proved to be an effective method for assessing the decontamination technologies, and the microscope images were not analyzed. The remainder of the laboratory analysis focuses on the XRF results. The performance results and user feedback (from the research team) on operation feasibility from laboratory testing were used to select the two technologies to be used in the operational assessment at AE/P-22.

3.1.2 Laboratory Assessment with 3 × 7 in. Pig Skins

During the first round of testing, it was determined that the 1 × 1 in. pig skins were not large enough to assess how the simulant may accumulate on the skin when using the wipe technologies. Additionally, the vacuum technologies pulled the 1 × 1 in. pig skin off the sample board in a way that would not be observed in field operations (similar to an article of clothing being pulled into a vacuum). The skins were held in place with a clamp to keep them from being entirely pulled into the vacuum. The second round of testing was conducted using 3 × 7 in. pig skins to assess how the simulant may accumulate on the skin during wiping, and they were secured to eliminate the pulling effect of the vacuum. This allowed them to better represent the skin of a forearm or leg. This round of testing assessed the FiberTect wipes and the HEPA vacuum because these were the best performers from the first lab tests and were to be used in the operational assessment at AE/P-22. Round two of testing also compared FiberTect wipes with and without the Dahlgren Decon spray. The cold temperatures did not impact the performance of the technologies during the cold chamber testing; therefore, round two of testing was only performed at 64°F, and a simulant concentration of 5 g/m^2 was used. A metal sampling

plate with catchment trays was developed to secure the pig skin and collect simulant during decontamination (Figure 2, Figure 3, and Figure 4).

The following is a list of the assessment goals:

1. Assess the fate of the simulant during decontamination.
2. Assess the accumulation of simulant during wiping.
3. Secure the pig skin for the HEPA vacuum assessment.
4. Assess the impact of the Dahlgren Decon spray with the FiberTect wipes.

Figure 2. Sampling rig, including collection trays for 3 × 7 in. pig skin.

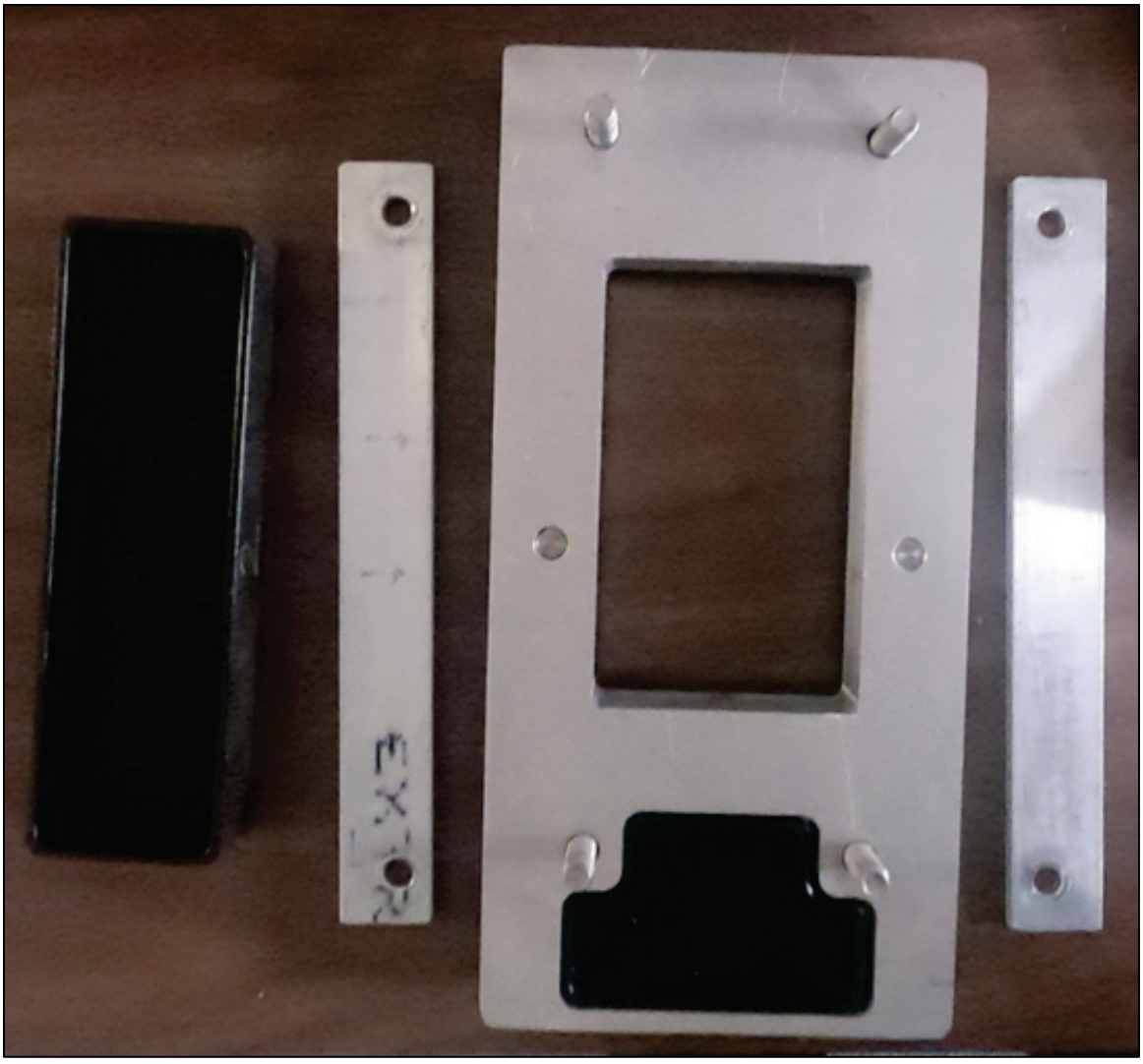


Figure 3. Sampling rig showing configuration with pig skin (nonrepresentative sample shown) for first stroke with FiberTect wipes.

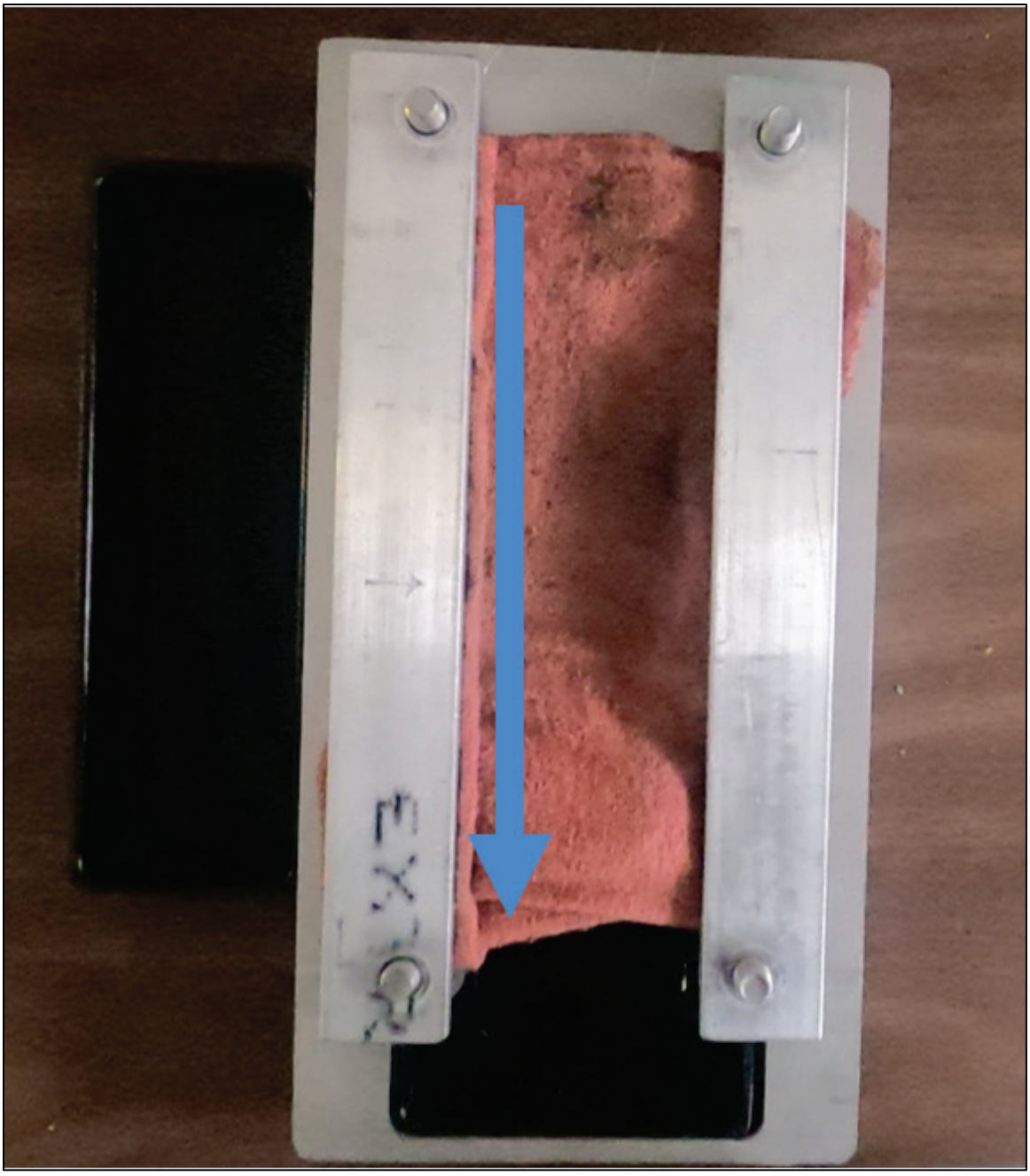
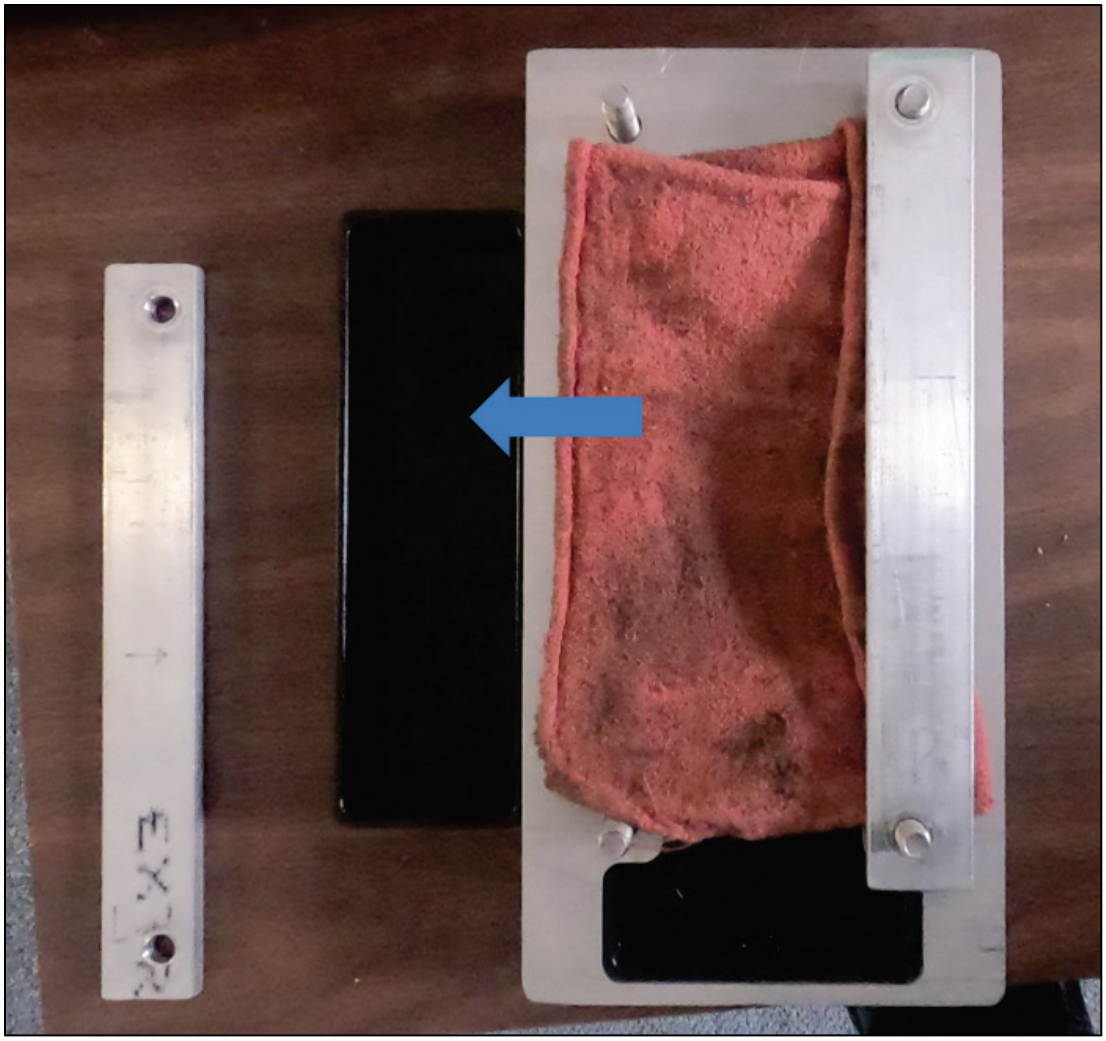


Figure 4. Sampling rig showing a configuration with pig skin for the second stroke with FiberTect wipes.



3.2 Results

3.2.1 Laboratory Assessment with 1 × 1 in. Pig Skins

Overall, the performance of all dry decontamination technologies assessed was not impacted by ambient temperature down to 5°F (Table 1). This was a key finding for this study as the temperature is the driving factor behind the need for dry decontamination. Once the decision is made to use dry decontamination technology below 35°F, it is important these technologies should all perform as expected down to 5°F. Additional testing below 5°F is required to determine their viability in an extremely cold environment. The difference in overall performance by technology is detailed below.

Table 1. Efficacy of decontamination technologies as a function of temperature for each starting simulant concentration. *Predecon* and *Postdecon* are the XRF measurement values for the simulant. Percent reduction is the portion of simulant that was removed with the technology. Values are an average of two replicates.

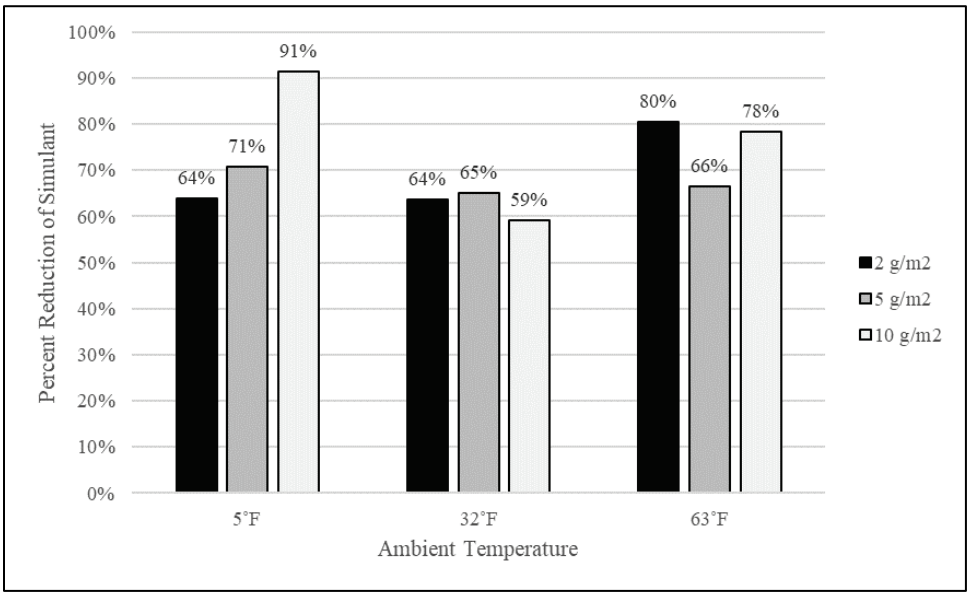
		Simulant Concentration								
		2 g/m²			5 g/m²			10 g/m²		
Technology	Temperature	Predecon*	Postdecon	% Reduction	Predecon	Postdecon	% Reduction	Predecon	Postdecon	% Reduction
CBR M2DCON	5°F	27.4	9.5	64%	51.5	15.1	71%	77.6	6.4	91%
	32°F	30.3	6.7	64%	47.9	17.0	65%	66.3	27.2	59%
	63°F	26.2	5.5	80%	40.5	14.8	66%	63.1	13.5	78%
FiberTect Wipe	5°F	24.0	4.6	83%	45.2	3.0	93%	64.8	3.9	94%
	32°F	28.7	4.7	87%	53.3	4.1	92%	63.2	9.1	87%
	63°F	25.5	3.9	89%	42.7	9.4	78%	73.3	4.0	95%
SX34 Spray and Vacuum	5°F	27.7	34.0	n/a	55.9	41.1	25%	62.1	41.8	31%
	32°F	58.2	40.4	31%	58.2	50.3	14%	69.0	35.8	48%
	63°F	48.6	38.9	23%	50.3	42.0	15%	58.3	43.7	24%
HEPA Vacuum	5°F	30.2	5.1	87%	59.1	5.4	91%	62.5	6.4	90%
	32°F	24.5	4.1	84%	51.9	6.2	81%	55.1	3.2	94%
	63°F	24.0	6.5	73%	53.7	3.0	95%	62.5	2.7	96%

*Predecon = Predecontamination; Postdecon = Postdecontamination.

3.2.1.1 Chemical, Biological, Radiological M2DCON Multipurpose Decontamination Wipe

This technology was the third-best performer with a percent removal range of 59%–91% (Figure 5). The project team found that this technology was easy to use and the directions were simple to follow. However, there were concerns with how well the wipe held the simulant as opposed to pushing it onto the floor or accumulating on the skin at the end of the wipe action. This technology was not recommended for the field trials at AE/P-22 due to its lower performance range.

Figure 5. M2DCON technology percent reduction of simulant for each ambient testing temperature and starting simulant concentration.

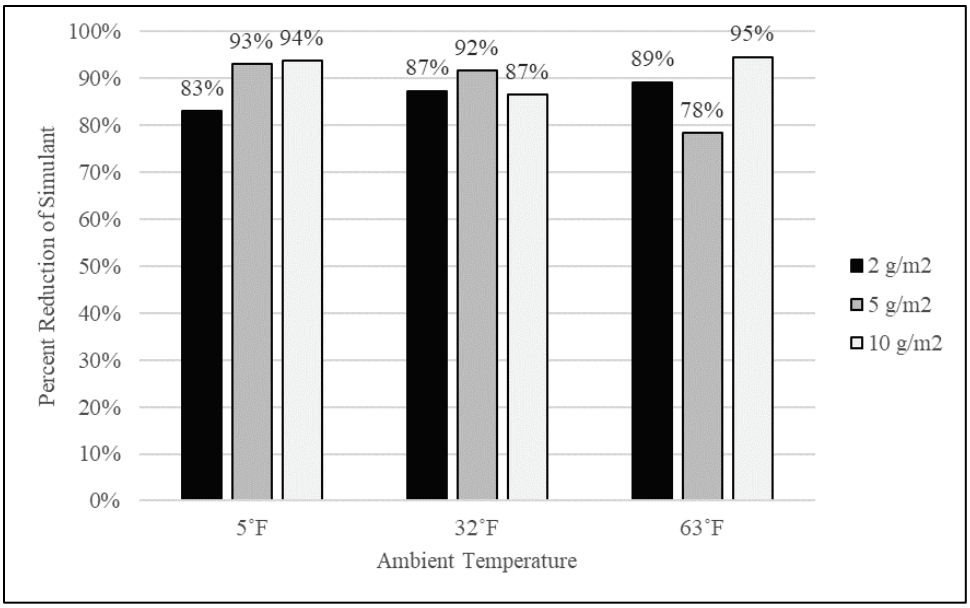


3.2.1.2 First-Line Technology FiberTect Wipe with Dahlgren Decon Spray

This was the top performer during the laboratory assessment with a percent removal range of 78%–95% (Figure 6). The project team found this technology easy to use, and the directions were simple to follow. The FiberTect wipe appeared to hold a majority of the simulant, reducing the amount that may fall to the floor or accumulate on the skin at the end of the wipe action. There was concern over the use of the Dahlgren Decon spray regarding the potential for wet skin exposure to cold ambient temperature and the logistics of shipping the spray to mass casualty decontamination sites. Additional testing of the FiberTect wipes with and without the Dahlgren Decon spray found that the spray did not impact performance. This technology was recommended (without the Dahlgren

Decon spray) for the operational assessment at AE/P-22 due to its high-performance range and ease of use.

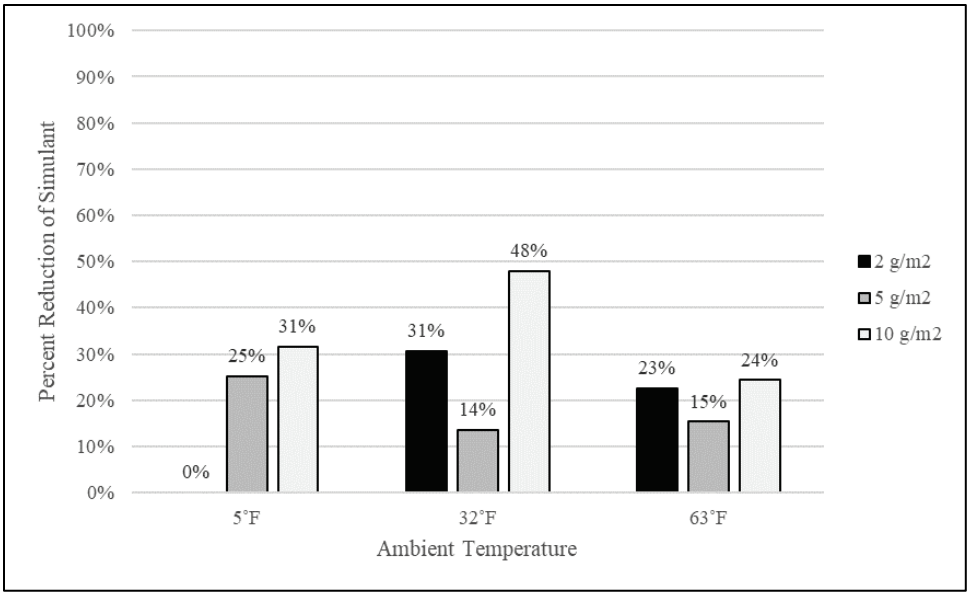
Figure 6. FiberTect wipes technology percent reduction of simulant for each ambient testing temperature and starting simulant concentration.



3.2.1.3 SX34 Waterless Decontamination Spray and High-Efficiency Particulate Air (HEPA) Vacuum

This technology had the lowest percent removal range of 11%–48% (Figure 7). These low removal rates were attributed to the powder spray influencing the analysis. After decontamination with the powder spray and vacuum, a significant amount of the spray is left behind. The spray likely had silica or another element that biased the XRF. This was verified using control skin with spray and no simulant that had XRF reading in the 10%–30% range. The spray is white when it dries, which reduced the contrast between the pig skin and the silica gel, which made it difficult to analyze via microscope. Note that the performance analysis for this technology is likely not accurate. The project team found the technology to be time consuming due to the dry times of the spray, which could take up to 5 min at 5°F. This would significantly slow down the decontamination processing line and put the casualties at risk of wet-skin exposure to cold temperatures. The project team found the instructions to be more complicated, and the vacuum did not appear as powerful as the NIKRO HEPA vacuum. This technology was not recommended for the field trials at AE/P-22 due to its dry times and more intricate methodology.

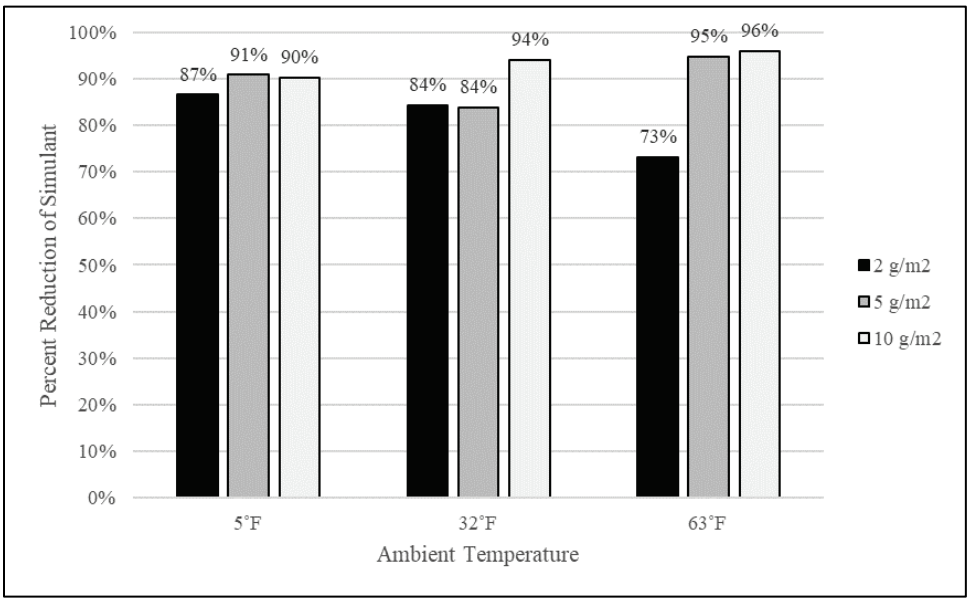
Figure 7. SX34 spray and vacuum technology percent reduction of simulant for each ambient testing temperature and starting simulant concentration. The value of 0% represents an event where the percent reduction was a negative value (see Table 1).



3.2.1.4 NIKRO HEPA Vacuum

Preexisting standard NIKRO HEPA vacuum technology was the second-highest performer with a percent removal range of 73%–96% (Figure 8). The research team found this technology to be easy to use, and the instructions were simple to follow. This technology was recommended for the field trials at AE/P-22 due to its high performance and ease of use.

Figure 8. NIKRO high-efficiency particulate air (HEPA) vacuum technology percent reduction of simulant for each ambient testing temperature and starting simulant concentration.



The SX34 spray and vacuum showed the lowest performance, and results were very inconsistent. This was attributed to potential elements in the spray influencing the XRF readings. For these reasons, this technology was removed from further statistical analyses.

Analysis of variance (ANOVA) was used to compare performance across the M2Decon, FiberTect wipes, and HEPA vacuum. The ANOVA compared the means and variance from the percent reduction data to determine if one or more groups are significantly different from the full population (or dataset). If the ANOVA showed a significant difference, posthoc Tukey's *t*-test was used to compare between groups. Conducting the ANOVA before the posthoc *t*-test increases the statistical power of the analyses and reduces type II error (false negative). For each test temperature and simulant concentration, there were two replicates, which limited the viability of statistically comparing the results from each testing temperature. Observationally, the temperature did consistently not impact the performance of any technology down to 5˚F (Table 1). Therefore, the temperature was removed, as a categorical variable and the data were grouped by technology and simulant concentrations.

For the 2 g/m^2 simulant concentration group, the ANOVA found there was not a significant difference in percent reduction across groups (p-value = 0.22, n = 18). For the 5 g/m^2 simulant concentration group, the ANOVA found there was a significant difference in performance across technologies (p-value = 0.007, n = 18). Posthoc analyses found that M2DCON had a significantly lower performance compared to the FiberTect wipes (p-value = 0.014) and the HEPA vacuum (p-value = 0.009). The FiberTect wipes and HEPA vacuum performance were not significantly different (p-value = 0.74). For the 10 g/m^2 simulant concentration group, the ANOVA found a significant difference in performance across technologies (p-value = 0.022, n = 18). Posthoc analyses found that M2DCON had a significantly lower performance compared to the HEPA vacuum (p-value = 0.024) but did not have a significantly different performance compared to the FiberTect wipes (p-value = 0.056). The FiberTect wipes and HEPA vacuum performance were not significantly different (p-value = 0.74).

3.2.2 Laboratory Assessment with 3 × 7 in. Pig Skins

The second round of laboratory testing focused on answering specific questions regarding the relative performance of the HEPA vacuum and the

FiberTect wipes, both with and without the standard Dahlgren Decon spray that manufacturer recommendations direct should be applied immediately before the decontamination process. A constant simulant density of 5 g/m^2 was used in the testing during the second phase, at a constant room temperature since the first round of laboratory testing had provided high confidence to rule out a temperature-driven impact on the performance of the dry decontamination technologies.

XRF and visual were the evaluation methods used in this phase. The graphs are coded as follows:

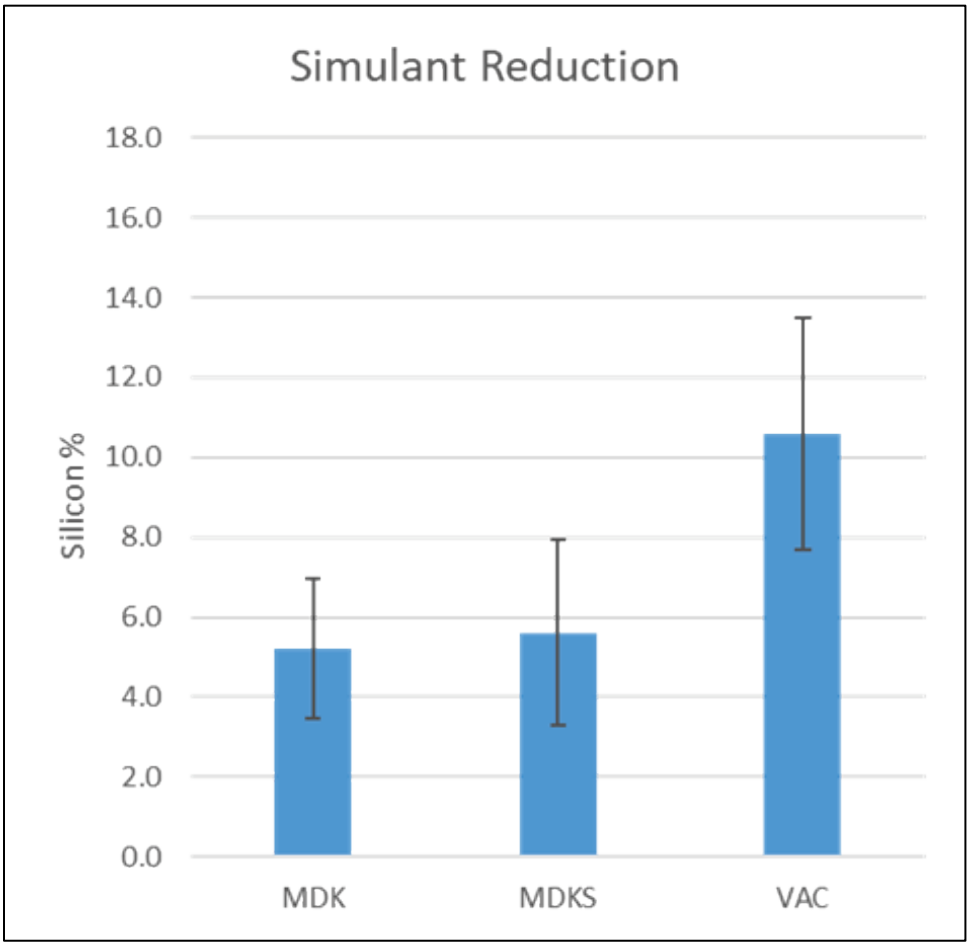
- Decontamination technology
    - FiberTect wipes (MDK)
    - FiberTect wipes with Dahlgren Decon spray (MDKS)
    - HEPA vacuum (VAC)

The objective of the analysis is to compare the performance of the technologies both in decontamination of the sample skin and in the success of the technology in capturing and containing the decontaminant rather than merely spreading it from the contaminated person into the local environment.

The results for the 3 × 7 in. pig-skin analysis showed no significant difference in decontamination performance between the FiberTect wipes with and without the spray. However, the HEPA vacuum performed better than the MDK (*p*-value less than 0.05) and MDKS (p-value less than 0.05). It was difficult to quantify the amount of simulant in the catchment trays due to the small starting quantity. Observationally, there appeared to be a difference in the performance of the technologies when considering the mass balance in the local environment. The FiberTect wipes used without the Dahlgren Decon spray transferred noticeably more contaminant into the local environment instead of successfully containing it within the wipe for disposal. With the Dahlgren Decon spray, the FiberTect wipes performed similarly to the HEPA vacuum in terms of both decontamination and the successful capture of the contaminant. These results indicate that the FiberTect wipes can be used without the Dahlgren Decon spray to successfully decontaminate a subject with equal statistical confidence to the wipes with the spray and the HEPA vacuum (Figure 9). The FiberTect wipes without the spray will

likely transfer more of the contaminants into the local environment instead of successfully containing it for disposal; however, a more robust assessment is required to quantify the amount of contaminant transfer.

Figure 9. XRF data, silicon percent reduction for each decontamination technology, with a *p*-value less than 0.05 to infer statistical significance.



3.3 Discussion

The goals of the lab testing at CRREL were to determine if cold weather influences the performance of the decontamination technologies and to compare the performance between the technologies. Due to a low number of replicates, this study was not able to make statistical inferences on how temperature impacted performance. Observationally, it was determined that the ambient temperature did not impact the performance of any of the technologies down to 5°F (Table 1). This is a promising indication that dry decontamination technologies may be a viable alternative to wet decontamination options in extremely cold environments.

By comparing the performance of each decontamination technology, this study found that the FiberTect wipes and the HEPA vacuum were the best overall performers with high statistical confidence. The SX34 spray and vacuum showed inconsistent results most likely due to the spray biasing the XRF reading. However, the length of time to conduct this method and the complicated directions provided additional justification to not move forward with this technology. The M2DCON had comparable performance to the FiberTect wipes and HEPA vacuum at lower simulant concentrations but had a significantly lower performance at the medium and higher concentrations. Therefore, the FiberTect wipes and HEPA vacuum were recommended to move forward to the next phase of lab testing with the larger pig skins and to be used for AE/P-22 operational assessment.

With the second round of Phase 2 testing using larger skin samples and testing the use of Dahlgren Decon spray or its absence, the results confirmed the performance of the FiberTect wipes and the HEPA vacuum as being essentially equivalent and favorable for utilization. The use of the Dahlgren Decon spray or its absence did not have a statistically significant impact on the performance of the FiberTect wipes in terms of percent reduction of contaminant on the subject. However, the Dahlgren Decon spray did significantly improve the retention of the contaminant into the wipe, making it comparable to the HEPA vacuum. Without the spray, the wipes underperformed the vacuum at preventing this secondary contamination, based on visual observation. The difference was enough that it is likely the use of the FiberTect wipes without the Dahlgren Decon spray would result in a noticeable increase in contaminant levels in the decontamination line.

3.4 Decimation

Data from the laboratory testing were used to determine the final configuration of the field exercise evaluations, including the technologies to be brought forward to the field exercise. Laboratory results made clear that the FiberTect wipes and HEPA vacuum were the two preferred technologies to bring forward for the field exercise. Significant gaps in the performance of the M2DCON and SX34 existed in terms of effectiveness, ease of use, and ability to complete decontamination procedures within a timeframe comparable to that required for the 3 min decontamination standard per ambulatory and 9 min decontamination per nonambulatory casualty. While these gaps might be remedied in the future by procedural

or technical changes, with the focus on rapid fielding of validated technologies after evaluating the outcome of the field exercise, and with the limitation of the field exercise format in terms of providing effectiveness data, as opposed to operational, it was necessary to proceed with the two most effective technologies in the laboratory scale testing.

During the field exercise, exercise planners made the decision not to incorporate the Dahlgren spray in the evaluation of the FiberTect wipes. The spray was not cleared for use on human skin, and the exercise planners could not find a suitable means of testing it within these limitations. Additionally, because the laboratory testing had evaluated the decontamination performance of the FiberTect wipes as equal with and without the Dahlgren Decon spray, the majority of the testing would take place dry. In an actual use-case scenario, this would potentially spread additional contaminants into the local environment, but for the field exercise, it was an adequate trial.

4 Operational Assessment

4.1 Data Collection

The third phase was completed during exercise AE/P-22 at the Anchorage, Alaska, Fire Training Center.

This specific portion of the experiment involved joint operations between Alaskan Command, Joint Forces USMC CBIRF, National Guard New England CBRN CERF-P, US Army 95th CBRN Company, as well as associated Canadian units, Federal Emergency Management Agency (FEMA) TF1, and state and local police and fire personnel including the Alaska State Police, Anchorage Fire Department, and Anchorage Police Department. Additionally, personnel from the following agencies observed and provided analysis data: USNORTHCOM, NGB, JPEO-CBRND, JTF-CS, USARNORTH, DoE, FEMA, Office of the Surgeon General, and Army Public Health Command–Radiological Advisory Medical Teams. The USMC CBIRF, National Guard New England CERF-P, and 95th CBRN Company conducted hands-on utilization of the technologies and procedures at the Anchorage Fire Training Center with CRREL and AFRRI collecting operational data, user feedback, and role-player feedback. CRREL and AFRRI collected operational data for evaluation to determine the feasibility of technologies to meet mission task standards and analyze user feedback to provide recommended revisions of procedures and equipment.

4.1.1 Measures of Merit—Field Exercise

The measures of merit were changed from the laboratory exercise. The temperature had already successfully been excluded as a variable in the performance of the dry decontamination technologies. Concentration could not be reliably conducted in the field environment. Particle characterization was limited to visual analysis of contaminated surfaces through photography.

The primary goal for this portion of the study was to evaluate and compare the operational feasibility of the FiberTect wipes and the HEPA vacuum.

The first measurement of merit was the qualitative assessment by the operators and role players. Note that the role players performed self-decontamination with some technologies, in some configurations, so their

input was necessary to have a full understanding of technology performance. Quantitative and qualitative assessments were conducted through standardized feedback forms on the technology.

The second measurement of merit was the average process time per person for ambulatory and nonambulatory decontamination cases. In measuring time, it is important to observe that batch processing of role players was conducted in the decontamination line. In the batch processing, multiple role players were being decontaminated at the same time, at the same step. This means that while the meantime for a role player to transit the decontamination line and be decontaminated successfully is important, the average calculated from the number of role players successfully decontaminated per hour is a more meaningful metric of the actual effectiveness of a decontamination line using that technology. In all cases, the times and averages were recorded and computed separately for ambulatory and nonambulatory.

The third method of evaluation was the effectiveness of the technology to remove simulant when performed in an operation at scale. Colored sand was used as the simulant for this portion of the study, and photography was used to evaluate the effectiveness of the decontamination technology to remove the simulant.

4.1.2 Exercise Test Execution

Uniformed service personnel from CBIRF, 95th CBRN, and National Guard CERF-P elements lead hands-on utilization of the technologies during the operational assessment and refined the techniques and procedures of use for the technology. Operators were able to innovate and improve upon the best techniques and procedures to use the technology during the assessment, assess its abilities and limitations, and provide recommendations for technology improvements.

The execution of the technology-usage assessment evaluated throughput and usability to meet mission task standards. Evaluation of field effectiveness was assessed as refinements to techniques and procedures. Actionable data were collected in all three categories. To compare the technologies, four basic configurations were evaluated:

1. FiberTect wipes with ambulatory role players
2. FiberTect wipes with nonambulatory role players

3. HEPA vacuum with ambulatory role players
4. HEPA vacuum with nonambulatory role players

Additionally, data were collected for two cases of interest to the uniformed service personnel representing the end-user community. In both cases, only ambulatory cases were evaluated:

1. Combo (FiberTect + HEPA vacuum)
2. FiberTect wipes, use on hands and feet only

The decontamination line was arranged atypically, without the normal decontamination tents, as a warm indoor space was available for the exercise. Role players were cycled through in a clockwise direction, following a standard pattern: Detect, Clothes Removal, Decontamination, Detect. This pattern is duplicated for both ambulatory and nonambulatory role players, but the nonambulatory cases were moved through on stretchers along a plastic support frame designed to facilitate elevated decontamination, with decontamination personnel lifting and rolling the simulated nonambulatory casualties to obtain complete physical decontamination.

Diagrams of the test layout during the demonstration are shown in Figure 10 through Figure 12. A selection of images taken during the exercise is provided in the following pages (Figure 13 through Figure 18). They illustrate the basic configuration of the decontamination line throughout the exercise. This configuration was not changed between tests of different technologies. The black containment matting served as the decontamination area. It was expected that role players should be fully *decontaminated* before leaving this area (Figure 14).

Figure 10. Diagram of the ambulatory and nonambulatory decontamination assembly at Arctic Eagle/Patriot 22 (AE/P-22).

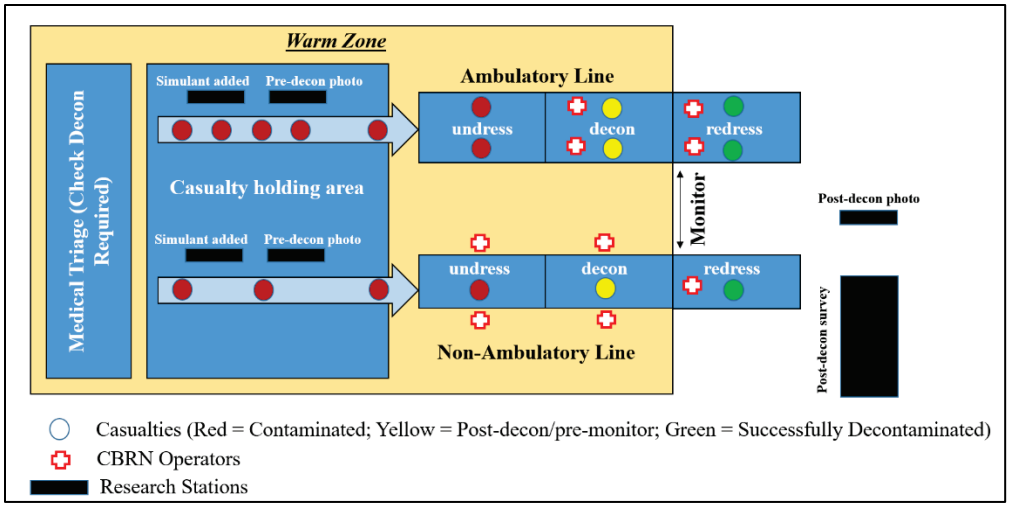


Figure 11. Diagram of the ambulatory decontamination assembly for the FiberTect wipes.

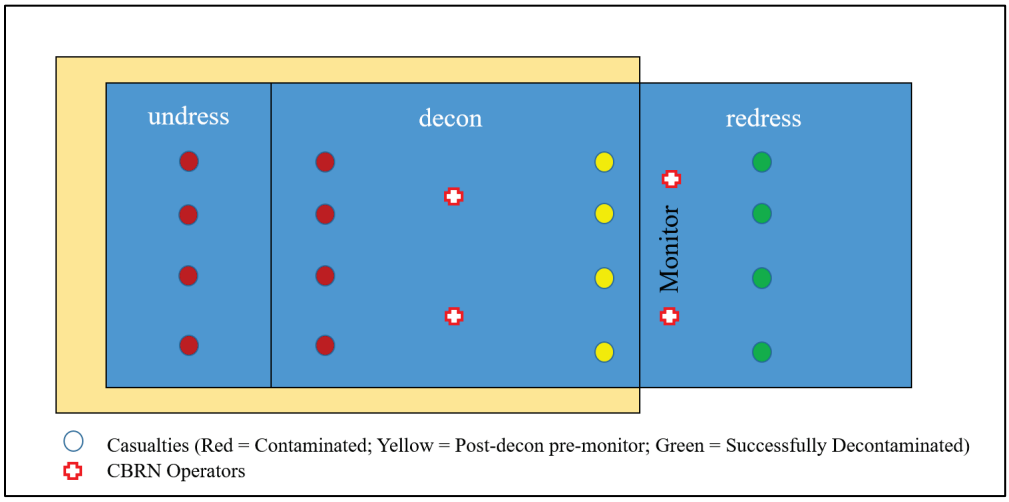


Figure 12. Diagram of the ambulatory decontamination assembly for the HEPA vacuum.

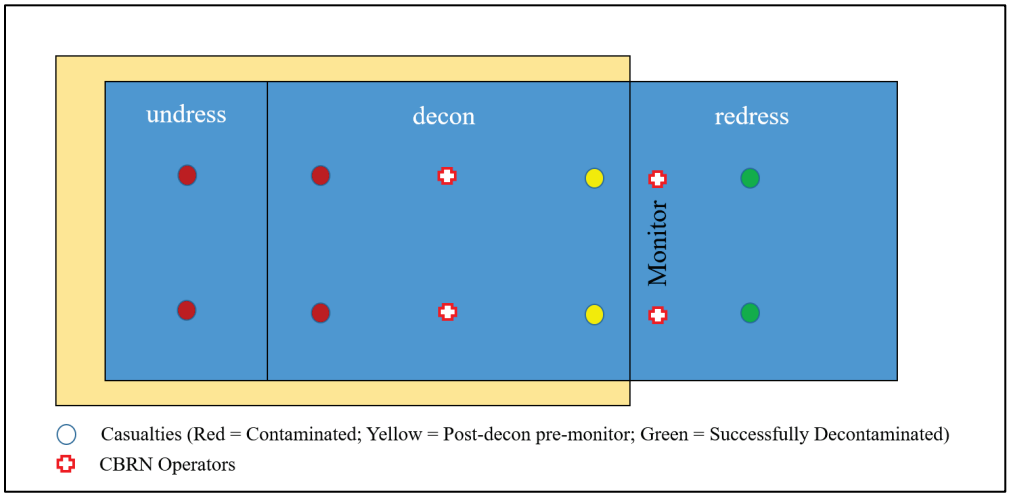


Figure 13. Demonstration of scanning technique for radiation detectors at AE/P-22, an activity that takes place at the beginning of the decontamination line where initial disrobing occurs.

Figure 14. View of the decontamination line from the *hot,* or approach, side at AE/P-22. Nonambulatory on the *right*, ambulatory on *left*. Wastebaskets are provided for disrobing contaminated garments.

Figure 15. The nonambulatory processing track, from the *clean* end, shows personnel setting up HEPA vacuums and preparing in protective suits at AE/P-22.

Figure 16. Photo of chemical, biological, radiological, and nuclear (CBRN) operators attending to the nonambulatory processing track at AE/P-22.

Figure 17. Photo of ambulatory role players being decontaminated by CBRN operators with the HEPA vacuum decontamination protocol at AE/P-22.

Figure 18. Photo of ambulatory role players being guided by CBRN operators on the FiberTect wipes decontamination protocol at AE/P-22.

4.1.3 Field Analytics and Observations

During AE/P-22, the technology was evaluated across 3 days of testing during the exercise at the Anchorage Fire Training Center. During the first 2 days, the primary comparison trials between FiberTect and HEPA vacuum decontamination of ambulatory and nonambulatory cases were conducted, with operator and role-player evaluations and performance assessments being conducted, as well as initial time trials. On the third day of the testing, a combination of both the FiberTect wipes being self-applied by role players and the use of the HEPA vacuum by the decontamination line personnel was tested, as well as an evaluation of throughput for the use of the wipes only. For the operational assessment, there were approximately 20–30 role players from various CERF-P units. Role players were dressed in mock clothing that was cut off in the undress section of the decontamination line for each assessment scenario. After processing through the decontamination line, role players were asked to obtain new clothing and recycle through the line to increase throughput.

4.1.3.1 Role-Player Questionnaire Methods

Role-player assessments focused on the relative performance of the FiberTect wipes vs. HEPA vacuum for ambulatory and nonambulatory cases. Ambulatory and nonambulatory cases were analyzed independently because the procedures and methodologies are substantially different. An assessment questionnaire was filled out by each role player immediately after completing the decontamination process (Appendix A). To increase throughput numbers, role players were asked to recycle through the decontamination process multiple times. Following each processing event, the role player filled out an assessment questionnaire. Technologies were rated independently on four metrics with four to five questions per metric (Appendix A). Answers were provided on a Likert scale of 1 = *strongly disagree* to 5 = *strongly agree* by the role players. The mean ratings for each question were statistically analyzed for performance and operational differences between the FiberTect wipes and the HEPA vacuum. The comparison of FiberTect wipes vs. HEPA vacuum was performed by the research team in postprocessing. This was done to avoid a subjective impact on the assessments during the field trials. The full questionnaire for role players can be found in Appendix A and the full questionnaire for operators can be found in Appendix B.

The following are the role player questionnaire metrics:

1. Simulant contamination effort
   a. Level of contamination on skin
2. Decontamination technology effectiveness
   a. Observational assessment of the tech to remove simulant
   b. Was the tech easy to use
3. Physical discomfort caused by the technology
   a. Was the skin irritated by the decontamination
   b. Did the tech decrease body temperature
4. Overall assessment of the technology
   a. Would you recommend this technology be used for future dry decontamination efforts

4.1.3.2 Role Player Assessment Results and Discussion

Results of this comparative analysis are presented below for each questionnaire section that had at least one statistically significant value; all other sections showed no statistical significance. Questions with statistically significant differences are presented with the mean response rating for each technology (e.g., if one decontamination technology caused discomfort, there would be a statistically significant difference in question 4.4 in Table 4, and the mean rating would indicate the least-comfortable technology).

The first comparative case is between FiberTect wipes and the HEPA vacuum in the case of use on ambulatory casualties. In this scenario, individuals who can walk through the decontamination line under their power were asked to self-decontaminate with the FiberTect wipes under the instruction of decontamination unit personnel. During the HEPA vacuum use, the decontamination unit personnel directly executed the decontamination of the individuals proceeding through the line.

The assessments indicate that the technologies were of equal effectiveness in terms of simulant removal and ease of use for ambulatory casualties. Users assessed the technologies as having no difference in the effective removal of simulant from any of the focus areas (hands, forearms) except

for the back of the ear (Assessment 2.3, Table 2). For the back of the ear, the HEPA vacuum showed better performance with a mean response value of 4.025 compared to the FiberTect wipes with a mean response value of 3.48 (Table 2). This was attributed to the difficulty of using the folded FiberTect wipes to reach the crevices of the ear fold to remove the stimulant. The HEPA vacuum was able to reach this area and vacuum the simulant away effectively.

Table 2. Results of the statistical analysis between the FiberTect wipes versus HEPA vacuum in the ambulatory-use case. Responses to each question were provided on a 1-to-5 Likert scale, and statistically significant results show the mean response values for that question.

	Survey Question	Results
2.1	The decontamination technology effectively removed the simulant from hands.	No significant difference between the two technologies
2.2	. . . forearms.	No significant difference
2.3	. . . back of ear.	*Significant difference* (FiberTect = 2.48; HEPA = 4.025)
2.4	The decontamination technology removed most or all of the simulant from exposed skin.	No significant difference
2.5	This technology was easy to use on an ambulatory casualty (if applicable).	No significant difference

The results for the nonambulatory case were similar to the ambulatory case. There was no significant difference in the effective removal of simulant from any of the focus areas (hands, forearms) except for the back of the ear (Assessment 2.3, Table 3). For the back of the ear, the HEPA vacuum showed better performance with a mean response value of 4.175 compared to the FiberTect wipes with a mean response value of 3.0 (Table 3). The crevices of the back of the ear folds were difficult to address with the folded FiberTect wipes, and this was more apparent when decontamination was performed by the operator in the nonambulatory line. The HEPA vacuum showed better performance when addressing the back of the ear for this scenario.

Table 3. Results of the statistical analysis between the FiberTect wipes versus HEPA vacuum in nonambulatory-use case. Responses to each question were provided on a 1-to-5 Likert scale, and statistically significant results show the mean response values for that question.

	Survey Question	Results
2.1	The decontamination technology effectively removed the simulant from hands.	No significant difference between the two technologies
2.2.	. . . forearms.	No significant difference
2.3	. . . back of ear.	*Significant difference* (FiberTect = 3; HEPA = 4.175)
2.4	The decontamination technology removed most or all of the simulant from exposed skin.	No significant difference
2.5	This technology was easy to use on an ambulatory casualty (if applicable).	No significant difference

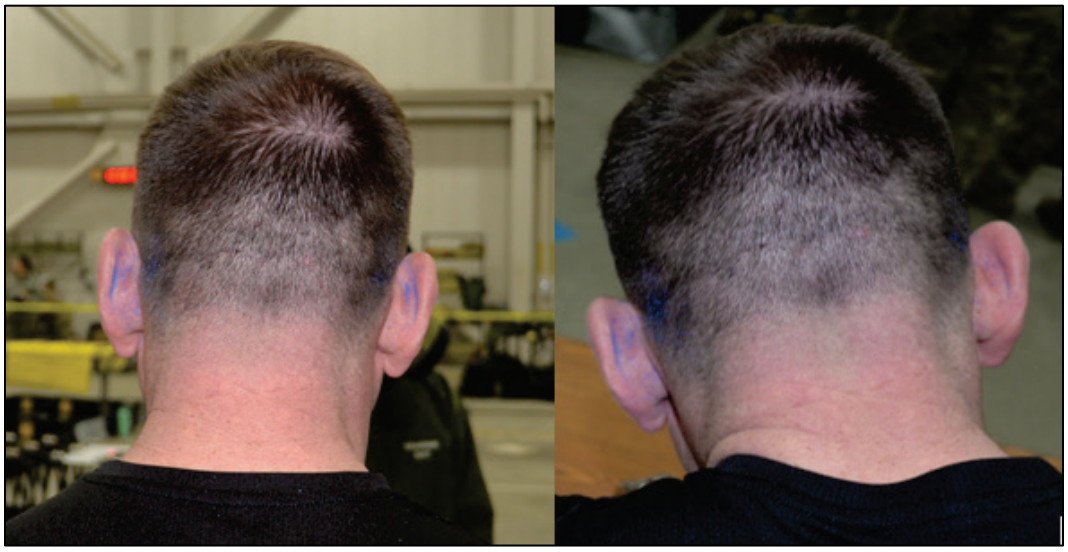
In terms of general performance, most categories showed no significant difference for the role player assessments. However, there was a significant difference in the level of physical discomfort caused by the technologies (Assessment 4.4, Table 4). The role players reported the HEPA vacuum caused greater physical discomfort with a mean response value of 4.36 compared to the FiberTect wipes with a mean response value of 3.71 (Table 4). This was observed only for the ambulatory scenario and was attributed to the brush tip on the HEPA vacuum causing minor skin abrasions (Figure 20).

Table 4. Results of the statistical analysis between the FiberTect wipes versus HEPA vacuum in ambulatory use case. Responses to each question were provided on a 1-to-5 Likert scale, and statistically significant results show the mean response values for that question.

	Survey Question	Results
4.1	This decontamination technology was easy to use.	No significant difference between the two technologies
4.2.	This decontamination technology was fast.	No significant difference
4.3	This decontamination technology was effective.	*Significant difference* (FiberTect = 4.36; HEPA = 3.71)
4.4	This decontamination technology did NOT give me physical discomfort.	No significant difference
4.5	I would recommend this decontamination technology for cold-region applications.	No significant difference

The assessments were tracked with observations made during the exercise. Canadian Major Christian Doucet, Member of the Order of Military Merit, CD1 Physical Protection, CBRN Defence, noted that the large 12 × 12 in. FiberTect wipes had considerable difficulty reaching into bodily crevices, especially in a manner where the contact surface of the wipe could effectively collect material in those crevices. This was observed using the simulant behind the role player's ears and collecting before and after photos with some role players being able to remove all the simulant and others could not (Figure 19). The operators will need to ensure that casualties are highly focused on cleaning body parts with folds. Accordingly, he suggested cutting the wipes into smaller segments. Tests were performed with 6 × 6 in. wipes (a 12 × 12 in. pad), and this was found superior, not merely for crevices but because it simplified the use of the wipes by the role players during self-decontamination, as it eliminated many of the folding procedures required for their use. CBIRF and 95th Chemical personnel concurred after testing that the precutting of the wipes into 6 × 6 in. pads was superior to using the 12 × 12 in. wipe and folding, and improved access to crevices. It did not change the superiority of the HEPA vacuum performance for accessing these difficult-to-reach areas of the body. Role players and operators found it difficult to communicate the folding of the pads and to remember which side had already been used. Printing numbers or pictures on each side of the 6 × 6 in. pad would help mitigate this issue by providing visual guidance that operators could point to. This would also be useful for casualties who do not speak the same language as the operator.

Figure 19. Before (*left*) and after (*right*) photo of a role player with *blue* simulant behind his ear. Decontamination was performed with 12 × 12 in. FiberTect wipes. Images are from AE/P-22 operational assessment.



The HEPA vacuum was found to be less comfortable for the role players. In a decontamination situation for civil support, the perceived discomfort could cause a backlash in a very large number of civilians being decontaminated (Figure 20). This was predominantly due to the bristle brush tip that interfaced with the role player skin. There was also concern over reusing the tips for multiple casualties as the brush is likely to retain contaminants. A solution would be to develop single-use tips that are soft to the skin, potentially with the FiberTect material (Figure 21).

Figure 20. Photo of role player after being decontaminated with the HEPA vacuum. The *red* lines down the back are scratch marks from the brush. Discomfort with this technique was observed by many of the role players. The image is from the AE/P-22 operational assessment.

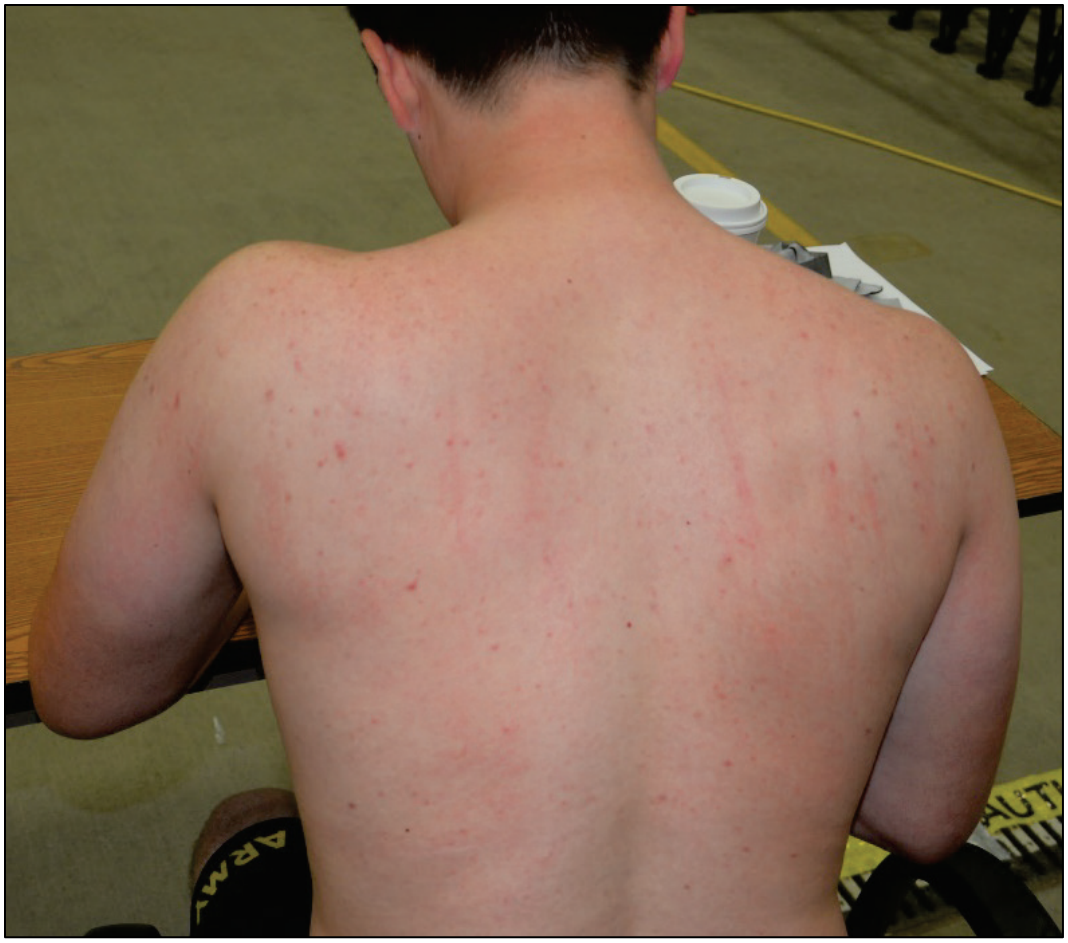


Figure 21. Photo of suggested modification to the brush end of the HEPA vacuum. This prototype uses a FiberTect wipe as the brush tip. Image is from the AE/P-22 operational assessment.

4.1.3.3 Operator Assessment Results

Operators from CBIRF and CERF-P units were surveyed for ease of training and logistics for both ambulatory conditions and decontamination technologies. Assessment questionnaires were filled out by each operator immediately after their shift on the decontamination line. The responses from the operator were consistent, and the results from the assessment questionnaires have been summarized in the following.

4.1.3.3.1 Training and Learning Requirements

Listed below are important metrics for determining the effectiveness and usability of the various decon technologies from a training perspective:

- Ease of learning how to use the equipment
- Ease of learning and explaining to casualties for operation
- Ease of learning the process
    - General

    - The background knowledge of typical aqueous decontamination allows operators to pick up the process quickly, 5–10 min. For operators who do not conduct mass casualty decontamination regularly, the learning curve was approximately 30–40 min of instruction and practical application with the dry decontamination technologies.
  - FiberTect
    - Operators found that training on this technology was easy to learn and convey to role players.
    - There were issues expressed over being heard through the masks
    - Issues with being able to show which side of the wipe to use after folding multiple times.
      Solution: Distribute wipes in 6 × 6 in. squares with a distinct number or picture on each side that can be easily referenced by pointing.
  - HEPA vacuum
    - Operators found that training on this technology was easy to learn and demonstrate to role players.

4.1.3.3.2 Preoperation

Listed below are important metrics for determining the effectiveness and usability of the various decon technologies from a preoperation perspective:

- Ease of use to set up a site
- Easier or harder than current water-based system to set up
- Approximate time to set up a site

  - General
    - The setup is faster and simpler than an aqueous setup. The water system is replaced with additional trashcans for disposing of hazardous waste and a table to place FiberTect supplies on. Ensuring some sort of elevation off of the ground is necessary to prevent casualties from stepping into contamination. The approximate set-up time for both technologies was 5–8 min.
  - FiberTect
    - The setup is faster and simpler than an aqueous setup.
  - HEPA vacuum
    - Easy setup and far less waste than aqueous and FiberTect wipes.

4.1.3.3.3 Operation

Listed below are important metrics for determining the effectiveness and usability of the various decon technologies from an operational perspective:

- Ease of use to monitor and process casualties through
- Impact on operators (is this more taxing on personnel than the current water-based system)
- Ease of use of the equipment (operator and casualty)
- Ease of the process

    - General
        * An identifier was used on the end of the line to ensure casualties are as low as reasonably achievable (ALARA). Throughput did not bottleneck the monitoring sites for both technologies.
        * The process is somewhat less taxing on the operators; however, to reach the effectiveness of aqueous solutions requires more time and thorough instruction.
        * The advantage of both technologies is their logistically small footprint, ideal for expeditionary units with a small number of people.
        * The disadvantage of both technologies is that in the event a mass casualty disaster occurs, they will require extensive time to ensure all contamination is removed.

4.1.3.3.4 Postoperations

Listed below are important metrics for determining the effectiveness and usability of the various decon technologies from a postoperational perspective:

- Ease of use to clear site
- Easier or harder than the current water-based system to clear site
- Approximate time to clear site

    - General
        * Closeout is similar to water based. The difference is the hazardous waste is in 33 gal bags with dry decontamination, and in water-based, the gray bladder and 33 gal trash bags are the residual waste.

    * Easier close out than water-based due to not having to clean up the water gear, hoses, heater, sump pump, and wastewater.
    * Closeout was a few minutes fast than water-based system with a close-out time of approximately 10–15 min.
  - FiberTect
    * Closeout is similar to a water-based system. The difference is the hazardous waste is in 33 gal bags with dry decontamination, and in water based, the gray bladder and 33 gal trash bags are the residual waste.
  - HEPA Vacuum
    * Closeout was simple, and waste management was far less for this technology as the waste is in the filters.

4.1.3.3.5 Resources and Maintenance

Listed below are important metrics for determining the effectiveness and usability of the various decon technologies from a maintenance perspective:

- Do these current technologies and processes require more or fewer personnel than the current system?
- Does this technology and process require more or fewer resources than the current system?
- What maintenance concerns do you have for using this technology?
- What are resource concerns of using this technology/process?

  - General
    * Fewer initial resources are required. No need to allocate a water source or use any of the water equipment which would remove a vehicle from our footprint.
  - FiberTect
    * If a mass casualty event occurred, the wipes may be expended quickly. Identifying how many wipes per person would allow the logistical needs to be specifically identified.
  - HEPA Vacuum
    * We conducted vacuum change out at approximately 1 hr of use. This was not necessary but wanted to see how it would work. We had three additional vacuums, so the process took only a couple of minutes and did not delay the process significantly.
    * Change out was a maximum of 2 min.

* The hose retains some contaminates in the ridges that operators cannot easily remove.
* The vacuum needs a means of containing the contamination and properly disposing of the hazardous waste as well as the vacuum after use.
* The hose needs to be smooth to prevent the accumulation of contamination in the ridges. The brush of the vacuum needs to be a cheap consumable, to dispose of it between casualties.

4.1.3.4 Process Throughput

Process throughput is a metric that directly relates to the specified decontamination times of 3 min per ambulatory casualty and 9 min per nonambulatory casualty. It was of particular interest for evaluating the technology. Note that when reviewing these figures, the batch processing occurred for the ambulatory cases; the decontamination line worked on multiple people at each step simultaneously. Thus, an individual might spend longer than 3 min in the line, but the average time per person for each group was lower. Throughput was measured from the moment the person entered the decontamination line before the undress station to the moment they left the line after the final contamination monitoring station, shown in Table 5.

Table 5. Process throughput for all decontamination iterations used at AE/P-22 operational assessment.

Technology	Ambulatory and Nonambulatory	Number of Role Players	Time (hr)	Role Players per hr
FiberTect	Ambulatory	72	2.43	29.62963
FiberTect	Nonambulatory	51	1.83	27.86885
HEPA	Ambulatory	73	1.61	45.34161
HEPA	Nonambulatory	52	1.68	30.95238
Combination (FiberTect + HEPA)	—	44	0.91	48.35165
Wipes (head, hands)	—	28	0.76	36.84211

In interpreting the results of the process throughput analysis, several interesting observations were made with merit for additional investigation. The HEPA vacuum is approximately 50% faster in processing ambulatory cases, but there is no significant difference with nonambulatory cases. In general, the performance delta between

ambulatory and nonambulatory cases is extremely low. Based on these assessments, the time values for ambulatory and nonambulatory casualties seem to have a skewed 1:3 ratio of ambulatory to nonambulatory, and the time required to process cases of each type is much closer to equal for both technologies.

The combination of the FiberTect wipes plus HEPA vacuum was validated with the best performance times. This decontamination method entailed role players decontaminating themselves with the FiberTect wipes before being decontaminated with the HEPA vacuum by the operators. For this assessment, not all role players were redressing between runs, and there was no simulant added. This may have attributed to the higher throughput as there were not as many clothes to remove or simulant to focus on. Throughput time was measured from the moment the role player entered the undress station to the moment they left the final contamination detection station.

In a run of only slightly less than 1 hr, with 44 role players, a decontamination rate of 48.35 role players/hr was obtained, the highest time-averaged hourly decontamination rate of any of the technologies and substantially exceeding the performance of the FiberTect wipes alone while being equal (a statistically insignificant difference) to the performance of the HEPA vacuum alone. Since the combination of two technologies should generally be slower than one, in terms of optimized process flow, it is hypothesized that there is a root cause for the improved performance of the combination technology. This root cause is best explained by the restriction on the number of HEPA vacuums in use. Only two HEPA vacuums were in use in the decontamination line, due to space and equipment constraints. Accordingly, self-decontamination with FiberTect wipes before the operator-applied HEPA vacuum-based decontamination step was occurring during the waiting time for the ambulatory casualties. During this waiting time, they could self-decontaminate with the wipes before proceeding to be decontaminated with the vacuums. The FiberTect wipe stage of the process did not achieve total decontamination; its length and thoroughness were dictated by the processing speed of the HEPA vacuum and operator run stage. Removing obvious bulk contamination before the HEPA vacuum operators had begun to work made the job of the operators easier, and layering the decontamination process into multiple steps would serve to theoretically increase effectiveness without increasing the processing time or reducing throughput.

4.1.3.5 Simulant Removal Assessment

The simulant removal assessment was performed using colored calcium sand (125–355 μ) as the simulant. A count of 125–255 μ is on the lower end of the expended radiological particle size but still within its range. The simulant was added to each role player's forearm with a salt shaker, and a predecontamination photo was taken with a camera mounted to a tripod for repeatability. After the role player was processed through the decontamination line, a postdecontamination photo was taken of the same forearm. Pre- and postdecontamination images were compared for percent coverage of simulant using Image J software (Schneider et al. 2012). Based on this metric, there was no significant difference in performance between the FiberTect wipes and the HEPA vacuum for both ambulatory and nonambulatory patients (Table 6). This analysis provides strong statistical confidence that contaminants larger than 125 μ are fully removed from easily accessible exposed areas of the hand and forearm by both decontamination technologies, and the effectiveness of both technologies is functionally equal in this metric.

Simulant was also applied to the back-of-the-ear fold for each role player, but systematic photos were not collected for this effort due to the feasibility of reliably collecting this data (i.e., each role player bending down to the camera station for a photo). Instead, the research team photographer collected pre- and postdecontamination photos of specific role players every few minutes. Results from this effort were used to justify the results from the role-player assessments (Figure 19).

Table 6. Table of results; removal of simulant by technology based on ambulatory or nonambulatory casualties from AE/P-22 operational assessment.

Technology	Ambulatory and Nonambulatory	Mean Percent Coverage (predecontamination)	Mean Percent Coverage (postdecontamination)	*p*-value
FiberTect	Ambulatory	9.2938	0	0.000108
FiberTect	Nonambulatory	13.44793333	0	6.98E-07
HEPA	Ambulatory	13.8238	0	0.000653
HEPA	Nonambulatory	16.22107143	0	1.95E-05

4.2 Discussion

The field assessment provided clear conclusions and observations requiring additional assessment. The assessment gave strong confidence with statistical measures of significance that both technologies are capable

of fully removing contamination in a field decontamination environment, not merely the laboratory environment. The assessment shows that the selected postdecimation FiberTect and HEPA vacuum technologies have sufficient capability for the dry decontamination mission against radiation-absorbed dose and dry chemical particulates in both the laboratory and field environments.

The operational assessments suggested that the technologies were equal except for two separate and distinct disadvantages. The HEPA vacuum caused significantly more discomfort to role players in use. The suction levels used on the skin, especially in sensitive areas of the head, were not comfortable and might cause hesitation or resistance from civilians in a use-case scenario whereas military role players were more resilient to this temporary discomfort.

The FiberTect wipes showed significantly more difficulty in successfully decontaminating bodily crevices. AFRRI medical personnel consistently observed residual contamination behind the ears, the main reference metric used in the exercise for difficulty in decontamination of bodily crevices.

In terms of decontamination time, there was no difference between the technologies on the nonambulatory line. The significant difference between the FiberTect wipes and the HEPA vacuums on the ambulatory line is not well controlled. A significant difference exists between the two technologies with ambulatory casualties as the ambulatory casualties were self-decontaminated with the FiberTect wipes but were decontaminated by operators (trained uniformed service personnel) when undergoing decontamination with the HEPA vacuums. Because of this difference in utilization, it is not possible to definitively conclude that the FiberTect wipes are slower were all independent variables to be controlled for. However, it would not be possible for the decontamination units to administer the wipes to ambulatory casualties. There is insufficient personnel for this. Thus, in practical, operational terms, the FiberTect wipes are slower at decontaminating ambulatory casualties in the decontamination line. The difference may be reduced if an increased number of operators were providing guidance to the self-decontamination process and had more formal education in coaching untrained personnel through the specific FiberTect wipe decontamination process, and if visual aids such as large pictogram instructions on the walls of the tents, and possibly voice amplification, were used to more effectively convey

information about the process to the casualties in a complex, loud, and stressful environment.

Uniformed service personnel involved in the exercise were encouraged to improvise and propose and trial improvements. MAJ Doucet's *Canadian Variation* of precutting the FiberTect wipes into 6 × 6 in. squares from 12 × 12 in. as *battle prep* for the decontamination line was universally agreed to improve the performance of the FiberTect wipes by both operators and role players. This modification may partially mitigate the problem of bodily crevice decontamination, though additional validation would have to be conducted which was beyond the limitations of time and personnel availability in the exercise conduct.

Likewise, a need for removable or disposable heads for the HEPA vacuum was found as significant quantities of contamination ended up entrained in the hose of the vacuum, which would fall back out when the vacuum was turned off, even briefly, and the brush used on the skin of the casualties could itself end up capturing contaminating, which would then be spread from person to person. A cheap, easily replaceable, disposable brush that can be used with the vacuum for each casualty was highly desired. Field-improvised experiments were conducted using the FiberTect wipe material to create improvised brushes of this type, but the results were inconclusive.

The combination approach of using both the FiberTect wipes and the HEPA vacuum was found to be most preferred by the operators and role players. This combination approach had the fastest throughput times and had a much lower rejection rate (ambulatory casualties sent back through for a second trip through the decontamination line) than the wipes alone. This approach is desirable, especially because having the wipes on hand means any interruptions in the electrical power supply for the vacuums can be overcome by wipe-only decontamination. The operators and role players felt it was the most effective strategy, and the use of the FiberTect wipes by the role players while waiting for their turn to be subjected to HEPA vacuum-based decontamination did not slow down the line by any significant measure over HEPA vacuum alone, and in fact, increased speed.

5 Conclusions

5.1 Summary of Findings

5.1.1 Bottom Line up Front

Nonaqueous decontamination of personnel with currently available technology is a viable option for casualty decontamination that is as good as or better than the current water-based system. A combination of FiberTect wipes and HEPA vacuum technologies and procedures provides the greatest flexibility and effectiveness.

5.1.2 Efficacy

- Throughput or time through system: nonaqueous decontamination of personnel with currently available technology will meet the NORTHCOM and Army task standard in accordance with Joint Mission Essential Task List and Combined Arms Training Strategy
- Personnel required to perform: nonaqueous decontamination of personnel with currently available technology requires the same amount of personnel as the current water-based system as observed from the operational assessment
- Pre- and postoperations: nonaqueous decontamination of personnel with currently available technology results in faster, easier pre- and postoperation site setup and site closure
- Maintenance: currently available technologies that were tested for nonaqueous decontamination of personnel require very little to no private military contractors and require much less maintenance than the current water-based system
- Waste: nonaqueous decontamination of personnel with currently available technology results in comparable waste to the current water-based system but a different waste stream 2–3 times more solid trash waste with wipes, but no wastewater to store or dispose of
- Logistical requirements: currently available technologies that were tested for nonaqueous decontamination of personnel require numerous wipes for the amount of projected throughput; vacuum requires generated power

5.2 Final Observations on Technologies

5.2.1 Overall

Of the technologies assessed, the FiberTect wipes and HEPA vacuum performed the best, possessing equivalent performance; the SX34 and M2DCON technologies did not meet the parameters to move on to operational assessment.

5.2.2 FiberTect Wipes

The following points show the pros of this technology:

- High percentage removal of simulant
- Not affected by ambient temperature
- Comfortable to skin

Recommended improvements for this technology include the following:

- Should be cut to 6 × 6 in. squares with identifying marks for each side
- Should have visual aid with decontamination steps for casualties to reference if they cannot hear or understand the line operator

5.2.3 HEPA Vacuum

The following points show the pros of this technology:

- High percentage removal
- The line operator is running the vacuum, which reduces the casualty's exposure to a contaminant
- Fast throughput

Recommended improvements for this technology include the following:

- Should change vacuum tips between casualties
- Should make tips that are more comfortable for the skin

5.2.4 Combination (FiberTect wipes and HEPA vacuum)

The following points show the pros of this technology:

- Increases throughput
- Allows for the FiberTect wipes to remove bulk contamination while HEPA vacuum can focus on technical areas

- Reduces overall waste
- Preferred by users and operators during the operational assessment

Recommended improvements for this technology include the following:

- Pushing the use of the FiberTect wipes into the hot zone for casualties to start wiping down exposed skin before they enter the decontamination tent

5.3 Further Recommended Experimentation

Further investigation is needed as to whether or not it is viable to push the issuance of FiberTect wipes as far forward into the hot zone as possible. Self-decontamination of the hands and face in the hot zone, removing bulk particulates, could reduce the particulate load in the vicinity of the decontamination line and reduce the total quantities of contaminants that must be removed during the structured decontamination line decontamination process. Distributing wipes for self-decontamination before the decontamination tent is reached by ambulatory casualties could serve to reduce the risk of contaminants being spread around the decontamination tent during dry decontamination operations when the decontamination line lacks water to eliminate contaminants continuously during the decontamination procedure. Additionally, FiberTect wipes material could be used to manufacture single-use tips for the HEPA vacuum that may be more comfortable for the skin and reduce cross contamination between casualties (Figure 21). To further reduce cross contamination and hazardous material hotspots, the hose for the HEPA vacuum should be smooth on the inside. The model used in this study had a ridged hose that accumulated material over time.

These technologies should be compared to wet decontamination technologies in a side-by-side study to determine if they are a viable replacement in temperate environments. This would reduce the logistical burdens on response units and waste streams. The application of these technologies could be expanded by assessing their viability to remove additional CBRN contaminants beyond radiation-absorbed dose simulant, such as chemical powders. These technologies should also be assessed for their viability to treat canine casualties as the fur on these species further limits the use of wet decontamination because these animals dry much slower and are at greater risk of hyperthermia.

References

Schneider, C. A., W. S. Rasband, and K. W. Eliceiri. 2012. "NIH Image to ImageJ: 25 Years of Image Analysis." *Nature Methods* 9 (7): 671–675.

Appendix A: Likert Scale Questionnaire

A Likert scale questionnaire was used to collect feedback data from the role-players on the decontamination technologies.

Data Collection Form
Decon User Data
22 February–01 March 2022
1.1 User ID _____
1.2 System Assessed _____
1.3 Run # _____ Date _____
2.0 Training assessment
2.1 Ease of learning how to use the technology: Easy Medium Hard
2.2 What changes to the training would you recommend?

3.0 Contamination assessment

	Strongly Disagree	Disagree	Neutral	Agree	Strongly Agree
Simulant contamination is visible on the skin	1	2	3	4	5
Simulant contamination is uniform across exposed skin and hair	1	2	3	4	5
Simulant contamination is uncomfortable on the skin	1	2	3	4	5
User is sufficiently contaminated with simulant	1	2	3	4	5
	1	2	3	4	5
	1	2	3	4	5
	1	2	3	4	5

Additional comments:

4.0 Decon effectiveness assessment

The decon technology effectively removed the simulant from:	Strongly Disagree	Disagree	Neutral	Agree	Strongly Agree
Hands	1	2	3	4	5
Forearms	1	2	3	4	5
Ears	1	2	3	4	5
The decon technology removed most or all of the simulant from exposed skin	1	2	3	4	5
This technology was easy to use on an ambulatory casualty (if applicable)	1	2	3	4	5
	1	2	3	4	5
	1	2	3	4	5

Additional comments:

5.0 Physical discomfort assessment

	Strongly Disagree	Disagree	Neutral	Agree	Strongly Agree
My skin felt comfortable during decon event	1	2	3	4	5
My skin felt comfortable after decon event	1	2	3	4	5
My skin felt irritated after decon event	1	2	3	4	5
It felt like the decon tech lowered my body temperature	1	2	3	4	5
I feel there are safety concerns when using this decon in cold environments	1	2	3	4	5
	1	2	3	4	5
	1	2	3	4	5

Additional comments:

6.0 Overall assessment

	Strongly Disagree	Disagree	Neutral	Agree	Strongly Agree
This decon technology was easy to use	1	2	3	4	5
This decon technology was fast	1	2	3	4	5
This decon technology was effective	1	2	3	4	5
This decon technology did NOT give me physical discomfort	1	2	3	4	5
I would recommend this decon technology for cold region applications	1	2	3	4	5
	1	2	3	4	5
	1	2	3	4	5
	1	2	3	4	5

Additional comments:

AP 22 Dry Decon
22 Feb-01 Mar, 2022
Data Collection Form: Operators
1. Training/Learning:

Ease of learning how to use the equipment (for operators): *Easy Medium Hard*

_____

Ease of learning / explaining to casualties for operation: *Easy Medium Hard*

_____

Appropriate time to learn how to utilize technology
(for operators):_____

Appropriate time to learn how to utilize for casualties:

_____

Ease of learning the process (for operators): *Easy Medium Hard*

_____

Appropriate time to learn the process (for operators):

_____

What changes to the training would you recommend (Operators)?

_____

What changes to the training would you recommend (Casualties)?

_____

2. Pre-operation:
Ease of use to set-up site: *Easy Medium Hard*

_____

Easier or harder than current water-based system?
Explain._____

Approximate time to set-up site:

_____

Is that more or less than the 90 minute time requirement for set-up of current wet-based system?

_____

Recommendations on improving set-up:

_____

3. Decon Technology:
Ease of use of the equipment (for operators): *Easy Medium Hard*

_____

Ease of use of the equipment (for casualties): *Easy Medium Hard*

_____

Advantages:

_____

Disadvantages:

_____

Recommendations on improving technology:

_____

4. Overall Process:
Does the decon technology appear to aerosolize the simulant (release it to the air)?
If so, at what rate: *Low Medium High*
Does the decon technology cause simulant to accumulate on the floor?
If so, at what rate: *Low Medium High*
Ease of overall process (for operators): *Easy Medium Hard*

_____

Ease of process overall (for casualties): *Easy Medium Hard*

_____

Ease of use to monitor and process casualties through: *Easy Medium Hard*

_____

Is this more taxing on operators than current water-based system?
Explain._____
Is this more taxing on casualties than current water-based system?
Explain._____

Advantages:

_____

Disadvantages:

_____

Recommendations on improving process:

_____

5. System maintenance:

Did the system require maintenance during the run?_____

How long was the system down?

_____

Were there any special maintenance requirements?

_____

If so, what?

_____

6. Post-operations:

Ease of use to clear site: *Easy Medium Hard*

_____

Easier or harder than current water-based system? Explain.

_____

Approximate time to clear site:

_____

Is that more or less than the 90 minute time requirement for set-up of current wet-based system?

_____

Recommendations on improving clearing site:

_____

How much trash was generated by the decon technology (number of full trash bags)?

_____

7. Resources and Maintenance:

Does this current technology and process require more or less personnel than the current wet decon system? Explain.

_____

Is it the right number of people to conduct? If not, how many people would you recommend? Explain.

_____

Does this technology and process require more or fewer resources than the current system? Explain.

_____

What maintenance concerns do you have for using this technology?

_____

What are your resource concerns of using this technology / process?

_____

What are your recommendations to improve?

_____

6. Overall:

Can this technology be used for Mass Causality Decon operations? Explain.

_____

Appendix B: Chemical Biological Incident Response Force (CBIRF) SSgt Gilbraith Feedback

The following is a summary of operators' feedback to the questionnaire, provided by CBIRF SSgt Gilbraith (Gilbraith, SSgt Steven A.).

AP 22 Dry Decon
22 Feb-01 Mar, 2022
Data Collection Form: Operators
1. Training/Learning:
Ease of learning how to use the equipment (for operators): ***Easy*** *Medium Hard*

The FiberTect wipe is a very simple technology that is easy to learn. The instruction is the key to its success. The personnel conducting the decontamination has to be clear and concise with their directions in order for casualties to understand proper use.

Ease of learning/explaining to casualties for operation: ***Easy*** *Medium Hard*

Once an operator understands the process, the explanation of the use is very simple.

Appropriate time to learn how to utilize technology (for operators): 5–10 Minutes.

Appropriate time to learn how to utilize for casualties: 10–30 Seconds.

Ease of learning the process (for operators): ***Easy*** *Medium Hard*

The process of decontamination is very much the same as the aqueous process. The difference is there is no "kill" bucket to neutralize contaminates on the wipe, the wipe is disposed of instead. The background knowledge of typical aqueous decon allows operators to pick up the process quickly, 5–10 Minutes. For operators that do not conduct mass casualty decon regularly, the learning curve was approximately 30–40 minutes of instruction and practical application.

Appropriate time to learn the process (for operators): 5–10 minutes depending on experience.

What changes to the training would you recommend (Operators)?

Clear and concise explanation of objectives and a classroom instruction period prior to execution. CBIRF Marines were provided instruction for months prior to execution and had an in person class from FirstLine personnel. This allowed them to be more knowledgeable and fluid in the process. Other personnel picked it up

quickly under CBIRF personnel instruction. Conduct operations outside to actually test the cold weather process. Recommend Fairbanks or other appropriate location.

What changes to the training would you recommend (Casualties)?

Ensure all casualties are aware they will be completely undressed or ensure appropriate alternative is implemented. Recommend having t-shirts w/"I'm Naked" on the front and direct all role players to wear bike shorts or other lower body garment they are comfortable dressing down to in order to accurately simulate removing all clothing.

2. Pre-operation:

Ease of use to set-up site: ***Easy*** *Medium Hard*

The setup is actually faster and more simple than aqueous setup. The water system is replaced with additional trashcans for disposing of hazardous waste and table to place FiberTect supplies on. Ensuring some sort of elevation off of the ground is necessary to prevent casualties from stepping in contamination.

Easier or harder than current water-based system? Explain.

The system is very similar. While the dry system can be implemented in a more rapid manner than water based systems, the closeout and waste produced is very similar. Where water based systems have gray water containment in a gray water bladder, dry systems produce 2–3 times more hazardous waste bags than the water based system. The number of personnel used in the water system is similar to the vacuum/wipe process

Dry Decon	Water Based
(4) litter bearers	(4) litter bearers
(2) clothing removal	(2) clothing removal
(2) vacuums	(2) decontaminate applicators
(2) wipes	(2) rinsers
(1) monitor	(1) monitor
(2) ambulatory decon line operators	(1) ambulatory decon line operators

Approximate time to set-up site: 5–8 Minutes.

Is that more or less than the 90 minute time requirement for set up of current wet-based system?

I am not sure where the 90 minute requirement comes from, however CBIRF gross decontamination can be set up in less than 5 minutes with operational amulatory and nonambulatory lines up in 15 minutes. The set up is essentially the same minus water acquisition.

Recommendations on improving set-up: No recommendations.

3. Decon Technology:

Ease of use of the equipment (for operators): ***Easy*** *Medium Hard*

Technologies (Vacuums and Wipes) are very simple to use and require a smaller logistical footprint than water based systems.

Ease of use of the equipment (for casualties): ***Easy*** *Medium Hard*

The technology is as simple as the operator explains it to be.

Advantages: Simplicity of technology allows for rapid employment and limited outside requirements (water source). The vaccum and wipes are easily contained in hazardous waste bags. Logistical footprint is minimal. Process is quick and simple to learn.

Disadvantages: Significant amount of wipes will be expended rapidly in the event a large scale mass casualty decon is required. Processing approximately (50) people produced approximately (10) 33 gallon hazardous waste bags. Limitations or vacuum are dry solid material. Wipes were not able to be adequately tested in conjunction with a soap or other adhesive decontaminate.

Recommendations on improving technology:

Vacuum could use a smooth sided hose to allow for minimal contaminates being traped in the hose. A expendable brush cartridge for the vacuum tip would allow changing tips between casualties, improving the process while preventing transfer. The wipe at 6 in x 6 in is ideal for personal use and explanation to casualties. Large pads of FiberTect were extremely useful table tops and floors to of the decon pit.

4. Overall Process:

Does the decon technology appear to aerosolize the simulant (release it to the air)?

Yes, however by implementing the vacuums at the beginning of the process, the bulk of contamination is removed. This reduces the amount of contaminate that is aerosolized or deposited onto the decon pit.

If so, at what rate: ***Low*** *Medium High*

Does the decon technology cause simulant to accumulate on the floor?

Yes, due to not having an adhesive such as soap the wipe can become saturated faster and excess simulant ended up on the floor.

The vacuum mitigated this.

If so, at what rate: ***Low*** *Medium High*

Ease of overall process (for operators): ***Easy*** *Medium Hard*

Ease of process overall (for casualties): ***Easy*** *Medium Hard*

Ease of use to monitor and process casualties through: ***Easy*** *Medium Hard*

Using a portal in extreme cold has proved unproductive, however the AN/PDR-77 X-Ray probe can be used to scan and quickly identify potentially "hot" areas proved effective. An Identifinder was used on the end of the line to ensure casualties are ALARA.

Is this more taxing on operators than current water-based system? Explain.

The process is somewhat less taxing on the operators, however the to reach the effectiveness of aqueous solutions requires more time and thorough instruction.

Is this more taxing on casualties than current water-based system? Explain.

Current aqueous processes require very little from the casualties than simply standing in place. The wipe process requires a casualtie that may be disoriented and scared to follow instructions and the chance of transfer is increased.

Advantages: Logistically small footprint, ideal for expeditionary units and small number of personnel

Disadvantages: Requires time and in the event mass casualty disaster occurs, will require extensive time to ensure all contamination is removed.

Recommendations on improving process: Use a solution such as Dahlgren Decon soap in conjunction with the wipe and ensure vacuums are a part of the process. Using the vacuum and wipes in conjuction proved most effective.

5. System maintenance

Did the system require maintenance during the run?

We conducted vacuum change out at approximately one hour of use. This was not necessary but wanted to see how it would work. We had (3) additional vacuums so the process only took a couple of minutes and did not delay the process much.

How long was the system down? Max of 2 minutes

Were there any special maintenance requirements?

No, however the hose does not retain some contaminates in the ridges.

6. Post-operations:

Ease of use to clear site: ***Easy*** *Medium Hard*

Close out is similar to water based. The difference is the hazardous waste is in 33 gallon bags with dry decon and in water based, the gray bladder and 33 gallon trash bags are the residual waste.

Easier or harder than current water-based system? Explain.

Easier close out than water based due to not having to clean up the water gear, hoses, heater, sump pump, waste water.

Approximate time to clear site: 10–15 minutes

Is that more or less than the 90 minute time requirement for set-up of current wet-based system?

This is a few minutes faster than our current water close out.

Recommendations on improving clearing site: None.

How much trash was generated by the decon technology (number of full trash bags)? I do not know the grand total, but 50 casualties produced approximately (10) 33 gallon bags.

7. Resources and Maintenance:

Does this current technology and process require more or less personnel than the current wet decon system? Explain.

Same. The positions of the dry decontamination are similar to water based, listed above.

Is it the right number of people to conduct? If not, how many people would you recommend? Explain.

The setup that was used is a half-site. If we were to set up a full site, there would be double the amount of personnel. A full site consists of (2) ambulatory, (2) nonambulatory and (1) Responder decon lines.

Does this technology and process require more or fewer resources than the current system? Explain.

Less initial resources required. No need to allocate a water source or use any of the water equipment which would remove a vehicle from our footprint. However, due to not consistently using the wipes in the exact same manner each time, it was hard to identify how many 6x6 wipes would be required per person. The process was an evolving test, so as the process progressed, more efficient means were discovered for use of the wipe (cutting down wipes to alleviate the folding of the wipe multiple times.

What maintenance concerns do you have for using this technology?

The vacuum needs a means of containing the contaminate and properly disposing of the hazardous waste. The hose needs to be smooth to prevent the accumulation of contaminate in the ridges. The brush of the vacuum needs to be a cheap consumable, in order to dispose of it between casualties.

What are your resource concerns of using this technology / process?

Both the vacuums and the wipes are readily available. The resource concern would be in the event we had to dispose of an entire vacuum due to contamination. If a mass casualty event occurred, the wipes may be expended quickly. Identifying how many wipes per person would allow the logistical needs to be specifically identified.

What are your recommendations to improve?

Make FiberTect wipes 6 in x 6 in in stacks of 50 in a sealed disposable box that can be quickly opened and used on the decon line and once expended, repurposed as a hazardous waste container.
For the vacuum, a disposable brush that allows change out between casualties. A smooth hose to prevent contaminates from being trapped in the hose. A battery powered back pack would alleviate the need for generators.

8. Overall

Can this technology be used for Mass Causality Decon operations? Explain.

These technologies can be used for mass casualty decon. For the vacuum a battery pack would remove the need for external power. The wipes are simple and provide a non reactive decon solution that water or other detergents do not provide. Additionally, these technologies can be used in all temperatures and climates.

Abbreviations

AE/P-22	Arctic Eagle/Patriot 22
AFRRI	Armed Forces Radiobiology Research Institute
ALARA	As low as reasonably achievable
ANOVA	Analysis of variance
CBR	Chemical, biological, radiological
CBRN	Chemical, biological, radiological, and nuclear
CERF-P	Enhanced Response Force Package
CRREL	Cold Regions Research and Engineering Laboratory
DOE	Department of Energy
FEMA	Federal Emergency Management Agency
HEPA	High-efficiency particulate air
JPEO-CBRND	Joint Program Executive Office CBRN Protection
JPM	Joint Project Manager
JTF-CS	Joint Task Force–Civil Support
MDK	FiberTect wipes
MDKS	FiberTect wipes with Dahlgren spray
NGB	National Guard Bureau
USARNORTH	US Army North
USMC CBIRF	US Marine Corps Chemical Biological Incident Response Force
USNORTHCOM	US Northern Command
VAC	HEPA vacuum
XRF	X-ray fluorescence

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14. ABSTRACT

This report provides a summary of the results obtained in laboratory-scale testing of dry-decontamination technologies. The purpose of the experiment is to assess nonaqueous technologies to determine the viability of a solution to mitigate chemical, biological, radiological, and nuclear (CBRN) defense, CBRN Response Enterprise, medical casualty care, and cold-weather operational gaps. The Cold Regions Research and Engineering Laboratory (CRREL) assessed the efficacy, via percentage reduction, of four nonaqueous technologies to decontaminate particulate contamination, at three operational temperatures, from three starting challenges. Testing was conducted by CRREL personnel according to protocols developed in conjunction with the Homeland Defense/Civil Support Office Maneuver Support Center of Excellence and the Armed Forces Radiobiology Research Institute (AFRRI) and approved by Joint Program Executive Office CBRN Protection. CRREL subsequently collected data and conducted statistical measures of significance and explored additional questions about the technology capabilities. CRREL personnel then deployed with AFRRI support to Arctic Eagle/Patriot 22 (AE/P-22) for field testing of the technologies and their evaluation from an operational perspective. AE/P-22 allowed for direct, full-scale testing of the technology in conditions approximating a use-case scenario. This report documents the culmination of analysis performed on CRREL- and AFRRI-collected test data results, operational factors, and user inputs.

15. SUBJECT TERMS

Biological decontamination; Decontamination (from gases, chemicals, etc.); Hazardous substances; Radioactive decontamination; Weapons of mass destruction

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