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Decontamination Line Protocol Evaluation for Biological Contamination Incidents

ASSESSMENT AND EVALUATION REPORT

Office of Research and Development
National Homeland Security Research Center

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Decontamination Line Protocol Evaluation for Biological Contamination Incidents

Assessment and Evaluation Report

National Homeland Security Research Center
Office of Research and Development
U.S. Environmental Protection Agency
Research Triangle Park, NC 27711

Disclaimer

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List of Acronyms and Abbreviations

ARC	ARCADIS
AT	attendant
CBRN	Chemical, Biological, Radiological, and Nuclear
CFR	Code of Federal Regulations
CMAD	CBRN Consequence Management Advisory Division
CRZ	contamination reduction zone
CS	control subject
DHS	U.S. Department of Homeland Security
EPA	U.S. Environmental Protection Agency
ERTG	Emergency Response Technical Group
EZ	exclusion zone
HAZMAT	hazardous material
HSPD	Homeland Security Presidential Directive
HSRP	Homeland Security Research Program
ID	identification
IRB	Institutional Review Board
NHSRC	National Homeland Security Research Center
OEM	Office of Emergency Management
OSHA	Occupational Safety and Health Administration
PPE	personal protective equipment
QA	quality assurance
QAPP	Quality Assurance Project Plan
QC	quality control
SOG	standard operating guideline
Stdev	standard deviation
SZ	support zone
TS	test subject
UNC	University of North Carolina
USPHS	U.S. Public Health Service
UV	ultraviolet

Executive Summary

This project supports the mission of the U.S. Environmental Protection Agency Office of Research and Development's Homeland Security Research Program (HSRP) by providing information relevant to the decontamination of areas contaminated as a result of a biological contamination incident. The primary objective of this investigation was to evaluate and improve the effectiveness of each stage of the standard operating guideline (SOG) that is used to provide guidance to EPA and contractors on decontamination of personnel and samples in long-term response to biological contamination. The "Long Term Biological Decontamination Line" SOG is used to prevent the spread of contamination beyond the exclusion zone (EZ), often called the hot zone; to remove personal protective equipment (PPE) without exposing personnel to contamination; and for verifying the effectiveness of procedures to ensure no contamination is present on samples leaving the EZ.

The evaluation tests described in this report were conducted using a fluorescently dyed powder as a surrogate for *Bacillus anthracis* (*B. anthracis*) spores. The use of non-pathogenic surrogate spores was considered for this project, but abandoned due to concerns of cross-contamination and background interference. The overall goal of the study was to identify any weaknesses in the SOG by detecting potential portals of contamination. Modification of the procedures described in the SOG to eliminate any weaknesses would reduce the chances of cross-contamination or spread of contamination outside the EZ. If an identified weakness cannot be removed, emphasizing the weakness in the SOG would increase awareness of the potential for cross-contamination. In an emergency response following an intentional release of *B. anthracis* spores, it is important for first responders to know what procedures and PPE can be used effectively to (1) contain contamination within the EZ, (2) protect responders from contamination, and (3) prevent cross-contamination from responders and collected samples that could result in spread of contamination into support areas.

This investigation focused on evaluating the decontamination (decon) line as a whole, not necessarily its individual parts. For instance, if contamination was still present on the boots after the boots were scrubbed, but the contamination remained on the doffed boots in the contamination reduction zone (CRZ), often called the warm zone, and was not transferred to a test subject, then the decon line was a success concerning the containment objective. While improvements to the SOG were not quantifiable, steps were identified and defined in the protocols that proved successful at preventing or significantly reducing cross-contamination in most situations.

Summary of Results

This study found that liquid and a scrub brush can be contaminant carriers. Therefore, unless a completely effective liquid decontaminant (with immediate efficacy) is used, large amounts of liquid should be avoided. The evaluation did not take into account, however, the use of disinfectants such as a hypochlorite solution to reduce the biological contaminants that might be encountered in an actual event. In addition, the results showed that the use of a secondary protective Tyvek® suit under the main Tyvek® or Tychem® suit, along with several other measures such as applying a light mist or spray to the outside of the primary suit to reduce reaerosolization and careful doffing of PPE with help from an attendant wearing a fresh pair of gloves, can reduce cross-contamination or eliminate it completely. Even with the best procedures, complete showering of personnel after leaving the decontamination line is recommended. Finally, if samples are collected, special consideration should be given to the sample-handling procedure to avoid and eliminate any cross-contamination from contaminated samples into any

areas outside decontamination and doffing areas. A specific multi-step sample-handling procedure involving two sample handlers was found to be very effective for avoiding the transfer of contamination. Modification of the “Long Term Biological Decontamination Line” SOG is recommended based on the results of this work.

1 Introduction

This project supports the mission of the U.S. Environmental Protection Agency (EPA) Office of Research and Development's (ORD) Homeland Security Research Program (HSRP) by providing information relevant to the decontamination of areas contaminated as a result of biological contamination incident. Homeland Security Presidential Directive (HSPD)-10 tasked the U.S. Department of Homeland Security (DHS) with coordinating the appropriate federal departments and agencies to develop comprehensive plans that "provide for seamless, coordinated federal, state, local, and international responses to a biological attack." As part of these plans, EPA, in conjunction with DHS and other agencies, is "developing strategies, guidelines, and plans for decontamination of persons, equipment, and facilities" to mitigate the risks of contamination following a biological weapons attack.

EPA's National Homeland Security Research Center (NHSRC) provides expertise and products that can be widely used to prevent, prepare for, and recover from public health and environmental emergencies arising from terrorist threats and incidents. NHSRC works with EPA's Office of Emergency Management (OEM), CBRN (Chemical, Biological, Radiological, and Nuclear) Consequence Management Advisory Division (CMAD), and OEM's Bioagent Workgroup within the Emergency Response Technical Group (ERTG).

The Bioagent Workgroup, which comprises members from each of EPA's 10 Regions, compiled the "Long Term Biological Decontamination Line" standard operating guide (SOG) (Appendix A) that was evaluated for this project. This SOG provides guidance to EPA and contractors on decontamination of personnel and samples in long-term responses to biological, chemical, and other toxic compound contamination. This decontamination (decon) line SOG is used to prevent the spread of contamination beyond the exclusion zone (EZ), to remove personal protective equipment (PPE) without exposing personnel to contamination, and to ensure no contamination is present on samples leaving the EZ. Ongoing testing and evaluation of the overall efficacy of the SOG is essential for identifying weaknesses and improving the procedures.

1.1 Process

This work evaluated the "Long Term Biological Decontamination Line" SOG for sources of cross-contamination or spread of contamination outside the EZ. Cross-contamination can occur any time there is contact between the outer surface of PPE and an inner body surface. This contact can be either direct or indirect through a carrier such as water or air. Contamination can then be spread by a responder leaving the EZ after doffing PPE. Potential cross-contamination and spread of contamination outside the EZ from a collected "contaminated sample" due to sample-handling procedures also was evaluated.

In this assessment of the SOG procedures, volunteer test subjects were dosed with a fluorescently dyed powder as a surrogate for contamination that was used to track cross-contamination or the spread of contamination outside the EZ. The use of non-pathogenic surrogate spores was considered for this project, but abandoned due to concerns of cross-contamination and background interference. Some of the volunteer test subjects were designated as control subjects (performed the same procedures as the designated test subjects but were not dosed) or attendants (who performed assigned assistance roles in the decon line and were not dosed). The test subjects were scanned with low-level ultraviolet (UV) light before and after dosing with the fluorescent powder and then were given a dosed "sample" to carry into the decon line. The test subjects proceeded through each step of the decon line, doffed their PPE, and

were reevaluated with the UV light to detect any cross-contamination to an inner suit (simulating skin and street clothes) that had occurred. The contaminated sample was carried and dropped off at a specified point in the decon line for later evaluation of the sample-handling procedure and its possible role in the spread of contamination.

It should be noted that this investigation focused on evaluating the decon line as a whole, not necessarily its individual parts. For instance, if contamination was still present on the boots after the boots were scrubbed, but the contamination was not transferred to the test subject and remained on the doffed boots in the contamination reduction zone (CRZ), the decon line was a success with respect to the objectives of the evaluation.

1.2 Project Objectives

In an emergency response following an intentional release of *Bacillus anthracis* (*B. anthracis*) spores, it is important for first responders to know what procedures and PPE can be used effectively to (1) contain contamination within the EZ, (2) protect responders from contamination, and (3) prevent cross-contamination from responders and collected samples that could result in spread of contamination into support areas. The primary objective of this project was to evaluate and improve, as necessary, the effectiveness of the “Long Term Biological Decontamination Line” SOG used to decontaminate personnel and samples during a long-term biological contamination event. The project aimed specifically to identify potential portals of contamination in the decon line procedures. Elimination of those weaknesses by procedural modifications of the SOG could substantially reduce the chance for cross-contamination or spread of contamination into support areas. Further, emphasizing weaknesses that cannot be removed could make users more aware of potential contamination issues.

While these test results do not quantify improvements or a lower chance of cross-contamination, they qualitatively identify and define protocols that proved successful at reducing or preventing cross-contamination in most situations. This report details the methods, study design, and results used in the evaluation, as well as the weaknesses identified in the SOG protocol and the optimizations made to reduce or prevent cross-contamination.

2 Materials and Methods

Evaluation of the "Long Term Biological Decontamination Line" SOG was conducted in EPA's Fluid Modeling Facility in Research Triangle Park, NC. Test subjects were dosed with a surrogate contaminant and then performed activities in the decon line. During the procedures they also carried and dropped off samples dosed with the surrogate contaminant. Seven scripts were evaluated beginning with the current SOG (Appendix A). After performing a script, the participants were evaluated for contamination on their inner suits (simulating their skin and street clothes) to identify modifications to the procedures that could potentially reduce or eliminate cross-contamination or spread of contamination outside of designated areas of the decon line. Each subsequent script tested the modifications derived from the previous script. All test activities were documented during each round of testing via narratives in laboratory notebooks, real-time data acquisition, photographs, and video recordings. This section describes the materials and methods used in the testing, including equipment, setup, study design, and data analysis.

2.1 Equipment and Supplies

Evaluating the efficacy of the decon line SOG required an extensive setup with a variety of equipment and a wide array of ancillary supplies. In addition, several types of PPE ensembles were needed for all test scripts and for redundant layers of protection. All equipment and supplies used during the evaluation, such as decontamination berms, sprayers, sponges, and brushes, were typical of products expected to be used in an actual long-term decon line. Table 2.1-1 lists the decontamination equipment and supplies used in this study.

Table 2.1-1. Decontamination Equipment and Supplies

Use	Description	Part Number	Company	Location
Containment	SPCC berm 3' x 3 'x 4"	907-030304	Aire Industrial	Meridian, ID, USA
	Go-Go berm 6' x 6'	909-060604B		
	Duck pond 4' x 4'	908-040404B		
	Inflatable swimming pool 103" x 62.5"	55192953	Walmart	Durham, NC, USA
Sprayers	1-gallon bleach sprayer	190360	D.B. Smith, The Fountainhead Group, Inc.	New York Mills, NY, USA
	4-gallon backpack sprayer	190359		
Evaluation tents	Barronett Blinds, Big Mike™ Blinds		Dunham's Sports	Asheboro, NC, USA
Decon tent		DAT 3030S	FSI, North America	Sheffield Lake, Ohio, USA
UV lamps	6 watt	UVP600	Sirchie	Youngsville, NC, USA
UV flashlight	UV LED	BMINI8-365	Risk Reactor Inc.	Santa Ana, CA, USA
Fans		1729K11	McMaster-Carr	Atlanta, GA, USA
Surrogate contaminant	Fluorescently dyed dry powder	PXT-071LB	Risk Reactor Inc.	Santa Ana, CA, USA
Applicator brush	Disposable applicator brush with metal handle 3/4" long x 3/8" wide	7237T83	McMaster-Carr	Atlanta, GA, USA

Continued on next page

Use	Description	Part Number	Company	Location
Brush	General wash brush, Blue Hawk® brand	226BHGM	Lowes, Inc.	Mooresville, NC, USA
Container	250-mL graduated non-sterile histology container with separate screw cap	6540	Globe Scientific Inc.	Paramus, NJ, USA
Polybag, inner	10" x 12" clear reclosable	P0165971	Papermate	
Polybag, outer	3-gallon clear reclosable, Ziploc®		SC Johnson	Racine, WI, USA
Bucket	5-gallon food-grade plastic bucket	50640	Encore Plastics	Sandusky, OH, USA
Cooking oil spray	Pam original cooking spray	6414403021 6414403031	ConAgra Foods, Inc.	Omaha, NE, USA
Vials	Borosilicate glass vials with screw cap	IRC126-0020	Purologix Water Services, Inc.	Holly Springs, NC, USA
Hand and face wash	Foot-operated hand wash	Use-Yer-Foot	Turtle Run Farm	Saxapahaw, NC, USA
Antiseptic	91% Isopropyl alcohol first aid antiseptic	551780428	Walmart	Durham, NC, USA
Wipes	Premoistened with isopropyl alcohol/deionized water	21910-110	A1 Supply	Raleigh, NC, USA
Isopropyl alcohol	91% isopropyl alcohol solution by volume	Cat #216440	CVS Pharmacy	Durham, NC, USA
Blood pressure monitor	Automatic wrist blood pressure monitor	800824	CVS Corporation	Woonsocket, RI, USA
	Self-taking blood pressure monitor	800232		
Digital video	Camcorders	HMX-F90	Samsung	BestBuy, Durham, NC, USA
Duct tape	General-purpose duct tape – silver 2.83" x 50 yards	1207805	Nashua Trusted Tape Products	Franklin, KY, USA

A variety of PPE was used throughout the study. While the scripts varied the number and type of PPE items used, all participants donned an inner Tyvek® coverall and first pair of disposable nitrile gloves, which represented skin and street clothes. All PPE suits used in the evaluation, both inner and outer suits, were either Tyvek® or Tychem® Class C HAZMAT suits. Level C protection is required when the concentration and type of airborne substances is known and the criteria for using air purifying respirators is met, as would be required when responding to an event such as that simulated in this evaluation (U.S. EPA, Personal Protective Equipment, http://www2.epa.gov/emergency-response/personal-protective-equipment). Table 2.1-2 lists the items of PPE used throughout the study.

Table 2.1-2. Personal Protective Equipment

PPE	Description	Size	Part Number	Company	Location
Outer suit	Tyvek® Class C HAZMAT	XL	DUPTY122SWHXL00	E. I. du Pont de Nemours and Company	Wilmington, DE, USA
	Tyvek® Class C HAZMAT	2X	DUPTY122SWH2X00	E. I. du Pont de Nemours and Company	Wilmington, DE, USA
	Tyvek® Class C HAZMAT	MD	DUPTY122SWHMD00	E. I. du Pont de Nemours and Company	Wilmington, DE, USA
	Tychem® Class C HAZMAT	XL	DUPSL122BWHXL00	E. I. du Pont de Nemours and Company	Wilmington, DE, USA
	Tychem® Class C HAZMAT	2X	DUPSL122BWH2X00	E. I. du Pont de Nemours and Company	Wilmington, DE, USA
Inner suit (used to represent skin)	Tyvek® Class C HAZMAT	XL	DUPTY122SWHXL00	E. I. du Pont de Nemours and Company	Wilmington, DE, USA
	Tyvek® Class C HAZMAT	2X	DUPTY122SWH2X00	E. I. du Pont de Nemours and Company	Wilmington, DE, USA
	Tyvek® Class C HAZMAT	MD	DUPTY122SWHMD00	E. I. du Pont de Nemours and Company	Wilmington, DE, USA
Outer gloves	Purple long-cuff	XL	32934-084	Kimberly-Clark Corporation	Dallas, TX, USA
	Purple long-cuff	LG	32934-082	Kimberly-Clark Corporation	Dallas, TX, USA
Suit gloves (taped to outer suit)	Green nitrile	LG	19-130-3712	Showa Best Glove. Inc.	Menlo, GA, USA
	Green nitrile	XL	19-130-3713	Showa Best Glove. Inc.	Menlo, GA, USA
Inner gloves (used to represent skin)	Blue nitrile	LG	82026-428	VWR International, LLC	Radnor, PA, USA
	Blue nitrile	XL	89107-332	Kimberly-Clark Corporation	Dallas, TX, USA
	Blue nitrile	LG	89107-330	Kimberly-Clark Corporation	Dallas, TX, USA
Boots	Heavy-duty	Various sizes	NA	AGM	San Diego, CA, USA
Respirator	Face mask	Various sizes	AV-3000	Scott Safety	Monroe, NC, USA

2.2 Methods

The methods used to evaluate the effectiveness of the decon line SOG are detailed here. These include participant roles, laboratory setup, test scripts, test procedures, and analysis methods.

2.2.1 Test Subjects

The test subjects for each evaluation were designated as one of three test subject types: (1) test subject (dosed with contaminant), (2) control subject (not dosed), or (3) attendant (not dosed and provided assistance to test and control subjects). All three types of test subject were trained to perform each step of the SOG (Appendix A). Attendants were given step-by-step directions (Appendix B) for guiding the test and control subjects through the decon line stations.

The total number of test subjects, control subjects, and attendants per tested script ranged from 7 to 15. Either two or three attendants were used, depending on the script. Each participant was assigned a unique four-character identification (ID) number based on their role in the test script (e.g., TS01, CS01, AT01). All participants donned PPE, but only those designated as test subject were dosed with a fluorescently dyed powder representing the contaminant, as described in Section 2.2.8.2; the attendants and control subjects were not dosed. The control subjects proceeded through the decon line after the test subjects, serving as an indicator of cross-contamination occurring from anything or anyone in the decon line itself.

The bodies of each test subject, control subject, and attendant were divided into seven distinct sections that were used as the evaluation areas:

- Head, neck, and shoulders
- Front torso: front central and side regions, including the thorax and abdomen but excluding the back, neck, shoulders, and arms
- Left and right arms: region extending down each arm from the shoulder, excluding the shoulder but including the arm pit
- Left and right legs: entire lower extremity of the body from the waist down, including feet, thighs, hips, and buttocks
- Back: large posterior area of the body opposite the chest, rising from the top of the buttocks until meeting (but excluding) the neck and shoulders

All results were analyzed and reported according to these section designations. A representative diagram of these sections (Figure 2.2-1) was created to illustrate all reported results (Section 3) in a consistent manner for easy comparison. This diagram is used in Section 3 to report the percentages of contamination for test subjects, control subjects, and attendants for all evaluations.

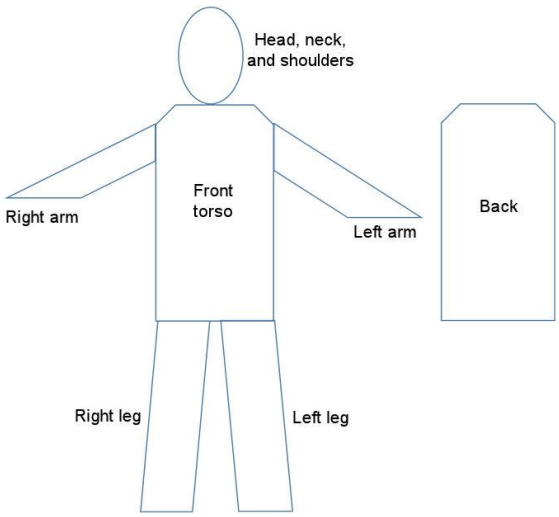


Figure 2.2-1. Representative test subject body areas used to identify contamination

2.2.2 Institutional Review Board

Because this project involved humans, approval was sought from the University of North Carolina (UNC) at Chapel Hill Institutional Review Board (IRB) for human participants, which serves as the IRB for EPA activities in Research Triangle Park, NC. The IRB submission was reviewed by UNC's Office of Human Research Ethics, which determined that this project did not constitute human subjects research as defined in the Code of Federal Regulations (45 CFR 46, 21 CFR 56, and 40 CFR 26) and therefore did not require IRB approval. EPA reviewers did note, however, that attention to certain safety and health aspects might still be required to protect the welfare of participants in this project, including adherence to Occupational Safety and Health Administration (OSHA) requirements and careful, thorough training of participants. All study participants were required to attend the Test Participant Briefing on Human Protection Issues (Appendix C). In addition, they were provided with the Safety Data Sheet for the fluorescently dyed powder that represented the contaminant and were required to sign a Research Subject Information and Consent Form (Appendix D).

2.2.3 Setup

Figure 2.2-2 shows the setup used for evaluating the SOG. The testing area was divided into three zones: support zone (SZ), exclusion zone (EZ), and contamination reduction zone (CRZ). Separate areas, or stations, for carrying out discrete activities were defined within each zone. The SZ, shaded in blue in Figure 2.2-2, surrounded the entire test area and contained specific areas for pre-contamination activities at the start and post-decontamination activities at the end of the evaluation. The zones, stations, and activities conducted in each area are described in detail in Section 2.2.8.

Two fans were in operation during the testing to help prevent cross-contamination. These fans were set to simulate 3 mph prevailing winds. One was located in the SZ staging area that was used for pre-contamination activities at the start of the evaluation and blew toward the EZ; the second fan was located in the SZ outside of the outer garment doffing station (near ARC 5) and blew into the CRZ. Two video cameras positioned in the SZ, one right outside the sample drop-off area and the other outside the outer garment doffing station, continuously recorded the decontamination and doffing procedures. While each test script varied with respect to procedural requirements (e.g., number of gloves, number and type of coveralls, number of attendants), the zones and decontamination line flow shown in Figure 2.2-2 are representative of all testing conducted.

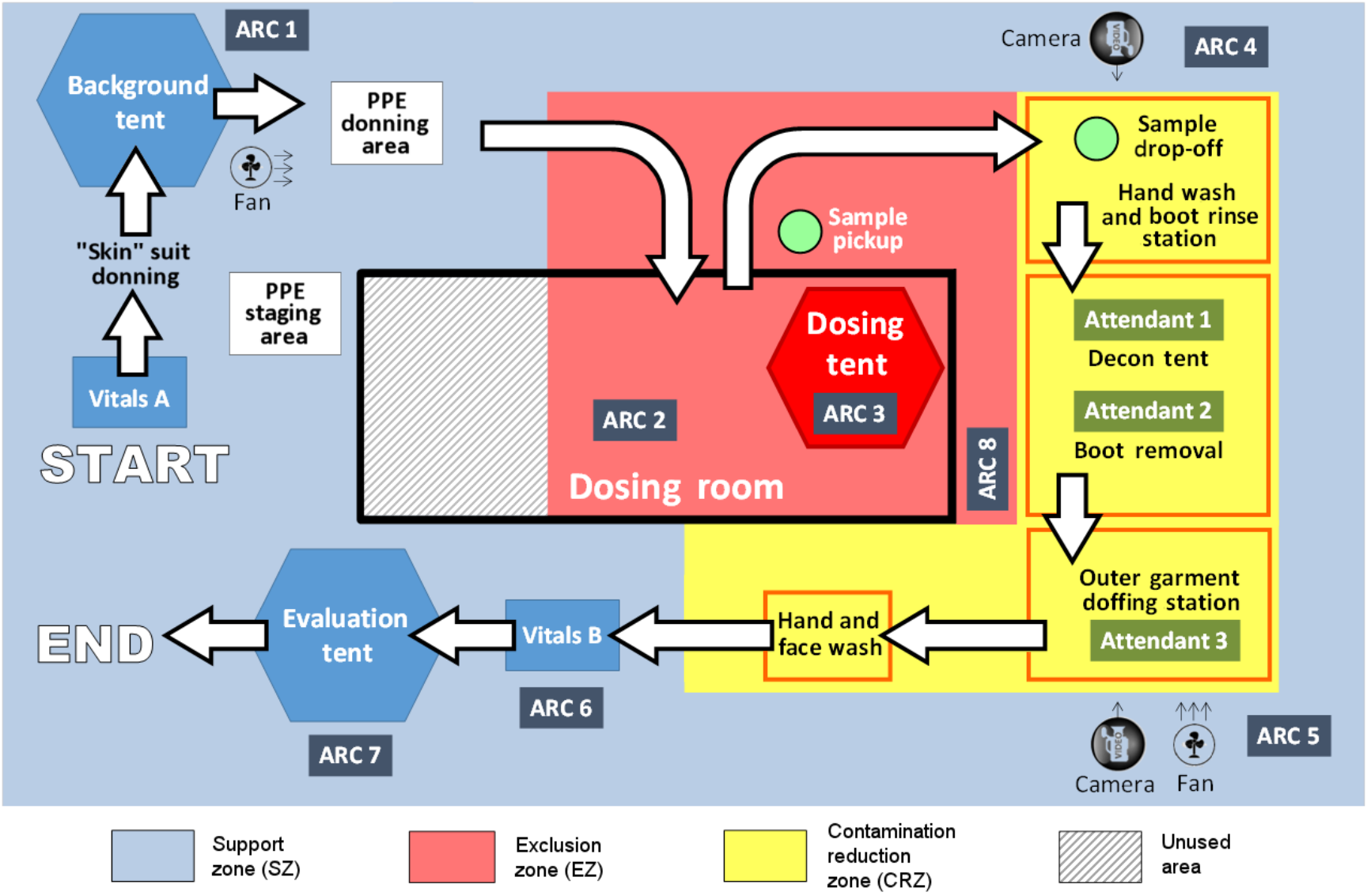


Figure 2.2-2. Decon line testing design

2.2.4 "Contaminated Samples"

One of the goals of this project was to determine if cross-contamination occurred outside the EZ from "contaminated samples," which were carried and dropped off by the test subjects and controls during the evaluation. The samples comprised one 250-mL graduated non-sterile histology container with a separate screw cap in a 10-inch by 12-inch clear, reclosable polybag. The test subjects' samples were dosed with the fluorescent powder representing the contaminant following the procedure described in Section 2.2.8.2. Each sample was labeled "77-MMDDYY-(1–25)" where 77 was the contract work assignment number; MMDDYY was the month, day, and year; and (1–25) was the number of the sample kit used. The labels were written on the bags with a permanent marker. The controls also carried sample bags, but their bags were not dosed with the fluorescent powder. The procedures for handling the samples after they were dropped off by the test subjects are described in Section 2.2.9.

2.2.5 Support Team

A support team of eight ARCADIS U.S., Inc. (ARC) contractor personnel (designated ARC 1 through ARC 8) was spread across the test area. Each support team member had specific responsibilities such as taking pre- and post-test vitals (called Vitals A and B, respectively), performing the dosing, and noting any anomalies or vulnerabilities in the decon procedures. The specific responsibilities of each support team member are detailed in Appendix E. To avoid cross-contamination, no one from the support team in the SZ—the support zone surrounding the decon line that was used for pre-contamination activities at the start and post-decontamination activities at the end of the evaluation—was allowed to participate in any activities being performed in the EZ unless instructed to do so. Only ARC 2 and ARC 3 were allowed in the EZ, where they remained until a test run was completed.

2.2.6 Test Scripts

Seven rounds of testing were conducted. Each round used a different script. Variations in the script were introduced following each prior round of testing to eliminate identified weaknesses in the SOG, with the goal of minimizing cross-contamination or spread of contamination from the EZ. Cross-contamination was identified visually by the presence of fluorescent material on surfaces of the inner suit (i.e., the "skin"), on the test samples, or in areas beyond the CRZ.

The seven rounds of testing that were evaluated are summarized below. Each script was modified by EPA and the contractor personnel following evaluation of the results of the preceding testing script. Script 1 represents the existing SOG (Appendix A) being evaluated. Details of each of the seven scripts can be found in Appendix F. One element that did not change from script to script was that the test subjects washed their outer gloves and boots in the hand wash and boot rinse station upon entering the CRZ.

Script 1: SOG using two attendants and a two-step outer garment spray-brush decontamination sequence (two tests)

In Script 1, the test subjects followed the existing SOG, as described in Appendix A, using two attendants. The first attendant's sole function was to wash down the test subject and remove their boots, while the second attendant helped the test subject doff their face mask and outer suit.

Script 2: SOG using two attendants with a three-step outer garment spray-brush-rinse decontamination sequence (one test)

Script 2 followed the Script 1 procedure, with the first attendant adding a rinse step following the test subject's outer suit spray-brush procedure. The rinse step was added to determine if it had a positive outcome in reducing cross-contamination during the doffing step.

Script 3: SOG using three attendants with a scripted three-step outer garment spray-brush-rinse decontamination sequence (two tests)

Script 3 followed the Script 2 procedure but with the addition of a third attendant to the decon line to evaluate whether extra doffing assistance would reduce contamination. The attendants were briefed prior to testing on their role of simulating real-life scenarios without directions from outside support personnel. Attendant 1 was charged with directing the test subjects through the decon station. Attendants 1 and 2 performed the three-step decontamination sequence. Attendant 3 assisted the test subjects with doffing their outer garments (gloves, mask, and coverall). The duties of each attendant were displayed on posters at the points of performance in the decon line to help the attendants carry out their roles.

Script 4: SOG using two attendants with a scripted one-step outer garment water mist spray decontamination sequence (two tests)

Script 4 followed the Script 2 procedure, but Attendant 1 used only a one-step light water spray from top down on the outer garment including the boots. The attendants were briefed prior to testing on their role of simulating real-life scenarios without directions from outside support personnel. Attendant 1 also directed test subjects through the decon station. Attendant 2 assisted the test subjects with doffing their outer garment. The scripted duties of each attendant were displayed on posters at the point of performance in the decon line to help the attendants carry out their roles.

Script 5: SOG using two attendants with a scripted one-step outer garment cooking oil spray decontamination sequence (two tests)

Script 5 followed the Script 4 procedure, but Attendant 1 used cooking oil spray (in place of the water spray) from top down on the outer garment including the boots. Cooking spray oil was suggested as a method to reduce reaerosolization of contaminants during the doffing procedure.

Script 6: SOG using two attendants with a scripted one-step outer garment water mist spray decontamination sequence with test subjects donning an extra inner Tyvek® suit (one test)

Script 6 followed the Script 4 procedure, but test subjects wore three coveralls (two inner Tyvek® coveralls and one outer Tychem® coverall). This test was designed to determine if an added layer of protection reduces test subject exposure to contamination.

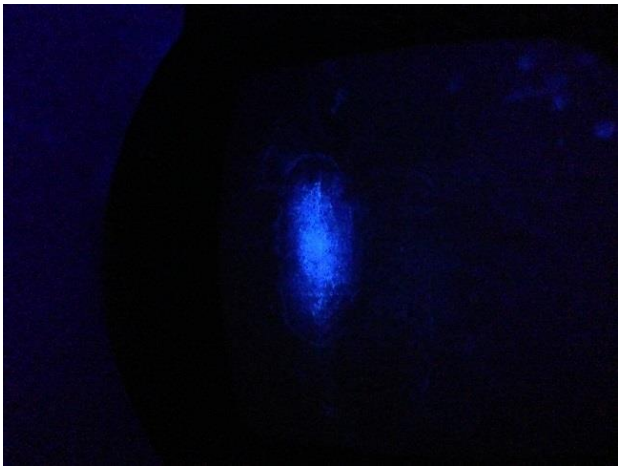
Script 7: SOG using two attendants with a scripted one-step outer garment water mist spray decontamination sequence with test subjects donning three Tyvek® suits and no outer Tychem® coverall (two tests)

Script 7 followed the Script 6 procedure with test subjects wearing three Tyvek® coveralls (no Tychem® coverall). This test was designed to determine if replacing the expensive, waterproof Tychem® suit with less expensive, more breathable Tyvek® would affect the protectiveness to inner suit contamination.

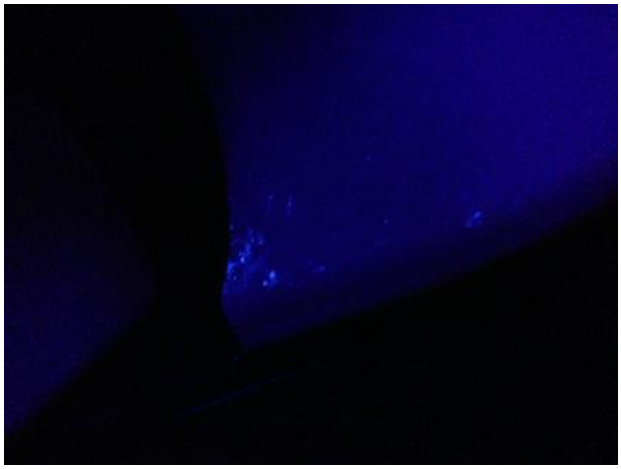
2.2.7 Test Facility Evaluation after Scripts 1 and 2

Following evaluation of the results of the Script 2 quantitative analysis, questions arose as to whether the test facility itself could be contributing to the observed contamination. Therefore, it was decided that a systematic evaluation of the test facility should be performed prior to developing and initiating Script 3 to determine the spread, if any, of contamination inside and outside the decontamination stations. The exit flap of the decon tent, the chair where test subjects were seated for outer garment removal, and the SZ Vitals B table were evaluated. The results of the evaluation showed that, even after decontamination, each area showed signs of cross-contamination, as illustrated in Figure 2.2-3. Thus, instructions were given thereafter to cover the tables with disposable Tyvek® materials at the start of each testing sequence to reduce or eliminate cross-contamination of clean areas and prevent migration of contamination to support areas. Additionally, movement of test subjects and support personnel was strictly monitored. The entire test facility area was cleaned and reassessed to remove any background contamination. The test facility was reevaluated daily, and no significant contamination was noted after Script 2.

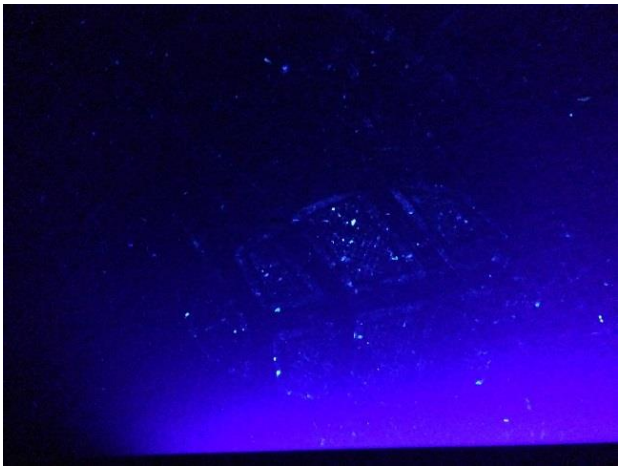
Exit flap of decon tent



Outer garment removal chair



Vitals B table



Footprint outside SZ evaluation tent

Figure 2.2-3. Script 2 post-test evaluation pictures

2.2.8 Decon Line Evaluation Procedures

The following subsections describe the activities conducted in each zone as the test subjects advanced through the decon line evaluation scripts. The overall evaluation process for all scripts was an initial UV scan, followed by each participant performing an assigned role in each step of the SOG, and then a final UV scan to determine the location and extent of cross-contamination that occurred in the decon line. Refer to Figure 2.2-2 for the locations of each zone and station.

During the tests, two video cameras continuously recorded the decon line activities. In addition, ARC 4, positioned just outside the sample drop-off area near the first video camera, and ARC 5, positioned outside the outer garment doffing station near the second camera, noted any anomalies or vulnerabilities during the performance of the decontamination procedures. A post-test questionnaire (Appendix G) was also completed by the participants at the end of the testing. Responses to this questionnaire, along with photographs and video recordings and the notes taken by the support team, aided in the evaluation of the decon line procedures and became part of the test results.

2.2.8.1 Support Zone – Pre-contamination Activities

ARC 1 had responsibility for the SZ pre-contamination activities at the start of the evaluation where each test subject was greeted, briefed on the protocol and PPE donning procedures, and assigned a unique (ID) number. Then pre-test vital signs (Vitals A)—blood pressure and pulse—were acquired, and the test subjects completed their paperwork (Figure 2.2-4).

Figure 2.2-4. Support zone area where Vitals A were acquired and paperwork was completed

Participants also donned their PPE in the SZ and underwent initial UV evaluations as a background contamination check. As show in Figure 2.2-5, a PPE staging area was set up in the SZ to make the PPE readily available and accessible for each test.

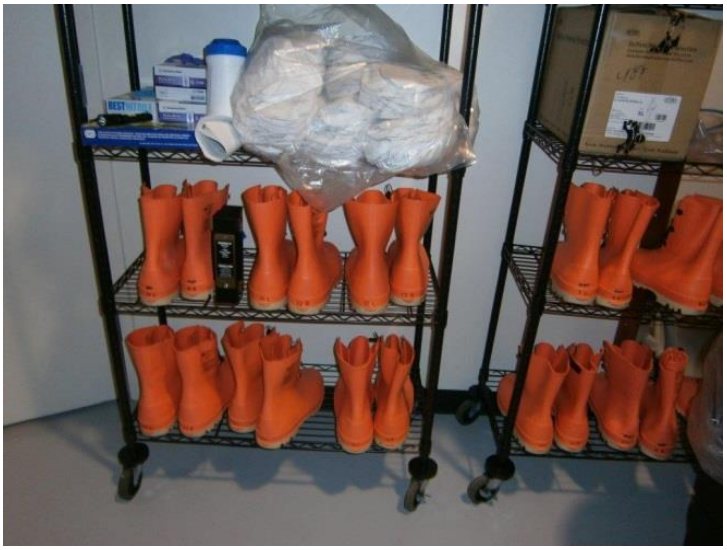


Figure 2.2-5. PPE staging area

A strict protocol for donning PPE was employed so that all personnel were representative of hazardous materials (HAZMAT) workers in the field, which included taping all seams with duct tape. The test subjects, control subjects, and attendants first donned an inner Tyvek® coverall and initial pair of blue disposable nitrile gloves (different color gloves were used to distinguish inner and outer PPE layers and the extra set of gloves when called for by the script). This inner suit represented skin and street clothes (Figure 2.2-6). The gloves were taped to the coverall. The participants, wearing just the inner suit, then entered the background tent (Figure 2.2-7) for evaluation by scanning with a UV LED flashlight for any initial contamination.

Figure 2.2-6. Test subject wearing Tyvek® inner suit and blue nitrile gloves, which represented skin and street clothes

Figure 2.2-7. SZ background tent for pre-contamination UV evaluations

After the initial UV assessment of the “skin” PPE, the participants donned their outer PPE garments, including green disposable nitrile gloves, heavy-duty boots, and face masks (Figure 2.2-8). All seams were taped with duct tape, including a large bib covering the area under the chin between the face mask and the suit. The participants were then reevaluated in the SZ background tent with the UV light. The ID number for each participant was written on each protective suit. Figure 2.2-9 shows the ID number fluorescing under the UV light.

Figure 2.2-8. Test subject with Tychem® outer suit, facemask, gloves, and boots

Figure 2.2-9. Test subject's ID number fluorescing under UV light

2.2.8.2 Exclusion Zone

After donning PPE and being UV scanned, the attendants immediately took their places in the decon line as specified by the test script, and test and control subjects proceeded to the EZ. In this zone, ARC 2 used an applicator brush to apply approximately 0.2 gram of the fluorescent powder surrogate contaminant to five discrete locations (Table 2.2-1) on each test subject (control subjects were not dosed), as illustrated in Figure 2.2-10. These locations were selected to provide a cross-section of potentially contaminated areas that could occur under field conditions. The test subjects then entered the dosing tent where they were again evaluated, by ARC 3, using one or more 6-watt UV lamps. Figure 2.2-11 shows the contaminated hand of a test subject. The controls bypassed the dosing tent.

Table 2.2-1. Dosing Locations

Location	Dosed Locations
1	Outside of face mask
2	Palm of right-hand glove
3	Left shoulder
4	Right hip
5	Inner side of left boot

Figure 2.2-10. Application of fluorescent powder to test subject

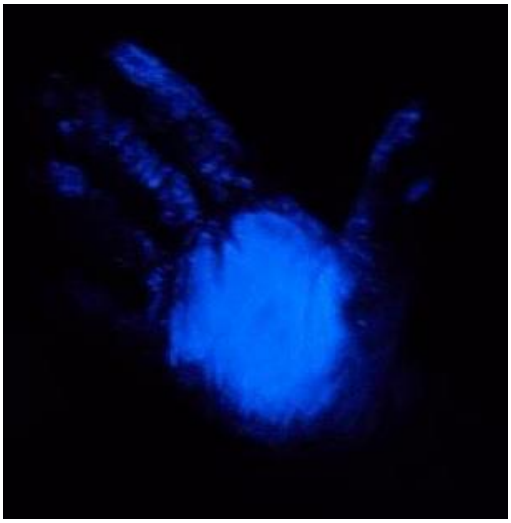


Figure 2.2-11. Contaminated hand of a test subject

The “contaminated sample” was also dosed in the EZ. ARC 2 dosed the outside of the bag just below the label with approximately 0.05 g of the fluorescent powder. The amount of powder applied was determined gravimetrically, weighing the brush before and after application. These dosed samples were placed on a rack just outside the dosing room but still within the EZ. After being dosed and evaluated, the test subjects exited the dosing room and each picked up one of the dosed samples before proceeding to the next step in the decon line.

2.2.8.3 Contamination Reduction Zone

Test and control subjects proceeded through the following CRZ areas:

1. Sample drop-off
2. Hand wash and boot rinse station
3. Decon tent
4. Boot removal
5. Outer garment doffing station
6. Hand and face wash

Sample drop-off

The test subjects advanced to an area designated for sample drop-off, where ARC 4 instructed them to place their samples in the bin located there. Figure 2.2-12a shows the sample drop-off bin, and Figure 2.2-12b shows a test subject dropping off a sample.

Figure 2.2-12a. Sample drop-off bin

Figure 2.2-12b.Test subject making a sample drop

Hand wash and boot rinse station

The next stop was the hand wash and boot rinse station (Figure 2.2-13) located next to where the samples were dropped off. At this station, the test and control subjects were instructed by ARC 4 to wash their hands, including between the fingers. They were then directed to place one foot into a collection berm and to scrub each boot, aiming the brush down and away. The same action was performed on the other boot. Figure 2.2-14a shows a test subject washing their hands and Figure 2.2-14b shows the boot scrubbing.

Figure 2.2-13. Hand wash (left) and boot rinse station (right)

Figure 2.2-14a. Test subject washing hands

Figure 2.2-14b. Test subject scrubbing boot

Decontamination tent

Next the test and control subjects were told to step from the berm into a second berm inside the decon tent. The decon tent was used for several decontamination methods including spraying (Figure 2.2-15), brushing, and rinsing by attendants, depending on the details of the test script.

Figure 2.2-15. Test subject having outer suit sprayed down in the decon tent

Boot removal

The test and control subjects then stepped into another area inside the decon tent that was designated for boot removal. Here an attendant assisted them with removing their boots.

Outer garment doffing station

After boot removal, the test and control subjects were directed to step out of the opposite side of the decon tent into the outer garment doffing station. An attendant assisted with removal of the test subjects' outer gloves (Figure 2.2-16), outer suit (Figures 2.2-17a and b), and face mask (Figure 2.2-18).

Figure 2.2-16. Test subject being assisted with outer glove removal

Figure 2.2-17a.Test subject being assisted with removal of tape on suit's zipper prior to suit removal

Figure 2.2-17b.Test subject being assisted with removal of outer Tychem® suit

Figure 2.2-18. Test subject being assisted with mask removal
(The suit pictured on the left represents the inner "skin" layer)

Hand and Face Wash

The subjects proceeded next to an area in the decon line where they were instructed to doff their secondary gloves if worn for the script and to wash their hands and face with a soap solution followed by a water rinse (Figure 2.2-19).

Figure 2.2-19. Hand and face wash setup

2.2.8.4 Support Zone – Post-decontamination Activities

At the conclusion of the decon line procedures, the test subjects, control subjects, and attendants moved from the CRZ into the SZ where ARC 6 took their post-decontamination blood pressure and pulse (Vitals B) (Figure 2.2-20). After having their vitals checked, the participants entered the evaluation tent, where ARC 7 performed the post-decontamination evaluation using 6-watt UV lamps while dictating notes to ARC 6 who was outside. Areas of fluorescence were outlined with a marker on the undergarment by ARC 7, who also provided estimates of contaminated areas in inches squared (in^2). The participants then stepped outside of the evaluation tent where they removed their inner gloves and inner suit (mimicking the skin) and handed them to ARC 7. ARC 7 bagged these PPE items and noted the test subject ID on the bag. Participants were evaluated under UV light one final time in their street clothes and then were asked to wash off any fluorescent material present on their hands and face. ARC 6 and ARC 7 donned new pairs of gloves between each test subject evaluation.

Figure 2.2-20. Support zone area where post-decontamination vitals (Vitals B) were acquired

2.2.9 "Contaminated Sample" Handling Procedure

On the day after each test script was completed, all samples that had been dropped off by the test subjects and controls were put through a standard sample-handling procedure devised to eliminate any cross-contamination. This sample-handling procedure involved two sample handlers (Samplers A and B) who followed the specific steps listed below:

Sampler A

1. Don a new pair of gloves before touching any parts of the inner sample bag.
2. Spray the outside of the sample bag using a spray bottle containing 91% isopropyl alcohol solution by volume.
3. Using a paper towel, wipe down the outside of the inner sample bag and the lip.
4. When Sampler B is ready, insert the wiped down bag into the 3-gallon bag outer bag held open by Sampler B.

Sampler B

1. Don a new pair of gloves.
2. Open a 3-gallon outer Ziploc® bag without touching the outside of the bag for Sampler A to insert the wiped down sample bag.
3. Press the 3-gallon bag to remove air and seal.
4. Wipe down the outside of the 3-gallon bag, including the lip of the zipper, using a pre-moistened wipe containing 70% reagent-grade isopropyl alcohol and 30% reagent-grade deionized water.
5. Don a new pair of gloves.
6. Repeat the wipe-down of the 3-gallon bag, including the lip of the zipper, using a new alcohol wipe.

2.3 Analysis

The test subjects, control subjects, and attendants were evaluated using two approaches for each test script to determine the presence of cross-contamination on the inner Tyvek® suits simulating their skin. The two approaches, a binary qualitative approach and a quantitative approach, were used to evaluate the effectiveness of each test script in reducing or eliminating cross-contamination from the outer suit to the inner suit of the test subjects, control subjects, and attendants.

2.3.1 Binary Qualitative Analysis

The first approach used was a binary qualitative evaluation. In this approach, either a 0 (no contaminant detected) or a 1 (contaminant observed) was applied for the contamination found on each region of the participant's body. The probability of occurrence (%) of cross-contamination for each test script was calculated by taking the average of the contamination for that region of the body for all test subjects, control subjects, or attendants who participated in that testing sequence. The resulting average probability of occurrence (%) and standard deviation (stdev) were used to evaluate the effectiveness of each test script. The results were represented graphically on a figure showing results for all test participants in a testing sequence. In order to make general comparisons at a glance, the figures used a percentage of shading corresponding to the percentage of contamination found in that region of the body (see Section 2.2.1 for a detailed description of the regions). Figure 2.3-1 illustrates the probability of occurrence (%) of cross-contamination for an example test script. Results for all test scripts in Section 3 are represented in this manner.

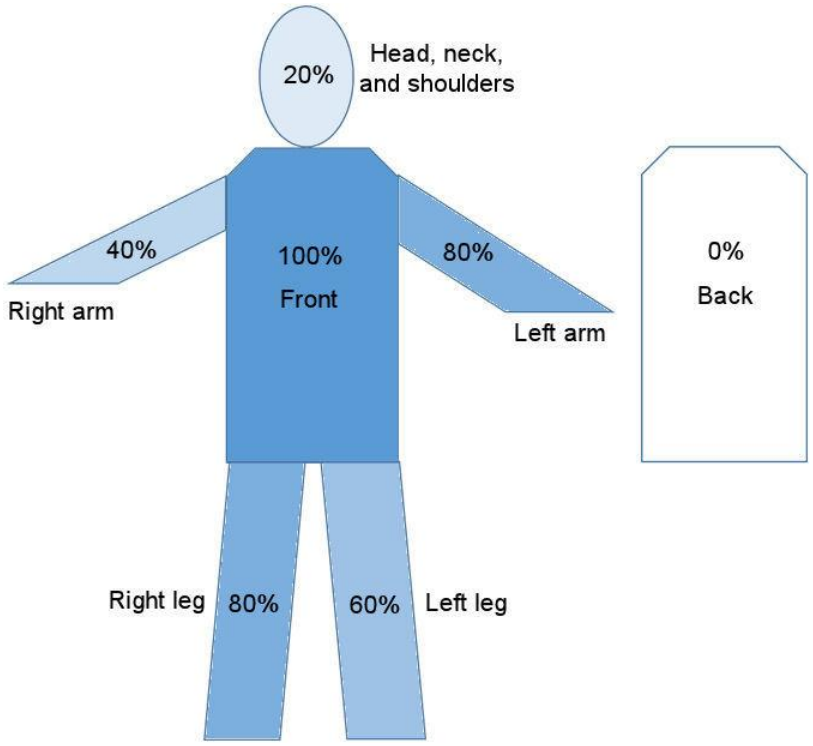


Figure 2.3-1. Test script probability of occurrence (%) of cross-contamination

2.3.2 Quantitative Area Analysis

The second approach for evaluating cross-contamination consisted of estimating the area that demonstrated increased fluorescence as a result of contamination on the innermost suit or “skin”. When applicable, the area estimate was of the broad area affected during a single event rather than of individual splatters, as seen in Figure 2.3-2.

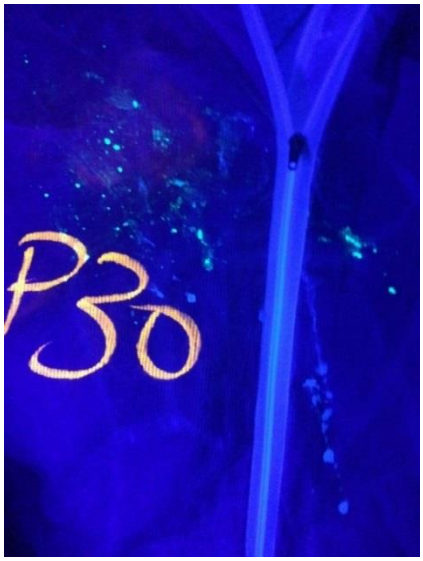


Figure 2.3-2. Front torso broad area cross-contamination

3 Results and Discussion

Both qualitative and quantitative analyses were conducted on the inner suit used to represent the skin for each of the seven scripts to determine if the test subjects were protected from contamination and if they were potential vectors of cross-contamination into any support areas outside the EZ. Note the results do not take into account any microbial population reduction potential that would occur under actual field conditions where effective sporicidal agents, such as 0.5% hypochlorite solution, would be used in the decontamination process. Script variations were introduced following each round of testing. These variations were based on the evaluations from the previous testing round with the ultimate goal of improving individual SOG procedures to minimize cross-contamination. The following subsections present the results of each script evaluation and a discussion of the reasoning and motivations that led to the script variations. Also briefly discussed here are the results of the "sample" decontamination procedures.

As explained in Section 2, for the binary qualitative evaluations either a 0 (contaminant detected) or a 1 (contaminant observed) was applied to each region of the participant's body. These values were then averaged and represented graphically. For the qualitative evaluations, the participants' inner suits were visually examined and areas of contamination were outlined and measured and are reported here in inches squared (in^2).

3.1 Script 1: SOG Using Two Attendants and a Two-Step Outer Garment Spray-Brush Decontamination Sequence (Two Tests)

Script 1: *This test script was conducted to reflect the current version of the SOG, which uses two attendants. The first attendant's function was to perform physical removal of the gross contaminants from the outer suits of the test subjects. A soap and water washdown was followed by brushing off the outer suit. This attendant also helped the test subjects remove their boots. The second attendant's role was to help the test subjects doff their outer suit, outermost layer of gloves, and face mask. The test script was run in duplicate, with different attendants, to determine if the techniques of the attendants had any effect on amount of cross contamination.*

3.1.1 Qualitative Analysis

The qualitative results for this test script are listed in Table 3.1-1 for Test 1 (five test subjects and two attendants) and Test 2 (four test subjects and two attendants). Figures 3.1-1a and 3.1-1b graphically represent the probability of occurrence (%) of cross-contamination for each region of the body in Tests 1 and 2, respectively. *These results show a high probability of cross-contamination for all regions of the body for both the test subjects and the attendants*. A 100% chance of contamination of the front torso (labeled "front" in all results tables and figures) is shown for this script, which is the region where the attendants are most exposed to contact with the test subjects during the doffing process. Test 2 shows that the attendants' contamination was reduced from all of the evaluated regions to only one area of the body (left arm). Significant variation was observed among attendants performing the same doffing technique (e.g., speed at which procedure was performed, attention to procedural details). The improvement observed in Test 2 can possibly be attributed to a better doffing technique used by the second pair of attendants.

The results show that the spread of contamination can be very large, more than 2 ft^2 in some regions of the body for certain test subjects. The results were consistent with reports by the test subjects that the soap and water being used for decontamination was penetrating the suit, probably at the taped seams at the neck and the gloves, and carrying contaminant particles into the inner skin suit. This liquid penetration might also be exacerbated during the brushing process. Note that the brush used to remove the gross contamination was reused on each test subject, thus providing a vehicle for cross-contamination among test subjects.

Although the Test 2 attendants came out cleaner than the Test 1 attendants, no correlation can be drawn on the spread of contamination by the attendants from one test subject to another. The change in attendants seemed to have a marginal effect, if any, in reducing or alleviating the cross-contamination among the test subjects.

Table 3.1-1. Script 1 Qualitative Analysis Occurrence of Cross-Contamination

Test Subject ID	Head, Neck, and Shoulders	Front	Left Arm	Right Arm	Back	Left Leg	Right Leg
Test 1							
TS31	0	1	1	0	0	0	1
TS00	0	1	0	1	1	0	1
TS02	0	1	1	0	1	1	1
TS79	0	1	1	1	1	1	0
TS62	1	1	1	0	1	1	1
AT10	1	1	1	1	1	1	1
AT32	1	1	1	0	0	0	0
Test Subject Average (%)	20	100	80	40	80	60	80
Test Subject Stdev	45	0	45	55	45	55	45
Attendant Average (%)	100	100	100	50	50	50	50
Attendant Stdev	0	0	0	71	71	71	71
Test 2							
TS10	1	1	1	1	0	0	0
TS79	0	1	0	1	0	0	1
TS02	0	1	1	1	0	1	1
TS26	1	1	1	1	0	0	0
AT62	0	0	0	0	0	0	0
AT00	0	0	1	0	0	0	0
Test Subject Average (%)	50	100	75	100	0	25	50
Test Subject Stdev	58	0	50	0	0	50	58
Attendant Average (%)	0	0	50	0	0	0	0
Attendant Stdev	0	0	71	0	0	0	0

Test Subject ID	Head, Neck, and Shoulders	Front	Left Arm	Right Arm	Back	Left Leg	Right Leg
Script 1 Overall							
Test Subject Average (%)	33	100	78	67	44	44	67
Test Subject Stdev	50	0	44	50	53	53	44
Attendant Average (%)	50	50	75	25	25	25	25
Attendant Stdev	58	58	50	50	50	50	50

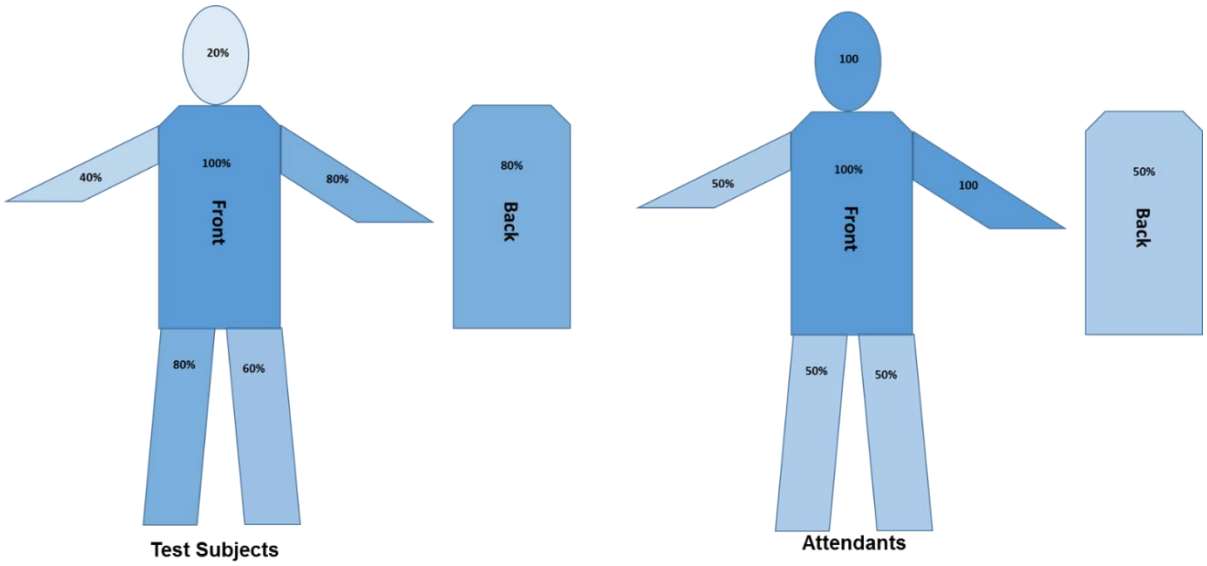


Figure 3.1-1a. Script 1, Test 1 occurrence (%) of cross-contamination

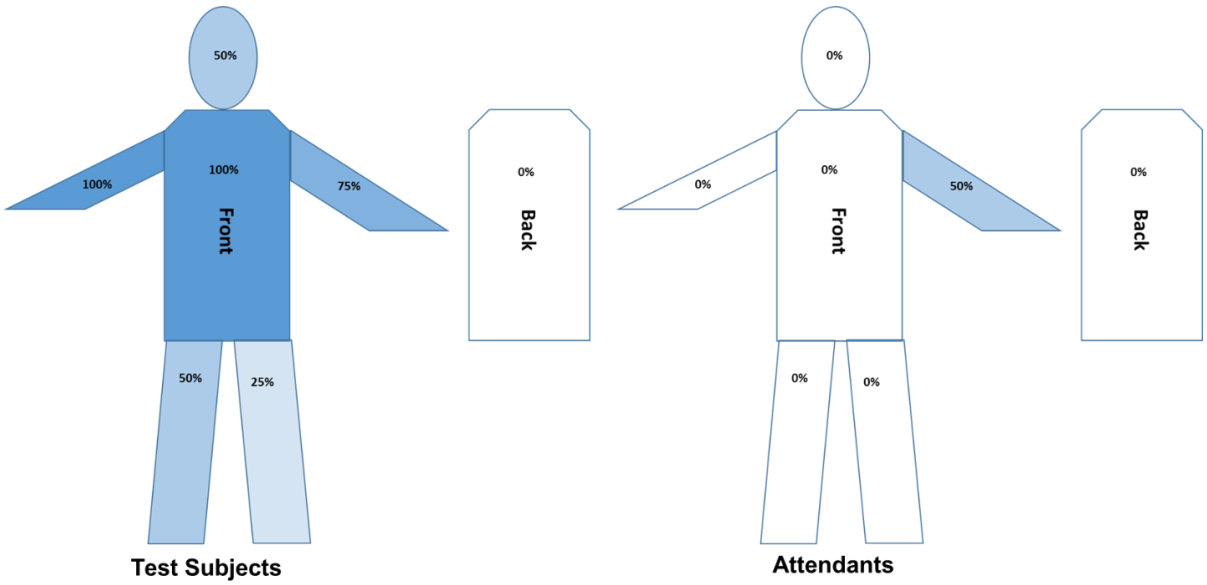


Figure 3.1-1b. Script 1, Test 2 occurrence (%) of cross-contamination

3.1.2 Quantitative Analysis

The quantitative areas for each region of the body for each test subject and attendant are presented in Table 3.1-2.

Table 3.1-2. Script 1 Estimated Contaminated Surface Area (in^2)

Test Subject ID	Head, Neck, and Shoulders	Front	Left Arm	Right Arm	Back	Left Leg	Right Leg	Total
Test 1								
TS31	NO*	21	2	NO	NO	NO	15	38
TS00	NO	32	NO	4	132	NO	36	204
TS02	NO	6	3	NO	2	10	79	100
TS79	NO	1	1	4	1	1	NO	8
TS62	36	1	6	NO	1	1	1	46
AT10	64	1	7	8	4	1	1	86
AT32	16	10	28	30	NO	NO	NO	84
Test 2								
TS10	29	6	4	18	NO	NO	NO	57
TS79	NO	144	NO	120	NO	NO	348	612
TS02	NO	240	16	144	NO	80	16	496
TS26	48	12	3	64	NO	NO	NO	127
AT62	NO	NO	NO	NO	NO	NO	NO	NO
AT00	NO	NO	2	NO	NO	NO	NO	2

*NO: contamination not observed

3.2 Script 2: SOG Using Two Attendants with a Three-Step Outer Garment Spray-Brush-Rinse Decontamination Sequence (One Test)

Script 2: *This test script was similar to Script 1 but with an added rinse step following the test subject's surface spray-brush procedure.*

3.2.1 Qualitative Analysis

The qualitative results for Script 2 are listed in Table 3.2-1 (four test subjects, one control subject, and two attendants). These results show a high probability of cross-contamination for all regions of the body for both the test subjects and the attendants. As was seen for Script 1, a 100% chance of contamination of the front torso was seen. This is the region that is most exposed to contact with the attendant during the doffing process and has potential for contamination due to leaking at the taped neck area. *The addition of the rinse step did not seem to reduce the cross-contamination of the front torso for the test subjects, control subject, or attendants* as illustrated in Figure 3.2-1.

Table 3.2-1. Script 2 Qualitative Analysis Occurrence of Cross-Contamination

Test Subject ID	Head, Neck, and Shoulders	Front	Left Arm	Right Arm	Back	Left Leg	Right Leg
TS10	0	1	1	1	0	0	1
TS02	0	1	1	0	0	1	0
TS62	0	1	1	0	0	0	0
TS00	0	1	1	0	0	1	0
CS26	0	1	0	0	0	0	0
AT90	0	1	0	0	0	0	0
AT79	0	1	0	0	1	0	0
Test Subject Average (%)	0	100	100	25	0	50	25
Test Subject Stdev	0	0	0	50	0	58	50
Attendant Average (%)	0	100	0	0	50	0	0
Attendant Stdev	0	0	0	0	71	0	0

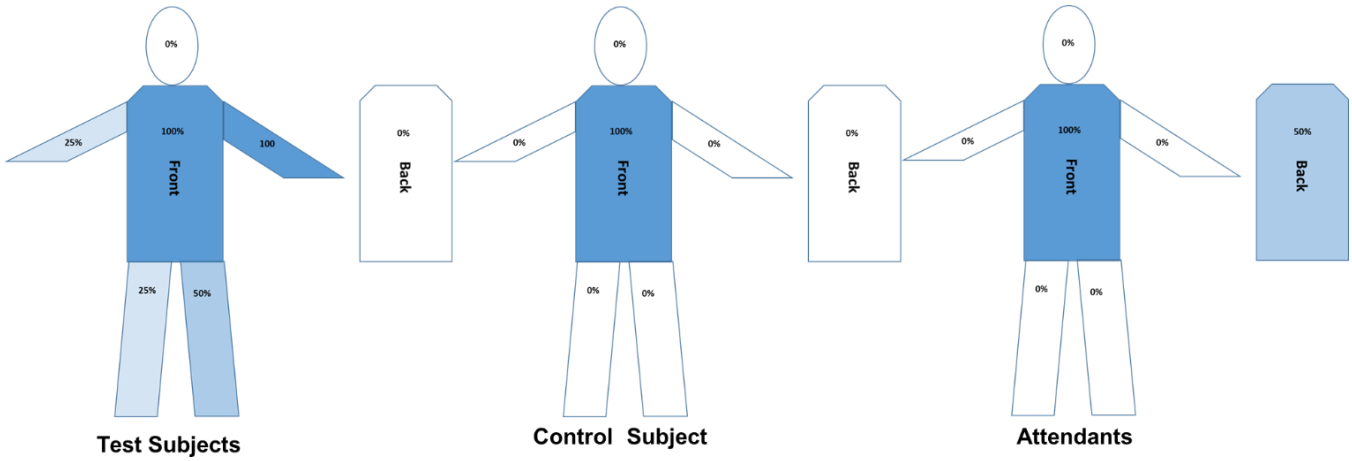


Figure 3.2-1. Script 2 occurrence (%) of cross-contamination

3.2.2 Quantitative Analysis

The addition of the rinse step in the decontamination process for this script seems to have had a minimal effect on reducing cross-contamination for most of the test subjects and the attendants (Table 3.2-2). The spread of contamination over relatively large surfaces observed in this script and in Script 1 suggests the likelihood of cross-contamination due to liquid penetration through vulnerabilities of the suit (e.g., seams, zipper, taped areas), the reused brush among test subjects, and/or the doffing process.

Table 3.2-2. Script 2 Estimated Contaminated Surface Area (in^2)

Test Subject ID	Head, Neck, and Shoulders	Front	Left Arm	Right Arm	Back	Left Leg	Right Leg	Total
TS10	NO*	12	55	8	NO	NO	8	83
TS02	NO	120	206	NO	NO	96	NO	422
TS62	NO	80	25	NO	NO	NO	NO	105
TS00	NO	36	240	NO	NO	10	NO	286
CS26	NO	16	0	NO	NO	NO	NO	16
AT90	NO	120	0	NO	NO	NO	NO	120
AT79	NO	100	0	NO	4	NO	NO	104

*NO: contamination not observed

3.3 Script 3: SOG Using Three Attendants with a scripted Three-Step Outer Garment Spray-Brush-Rinse Decontamination Sequence (Two Tests)

Script 3: *This script followed the Script 2 testing procedure with the addition of a third attendant. Attendants 1 and 2 were housed inside the decon tent, while Attendant 3 was in charge solely of helping the test subjects in the outer garment doffing station.*

Note: *After Scripts 1 and 2, questions arose about the facility itself possibly contributing to contamination. An evaluation of the entire test facility (see Section 2.2.7) was conducted prior to the Script 3 evaluation.*

3.3.1 Qualitative Analysis

The qualitative results for this test script are listed in Table 3.3-1 for Test 1 (five test subjects and three attendants) and Test 2 (four test subjects and three attendants). The probability of occurrence (%) of cross-contamination for each region of the body is illustrated in Figures 3.3-1a and 3.3-1b for Tests 1 and 2, respectively. *The addition of a third attendant as well as a full facility cleaning, movement restrictions, and disposable covering on work surfaces did not seem to decrease the probability of cross-contamination for all regions of the body for either test subjects or attendants*. The most probable zone of the body for contamination was still the front torso region due to vulnerabilities of the suit, which include the zipper and taped areas.

Table 3.3-1. Script 3 Qualitative Analysis Occurrence of Cross-Contamination

Test Subject ID	Head, Neck, and Shoulders	Front	Left Arm	Right Arm	Back	Left Leg	Right Leg
Test 1							
TS31	0	1	0	0	0	0	1
TS00	0	1	1	0	0	0	1
TS63	0	1	1	0	0	0	1
TS06	0	1	1	0	1	1	0
TS62	0	0	0	0	0	0	0
AT50	0	0	0	1	0	0	0
AT79	0	1	0	0	0	0	0
AT02	0	1	1	0	0	0	0
Test Subject Average (%)	0	80	60	0	20	20	60
Test Subject Stdev	0	45	55	0	45	45	55
Attendant Average (%)	0	67	33	33	0	0	0
Attendant Stdev	0	58	58	58	0	0	0
Test 2							
TS00	1	1	1	0	0	0	0
TS79	1	0	1	0	0	1	0
TS50	1	1	1	0	0	1	0
TS02	0	1	1	0	0	0	0
AT63	0	1	1	0	0	0	0
AT62	0	1	0	0	0	0	1
AT31	0	0	0	0	0	1	0
Test Subject Average (%)	75	75	100	0	0	50	0
Test Subject Stdev	0	58	0	0	0	58	0
Attendant Average (%)	0	67	33	0	0	33	33
Attendant Stdev	0	58	58	0	0	58	58
Script 3 Overall							
Test Subject Average (%)	33	78	78	0	11	33	33
Test Subject Stdev	50	44	44	0	33	50	50
Attendant Average (%)	0	67	33	17	0	17	17
Attendant Stdev	0	52	52	41	0	41	41

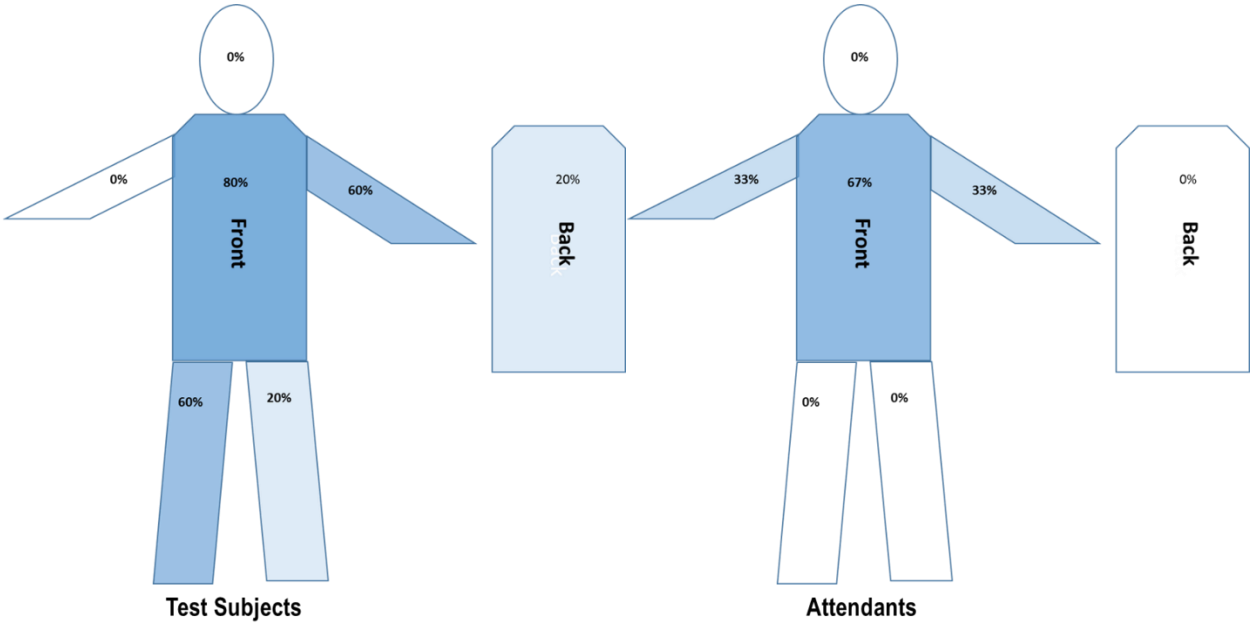


Figure 3.3-1a. Script 3, Test 1 occurrence (%) of cross-contamination

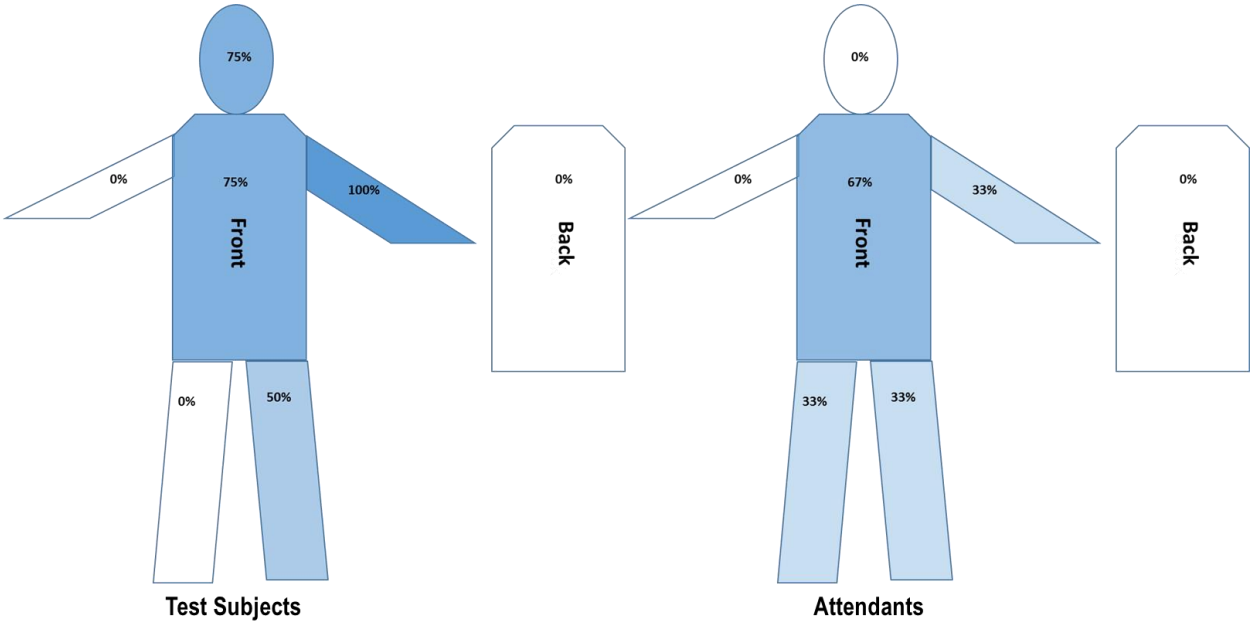


Figure 3.3-1b. Script 3, Test 2 occurrence (%) of cross-contamination

3.3.2 Quantitative Analysis

The results of the quantitative analysis (Table 3.3-2) for this script confirm the fact that the spread of contamination was not reduced by adding a third attendant helping with the doffing process and was likely the result of the decon process (with suit vulnerabilities being the primary culprit and possibly the reuse of the brush for each test subject).

The spreading of contamination over relatively large surface areas suggests that the three-step spray-brush-rinse decontamination process might have been caused by liquid penetrating the outer suit to the skin through vulnerabilities of the suit (e.g., seams, zipper, taped areas) as reported by some of the test subjects on the post-test questionnaire. TS00 reported feeling that when his arms were raised, water came down both sides of his arms towards his legs during the spraying process. TS79 reported water running under his armpits.

Table 3.3-2. Script 3 Estimated Contaminated Surface Area (in^2)

Test Subject ID	Head, Neck, and Shoulders	Front	Left Arm	Right Arm	Back	Left Leg	Right Leg	Total
Test 1								
TS31	NO*	195	NO	NO	NO	NO	15	210
TS00	NO	225	48	NO	NO	NO	504	777
TS63	NO	240	36	NO	NO	NO	240	516
TS06	NO	12	304	NO	6	54	NO	376
TS62	NO	NO	NO	NO	NO	NO	NO	0
AT50	NO	NO	NO	12	NO	NO	NO	12
AT79	NO	100	NO	NO	NO	NO	NO	100
AT02	NO	1	1	NO	NO	NO	NO	2
Test 2								
TS00	5	8	34	NO	NO	NO	NO	47
TS79	12	NO	72	NO	NO	2	NO	86
TS50	3	82	12	NO	NO	3	NO	100
TS02	NO	2	1	NO	NO	NO	NO	3
AT63	NO	6	1	NO	NO	NO	NO	7
AT62	NO	2	NO	NO	NO	NO	2	4
AT31	NO	NO	NO	NO	NO	3	NO	3

*NO: contamination not observed

3.4 Script 4: SOG Using Two Attendants with a Scripted One-Step Outer Garment Water Mist Spray Decontamination Sequence (Two Tests)

Script 4: *This script followed the Script 2 procedure, but Attendant 1 used only a one-step light water mist from top down on the outer garment including the boots, whereas Script 2 had a more involved spray-brush technique that focused on hard-to-reach areas such as armpits, backs of knees, inside arms, between fingers, etc. Script 4 was designed to reduce contaminant reaerosolization rather than to remove the contaminant.*

3.4.1 Qualitative Analysis

The qualitative results for this test script are listed in Table 3.4-1 for Test 1 (three test subjects, one control subject, and two attendants) and Test 2 (three test subjects, one control subject, and two attendants). The probability of occurrence (%) of cross-contamination for each region of the body is illustrated in Figures 3.4-1a and 3.4-1b for Tests 1 and 2, respectively. *The elimination of the spraying and brushing steps seems to reduce the probability of cross-contamination of the different regions of the test subjects, control subject, and attendants*. The spraying and brushing might have increased the chances of the water/soap solution infiltrating the outer ensemble of Tychem® suit, gloves, face mask, and tape, thereby contaminating the inner suit (skin). The front torso region remains the most vulnerable area for contamination for this script.

Table 3.4-1. Script 4 Qualitative Analysis Occurrence of Cross-Contamination

Test Subject ID	Head, Neck, and Shoulders	Front	Left Arm	Right Arm	Back	Left Leg	Right Leg
Test 1							
TS62	0	1	0	0	0	0	0
TS31	1	1	1	0	0	1	0
TS79	1	0	0	0	0	0	0
CS63	0	0	1	0	0	0	0
AT02	0	0	1	0	0	0	0
AT50	1	0	1	0	0	0	0
Test Subject Average (%)	67	67	33	0	0	33	0
Test Subject Stdev	58	58	58	0	0	58	0
Attendant Average (%)	50	0	100	0	0	0	0
Attendant Stdev	71	0	0	0	0	0	0
Test 2							
TS61	0	0	0	0	0	1	1
TS77	0	1	1	0	0	0	0
TS52	1	0	0	0	0	0	0
CS62	0	0	0	0	0	0	0
AT31	1	0	0	0	0	0	0
AT79	0	0	0	0	0	0	0
Test Subject Average (%)	33	33	33	0	0	33	33
Test Subject Stdev	58	58	58	0	0	58	58
Attendant Average (%)	50	0	0	0	0	0	0
Attendant Stdev	71	0	0	0	0	0	0

Test Subject ID	Head, Neck, and Shoulders	Front	Left Arm	Right Arm	Back	Left Leg	Right Leg
Script 4 Overall							
Test Subject Average (%)	50	50	33	0	0	33	17
Test Subject Stdev	55	55	52	0	0	52	41
Control Subject Average (%)	0	0	50	0	0	0	0
Control Subject Stdev	0	0	71	0	0	0	0
Attendant Average (%)	50	0	50	0	0	0	0
Attendant Stdev	58	0	58	0	0	0	0

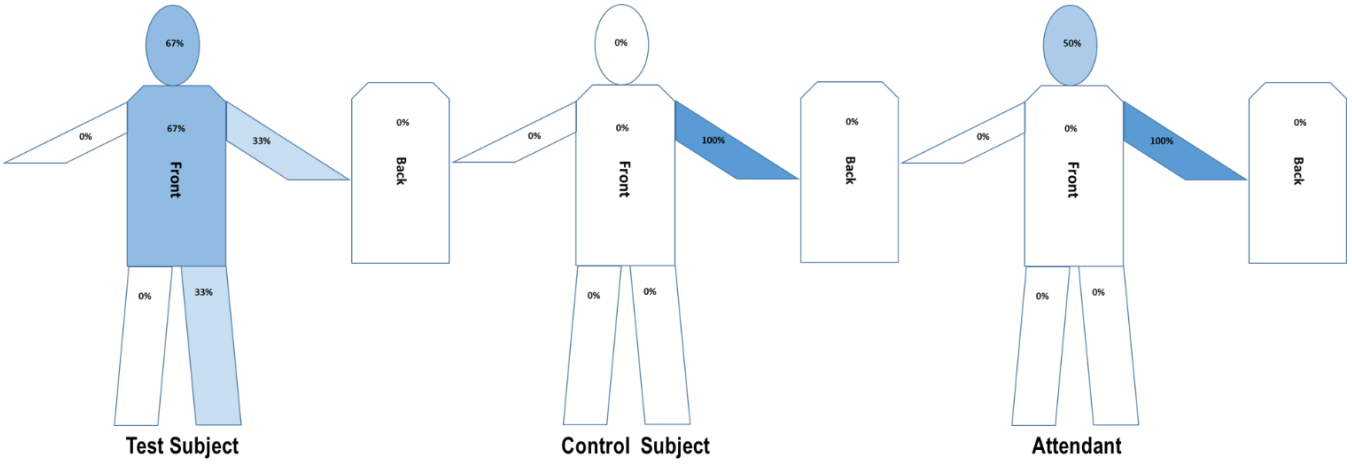


Figure 3.4-1a. Script 4, Test 1 occurrence (%) of cross-contamination

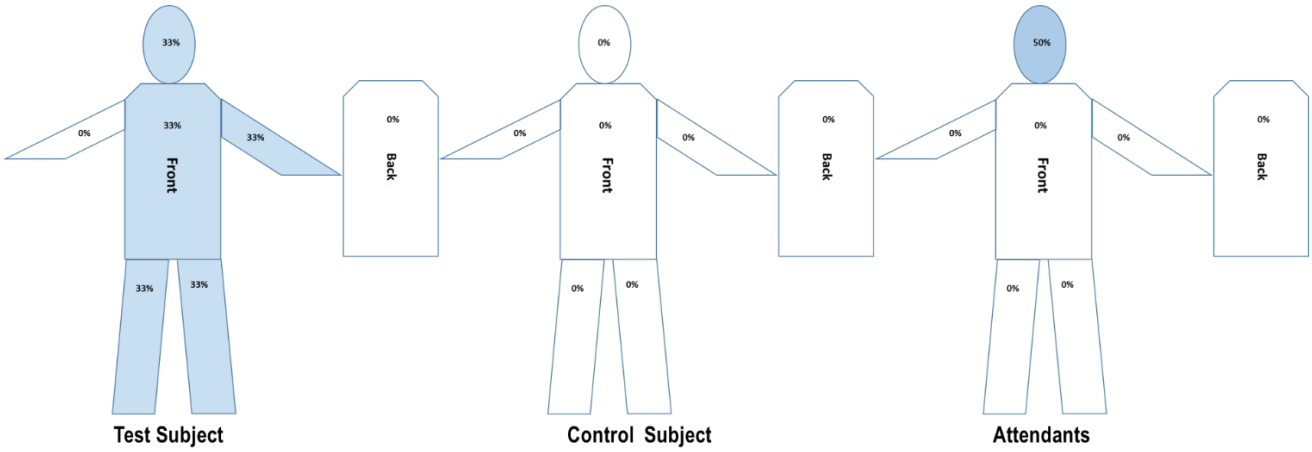


Figure 3.4-1b. Script 4, Test 2 occurrence (%) of cross-contamination

3.4.2 Quantitative Analysis

The results of the quantitative analysis (Table 3.4-2) for this script confirm the reduction of the spread of contamination that resulted from switching from a vigorous spraying and brushing decontamination approach to a more gentle water mist. This appears to have been effective in keeping the contamination from spreading.

Table 3.4-2. Script 4 Estimated Contaminated Surface Area (in^2)

Test Subject ID	Head, Neck, and Shoulders	Front	Left Arm	Right Arm	Back	Left Leg	Right Leg	Total
Test 1								
TS62	NO*	28	NO	NO	NO	NO	NO	28
TS31	1	9	1	NO	NO	16	NO	27
TS79	6	NO	NO	NO	NO	NO	NO	6
CS63	NO	NO	4	NO	NO	NO	NO	4
AT02	NO	NO	4	NO	NO	NO	NO	4
AT50	3	NO	1	NO	NO	NO	NO	4
Test 2								
TS61	NO	NO	NO	NO	NO	1	1	2
TS77	NO	10	1	NO	NO	NO	NO	11
TS52	12	NO	NO	NO	NO	NO	NO	12
CS62	NO	NO	NO	NO	NO	NO	NO	NO
AT31	79	NO	NO	NO	NO	NO	NO	79
AT79	NO	NO	NO	NO	NO	NO	NO	NO

*NO: contamination not observed

3.5 Script 5: SOG Using Two Attendants with a Scripted One-Step Outer Garment Cooking Oil Spray Decontamination Sequence (Two Tests)

Script 5: *This script followed the Script 4 procedure, but Attendant 1 used spray cooking oil (canola oil) instead of water to spray from top down on the outer garment including the boots.* ***Note:*** *Spray cooking oil was suggested as a potential expeditious field method to reduce reaerosolization from the outer suit.*

3.5.1 Qualitative Analysis

The qualitative results for this test script are listed in Table 3.5-1 for Test 1 (three test subjects, one control subject, and two attendants) and Test 2 (four test subjects and two attendants). The probability of occurrence (%) of cross-contamination for each region of the body is illustrated in Figures 3.5-1a and 3.5-1b for Tests 1 and 2, respectively. *The use of cooking oil seems to have the same positive effect as the light water spray on reducing the probability of contamination on different regions of the test subjects,*

control subject, and attendants. The front torso region remains the primary vulnerability for contamination for this script.

Table 3.5-1. Script 5 Qualitative Analysis Occurrence of Cross-Contamination

Test Subject ID	Head, Neck, and Shoulders	Front	Left Arm	Right Arm	Back	Left Leg	Right Leg
Test 1							
TS62	1	1	1	0	0	0	1
TS77	0	1	0	0	0	0	1
TS31	0	1	0	0	0	0	0
CS79	0	0	0	1	0	0	0
AT52	0	0	0	0	0	0	0
AT61	0	1	0	0	0	0	0
Test Subject Average (%)	33	100	33	0	0	0	67
Test Subject Stdev	58	0	58	0	0	0	58
Attendant Average (%)	0	50	0	0	0	0	0
Attendant Stdev	0	71	0	0	0	0	0
Test 2							
TS31	1	0	1	0	0	0	0
TS79	0	0	1	0	0	0	0
TS61	1	1	1	0	0	1	0
TS52	0	1	1	0	1	0	0
AT62	0	0	0	0	0	0	0
AT77	0	0	0	0	0	0	0
Test Subject Average (%)	50	50	100	0	25	25	0
Test Subject Stdev	58	58	0	0	50	50	0
Attendant Average (%)	0	0	0	0	0	0	0
Attendant Stdev	0	0	0	0	0	0	0
Script 5 Overall							
Test Subject Average (%)	43	71	71	0	14	14	29
Test Subject Stdev	53	49	49	0	38	38	49
Attendant Average (%)	0	25	0	0	0	0	0
Attendant Stdev	0	50	0	0	0	0	0

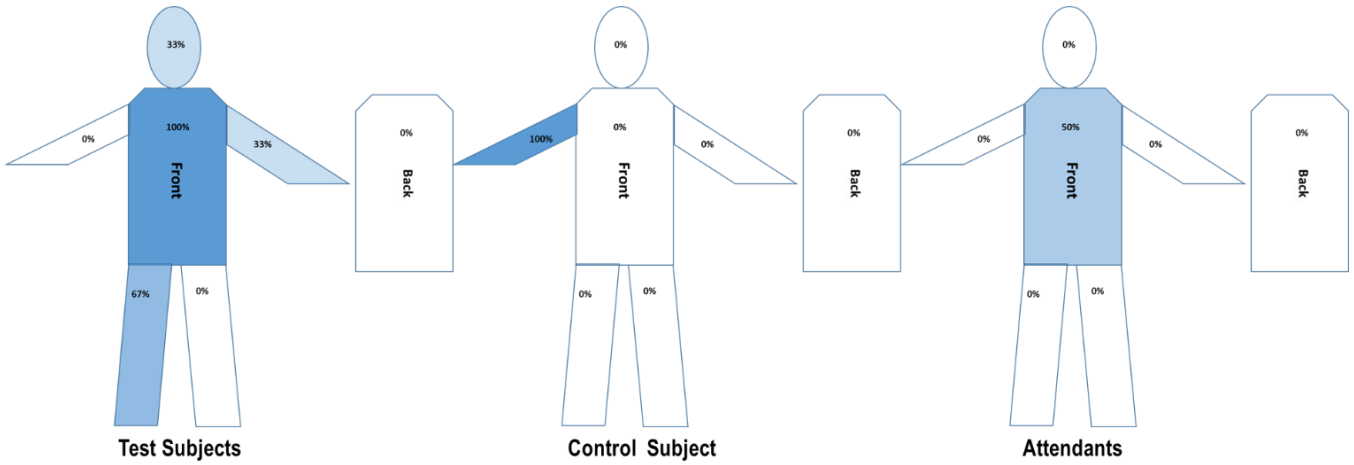


Figure 3.5-1a. Script 5, Test 1 occurrence (%) of cross-contamination

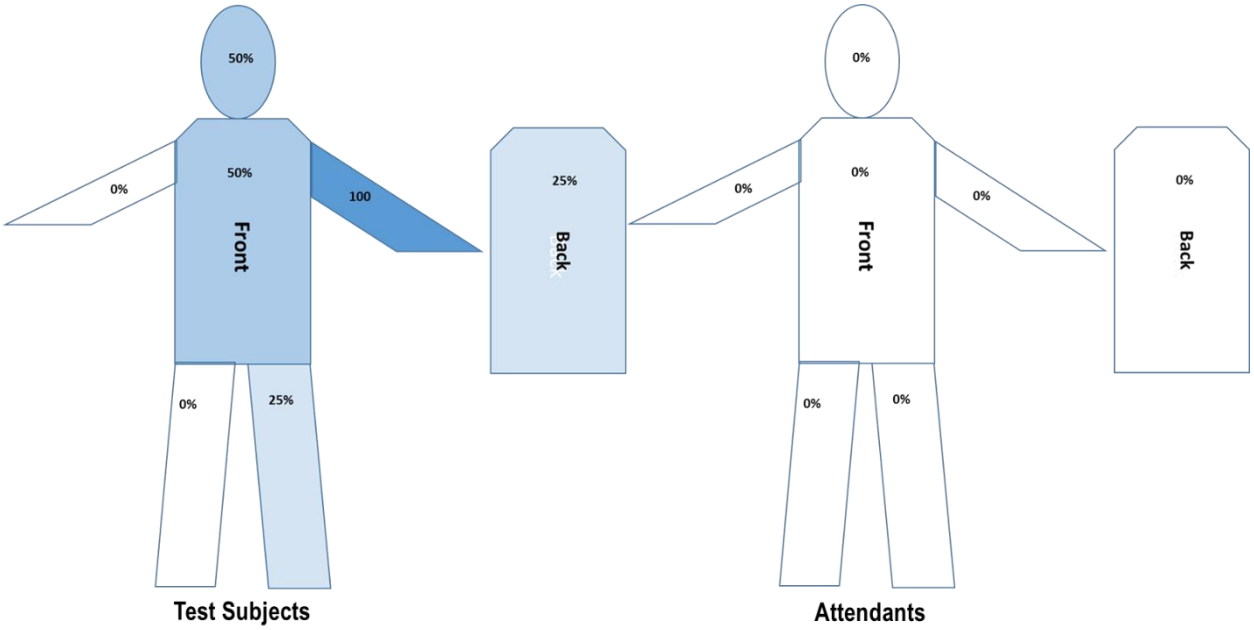


Figure 3.5-1b. Script 5, Test 2 occurrence (%) of cross-contamination

3.5.2 Quantitative Analysis

The results of the quantitative analysis (Table 3.5-2) provides the same results for spraying cooking oil as water mist alone. As a note, *the disadvantages of using cooking oil are its cost, it makes the decontamination area harder to clean, and it does not have disinfecting properties against a biological agent*.

Table 3.5-2. Script 5 Estimated Contaminated Surface Area (in^2)

Test Subject ID	Head, Neck, and Shoulders	Front	Left Arm	Right Arm	Back	Left Leg	Right Leg	Total
Test 1								
TS62	1	2	1	NO*	NO	NO	1	5
TS77	NO	4	NO	NO	NO	NO	6	10
TS31	NO	2	NO	NO	NO	NO	NO	2
CS79	NO	NO	NO	9	NO	NO	NO	9
AT52	NO	NO	NO	NO	NO	NO	NO	NO
AT61	NO	2	NO	NO	NO	NO	NO	2
Test 2								
TS31	20	NO	9	NO	NO	NO	NO	29
TS79	NO	NO	35	NO	NO	NO	NO	35
TS61	2	36	8	NO	NO	4	NO	50
TS52	NO	96	1	NO	80	NO	NO	177
AT62	NO	NO	NO	NO	NO	NO	NO	NO
AT77	NO	NO	NO	NO	NO	NO	NO	NO

*NO: contamination not observed

3.6 Script 6: SOG Using Two Attendants with a Scripted One-Step Outer Garment Water Mist Spray Decontamination Sequence with Test Subjects Donning an Extra Inner Tyvek® Suit (One Test)

Script 6: *This script followed the Script 4 procedure, but test subjects, the control subject, and attendants wore three coveralls (an inner Tyvek® suit representing the skin, a second protective inner suit, and a protective outer Tychem® suit). This test was designed to determine if an added layer of protection would reduce test subject exposure to contamination.*

3.6.1 Qualitative Analysis

The qualitative results for this test script are listed in Table 3.6-1 (seven test subjects, one control subject, and two attendants). A second test was not performed due to the sample size, and the similarity in procedure to script 7 (changed suit from Tychem® to Tyvek®). Two test subjects, TS00 and TS63, proceeded through the decon line twice. The probability of occurrence (%) of cross-contamination for each region of the body is illustrated in Figure 3.6-1. *The addition of a protective suit to the already effective water misting approach considerably reduced the probability of occurrence of cross-contamination among the test subjects, control subject, and attendants*. The examination of the inner suit (skin) of the attendants and the control subject revealed no cross-contamination.

Table 3.6-1. Script 6 Qualitative Analysis Occurrence of Cross-Contamination

Test Subject ID	Head, Neck, and Shoulders	Front	Left Arm	Right Arm	Back	Left Leg	Right Leg
TS00	0	0	0	0	0	0	0
TS63	0	0	0	0	0	0	0
TS79	0	1	0	0	0	0	1
TS77	0	0	0	0	0	0	0
TS52	0	0	1	0	0	0	0
TS00B*	0	0	0	0	0	0	0
TS63B*	0	0	0	0	0	0	0
CS30	0	0	0	0	0	0	0
AT61	0	0	0	0	0	0	0
AT31	0	0	0	0	0	0	0
Test Subject Average (%)	0	14	14	0	0	0	14
Test Subject Stdev	0	38	38	0	0	0	38
Attendant Average (%)	0	0	0	0	0	0	0
Attendant Stdev	0	0	0	0	0	0	0

* Second round – test subject proceeded through decon two times

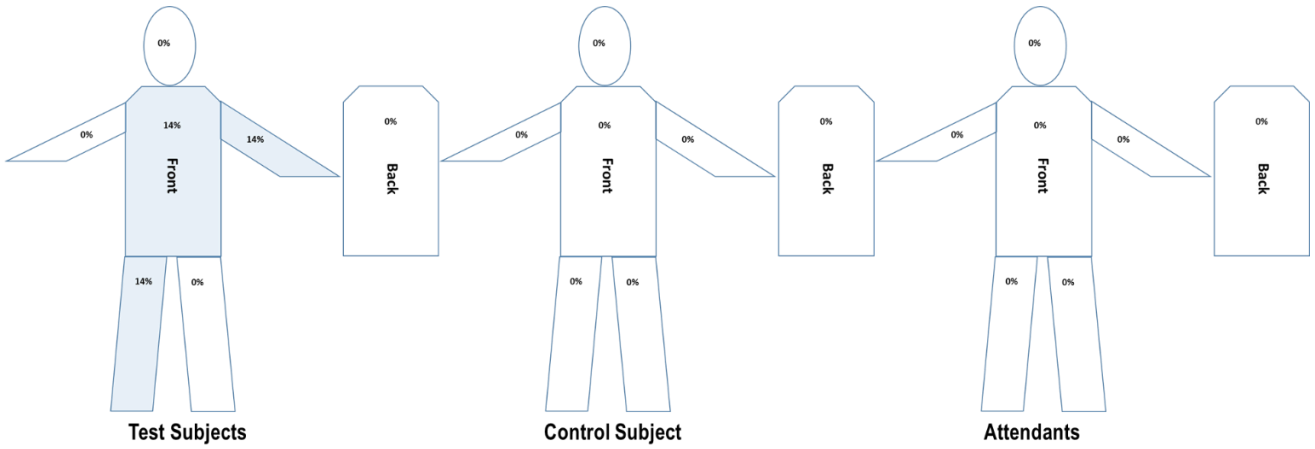


Figure 3.6-1. Script 6 occurrence (%) of cross-contamination

3.6.2 Quantitative Analysis

The results of the quantitative analysis (Table 3.6-2) confirmed very low, if any, cross-contamination (less than 1-inch spots observed on the innermost “skin” suits of some test subjects). No cross-contamination was observed for either the control subject or the attendants.

Table 3.6-2. Script 6 Estimated Contaminated Surface Area (in^2)

Test Subject ID	Head, Neck, and Shoulders	Front	Left Arm	Right	Back	Left Leg	Right Leg	Total
TS30	NO*	NO	NO	NO	NO	NO	NO	NO
TS63	NO	NO	NO	NO	NO	NO	NO	NO
TS79	NO	1	NO	NO	NO	NO	2	3
TS77	NO	NO	NO	NO	NO	NO	NO	0
TS52	NO	NO	2	NO	NO	NO	NO	2
TS00B	NO	NO	NO	NO	NO	NO	NO	NO
TS63B	NO	NO	NO	NO	NO	NO	NO	NO
CS30	NO	NO	NO	NO	NO	NO	NO	NO
AT61	NO	NO	NO	NO	NO	NO	NO	NO
AT31	NO	NO	NO	NO	NO	NO	NO	NO

*NO: contamination not observed

3.7 Script 7: SOG Using Two Attendants with a Scripted One-Step Outer Garment Water Mist Spray Decontamination Sequence with Test Subjects Donning Three Tyvek® Suits (Two Tests)

Script 7: *This script is similar to the Script 6 procedure, with all test subjects, the control subject, and attendants again wearing three coveralls, but with the difference that the outermost protective suit was Tyvek® instead of Tychem®. This test was designed to determine if replacing the expensive, chemical-resistant outer Tychem® coverall with the less expensive and more breathable Tyvek® would affect the protectiveness to inner suit contamination.*

3.7.1 Qualitative Analysis

The qualitative results for this test script are listed in Table 3.7-1 for Test 1 (five test subjects and two attendants) and Test 2 (three test subjects, one control subject, and two attendants). The probability of occurrence (%) of cross-contamination for each region of the body is illustrated in Figures 3.7-1a and 3.7-1b for Tests 1 and 2, respectively. Exchanging the more expensive outer Tychem® coverall for the less expensive Tyvek® coverall appeared to make no difference in results under the test conditions. These tests also confirmed the results of Script 6. *The use of a secondary (inner) protective suit, in conjunction with the water mist decontamination approach, resulted in minimal or non-existent cross-contamination to the innermost suit (skin)*.

Table 3.7-1. Script 7 Qualitative Analysis Occurrence of Cross-Contamination

Test Subject ID	Head, Neck, and Shoulders	Front	Left Arm	Right Arm	Back	Left Leg	Right Leg
Test 1							
TS61	0	0	0	0	0	0	0
TS31	0	0	0	0	0	0	0
TS00	0	0	0	0	0	0	0
TS63	0	0	0	0	0	0	0
TS30	0	0	0	0	0	0	0
AT77	0	1	0	0	0	0	0
AT52	0	0	0	0	0	0	0
Test Subject Average (%)	0	0	0	0	0	0	0
Test Subject Stdev	0	0	0	0	0	0	0
Attendant Average (%)	0	50	0	0	0	0	0
Attendant Stdev	0	71	0	0	0	0	0
Test 2							
TS61	0	0	0	0	0	0	0
TS30	0	0	0	0	0	0	0
TS77	0	0	0	0	0	0	0
CS52	0	0	0	0	0	0	0
AT63	0	0	0	0	0	0	0
AT00	0	0	0	0	0	0	0
Test Subject Average (%)	0	0	0	0	0	0	0
Test Subject Stdev	0	0	0	0	0	0	0
Attendant Average (%)	0	0	0	0	0	0	0
Attendant Stdev	0	0	0	0	0	0	0
Script 7 Overall							
Test Subject Average (%)	0	0	0	0	0	0	0
Test Subject Stdev	0	0	0	0	0	0	0
Attendant Average (%)	0	25	0	0	0	0	0
Attendant Stdev	0	50	0	0	0	0	0

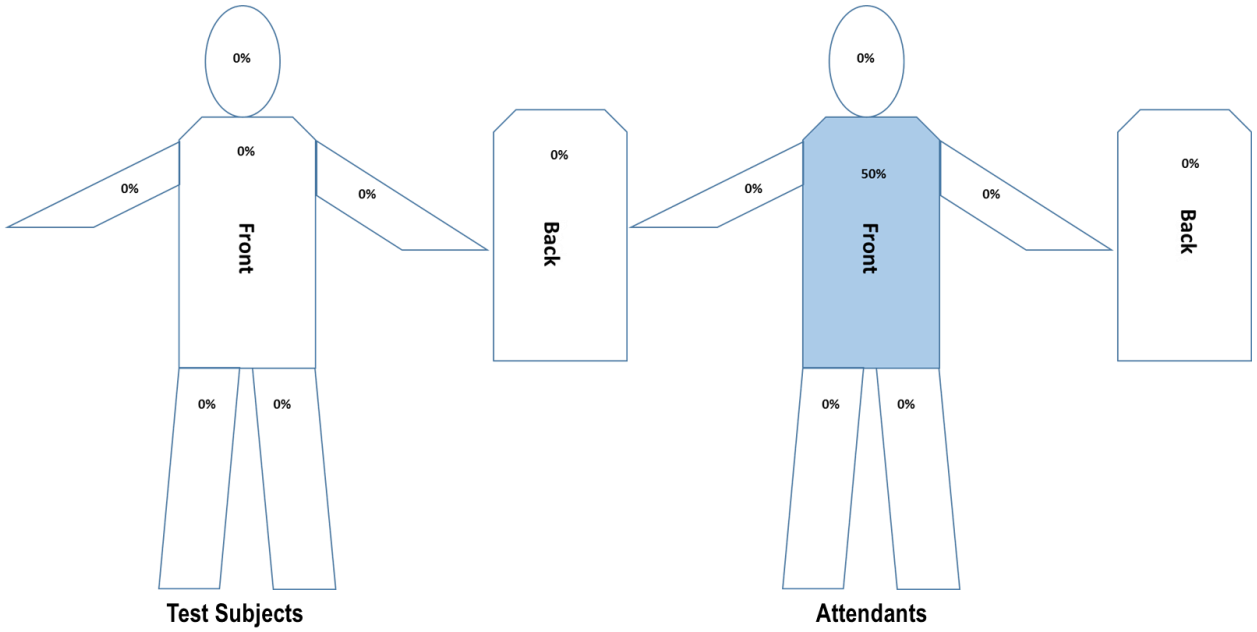


Figure 3.7-1a. Script 7, Test 1 occurrence (%) of cross-contamination

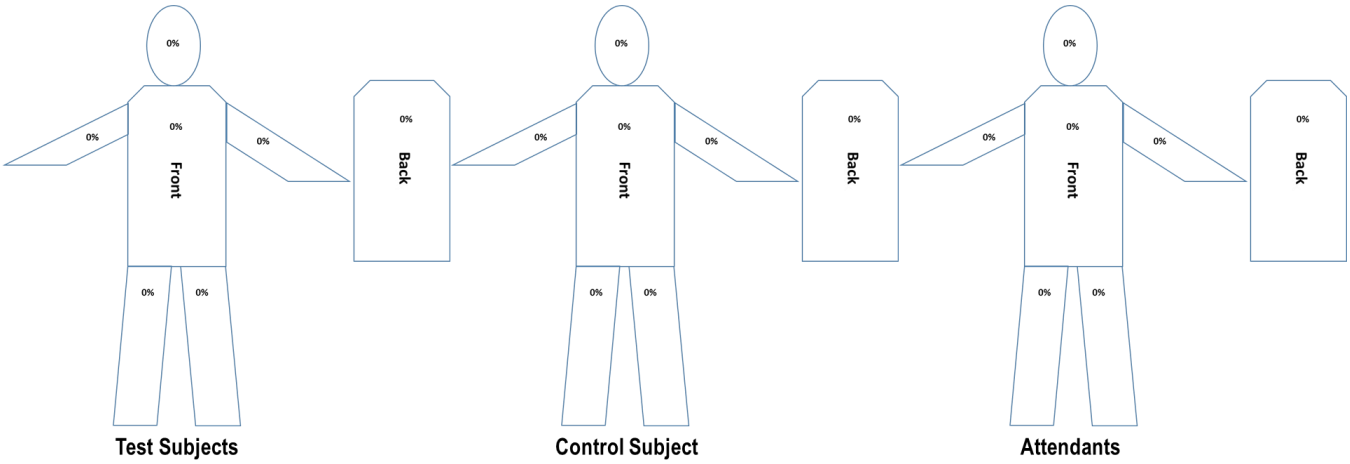


Figure 3.7-1b. Script 7, Test 2 occurrence (%) of cross-contamination

3.7.2 Quantitative Analysis

The results of the quantitative analysis (Table 3.7-2) confirm the very low cross-contamination. No cross-contamination was observed for either the test subjects or the control subject for this test script. Spots of contamination of less than 1 inch were observed on one of the attendants (front torso). The results of this script along with the results of Script 7 suggest that the use of a secondary (inner) protective Tyvek® suit might serve to completely protect the test subjects from cross-contamination.

Table 3.7-2. Script 7 Estimated Contaminated Surface Area (in^2)

Test Subject ID	Head, Neck, and Shoulders	Front	Left Arm	Right Arm	Back	Left Leg	Right Leg	Total
Test 1								
TS61	NO*	NO	NO	NO	NO	NO	NO	NO
TS31	NO	NO	NO	NO	NO	NO	NO	NO
TS00	NO	NO	NO	NO	NO	NO	NO	NO
TS63	NO	NO	NO	NO	NO	NO	NO	NO
TS30	NO	NO	NO	NO	NO	NO	NO	NO
AT77	NO	1	NO	NO	NO	NO	NO	1
AT52	NO	NO	NO	NO	NO	NO	NO	NO
Test 2								
TS61	NO	NO	NO	NO	NO	NO	NO	NO
TS30	NO	NO	NO	NO	NO	NO	NO	NO
TS77	NO	NO	NO	NO	NO	NO	NO	NO
CS52	NO	NO	NO	NO	NO	NO	NO	NO
AT63	NO	NO	NO	NO	NO	NO	NO	NO
AT00	NO	NO	NO	NO	NO	NO	NO	NO

*NO: contamination not observed

3.8 "Contaminated Sample" Analysis

All "samples" that had been dropped off by the test subjects were put through the standard sample-handling procedure detailed in Section 2.2.9, which was devised to eliminate any cross-contamination. This sample-handling procedure led to complete elimination of potential cross-contamination from the collected samples into areas of the SZ.

4 Quality Assurance

This project was performed under an approved Category III Quality Assurance Project Plan (QAPP) titled "Decontamination Line Protocol Evaluation for Biological Contamination Incidents (April 2014)."

4.1 Sampling, Monitoring, and Analysis Equipment Calibration

The majority of samples were qualitative rather than quantitative in nature. None of the sampling and analysis equipment required calibration, with the exception of the scale(s) used to weigh the fluorescent dye and brushes. All scales were certified by the manufacturer as calibrated or had the calibration verified annually by EPA's Air Pollution Prevention and Control Division (APPCD) on-site Metrology Laboratory (RTP, NC). Calibration checks were performed prior to each measurement for proper performance by comparing the reading to Class S weights. If deficiencies were noted (e.g., reading fell outside of the accepted ± 1% tolerance), the instrument was adjusted to meet calibration tolerances and recalibrated within 24 hours. If tolerances were not met after recalibration, additional corrective action was taken, including recalibration and/or replacement of the scale.

4.2 Data Quality

The purpose of this study was to evaluate the effectiveness of variations of the decontamination and PPE doffing procedures of the SOG used to provide guidance to EPA and contractors on decontamination of personnel and samples in long-term response to biological contamination. This long-term decon line procedure is used to remove PPE without exposing personnel to contamination and to prevent the spread of contamination beyond the EZ.

The QAPP in place for this project was followed with only a couple of deviations:

- All microbiological evaluation of the SOG was deferred until this optimization task was completed.
- Air purifying respirator full-face masks (Scott Safety AV-3000) were used during the evaluation instead of the same mask with powered air purifying respirators adaptors. This change was deemed to have no significant impact on the usability of the test results and was implemented primarily for simplicity.

4.3 Quality Assurance (QA)/Quality Control (QC) Checks

Uniformity of the test materials was critical for assuring reliable test results. Uniformity was maintained by obtaining a large enough quantity of PPE from a limited number of reputable suppliers to complete these tests. All PPE was stored away from the EZ, which has areas that could cause cross-contamination. Supplies and consumables were examined for evidence of tampering or damage upon receipt and prior to use, as appropriate. Supplies and consumables showing evidence of tampering or damage were not used. All examinations were documented, and supplies were appropriately labeled. Project personnel checked supplies and consumables prior to use to verify that they met specified task quality objectives and did not exceed expiration dates.

4.4 Acceptance Criteria for Critical Measurements

The data quality objectives assigned to this study were qualitative (fluorescent light being used to detect visible areas of contamination) rather than quantitative in nature, and no critical measurements were needed to address the stated objectives. Photographs have been retained for further inspection.

A variety of media (still images and video recordings) and records (e.g., raw data collected during the testing process, laboratory notebook narratives) were used to document the project. Negative controls tests, or pre-contamination checks, of the inner suits and gloves were performed under UV light on all test subjects prior to contamination. Test subjects that were found wearing a suit that fluoresced were rejected and asked to don new inner suits and gloves. Control subjects served as field blanks (i.e., were not dosed but went through the entire decon line) for each test script. They were always the final participant to indicate whether cross-contamination was occurring from anything or anyone in the decon line itself.

Table 4.4-1 lists the QA/QC samples, the acceptance criteria, and the corrective actions implemented.

Table 4.4-1. QA/QC Sample Acceptance Criteria

Sample Type	Description	Purpose	Acceptance Criteria	Corrective Actions	Frequency
Negative control – personnel and items	A person or item not dosed and checked for background contamination prior to dosing	Demonstrate that evidence of cross-contamination is not inherent in personnel or items	No detectable contamination	Replace inner suit or other source of contamination; instruct test subject to remove PPE and don new	Once prior to each round
Field blank – personnel and items	A person or item not dosed and run through the decon line after contamination is present	Identify sources of cross-contamination between test subjects	NA	Refine decon line procedures	One per sample type per round

4.5 Data Quality Audits

This project was QA Category III and did not require technical systems or performance evaluation audits.

4.6 QA/QC Reporting

QA/QC procedures were performed in accordance with the QAPP for this investigation.

5 Summary and Recommendations

While improvements to the SOG were not quantifiable, steps were identified and defined in the protocols that proved successful at preventing cross-contamination in most situations. The overall test results of this study indicated that the liquid in the existing protocol can be a contaminant carrier, so procedures using large amounts of liquid and scrubbing should be avoided. It must be noted that the test did not take into account the disinfecting properties of a decontamination solution, such as 1:10 hypochlorite bleach solution, but rather focused on the transport of contaminants.

Several procedural elements resulted in a large reduction or complete elimination of cross-contamination among test participants and decon line personnel:

- A secondary protective Tyvek® suit under the main Tyvek® or Tychem® suit
- A light mist or spray
- Careful doffing with the help of an attendant who changes gloves between each test subject

Even with a greatly improved process for reducing contamination, a small probability still exists for potential contamination. To that end, showering after leaving the decon line is recommended.

The following summarizes the main results of this study:

- The use of a three-step decontamination approach (spray-brush-rinse) of the test subjects can potentially increase the chances of liquid infiltration through the vulnerabilities of the protective ensemble of suit, gloves, respirator, and tape, resulting in contamination of the skin. Further, the reuse of the brush on multiple test subjects during the decon process can increase the likelihood of cross-contamination.
- The addition of a second attendant in the doffing tent (boot removal) does not appear to have a positive impact on reducing or eliminating cross-contamination among the attendants and the test subjects. To the contrary, the results suggest an increase in the number of personnel that will be cross-contaminated.
- A gentle water mist is likely to prove more efficient in reducing contamination of workers than the more complex three-step (spray-brush-rinse) decontamination approach. Although the use of a gentle spray of cooking oil seems to be as effective as the light water spray, it has disadvantages such as cost and increased difficulty of cleanup.
- The use of multiple gloves by the attendants in the doffing section can help reduce or eliminate cross-contamination. The attendants should be instructed to doff outer gloves whenever helping with parts of the PPE with suspected vulnerabilities. For instance, the outer tape and gloves of the test subjects can be assumed to be contaminated. After touching these items, gloves should be doffed before touching the outside of the suit during doffing.
- The use of a secondary inner Tyvek® suit by responders can drastically decrease or eliminate cross-contamination.

- Special consideration should be given to procedures for handling the sample collection bags to avoid any cross-contamination from collected “samples” into any SZ areas. The multi-step decontamination procedure involving two sample handlers that was used in this testing can be very effective in avoiding transfer of contamination during sample handling.
- Even with modified procedures, the best test result demonstrated minor contamination of one test subject. Therefore, complete showering of the skin after doffing PPE can further ensure that no contaminants are spread.
- Future evaluations are recommended to assess any changes to the biological decon line that have not been tested.

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