Personnel Decontamination Line Sprayer Options for Biological Contamination Incident Response

PURPOSE

To provide EPA responders information on conventional and innovative methods for conducting personnel decontamination during a *Bacillus anthracis* (*Ba*) or other biological agent response. This brief summarizes comparison studies (coupon and manikin) of two different types of sprayers for use in the personnel decontamination (decon) line.

SUMMARY

This Technical Brief summarizes two studies (large coupon testing [1] and manikin testing [2]) that compared the efficacy and performance of electrostatic sprayers (ESSs) and conventional backpack sprayers (CBSs) for personnel decontamination in a decon line.

Both sprayer types performed well in the PPE decontamination efficacy studies, as liquid and aerosol inoculation of a *Ba* surrogate onto PPE were evaluated. Operational parameters of the sprayers were also assessed. **Table 1** provides a summary and comparison of both sprayers as used in these studies.

Table 1. Decon Line Sprayer Comparison

	Conventional Backpack Sprayer (CBS)	Electrostatic Sprayer (ESS)
Efficacy*	>6 log reduction	>6 log reduction
Spray Rate	996 mL/min	62 mL/min
Aqueous Spray Volume	~2000 mL	~250 mL (with 2X spray duration)
Waste Generated	450 mL (coupon)	6 mL (coupon)
PPE Coverage Spray Duration	2 minutes (manikin)	4 minutes (manikin)
Liquid Runoff	1 Liter (manikin)	Minimal; not quantifiable (manikin)
Reaerosolization During Spray	1 X 10^4 CFU (manikin aerosol inoculation)	2.8 X 10^1 CFU (manikin aerosol inoculation)

**Decontamination efficacy was calculated in terms of the log reduction (LR). An efficacy benchmark of 6 LR was used to distinguish between effective and ineffective decontamination approaches.*
CFU = colony forming units

INTRODUCTION

The personnel decon line, established in the contamination reduction zone (CRZ) following a biological incident, is essential for ensuring that potential contamination from workers' personal protective equipment (PPE) does not migrate outside this zone. Conventional decon procedures can lead to the physical removal of biological contaminants, but copious amounts of decontaminant solution are often used, leading to large volumes of aqueous-based waste.

CBSs frequently used in decon lines, have the potential to generate a significant quantity of aqueous-based waste due to the volume of decontaminant sprayed and runoff liquid from PPE, following multiple

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entry teams moving through the decon line. Additionally, these sprayers may cause liquid splash-off when spraying PPE surfaces, which could lead to reaerosolization. It has been demonstrated in a previous decon line study [3] with fluorescent tracer particles, that a CBS in conjunction with scrub brushes led to contamination spread outside the CRZ. This contamination spread was minimized by the elimination of the scrub brush process and the use of a misting nozzle on the decontaminant sprayer. However, runoff liquid volume and reaerosolization were not measured.

As a continuing effort to improve and optimize biological decon line procedures, recent EPA research efforts have been conducted to determine if portable ESSs are feasible alternatives to conventional sprayers used by the emergency response community. ESSs have been used for decades in various industries such as agriculture, automotive industries, and healthcare because of their uniform surface coverage characteristics [4]. More recently, ESSs have been used for personnel decontamination in emergency responder decon lines, though their use has not been thoroughly evaluated.

Both studies summarized here used the same biological surrogate, sprayers and aqueous-based decontamination solutions [dilute bleach (1 in 10 diluted with water)] as described below.

DECONTAMINATION MATERIALS

Sprayers Tested

The two sprayers shown in **Figure 1** were tested on PPE-covered coupons and manikins dressed in PPE.

The electric backpack sprayer (**Figure 1A**) is approximately 36 inches (in) high by 24 in wide by 6 in long. This CBS has a variable speed pump, an adjustable spray cone nozzle, a 4-gallon capacity, and a hose made of reinforced/braided polyvinyl chloride (PVC). This sprayer has been used in previous EPA decontamination studies and is representative of the type of conventional handheld sprayer nozzle typically used in personnel decon lines.

The ESS (**Figure 1B**) is approximately 22 in high by 16 in wide by 10 in long and produces smaller electrically charged spray droplets that are carried to the target in a gentle low-pressure air stream. The sprayer tank has a capacity of 1 gallon and a spray gun with hose length of 15 feet (ft). The sprayer also is equipped with a patented MaxCharge™ technology electrostatic spray gun that delivers droplets with a volume median diameter (VMD) of 40 micrometers (µm) [5].

(A)

SHURFlo 4 ProPack Rechargeable Electric Back Pack Sprayer SRS-600 (Pentair-SHURFlo, Costa Mesa, CA)

(B)

SC-ET HD electrostatic sprayer (Electrostatic Spraying Systems ESS, Watkinsville, GA)

Figure 1. Electric Backpack Sprayer (A); SC-ET HD Air-Assisted Electrostatic Sprayer (B)

Decontaminant

The decontamination agent used in the sprayers consisted of 10% diluted bleach (DB) as referenced in the EPA Consequence Management Advisory Division's "BioResponse Decontamination Line Standard Operating Protocol" (SOP) [6]. The solution was prepared in fresh 1-liter batches on each test day. Neutralizing agents were used to stop the decontamination reaction to achieve a prescribed contact time of 5 minutes as specified in the SOP.

COUPON TEST RESULTS

Figure 2. PPE Test Coupons

This study compared the performance of an ESS and a CBS by evaluating the efficacy of each sprayer in removing or inactivating spores of *Bacillus atrophaeus* var. *globigii* (*Bg*), a surrogate for *Bacillus anthracis (Ba)*, from different types of PPE materials. Coupons measuring 14 by 14 in were prepared from each PPE material (**Figure 2)** and inoculated with 1×10^7 *Bg* spores per coupon via a metered-dose inhaler (MDI) [7]. Test coupons were then placed in a vertical orientation in a decontamination test chamber and sprayed with 10% DB until completely visibly wet using either the ESS or CBS sprayer.

After a 5-minute contact time, the coupons were removed from the test chamber and sampled using a wipe sampling method, then analyzed for the presence of viable spores. The sprayer decontamination efficacy was determined by comparing the mean log number of colony forming units (CFU) observed for the controls (stainless-steel coupons inoculated but not exposed to decontamination treatment) to the mean log number of CFU observed for the decontaminated test coupons.

Figure 3 summarizes decontamination efficacy by PPE material type. Both sprayers achieved a surface log reduction (LR) of greater than or equal to 6 (except latex material sprayed with the ESS), with no statistically significant difference between the two sprayers (p-value = 0.49) when LR values were pooled. For three of the seven test materials (denoted by an asterisk), no CFU were detected on material surfaces when the ESS was used.

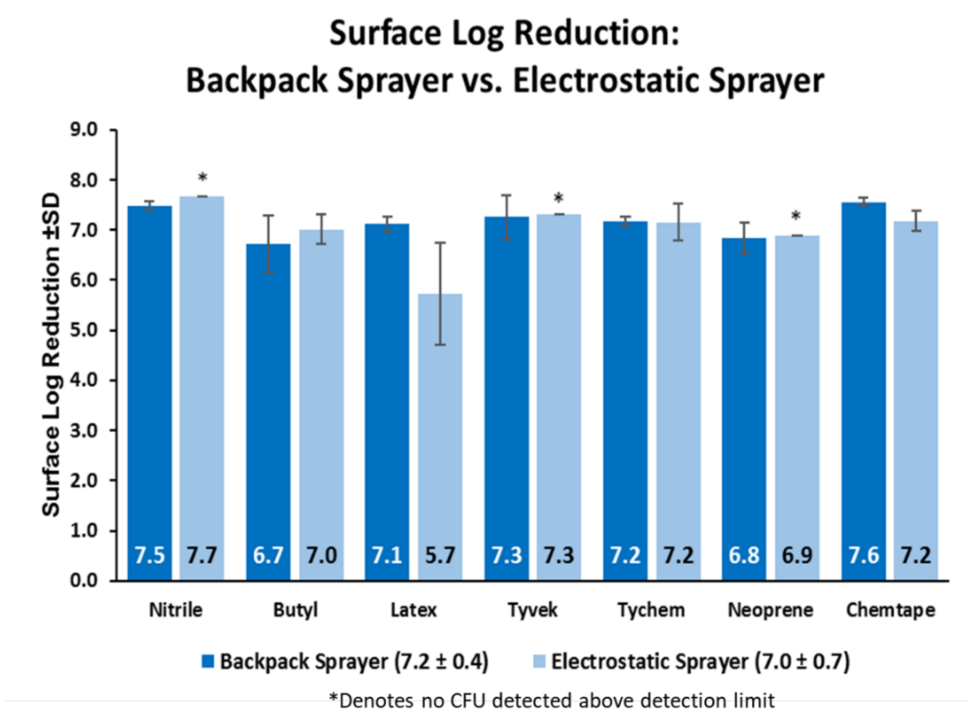

Figure 3. Surface Decontamination Efficacy by Material Type

MANIKIN TEST RESULTS

Figure 4. Manikin without (A) and with Level C PPE

In this follow-on study, a comparison of the two sprayer types (ESS and CBS) for personnel decontamination was performed on manikins with PPE ensembles to provide more realistic conditions as compared to flat coupon surfaces. Manikins (**Figure 4A**) in Level C ensembles (**Figure 4B**) were inoculated with *Bg* in seven delineated sampling locations using either liquid or aerosol inoculation techniques. The average concentration at each location was 1 X 10^7 *Bg* spores, based on triplicate positive control manikins, which allowed for a 6 LR to be quantified.

The 10% DB solution was applied using either the ESS or CBS for decontamination of the manikin PPE surfaces. A 2-min spray duration was initially selected for both sprayers, but the spray duration for the ESS was increased to 4 minutes in subsequent testing to determine if a longer spray duration would result in increased efficacy. The full decontamination was completed for a 5-min contact time followed by surface wipe sampling. Liquid runoff was also captured in secondary containment (kiddie pool) and measured to evaluate liquid waste generated by the decon line. High volume air samplers (Dry Filter Units) were used to assess the reaerosolization of spores during the decontamination spraying process.

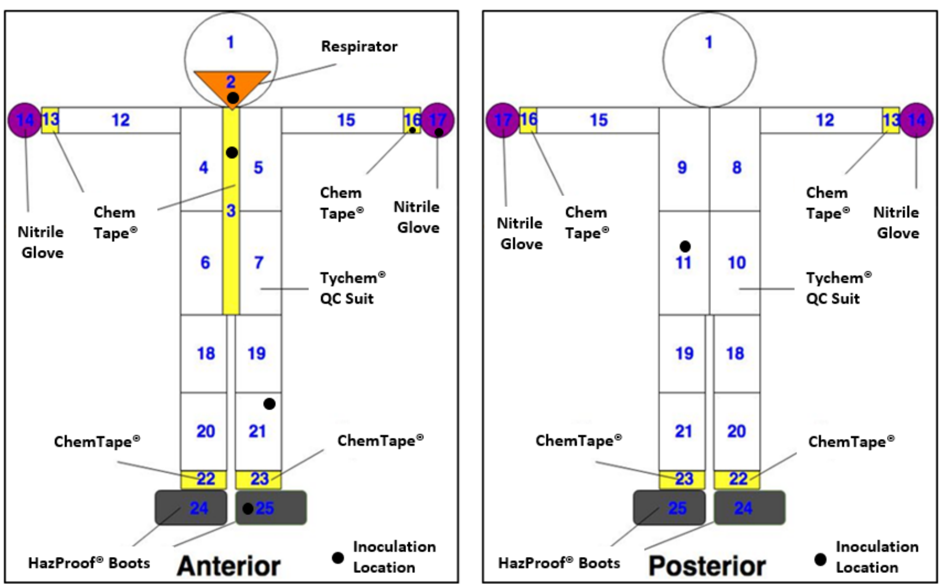

Figure 5. Sampling Locations for Wipe Sampling from PPE Surfaces on Manikins Post Decontamination

Wipe sampling of manikin PPE surfaces was used to evaluate the surface decontamination efficacy for the ESS and CBS at each of 25 delineated locations that completely sampled the PPE ensemble, as shown in **Figure 5**. Inoculation locations are denoted with black dots.

Figure 6 provides a side-by-side comparison of manikin heat map results for liquid and aerosol inoculations. Positive control manikins for liquid and aerosol inoculation on PPE are shown in **Figures 6A** and **6E**, respectively. Even with careful inoculation procedures, results indicate the entire manikin was contaminated during the inoculation. Post-decontamination heat map results with the ESS and CBS for liquid and aerosol inoculations on PPE are shown in **Figures 6B-D** and **6F-H**, respectively. The conditions cover 2-min spray times for the CBS and 2- or 4-min spray times for the ESS.

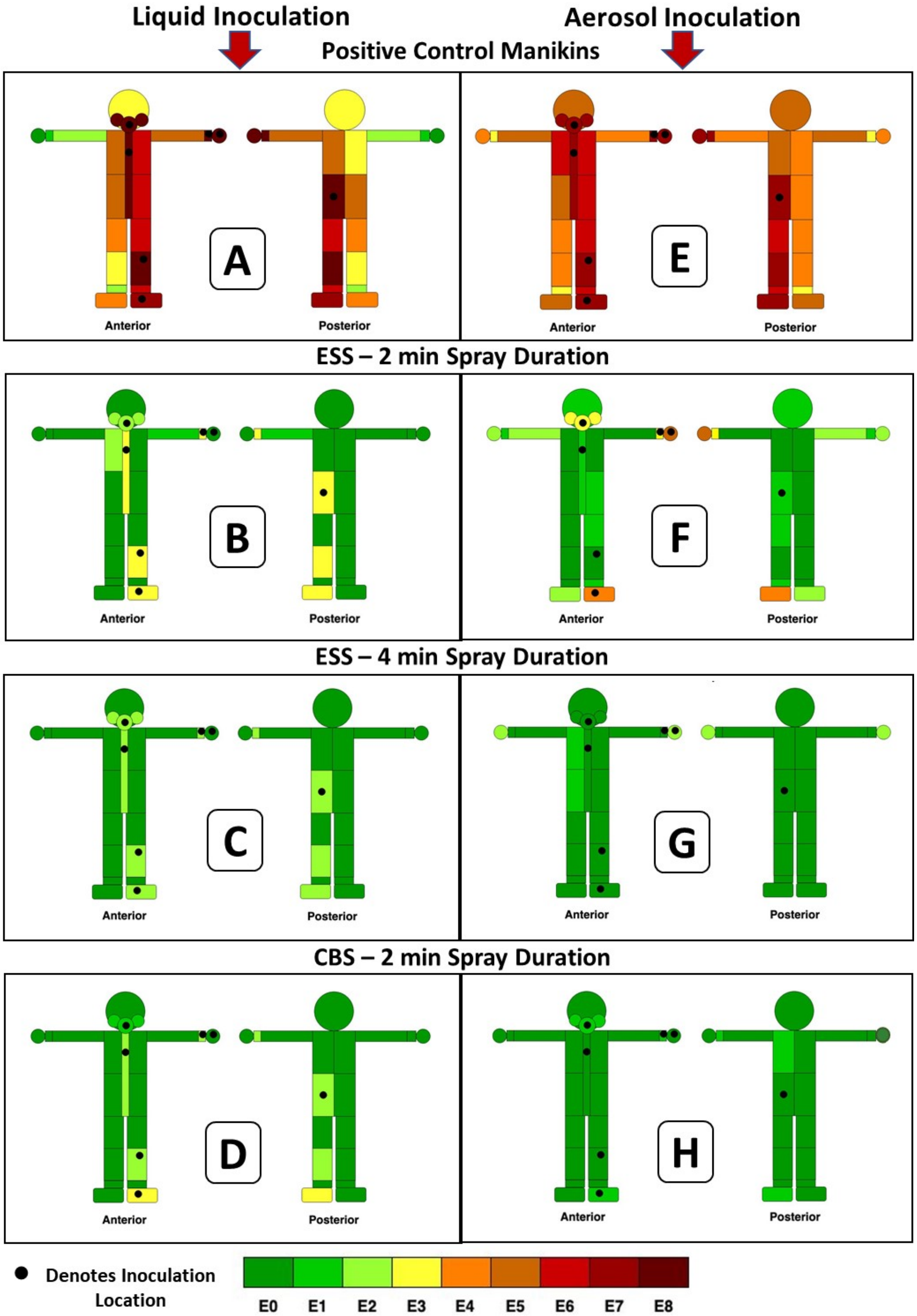

Figure 6. Sample Recoveries for Liquid Inoculations (A-D) and Aerosol Inoculations (E-H). Heat map legend shows concentration in exponential form where E1 = 10, E8 = 10^8, etc.

Decontamination efficacy for both sprayers using DB was greater following aerosol inoculation as compared to liquid inoculation, potentially due to the pooling or clumping of spores that can be characteristic of liquid inoculation. The pooling/clumping can shield the lower layers of spores from direct contact with the decontaminant and inhibit efficacy.

When further comparing the ESS with the CBS, both sprayers were successful in decontaminating a complete PPE assembly donned on manikins. However, some low-level spore contamination remained in hard-to-reach areas (glove, boot) following decontamination with the CBS (liquid inoculation, **Figure 6D**) and the ESS for the 2-min spray duration (liquid and aerosol inoculation, **Figures 6B** and **6F**). Therefore, it was decided to add an additional time point of a 4-min spray duration for the ESS. With the additional 2 minutes of spray duration, the ESS overall average decontamination efficacy for both liquid and aerosol inoculation was greater than a 6 LR (**Figures 6C** and **6G)**. The CBS also demonstrated a greater than 6 LR for both liquid and aerosol inoculation (**Figures 6D** and **6H)**.

Table 2 provides a summary of test results by sprayer type including decontamination efficacy and reaerosolization. Reaerosolization was observed to be 2-3 orders of magnitude higher for the CBS during the spray decon process, likely due to the higher sprayer pressure and volume of decontaminant sprayed onto the manikin from the CBS. Higher levels of aerosolized spores were observed with aerosol inoculation relative to liquid inoculation, regardless of sprayer type used.

Table 2. Summary of Manikin Findings by Sprayer Type

Sprayer	Inoculation Type	Spray Duration	Contact Time	Decon Efficacy (Avg LR)	Reaerosolization (Avg Log CFU)
ESS	Aerosol	2 min	5 min	4.9	1.4
	Liquid	2 min	5 min	5.6	0.26
	Aerosol	4 min	5 min	7.5	1.2
	Liquid	4 min	5 min	6.1	0.28
CBS	Aerosol	2 min	5 min	6.8	4.0
	Liquid	2 min	5 min	6.2	1.7

CONCLUSIONS

In both studies (coupon and manikin), ESS and CBS were shown to be effective and achieved a > 6 LR on PPE using DB as a decontaminant, though the ESS needed double the spray duration. The ESS used less decontaminant, produced less aqueous waste and reaerosolized less spores from the PPE during decontamination. However, thorough coverage of the PPE with the ESS, due to lower liquid volume, is essential for efficacy. The advantages and disadvantages of each sprayer type should be weighed when using in a decon line scenario.

The ESS still needs to be tested for efficacy and functionality in a field setup to fully determine its logistical feasibility in a personnel decon line. Additional efforts will evaluate scale-up to an automated field deployable decon unit and investigate efficacy of additional decontaminants and ESS sprayers.

DISCLAIMER

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68HERC19A0004. This summary has been subjected to the Agency's review and has been approved for publication. Note that approval does not signify that the contents reflect the views of the Agency. Mention of trade names, products, or services does not convey official EPA approval, endorsement, or recommendation.

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