Developing a Full-Body Methodology for Decontamination Visualization

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ABSTRACT

Full and effective decontamination is highly important in HAZMAT or weapons of mass destruction (WMD, including chemical and biological warfare) situations. Decontamination aims to prevent adverse health outcomes that can be experienced by both first responders and victims after contact with hazardous materials. This work aims to develop a full-body methodology by which contamination and the extent of decontamination can be quantified quickly and easily using image analysis. A UV fluorescent tracer was used as a surrogate contaminant. Images were taken before and after each step of testing and compared using ImageJ. This allowed quantification of the extent of contamination. Results showed that imaging the extent of contamination on porous surfaces, such as clothing, was possible with mixed results, while extent of contamination was much more apparent on non-porous surfaces. This led to difficulties in quantifying the extent of contamination on the clothing, and thus the amount of contamination removed by disrobing. Nonetheless, the extent of contamination after disrobing is significant, indicating little protection is afforded by the clothing used.

Situation/Problem

Civilian and military disaster planning guides for HAZMAT or WMD situations often claim that 90% of contamination will be removed by disrobing[1-3]. This is applied across the board, without regard to the population affected or the differences between different situations. Despite being a main tenet of planning guidelines, this claim has not been thoroughly investigated. While this does appear to be a reasonable assumption for certain populations, no data has been found to support the claim. Due to the difficulties involved in quantifying contamination on the large surface areas presented by full mannequins, few studies have been conducted[4, 5]. Therefore, this research aimed to evaluate this claim by creating a method for visualizing and quantifying contamination and decontamination using a UV fluorescent tracer as a chemical warfare agent surrogate. Image analysis was to be used to quantify the spread of contamination.

In addition, this will advance the science of IH by introducing a new method for evaluation of decontamination. In addition, this technique can be applied to testing and evaluation of personal protective equipment efficacy as well as dermal exposure to workers in operations where liquid chemicals are sprayed or used in other ways.

Preliminary Modeling

As a starting point for analysis, a model was created based on values from the US Environmental Protection Agency's Exposure Factors Handbook[6]. Recommended average values for total body surface area and surface area for each body part were used and shown below. The percent total surface area for each body part was calculated as shown. Three different scenarios were considered including different clothing types. In all three scenarios, it was assumed that deposition of the contaminant was uniform across the entire body and that there was no penetration of the contaminant through the clothing. The first was to consider a military population (or civilian population in winter) in which long sleeves and pants would be worn, along with full covered shoes. The second scenario considered a civilian population in a spring/fall weather scenario (or military without the jacket) in which short sleeves, long pants and full covered shoes would be worn. The third scenario considered a civilian population in the summer months, considering clothing to be short sleeve shirt, knee length shorts, and shoes.

Body Surface Area Values from the EPA Exposure Factors Handbook – Adult Male

	Surface Area (m^2)	Percent of Whole Body
Whole Body	2.065714	
Head	0.136	6.58%
Trunk	0.827	40.03%
Arms	0.314	15.20%
Hands	0.107	5.18%
Legs	0.682	33.02%
Feet	0.137	6.63%

Table 1. (above) Average total body surface area for an adult male, and percent of the entire body for specified body parts.

Scenario A

Body Part	Covered	Percent of Body Uncovered	Percent of Contamination Removed
Head	0%	6.58%	88.24%
Trunk	100%	0%	
Arms	100%	0%	
Hands	0%	5.18%	
Legs	100%	0%	
Feet	100%	0%	

Scenario B

Body Part	Covered	Percent of Body Uncovered	Percent of Contamination Removed
Head	0%	6.58%	76.84%
Trunk	100%	0%	
Arms	25%	11.40%	
Hands	0%	5.18%	
Legs	100%	0%	
Feet	100%	0%	

Scenario C

Body Part	Covered	Percent of Body Uncovered	Percent of Contamination Removed
Head	0%	6.58%	60.33%
Trunk	100%	0%	
Arms	25%	11.40%	
Hands	0%	5.18%	
Legs	50%	16.51%	
Feet	100%	0%	

Table 2. (above) Results of three quick modeling scenarios. A) If a person is wearing full clothing, 88% of contamination would be removed by disrobing. B) If arms are not fully covered, only 76% would be removed. C) If arms and legs are only partially covered, only 60% of contamination would be removed.

Methods

To test the research question, a UV fluorescent dye was aerosolized by a Collison nebulizer inside an aerosol test chamber. For decontamination experiments, a mannequin dressed in black clothing was imaged under UV light to obtain a background reading. It was then placed into the test chamber and the nebulizer was run for 70 minutes. This time was chosen based on the average volume of liquid aerosolized per minute, in order to deposit approximately 10 g/m^2 on the mannequin. The mannequin was again imaged under UV light to see the extent of contamination. The mannequin was disrobed by carefully pulling clothing over the head (trying to avoid extra contamination of the face) and off of the legs and imaged again. It was proposed that cutting the clothing off (similar to non-ambulatory patients) would be more repeatable and representative of a true emergency situation but was not able to be tested in this scenario. Images were taken in triplicate and averaged at each step to minimize the effects of outlier pixels. A Stouffer 21-step wedge, fluorescence reference slide, and dilution standard created from the UV tracer were used for calibration of images. These images were analyzed for differences between images using ImageJ.

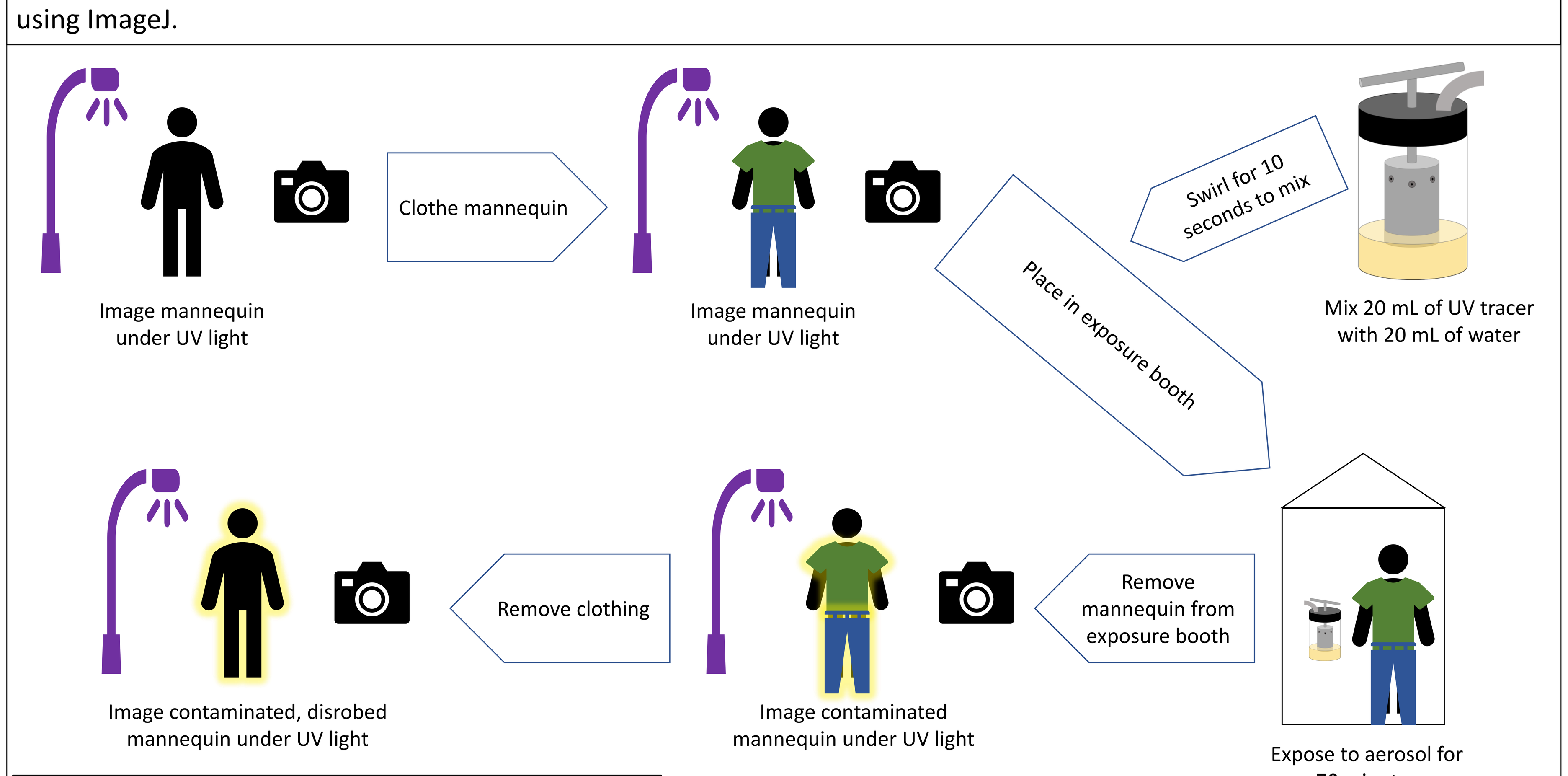


Figure 1. Process flow chart for experimental data collection.

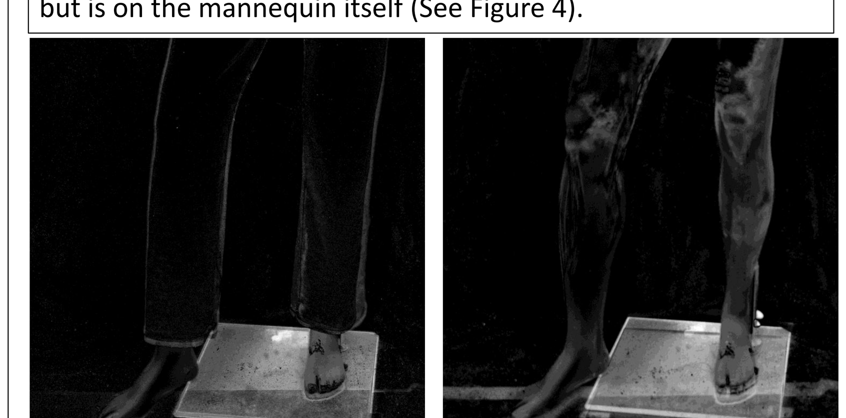
Results

Images were taken in 3 parts, but combined for illustrative purposes. The extent of contamination was difficult to visualize on porous surfaces, such as clothing, though was visible in a few locations (left shoulder, both sides of the torso). The extent of contamination was much more apparent on the mannequin's "skin". These images were opened in ImageJ (version 1.52p), converted to 32-bit grayscale, and analyzed. First the background was subtracted from the respective contaminated photos using the Image Calculator and Difference function. This resulted in images that show pixels with different gray values represented in white or light gray, while those with similar values represented by black or dark gray. Then these two images with resulting background removed were again subtracted using the Image Calculator Difference function to give an image which would represent the differences in contamination between the clothed and disrobed images. Due to difficulties in visualizing the extent of contamination on clothing, quantification of the extent of decontamination/removal by disrobing was difficult, in many cases presenting as an increase in contamination after disrobing.

A) Before contamination, no clothing **B)** Before contamination, clothed **C)** After contamination, clothed **D)** After contamination, disrobed

Figure 2. (above) Shown are the combined raw images for each step of the process. A) and B) are background images, and C) and D) are experimental images.

Figure 3. (below) Shown are the background subtracted images for the feet section of the front. Little contamination was visible on the clothing (A) indicated by only the outline being visible. More significant contamination is visible on the mannequin itself (B), shown by the lighter gray areas visible on the legs. This also explains the negative values for percent difference in contamination as contamination is not visible on the clothing, but is on the mannequin itself (See Figure 4).



A) Difference of contaminated and uncontaminated clothing **B)** Difference of contaminated and uncontaminated mannequin

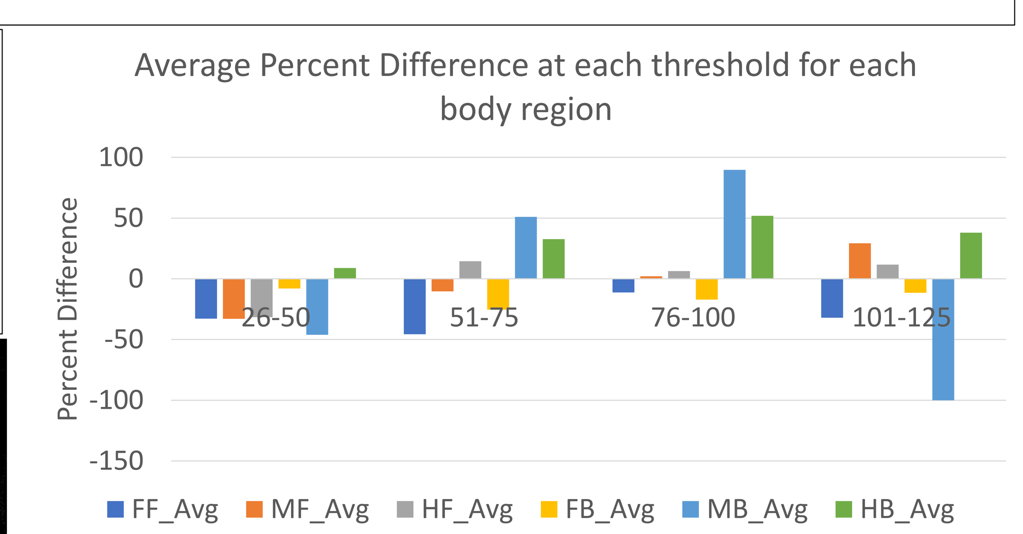


Figure 4. Average percent difference for each body region at each threshold was calculated. For each image, the total area of pixels contained at each gray value threshold was measured. Most contamination/fluorescence is captured at 25 – 125 gray value on clothing and 50 – 125 gray value on the mannequin so only these thresholds are shown. Negative percent difference indicates that fluorescence was captured on the mannequin but not the clothing. Positive percent differences are true removal of contamination.

Discussion and Conclusions

These results show that contamination can be visualized and quantified on the mannequin surface, and much more effectively than on clothing. This indicates that particles of the size generated by the Collison nebulizer (less than 600 nm, in the range of some biological aerosols) may penetrate easily through clothing. This is particularly an issue in the case of general employees or civilian victims of WMD events as they are likely to be wearing similar types of clothing during these situations, indicating that there may be little to no protection afforded by clothing. In addition, the inability to visualize fluorescence on porous surfaces could be due to absorption into the interior of the material, or increased surface area and loose fibers masking fluorescence. Investigations should be done with the fabric types used in these experiments to determine the likely reason for this inability.

While the results are encouraging, there are still further refinements to be made. For instance, the limitations on visualizing fluorescence on clothing samples. In addition, there are artefacts created through the process of background subtraction (wide gray line at the bottom of Figure 2B).

Further experiments will be done to test the penetration through other types of clothing, such as military uniforms and particularly the JSLIST suit. This suit is the one worn by personnel in situations where significant protection is needed, and thus are highly resistant to penetration by gases/vapors, liquids, and solids. In addition, this protocol could be used to test different decontamination methods (water only, water and soap, or commercial decontaminants) and evaluate the efficacy of their decontamination ability.

Once refined, the techniques explored here could be used in many real-world applications. For instance, dermal exposures are important to pesticide applicators, who may be affected by residual spray on their bodies, or who may carry residual contamination to their homes and families. Having a quick method by which to assess potential cross contamination would improve quality of life for these workers. In addition, it could be used as a training tool, to teach proper methods of PPE doffing to medical or other professionals as an important visual aid. In fact, this has been done by groups in hospital settings[6].

References/Acknowledgements

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