Developing a Full-Body Methodology for Decontamination Visualization

E Titus1,2, J Slagley2, C Cooper2, R Eninger3
1Centauri, Beavercreek, OH, 2Air Force Institute of Technology, Wright-Patterson AFB, OH, 3United States Air Force, Wright-Patterson AFB, OH

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 fluorescence 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.

This represents the technical approach to evaluating the use of ImageJ as a new tool for 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.

SITUATION/PROBLEM

Civilian and military disaster planning guides for HAZMAT and WMD situations often claim that 90% of contamination will be removed by disrobing[1]. 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, it does not 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[2-6]. 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 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[7]. The results show the average values for total body surface area for each body part were calculated as shown. Three different scenarios were considered including different clothing types. In all three scenarios, it was assumed the strength of the contaminant is uniform across the entire body and that there was no penetration of the contaminant through the clothing. The first was to cover 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/summer 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 summertime, including clothing to be short sleeve shirt, knee length shorts, and shoes.

Methods

To test the research question, a UV fluorescent dye was aerosolized on a Centauri mannequin on 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 in the test chamber and the fogging 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/m² on the mannequin. The mannequin was then 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 limbs and torso. It was then discarded. It was noted that cutting the clothing off (similar to non-ambulatory patients) would be more representative 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 Stoofer 21-steps 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.

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 most 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 an increase in contamination after disrobing.

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 Centauri 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 making fluorescence. Investigations should be done with the fabric types used in these experiments to determine the likelihood 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 artifacts 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 2L5ST 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 protocols (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 donning to medical or other professionals as an important visual aid. In this case, it has been done by groups in hospital settings[8].

REFERENCES/ACKNOWLEDGEMENTS


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AUTHOR CONTACT INFORMATION

Emily Titus
ethat@email.com


