DECONTAMINATION OF FIRE FIGHTERS' PROTECTIVE CLOTHING WITH TRICHLOROTRIFLUOROETHANE

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ABSTRACT

A limited laboratory study was conducted to evaluate the efficiency of a 1,1,2-trichloro-1,2,2-trifluoroethane-based system to decontaminate Nomex® protective clothing worn by fire fighters during a fire at an electrical transformer oil reclamation facility. Both garments contaminated at the site of the fire and garments that were contaminated in the laboratory with a known concentration of polychlorinated biphenyls (PCBs) were laundered using the 1,1,2-trichloro-1,2,2-trifluoroethane-based system. The removal efficiency of the system was determined by the ratio of the after to before PCB concentrations in terms of micrograms of PCB per gram of fabric. Overall, the PCB removal efficiencies ranged from 66 to 99%. Until permissible fabric concentration levels for PCBs are established, it can not be determined whether this system is adequate to allow the safe reuse of the clothing. Research is urgently needed to define decontamination end-points for reusable protective clothing, i.e., "how clean is clean".

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INTRODUCTION

Uncontrolled fires involving polychlorinated biphenyl (PCB) containing fluids produce a complex and potentially highly toxic mixture of chlorinated products in the soot, including polychlorinated dibenzofurans and polychlorinated dibenzo-p-dioxins (1-6). In some of the incidents, there also has been the formation of polychlorinated derivatives of biphenylene, chrysane, and pyrene (4,5,7). These incidents have resulted in the contamination of fire fighters' protective clothing and equipment with PCBs (8-10) and most probably the polychlorinated pyrolysis products.

In early 1984, a fire occurred at an electrical transformer oil reclamation facility in Jacksonville, Florida (11). The fire destroyed the building and several storage tanks containing PCB-transformer fluids and various organic solvents. A sample of the soot contained 1460 micrograms PCB (as Aroclor 1260) per gram (ug/g), and samples of liquid that had pooled on the site contained 67 to 5330 ug/g Aroclor 1260 (11). Neither the soot nor the liquid samples contained detectable concentrations of polychlorinated dibenzofurans, or dibenzo-p-dioxins (tetra-through octa-chloro homologs), or the respective 2,3,7,8-tetra isomers (11).

The protective clothing worn by the approximately 40 fire fighters, Nomex® turnout coats in combination with bunker pants, was assumed to be contaminated with PCBs. An attempt by the on-site cleanup contractor to decontaminate the garments with a common method (i.e., detergent-water wash with a water rinse) showed a mean residual PCB

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concentration of 239 ug/g (S.D. ± 411, range 15 to 1060, n=5). These levels of contamination remaining in the protective clothing after the detergent wash prompted a limited laboratory study to evaluate the efficiency of a 1,1,2-trichloro-1,2,2-trifluoroethane-based system to remove PCBs from the Nomex® fabric protective clothing. This paper describes the results of the laboratory evaluation.

METHODS AND MATERIALS

Decontamination Process Description

A RADKLEEN® Model 1550 Clothing Decontamination System* was used to remove the PCB contamination from the protective clothing (12). The RADKLEEN® System is a 1,1,2-trichloro-1,2,2-trifluoroethane (Freon® 113)-based dry cleaning machine (Figure 1). The contaminated clothing is placed in the cleaning chamber which consists of a sealed, rotating drum that will cause the garments to tumble through the solvent. Solvent is pumped from the solvent reservoir through the filter adsorber set and then flows through the cleaning chamber. The contaminated solvent then returns to the solvent reservoir. Freon® 113 vapor and vapor pressure buildup within the sealed system are controlled by vapor recirculation across a condenser coil, with condensate returning to the solvent

*Mention of company names or products does not constitute endorsement by the National Institute for Occupational Safety and Health.

reservoir. Periodically, the solvent is regenerated and purified by a built-in distillation process. Contaminants are removed from the system as still bottoms and materials trapped on replaceable filter-adsorber cartridges.

Fabric Sampling Protocol

The test protocol consisted of decontaminating both site-contaminated and laboratory-contaminated garments. The site-contaminated garments are those that were presumably contaminated during the fire. The laboratory-contaminated garments are those that were site-contaminated, but also were contaminated in the laboratory with a known concentration of PCB as Aroclor 1242. The PCB test concentrations of 2.4, 9.0, 33% (volume-to-volume in dielectric grade mineral oil) and 100% were applied via a brush to selected areas on the garments to the point of saturation. The volume of PCB applied was approximately 20 milliliters.

The fabric sampling technique consisted of marking an area five inches square (12.7 cm) and within that area marking off five one-inch squares (2.54 cm). Four of these five one-inch squares were located at the four corners of the larger square, with the fifth located at the center. To determine the pre-decontamination concentration, each of the five one-inch squares were cut from the larger square to form a composite sample. To determine the post-decontamination concentration within the same area, the remaining fabric within the marked off section was removed. This checkerboard technique was used to average out or minimize

concentration variations within the sample area. To eliminate variations based on cutting errors and unequal areas being removed, all results were normalized by reporting the contaminant concentration in terms of micrograms of PCB per gram of fabric (ug/g). The authors assumed that bulk density variations in the fabric and substrate were minor. For comparison consistency, fabric sections were removed from the same approximate location on each turnout coat and bunker pant sampled.

The removal efficiency of the system was determined by the ratio of the after to before PCB concentrations in terms of ug PCB/g fabric. The pre-and post-decontamination changes in PCB concentration were compared using a paired t-test.

The Nomex® fabric samples were extracted with toluene and analyzed by gas chrometography with electron capture detection. The presence of Aroclors 1242 and 1260 was determined by comparison with standard samples of same obtained from U.S. Environmental Protection Agency. Quantitation was performed by summing the heights of the five major peaks of the standards, and comparing that to the sum of the same peaks in the sample. The instrumental limit of detection was 0.5 ug/g for both Aroclors. Since no recovery studies were performed on the Nomex® fabric, the results are considered to be the minimum amount of Aroclor present.

RESULTS AND DISCUSSION

Table 1 presents the pre-and post-decontamination concentrations of PCBs and percent removal for the site-contaminated garments. The PCB concentrations prior to laundering ranged from 5.3 to 480 ug/g (mean 85, S.D. $\pm$ 130). By comparison, the post-decontamination concentrations ranged from 1.1 to 25 ug/g (mean 4.8, S.D. $\pm$ 6.4). The percent of PCBs removed ranged from 66 to 99%, with a mean of 88% and a 95% lower confidence limit of 82% removed.

Table 2 presents the pre-and post-decontamination concentrations of PCBs and percent removal for the laboratory-contaminated garments. Although the PCB concentrations applied to the garments ranged from 2.4×10^4 to 1.0×10^6 ug/g (2.4 to 100%, volume-to-volume), the actual concentration in the fabrics ranged from 1.6×10^4 to 9.9×10^5 ug/g (1.6 to 99%, weight-to-weight). The post-laundered concentrations ranged from 5.4 to 230 ug/g (mean 63.5, S.D. $\pm$ 64.2). The reduction in PCB concentration exceeded 99% for all of the garments tested.

Post-laundering inspection of the garments revealed that the tumble-wash action of the machine did not appear to cause any physical damage to the garments such as cuts, abrasions, or alteration of the retro-reflective trim. Tests are currently being conducted by an independent laboratory to determine if solvent-washed garments still meet key performance criteria specified in the National Fire Protection Association (NFPA) 1971 Standard on Protective Clothing for Structural Fire Fighting (13).

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CONCLUSIONS

This limited study indicates that a relatively high percentage of fire-borne and liquid PCB contamination can be removed from fire fighters' protective clothing using a trichlorotrifluoroethane-based system. The toxicological significance of the PCB contamination levels remaining in the garments is uncertain. However, until permissible fabric concentration levels of PCBs are established, it cannot be determined whether this technique is adequate. The discarding and replacement of fire fighters' protective clothing and equipment can be very costly (10,11). The incident described in this paper resulted in the replacement of approximately 40 sets of bunker gear (including turnout coats, pants, and boots) with a replacement cost of approximately $20,000. Research is urgently needed to define decontamination end-points for reusable protective clothing, i.e., "how clean is clean".

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REFERENCES

1. U.S. Environmental Protection Agency. Polychlorinated Biphenyls (PCBs) Manufacturing, Processing, Distribution in Commerce and Use Prohibitions: Use in Electrical Equipment Transformers. 40 CFR 761 Federal Register Vol. 49, April 19, 1984, pp. 11070-11083.

2. Schecter, A. Contamination of an Office Building in Binghamton, New York, by PCBs, Dioxins, Furans and Biphenylenes after an Electrical Panel and Electrical Transformer Incident. Chemosphere, Vol. 12, No. 415, pp. 669-680, 1983.

3. Des Rosiers, P.E., PCBs, PCDFs, and PCDDs Resulting from Transformer/Capacitor Fires: An Overview. In: Proceedings: 1983 PCB Seminar. Electrical Power Research Institute, EPRI EL-3581, June 1984.

4. Rappe, C., Marklund, S., Bergqvist, P., et al. Polychlorinated Dioxins (PCODs), Dibenzofurans (PCDFs) and Other Polynuclear Aromatics (PCPNAs) Formed During PCB Fires. Chemica Scripta, Vol. 20, pp. 56-61, 1982.

5. Williams, C.H., Prescott, C.L., Stewart, P.B., et al. Formation of Polychlorinated Dibenzofurans and Other Potentially Toxic Chlorinated Pyrolysis Products in PCB Fires. In Chlorinated Dioxins and Dibenzofurans in the Total Environment, Keith, L.H., Editor, Butterworth Publishers, Stoneham, Massachusetts, 1984.

6. Kominsky, J.R. The Chemistry of Electrical Transformer Fires. Presented at the American Public Health Association Meeting, Anaheim, California, November 11-15, 1984.

7. Stallings, O.L. Chlorinated Dibenzofurans and Related Compounds in Soot Formed in a Transformer Fire in Binghamton, New York. Preliminary Report, Columbia National Fisheries Research Laboratory, U.S. Fish and Wildlife Service, Columbia, Missouri, March 31, 1981.

8. Orris, P., Kominsky, J.R., Melius, J.M., et al. Exposure to Polychlorinated Biphenyls from an Overheated Transformer. Submitted for publication, 1984.

9. Kominsky, J.R. Health Hazard Evaluation No. HETA 84-490. National Institute for Occupational Safety and Health, Cincinnati, Ohio, 1984.

10. Kominsky, J.R. and Melius, J.M. Health Hazard Evaluation No. 84-372. National Institute for Occupational Safety and Health, Cincinnati, Ohio, 1984.

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11. Kominsky, J.R. Health Hazard Evaluation No. 84-169. National Institute for Occupational Safety and Health, Cincinnati, Ohio. 1984.

12. RADKLEEN® OC Model 1550, Operating and Maintenance Manual, Quadrex HPS Inc, Gainesville, Florida 32606.

13. National Fire Protection Association. NFPA 1971: Standard on Protective Clothing for Structural Fire Fighting, 1981 Ed., National Fire Protection Association, Quincy, Massachusetts, 1981.

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Figure 1

Basic Freon® 113 Decontamination Process

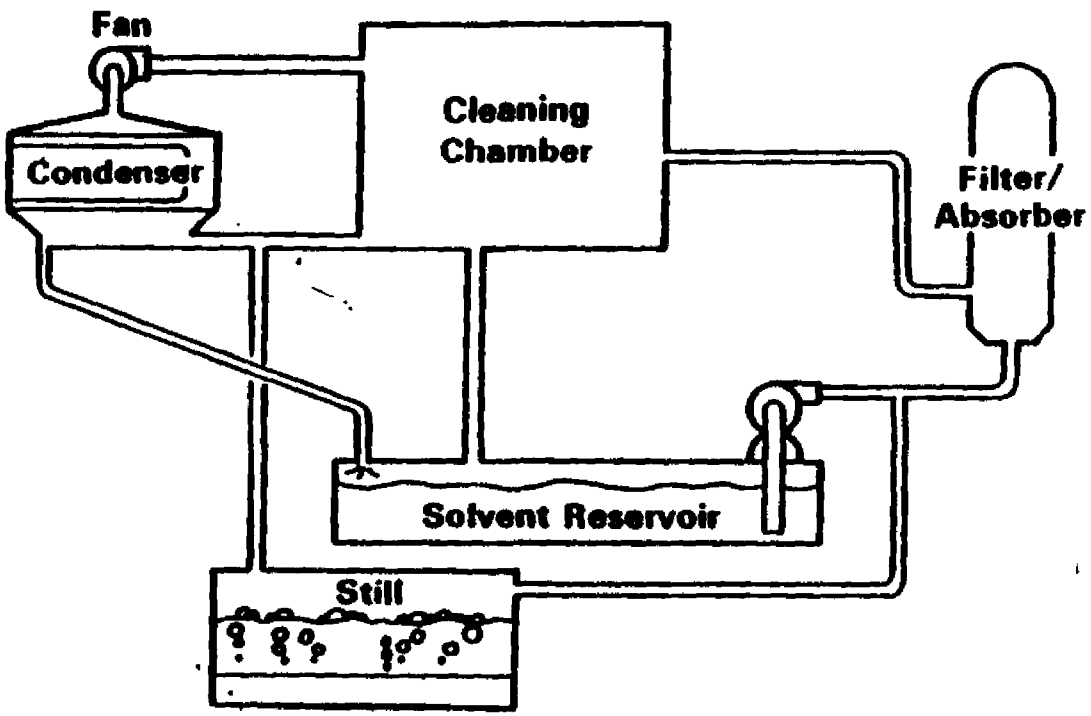

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Table 1

PCBs Removed from Site-Contaminated Garments

ug PCB/g fabric		
Pre-Decon	Post-Decon	% Removal
480	25	95
240	13.3	95
200	1.8	99
68	1.3	98
60	5.4	91
56	3.5	94
37	5.1	86
35	4.2	88
35	2.4	93
15	1.1	93
14	2.9	79
10	1.2	88
7.8	1.3	83
6.7	2.2	67
5.3	1.8	66

$p<0.05$, $t=2.49$

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Table 2

PCBs Removed from Lab-Contaminated Garments

ug PCB/g fabric		
Pre-Decon	Post-Decon	% Removal
9.9×10^5	24	99
9.4×10^5	180	99
6.3×10^5	60	99
6.3×10^5	53	99
5.4×10^5	230	99
2.5×10^5	110	99
1.8×10^5	97	99
1.8×10^5	62	99
7.2×10^4	13	99
6.1×10^4	8.2	99
5.8×10^4	63.1	99
5.7×10^4	63.5	99
2.0×10^4	18.4	99
1.8×10^4	5.4	99
1.7×10^4	18	99
1.6×10^4	11.9	99

$p < 0.05$, $t = 3.34$

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