U.S. DEPARTMENT OF HEALTH AND HUMAN SERVICES • Public Health Service
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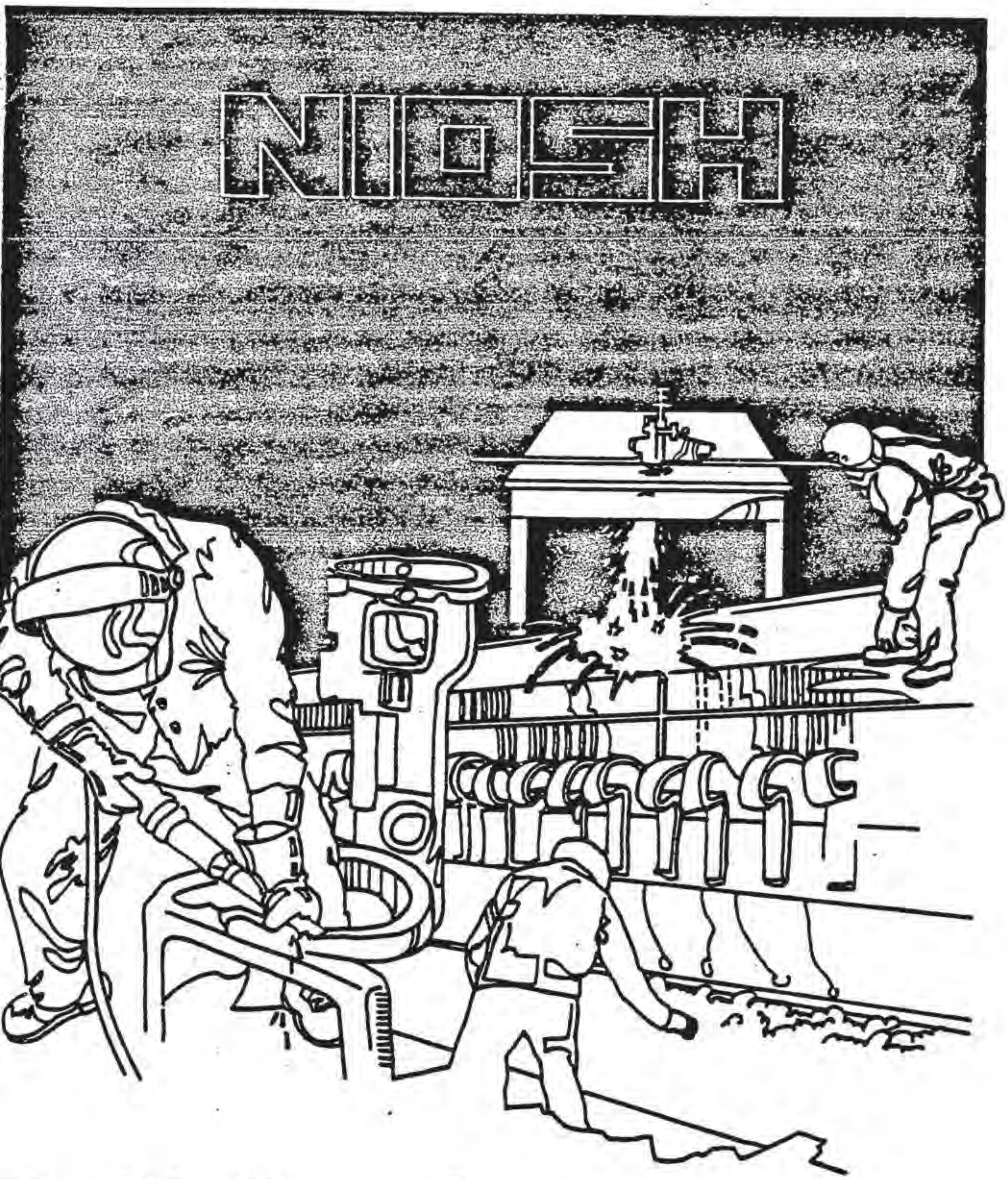

Health Hazard Evaluation Report

HETA 84-180-1776
JACKSONVILLE FIRE DEPARTMENT
JACKSONVILLE, FLORIDA

PREFACE

The Hazard Evaluations and Technical Assistance Branch of NIOSH conducts field investigations of possible health hazards in the workplace. These investigations are conducted under the authority of Section 20(a)(6) of the Occupational Safety and Health Act of 1970, 29 U.S.C. 669(a)(6) which authorizes the Secretary of Health and Human Services, following a written request from any employer or authorized representative of employees, to determine whether any substance normally found in the place of employment has potentially toxic effects in such concentrations as used or found.

The Hazard Evaluations and Technical Assistance Branch also provides, upon request, medical, nursing, and industrial hygiene technical and consultative assistance (TA) to Federal, state, and local agencies; labor; industry and other groups or individuals to control occupational health hazards and to prevent related trauma and disease.

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I. SUMMARY

On January 29, 1984, a fire occurred at a transformer oil reclamation facility in Jacksonville, Florida. The Nomex® fabric garments worn by the fire fighters were assumed to be contaminated with polychlorinated biphenyls (PCBs). An attempt to decontaminate the garments with a common method (detergent wash with water rinse) showed a mean residual concentration of 239 ug PCB/g fabric (range 15 to 1060 ug/g). These results prompted the Jacksonville Fire Department (IAFF, Local 122) to request that the National Institute for Occupational Safety and Health (NIOSH) evaluate the efficiency of a trichlorotrifluoroethane-based system to remove PCBs from Nomex® fabric garments. The system is a dry cleaning machine with a revolving chamber where the garments are tumble-washed in a fluorocarbon solvent.

A limited study consisting of decontaminating both site-contaminated and laboratory-contaminated garments (Nomex® fabric coats and trousers) was conducted on February 13-15, 1984. The site-contaminated garments were those that were contaminated during the incident (mean 85 ug PCB/g fabric, range 5.3 to 480 ug PCB/g fabric). The laboratory-contaminated garments were those that were site-contaminated, but also were contaminated in the laboratory with PCB concentrations of 2.4, 9.0, 33 and 100% (volume-to-volume). The reduction of PCB for site-contaminated garments ranged from 66 to 99% with a mean of 88% and a 95% lower confidence limit removal of 82%. The reduction for all laboratory-contaminated garments exceeded 99%.

This study demonstrates 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. However, until scientifically derived permissible fabric concentration levels of PCBs are established, it cannot be absolutely determined whether this technique is adequate.

KEYWORDS: SIC 9224 (Fire Fighters), PCBs, polychlorinated biphenyls, decontamination, protective clothing, Freon® 113, trichlorotrifluoroethane.

II. INTRODUCTION

On February 8, 1984, the the National Institute for Occupational Safety and Health (NIOSH) was requested to test the efficiency of a trichlorotrifluoroethane based decontamination process for removing polychlorinated biphenyls (PCBs) from fire fighters Nomex® protective clothing. The request was submitted by the International Association of Fire Fighters (IAFF) on behalf of their affiliate, Local 122, in Jacksonville, Florida.

On February 13-15, 1984, a limited laboratory study was conducted to test the efficiency of a RADKLEEN® Model 1550 Clothing Decontamination System to remove PCBs from Nomex® fabric protective clothing. The test was conducted in conjunction with Quadrex HPS at their facility in Gainesville, Florida. The results of the test were presented to the IAFF, Local 122, in a letter report dated March 12, 1984.

III. BACKGROUND

On January 29, 1984, a fire occurred at an electrical transformer oil reclamation facility in Jacksonville, Florida [1]. The fire destroyed the building and several storage tanks containing PCB-transformer fluids and various chlorinated and unchlorinated organic solvents. A sample of the soot contained 1460 micrograms Aroclor 1260 per gram (ug/g), and samples of liquid that had pooled on the site contained 67 to 5330 ug/g Aroclor 1260. (Aroclor 1260 is a commercial mixture of PCBs with approximately 60 weight percent chlorine). Neither the soot nor the liquid samples contained detectable concentrations of polychlorinated dibenzofurans, or dibenzo-p-dioxins (tetra through octa- chloro isomer groups), or the respective 2,3,7,8-tetra isomers. The dibenzofurans and, to a lesser extent, PCDDs, can be present in soot resulting from fires involving PCB-containing electrical equipment [2,3].

The protective clothing worn by the approximately 40 fire fighters, Nomex® fabric 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 concentration of 239 ug/g (S.D. ± 411, range 15 to 1060, n=5). These garments were judged to be unusable based upon this residual contamination. Due to the lack of an effective means of decontamination, these garments were placed temporarily in secure storage prior to disposal. This incident provided the opportunity for

NIOSH to secure turnout gear which had been exposed to a PCB fire and conduct a limited study to test the removal efficiency of a trichlorotrifluoroethane based decontamination technique.

IV. EVALUATION CRITERIA

A. Environmental - PCBs

NIOSH recommends that airborne exposure to PCBs in the work place be limited to, or below, the minimum reliable detectable concentration of 1 microgram of PCB per cubic meter of air (ug/m^3) (using the recommended sampling methods) determined as a TWA for up to a 10-hr workday, 40-hr workweek. The NIOSH Recommended Exposure Limit (REL) was based upon the findings of adverse reproductive effects in experimental animals, on the conclusion that PCBs are carcinogenic in rats and mice and, therefore, potential human carcinogens in the work place, and on the conclusion that human and animal studies have not demonstrated a level of exposure to PCBs that will not subject workers to possible liver injury.

The Occupational Safety and Health Administration (OSHA) promulgated its permissible exposure limit (PEL) of 1 mg/m^3 for airborne chlorodiphenyl products (PCBs) containing 42% chlorine and 0.5 mg/m^3 for chlorodiphenyl products containing 54% chlorine determined as 8-hr time-weighted average (TWA) concentrations based on the 1968 Threshold Limit Values (TLVs) of the American Conference of Governmental Industrial Hygienists (ACGIH). The TLVs, which have remained unchanged at 1 mg/m^3 and 0.5 mg/m^3 through 1986, are based on the prevention of liver injury in exposed workers. The ACGIH Short Term Exposure Limits (STEL) for airborne chlorodiphenyls are 2 mg/m^3 and 1 mg/m^3 for 42% and 54% chlorine products, respectively. The OSHA PEL and the ACGIH TLV and STEL values include a "Skin" notation which refers to the potential contribution to overall exposure by the cutaneous route, including the mucous membranes and eyes, by either airborne or direct skin contact with PCBs.

There are no standard evaluation criteria (RELs, PELs, or TLVs) for industrial surfaces contaminated with PCBs. In July of 1985, an advisory panel was convened to provide guideline recommendations for air and surface clean up for PCBs, dioxins, and furans for the State Highway Department Building in Santa Fe, New Mexico. Both NIOSH and the Environmental Protection Agency were represented on this panel. These guidelines included specifications for PCB concentrations not to exceed 50 ug/m^2 on "working" surfaces.

Examples of working surfaces included "high contact" items such as desk tops and chairs. Although application of these guidelines to the industrial environment is difficult, recent recommendations by NIOSH (June 1986) for surface clean up of PCBs in an aircraft maintenance facility proposed 250 ug/m^2 for low contact surfaces, and 100 ug/m^2 for actual aircraft parts, or "high contact" items. In interpretation of these guidelines and proposals, it should be noted that there is a great deal of scientific uncertainty about the potential human risks from exposure to PCBs.

There are no standard criteria for permissible fabric concentrations of PCBs in personal protective clothing garments.

B. Health Effects - PCBs

Polychlorinated biphenyls (PCBs) are a class of compounds that have various combinations of chlorine atoms attached to a biphenyl molecule [8]. Since commercial introduction in the late 1920s, over 1.25 billion pounds of PCBs have been manufactured and used in the United States, primarily in mixtures with chlorobenzenes known as askarels which are used as dielectric fluids for electrical transformers and capacitors, heat transfer systems, and hydraulic systems [9]. PCBs also have been used as lubricants, plasticizers, pesticide extenders, and components of inks and surface coatings [10]. The main uses of Commerical PCBs are mixtures of isomers of chlorinated biphenyls. The basic structure of PCBs is a biphenyl backbone to which is attached up to ten chlorine atoms. Although there are 209 possible positional chlorobiphenyl isomers, only 100 individual isomers are likely to occur at significant concentrations in commercial PCB mixtures [11]. PCBs were manufactured in the United States and marketed under th "Trade name Aroclor" according to the average percent chlorine content of the mixture. The Aroclor products were designated by numbers such as 1221, 1242, 1248, 1254, and 1260, with the last two digits representing the approximate percent by weight of chlorine in the mixtures. Aroclor 1016, however, contained 41% chlorine [8].

PCB residues are detectable in various tissues of persons without known occupational exposure to PCBs. Mean whole blood PCB levels have been found to range from 1.1 to 8.3 parts per billion (ppb), while mean serum PCB levels range from 2.1 to 24.2 ppb [12]. Mean serum PCB levels among workers in one capacitor manufacturing plant studied by NIOSH ranged from 111 to 546 ppb, or approximately 5 to 22 times the background level in the community. Mean serum PCB levels among workers in transformer maintenance and repair have been found to range from 12 to 51 ppb, considerably lower than among workers at capacitor manufacturing plants [13].

Chlorobiphenyl toxicity is complicated by the presence of highly toxic impurities, especially the polychlorinated dibenzofurans (PCDFs) [14], which vary in amount between PCBs of manufacturers [15], and PCBs of different percent chlorination [16], and which are found in increased concentration when PCBs undergo incomplete pyrolysis [17,18]. As well, different animal species, including man, vary in their pattern of biologic response to PCB exposure [19].

Two human epidemics of chloracne, "Yusho" and Yu-cheng," from ingestion of cooking oil accidentally contaminated by a PCB heat-exchange fluid used in the oil's pasteurization, have been described in detail [20,21]. Although PCBs were initially regarded as the etiologic agent of Yusho, analyses of the offending cooking oil demonstrated high levels of polychlorinated dibenzofurans and polychlorinated quarterphenyls, as well as other unidentified chlorinated hydrocarbons, in addition to PCBs [22].

The results of individual studies of PCB-exposed workers are remarkably consistent. Among the cross-sectional studies of the occupationally exposed, a lack of clinically apparent illness in situations with high PCB exposure seems to be the rule. Chloracne was observed in recent studies of workers in Italy, [23] but not among workers in Australia, [24] Finland [25], or in the United States [13,26-28]. Weak positive correlations of PCB exposure or serum PCB levels have been reported with SGOT [23,25-27], GGTP [13,23,27,28], and plasma triglycerides [13,29,20]. Correlations with plasma triglycerides [31] and GGTP [32] are also found among community residents with low level PCB exposures. Causality cannot necessarily be imputed to PCBs in these cross-sectional studies.

The International Agency for Research on Cancer has concluded that the evidence for PCBs' carcinogenicity to animals and to humans is limited. "Certain polychlorinated biphenyls are carcinogenic to mice and rats after their oral administration, producing benign and malignant liver neoplasms. Oral administration of polychlorinated biphenyls increased the incidence of liver neoplasms in rats previously exposed to N-nitrosodiethylamine" [33].

In a mortality study among workers at two capacitor manufacturing plants in the United States [34] a greater than expected number of observed deaths from cancer of the liver and cancer of the rectum were noted. Neither increase was statistically significant for both study sites combined. However, in a recent update of this study (in press), with follow-up through 1982, the excess in liver/biliary tract cancer was statistically significant (5 observed vs. 1.9 expected)/whereas, the excess in cancer of the rectum was still elevated but not statistically significant. In a mortality study among workers at a capacitor manufacturing plant in Italy [35] males had a statistically significant increased number of deaths from all neoplasms. When analyzed separately by organ system, death from neoplasms of the digestive organs and peritoneum (3 observed vs. 0.88 expected) and from lymphatic and hematopoietic tissues (2 observed vs. 0.46 expected) were elevated. This study was recently expanded to include all workers with one week or more of employment with vital status follow-up through 1982. In the updated results, there was a statistically significant excess in cancer among both females (12 observed vs. 5.3 expected) and males (14 observed vs. 7.6 expected). In both groups there were non-significant excess in digestive cancer among males (6 observed vs. 2.2 expected). Unfortunately, not enough information is provided to determine the risk specifically for liver cancer.

C. Health Effects - PCDFs and PCDDs

Polychlorinated dibenzofurans (PCDFs) and polychlorinated dibenzo-p-dioxins (PCDDs) are two series of tricyclic aromatic compounds. The number of chlorine atoms can vary between 1 and 8 (mono- through octa-chloro isomer groups) resulting in 75 PCDDs and 135 PCDF positional isomers.

The toxic effects of these compounds are associated with the number and specific placement in the chlorine atoms on the molecule. The tetra-, penta- and hexa-chlorinated isomer groups exhibit greater toxicity than the other chlorinated forms [36-38], PCDDs and PCDFs with chlorine at positions 2,3,7, and 8 are particularly toxic [39-41], PCDDs and PCDFs are highly toxic in experimental animals when administered acutely subchronically, or chronically [41-49]. Toxic effects include severe weight loss, liver necrosis and hypertrophy, skin lesions, immunosuppression, reproductive toxicity, teratogenesis and death. Of the 75 PCDD and 135 PCDF isomers, only 2,3,7,8-TCDD and a mixture of hexa-chlorinated dibenzo-p-dioxins with four of the six chlorines in positions 2,3,7, and 8 have been tested for carcinogenicity. Two independent studies of 2,3,7,8,-TCDD resulted in significant increases in the incident of liver and/or lung tumors in treated rodents [50]. A mixture of two 2,3,7,8-substituted hexa chlorinated dibenzodioxins were found to produce an increased incidence of liver tumors or neoplastic modules in exposed rats and mice [51]. Exposure of humans to PCDDs had caused chloracne (a skin lesion which resembles mild to very severe acne and which may last many years); and liver toxicity [47,52]. There is humans and exposure to PCBs containing significant PCDFs [53,54] and to phenoxyacetic herbicides contaminated with PCDDs including TCDD [55,56]. However, definite causal relationships between exposure and carcinogenic effects in humans remain unclear due to the inadequately defined population studies and the influences of mixed exposures.

V. METHODS AND MATERIALS

A. Decontamination Process Description

A RADKLEEN® Model 1550 Clothing Decontamination System was used to remove the PCB contamination from the protective clothing [4]. 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 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.

B. Fabric Sampling Protocol

The test protocol consisted of decontaminating both site-contaminated and laboratory-contaminated garments (Table 1). 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 of the fabric 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). It was 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 using the following equation:

$$\text{Removal Efficiency (\%)} = \frac{(A - B)}{(A)} \quad X \quad 100$$

where "A" is the initial and "B" is the final concentration of PCB in the fabric in terms of ug PCB/g fabric. The pre- and post-decontamination measurements of PCB concentration were compared using a paired t-test.

The Nomex® fabric samples were extracted with toluene and analyzed by gas chromatography with electron capture detection. The presence of Aroclors 1242 and 1260 was determined by comparison with standard samples of the same Aroclors obtained from the 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.

VI. RESULTS

Table 2 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. ± 130). By comparison, the post-decontamination concentrations ranged from 1.1 to 25 ug/g (mean 4.8, S.D. ± 6.4). The percent of PCBs removed, therefore, ranged from 66 to 99%, with a mean of 88% and a 95% lower confidence limit of 82% removed.

Table 3 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 measured 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. ± 64.2). The reduction in PCB concentration exceeded 99% for all of the garments tested.

Post-laundered 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.

VII. DISCUSSION AND CONCLUSIONS

Uncontrolled fires involving polychlorinated biphenyl (PCB) containing fluids can produce a complex and potentially highly toxic mixture of chlorinated products in the soot, including polychlorinated dibenzofurans and polychlorinated dibenzo-p-dioxins [2,3]. These incidents have resulted in the contamination of fire fighters' protective clothing and equipment with PCBs [5-7] and, most probably with their polychlorinated pyrolysis products.

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 scientifically derived health related 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 [1, 5-7]. The Jacksonville incident in fact resulted in the replacement of approximately 40 sets of turnout 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."

VIII. RECOMMENDATIONS

1. Fire fighters and other emergency response personnel responding to fires involving PCB-containing fluids may be at risk of exposure to PCBs and their more toxic thermal conversion products polychlorinated dibenzofurans (PCDFs) and polychlorinated

dibenzo-p-dioxins (PCDDs). All emergency response workers should understand that exposure can occur through inhalation, ingestion, and skin absorption (by direct contact or by contact with contaminated surfaces, clothing, and equipment) and recognize that exposure to some of these compounds may result in long term health effects.

2. The number of fire fighters responding and entering the potentially contaminated area(s), (e.g., interior of the building) should be limited. This action would minimize the number of fire fighters exposed and would reduce the amount of protective clothing and equipment potentially contaminated.

3. The fire fighters who enter the potentially contaminated areas should wear a self-contained breathing apparatus (SCBA) operated in the positive pressure mode and standard turn-out gear. Although the neoprene vapor barrier commonly used in fire fighter protective clothing may not prevent penetration of vaporous PCBs and other compounds, practical alternatives are not readily available. When possible, flame resistant disposable protective clothing should be worn over the usual primary protective turn out gear. This use of disposable protective clothing will serve as a barrier against combustion particulates and ultimately reduce the problem of decontamination of the turn-out gear, as there is currently no recommended method of decontamination.

4. Reusable equipment should be grouped according to perceived degree of contamination (i.e., high, moderate, or low) and washed with an alkaline (trisodium phosphate base or nonionic (octylphenoxypolyethoxyethanol base) synthetic detergents. (All wash water should be collected, tested and disposed of in accordance with applicable EPA regulations.) Decisions concerning decontamination end points are often based on the lack of visible contamination; however, the absence of observable surface contamination does not necessarily indicate the absence of contaminants absorbed into the material. The equipment should, therefore, be tested for residual contamination before reuse or storage.

IX. REFERENCES

1. Kominsky, J.R. and Seligman, P. Health Hazard Evaluation Report No. HETA 84-169. the National Institute for Occupational Safety and Health. Cincinnati, Ohio.

2. Kominsky, J.R., and Melius, J.M. (1985) PCB, PCDF and PCDD Contamination of Structures Resulting from Electrical Equipment Fires and Failures, Proceedings of the 7th Annual RMCOEH Conference "Hazardous Waste Management and Control: Weighing the Risks", Park City, UT, in print.

3. Current intelligence bulletin no. 45, Polychlorinated Biphenyls (PCBs): Potential Health Hazards from Electrical Equipment Fires or Failures. Cincinnati: U.S. Department of Health and Human Services, Public Health Service, Centers for Disease Control, National Institute for Occupational Safety and Health, 1986; DHHS (NIOSH) publication no. 86-111.

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

5. Orris, P., Kominsky, J.R., Horyhorczuk, D., and Melius, J.M. Exposure to Polychlorinated Biphenyls from an Overheated Transformer. Chemosphere, Vol. 15, No. 9-12:1305-1311, (1986).

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

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

8. Hutzinger O, Safe S, Zitko V. The chemistry of PCB's. Florida: CRC Press, Inc., 1974:3,7,13,17,120.

9. EPA. PCBs in the United States: Industrial Use and Environmental Distribution Task 1. Final Report. EPA 560/6-76-005. Prepared by Versar, Inc. February 25, 1976.

10. Lloyd JW, Moore RM, Woolf BS, Stein HP. Polychlorinated biphenyls. J Occup Med 1976;18:109.

11. Pomerantz L, Burke J, Firestone D, McKinney J, Roach J, Trotter W. Chemistry of PCBs and PBBs. Environ Health Perspect 1978;24:133-46.

12. Landrigan PJ. General population exposure to halogenated biphenyls. In: Kimbrough RD, ed. Halogenated biphenyls, terphenyls, naphthalenes, dibenzodioxins, and related products. Amsterdam: Elsevier/North-holland Biomedical Press, 1980:267.

13. Smith AB, Schloemer J, Lowry LK, et al. Metabolic and health consequences of occupational exposure to polychlorinated biphenyls (PCBs). Br J Ind Med 1982;39:361.

14. Vos JG, Koeman JG. Comparative toxicologic study with polychlorinated biphenyls in chickens, with special reference to porphyria, edema formation, liver necrosis, and tissue residues. Tox Appl Pharm 1970;17:656.

15. Vos JG, Koeman JH, van der Mass HL, ten Noever de Brauw MC, de vos RH. Identification and toxicological evaluation of chlorinated dibenzofuran and chlorinated naphthalene in two commercial polychlorinated biphenyls. Fd Cosmet Toxicol 1970;8:625.

16. Bowes GW, Mulvihill MJ, Simoneit BRT, Burlingame AL, Risebrough RW. Identification of chlorinated dibenzofurans in American polychlorinated biphenyls. Nature 1975;94:125.

17. Buser HR, Bosshardt HP, Rappe C. Formation of polychlorinated dibenzofurans (PCDFs) from the pyrolysis of PCBs. Chemosphere 1978;7:109.

18. Buser HR, Rappe C. Formation of of polychlorinated dibenzofurans (PCDFs) from the pyrolysis of PCBs. Chemosphere 1977;8:157.

19. Vos JG. Toxicology of PCBS for mammals and for birds. Env Health perspect 1969;21:29.

20. Kuratsune M, Yoshimura T, Matsuzaka J, Yamaguchi A. Epidemiologic study on Yousho, a poisoning caused by ingestion of rice oil contaminated with a commercial brand of polychlorinated biphenyl. Environ Health Perspect 1972;1:119.

21. Wong CK. PCB poisoning special issue. Clinical Medicine (Taipel). Volume 7, no. 1, 1981.

22. Masuda Y, Kuroki H. Polychlorinated dibenzofurans and related compounds in patients with "Yusho." In: Hutzinger O, Frei R W, Merian E, Pocchiari F, eds. Chlorinated dioxins and related compounds. Oxford: Pergamon Press, 1982:561.

23. Maroni M, Colombi A, Arbosti G, Cantoni S, Foa V. Occupational exposure to polychlorinated biphenyls in electrical workers, II. Health effects. Br J Ind Med 1981;38:55.

24. Ouw KH, Simpson GR, Siyali DS. The use and health effects of Aroclor 1242, a polychlorinated biphenyl in the electrical industry. Arch Environ Health 1976;31:189.

25. Karppanen E, Kolho L. The concentration of PCB in human blood and adipose tissue in three different research groups. In: PCB Conference II, Stockholm, 1972. National Swedish Environmental Protection Board. 1973, 124

26. Fischbein A, Woolf MS, Lillis R, Thornton J, Selikoff IJ. Clinical findings among PCB-exposed capacitor manufacturing workers. Ann NY Acad Sci 1979;320:703.

27. Chase KH, Wong O, Thomas D, Berney BW, Simon RK. Clinical and metabolic abnormalities associated with occupational exposure to polychlorinated biphenyls (PCBs). J Occup Med 1982;24:109.

28. Emmett EA, Agnew J, Bleeker ML, Ferrara JM, Levin BK, Jeffreys J, Maroni M. Health effects of PCB Exposure of GSA Switchgear employees. NIOSH Technical Assistance Request #80-7, The Johns Hopkins University School of Hygiene and Public Health, Baltimore, Maryland, 1983.

29. Lawton RW, Sack BT, Ross MR, Feingold J. Studies of employees occupationally exposed to PCBs. General Electric Research and Development Center, Schenectady, 1981.

30. Crow KD. Chloracne: a critical review including a comparison of two series of cases of acne from chloronaphthalene and pitch fumes. Trans St John's hosp Dermatol Soc 1970;56:79.

31. Baker EL Jr, Landrigan PJ, Glueck CJ. Metabolic consequences of exposure to polychlorinated biphenyls in sewage sludge. Am J Epid 1980;112:553.

32. Kreiss K, Zack MM, Kimbrough RD, Needham LL, Smrek AL, Jones BT. Association of blood pressure and polychlorinated biphenyl levels. JAMA 1981;245:2505.

33. International Agency for Research on Cancer. IARC monographs on the evaluation of the carcinogenic risk of chemicals to humans. Chemicals, Industrial Process, and Industries Associated with Cancer in Humans. IARC Monographs, Volumes 1 to 29. Supplement 4, Lyon, france, 1982, p. 218.

34. Brown DP, Jones M. Mortality and industrial hygiene study of workers exposed to polychlorinated biphenyls. Arch Environ Health 1981;36:120.

35. Bertazzi PA, Zocchetti C, Guercilena s, Foglia MD, Pesatori A, Riboldi L. Mortality study of male and female workers exposed to PCBs. Presented at the International Symposium on Prevention of Occupational Cancer, April, 1981, Helsinki, Finland.

36. Goldstein JA. The structure-activity relationships of halogenated biphenyls as enzme inducers. Ann NY Acad Sci 1979;320:164-78.

37. Yoshimura H, Yoshihara S, Ozawa N, Miki M. Possible correlation between industion modes of hepatic enzymes by PCBs and their toxicity in rats. Ann NY Acad Sci 1979;320:179-92.

38. Poland A, Greenlee W, Kende AS. Studies on the mechanism of action of the chlorinated dibenzo-p-dioxins and related compounds. Ann NY Acad Sci 1979;320:214-30.

39. McConnell EE, Moore JA, Haseman JK, Harris MW. The comparative toxicity of chlorinated dibenzo-p-dioxins in mice and guinea pigs. Toxicity Appl Pharmacol 1978;44:335-56.

40. Nagayama J, Kuroki H, Masuda Y, Kuratsune M. A comparative study of polychlorinated dibenzofurans, polychlorinated biphenyls and 2,3,7,8-tetrachlorodibenzo-p-dioxin on aryl hydrocarbon hydroxylase inducing potency in rats. Arch Toxicol 1983;53:177-84.

41. Yoshihara S, Nagata K, Yoshimura H, Kuroki H, Masuda Y. Indusctive effect on hepatic enzymes and acute toxicity of individual polychlorinated dibenzofuran congeners in rats. Toxicol Appl Pharmacol 1981;59:580-8.

42. Moore JA, McConnell EE, Dalgard DW, Harris MW. Comparative toxicity of three halogenated dibenzofurans in guinea pigs, mice, and rhesus monkeys. Ann NY Acad Sci 1979;320:151-63.

43. Schwetz BA, Norris JM, Sparschu GL, et al. Toxicology of chlorinated dibenzo-p-dioxins. Environ Health Perspect 1973;5:87-99.

44. McConnell EE, Moore JA, Dalgard DW. Toxicity of 2,3,7,8-tetrachloro-dibenzo-p-dioxin in rhesu monkeys (macaca mulatta) following a single oral dose. Toxicol Appl Pharmacol 1978;43:175-87.

45. Garthoff LH, Cerra FE, Marks EM. Blood chemistry alterations in rats after single and multiple gavage administration of polychlorinated biphenyl. Toxicol Appl Pharmacol 1981;60:33-44.

46. Moore JA, Gupta BN, Vos JG. Toxicity of 2,3,7,8-tetrachlorodibenzo-furan - preliminary results. In: Proceedings of the National Conference on Polychlorinated Biphenyls, held 1975 November 19-21 in Chicago, EPA-560/6-75-004. Environmental Protection Agency, Office of Toxic Substances, 1976:77-80.

47. Current intelligence bulletin no. 40-2,3,7,8-tetrachlorodibenzo-p-dioxin (TCDD, "dioxin"). Cincinnati: U.S. Department of Health and Human Services, Public Health Service, Centers for Disease Control, National Institute for Occupational Safety and Health, 1984;DHHS (NIOSH) publication no. 84-104.

48. Hassoun E, d'Argy R, Dencker L. Teratogenicity of 2,3,7,8-tetrachloro-dibenzofuran in the mouse. J Toxicol Environ Health 1984;14:337-51.

49. Kociba RJ, Keyes DG, Beyer JE, et al. Results of a two-year chronic toxicity and oncogenicity study of 2,3,7,8-tetrachlorodibenzo-p-dioxin in rats. Toxicol Appl Pharmacol. 1978;46:279-303.

50. NTP (National Toxicology Program). Bioassay of 2,3,7,8-tetrachlorodibenzo-p-dioxin for possible carcinogenicity (gavage study). DHHS Publ No. (NIH) 82-1765. Carcinogenesis Testing Program, NCI, Bethesda, DM. NIH, and Research Triangle Park, NC, NTP. 1982

51. NTP (National Toxicology Program). Bioassay of 1,2,3,6,7,8- and 1,2,3,7,8,9-hexachlorodibenzo-p-dioxin for possible carcinogenicity (gavage study). DHHS Publ No. (NIH) 80-1758. Carcinogenesis Testing Program, NCI, Bethesda, MD, NIH, and Research Triangle Park, NC, NTP.

52. Ideo G, Bellati G, Bellobuono A, Bissanti L. Urinary D-glucaric acid excretion in the Seveso area, polluted by tetrachlorodibenzo-p-dioxin (TCDD): five years of experience. Environ Health Perspect 1985;60:151-7.

53. Urabe H, Koda H, Asahi M. Present state of Yusho patients. Ann NY Acad Sci 1979;320:273-6.

54. Kuratsune M. Epidemiologic studies on Yusho. In: Higuchi K, ed. PCB poisoning and pollution. Tokyo: Kodansha LTD., 1976:9-23.

55. Hardell L, sandstrom A. Case-control study: soft tissue sarcomas and exposure to phenoxyacetic acids or chlorophenols. Br J Cancer 1979;39:711-7.

56. Hardell L. Malignant Lymphoma of histiocytic type and exposure to phenoxyacetic acids or chlorophenols. Lancet L 1979;(Jan 6):55-6.

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XI. DISTRIBUTION AND AVAILABILITY OF REPORT

Copies of this report are currently available upon request from NIOSH, Division of Standards Development and Technology Transfer, Publications Dissemination Section, 4676 Columbia Parkway, Cincinnati, Ohio 45226. After 90 days, the report will be available through the National

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1. President, Local 122, IAFF, Jacksonville, Florida
2. Director of Health and Safety, IAFF, Washington, D.C.
3. City of Jacksonville Fire Department, Jacksonville, Florida
4. Quadrex HPS, Gainesville, Florida
5. NIOSH, Atlanta Region
6. OSHA, Region IV.

For the purpose of informing affected employees, copies of this report shall be posted by the employer in a prominent place accessible to the employees for a period of 30 calendar days.

Table 1

Outline of Test Protocol

City of Jacksonville Fire Department
IAFF, Local 122
Jacksonville, Florida

February 13-15, 1984

No. of Garments	Type of Garment	Site Contaminated No. of Samples Pre-decon	 Post-decon	 Total	Lab Contaminated* No. of Samples Pre-decon	 Post-decon	 Total
4	Nomex Coat	4	4	8	-	-	-
4	Nomex Coat	-	-	-	4	4	8
4	Nomex Trouser	4	4	8	-	-	-
4	Nomex Trouser	-	-	-	4	4	8

*Contamination sequence: 2 coats - 100% PCB Aroclor 1242, 2 coats - 33% PCB, 2 trousers - 9% PCB, 2 trousers - 2.4% PCB.

Table 2

PCBs Removed from Site-Contaminated Garments

City of Jacksonville Fire Department
IAFF, Local 122
Jacksonville, Florida

February 13-15, 1984

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, $t=2.49$

Table 3

PCBs Removed from Lab-Contaminated Garments

City of Jacksonville Fire Department
IAFF, Local 122
Jacksonville, Florida

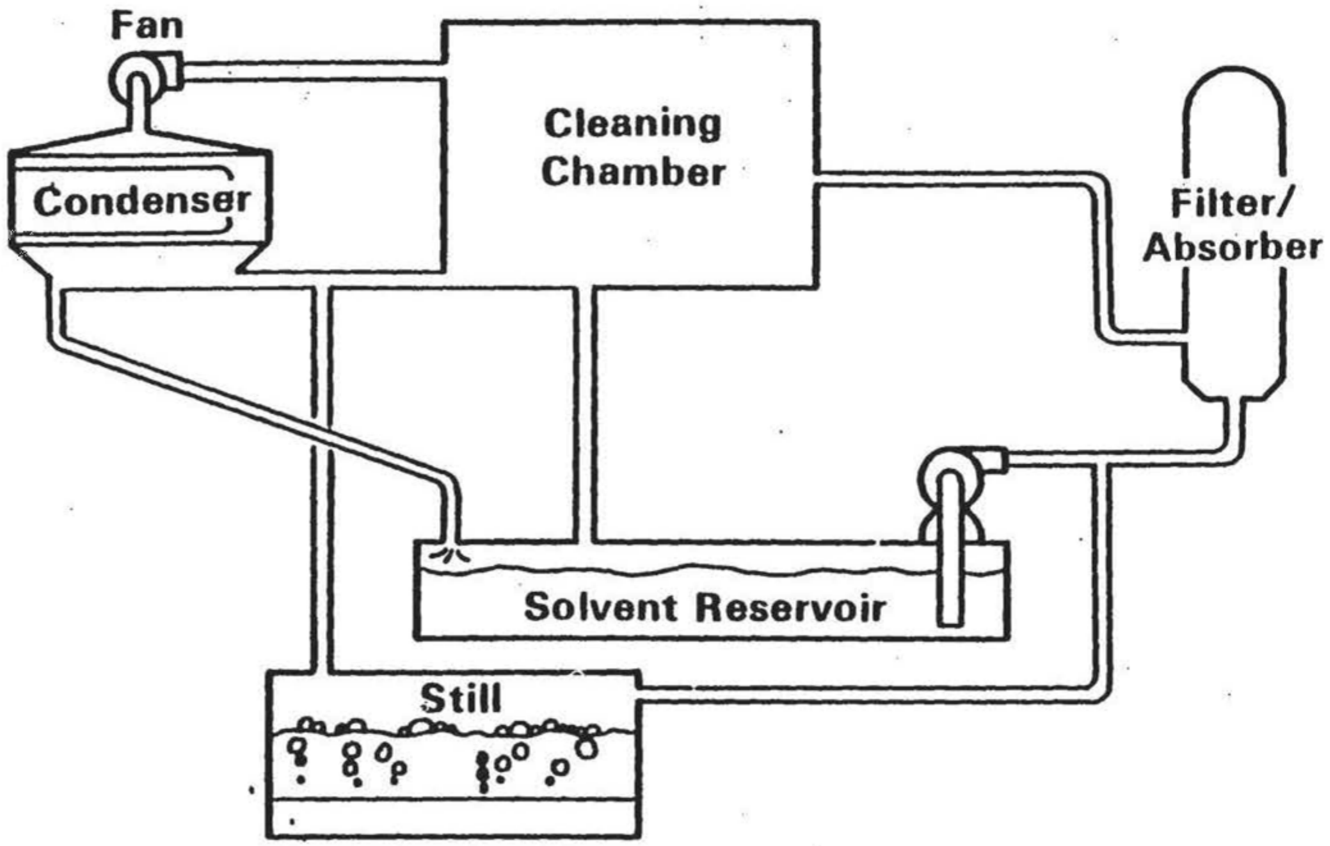
February 13-15, 1984

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

$p<0.05$, $t=3.34$

Figure 1

Basic Freon° 113 Decontamination Process



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