NIOSH

Current Intelligence Bulletin 45

February 24, 1986

Polychlorinated Biphenyls (PCB's):

Potential Health Hazards from Electrical Equipment Fires or Failures

U.S. DEPARTMENT OF HEALTH AND HUMAN SERVICES
Public Health Service
Centers for Disease Control
National Institute for Occupational Safety and Health

DISCLAIMER

DHHS (NIOSH) Publication No. 86-111

FOREWORD

Current Intelligence Bulletins (CIB's) are reports issued by the National Institute for Occupational Safety and Health (NIOSH), Centers for Disease Control, Atlanta, Georgia, for the purpose of disseminating new scientific information about occupational hazards. A CIB may draw attention to a hazard previously unrecognized or may report new data suggesting that a known hazard is either more or less dangerous than was previously thought.

CIB's are prepared by the staff of the Division of Standards Development and Technology Transfer, NIOSH (Robert A. Taft Laboratories, 4676 Columbia Parkway, Cincinnati, Ohio 45226) and are distributed to representatives of organized labor, industry, public health agencies, academia, and public interest groups as well as to those federal agencies, such as the Department of Labor, which have responsibilities for protecting the health of workers. It is our intention that anyone with the need to know should have ready access to the information contained in these documents; we welcome suggestions concerning their content, style, and distribution.

Because of the recent attention given to human exposure to polychlorinated biphenyls (PCB's), polychlorinated dibenzofurans (PCDF's), polychlorinated dibenzo-p-dioxins (PCDD's), and related compounds resulting from electrical equipment fires or failures, we think it necessary to present a review of the pertinent data and a summary of findings related to the potential human health hazards of these compounds. Because the voluminous literature on PCB's, PCDF's, and PCDD's has been compressed in this bulletin, it is suggested that readers wanting additional details of the reported studies consult the appended references.

J. Donald Millar, M.D., D.T.P.H. (Lond.)
Assistant Surgeon General
Director, National Institute for
  Occupational Safety and Health
Centers for Disease Control

CURRENT INTELLIGENCE BULLETIN #45

POLYCHLORINATED BIPHENYLS (PCB's): POTENTIAL HEALTH HAZARDS FROM ELECTRICAL EQUIPMENT FIRES OR FAILURES

FEBRUARY 24, 1986

ABSTRACT

Numerous fire-related incidents involving electrical equipment containing polychlorinated biphenyls (PCB's) have resulted in widespread contamination of buildings with PCB's and, in some cases, with polychlorinated dibenzofurans (PCDF's) and polychlorinated dibenzo-p-dioxins (PCDD's), including 2,3,7,8-tetrachlorodibenzo-p-dioxin (TCDD). Emergency response personnel, maintenance or cleanup workers, or building occupants may be exposed to the compounds by inhalation, ingestion, or skin contact.

In experimental animal studies, exposure to PCB's, PCDF's, or PCDD's has resulted in various effects, including decreased body weights, hepatic lesions, thymic atrophy, and adverse reproductive effects, at a wide range of exposure concentrations. In addition, PCB's and TCDD have been shown to be carcinogenic in rats and mice. Humans exposed to PCB's, PCDF's, or PCDD's have developed chloracne, gastrointestinal disturbances, elevated serum enzyme and triglyceride levels, and numbness of the extremities. Epidemiologic studies of humans exposed to PCB's or PCDD's including TCDD are suggestive of an association between exposure to these compounds and increased incidences of cancer.

Based on existing evidence, the National Institute for Occupational Safety and Health (NIOSH) continues to recommend that PCB's and TCDD be regarded as potential human carcinogens in the workplace. Existing evidence also suggests that PCDF's may pose a risk to human health. Therefore, NIOSH recommends that occupational exposure to PCB's, PCDF's, and PCDD's resulting from electrical equipment fires or failures be controlled to the lowest feasible limit, and that workers involved in decontamination activities use all necessary protective measures to prevent exposure.

BACKGROUND

Physical and Chemical Properties of Polychlorinated Biphenyls (PCB's)

Polychlorinated biphenyls (PCB's)* comprise a class of nonpolar chlorinated hydrocarbons with a biphenyl nucleus in which any or all of the hydrogen atoms have been replaced by chlorine [1]. Commercial PCB's are mixtures of isomers of chlorinated biphenyls exhibiting varying degrees of chlorination. Although there are 209 possible positional chlorobiphenyl isomers, only 100 individual isomers are likely to occur at significant concentrations in commercial PCB mixtures [2].

In pure form, the individual chlorobiphenyl isomers are colorless crystals, but the commercial mixtures are liquid due to depression of the melting points through interaction of the individual isomers [3]. The physical and chemical properties of the individual isomers vary widely according to the degree and to the position of chlorination. The PCB compounds have low solubilities in water (0.007 to 5.9 milligrams per liter) [3] and low vapor pressures (10^{-6} to 10^{-3} millimeters of mercury at 20°C) [1]. PCB's are soluble in most of the common organic solvents, oils, and fats. The compounds are stable to acids and alkali and are resistant to oxidation but are subject to photodechlorination when exposed to sunlight (spectral region above 290 nanometers) [1].

Use of PCB's in Electrical Equipment

Commercial products containing PCB's were widely distributed between 1957 and 1977, when large quantities of PCB's were manufactured in the United States and marketed under the trade name Aroclor®. 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 [1].

Properties of PCB's such as thermal stability, nonflammability, and dielectric capability resulted in their use in electrical capacitors and transformers. Electrical capacitors (small and large) contained nearly 100% PCB's [4]. Small capacitors containing 0.1-0.6 pound of PCB's were commonly used in household appliances such as television sets, air conditioners, and fluorescent light fixtures, and have been estimated to have service lives of at least 10 years [5]. Based on Environmental Protection Agency (EPA) estimates that 10% of the small PCB capacitors (<3 pounds of dielectric fluid) are removed from service annually [4], approximately 350 million of

---

*Abbreviations used for chemical compounds are:

PCB -- polychlorinated biphenyl
PCDF -- polychlorinated dibenzofuran
PCDD -- polychlorinated dibenzo-p-dioxin
TCDF -- 2,3,7,8-tetrachlorodibenzofuran
TCDD -- 2,3,7,8-tetrachlorodibenzo-p-dioxin
CDF -- chlorodibenzofuran
CDD -- chlorodibenzo-p-dioxin

the capacitors were still in use in 1984. Large capacitors, with a PCB content of more than 3 pounds, have been used in electrical substations, within buildings, and on utility poles. The latest available information indicates that there were approximately 3.3 million large PCB capacitors in service in 1981 [4].

In transformers containing PCB's, the dielectric fluid generally consists of 60-70% PCB's [4] and up to 40% chlorinated benzenes [6]. Trade names of PCB askarels (the generic term used to refer to a broad class of nonflammable, synthetic, chlorinated hydrocarbon insulating liquids) formulated in the United States include Pyranol®, Inerteen®, and Noflamol® [7]. The volume of fluid in transformers ranges from 40 to 1,500 gallons [8]. PCB transformers have been used mainly in or near buildings where the proximity of electrical equipment to people and/or property warranted the use of a fire-resistant dielectric fluid. According to EPA estimates, at the end of 1984 there were approximately 107,000 PCB transformers in use or in storage for reuse [9], including approximately 77,600 PCB transformers used in or near commercial buildings (e.g., office buildings, shopping centers, hospitals, and schools) [10].

In 1976, the United States Congress enacted the Toxic Substances Control Act (TSCA) (Public Law 94-469), which gave the EPA authority to control the production and use of chemicals in the United States. Under Section 6(e) of TSCA the manufacture, processing, distribution in commerce, and use of PCB's after January 1, 1978 was prohibited; however, the EPA may, by rule, allow a particular use of PCB's to continue. In 1982, the EPA issued a final rule on the use of PCB's in electrical equipment. This rule permits the use of certain electrical equipment containing PCB's (e.g., small capacitors, large capacitors, and transformers) to continue under specified conditions for their remaining useful service lives [4]. In 1985, the EPA issued a final rule on the use of PCB's in electrical transformers. The use of high secondary voltage network PCB transformers in or near commercial buildings (approximately 7,400 transformers) after October 1, 1990, is prohibited. Low secondary voltage network and high secondary voltage radial PCB transformers in or near commercial buildings (approximately 70,200 transformers) must be equipped with enhanced electrical protection devices by October 1, 1990, to avoid overheating from sustained electrical faults [10].

Potential for Exposure to PCB's and Related Compounds Following Electrical Equipment Fire or Failure

Fire-related incidents are defined as incidents involving electrical equipment containing PCB's in which sufficient heat from any source causes the release of PCB's from the equipment casing. In soot-producing incidents an actual fire occurs in or near the PCB-containing electrical equipment eventually resulting in exposure of the PCB's to extremely high temperatures and in the formation and distribution of a black, carbonaceous material. PCB's have been identified in soot following numerous electrical equipment fires [11-17]. Polychlorinated dibenzofurans (PCDF's) [11-15,17-20] and polychlorinated dibenzo-p-dioxins (PCDD's) [12-15,17-20] have also been identified following this type of fire-related incident. Laboratory studies have confirmed that PCDF's and PCDD's are formed from the pyrolysis of PCB's [21-24] or chlorobenzenes [25] at temperatures ranging from 500° to 700°C (932° to 1292°F).

In addition to PCDD's and PCDF's, other polychlorinated hydrocarbons have been identified in soot from electrical equipment fires. Polychlorinated biphenylenes [13,26], polychlorinated pyrenes [26], and polychlorinated diphenyl ethers [18] have been detected in soot samples collected following capacitor or transformer fires.

Fire-related incidents in which soot is not produced have occurred from the release of PCB's through the pressure relief valves of overheated transformers [27-31]. The pressurized release of hot PCB vapors can entrain considerable quantities of liquid PCB's forming a fine aerosol. Documented safety valve releases of PCB's from transformers demonstrate that the aerosol can be distributed to areas beyond the transformer vault by convective air currents [27,28,30,31]. Although PCB's manufactured in the United States contained up to 2 micrograms of PCDF's per gram of PCB's (μg/g) [32], recent evidence indicates that additional PCDF's may be formed as a result of the sustained high temperatures in non-soot-producing incidents [31].

Air, soot, and surface values for PCB's, PCDF's, PCDD's, 2,3,7,8-tetrachlorodibenzofuran (TCDF), and 2,3,7,8-tetrachlorodibenzo-p-dioxin (TCDD) measured following fire-related incidents in the United States are presented in Table 1.

An example of each type of fire-related incident involving PCB transformers is described in the Appendix.

Exposure Limits

The Occupational Safety and Health Administration (OSHA) promulgated its permissible exposure limits (PEL) of 1 milligram per cubic meter of air (mg/m^3) for chlorodiphenyl products containing 42% chlorine and 0.5 mg/m^3 for chlorodiphenyl products containing 54% chlorine determined as 8-hour time-weighted average (TWA) concentrations [35] based on the 1968 Threshold Limit Values (TLVs®) of the American Conference of Governmental Industrial Hygienists (ACGIH) [36]. The TLVs, which have remained unchanged at 1 mg/m^3 (42%) and 0.5 mg/m^3 (54%) through 1985 [37], are based on the prevention of liver injury in exposed workers [38]. The ACGIH Short Term Exposure Limits (STEL) for 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 PCB's [37].

TABLE 1. CONCENTRATIONS OF PCB's AND RELATED COMPOUNDS FOLLOWING FIRE-RELATED INCIDENTS IN THE UNITED STATES[a]

				AIR ($\mu g/m^3$)[b]	SOOT ($\mu g/g$)					SURFACE ($\mu g/100cm^2$)[c]					
DATE	LOCATION	ELECT EQUIP	SAMPLING DATE	PCB	PCB	TCDF	PCDF	TCDD	PCDD	PCB	TCDF	PCDF	TCDD	PCDD	REF
FIRES															
12/80	Cincinnati, OH	Cap	03/81	ND[d]	—	—	—	—	—	7,200	ND	ND	ND	ND	33
02/81	Binghamton, NY	Tran	02/81	80	200,000	12	2,160	0.6	19.9	—	—	—	—	—	13
10/81	Boston, MA	Tran	12/81	—	114,000	3	162	ND	ND	—	—	—	—	—	11
04/82	Miami, FL	Tran	04/82	—	—	ND	1.89	ND	ND	860	--	--	—	—	18
04/82	Tulsa, OK	Tran	04/85	0.5	11	0.007	0.11	ND	0.16	1,100	8.5[e]	81.6[e]	ND	1,408[e]	15
06/82	Jersey City, NJ	Caps	—	2.3	—	—	—	—	—	22	ND	0.14	ND	0.09	20
05/83	San Francisco, CA	Tran	05/83	1,500	86,000	6.3	28.9[f]	0.059	0.32[f]	—	29[e]	101.5[e]	—	--	17
09/83	Chicago, IL	Tran	09/83	58	39,100	—	—	—	—	3,263	0.41	12.2	ND	0.05	12
12/83	Tulsa, OK	Tran	01/84	—	—	—	—	—	—	1,607	—	—	—	—	34
03/84	Columbus, OH	Caps	04/84	—	6,415	3.2	46.4	0.016	4.1	—	—	--	—	—	19
05/84	Miami, FL	Tran	06/84	—	50,000	0.27	98.5	0.004	2.3	—	—	--	—	—	14
PRESSURIZED RELEASES					FLUID ($\mu g/g$)										
—/74	Wappingers Falls, NY	Tran	02/84	—	117,000	—	0.97	—	ND	92	—	--	—	--	30
06/82	Washington, DC	Tran	06/84	—	—	<.074[h]	<7.02[h]	ND	<1.3[h]	320,000	ND	<114[h]	ND	ND	28
06/82	Maplewood, MN	Tran	06/82	90	—	—	ND	—	ND	5,000	—	—	—	—	27
12/83	Syracuse, NY	Tran	12/83	1.1	—	—	—	—	—	7.3	0.02[i]	0.17[f i]	ND	—	29
06/85	Santa Fe, NM	Tran	06/85	41.9	870,000	1.6	44.2	ND	ND	280,000	0.41	3.99	ND	0.19	31

[a] Values represent the highest measurements reported
[b] Micrograms per cubic meter($\mu g/m^3$)
[c] Micrograms per 100 square centimeters ($\mu g/100\ cm^2$)
[d] None detected, ND
[e] Values expressed as nanograms per square meter (ng/m^2)
[f] Values represent total tetrachlorinated forms only
[h] Values represent results obtained in the presence of interfering chemicals
[i] Values reported as μg per wipe sample (area undefined)

Note: Cap = Capacitor
Caps = Capacitors
Tran = Transformer

The National Institute for Occupational Safety and Health (NIOSH) recommends that exposure to PCB's in the workplace be limited at or below the minimum reliable detectable concentration of 1 $\mu g/m^3$ (using the recommended sampling and analytical methods) determined as a TWA for up to a 10-hour workday, 40-hour workweek. The NIOSH recommended exposure limit (REL) was based on the findings of adverse reproductive effects in experimental animals, on the conclusion that PCB's are carcinogens in rats and mice and, therefore, potential human carcinogens in the workplace, and on the conclusion that human and animal studies have not demonstrated a level of exposure to PCB's that will not subject the worker to possible liver injury [39].

TOXICITY

Results of Animal Studies

Effects of PCB's, PCDF's, and PCDD's

In general, the toxic responses observed in animals treated with PCB's, PCDF's, or PCDD's are similar, but the potencies of individual compounds vary according to the degree and position of chlorination. The tetra-, penta-, and hexa-chlorinated isomer groups exhibit greater toxicity than the other chlorinated forms [40-42]. Dibenzofuran and dibenzo-*p*-dioxin compounds with chlorine at positions 2, 3, 7, and 8 are particularly toxic [43-45]. The lethal doses in milligrams per kilogram of body weight (mg/kg) for 50% (LD_{50}) of the animals tested by the single oral administration of PCB's, TCDF, or TCDD in four animal species are presented in Table 2.

TABLE 2. ACUTE ORAL TOXICITY OF PCB's, TCDF, AND TCDD

	Single-Dose LD_{50} (mg/kg)		
	PCB's	TCDF	TCDD
Guinea pig	NR[a]	>.005 [46] <.010 [46]	.0006 [47] .002 [43]
Monkey	NR	1.000 [46]	<.070 [48]
Rat	1,010 [49]	>1.000 [50]	.047 [48]
Mouse	1,900 [51]	>6.000 [50]	.114 [52] .284 [43]

[a] Not reported, NR

Mice, rats, guinea pigs, and monkeys displayed progressive weight loss with death occurring up to several weeks after administration of a single lethal dose of PCB's, TCDF, or TCDD. Few other overt signs of toxicity were observed in mice, rats, and guinea pigs. Monkeys exhibited facial edema, loss of eyelashes and fingernails, and acneform skin eruptions [46,48].

Prominent histopathologic findings included: hepatic lesions in mice [43] and rats [53], hyperplasia of the urinary tract epithelial tissues and lymphoid hypoplasia in monkeys [46,48], and thymic atrophy in all four animal species.

Adverse reproductive effects in experimental animals have been observed in response to PCB's (rats, rabbits, monkeys, dogs, and pigs) [39], TCDD (mice and rats) [54], and TCDF (mice) [55,56]. Rats and mice exposed to PCB's [39] or TCDD [54] have developed liver cancers. No studies regarding the carcinogenicity of PCDF's in animals have been reported.

Effects of Soot Containing PCB's, PCDF's, and PCDD's

A composite sample of soot collected following a transformer fire in Binghamton, New York in 1981, contained 5,000 μg PCB's/g, 48 μg TCDF/g, and 1.2 μg TCDD/g. Single oral administration to guinea pigs of the soot in aqueous methyl cellulose or of a benzene extract of the soot in the same aqueous vehicle produced LD_{50} values of 410 and 327 mg/kg, respectively. Single oral administration of TCDD in aqueous methyl cellulose or in corn oil produced LD_{50} values of 19 and 2.5 μg/kg, respectively. Animals surviving for 42 days after administration of the soot showed dose-related evidence of decreased weight gain and kidney weight, thymic atrophy, increased serum triglycerides, goblet cell hyperplasia of pancreatic interlobular ducts, and metaplasia of salivary gland interlobular duct epithelium. In rabbits, dermal application of the saline-moistened soot or of a benzene extract of the soot at a dose comparable to 500 mg soot/kg body weight for 24 hours produced hypertrophy of centrilobular hepatocytes in 50% of the rabbits at the end of the 65-day observation period. No signs of overt toxicity were observed in the rabbits, except dermal inflammatory reactions noted in rabbits treated with the soot extract [57]. The dermal LD_{50} of TCDD in rabbits is 275 μg/kg [47], while the dermal minimum lethal dose of PCB's (as Aroclor 1260) is from 1.26 to 2.00 grams/kg [58]. Because the measured amounts of TCDF and TCDD in the soot were low, other congeners may have contributed to the toxic effects observed in guinea pigs and rabbits [16,57].

In a subchronic toxicity study, the total soot contained in food that was consumed in 90 days by guinea pigs was 1.2, 22, 55, or 275 mg soot/kg body weight. A fifth group of guinea pigs was terminated after 32 days (total consumption of 400 mg soot/kg body weight) because mortality had reached 35%. The intensities of the toxic responses were dose-related, but no signs of toxicity were detected in guinea pigs with a total consumption of 1.2 mg soot/kg body weight [59].

Human Health Effects

Several cases of chloracne, hyperpigmentation, gastrointestinal disturbances, elevated serum enzyme and triglyceride levels, and numbness of the extremities have been reported among people exposed to PCB's [39,60,61] or PCDD's [54,62]. Comparative human and animal studies indicate that PCDF's were the main causative agents of similar symptoms reported in individuals who ingested cooking oils contaminated with PCB's and PCDF's [63].

There is suggestive evidence of associations between increased incidences of cancer and exposure to PCB's [64], to PCB's containing significant PCDF's [65,66], and to phenoxyacetic herbicides contaminated with PCDD's including TCDD [67,68]. However, definite causal relationships between exposure and carcinogenic effects in humans remain unclear due to the inadequately defined populations studied and the influences of mixed exposures.

The firefighters and other workers involved in the Binghamton transformer fire cleanup have been followed through a medical surveillance program. Medical evaluation of these workers approximately one year after the fire showed slight increases in serum PCB levels but no observable adverse health effects from this exposure [69]. Selected workers from this study group have been found to have elevated adipose tissue levels of PCDF's and PCDD's [70] and associated histologic changes in the liver [71]. Further monitoring of this population is in progress.

RECOMMENDATIONS

There are several classifications for identifying a substance as a carcinogen. Such classifications have been developed by the National Toxicology Program (NTP) [72], the International Agency for Research on Cancer (IARC) [73], and OSHA in its "Identification, Classification, and Regulation of Potential Occupational Carcinogens" 29 CFR 1990 [74], also known as "The OSHA Cancer Policy." NIOSH considers the OSHA classification the most appropriate for use in identifying potential occupational carcinogens* [74]. Because exposure to PCB's or TCDD has been shown to produce malignant tumors in rats and mice, they meet the OSHA criteria. Therefore, NIOSH continues to recommend that PCB's and TCDD be considered as potential human carcinogens in the workplace. Limited evidence from animal and human studies suggests that PCDF's may also pose a risk to human health. As prudent public health policy, NIOSH recommends that occupational exposure to PCB's, PCDF's, and PCDD's resulting from electrical equipment fires or failures be controlled to the lowest feasible limit.

---

*"'Potential occupational carcinogen' means any substance, or combination or mixture of substances, which causes an increased incidence of benign and/or malignant neoplasms, or a substantial decrease in the latency period between exposure and onset of neoplasms in humans or in one or more experimental mammalian species as the result of any oral, respiratory or dermal exposure, or any other exposure which results in the induction of tumors at a site other than the site of administration. This definition also includes any substance which is metabolized into one or more potential occupational carcinogens by mammals" (29 CFR 1990.103).

As a result of fire-related incidents involving PCB-containing electrical equipment, emergency response personnel, maintenance and cleanup workers, and building occupants may be at risk of exposure to PCB's, PCDF's, and PCDD's. The following recommendations are intended to minimize worker exposure to these compounds and reflect experiences NIOSH personnel and others have gained in responding to such incidents. These recommendations focus primarily on PCB transformer fires, although many of the recommendations apply to other types of fire-related incidents involving PCB's.

Recognition of Potential Hazard

Emergency response personnel should be informed of the presence of PCB-containing electrical equipment and of the potential health hazards associated with exposure to emissions from such equipment. All 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.

Required registration of PCB transformers with local fire departments [10] is intended to assure early recognition of the potential hazards when a fire-related incident occurs. The registration for each transformer should include: building location; location of transformer(s) within or near the building; transformer serial number, manufacturer, and kilovolt/amperage rating; and total volume and generic composition of the dielectric fluids. This information should be readily accessible to those persons responsible for the health and safety of emergency response personnel and others who may come into contact with PCB transformers.

To assist in the identification of PCB transformers the effective use of signs and labeling should be instituted. While labeling of PCB transformers is required (using the mark "M_L") [10], additional signs and labels should be placed in areas near the location of a PCB transformer(s).

The number of emergency response personnel or cleanup workers entering a potentially contaminated area(s), (e.g., interior of the building or transformer vault) should be limited. This action would minimize the number of workers exposed and would reduce the amount of protective clothing and equipment potentially contaminated.

Assessment of Exposure

Contamination assessment is necessary to determine the extent and relative degrees of contamination of an area following a fire-related incident. NIOSH's Occupational Exposure Sampling Strategy Manual is useful in developing appropriate strategies to monitor worker exposure to PCB's and related pyrolysis products [75]. Air and surface wipe samples should be collected in all areas potentially contaminated by the incident. Air sampling should include both the particulate and vapor phase. Wipe samples should be taken on both vertical and horizontal surfaces. Additional samples may include residual fluid in the transformer, fluid deposited in the vault, or soot. Air and surface wipe samples should be analyzed for PCB's, tetra- through octa-chloro homologs of PCDF and PCDD, and the respective 2,3,7,8-tetrachloro isomers. Detailed descriptions of sampling and analytical techniques for PCB's may be found in the NIOSH Manual of Analytical Methods [76,77]. Sampling procedures and sensitive methods for the analyses of PCDF's and PCDD's have been developed by the New York State Department of Health [16,78].

Personal Protective Clothing

All workers who may be exposed to PCB's, PCDF's, and PCDD's should be equipped with chemical protective clothing to ensure their protection. In the selection of protective clothing, consideration should be given to the utilization of disposable apparel because of the uncertainty of decontamination of reusable clothing.

Outer protective garments should consist of a zippered coverall with attached hood and draw string, elastic cuffs, gloves, and closure boots. If exposure to soot is anticipated, workers should wear outer coveralls made of a nonwoven fabric such as spunbonded Tyvek® to exclude particulates. If exposure to liquids or to both soot and liquids is anticipated, or if the form of the contaminants is unknown, the outer coveralls should be made of chemically resistant materials such as Saranax®-coated Tyvek or Viton®-coated neoprene. Gloves and boots should be made of neoprene, nitrile, butyl rubber, or Viton which have been shown to be resistant to permeation by PCB's [79,80]. For personal comfort workers may wear inner garments consisting of cotton coveralls, undershirts, undershorts, gloves, and socks. Inner garments should be disposed of after use because small amounts of contaminants may be transferred in removing outer garments [79]. All disposable clothing should be placed in approved containers and disposed of according to EPA disposal procedures [4].

Respiratory Protection

The use of respiratory protection for those involved in cleanup operations requires that a respiratory protection program be instituted which, at a minimum, meets the requirements of 29 CFR 1910.134 [81] and that the respirators selected be approved by the Mine Safety and Health Administration (MSHA) and by NIOSH. The respiratory protection program should include training of workers regarding the proper use, fit testing, inspection, maintenance, and cleaning of respirators. The program should be evaluated regularly.

Where a risk of exposure to airborne contaminants exists, such as when visible quantities of soot are to be removed, workers should wear a self-contained breathing apparatus with a full facepiece operated in pressure-demand or other positive pressure mode. Alternatively, a combination supplied air respirator, with full facepiece, operated in pressure-demand or other positive pressure mode and equipped with auxiliary positive pressure self-contained air supply can be used. When cleanup operations have advanced to a point where airborne PCB's can no longer be detected, air-purifying full facepiece respirators equipped with a high efficiency particulate air filter and organic vapor cartridge should be used, as a precaution, until final decontamination is completed [82].

Decontamination and Worker Protection Programs

In general, decontamination procedures must provide an organized process in which the extent and degree of contamination are systematically reduced. This should include procedures that take into account containment, collection, and disposal of contaminated solutions and residues generated during the incident and cleanup. Separate facilities should be provided for decontamination of large equipment. The EPA's Guide for Decontaminating Buildings, Structures, and Equipment at Superfund Sites provides information for developing a decontamination strategy [83].

Each stage of decontamination, such as gross decontamination and repetitive wash/rinse cycles, should be conducted separately, either by using different locations or by spacing in time. Personnel decontamination locations should be physically separated from the contaminated area(s) to prevent cross-contact and should be arranged in order of decreasing level of contamination. Separate entry/exit routes and locations should be well marked and controlled. Access to the decontamination area should be separate from the path between the contaminated and clean areas. Dressing stations for entry should be separate from redressing areas for exit.

All reusable clothing and equipment should be grouped according to perceived degree of contamination (i.e., high, moderate, or low) and thoroughly cleaned. 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. Reusable clothing and equipment should, therefore, be analyzed for residual contamination before reuse or storage.

Soot from transformer fires is typically black, friable, carbonaceous material. Preliminary cleanup of the areas visibly contaminated with soot should involve dry vacuuming of both horizontal and vertical surfaces with a vacuum cleaning system equipped with a high efficiency particulate (HEPA) filter.

Final cleanup methods should include washing surfaces with alkaline [27] or nonionic [84] synthetic detergents in water. The addition of a caustic agent, such as trisodium phosphate, may help to remove grease deposits, floor waxes, and furniture polishes. Waxed and polished surfaces tend to absorb contaminants from the air. Cleaning with organic solvents is useful for nonporous electrical and mechanical equipment where contact with water-based cleaning fluids may damage the equipment. Organic solvents, such as kerosene, mineral spirits, and trichlorotrifluoroethane, may carry contaminants deeper into porous materials and should not be used on these surfaces. Complete decontamination of porous surfaces, such as concrete and masonry surfaces in vaults, may not be possible; therefore, application of an elastomeric, abrasion- and flame-resistant sealant may be required.

Post-Decontamination Testing

The adequacy of the decontamination effort should be determined by followup sampling and analysis of the contaminated areas and reusable protective equipment. This testing should be conducted as each area is decontaminated and again after the entire facility has been cleaned. Decontamination guidelines for the cleanup of specific buildings following fires involving PCB transformers [83,85] have been proposed by the New York State Department of Health [86], the New Mexico Expert Advisory Panel [87], the California Department of Health Services [88], and the San Francisco Department of Health [89].

Medical Surveillance

A medical surveillance program should be established to prevent (or to attempt to detect at an early stage) adverse health effects in workers resulting from exposure to PCB's or related compounds. Medical and work histories, including previous exposure to PCB's or other toxic agents, should be taken for each worker prior to job placement and updated periodically. The physician responsible should be provided with information concerning the adverse health effects from exposure to PCB's and related compounds and an estimate of the worker's potential exposure, including any available workplace sampling results and a description of all protective clothing or equipment the worker may be required to use.

The examining physician should direct particular attention to the skin, liver, and nervous system as these are the most likely targets of exposure to PCB's and related compounds. Blood determinations which reflect liver function may be useful. Measurement of blood PCB's may also be useful but should not be interpreted as a sensitive indicator of acute exposure. Adipose tissue levels of PCB's, PCDF's, and PCDD's are indicative of total body burden, but these tissue samples are not routinely available. Further studies of exposed populations will permit more definitive medical monitoring recommendations.

REFERENCES

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

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

3. Rappe C, Buser HR. Chemical properties and analytical methods. In: Kimbrough RD, ed. Topics in environmental health--halogenated biphenyls, terphenyls, naphthalenes, dibenzodioxins and related products. New York: Elsevier/North-Holland Biomedical Press, 1980;4:41-76.

4. Federal Register. Environmental Protection Agency: Part II. 1982 Aug 25;47:37342-60.

5. Rollins RL. PCBs in capacitor applications. 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, 1976:306-8.

6. Vuceta J, Marsh JR, Kennedy S, Hildemann, Wiley S. State-of-the-art review: PCDDs and PCDFs in utility PCB fluid. Palo Alto, California: Electric Power Research Institute, 1983:3-14 to 3-19.

7. Lloyd JW, Moore RM, Woolf BS, Stein HP. Polychlorinated biphenyls. J Occup Med 1976;18:109-13.

8. Durfee RL, Contos G, Whitmore FC, Barden JD, Hackman EE, III, Westin RA. PCBs in the United States - industrial use and environmental distribution. Washington, DC: U.S. Environmental Protection Agency, 1976;EPA publication no. 560/6-76-005:88.

9. Federal Register. Environmental Protection Agency: Part III. 1984 Oct 11;49:39966-89.

10. Federal Register. Environmental Protection Agency: Part IV. 1985 July 17;50:29170-201.

11. Melius JM. Memorandum to Richard A. Lemen, NIOSH, regarding analyses following a fire-related incident involving PCB's in Boston, Massachusetts. U.S. Department of Health and Human Services, Public Health Service, Centers for Disease Control, National Institute for Occupational Safety and Health, Division of Surveillance, Hazard Evaluations, and Field Studies, Cincinnati, Ohio. August 5, 1985.

12. Melius JM. Memorandum to Richard A. Lemen, NIOSH, regarding analyses following a fire-related incident involving PCB's in Chicago, Illinois. U.S. Department of Health and Human Services, Public Health

Service, Centers for Disease Control, National Institute for Occupational Safety and Health, Division of Surveillance, Hazard Evaluations, and Field Studies, Cincinnati, Ohio. August 5, 1985.

13. 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 1983;12:669-80.

14. Melius JM. Memorandum to Richard A. Lemen, NIOSH, regarding analyses following a fire-related incident involving PCB's in Miami, Florida. U.S. Department of Health and Human Services, Public Health Service, Centers for Disease Control, National Institute for Occupational Safety and Health, Division of Surveillance, Hazard Evaluations, and Field Studies, Cincinnati, Ohio. August 5, 1985.

15. Melius JM. Memorandum to Richard A. Lemen, NIOSH, regarding analyses following a fire-related incident involving PCB's in Tulsa, Oklahoma. U.S. Department of Health and Human Services, Public Health Service, Centers for Disease Control, National Institute for Occupational Safety and Health, Division of Surveillance, Hazard Evaluations, and Field Studies, Cincinnati, Ohio. August 5, 1985.

16. O'Keefe PW, Silkworth JB, Gierthy JF, et al. Chemical and biological investigations of a transformer accident at Binghamton, NY. Environ Health Perspect 1985;60:201-9.

17. Exposure assessment: fires involving PCB transformers. [Report prepared for U.S. Environmental Protection Agency, EPA contract no. 68-01-6271, by Versar, Inc., Springfield, Virginia, March, 1984].

18. Health hazard evaluation--determination report no. 82-224-1336, Miami Fire Department, Miami, Florida. Cincinnati: U.S. Department of Health and Human Services, Public Health Service, Centers for Disease Control, National Institute for Occupational Safety and Health, 1983.

19. Melius JM. Memorandum to Richard A. Lemen, NIOSH, regarding analyses following a fire-related incident involving PCB's in Columbus, Ohio. U.S. Department of Health and Human Services, Public Health Service, Centers for Disease Control, National Institute for Occupational Safety and Health, Division of Surveillance, Hazard Evaluations, and Field Studies, Cincinnati, Ohio. August 5, 1985.

20. Chemical contamination associated with car 643 fire. [Report submitted to The Port Authority of New York and New Jersey by Arthur D. Little, Inc., Cambridge, Massachusetts, contract no. 88162, May 1983:1-10].

21. Buser HR, Bosshardt H-P, Rappe C. Formation of polychlorinated dibenzofurans (PCDFs) from pyrolysis of PCBs. Chemosphere 1978;7:109-19.

22. Buser HR, Rappe, C. Formation of polychlorinated dibenzofurans (PCDFs) from the pyrolysis of individual PCB isomers. Chemosphere 1979;8:157-74.

23. Buser HR, Bosshardt H-P, Rappe C, Lindahl R. Identification of polychlorinated dibenzofuran isomers in fly ash and PCB pyrolyses. Chemosphere 1978;7:419-29.

24. Paasivirta J, Herzschuh R, Humppi T, et al. Pyrolysis products of PCBs. Environ Health Perspect 1985;60:269-78.

25. Buser HR. Formation of polychlorinated dibenzofurans (PCDFs) and dibenzo-p-dioxins (PCDDs) from the pyrolysis of chlorobenzenes. Chemosphere 1979;8:415-24.

26. Rappe C, Marklund S, Bergqvist P-A, Hansson M. Polychlorinated dioxins (PCDDs), dibenzofurans (PCDFs), and other polynuclear aromatics (PCPNAs) formed during PCB fires. Chemica Scripta 1982;20:56-61.

27. Health hazard evaluation--determination report no. 82-310-1475, Hill-Murray High School, Maplewood, Minnesota. Cincinnati: U.S. Department of Health and Human Services, Public Health Service, Centers for Disease Control, National Institute for Occupational Safety and Health, 1984.

28. Lees PSJ, Breysse PN. Industrial hygiene assessment: PCB exposure of GSA switchgear operators. [Final report submitted to General Services Administration, Washington, DC, by Johns Hopkins University, Center for Occupational and Environmental Health, Baltimore, Maryland, 1983].

29. Melius JM. Memorandum to Richard A. Lemen, NIOSH, regarding analyses following a fire-related incident involving PCB's in Syracuse, New York. U.S. Department of Health and Human Services, Public Health Service, Centers for Disease Control, National Institute for Occupational Safety and Health, Division of Surveillance, Hazard Evaluations, and Field Studies, Cincinnati, Ohio. August 5, 1985.

30. Melius JM. Memorandum to Richard A. Lemen, NIOSH, regarding analyses following a fire-related incident involving PCB's in Wappingers Falls, New York. U.S. Department of Health and Human Services, Public Health Service, Centers for Disease Control, National Institute for Occupational Safety and Health, Division of Surveillance, Hazard Evaluations, and Field Studies, Cincinnati, Ohio. August 5, 1985.

31. Melius JM. Memorandum to Richard A. Lemen, NIOSH, regarding analyses following a fire-related incident involving PCB's in Santa Fe, New Mexico. U.S. Department of Health and Human Services, Public Health Service, Centers for Disease Control, National Institute for Occupational Safety and Health, Division of Surveillance, Hazard Evaluations, and Field Studies, Cincinnati, Ohio. August 5, 1985.

32. Bowes GW, Mulvihill MJ, Simoneit BRT, Burlingame AL, Risenbrough RW. Identification of chlorinated dibenzofurans in American polychlorinated biphenyls. Nature 1975;256:305-7.

33. Health hazard evaluation--determination report no. 81-237-915, Our Lady of Visitation Elementary School, Cincinnati, Ohio. Cincinnati: U.S. Department of Health and Human Services, Public Health Service, Centers for Disease Control, National Institute for Occupational Safety and Health, 1981.

34. Landsing Property Corporation. [Comments in response to EPA proposed rule: Polychlorinated biphenyls (PCBs); manufacture, processing, distribution in commerce and use prohibitions: Use in electrical transformers (Federal Register. Environmental Protection Agency: Part III. 1984 Oct 11;49:39966-89), EPA docket no. OPTS 62035-N5]. Jan 8, 1985.

35. Code of Federal Regulations. U.S. Department of Labor. Occupational Safety and Health Administration. 29 CFR 1910.1000, OSHA 2206, rev. 1983.

36. American Conference of Governmental Industrial Hygienists. Threshold limit values of air-borne contaminants for 1968, recommended and intended changes. Cincinnati: ACGIH, 1968:6.

37. American Conference of Governmental Industrial Hygienists. TLVs® Threshold limit values and biological exposure indices for 1985-86. Cincinnati: ACGIH, 1985:5,6,13.

38. American Conference of Governmental Industrial Hygienists, Inc. Documentation of the threshold limit values. 4th ed. Cincinnati: ACGIH, 1980:88-9.

39. Criteria for a recommended standard....occupational exposure to polychlorinated biphenyls (PCBs). Cincinnati: U.S. Department of Health, Education and Welfare, Public Health Service, Center for Disease Control, National Institute for Occupational Safety and Health, 1977;DHEW (NIOSH) publication no. 77-225.

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

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

42. 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.

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

44. 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.

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

46. 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.

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

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

49. 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.

50. Moore JA, Gupta BN, Vos JG. Toxicity of 2,3,7,8-tetrachlorodibenzofuran - 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.

51. Tanaka K, Fijita S, Komatsu F, Tamura N. [Experimental subacute poisoning of chlorobiphenyls, particularly the influence on the serum lipids in rats]. Fukuoka Igaku Zasshi 1969;60:544-7 (Jap.).

52. Vos JG, Moore JA, Zinkl JG. Toxicity of 2,3,7,8-tetrachlorodibenzo-p-dioxin (TCDD) in C57B1/6 mice. Toxicol Appl Pharmacol 1974;29:229-41.

53. Linder RE, Gaines TB, Kimbrough RD. The effect of polychlorinated biphenyls on rat reproduction. Food Cosmet Toxicol 1974;12:63-76.

54. 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.

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

56. Weber H, Lamb JC, Harris MW, Moore JA. Teratogenicity of 2,3,7,8-tetrachlorodibenzofuran (TCDF) in mice. Toxicol Lett 1984;20:183-8.

57. Silkworth J, McMartin D, DeCaprio A, Rej R, O'Keefe P, Kaminsky L. Acute toxicity in guinea pigs and rabbits of soot from a polychlorinated biphenyl-containing transformer fire. Toxicol Appl Pharmacol 1982;65:425-39.

58. Fishbein L. Toxicity of chlorinated biphenyls. Annu Rev Pharmacol 1974;14:139-56.

59. DeCaprio AP, McMartin DN, Silkworth JB, Rej R, Pause R, Kaminsky LS. Subchronic oral toxicity in guinea pigs of soot from a polychlorinated biphenyl-containing transformer fire. Toxicol Appl Pharmacol 1983;68:308-22.

60. Fischbein A. Liver function tests in workers with occupational exposure to polychlorinated biphenyls (PCBs): comparison with Yusho and Yu-Cheng. Environ Health Perspect 1985;60:145-50.

61. Seppalainen AM, Vuojolahti P, Elo O. Reversible nerve lesions after accidental polychlorinated biphenyl exposure. Scand J Work Environ Health 1985;11:91-5.

62. 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.

63. Kunita N, Kashimoto T, Miyata H, Fukuskima S, Hori S, Obana H. Causal agents of Yusho. Am J Ind Med 1984;5:45-58.

64. Brown DP, Jones M. Mortality and industrial hygiene study of workers exposed to polychlorinated biphenyls. Arch Environ Health 1981;36:120-9.

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

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

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

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

69. Fitzgerald EF, Melius JM, Standfast SS, Janerick DT, Beckerman BS, Youngblood LG. Status report for the Binghamton State Office Building medical surveillance program. [Report prepared by New York State Department of Health, Division of Community Health and Epidemiology, Albany, New York, 1984].

70. Schecter A, Tiernan TO, Taylor ML, et al. Biological markers after exposure to polychlorinated dibenzo-p-dioxins, dibenzofurans, biphenyls and biphenylenes. Part I: Findings using fat biopsies to estimate exposure. In: Keith LH, Rappe C, Choudhary G, eds. Chlorinated dioxins and dibenzofurans in the total environment. Boston: Butterworth, 1985;2:215-45.

71. Schecter A, Schaffner F, Tiernan TO, et al. Biological markers after exposure to polychlorinated dibenzo-p-dioxins, dibenzofurans, biphenyls, and related chemicals. Part II: Ultrastructural characterization of human liver biopsies. In: Keith LH, Rappe C, Choudhary G, eds. Chlorinated dioxins and dibenzofurans in the total environment. Boston: Butterworth, 1985;2:247-65.

72. National Toxicology Program--technical report series no. 288, NTP-83-071. Toxicology and carcinogenesis studies of 1,3-butadiene (CAS No. 106-99-0) in B6C3F$_1$ mice (Inhalation Studies). U.S. Department of Health and Human Services, Public Health Service, National Institutes of Health, Aug 1984;NIH publication no. 84-2544:2.

73. World Health Organization. International Agency for Research on Cancer. IARC monographs on the evaluation of the carcinogenic risk of chemicals to humans. Lyon, France: IARC, 1979;34:11-27.

74. Code of Federal Regulations. U.S. Department of Labor. Occupational Safety and Health Administration. 29 CFR 1990, rev. 1984.

75. Leidel NA, Busch KA, Lynch JR. Occupational exposure sampling strategy manual. Cincinnati: U.S. Department of Health, Education, and Welfare, Public Health Service, Centers for Disease Control, National Institute for Occupational Safety and Health, 1977;DHEW (NIOSH) publication no. 77-173.

76. Eller, PM. NIOSH manual of analytical methods. 3rd ed. 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. 84-100:5503-1 to 5503-5.

77. Taylor, DG. NIOSH manual of analytical methods. 2nd ed. Cincinnati: U.S. Department of Health Education and Welfare, Public Health Service, Centers for Disease Control, National Institute for Occupational Safety and Health, 1977;DHEW (NIOSH) publication no. 77-157-A;1:244-1 to 244-12, 253-1 to 253-7; publication no. 77-157-B;2:S121-1 to S121-7.

78. O'Keefe PW, Smith RM, Hilker DR, Aldous KM, Gilday W. A semiautomated cleanup method for polychlorinated dibenzo-p-dioxins and polychlorinated dibenzofurans in environmental samples. In: Keith LH, Rappe C, Choudhary G, eds. Chlorinated dioxins and dibenzofurans in the total environment. Boston: Butterworth, 1985;2:111-24.

79. Schwope AD, Costas PP, Jackson JO, Weitzman DJ. Guidelines for the selection of chemical protective clothing. 2nd ed. [Report sponsored by the U.S. Environmental Protection Agency, Office of Occupational Health and Safety, Washington, D.C.]. Arthur D. Little, Inc., Cambridge, Massachusetts, 1985;1:29-36,51,A-3 to A-6, C-3, C-9, C-10, C-12 to C-17, C-29, C-30, F-3, G-14 to G-17.

80. Stampfer JF, McLeod MJ, Betts MR, Martinez AM, Berardinelli SP. Permeation of polychlorinated biphenyls and solutions of these substances through selected protective clothing materials. Am Ind Hyg Assoc J 1984;45:634-41.

81. Code of Federal Regulations. U.S. Department of Labor. Occupational Safety and Health Administration. 29 CFR 1910.134, OSHA 2206, rev. 1983.

82. Mackison FW, Stricoff RS, Partridge LJ. NIOSH pocket guide to chemical hazards. Cincinnati: U.S. Department of Health and Human Services, Public Health Service, Centers for Disease Control, National Institute for Occupational Safety and Health, 5th revised printing, Sep 1985;DHHS (NIOSH) publication no. 78-210:122-3.

83. Esposito MP, McArdle JL, Crone AH, et al. Guide for decontaminating buildings, structures, and equipment at Superfund sites. Washington, DC: U.S. Environmental Protection Agency, 1985;EPA publication no. 600/2-85/028.

84. Effectiveness of cleaning compounds on vinyl floor tile (task 11-phase I). [Report submitted to New York State Office of General Services by Versar New York, Inc., Dec 1982].

85. Milby TH, Miller TL, Forrester TL. PCB-containing transformer fires: decontamination guidelines based on health considerations. J Occup Med 1985;27:351-6.

86. Kim NK, Hawley J. Re-entry guidelines Binghamton State Office Building. [Report prepared by New York State Department of Health, Bureau of Toxic Substance Assessment, Division of Health Risk Control, Albany, New York, July 1985].

87. Melius J. Written communication to Toney Anaya, Governor of the State of New Mexico, regarding cleanup levels recommended by the PCB Expert Advisory Panel. U.S. Department of Health and Human Services, Public Health Service, Centers for Disease Control, National Institute for Occupational Safety and Health, Division of Surveillance, Hazard Evaluation, and Field Studies, Cincinnati, Ohio. July 17, 1985.

88. Gravitz N, Fan A, Neutra RR. Interim guidelines for acceptable exposure levels in office settings contaminated with PCB and PCB combustion products. [Report prepared by California Department of Health Services, Epidemiological Studies Section, Berkeley, California, Nov 1983].

89. Silverman MF. Written communication to Wynn Oliver, Tishman West Building Management Corporation, regarding cleanup levels following a transformer fire. Department of Public Health, City and County of San Francisco, California. September 30, 1983.

90. Smith RM, O'Keefe PW, Hilker DR, Jelus-Tyror BL, Aldous KM. Analysis for 2,3,7,8-tetrachlorodibenzofuran and 2,3,7,8-tetrachlorodibenzo-p-dioxin in a soot sample from a transformer explosion in Binghamton, New York. Chemosphere 1982;11:715-20.

APPENDIX

REPORTS OF FIRE-RELATED INCIDENTS INVOLVING PCB TRANSFORMERS

Fire in a Multi-Story Office Building in Binghamton, New York

On February 5, 1981, an electrical fire occurred in the switchgear adjacent to a PCB transformer in the basement mechanical room of the Binghamton State Office Building. The transformer contained 1,060 gallons of askarel consisting of Aroclor 1254 (65%) and a mixture of tri- and tetra-chlorinated benzenes (35%). A ceramic bushing on the transformer cracked during the fire, resulting in the release of approximately 180 gallons of askarel onto the floor near the fire. The smoke was distributed by convection throughout the building through an open vertical shaft that extended from the mechanical room to the top of the building. The shaft contained the duct for the exhaust air from the restrooms on all the floors. The shaft and ducts were not airtight and allowed smoke and soot to contaminate the work areas of the building, air-conditioning ducts, false ceiling areas, and elevator shafts [13].

Analyses of the soot revealed significant concentrations of PCB's, PCDF's, TCDF, PCDD's, TCDD, and polychlorinated biphenylenes [13,16,90]. Based on analyses of dry surface wipe samples, horizontal surfaces showed higher levels of contamination than vertical surfaces [17]. In soot samples obtained from 11 floors of the building, the absolute amounts of the tetra- through octa-chlorodibenzofuran (CDF) isomer groups varied from sample to sample, but the relative proportions with respect to the amount of PCB in the soot were consistent. The ratio of PCDF to PCB averaged 0.067 ± 0.026 (± one standard deviation) [16].

Air samples collected on the seventh floor after cleanup of most of the surface soot deposits contained 292 picograms of total tetra-CDF per cubic meter of air (pg/m^3) including 26 pg TCDF/m^3 and 5 pg total tetra-chlorodibenzo-p-dioxin (CDD)/m^3 including 3 pg TCDD/m^3 [16].

The cleanup of the Binghamton building has been complex and costly. The building remains closed to normal use pending complete cleaning and renovation. Criteria for reoccupancy are being considered by the New York State Department of Health Expert Advisory Panel based on toxicity studies in guinea pigs using the soot from the building, on chemical analyses of the soot, and on published toxicologic studies of TCDD [86].

Electrical Malfunction in an Office Building in Santa Fe, New Mexico

On June 17, 1985, an electrical malfunction occurred in a transformer located in the basement transformer vault in the main building of the New Mexico State Highway Department Office Building. The transformer contained 245 gallons of askarel consisting of Aroclor 1260 (87%) and a mixture of tri- and tetra-chlorinated benzenes (13%). The electrical malfunction caused the transformer to overheat resulting in the release of vaporized askarel through the safety valve which continued until the unit was de-energized (approximately 65 minutes after initial detection). There was no fire, but charred (blistered) paint on the transformer casing indicated that the temperature of the casing may have approached 316°C (600°F).

The emission products were distributed throughout the 2-story building by convective air currents and by mechanical transfer via the heating, ventilating, and air conditioning systems. Because the emitted vapor condensed as it reached cooler temperatures, the askarel apparently "rained" in the heavily contaminated rooms adjacent to and above the basement transformer vault.

Air, fluid, and surface wipe samples were collected within 7 days of the incident. Airborne concentrations of PCB's in the main building were 41.94 $\mu g/m^3$ inside the vault, 0.34-25.87 $\mu g/m^3$ in other basement areas, 1.00-19.45 $\mu g/m^3$ in first floor areas, and 0.73-5.96 $\mu g/m^3$ in second floor areas. PCDF's were detected at concentrations ranging from 10.4 to 501.6 pg/m^3 including 0.9-56.2 pg $TCDF/m^3$. Airborne PCDD's ranged from 7.1 to 21.0 pg/m^3 but TCDD was not detected.

The surface concentrations of PCB's were as high as 280,000 $\mu g/100\ cm^2$ in basement areas, 98,000 $\mu g/100\ cm^2$ in first floor areas, and 190 $\mu g/100\ cm^2$ in second floor areas. PCDF's, TCDF, and PCDD's were present in surface wipe samples from areas of the basement and first floor, but TCDD was not detected. Surface wipe samples from second floor areas were not submitted for measurement of the pyrolysis products [31].

The New Mexico PCB Expert Advisory Panel convened on July 16, 1985, to propose air and surface cleanup guidelines for the building. The guidelines were based on the potential risk of cancer resulting from exposure to PCB's, PCDF's, and PCDD's. Animal studies on the carcinogenicity of TCDD were used to estimate the potential cancer risks. It was also necessary to make certain judgments and assumptions regarding the toxicity of the related compounds and the potential for exposure to occupants of the building. The guidelines are intended to maintain the risk of developing cancer below one in one million for a person spending the rest of his/her working lifetime in the building. The Panel recommended cleanup levels of 2 pg TCDD equivalents/m^3 of air and 1 ng TCDD equivalents/m^2 of surface area. Values for other PCDF and PCDD isomer groups can be converted to TCDD equivalents using the following conversion factors:

TO CONVERT VALUES TO TCDD EQUIVALENTS

PCDF's	Factor	PCDD's	Factor
TCDF	0.33	TCDD	1.0
Other tetra-CDF's	0.0	Other tetra-CDD's	0.0
Penta-CDF's	0.17	Penta-CDD's	0.5
Hexa-CDF's	0.005	Hexa-CDD's	0.02
Hepta-CDF's	0.0005	Hepta-CDD's	0.0
Octa-CDF's	0.0	Octa-CDD's	0.0

Concentrations of these compounds can be converted to TCDD equivalents by multiplying the measured values by the appropriate conversion factor. The TCDD equivalents can then be summed and compared to the guideline values. The Panel did not establish cleanup guidelines for PCB's on surfaces [87].

CUMULATIVE LIST OF NIOSH CURRENT INTELLIGENCE BULLETINS

1. Chloroprene - January 20, 1975
2. Trichloroethylene - June 6, 1975
3. Ethylene Dibromide - July 7, 1975
4. Chrome Pigment - June 24, 1975 - October 7, 1975 - October 8, 1976
5. Asbestos - Asbestos Exposure during Servicing of Motor Vehicle Brake and Clutch Assemblies - August 8, 1975
6. Hexamethylphosphoric Triamide (HMPA) - October 24, 1975
7. Polychlorinated Biphenyls - November 3, 1975
8. 4,4'-Diaminodiphenylmethane (DDM) - January 30, 1976
9. Chloroform - March 15, 1976
10. Radon Daughters - May 11, 1976
11. Dimethylcarbamoyl Chloride (DMCC) Revised - July 7, 1976
12. Diethylcarbamoyl Chloride (DECC) - July 7, 1976
13. Explosive Azide Hazard - August 16, 1976
14. Inorganic Arsenic - Respiratory Protection - September 27, 1976
15. Nitrosamines in Cutting Fluids - October 6, 1976
16. Metabolic Precursors of a Known Human Carcinogen, Beta-Naphthylamine - December 17, 1976
17. 2-Nitropropane - April 25, 1977
18. Acrylonitrile - July 1, 1977
19. 2,4-Diaminoanisole in Hair and Fur Dyes - January 13, 1978
20. Tetrachloroethylene (Perchloroethylene) - January 20, 1978
21. Trimellitic Anhydride (TMA) - February 3, 1978
22. Ethylene Thiourea (ETU) - April 11, 1978
23. Ethylene Dibromide and Disulfiram Toxic Interaction - April 11, 1978
24. Direct Black 38, Direct Blue 6, and Direct Brown 95 Benzidine Derived Dyes - April 17, 1978
25. Ethylene Dichloride (1,2-Dichloroethane) - April 19, 1978
26. NIAX® Catalyst ESN - May 22, 1978
27. Chloroethanes - Review of Toxicity - August 21, 1978
28. Vinyl Halides - Carcinogenicity Vinyl Bromide, Vinyl Chloride, and Vinylidene Chloride - September 21, 1978
29. Glycidyl Ethers - October 12, 1978
30. Epichlorohydrin - October 12, 1978
31. Adverse Health Effects of Smoking and the Occupational Environment - February 5, 1979
32. Arsine (Arsenic Hydride) Poisoning in the Workplace - August 3, 1979
33. Radiofrequency (RF) Sealers and Heaters: Potential Health Hazards and Their Prevention - December 4, 1979
34. Formaldehyde: Evidence of Carcinogenicity - April 15, 1981
35. Ethylene Oxide (EtO): Evidence of Carcinogenicity - May 22, 1981
36. Silica Flour: Silicosis - June 30, 1981
37. Ethylene Dibromide (EDB) Revised - October 26, 1981

CUMULATIVE LIST OF NIOSH CURRENT INTELLIGENCE BULLETINS (CONTINUED)

38. Vibration Syndrome - March 29, 1983
39. The Glycol Ethers, with Particular Reference to 2-Methoxyethanol and 2-Ethoxyethanol: Evidence of Adverse Reproductive Effects - May 2, 1983
40. 2,3,7,8-Tetrachlorodibenzo-*p*-dioxin (TCDD, "Dioxin") - January 23, 1984
41. 1,3-Butadiene - February 9, 1984
42. Cadmium - September 27, 1984
43. Monohalomethanes: Methyl Chloride, Methyl Bromide, and Methyl Iodide - September 27, 1984
44. Dinitrotoluene - July 4, 1985
45. Polychlorinated Biphenyls (PCB's): Potential Health Hazards from Electrical Equipment Fires or Failures - February 24, 1986

NOTE: For the convenience of those who desire a complete series of Current Intelligence Bulletins, #1 through #18 and #19 through #30 have been reprinted as NIOSH publications #78-127 and #79-146, respectively. These publications and single copies of Bulletins #31 and higher are available from Information Dissemination, DSDTT; National Institute for Occupational Safety and Health; 4676 Columbia Parkway, Cincinnati, Ohio 45226 (513) 841-4287

☆U. S. GOVERNMENT PRINTING OFFICE:1986/646-117/20923