

PCB, PCDF, AND PCDD EXPOSURE FOLLOWING A TRANSFORMER FIRE: CHICAGO

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ABSTRACT

On September 28, 1983, an electrical fire in a transformer vault resulted in the loss of 15 gallons of transformer oil composed of 65% PCBs (Aroclor 1260) and 35% trichlorobenzene and forced the precautionary evacuation of a major Chicago office building. A square foot wipe sample of soot on the vault ceiling contained 28,000 ng total TCDFs, 3,800 ng 2,3,7,8-TCDF, 40,000 ng PCDFs, 33,000 ng HxCDFs, 11,200 ng HpCDFs, 1,238 ng OCDFs, 314 ng HpCDDs, and 127 ng OCDDs. No PCDFs or PCDDs were detected in the blood (detection limit 3-40 ppt) of two fire fighters hospitalized with smoke inhalation nor of two office employees similarly exposed.

INTRODUCTION

On September 28, 1983, a fire occurred in a bus bar between a transformer and the switchgear in a transformer vault located under the plaza of a major Chicago office building. The plaza structure and the main office tower are connected at several sublevels but have separate ventilation systems. Although the transformer was de-energized after 10 minutes, smoke continued to rise from the vault's ventilation shafts through grills onto the sidewalk for 45 minutes. One of the four transformers in the vault had leaked approximately 15 gallons of askarel consisting of 65% Aroclor 1260 and 35% trichlorobenzene. The source of the leak was a small hole in the transformer's steel casing that was caused by the intense heat generated by electrical arcing.

Spread of the smoke into the office tower was prevented by the presence of the two separate ventilation systems and intentional positive pressurization of the office tower during the fire. Contamination of the plaza structure was minimized by shutting off the ventilation fans and the presence of high efficiency filters on these fans. Smoke was purposefully routed into the underground garage from the fan room by opening the ventilation duct leading to the garage.

## METHODS

During the next 24 hours, the utility company and the Illinois Environmental Protection Agency collected surface wipe samples, air samples, and filters from the ventilation systems to determine the extent of PCB contamination. Wipe samples for PCB analysis were collected using Whatman filter paper saturated with hexane. The area wiped was one square foot. Air samples for measurement of PCB concentration were collected on Florisil tubes at a flow rate of 100 cc/minute for 1, 6 and 8 hours. NIOSH investigators supervised the collection of a wipe sample taken from the vault wall and a bulk askarel sample from the damaged transformer for PCDD and PCDF analysis. This square foot wipe sample was collected using a glass wool fiber wipe soaked in pesticide grade hexane.

Within 24 to 48 hours of the fire, NIOSH investigators interviewed and drew blood samples for PCB, PCDF, and PCDD analysis from 5 individuals with the highest estimated exposures. The blood samples from one individual were damaged in transit and no analysis was possible. The remaining 4 subjects included 2 off-duty firefighters who were hospitalized for smoke inhalation after a 15 minute exposure and 2 maintenance workers who were in areas adjacent to the vault for 3 and 12 hours. None of these exposed individuals had worn respiratory protection.

PCB environmental samples were analyzed by the utility company using hexane extraction and gas chromatography. PCB blood samples were analyzed by Metpath Laboratories using gas chromatography with an electron capture detector. Samples for PCDD and PCDF analysis were sent to the Brehm Laboratory at Wright State University. The PCDDs and PCDFs were extracted from the blood with hexane and cleaned using a combination of silica and alumina gel chromatography. The askarel proceeded through a two-step cleanup procedure: 1) separation of the PCBs and any PCDFs and PCDDs from the askarel matrix by column chromatography on florisil with subsequent liquid-liquid partition; and 2) separation of the PCBs from any PCDFs and PCDDs by selective absorption on alumina. The cleanup procedure was effective in removing approximately 99% of the PCBs from a 3.66 gram sample of askarel. Analysis of the cleaned-up extracts was completed using a high resolution capillary column gas chromatograph (HR/GC) interfaced to a mass spectrometer operated in the selected ion monitoring mode (SIM-MS). The samples were analyzed for PCDFs and PCDDs by chlorine isomer group (tetrachloro through octachloro compounds).<sup>1</sup>

## RESULTS

The results of the environmental sampling for PCBs are presented in Table 1. PCB contamination was limited to the vault (20,900 mcg/ft<sup>2</sup>), the adjacent fan room which supplied ventilation to the plaza building and sublevels (22,000 to 39,100 mcg/g on the air handling filters), the ventilation shafts from the vault itself (16,800 and 14,300 mcg/ft<sup>2</sup>), and the exterior surface of the one-story plaza building (8,900 mcg/ft<sup>2</sup>). PCB levels from the office tower (.03-1.1 mcg/ft<sup>2</sup>) were comparable to background surface concentrations (0.5 to 4.7 mcg/ft<sup>2</sup>), while PCB levels in the parking garage (18.9 to 47.6 mcg/ft<sup>2</sup>) were above background. The air concentration of PCB in the vault 4 hours after the fire was 58 mcg/m<sup>3</sup>, which is in excess of the NIOSH recommended exposure limit of 1 mcg/m<sup>3</sup>.

TABLE 1

PCB Sampling Results Following A Transformer Fire  
Chicago, 1983

<u>Location</u>	<u>Type of Sample</u>	<u>Result</u>
Transformer Vault Wall	Wipe (mcg/ft <sup>2</sup> )	20,900
Street Above Vault		
Intake grill	Wipe	16,800
Exhaust	Wipe	14,300
Building window above vault	Wipe	8,900
Sidewalk 100 ft. E. of vault	Wipe	51
Plaza Building Corridor	Wipe	0.3
Office Tower		
Main floor south	Wipe	1.1
Level 2 W. entrances	Wipe	1.1
20th floor interior	Wipe	0.03
32nd floor southwest	Wipe	0.03
50th floor interior	Wipe	0.03
Garage (Plaza Sublevels)		
N. end lower level	Wipe	47.6
S. end lower level	Wipe	18.9
N. end upper level	Wipe	31.8
S. end upper level	Wipe	41.4
Exhaust Air Filters		
	Front of filter/ Rear of filter (ppm)	
Office Tower		
58th floor S.W.	Filter F/R	9/7
40th floor S.E.	Filter F/R	12/6
23rd floor S.E.	Filter F/R	41/51
4th floor S.W.	Filter F/R	89/93
3rd floor S.W.	Filter F/R	19/16
Plaza Building and Sublevels		
Vault level (plaza supply)	Filter F/R	22,000/11,300
Vault level	Filter F/R	18.3/8.4
Vault level	Filter F/R	4.4/3.2
Garage	Filter F/R	39,100/28,100
Plaza Building	Air (mcg/m <sup>3</sup> )	10
Transformer Vault (4 hrs. after fire)	Air	58

Table 2 presents the PCDF/PCDD analysis of soot from a surface wipe sample taken from the ceiling of the transformer vault. The sample contained 114 mcg/ft<sup>2</sup> of total PCDF/PCDD (tetra through octa chlorohomologs). A corresponding surface wipe sample obtained from the wall of the vault contained 20,900 mcg/ft<sup>2</sup> of PCBs. The ratio of PCBs to total PCDF/PCDDs is approximately 183:1. TCDFs comprised 25% of total PCDFs. 2,3,7,8-TCDF comprised 3% of total PCDFs.

TABLE 2

PCBs, PCDFs, and PCDDs in Wipe Samples From the Interior of the Transformer Vault (ng/ft<sup>2</sup>), Chicago, 1983

<u>PCDFs</u>		<u>PCDDs</u>	
<u>PCBs</u> <sup>1</sup> 20,900,000			
2,3,7,8-TCDF <sup>2</sup>	3,800	2,3,7,8-TCDD	N.D. <sup>3</sup> ( 5)
Total Tetra	28,000	Total Tetra	N.D. ( 5)
Penta	40,000	Penta	N.D. (25)
Hexa	33,000	Hexa	N.D. (55)
Hepta	11,200	Hepta	314
Octa	1,238	Octa	127
Total PCDFs	113,438	Total PCDDs	441

1. PCBs from wipe of vault wall; PCDFs and PCDDs from wipe of vault ceiling.
2. 2,3,7,8-TCDF and Co-eluting isomers.
3. Not Detected; detection limit in parentheses.

Table 3 presents the PCDF/PCDD analysis of the askarel from the damaged transformer. The askarel contained 5.1 ppm of total PCDF. The ratio of PCBs to total PCDF/PCDDs is 127,451:1. TCDFs comprised 4.5% of total PCDFs in the unburned askarel.

TABLE 3

PCBs, PCDFs, and PCDDs in the Askarel After the Fire (ng/g or ppb) Chicago, 1983

<u>PCDFs</u>		<u>PCDDs</u>	
<u>PCBs</u> 650,000,000			
2,3,7,8-TCDF <sup>1</sup>	75	2,3,7,8-TCDD	N.D. <sup>2</sup> (2.5)
Total Tetra	230	Total Tetra	N.D. (2.5)
Penta	440	Penta	N.D. (2.5)
Hexa	980	Hexa	N.D. (3.0)
Hepta	1,850	Hepta	N.D. (2.0)
Octa	1,600	Octa	8.0
Total PCDFs	5,100	Total PCDDs	8.0

1. 2,3,7,8-TCDF and Co-eluting Isomers.
2. Not Detected; detection limit in parentheses.

Serum PCB levels were less than the detection limit of 10 ppb on all 4 exposed individuals. No PCDFs or PCDDs were detected in the blood of these individuals at a detection limit of 3 to 40 ppt.

#### DISCUSSION

The potential health hazards from PCB-askarel transformer and capacitor fires have only been recognized in recent years. Capacitor grade PCB-askarel is usually pure PCB fluid. Transformer grade PCB-askarel may be pure PCBs or a mixture of PCBs and chlorinated benzenes. In 1978 Buser, Bosshardt, and Rappe demonstrated the formation of PCDFs from the pyrolysis of PCBs.<sup>2,3</sup> In 1979 Buser reported the formation of PCDFs and PCDDs from the pyrolysis of chlorinated benzenes.<sup>4</sup> PCDFs and other pyrosynthesis products have been detected in the soot from transformer fires in Canada in 1977<sup>5</sup>, and the U.S.A. in 1981 and 1983;<sup>6,7</sup> and capacitor fires in Sweden in 1978 and 1981<sup>8,9</sup> and Sweden and Finland in 1982.<sup>9,10</sup>

Soot formed from the incomplete combustion of PCB askarels in transformer and capacitor fires can contain a complex mixture of potentially toxic chlorinated products. In addition to PCDFs and PCDDs, the soot may contain polychlorinated biphenylenes and polychlorinated nuclear aromatics such as chlorinated pyrenes and chrysenes<sup>6,9</sup>. The concentrations of these pyrosynthesis products can vary widely depending on the specific conditions of the fire. The major pyrosynthesis product relative to concentration in soot appears to be PCDFs. TCDFs comprise a major fraction of PCDFs, of which 2,3,7,8-TCDF is one of the most abundant isomers. PCDF concentrations in several U.S. transformer fires have ranged from 46 to 4761 mcg/g of soot<sup>6</sup>. Concentrations of 2,3,7,8-TCDF in these same fires ranged from 3 to 273 mcg/g of soot.

The ratio of PCBs to total PCDFs/PCDDs is useful in assessing the extent of PCDF/PCDD contamination. Once the range of these ratios has been established for a given fire, these ratios can permit the use of PCB analysis as a crude surrogate for PCDF/PCDD analysis. The PCB:PCDF/PCDD ratio in the Chicago fire was 183:1, which falls between the ratios in the San Francisco fire (300:1) and the Binghamton fire (16:1). 2,3,7,8-TCDF comprised 3% of the total PCDFs in the Chicago fire compared to 2% in the San Francisco fire and 17% in the Binghamton fire. A comparison of the PCB:PCDF/PCDD ratio and relative distribution of PCDF congeners in the unburned askarel with those in soot demonstrates the pyrosynthesis of PCDFs.

Few investigators have examined firefighters or clean-up workers to evaluate the acute and subacute health effects from these types of exposures. Seppalainen et al. reported quick resolution of acute symptoms of nausea, intensive perspiration, and headache in workers briefly exposed to PCBs and PCDFs following a capacitor explosion<sup>10</sup>. Neurophysiologic testing of these workers revealed slight, reversible impairment of distal sensory nerve conduction velocity. Serum PCB concentrations were maximum at 3 days (5-30 ppb; median = 13 ppb) but decreased to baseline values

within 1-2 months of exposure. Orris and Kominsky reported acute symptoms of skin irritation, unusual tiredness, and headaches in approximately 20% of firefighters exposed to a PCB aerosol following the pressurized release of PCB askarel from an overheated transformer.<sup>11</sup> Serum PCB levels in these firefighters 1-2 days after exposure ranged from less than 10 to 16 ppb. Jansson and Sundstrom reported serum PCB levels of 2.3-3.6 ppb in firefighters several weeks after their exposure to PCBs and PCDFs in a capacitor fire<sup>8</sup>. No PCDFs were detected in the blood of these firefighters at a detection limit of 100-200 ppt. Tiernen et al. found no PCDFs or PCDDs (detection limit 10-30 ppt) in the blood of individuals exposed to PCDF and PCDD-containing soot after the Binghamton transformer fire. The failure to detect PCBs at a detection limit of 10 ppb or PCDFs/PCDDs at a detection limit of 3-40 ppt in the blood of the 4 individuals exposed in the Chicago fire is consistent with these previous studies.

There are as yet no epidemiologic studies of chronic health effects in persons exposed to PCB-askarels and their pyrolysis products as the result of transformer or capacitor fires. Risk assessments have been based on extrapolation of dose-response relationships for these compounds from animals to man. The underlying assumptions have varied for different transformer fires. Decontamination guidelines for the Binghamton transformer fire were based on the assumption that the major hazard of exposure to PCDFs and PCDDs, expressed as 2,3,7,8-TCDD equivalents, was the development of non-neoplastic long term health effects. Decontamination guidelines for the San Francisco transformer fire were based on the assumption that the major hazard of exposure to these compounds is carcinogenesis.

The New York State Department of Health has developed re-entry guidelines to assist in the clean-up of the Binghamton office building. The maximal surface contamination level of 2,3,7,8-TCDD equivalents depends on the air concentration: if the air concentration is less than 10  $\mu\text{g}/\text{m}^3$ , then the maximal surface level is 28  $\text{ng}/\text{m}^2$ ; if the air concentration is greater than 10  $\mu\text{g}/\text{m}^3$ , then the maximal surface level is 3.3  $\text{ng}/\text{m}^2$ . The equivalent toxicity of the known contaminants on the surface of the vault in the Chicago fire would be 90,400  $\text{ng}/\text{m}^2$  (8,405  $\text{ng}/\text{ft}^2$ ) which is in excess of the NYSDH 3.3  $\text{ng}/\text{m}^2$  guideline.

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