PCBs, PCDFs, and PCDDs Resulting from Transformer/Capacitor Fires: An Overview

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Abstract

The purpose of this paper is to give an overview of what the author considers to be current information concerning PCB transformer/capacitor fires in the U.S. On December 15, 1983, the Environmental Protection Agency issued a national dioxin strategy for investigating, identifying, and cleaning up sites contaminated by dioxin. Within the framework of this strategy is a plan that calls for research to be conducted on PCB transformer/capacitor fires. This research will entail an investigation into the characterization of sources of PCDFs and PCDDs, that is, the chemistry of PCB fires and theoretical products of thermal stress based on composition of askarel used; emergency response protocols for firemen, including protective clothing; and practical remedial measures for building cleanup.

The author also feels that only through the sharing of information and full cooperation among electrical utilities, chemical manufacturers, firemen, insurers, EPRI, EPA, and NIOSH can "preventive maintenance" be performed to minimize or preclude future impacts of PCB transformer/capacitor fires.

PREFACE

On January 10, 1979, a railroad tank car carrying 75,000 liters of crude o-chlorophenol ruptured near Sturgeon, Missouri. Forty-seven workers from the Norfolk & Western Railway Company were employed to clean up the spill and in the process were exposed to a variety of toxic chemicals, including chlorinated phenols, phenol, and the toxic artifact, 2,3,7,8-TCDD (1). In fact, the concentration of this dioxin isomer amounted to only 22 ug/kg (ppb) (2). As a result of alleged exposure and the manifestation of certain perceived health effects and physiological symptoms, e.g., rashes, dizziness, loss of memory, extreme fatigue, impotence, upper respiratory difficulties, and in one case, cancer of the testicles and the skin, the workers brought suit in an Illinois court against the railroad company and the manufacturers of the tank car and the faulty coupling, including Monsanto, the manufacturer of the orthochlorophenol. On August 26, 1982, the Edwardsville, Illinois jury awarded the highest monetary judgments ever made as a result of a

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single tankcar spill - $57.95 million (1). Prior to the commencement of the April 5 trial, Monsanto, General American Transportation, and Dresser Industries settled out of court for an estimated $8 million. This court decision represents the first time a jury has concluded that dioxin caused permanent harm to humans and thus has highlighted the more than 30 waste disposal sites within the State of Missouri that contain polychlorinated dibenzo-p-dioxins (PCDDs)(3).

Recently, in November and December of 1983, three separate suits (4)(5) were filed in St. Louis Circuit Court: in one case, by 57 persons who contend they suffered general systemic effects from dioxin-tainted soils at six sites in eastern and central Missouri - for $684 million; in a second case, by 25 dockworkers and a widow of a former dockworker of a trucking firm in St. Louis - for $620 million; and finally, by 183 people at Times Beach and Castlewood who assert that they suffered serious health deficiencies as a result of dioxin exposure - for $1.8 billion.

Therefore, this situation has catalyzed an acute public and governmental awareness of the potential severity and explosiveness of the PCDD problem. PCB transformer fires, accidental spills, and inappropriate disposal have compounded the problem particularly in regards to PCDFs (furans) and to some extent PCBPs (biphenylenes).

INTRODUCTION

The most toxic and extensively studied polychlorinated dibenzo-p-dioxin (PCDD) and -furan (PCDF) isomers are 2,3,7,8-tetrachloro-p-dioxin (2,3,7,8-TCDD) and 2,3,7,8-tetrachlorodibenzofuran (2,3,7,8-TCDF), respectively. There are pronounced differences in biological and toxicological effects between different PCDD and PCDF isomers. Those isomers with the highest acute toxicity are 2,3,7,8-TCDD, 1,2,3,7,8-PCDD, 1,2,3,4,7,8-HCDD, 1,2,3,6,7,8-HCDD, 1,2,3,7,8,9-HCDD, 2,3,7,8-TCDF, 1,2,3,7,8-PCDF, 2,3,4,7,8-PCDF, and 2,3,4,6,7,8-HCDF (See Figure 1).

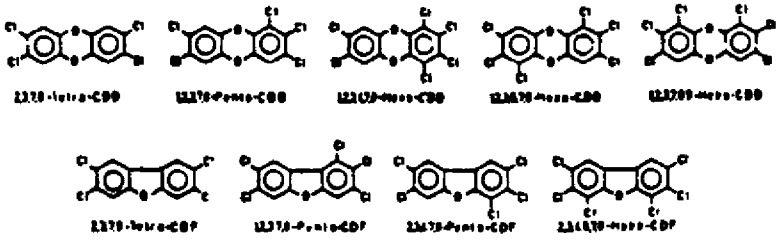


Figure 1. The most toxic PCDD and PCDF isomers (6).

Each of these isomers has its respective four lateral positions substituted for chlorine and each has LD_{50} values in the range of 1-100 ug/kg for the most sensitive animal species (generally the male guinea pig). There exist 75 PCDD isomers and 135 PCDF isomers. Acute toxicity among the isomers can vary up to 100,000 times (See Table 1). In comparison, the most acutely toxic PCB isomer is only about one-fourth as toxic as 2,3,7,8-TCDD (8).

Table 1. Acute oral toxicity of polychlorinated dibenzo-p-dioxins as dose expected to cause death of 50% of the animals within 30 days (7).

	Acute Oral LD_{50}, ug/kg Body Weight		
PCDD	Guinea Pig	Rat	Mouse
Di 2,7		>1,000,000	>2,000,000
2,8	>300,000		
Tri 2,3,7	30,000		>3,000
Tetra 1,3,6,8 mixed		>100,000	
1,3,7,9			
2,3,7,8	0.6	22 (M)	
	2.1	45 (F)	
	2		280
Penta 1,2,3,7,8	3		340
1,2,4,7,8	1,100		>5,000
Hexa 1,2,3,4,7,8	73		825
1,2,3,6,7,8	70-100		1,250
1,2,3,7,8,9	60-100		>1,440
Mixed Isomers		100,000	
Hepta 1,2,3,4,6,7,8	>600		
Octa 1,2,3,4,6,7,8,9		>1,000,000	>4,000,000

Recent information arising from a 1983 National Cancer Institute carcinogenicity study of a mixture of 1,2,3,6,7,8- and 1,2,3,7,8,9-HCDD in female rats led to the preliminary conclusion that this mixture of hexachlorodioxins was carcinogenic. Because public comment criticized the manner in which the experiments were conducted, the National Institute of Environmental Health Sciences/National Toxicological Program (NIEHS/NTP) was asked to reexamine the results of the study. It is therefore the opinion of NIEHS/NTP that the hexachlorodioxin mixture was indeed carcinogenic under the conditions of the test (9).

Analyses of Commercial PCB Mixtures

PCBs contain a complex mixture of PCDFs with up to 40 isomers being present. Rappe and Buser (6) have analyzed a number of commercial PCBs and their findings are shown in Table 2. The highest concentration of PCDFs, found in a Mitsubishi PCB fluid used for over two years, amounted to 10 ug/g (ppm), with 1.25 ug/g being the 2,3,7,8-TCDF isomer. When commercial mixtures or well defined isomers are heated in air in a sealed glass container or ampoule, yields of PCDFs have been observed in the 1-5% range and this technique has been successfully employed to prepare PCDF standards (10). Using the synthetic standards currently available, the major PCDF isomers present in commercial PCBs have been identified (See Figure 2).

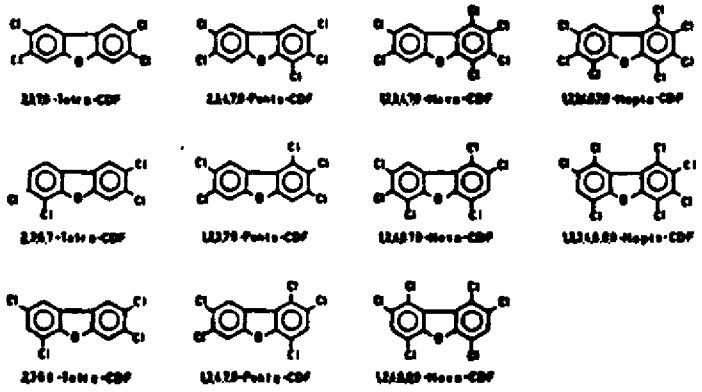


Figure 2. PCDF isomers identified in commercial PCBs (6).

Table 2. Concentrations of PCDFs in commercial PCBs, ug/g (6).

Sample	3-Cl	4-Cl	5-Cl	6-Cl	7-Cl	Total PCDF
Aroclor 1248 (1960)	-	0.5	1.2	0.3	-	2.0
Aroclor 1254 (1969)	-	0.1	0.2	1.4	-	1.7
Aroclor 1254 (1970)	-	0.2	0.4	0.9	-	1.5
Aroclor 1254	0.10	0.25	0.70	0.81	-	1.9
Aroclor 1254 (lot KK 602)	-	0.05	0.10	0.02	-	0.2
Aroclor 1260 (1969)	-	0.1	0.4	0.5	-	1.0
Aroclor (Lot AK 3)	-	0.2	0.3	0.3	-	0.8
Aroclor 1260	0.06	0.30	1.0	1.10	1.35	3.8
Aroclor 1016 (1972)	-	<0.001	<0.001	<0.001	-	-
Clophen A 60	-	1.4	5.0	2.2	-	8.4
Clophen T 64	0.10	0.30	1.73	2.45	0.82	5.4
Phenoclor DP-6	-	0.7	10.0	2.9	-	13.6
Prodelec 3010	0.41	1.00[a]	0.35	0.07	-	2.0
Mitsubishi (used)	2.13	4.00[b]	3.30	0.53	-	10.0

[a] Major isomer 2,3,7,8-TCDF
[b] Contains 1.25 ug/g 2,3,7,8-TCDF

Discussion of Various PCB Fires

* Binghamton, New York

On February 5, 1981 at approximately 5:30 a.m., an electrical panel in the basement of a 22 story office building located in a governmental complex was involved in an incident described as an explosion. A nearby electrical transformer containing about 1100 gallons of Aroclor 1254 (65%) and tri- and tetrachlorinated benzenes (35%) was involved. Leakage occurred and about 180 to 200 gallons of fluid leaked from the transformer. Due to the ventilation system of the building, smoke contaminated with soot-containing chemicals, was spread in a non-uniform fashion to most work areas of the building as well as to interstices within air conditioning ducts, false ceiling areas, elevator shafts, and within desks and file cabinets. This appears to have been facilitated by air ducts or simply open shafts running from the basement area, up to the top of the building, with openings into the men's and women's bathrooms on each floor. These bathrooms had only metal gratings separating them from the open shaft area. In addition to this architectural arrangement, fire or smoke safety doors, which were designed to open in the presence of smoke as a health measure, did just that during the series of explosions that occurred at the time of the incident. Because the outside air temperature was below freezing at the time, the opening of safety doors on the roof, which were located above the building's two stairways, caused a small vacuum that sucked air containing smoke, soot, and as was later found, toxic chemicals from the bathroom areas on each floor and deposited the residue in a non-uniform fashion into most areas of the office building later tested.

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Chemical analyses were performed at: Galson Laboratory in Syracuse, New York and at General Electric Laboratory in Schenectady, New York and revealed PCBs in soot and air, which was strongly suggestive of PCDFs present in substantial amounts; The National Fish and Wildlife Laboratory in Columbia, Missouri, which established the presence of many of the dioxin isomers; and by the New York State Health Department's Division of Laboratories and Research, which established the presence of 2,3,7,8-TCDD. A later examination of material from the underground garage that was contaminated and washed (twice with steam and detergent) was found still to have trace amounts (nanograms per square meter) of PCDFs and PCDDs in some areas by Wright State University. Total PCDF isomers in the soot were initially found to be as high as 2160 ug/g, PCDDs 10-20 ug/g, and PCBs 100,000-200,000 ug/g (See Table 3). It is noteworthy that the most toxic isomers are the major components within each group, viz., 2,3,7,8-TCDD, 2,3,7,8-TCDF, 1,2,3,7,8-PCDD, 1,2,3,7,8-PCDF, and 2,3,4,7,8-PCDF (See Figure 1). Since the tri- and tetrachlorinated benzenes comprise 35% of the dielectric fluid, it is not unreasonable to assume that this diluent mixture represents the precursor to the PCDDs produced as a result of the fire.

Nearby Binghamton City Hall, which was used as a staging area during the initial cleanup efforts in February 1981, was also contaminated. The County Building also next door to the Binghamton State Office Building was contaminated to a lesser extent.

There have been $12 million allocated so far by the State of New York for the cleanup. The building is self-insured so no insurance funds are available. It has been closed since February 5, 1981. Over $1 billion in lawsuits have been threatened by some of the more than 500 persons who were, or believe they were, exposed to toxic chemicals, and who are themselves concerned with physical or psychological/medical damages.

* Stockholm, Sweden

In August 1981, a fire broke out in a 10 KV capacitor battery in an electrical power station in Stockholm, which was probably caused by a malfunctioning electrical system. Wipe tests were taken about one meter from the capacitor (13). Inspection of the chromatograms revealed several peaks, in addition to PCBs, with molecular weights corresponding to di-, tri-, tetra-, and pentachlorobiphenylenes (PCBPs). It is probable that these PCBPs were formed by a direct cyclization of PCBs present. The level of PCDFs was found to be 1375 ng/m^2 (See Table 4), whereas a rough estimate for PCBPs gave levels of 25,000-30,000 ng/m^2. Polychlorinated pyrenes (PCPYs) were also detected, but not quantified.

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Table 3. Levels of PCDFs (ug/g) from accidental burning of PCB-containing electrical equipment.

Isomers	Capacitor Skövde, Sweden(10) 0.5m*	Capacitor Skövde, Sweden(10) 3m**	Transformer Binghamton(10)	Transformer Miami (11)#	Transformer Boston (12)¢
Total PCDFs	0.8	0.2	2160	n.d.-1.79	165
Total Tri-CDFs				n.d.-0.18	50
Total Tetra-CDFs	0.6	0.1	28	n.d.-0.53	60
2,3,7,8-Tetra-CDF	0.1	0.02	12	n.d.	3
Other isomers	0.5	0.06	16		
Total Penta-CDFs	0.1	0.04	670	n.d.-1.0	35
1,3,4,7,8-Penta-CDF			65		
1,2,4,7,8- "			25		
1,2,4,7,9- "			22		
1,2,3,7,8- "			310		
1,2,3,6,7- "			60		
1,2,6,7,8- "			25		
2,3,4,7,8- "			48		
2,3,4,6,7- "			12		
Other isomers			110		
Total Hexa-CDFs	0.04	0.04	965	n.d.-0.18	15
1,2,3,4,6,8-Hexa-CDF			50		
1,3,4,6,7,8- "			125		
1,2,4,6,7,8- "			50		
1,2,3,4,7,8- "			510		
1,2,3,6,7,8- "			150		
1,2,3,6,8,9- "			58		
2,3,4,6,7,8- "			10		
Other isomers			250		
Total Hepta-CDFs	0.01	0.01	460	n.d.	2
1,2,3,4,6,7,8-Hepta-CDF			230		
1,2,3,4,6,7,9- "			120		
1,2,3,4,6,8,9- "			55		
1,2,3,4,7,8,9- "			55		
Octa-CDF	0.005	0.005	40	n.d.	n.d

* soot sample taken 0.5m from capacitor on the floor
** soot sample taken 3m above capacitor on the wall
# Detection limit: 10 ng/g
¢ Detection limit: 100 ng/g

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Table 3. Levels of PCDDs (ug/g) from accidental burning of PCB-containing electrical equipment. (cont'd)

Isomers	Capacitor Skövde, Sweden(10) 0.5m*	3m**	Transformer Binghamton(10)	Transformer Miami (11)#	Transformer Boston (12)¢
Total PCDDs	-	-	20	n.d.	n.d.
Total Tri-CDDs				n.d.	n.d.
Total Tetra-CDDs	-	-	1.2	n.d.	n.d.
2,3,7,8-Tetra-CDFs	-	-	0.6	n.d.	n.d.
Other isomers	-	-	0.6		
Total Penta-CDDs	-	-	5.0	n.d.	n.d.
1,2,3,7,8-Penta-CDDs	-	-	2.5		
Other isomers	-	-	2.5		
Total Hexa-CDDs	-	-	4.7	n.d.	n.d.
1,2,3,4,6,8-Hexa-CDD	-	-	1.2		
1,2,4,6,8,9 "	-	-	1.2		
1,2,3,4,7,8 "	-	-	0.7		
1,2,3,6,8,9 "	-	-	0.6		
1,2,3,7,8,9 "	-	-	0.4		
1,2,3,4,6,7 "	-	-	0.5		
1,2,3,4,6,7,9-Hepta-CDD	-	-	4	n.d.	n.d.
1,2,3,4,6,7,8- "	-	-	3	n.d.	n.d.
Octa-CDD	-	-	2	n.d.	n.d.

* soot sample taken 0.5m from capacitor on the floor
** soot sample taken 3m above capacitor on the wall
# Detection limit: 10 ng/g
¢ Detection limit: 100 ng/g

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Table 4. Analyses of wipe samples from various PCB fires.

Isomers	Skövde(14) ng/m^2	Stockholm(14) ng/m^2	Cincinnati(13) ng/m^2
Total PCDFs	n.d.-873	1375	n.d.
2,3,7,8-Tetra-CDF	n.d.-100	150	n.d.
1,2,7,8-Tetra-CDF		150	
2,3,6,8-Tetra-CDF		125	
1,4,6,9-Tetra-CDF		75	
2,4,6,7-Tetra-CDF		37	
3,4,6,7-Tetra-CDF		7.5	
1,3,6,7-/1,3,6,9-Tetra-CDF		300	
Other Tetra-CDFs		750	
Total Tetra-CDFs	<1-600	1200	n.d.
2,3,4,7,8-Penta-CDF		45	
1,2,4,7,8-Penta-CDF		38	
1,2,3,6,7-Penta-CDF		15	
1,3,4,7,8-Penta-CDF		11	
2,3,4,6,7-Penta-CDF		7.5	
1,2,4,6,8-Penta-CDF		3.8	
1,2,4,7,8-Penta-CDF		3.8	
1,2,3,6,7-Penta-CDF		3.8	
1,2,4,8,9-Penta-CDF		3.8	
2,3,4,6,8-Penta-CDF		2	
1,2,3,7,8-/1,2,3,4,8-Penta-CDF		15	
Other Penta-CDFs		19	
Total Penta-CDFs	n.d.-100	175	
Total Hexa-CDFs	n.d.-60	<0.5	
Total Hepta-CDFs	n.d.-8		
Octa-CDF	n.d.-5		
Total PCDDs	n.d.		n.d.
Total Tetra-CDDs	n.d.		n.d.
2,3,7,8-Tetra-CDDs	n.d.		n.d.

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- Skövde, Sweden

In March 1982, a 400 volt capacity battery, serving a high frequency oven in a casting line of a foundry in Skövde, experienced an electrical malfunction leading to a fire (13)(14). The dielectric fluid employed comprised either mineral oil or PCBs. The fire started in a mineral oil capacitor and burned for about two hours before being extinguished. Temperatures exceeding 1100°C were realized because copper electrical wiring melted. The smoke spread from the basement into the building above, an area of 60 x 30 meters. The capacitor battery contained 21 capacitors filled with 5 kgs of PCBs each. Post-fire inspection showed leakage from 12 of these capacitors. Both wipe tests and soot samples were taken. Results are tabulated in Tables 3 and 4. These show that high levels of PCDFs (>100 ng/m^2 and <800 ng/g) could only be found in an area near the fire. Concentrations of PCDFs dropped off dramatically with distance from the fire. The highly toxic 2,3,7,8-TCDF was one of the major tetra-CDF isomers present. Other chlorinated compounds that may be present are the PCPYs, but verification could not be obtained due to lack of standards. No PCDDs were identified in samples taken from this fire (there were no chlorinated benzenes used as diluents). No PCBPs were observed.

- Miami, Florida

On April 13, 1982, an underground electrical fire occurred in a transformer vault in Miami. City of Miami firemen were called in to extinguish the blaze. They also voiced their concerns about the possible contamination of fire equipment and protective clothing used during the performance of their duties. As a result, the International Association of Fire Fighters in Washington, DC, contacted the NIOSH Region IV representative and the latter agency conducted a thorough investigation. Table 5 contains the results of the analyses of surface samples taken during the investigation. As expected, samples removed from inside the vault indicate the heaviest contamination levels (up to 27,400 ug/100 cm^2 PCBs). Results of prior NIOSH investigations indicate that normal background levels of PCBs on uncontaminated surfaces should be less than 0.5 ug/100 cm^2. As indicated by the sampling results, turnout coats, boots, helmets, and other personal protective equipment were not found to be contaminated from the fire. This is probably due to the decision to allow the fire to self-extinguish, thus minimizing exposures to the smoke and soot. The only contaminated piece of equipment found at the station was the smoke ejector fan, which contained greater than 31 ug/100 cm^2 PCBs because the area wiped for this particular sample was estimated to be less than the standard 100 cm^2. The fan blade guard was found to be heavily coated with soot and dirt from the smoke exhausted from the vault fire.

Results of PCDD and PCDF analyses are shown in Table 3. No PCDDs were detected, but tri-, tetra-, penta-, and hexa-CDFs were found, ranging from non-detectable (n.d.) to 1790 ng/g. No 2,3,7,8-TCDF was detected in any of the samples. However, the samples did exhibit high levels of PCBs through Cl_{10} and polychlorinated diphenylethers (PCDPEs) through Cl_8.

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Table 5. PCB residue from Miami transformer vault fire (11).

Sample Location	Type Sample#	PCBs* (ug/100 cm^2)
Inside transformer vault		
Wall behind transformer	(soot) wipe	434**
Top of primary cable above fire	(soot) wipe	389
Primary cable support bracket	(soot) wipe	704
Floor near isolating switch	(dirt) wipe	27,400
Ceiling near fire location	(soot) wipe	860
Secondary bus near vault ceiling	(dirt) wipe	195
Wall next to exit ladder	(dust) smear tab--dry	2
Rung of exit ladder	(dust) smear tab--dry	79
Above transformer vault:		
Sidewalk grating	smear tab--dry	2
Water at curb near vault	wipe	3
Firemen's clothing/equipment:		
Miscellaneous clothing	smear tab--dry	<0.1
Smoke ejector fan	smear tab--dry	>31
Normal PCB Background***	wipe	<0.5

* As Aroclor 1260 (used as standard for quantifying samples).

** As mixture of Aroclor 1254 (231 ug) + Aroclor 1260 (203 ug).

*** As determined by previous NIOSH Health Hazard Evaluation.

Wipe samples were collected on sterile cotton pads soaked in n-hexane.

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* Cincinnati, Ohio

On December 3, 1980, a capacitor containing PCBs for a 1/2 HP electric motor overheated in a basement storage room of a private elementary school. This capacitnr contained ?? ml of dielectric fluid comprised of 21.9 ml of a biodegradable fluid and 0.1 ml of PCBs. Approximately one-half of the fifth-grade students using three classrooms in the basement area complained of itchiness of the skin. Power to the electric motor was shut off and the exterior door was opened to allow ventilation of the smoke from the room. Since air is locally recirculated, central distribution via a mechanical system throughout the school did not occur.

PCBs were not detected in any air sample at a limit of detection of 0.05 ug/sample, which is equivalent to an airborne concentration of approximately 1 ug/m^3.

Table 6 summarizes the results of 63 wipe samples collected by NIOSH. Fifty-one of the 63 samples were taken from surfaces within the school including books, desks, walls, floors, ceilings, and other surfaces. Two were taken from surfaces within a mobile classroom and ten were obtained from surfaces at three locations in eastern, central, and western Cincinnati to establish background levels of PCBs for this area. The 20 samples obtained from Room 27, which contained the overheated capacitor, ranged from non-detectable to 7200 $ug/100\ cm^2$ PCBs. The remaining rooms ranged from non-detectable to 0.45 $ug/100\ cm^2$.

The two wipe samples with the highest PCB concentrations were also analyzed for PCDDs and PCDFs, with particular emphasis on the 2,3,7,8-tetra-isomers. Neither PCDDs nor PCDFs (See Table 4) were detected in either of the samples. The detection limits employed were 0.10 and 0.09 ug/sample, respectively.

* Boston, Massachusetts

In January 1982, there was an electrical fire involving PCBs in a Boston office building. One bulk soot sample was analyzed for PCDDs and PCDFs. Table 3 shows that high concentrations of the tri- through the hepta-CDFs were found in the soot sample, ranging from 2 - 60 ug/g (detection limit = 0.1 ug/g). No PCDDs were found. A considerable amount of the highly toxic 2,3,7,8-TCDF was detected--3 ug/g. Levels of PCBs were also found at 10 - 100 times that of the PCDFs.

Table 6. Summary of PCBs wipe sample results, Our Lady of Visitation School, Cincinnati, OH (capacitor fire) (15).

Sample Location	Mean PCB level, ug/100 cm^2 *
Room 27 (capacitor location)	n.d. - 7200**
Room 25	n.d. - 0.14
Room 24	n.d. - 0.06
Room 26	n.d.
Hallway	n.d. - 0.07
Room 8	n.d. - 0.08
Room 22	n.d. - 0.29
Room 10	n.d. - 0.20
Room 11	0.07 - 0.11
Room 12	0.06 - 0.09
A.V. Room	n.d.
Principal's Office	0.05 - 0.45
Mobile Classroom	0.06
Background Levels (3 Cincinnati locations)	n.d. - 0.13

* Detection limit: 0.05 ug/sample (sample = quantity wiped per 100 cm^2).

** Two wipe samples with highest concentrations of PCBs were found to contain no detectable PCDFs or PCDDs.

* St. Paul, Minnesota

On June 22, 1982, a transformer fire occurred in a public high school in St. Paul. NIOSH took both surface wipe and air samples on June 23 (the day after the fire) and on July 7 (after the area was decontaminated). Table 7 contains measurements of air contamination, pre- and post-cleanup, by PCBs, trichlorobenzenes, and tetrachlorobenzenes. The NIOSH recommended permissable limit of 0.001 mg/m^3 (8-hr TWA) for PCBs was exceeded in all areas sampled except for two locations. The tri- and tetrachlorobenzenes found did not exceed any existing limits.

Table 8 shows the effect of the decontamination methods employed. The transformer vault room PCBs (wipes) were reduced from a high of 4,000 ug/100 cm^2 to 120 ug/100 cm^2 or less. No PCDDs or PCDFs were found in the liquid sample of Askarel provided (detection limit = 40 ng/g (40 ppb)). However, it is interesting to note that NIOSH did not analyze for PCDDs or PCDFs in the soot. The results may have shown significant concentrations of these isomers, given the areal concentrations of tri- and tetrachlorobenzenes detected.

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Table 7. Areal concentration of PCBs and chlorinated benzenes, Hill-Murray High School, St. Paul, MN (transformer)(16).

Sample Site	Airborne Concentration, mg/m^3					
	PCRs*#		T_3CBs		T_4CRs	
	A	B	A	B	A	B
Transformer vault, 5 ft above floor	0.05	0.007[c]	22.6	0.331	18.2	0.651
Transformer vault, 1 ft above floor	0.09	-	17.6	-	25.7	-
Outside of transformer vault doors	0.02	n.d.	10.2	0.048	11.7	0.229
Woodshop	0.004	n.d.	0.73	0.020	1.21	0.089
Head of stairs	n.d.	n.d.	0.12	0.011	0.26	0.037
Cafeteria	n.d.	n.d.	0.35	0.010	0.27	0.032
8-hr time-weighted average exposure criteria	0.001[a]		40[b]		none	

A = June 23, 1982; B = July 7, 1982

* = Detection limit : 0.001 mg/m^3

= as Aroclor 1260

a NIOSH recommended permissable exposure limit. OSHA permissable exposure limit is 0.001 mg/m^3 8-hour time weighted average.

b ACGIH threshold limit value. Neither NIOSH nor OSHA has exposure criteria.

c sample taken 3 ft above floor

Table B. Analyzed PCBs# in wipe samples,
Hill-Murray High School, St. Paul, MN (transformer) ¢(16).

Sample Site	PCBs#, ug/100 cm^2	
	A	B
Vault room	n.d. - 4000	2 - 120
Ventilation dust	n.d.	-
Corridor outside vault room	n.d.	-
Cafeteria	0.22 - 0.24	n.d.
Gymnasium	0.29	
Rooms 106, 109, 138	0.26 - 2.1	n.d. - 0.8
Outside Room 106	5.8	0.8
Woodshop	n.d.	-

Detection Limit : 5 ug/sample

A = June 23, 1982; B = July 7, 1982

¢ = no analyses conducted for PCDFs or PCDDs.

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DISCUSSION

The previous PCB transformer/capacitor incidents are but a representative sampling of cases where data are readily available. Other electrical equipment episodes include: Toronto, Ontario, Canada in 1977; and Norrtälje and Surahammar, Sweden and Imatra, Finland in 1982 (17). More recently, in the U.S., three such episodes have occurred:

Date	Location	PCB Fluid
5/15/83	San Francisco, CA	1242 only
9/28/83	Chicago, IL	65% Aroclor/35% Chlorobenzenes
12/21/83	Syracuse, NY	87% 1254

Because of the continuance of such incidents, the Environmental Defense Fund and the Natural Resources Defense Council challenged the August 25, 1982 PCB Electrical Use Rule issued by EPA. As a result, a Start Action Request has been initiated by the EPA Office of Pesticides and Toxic Chemicals, which includes the following court-ordered schedule for the issuance of an Advanced Notice of Proposed Rulemaking (ANPR) regarding PCB transformer fires (18):

ANPR: March 1984
Proposed Rule: October 1984
Final Rule: July 1985

The objective of an ANPR is to present data that indicate a reason for concern and, more importantly, to solicit data for the Proposed Rule. The major elements of the ANPR include:

- Description of risks associated with PCB transformer fires through analyses of Binghamton, San Francisco, Chicago, Syracuse, etc. events.
- Description of number and distribution of PCB transformers.
- Solicitation of data on number and location of such electrical equipment.
- Presentation of information on other lesser-known fires.
- Presentation of estimates of frequency of fires.
- Solicitation of data on other fires and frequency of other fires.
- Discussion of PCDF/PCDD formation (and PCBP, PCCY (crysenes), PCDPE, PCPY, etc. where data are available on these compounds).
- Solicitation of data on mechanisms of formation.
- Presentation of possible regulatory options.
  - Substitutes
  - Retrofilling
  - Fire hazard inspections
  - Costs/benefits of various mechanisms to reduce spread of PCBs, PCDFs, PCDDs, etc. from fires - use of early warning protection devices

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Currently, the EPA Office of Research and Development (ORD), in support of the Agency's Dioxin Strategy (18), released publicly on December 15, 1983, is planning to conduct research on PCB fires, which will cover three areas: (a) the chemistry of PCB fires and a theoretical discussion of products of thermal stress based on composition of askarel used; (b) emergency response protocols for firemen, including protective clothing (this research will be conducted in cooperation with NIOSH); and (c) practical remedial measures for building cleanup.

As a result of my participation in the preparation of the Dioxin Strategy document and in several Agency dioxin workgroups, including the Dioxin Disposal Advisory Group and the PCB Transformer Fires Workgroup and based upon my expertise concerning the subject matter (20), I believe that I enjoy a perspective that few EPA technical staff have. Because of this, I can relate to you the following facts: Given that chemical production facilities in the U.S. no longer produce 2,4,5-trichlorophenol (the most significant historical source of 2,3,7,8-TCDD), I can state that soot produced as a result of PCB transformer/capacitor fires contains the highest concentrations of PCDFs and PCDDs (the latter only if chlorobenzene diluents are present in the askarel mixture) found in the U.S. today; on a weight basis, however, municipal combustion devices account for the largest quantity of PCDFs and PCDDs produced currently. The soot from the Binghamton fire was evaluated by the New York State Department of Health in tests using chick embryos in 1981 (21). Results were positive. In other words, the PCDDs and PCDFs in the soot were not inactivated (as in the case of fly ash from an incinerator or by activated carbon) as demonstrated by the chick embryo fetotoxicity and teratogenicity tests performed. The soot can therefore be considered toxic and may contribute to "environmentally induced or promoted cancers, reproductive abnormalities, immunologic deficiency, and possibly premature death from infection, neurologic and gastrointestinal system pathology and possibly, by elevating serum triglyceride and cholesterol levels, excess or avoidable cardiovascular and cerebrovascular pathology" (22, p. 678).

I thus stand firmly behind the convictions that firemen responding to such incidents must have the most up-to-date information at their disposal and that remedial methods employed must be practical, sound, and effective. As a result, EPA-ORD is in the process of securing PCB samples from Binghamton, NY, Chicago, IL, San Francisco, CA, and Syracuse, NY. The EPA analytical laboratory in Cincinnati, OH will conduct a chlorobenzene isomer screen on the samples together with homologue analyses for PCBs, the purpose being an attempt to correlate PCDDs and PCDFs content of soot and wipe samples (in the vaults) with chlorobenzene and PCB content in the transformer fluid. The information gathered will be shared among the electrical utilities, insurers, firemen associations, EPRI and NIOSH.

In closing, I wish to share some recent and quite pertinent information. The NIEHS/NTP has concluded two animal studies involving bioaccumulation of 2,3,7,8-TCDD from contaminated soils and has submitted these papers (23) to Science for publication. These papers conclude that 2,3,7,8-TCDD in soil from two sites in Missouri, namely, Times Beach and Minker-Stout, is absorbed in a highly efficient manner (>50%) and that 2,3,7,8-TCDD

-contaminated soil presents a hazard to humans if ingested. Thus, further laboratory evidence has been amassed regarding potential risk to humans for 2,3,7,8-TCDD. I believe that this audience is sufficiently astute to comprehend the long-term implications of these investigations.

References

1. Chemical Week, September 1, 1982, p. 14.

2. Harless, Robert. Deposition in Lowe v. Norfolk & Western Railway Company, Circuit Court, Third Judicial Court of Illinois, Madison County, No. 79-L-810.

3. Kleopfer, R.D., Nunn, W.W., Yue, K.T., and Harris, D.J. (1982). "Occurrence of TCDD in Environmental Samples from Southwest Missouri." Paper presented at the 184th ACS National Meeting, Kansas City, MO, September 14, 1982.

4. Anonymous (1983). "57 Missourians File $684 million Dioxin Suit." Post Tribune, Jefferson City, MO, November 29, 1983.

5. Anonymous (1983). "Missouri Dioxin Suit Seeks $1.8 billion." New York Times, New York, NY, December 17, 1983.

6. Rappe, Christoffer and Buser, Hans Rudolf (1981). "Occupational Exposure to Polychlorinated Dioxins and Dibenzofurans" in Chemical Hazards in the Workplace--Measurement and Control, ACS Symposium Series No. 149.

7. Leng, M. L. (1979). "Comparative Toxicology of Various Chlorinated Dioxins as Related to Chemical Structure" in CIPAC Proceedings Symposium Series I, Heffers Printers Ltd., Cambridge, England.

8. Safe, S., et al. (1982). "PCBs: Structure-Activity Relationships." Paper presented at the Symposium: "Recent Advances in Exposure, Health, and Environmental Effects Studies of PCBs," Bethesda, MD, May 12-13, 1982.

9. Letter of October 31, 1983 from Paul K. Hildebrandt, D.V.M., Tracor Jitco, Rockville, MD, to E.E. McConnell, NIEHS/NTP, Research Triangle Park, NC, subject: Review of NCI Carcinogenicity Study of Hexachlorodibenzo-p-dioxin in Rats.

10. Rappe, Christoffer and Marklund, Stellan (1982). "Thermal Degradation of Pesticides and Xenobiotics: Formation of Polychlorinated Dioxins and Dibenzofurans." Department of Organic Chemistry, University of Umeå, Umeå, Sweden.

11. Letter of October 27, 1982 from Stanley A. Salisbury, NIOSH Region IV to Richard Duffy, International Association of Fire Fighters, subject: PCB Transformer Vault Fire, Miami, FL.

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12. Memorandum of October 1, 1982 from G. Choudhary and J. C. Posner, NIOSH, Cincinnati, OH to Kevin McManus, NIOSH Region I, subject: PCB Soot Analysis from Fire at U.S. DOL-OSHA.

13. Rappe, C., Marklund, S., Bergqvist, P.-A., and Hansson, M. (1982). "Polychlorinated Dioxins, Dibenzofurans and Other Polychlorinated Polynuclear Aromatics Forming During Incineration and PCB Fires." Department of Organic Chemistry, University of Umeå, S-90187, Umeå, Sweden.

14. Rappe, C., Marklund, S., Bergqvist, P.-A., and Hansson, M. (1982). "Polychlorinated Dioxins (PCDDs), Dibenzofurans (PCDFs) and other Polynuclear Aromatics (PCPNAs) Formed During PCB Fires." Chemica Scripta, Vol. 20, pp. 56-61.

15. Health Hazard Evaluation Report: Our Lady of Visitation Elementary School, Cincinnati, OH. NIOSH Report No. HETA 81-237-915, July 1981.

16. Letter of July 26, 1982 from John R. Kominsky, NIOSH, Cincinnati, OH to Darrell E. Anderson, State of Minnesota Department of Health, Minneapolis, MN, subject: PCB Fire at Hill-Murray High School, St. Paul, MN.

17. Vuceta, J., Marsh, J.R., Kennedy, S., Hildemann, L. and Wiley, S. (1983). "State-of-the-art Review: PCDDs and PCDFs in Utility PCB Fluid." Prepared by SCS Engineers, Inc. for the Electric Power Research Institute, Palo Alto, CA. EPRI CS-3308, Research Project 1263-11, November 1983.

18. Memorandum of October 11, 1983 from Martin P. Halper, EPA Exposure Evaluation Division to Irwin P. Baumel, EPA Health and Environmental Review Division, subject: PCB Transformer Fires in Buildings.

19. Environmental Protection Agency (1983). "Dioxin Strategy." Office of Water Regulation and Standards and Office of Solid Waste and Emergency Response in conjunction with the Dioxin Strategy Task Force, Washington, D.C., November 28, 1983.

20. desRosiers, Paul E. (1983). "Remedial Measures for Wastes Containing Polychlorinated Dibenzo-p-dioxins (PCDDs) and Dibenzofurans (PCDFs): Destruction, Containment or Process Modification." Ann. occup. Hyg., Vol. 27, No. 1, pp. 57-72.

21. Seely, Hart (1983). "The Building That Won't Come Clean." The Syracuse Herald, July 31, 1983.

22. Schecter, Arnold (1983). "Contamination of an Office Building in Binghamton, New York by PCBs, Dioxins, Furans, and Biphenylenes after an Electrical Panel and Electrical Transformer Incident." Chemosphere, Vol. 12, No. 4/5, pp. 669-680.

23. Letter of November 9, 1983 from Edward N. Brandt, Jr., M.D., Assistant Secretary for Health, to Lee Thomas, EPA, AA for Solid Waste and Emergency Response, subject: NIEHS/NTP Studies on Bioavailability in Guinea Pigs and Rats of Dioxin in Soil (with two abstracts submitted to Science for publication.)