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Assessment of the Contamination of a Multibuilding Facility by Polychlorinated Biphenyls, Polychlorinated Dibenzo-*p*-dioxins, and Polychlorinated Dibenzofurans

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■ This study describes a unique site of polychlorinated biphenyl (PCB), polychlorinated dibenzo-*p*-dioxin (PCDD), and polychlorinated dibenzofuran (PCDF) contamination. The extent of the contamination was characterized by the results of the analyses of several hundred surface wipe samples. In addition, smaller numbers of air samples and dust samples were analyzed. The hypothesis that octachlorodibenzo-*p*-dioxin (OCDD) can be used as a marker for all the PCDDs and PCDFs and that total PCBs can be used as a marker for the semiquantitative estimation of the PCDDs and PCDFs was tested. The hypothesis was validated in this application because the ratios of OCDD/heptachlorodibenzo-*p*-dioxins (HpCDDs) and PCBs/OCDD in wipe and dust samples showed good agreement and were reasonably consistent. The data from the contamination assessment indicate that the route of contamination of the complex was through the fresh air intake vents and that the source was the on-site incinerator.

Introduction

Polychlorinated dibenzofurans (PCDFs), polychlorinated dibenzo-*p*-dioxins (PCDDs), and polychlorinated biphenylenes (PCBPs) are formed during fires involving electrical equipment containing polychlorinated biphenyls (PCBs) (*1–6*). PCDFs have been identified as the major combustion product in soot from PCB fires, with the maximum concentration commonly represented by the tetra homologue (*1, 3, 6*). Recent occurrences of several transformer fires in the United States have resulted in widespread contamination of buildings with PCBs, PCDFs, and PCDDs (*7–9*). PCDFs and PCDDs also have been identified in fly ash from municipal and industrial incinerators (*10–13*).

In this report, a unique site of PCB, PCDD, and PCDF contamination is described. The contamination is believed to be due to the improper incineration of approximately 200 gallons of Aroclor 1254 askarel at the site over 12 years ago. The combustion parameters of the incinerator were thought to be about 650 °C for a 2-s dwell time; feed and oxygen conditions are not known. Current guidelines for land-based incineration of PCB liquids specify a 2-s dwell time at 1200 °C (±100 °C) and 3% excess oxygen in the stack gas (*14*). Thus, it is believed that the incineration of the PCB askarel at this facility resulted not only in incomplete destruction of PCBs but also in formation of PCDFs and PCDDs (*1, 2*). Contamintation of the multibuilding facility by PCBs, PCDFs, and PCDDs has been found to be widespread. On the basis of the observed levels of contamination in the buildings and the distribution throughout the facility, it is postulated that products of incomplete combustion of the PCB askarel were airborne and entered the buildings via fresh air intake vents.

The objectives of this study were to (a) assess the extent of contamination at the facility, (b) attempt to demonstrate the route of contamination of the facility, and (c) test the hypothesis that octachlorodibenzo-*p*-dioxin (OCDD) could be used as a marker for all of the PCDDs and PCDFs and that total PCBs could be used as a marker for the estimation of the PCDDs and PCDFs in a given sample.

Experimental Section

All solvents used for sampling and cleanup of samples were pesticide residue grade obtained from Burdick & Jackson. The sulfuric acid used was Reagent A.C.S. grade obtained from Fisher.

Sample Collection. Three types of samples were collected for analysis: surface wipes, dust, and air. All samples were analyzed for PCBs, and selected samples were analyzed for octachlorodibenzo-*p*-dioxin (OCDD) and heptachlorodibenzo-*p*-dioxins (HpCDDs) or for PCDDs and PCDFs. The majority of the samples were surface wipes.

Two groups of surface wipe samples were collected (I and II). The method used for collecting the group II samples was found to be more easily implemented, and about 90% of the surface wipe samples were collected by this method. Samples were taken from each building of the facility in order to demonstrate the extent of the contamination.

The first group of surface wipe samples (I) was collected from 0.25-m^2 areas wetted with toluene and wiped a single time with three absorbent tissues (12.5 cm × 21.5 cm Kimwipes). The tissues were then placed into a 38 mm × 200 mm culture tube which was sealed with a Teflon-lined screw cap. The second group of samples (II) was collected by single wiping an area of 100 cm^2 with a 5 cm by 5 cm cyclohexane extracted cotton gauze swatch wetted with cyclohexane. The cotton gauze swatch was then placed in a 17 mm × 125 mm culture tube which was sealed with a Teflon-lined screw cap.

Areas designated for sampling that contained excessive amounts of dust and debris were sampled by collecting the residue in a 17 mm × 125 mm culture tube which was sealed with a Teflon-lined screw cap.

The collection and analysis of air samples is described in a separate section.

Sample Extraction. Group I surface wipe samples were extracted by adding 50 mL of hexane to the culture tube and extracting for 1 h on a mechanical shaker. Group II surface wipe samples were extracted by adding 10 mL of hexane to the culture tube containing the samples and extracting for 1 h on a mechanical shaker.

Dust samples (0.1–1 g) were weighed into Soxhlet thimbles and extracted with 100 mL of hexane for 2 h. The extracts were then taken to dryness on a rotary evaporator and redissolved in 10 mL of hexane.

Cleanup of Extracts for PCB Analysis. Group I surface wipe extracts were prepared for analysis by transferring 5 mL of the extract to a 17 mm × 125 mm culture tube containing 5 mL of concentrated sulfuric acid and shaking for 30 s. After phase separation, the hexane phase (top layer) was ready for PCB analysis. The remainder (45 mL) of the sample extract was reserved for OCDD and HpCDD analysis.

Group II surface wipe and dust extracts were prepared for analysis by transferring 5 mL of the extract to a 17 mm × 125 mm culture tube containing 5 mL of concentrated sulfuric acid and shaking for 30 s. After phase separation, the hexane phase (top level) was ready for analysis. The remainder (5 mL) of the sample extract was reserved for OCDD and HpCDD analysis.

Cleanup of Extracts for OCDD and HpCDD Analysis. The remaining 45 mL of each group I surface wipe extract was transferred to a 250-mL separatory funnel. The extract was washed 2 times with 100 mL of 1 M KOH solution, once with 10 mL of deionized water, once with 100 mL of a 1% (v/v) H_2SO_4 solution, and then twice with deionized water. The hexane fraction was percolated through a sodium sulfate column and collected in a 250-mL round-bottom flask. The sample was then taken to dryness on a rotary evaporator and then, with several milliliters of hexane, was transferred to a 50-mL round-bottom flask. The sample was then taken to dryness under a water pump vacuum in a 50 °C water bath, and the residue was dissolved in 500 μL of a 50/50 (v/v) cyclohexane/dichloromethane solution and subjected to the high-pressure liquid chromatographic (HPLC) procedure described previously (*15*) to remove the PCBs from the sample. Samples that were heavily colored or of an oily nature were diluted to 5 mL before removing 500 μL for HPLC cleanup to prevent overloading of the cleanup column. After HPLC cleanup, the sample was ready for GC/ECD analysis for OCDD and HpCDDs.

The remaining 5 mL of each group II sample or dust extract was transferred to a 15-mL conical-tipped centrifuge tube equipped with a Teflon-lined screw cap and diluted with hexane to 10 mL. Five milliliters of a 1 M KOH solution was added to each tube, and the tubes were then rotated by mechanical rotation (Fisher Roto-Rack, Model 343) at medium speed for 15 min. The samples were centrifuged at 2000 rpm (Du Pont Sorvall centrifuge, model GLC-2B) for 5 min, and the aqueous phase was removed by using a Pasteur pipet and discarded. Five milliliters of 1% H_2SO_4 was added to each of the tubes, and they were again rotated for 15 min. After the samples were centrifuged at 2000 rpm for 5 min, the aqueous phase was removed by using a Pasteur pipet and discarded. Five milliliters of deionized water was added to each of the tubes, and they were rotated for 15 min. The samples were centrifuged as before, and the aqueous phase was removed by using a Pasteur pipet and discarded. Each sample was percolated through a 3 cm × 2 cm plug of hexane-washed sodium sulfate followed by four rinses of the sodium sulfate with 4-mL portions of hexane. The sample was collected in a 50-mL round-bottom flask and was taken to dryness under a water pump vacuum in a 50 °C water bath. At this point, each sample was dissolved in 500 μL of 50/50 (v/v) cyclohexane/dichloromethane and subjected to the HPLC cleanup procedure previously described (*15*). The sample was then ready for GC/ECD analysis for OCDD and HpCDDs.

GC/ECD Analysis of PCBs. An aliquot of the cleaned-up hexane extract was transferred to a sample vial (1 mL, Wheaton 223682) and sealed with a Teflon-lined aluminum seal (11 mm, Wheaton 224211). High concentration samples were diluted with hexane such that the resultant concentration was within the approximate range of 500–2000 ng/mL Aroclor. Low concentration samples were concentrated by using a stream of nitrogen such that the resultant concentration was within the approximate range of 100–2000 ng/mL total Aroclor.

The gas chromatograph used for the analysis of PCBs was a Hewlett-Packard Model 5880 GC equipped with an electron-capture detector and automatic sampler (Hewlett-Packard Model 7672A). The column was a 2 m × 2 mm i.d. glass column packed with 3% OV-101 on Supelcoport, 80–100 mesh. The gas chromatographic conditions were 240, 220, and 300 °C for the injection port, oven, and detector, respectively. The carrier gas was 95% argon–5% methane with a flow rate of approximately 35 mL/min.

In samples that contained both Aroclor 1254 and Aroclor 1260, the contribution from Aroclor 1260 to the total peak height was calculated to approximate the quantity of Aroclor 1254 present. A ratio between the peaks used for quantitation of Aroclor 1254 and Aroclor 1260 was determined on the basis of an Aroclor 1260 standard. By use of this ratio and the calculated amount of Aroclor 1260 present, the contribution to Aroclor 1254 was subtracted. Then on the basis of the Aroclor 1254 standard, the amount of Aroclor 1254 present in the sample was calculated. For any sample in which the calculated concentration of one Aroclor was greater than 5 times the concentration of the other Aroclor, the Aroclor with the lowest concentration was reported as "none detected". The Aroclor levels were summed and reported as "total PCBs".

GC/ECD of OCDD and HpCDDs. The cleaned-up samples were assayed for OCDD and HpCDDs by using the procedure of Korfmacher et al. (*15*).

PCDD and PCDF Analysis. Selected surface wipe samples were analyzed for PCDDs and PCDFs by the CNFRL using the method of Smith et al. (*16*). Selected dust samples were Soxhlet-extracted for 24 h with benzene, and the extract was analyzed for PCDDs and PCDFs as described by Smith et al. (*16*).

Air Samples. Fifty-three air samples and five field blanks were taken at 32 separate sites, 14 of which were duplicates for future consideration and 44 of which were analyzed for PCBs. The samples for PCB analysis were collected by using the methodology developed by the New York State Department of Health for use in the Binghamton State office building which was contaminated after a 1981 fire involving a transformer (*7*). The sampling procedure for the determination of PCB air concentrations is termed the "New York State Florisil (NYSF) stick" procedure. The samples were collected at a flow rate of 1 L/min for a duration of approximately 8 h. The sampling period was chosen to coincide with normal working hours. The NYSF sticks were made with two sections of

Table I. PCDD and PCDF Analysis of Dust Samples

building	homologue type	2,3,7,8-tetra[b]	sum of isomers, ng/g[a] tetra	penta	hexa	hepta	octa
27[c]	PCDDs	ND (0.5)	ND (0.5)	ND	62	1160	1770
	PCDFs	6	6	35	180	220	110
21[d]	PCDDs	3	3	ND	200	2800	18000
	PCDFs	350	700	1400	600	440	540
23[e]	PCDDs	ND (0.5)	ND (0.5)	ND	96	600	2430
	PCDFs	11	11	44	182	190	160
29[e]	PCDDs	ND (0.5)	ND (0.5)	ND	55	475	1200
	PCDFs	10	10	9	17	36	30
26[e]	PCDDs	ND (0.5)	ND (0.5)	ND	ND	130	810
	PCDFs	4	4	4	20	38	32
2–5[e]	PCDDs	ND (0.5)	ND (0.5)	ND	3	24	16
	PCDFs	ND (0.5)	ND (0.5)	ND	1	19	0.6

[a] ND = none detected; the number in parentheses is the detection limit per isomer. [b] ng/g of the 2,3,7,8-tetra isomer. [c] Sample taken from one room. [d] Sample taken from air intake facing incinerator (see Figure 4). [e] Sample is a composite from indicated buildings.

Table II. PCDD and PCDF Analysis of Group I Surface Wipe Samples

building[a]	homologue type	2,3,7,8-tetra[c]	sum of isomers,[b] ng/m^2 [a] tetra	penta	hexa	hepta	octa
27	PCDD	ND (0.8)	ND (0.8)	68	270	1520	840
	PCDF	20	36	64	72	44	ND (2.0)
4	PCDD	ND (0.8)	ND (0.8)	ND	7	39	320
	PCDF	1	1	ND	10	18	36
29	PCDD	ND (0.8)	ND (0.8)	3	38	2200	3440
	PCDF	3	10	ND	16	440	480
25	PCDD	ND (0.8)	ND (0.8)	ND	28	192	1080
	PCDF	6	13	12	8	10	17
23	PCDD	ND (0.8)	ND (0.8)	I[a]	1980	4160	4520
	PCDF	16	16	60	220	360	48
27	PCDD	ND (0.8)	ND (0.8)	12	67	1304	2200
	PCDF	7	16	24	18	52	32
23	PCDD	ND (0.2)	ND (0.2)	ND (0.2)	23	420	470
	PCDF	8	16	17	17	89	21
23	PCDD	ND (0.2)	ND (0.2)	ND (0.2)	24	260	450
	PCDF	5	10	7	10	20	10

[a] Samples from the same building were taken from different rooms. [b] ND = none detected; the number in parentheses is the detection limit per isomer; I = interferences prevented detection. [c] ng/m^2 of 2,3,7,8-tetra isomer.

Florisil. Each section contained 0.4 g of Florisil preceded and followed by a glass wool plug. The front and back sections were separated by two plugs of glass wool. The front of each tube was spiked with 0.1 μg of *p,p′*-dichlorophenyldichloroethylene (*p,p′*-DDE) as an internal standard for measurement of recovery and as an indication of analyte migration. *p,p′*-DDE was chosen as the internal standard because it behaves chromatographically like PCBs and can be easily analyzed with PCBs by GC/ECD.

The Florisil sticks were scored with a file and broken between the two glass wool plugs that separated the Florisil sections. Each Florisil section (front and back) was eluted with 7 mL of hexane. The eluate was collected in a centrifuge tube and concentrated under a gentle stream of nitrogen. The concentrate from each Florisil section was analyzed by packed column GC/ECD. The detection limit was 0.1 μg of PCBs/m^3 of air. Quantitation was performed by the Webb–McCall method (*17*).

Results and Discussion

After detection of PCDDs and PCDFs in surface wipes of a room, a larger set of samples was analyzed for PCDD and PCDF content in order to define the nature of the problem at the facility. The results of the analyses of dust samples are shown in Table I and for surface wipe samples in Table II. Figure 1 shows the relative ratios of the tetra- through octa-CDDs and tetra- through octa-CDFs for samples analyzed from the facility. OCDD and the HpCDDs were the major components of the tetra- through octa-CDDs and tetra- through octa-CDFs (Figure 1). Additional preliminary samples were analyzed by GC/MS (by NCTR) and found to contain PCBs at levels of 100–1000 times that of the PCDFs and PCDDs.

Due to the large number of samples needed to determine the extent of the contamination, a multitiered approach was applied to the sample analysis. After the preliminary samples were analyzed by GC/MS using the method of Smith et al. (*16*) to determine the level and ratios of the tetra- through octa-CDFs and the tetra- through octa-CDDs. These same samples were also analyzed for PCB levels. A larger set of samples was analyzed by GC/ECD for OCDD and HpCDDs by using the method of Korfmacher et al. (*15*). All of the samples were analyzed for PCBs. By this approach, a detailed assessment of the contamination was obtained.

The chromatographic patterns for Aroclors 1254 and 1260 and the GC/ECD results of a surface wipe sample extract analyzed for PCBs are shown in Figure 2. Because peaks used for quantitation of Aroclor 1254 are also present in Aroclor 1260, accurate quantitation of Aroclor 1254 was difficult in samples that contained both Aroclors. The peaks used for quantitation of Aroclor 1260 are relatively specific for Aroclor 1260 and are not present in significant quantity in Aroclor 1254. For simplicity, the results were reported as "total PCBs".

The levels of PCBs found in one of the buildings at the site are listed in Table III. Samples were taken on each of the seven floors in this building. The level of PCBs

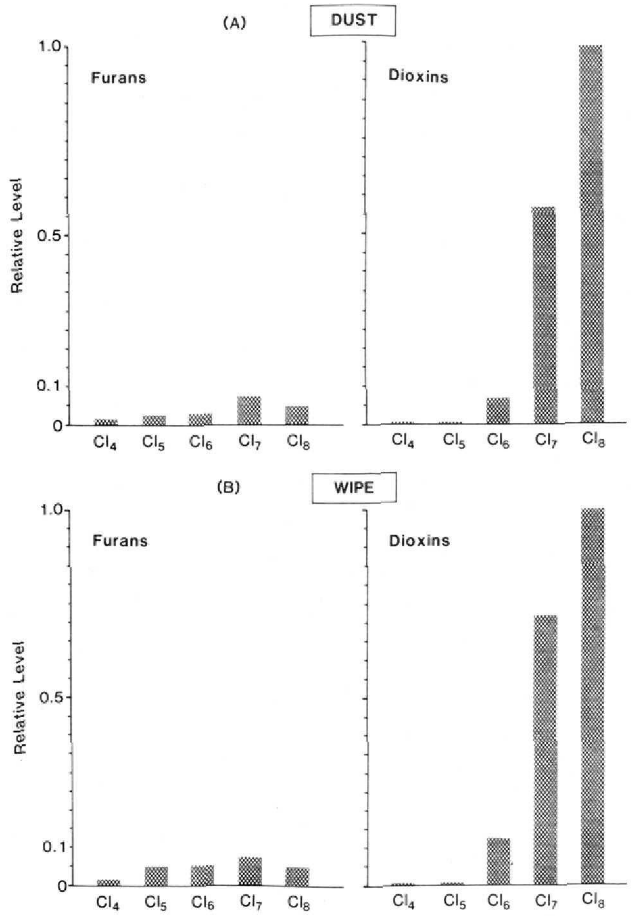

Figure 1. Relative weight ratios of the tetra-through octa-CDDs and tetra- through octa-CDFs for (A) dust samples and (B) surface wipe samples.

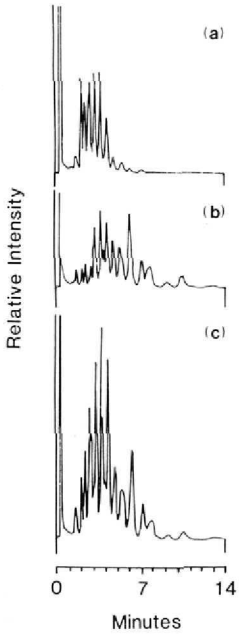

Figure 2. Typical GC/ECD results for (a) Aroclor 1254, (b) Aroclor 1260, and (c) a surface wipe sample containing PCBs.

Table III. Level of PCBs Found in Building 21

	sample type			
			EHS[b]	
floor no.	floor[a] wipe, mg/m^2	wall[a] wipe, mg/m^2	wipe,[c] mg/m^2	dust,[d] μg/g
1	10	1.5	14	
2	5.1	1.1		590
3	7.3	0.8	7.4	635
4	9.4	1.0	4.1	210
5	11	5.1	8.5	620
6	11	1.0	20	505
7	8.4	2.5	4.8	160
mean	8.9	1.9	9.8	453
SD	2.1	1.5	6.1	213

[a] Mean of three samples. [b] Elevated horizontal surfaces. [c] Zero to three samples per floor. [d] Zero to three samples per floor.

Table IV. Total PCBs in Air Samples

building	n[a]	average PCB level, μg/m^3
1	1	1.1
2	2	0.51
3	1	0.52
4	3	0.80
7	1	0.31
11	1	0.56
12	1	0.37
13	1	0.14
16	1	0.19
20	1	0.22
22	3	0.95
23	6	1.2
24	1	0.45
25	2	1.8
26	3	1.7
27	2	2.1
29	5	1.4
30	1	0.32
31	3	3.2
field blanks	5	<0.1
mean of 39 samples		1.2
SD		0.9

[a] Number of samples analyzed.

found on the floors and the elevated horizontal surfaces (EHS) were significantly higher than the levels found on the interior walls of the building (Table III). These results suggest that the source of the PCBs found in this building was airborne particulate matter and that the particulates settled out onto the floors and horizontal surfaces of the building. The level of PCBs was fairly uniform throughout this building with the PCB concentrations of the floor samples ranging from 5.1 to 11 mg/m^2. The average concentration of PCBs in floor samples was 8.9 mg/m^2.

Because PCBs were found on floor and wall surfaces and dust samples, it was decided that the level of PCBs in the air inside several of these buildings should be measured to evaluate the potential hazard posed to employees in occupied areas. The average recovery value for the *p,p'*-DDE internal standard in these samples was 96%. Sample blanks contained no detectable level of PCBs or *p,p'*-DDE. The results from these samples are summarized in Table IV. The NIOSH-recommended standard for occupational exposure to PCBs is a time-weighted average of 1.0 μg/m^3 for up to a 10-h workday, 40-h workweek. As shown in Table IV, the air sample PCB concentration was greater than or equal to 1.0 μg/m^3 for 15 of the 32 sites studied. The highest PCB level measured was 3.4 μg/m^3.

The average concentrations of PCBs found in 32 buildings at the site are listed in Table V. These are averages of wipe samples from floors and EHS. As this table shows, the average level of PCBs varied from none detected to 121 mg/m^2. Building 25 had the highest concentration of PCBs and was the site of a known PCB

Table V. Average Level of PCBs in Buildings, on Floors and Elevated Horizontal Surfaces[a]

building	n[b]	average PCB level,[c] mg/m²	building	n[b]	average PCB level,[c] mg/m²
1	3	4.0	17	2	0.093
2	6	<0.01	18	2	0.50
3	5	0.10	19	2	0.041
4	10	0.16	20	3	0.097
5	10	0.11	21	30	9.1
6	5	<0.01	22	5	0.53
7	3	0.04	23	54	4.8
8	2	0.05	24	17	0.81
9	2	0.37	25	26	121
10	1	0.07	26	15	1.7
11	5	0.34	27	19	40
12	5	0.016	28	4	0.089
13	2	0.15	29	69	5.9
14	2	0.019	30	8	0.18
15	2	<0.015	31	6	11
16	3	0.028	32	2	4.3

[a] Includes wipe samples from floors and elevated horizontal surfaces. [b] Number of samples analyzed. [c] Sum of Aroclor 1254 and Aroclor 1260.

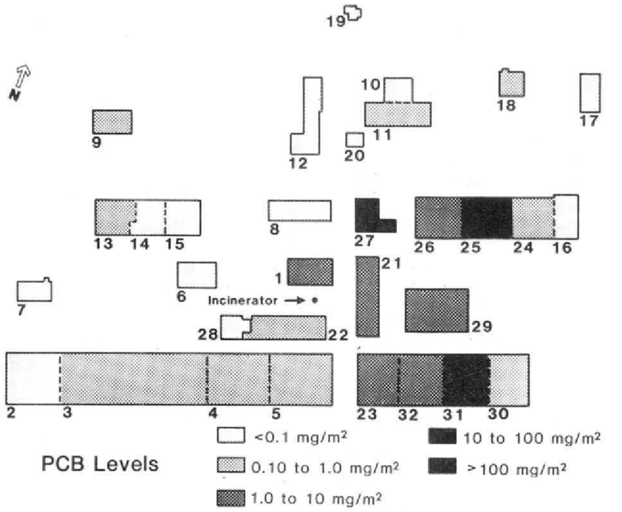

Figure 3. Schematic diagram of the facility indicating the average level of PCBs on the interior surfaces of the buildings.

spill. Therefore, the majority of the PCBs in this building are assumed to be due to that spill and not the result of the airborne contamination thought to be the cause of contamination at the other buildings. The next highest concentration was in building 27 which had an average PCB level of 40 mg/m². Building 27 is located near the incinerator (see Figure 3), as is building 21 which had an average PCB level of 9.1 mg/m².

A schematic diagram of the multibuilding facility indicating the average levels of the PCBs found on the interior surfaces of various buildings at the facility is shown in Figure 3. It can be seen that the PCB levels were higher on the east side of the incinerator than on the west side. It is thought that this is due to the wind direction at the time of incineration of the PCB askarel.

The data for samples that were analyzed for PCBs, OCDD, and HpCDDs by the GC/ECD method are summarized in Table VI. This table includes those samples that had detectable levels of both PCBs and OCDD. This data set shows that the results covered a wide concentration range.

This data set was used to test the hypothesis that the ratio of the concentration of total PCBs ([PCBs]) to the concentration of OCDD ([OCDD]) in a given sample was constant and the hypothesis that the ratio of the concentration of total HpCDDs ([HpCDDs]) to the [OCDD] in a given sample was also constant. The correlation coefficient between the [PCBs] and the [OCDD] was calculated to be 0.59, suggesting that there was a relationship. The correlation coefficient between the [HpCDDs] and the [OCDD] was calculated to be 0.94, strongly suggesting a relationship between these parameters. A general functional relationship between the [PCBs] and the [OCDD] could be described by

$$[\mathrm{PCBs}] = r[\mathrm{OCDD}]^k \tag{1}$$

By use of this relationship, if $k = 1$, then r is the ratio of the [PCBs] to the [OCDD]. Due to the wide degree of variation of the data, a logarithmic transformation of the data was performed. After transformation, the relationship was described by

$$\ln([\mathrm{PCBs}]) = \ln(r) + k \ln([\mathrm{OCDD}]) \tag{2}$$

The calculated regression estimates of k ± the standard deviation were 0.62 ± 0.33, 1.04 ± 0.24, and 0.88 ± 0.12 for the dust, wipe, and combined dust and wipe samples, respectively. Therefore, these estimates of k indicated that k could be equal to 1. Assuming that $k = 1$, then r represents the ratios of the [PCBs] to the [OCDD]. The estimated ratios of the [PCBs] to the [OCDD] calculated in this manner for the data summarized in Table VI are listed in Table VII. By use of the same methodology, the ratios of the [HpCDDs] to the [OCDD] were also calculated. These estimated ratios along with their 95% confidence limits are also listed in Table VII.

As an additional test of the utility of the relationship described by eq 1 and the corresponding relationship between the [HpCDDs] and the [OCDD] as mathematical descriptions of the data, χ^2 tests for the goodness-of-fit of the models were conducted. The calculated levels of significance of the tests (p values) were 0.44 and 0.45 for the [PCBs]/[OCDD] and the [HpCDDs]/[OCDD], respectively, indicating that the data fit the model (eq 1) well.

Table VII also includes the calculated ratios obtained from dust and wipe samples listed in Tables I and II. These ratios were calculated in the same manner as those

Table VI. Data Summary for Samples Analyzed for PCBs, OCDD, and HpCDDs[a]

			concentration[b]			
matrix	N[c]	analyte	x[d]	SD[e]	min[f]	max[g]
wipe	33	PCBs	30	94	0.01	530
	33	OCDD	0.017	0.027	0.0006	0.114
	28	HpCDDs	0.0079	0.013	0.0006	0.062
dust	24	PCBs	296	548	3.5	2000
	24	OCDD	0.030	0.41	0.009	1.7
	10	HpCDD	0.16	0.14	0.026	0.44

[a] This table includes those samples that had detectable levels of both PCBs and OCDD. The analysis for OCDD and HpCDDs was performed by using the GC/ECD method. [b] mg/m² for wipe samples; μg/g for dust samples. [c] Number of samples. [d] Mean concentration. [e] Standard deviation. [f] Minimum concentration. [g] Maximum concentration.

Table VII. Summary of Weight Ratios

sample	N[b]	[PCBs]/[OCDD]	conf limits[c] lower	conf limits[c] upper	N[b]	[HpCDDs/[OCDD]	conf limits[c] lower	conf limits[c] upper
On the Basis of GC/ECD Method of Analysis for OCDD and HpCDDs[a]								
wipe	33	497	262	1944	28	0.40	0.35	0.46
dust	24	334	148	750	10	0.29	0.18	0.45
combined	57	420	257	679	38	0.37	0.31	0.43
On the Basis of CNFRL GC–MS Method of Analysis for OCDD and HpCDDs								
wipe	5	641	177	1105	8	0.72	0.28	1.16
dust	5	891	0	2416	6	0.52	0	1.06
combined	10	766	147	1386	14	0.63	0.34	0.93
average[d]		593				0.50		

[a] Ratios obtained from the logarithmic transformation of the data (see text). [b] Number of samples. [c] 95% confidence limits. [d] Combined average of the two data sets.

described above, except that because of the relatively narrow range and smaller amount of variation of this data set, logarithmic transformation was not necessary.

Considering the range of the data, the [PCBs]/[OCDD] ratio was fairly consistent as was the [HpCDDs/[OCDD] ratio. The data in Table VII show that the [PCBs]/[OCDD] ratio was 593 and that the ratio of the [HpCDDs]/[OCDD] was 0.50. The good agreement between the wipe and dust samples strongly suggested that the source of contamination was the same for both. In addition, the agreement between the two methods of analysis for OCDD and HpCDDs suggested that these two methods provided similar results for these samples. The ability of these two methods to provide similar results for dust samples was demonstrated previously by Korfmacher et al. (*15*). Thus, the data shown in Table VII and described in Figure 1 support the hypothesis that OCDD can be used in these samples as a marker for all of the PCDDs and PCDFs and that total PCBs can also be used as a marker for the semiquantitative estimation of the PCDDs and PCDFs because the ratios were reasonably consistent. Therefore, in this case, the use of total PCBs as an indicator of total PCDDs and PcDFs appears to have been justified.

In order to establish the contamination route, dust samples were taken in the fresh air intake vents of buildings near the incinerator. Figure 4A is a three-dimensional view of buildings near the incinerator. The sites of the two air intake vents in tall building 21 which were sampled are indicated as black rectangles and exhibited levels of PCBs of 1800 and 90 µg of PCBs/g of dust. All other values shown in Figure 4 are averages of samples from two or more air intake vents for each building indicated.

The dust sample that displayed the highest level of PCBs was taken from the air intake vent near the top of tall building 21 (Figure 4A) that directly faces the incinerator and is at about the same height as the top of the incinerator stack.

Air intake vent samples from the other buildings shown in Figure 4 exhibited much lower PCB levels than the 1800 µg/g sample but were, however, still significant. The sample containing 1800 µg of PCBs/g of dust also was analyzed for PCDD and PCDFs, and the results are listed in Table I. As shown in Table I, this sample had high levels of PCDDs and PCDFs and was the only sample in which 2,3,7,8-TCDD was detected. These results suggest that PCBs, PCDDs, and PCDFs entered the building via the air intake vents and that the incinerator was the source of the problem.

In the 1960s large diffusion pumps were used in building 25 which were charged with 100 gallons of Aroclor 1254. The pumps were occasionally recharged, and the waste PCBs were incinerated. It was estimated that in the late sixties or early seventies (pre-1974) two separate 100-gallon burns of Aroclor 1254 probably occurred. Unfortunately, the incinerator was not designed to destroy PCBs. The incinerator was typically operated at approximately 650 °C with a 2-s residence time. Current research has shown that to destroy PCBs an incinerator should operate at 1200 °C and have a 2-s residence time (*14*). Therefore, it appears that the incineration of the Aroclor 1254 under the described conditions resulted not only in the incomplete destruction of the PCBs but also *in the production of* PCDDs and PCDFs.

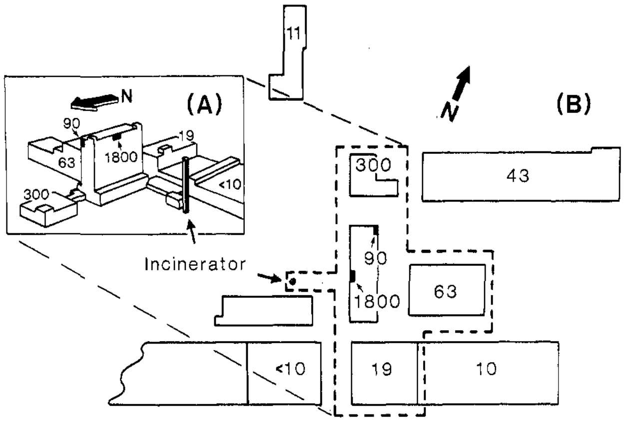

Figure 4. Schematic diagram (B) of the central part of the facility showing the level of PCBs in dust samples taken from air intake vents of the buildings shown in the figure. The levels are shown in the figure and have units of micrograms of PCBs per gram of dust. The insert (A) is a three-dimensional view of the buildings nearest the incinerator. In each case, the sites of the two air intake vents in the tall building (21) which were sampled are indicated.

The pattern of the PCDDs and PCDFs is not similar to that observed in transformer fires. Generally, in a PCB transformer fire, the levels of PCDFs produced are significantly greater than the level of PCDDs (*1, 3, 6, 22*). Emissions from incinerators have also shown greater levels of PCDFs than PCDDs (*10, 18, 19*). Thus, the pattern for the relative level of PCDDs and PCDFs does not match that which would be predicted from current research on the incineration of PCBs (*1, 2, 22*). The higher-than-expected level of PCDDs suggests the possibility that chlorinated benzenes were incinerated along with the PCBs. Alternately, the relatively high levels of OCDD and HpCDDs could indicate pentachlorophenol contamination (*20, 21*), but no evidence of pentachlorophenol incineration or contamination was found at the facility.

It is unclear what effect "weathering" had on the material, i.e., the 12–17 years of residence time after the incineration until the samples were taken. Thus, this site is indeed unique. Generally, samples are taken shortly after an incident, such as a transformer fire, but at the described site, samples were not taken until 12–17 years after the incineration (which is thought to have caused the problem) took place. Recently, we learned of one other site in which there was a significant interval between the incident and the sampling and analysis. Preliminary results from a building that was the site of a transformer fire, but for which wipe samples were not taken until 3 years after the fire, indicated a similar profile for the tetra- to octa-CDDs and tetra- to octa-CDFs; OCDD was the component at the highest level and was 100 times the level of OCDF (*23*).

These results demonstrate that the multibuilding facility was contaminated by PCBs, PCDDs, and PCDFs and that the source was most likely due to the incomplete incineration of PCB askarel at an incinerator at the site. The effluent from the incinerator was airborne and spread throughout the complex through ventilation systems.

Efforts have been taken to clean up this facility, and the results of the initial decontamination efforts will be reported elsewhere.

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Registry No. 2,3,7,8-TCDD, 1746-01-6; PCDD, 36088-22-9; HpCDD, 37871-00-4; OCDD, 3268-87-9; 2,3,7,8-TCDF, 51207-31-9; PCDF, 36088-22-9; HpCDF, 38998-75-3; OCDF, 39001-02-0; hexachlorodibenzo-*p*-dioxin, 34465-46-8; hexachlorodibenzofuran, 55684-94-1.

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