

BACKGROUND CONCENTRATIONS OF POLYCHLORINATED DIBENZOFURANS (PCDFs)
AND POLYCHLORINATED DIBENZO-P-DIOXINS (PCDDs) IN OFFICE BUILDINGS
IN BOSTON, MASSACHUSETTS

John R. Kominsky*

Division of Surveillance, Hazard Evaluations, and Field Studies
National Institute for Occupational Safety and Health
Cincinnati, Ohio 45226

Christopher D. Kwoka

Environmental Engineering Division
SOS International
South San Francisco, California 94080

ABSTRACT

Two office buildings were tested to determine the background surface and air concentrations of PCDFs and PCDDs. Surface samples showed higher concentrations of PCDDs than PCDFs, increase of PCDD concentration with degree of chlorination, similar concentrations of PCDFs irrespective of degree of chlorination, and significant correlations between concentrations of PCBs, and PCDFs and PCDDs. Air samples generally contained non-detectable concentrations of PCDFs and lower chlorinated PCDDs; and a predominance of higher chlorinated PCDDs. These data define a concentration baseline for PCDFs and PCDDs in these buildings, but may be indicative of the concentrations present in other office buildings.

INTRODUCTION

It is now recognized that polychlorinated dibenzofurans (PCDFs) and polychlorinated dibenzo-p-dioxins (PCDDs) are ubiquitous contaminants of the environment. These compounds can be found in various environmental samples and living organisms, including man (1). Environmental contamination from PCDFs and PCDDs can occur through the use of chemical products contaminated with these compounds and emissions from combustion sources (2). Fire-related incidents involving electrical equipment containing polychlorinated biphenyls

(PCBs) have resulted in contamination of buildings with PCDFs and PCDDs (3). Interpretation of contamination assessment data is complicated by the absence of consensus standards and the paucity of comparative background data for these compounds in office buildings (4).

This paper presents the results of a study conducted to determine the concentrations of PCDFs and PCDDs present as normal levels of background contamination in two multi-story office buildings in Boston, MA. The buildings were both constructed in the mid-1960's and had no history of electrical transformer fire or failure.

STUDY DESIGN AND METHODS

The buildings were tested for surface and air concentrations of PCDFs and PCDDs (2,3,7,8-tetra CDF and CDD isomers, and total tetra- through octa-chlorinated homologs). Wipe samples were obtained on building surfaces and interior air-handling unit (AHU) surfaces. Building surfaces included high skin contact and elevated horizontal surfaces. High skin contact surfaces are those with which a person would probably have frequent and/or prolonged direct dermal contact such as desks, tables, counters and file cabinets. Elevated horizontal surfaces are those surfaces at a height of greater than six-feet above the floor such as tops of storage cabinets or bookshelves. The interior AHU surfaces included the floor of the fan's air intake plenum and fan housing. The PCDF and PCDD surface wipe samples were collected at locations paired to the collection of PCB samples to determine the existence of a statistical relationship. Air samples for PCDFs and PCDDs were obtained in the workspace and ambient air intake plenums of the buildings.

Surface Sampling Methods

The surface samples were collected using 3" x 3" soxhlet extracted cotton gauze pads wetted with 8-ml of pesticide grade hexane. The sampling procedure consisted of marking off a surface into a 0.25 m² area using a galvanized steel template or a metal tape measure. Each 0.25 m² area was wiped, with a gauze pad held with a gloved-hand, in two directions; the second direction was performed at a 90° angle to the first direction. The gauze pad sample was then placed in a glass sample container equipped with a Teflon-lined lid. Each PCDD and PCDF sample was a composite of four 0.25 m² samples for a total area of 1.0 m², whereas the PCB samples consisted of a single sample from an area of 0.25 m². The samples were extracted and analyzed for PCDFs and PCDDs using high resolution capillary column gas chromatography and selected ion monitoring mass spectrometry (5). The samples were extracted and analyzed for PCBs using capillary column gas chromatography electron capture detection (6).

The air samples for PCDDs and PCDFs were collected using a two-stage sampling device developed by the New York State Health Department (7). The first stage is a 47-mm diameter, 0.3 µm pore size binderless glass fiber filter. The second stage is a cartridge of 8 gms of silica gel adsorbent which is spiked with 2.5 ng each of labelled 2,3,7,8-TCDD

and 2,3,7,8-TCDF before sampling. The samples were collected for approximately a 50-hour period at a flow rate of 20 L/min to achieve an air volume of approximately 60 m³. The samples were analyzed using the same procedures as the surface wipe samples.

RESULTS AND DISCUSSION

Surface Concentrations

A total of 28 surface wipe samples were collected for analysis of 2,3,7,8-tetra CDF and CDD isomers, and total tetra- through octa-chlorinated homologs. Twenty-four of the 28 samples were collected on building surfaces; and four samples were collected on interior AHU surfaces.

The concentrations measured on building surfaces are summarized in Table 1. The total PCDDs (range 2.8 to 146 ng/m²) are present in higher concentrations than PCDFs (range 0.47 to 5.4 ng/m²) with the concentration of PCDDs increasing about two orders of magnitude on chlorination from penta- to octa-CDD. The 2,3,7,8-TCDF isomer was consistently present (19 of 24 samples) at concentrations ranging from 0.06 to 0.40 ng/m²; 2,3,7,8-TCDD was not detected in any of the samples. The distribution of PCDF and PCDD homologs are shown in Figure 1. PCDFs are more uniform in their distribution with the presence of both lower- and higher- chlorinated homologs. PCDDs are non-detected in the lower chlorinated homologs but their presence increases with degree of chlorination. Octa-CDD represented approximately 86% of the total PCDDs present.

The concentrations of PCDFs and PCDDs measured on high skin contact and elevated horizontal surfaces are summarized in Table 2. The log transformed concentrations of PCDFs on high skin contact surfaces are numerically lower than those on elevated horizontal surfaces, but this difference is not statistically significant ($t = 1.84$, $p > 0.086$). The log transformed concentrations of PCDDs on high skin contact surfaces are significantly lower ($t = 2.16$, $p < 0.046$) than those present on elevated horizontal surfaces.

The 24 PCDF and PCDD samples were collected at locations paired to the collection of PCB samples to determine the existence of a statistical relationship. Twenty-three of the 24 PCB samples showed detectable concentrations; overall, the PCB concentrations ranged from non-detected (<1 ug /m²) to 40 ug/m² with an arithmetic mean of 14 ug/m². Linear regression analysis of the log transformed concentrations shows that a significant correlation (Table 3) exist between the concentrations of PCBs and concentrations of PCDFs and PCDDs in these buildings.

The concentrations of PCDFs and PCDDs measured on interior air-handling unit (AHU) surfaces are summarized in Table 4. Qualitatively the data are very similar to that shown for building surfaces (Table 1 and Figure 1). PCDDs (range 69 to 421 ng/m²) are present in higher concentrations than PCDFs (range 6.5 to 53 ng/m²) with the concentration of PCDDs increasing with degree of chlorination (Figure 2), and similar concentrations of PCDFs

irrespective of degree of chlorination (Figure 2). Quantitatively the data are dissimilar in that the concentrations of PCDFs and PCDDs on AHU surfaces are significantly higher ($t = 6.51$ and 4.11 , $p < 0.001$, respectively) than those present on building surfaces. The 2,3,7,8-TCDF isomer was present in all samples ranging from 0.37 to 1.9 ng/m^2 ; 2,3,7,8-TCDD was not detected in any of the samples.

The four PCDF and PCDD AHU samples were collected at locations paired to the collection of PCB samples to determine the existence of a statistical relationship. The PCB samples all contained detectable concentrations ranging from 19 to 280 ug/m^2 with an arithmetic mean of 158 ug/m^2 . Linear regression analysis of the log transformed data did not demonstrate a significant relationship between the concentrations of PCBs and concentrations of PCDFs and PCDDs on AHU surfaces. In the case of the PCDFs, there was not a large enough sample to demonstrate a statistically significant correlation. The sample size would have to be increased to at least ten paired observations in order for a correlation coefficient of 0.63 to be statistically significant ($p < 0.05$).

The concentrations of PCDFs and PCDDs on building and interior AHU surfaces were converted to 2,3,7,8-TCDD equivalents using the toxicity equivalence factors recommended by U.S. EPA (8). The concentrations of 2,3,7,8-TCDD equivalents ranged from 0.01 to 0.17 ng/m^2 (arithmetic mean 0.05 ng/m^2) and from 0.31 to 2.3 ng/m^2 (arithmetic mean 0.93 ng/m^2), respectively.

Airborne Concentrations

A total of 16 air samples were collected for analysis of 2,3,7,8,-tetra CDF and CDD isomers, and total tetra- through octa-chlorinated homologs. Twelve of the 16 samples were collected in the workspace of the buildings (Table 5); and four samples were collected in the ambient air intake plenums of the buildings (Table 6).

PCDFs were generally non-detected, except for three samples that showed detectable concentrations of tetra- and penta-CDFs. Two of these samples (one workspace and one ambient air) contained 2,3,7,8-TCDF (1.4 and 0.83 pg/m^3 , respectively). The distributions of total PCDD homologs are quite similar to those shown for the surface wipe samples. In both, there is an absence of the lower chlorinated CDDs and a predominance of the higher chlorinated homologs with the maximum concentrations represented by octa-CDD. The calculated concentrations of 2,3,7,8-TCDD equivalents for the two samples containing 2,3,7,8-TCDF are 0.34 and 0.20 pg/m^3 , respectively.

CONCLUSIONS

PCDFs and PCDDs are present as background contaminants in two office buildings studied. PCDDs are present at higher concentrations than PCDFs in these buildings. PCDDs showed an absence of lower chlorinated homologs and a predominance of octa-CDD. PCDFs were more

uniform in distribution with the consistent presence of 2,3,7,8-TCDF on surfaces. Interpretation of contamination assessment data should consider the inherent concentrations of PCDFs and PCDDs that may exist in other office buildings.

ACKNOWLEDGEMENTS

The authors are grateful to Don Nalls and Bill Upton, SOS International; Wes Straub, NIOSH; and Joan Parker and Elise Morse, Department of Labor and Industry, Commonwealth of Massachusetts for their administrative efforts in coordinating the study. The authors also are greatly appreciative for the field assistance provided by the following persons: Don Nalls, Pat O'Neill, Brenda Lothridge, Holli Rauvola, Jim Newcomb, Linda Newcomb and Bill Upton, Environmental Engineering Division, SOS International; Joan Parker and Elise Morse, Commonwealth of Massachusetts; and Wes Straub and Kevin McManus, NIOSH. Chemical analysis of samples for PCDFs and PCDDs by Battelle-Columbus Laboratories, and PCBs by Versar Inc. - all of which is greatly appreciated. The authors are also grateful to Mr. Bill Stringer, NIOSH statistician, for assistance in the analysis of the data.

REFERENCES

1. J.S. Stanley, K.E. Boggess, J. Onstat et al. PCDDs and PCDFs in Human Adipose Tissue from the EPA FY 82 NHNATS Repository. *Chemosphere* 15 (9-12):1605-1612, 1986.
2. Environmental Protection Service, Environment Canada. Polychlorinated Dibenzo-p-Dioxins and Polychlorinated Dibenzofurans: Sources and Releases. Report EPA 5/HA/2, July 1985.
3. J.R. Kominsky and J.M. Melius. PCB, PCDF, and PCDD Contamination of Structures Resulting from Electrical Equipment Fires and Failures. Proceedings of the 7th Annual RMCOEH Conference "Hazardous Waste Management and Control: Weighing the Risks", Park City, UT, 1985.
4. J.R. Kominsky, W.T. Slade and R. Mooring. Background Concentrations of Polychlorinated Biphenyls, Polychlorinated Dibenzo-p-Dioxins, and Polychlorinated Dibenzofurans in Office buildings in Santa Fe, New Mexico. Proceedings of the 1987 PCB Conference. Electric Power Research Institute, Palo Alto, CA, 1987.
5. F.L. DeKoos and S.C. Watson. Analytical Report: Determination of Polychlorinated Dibenzo-p-Dioxin and Polychlorinated Dibenzofurans in Samples from Boston, MA. Battelle, Columbus Division, Columbus, OH, December 19, 1986.
6. Versar Inc. Analytical Report: Determination of PCBs in Surface Wipe Samples. Versar, Inc. Springfield, VA, November 1986.

7. P.W. O'Keefe, J.B. Silkworth, J.F. Gierthy et al. Chemical and Biological Investigations of a Transformer Accident at Binghamton, NY. Environ. Health Perspect. 60:201-209, 1985.
8. U.S. EPA. Interim Procedures for Estimating Risks Associated with Exposures to Mixtures of Chlorinated Dibenzo-p-Dioxins and Dibenzofurans. Risk Assessment Forum, EPA 625/3-87/012.

Table 1

Concentrations of PCDFs and PCDDs on Surfaces in Office Buildings

	n/N ^a	Concentration ng/m ²		
		Mean ^b	Range	
2,3,7,8-TCDF	19/24	0.18	(0.04) ^c	- 0.40
TCDFs	19/24	0.32	(0.04)	- 0.84
PeCDFs	16/24	0.13	(0.01)	- 1.0
HxCDFs	18/24	0.21	(0.01)	- 1.2
HpCDFs	23/24	0.54	(0.09)	- 1.8
OCDF	24/24	0.50	0.11	- 2.0
Total PCDFs	-	1.70	0.47	- 5.4
2,3,7,8-TCDD	0/24	-	(0.01	- 0.28)
TCDDs	0/24	-	(0.01	- 0.28)
PeCDDs	1/24	-	(0.02)	- 0.19
HxCDDs	20/24	0.34	(0.02)	- 1.1
HpCDDs	24/24	3.3	0.46	- 15
OCDD	24/24	22	2.1	- 130
Total PCDDs	24/24	26	2.8	- 146

^a n/n denotes the number of samples above the detection limit/the total number of samples.

^b Arithmetic mean calculated with non-detected values treated as one-half the detection limit.

^c Value in parentheses is the limit of detection.

Table 2

Concentrations of PCDFs and PCDDs on High Skin Contact
and Elevated Horizontal Surfaces in Office Buildings

	PCDFs ng/m ²			PCDDs ng/m ²		
	<u>N</u>	<u>Mean</u>	<u>Range</u>	<u>N</u>	<u>Mean</u>	<u>Range</u>
High Skin Contact	12	0.98	0.50 - 1.9	12	12	4.1 - 42
Elevated Horizontal	12	2.4	0.47 - 5.4	12	40	2.8 - 146
Overall	24	1.7	0.47 - 5.4	24	26	2.8 - 146

Table 3

Correlation Between PCBs, and PCDFs and PCDDs on Surfaces in Office Buildings

	Building Surfaces			Interior AHU Surfaces		
	<u>N</u>	<u>Corr. Coeff.</u>	<u>P</u>	<u>N</u>	<u>Corr. Coeff.</u>	<u>P</u>
PCDFs	24	0.49	<0.02	4	0.63	>0.36
PCDDs	24	0.48	<0.02	4	0.03	>0.97

Table 4

Concentrations of PCDFs and PCDDs
on Interior Air-Handling Unit Surfaces in Office Buildings

	n/N ^a	Concentration ng/m ²	
		Mean ^b	Range
2,3,7,8-TCDF	4/4	1.1	0.37 - 1.9
TCDFs	4/4	3.3	0.81 - 8.3
PeCDFs	4/4	2.3	0.56 - 5.4
HxCDFs	4/4	5.3	1.4 - 9.9
HpCDFs	4/4	13	1.3 - 30
OCDF	4/4	5.0	1.3 - 8.5
Total PCDFs	-	29	6.5 - 53
2,3,7,8-TCDD	0/4	-	(0.02 - 0.27) ^c
TCDD	0/4	-	(0.02 - 0.27)
PeCDDs	3/4	0.63	(0.11) - 2.0
HxCDDs	4/4	4.4	1.3 - 9.7
HpCDDs	4/4	33	7.7 - 89
OCDD	4/4	135	58 - 320
Total PCDDs	-	173	69 - 421

^a n/N denotes the number of samples above the detection limit/the total number of samples.

^b Arithmetic mean calculated with non-detected values treated as one-half the detection limit.

^c Value in parentheses is the limit of detection.

Table 5
Airborne Concentrations of PCDFs and PCDDs in Office Buildings

	n/N ^a	Concentration pg/m ³		
		Mean	Range	
2,3,7,8-TCDF	1/12	-	(0.37) ^b	- 1.4
TCDFs	2/12	-	(0.64)	- 6.2
PeCDFs	2/12	-	(0.12)	- 1.9
HxCDFs	1/12	-	(0.09)	- 0.36
HpCDFs	0/12	-	(0.39)	- 1.5)
OCDF	0/12	-	(0.54)	- 1.8)
2,3,7,8-TCDD	0/12	-	(0.32)	- 1.4)
TCDDs	0/12	-	(0.32)	- 1.4)
PeCDDs	0/12	-	(0.19)	- 1.1)
HxCDDs	0/12	-	(0.25)	- 0.95)
HpCDDs	6/12	-	(0.66)	- 2.0
OCDD	12/12	4.8	3.2	- 7.6

^a n/N denotes the number of samples above the detection limit/the total number of samples.

^b Value in parentheses is the limit of detection.

Table 6
Ambient Air Concentrations of PCDFs and PCDDs in Boston
October 17-20, 1986

	n/N ^a	Concentration pg/m ³		
		Mean	Range	
2,3,7,8-TCDF	1/4	-	(0.72) ^b	- 0.83
TCDFs	1/4	-	(0.72)	- 4.4
PeCDFs	1/4	-	(0.23)	- 1.2
HxCDFs	0/4	-	(0.11)	- 0.29)
HpCDFs	0/4	-	(0.51)	- 1.5)
OCDF	0/4	-	(0.51)	- 2.8)
2,3,7,8-TCDD	0/4	-	(0.40)	- 0.57)
TCDDs	0/4	-	(0.40)	- 0.57)
PeCDDs	0/4	-	(0.51)	- 1.6)
HxCDDs	0/4	-	(0.27)	- 0.51)
HpCDDs	2/4	-	(1.2)	- 1.6
OCDD	4/4	4.8	3.5	- 5.6

^a n/N denotes the number of samples above the detection limit/the total number of samples.

^b Value in parentheses is the limit of detection.

Figure 1. PCDF AND PCDD homolog distributions for wipe samples obtained on building surfaces

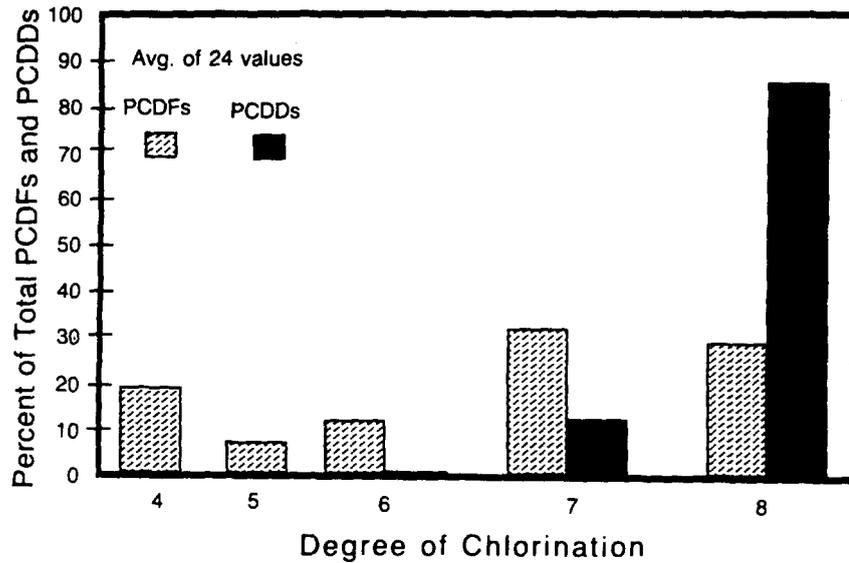


Figure 2. PCDF and PCDD homolog distributions for wipe samples obtained on interior air – handling unit surfaces

