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COMMERCIAL OFFICE BUILDINGS
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I. SUMMARY

In October 1986 a study was conducted to determine the surface and air concentrations of polychlorinated biphenyls (PCBs), polychlorinated dibenzofurans (PCDFs), and polychlorinated dibenzo-p-dioxins (PCDDs) present as background contamination in two office buildings in Boston, and compare these data to the guidelines selected for cleanup of the 50 Staniford Street Office Building; the latter building experienced a transformer fire in 1981. Two office buildings, which had no history of experiencing an electrical transformer fire or failure, were tested for PCBs, as well as PCDFs and PCDDs (tetra- through octa-chlorinated homologs, and the respective 2,3,7,8-tetra isomers). Wipe samples were obtained on workspace surfaces (floors, walls, desks, cabinets, etc.) and interior air-handling unit (AHU) surfaces. Air samples were obtained in the workspace and fresh-air intake plenums of the buildings.

The PCB concentrations on workspace surfaces ranged from <1 - 69 ug/m^2 (n = 101, geometric mean = 11 ug/m^2) and <1 - 110 ug/m^2 (n = 97, geometric mean = 5.6 ug/m^2) in Building One and Two, respectively. In both buildings, the measured PCB concentrations (log transformed) were significantly (t = -2.35 and t = -2.51, $p < 0.05$) less than the guideline of 50 ug/m^2 (log transformed). The PCB concentrations on interior AHU surfaces ranged from 22 - 470 ug/m^2 (n = 11, geometric mean = 129 ug/m^2) and from 14 - 150 ug/m^2 (n = 15, geometric mean = 47 ug/m^2) in Building One and Two, respectively. In Building One, the geometric mean concentration was numerically greater than 50 ug/m^2, but this difference was not statistically significant (t = 1.0, $p > 0.05$). In Building Two, the mean concentration (log transformed) was not significantly different (t = -0.091, $p > 0.05$) from the guideline value (log transformed). The PCDF concentrations on workplace surfaces ranged from 0.48 - 5.4 ng/m^2 (n = 24, arithmetic mean = 1.7 ng/m^2), and those on AHU surfaces ranged from 6.5 to 53 ng/m^2 (n = 4, arithmetic mean = 28 ng/m^2). The PCDD concentrations on workplace surfaces ranged from 2.8 - 146 ng/m^2 (n = 24, arithmetic mean = 26 ng/m^2), and those on AHU surfaces ranged from 69 - 421 ng/m^2 (n = 4, arithmetic mean = 173 ng/m^2). The concentrations of PCDFs and PCDDs for all 28 samples, converted to 2,3,7,8-TCDD equivalents, ranged from 0.02 to 2.3 ng/m^2, with one value (AHU sample) exceeding the guideline of 1 ng/m^2. The PCB air concentrations in the workspace ranged from 0.06 - 0.31 ug/m^3 (n = 24, arithmetic mean = 0.17 ug/m^3), which are all below the guideline of 0.5 ug/m^3. Two of the three ambient air samples showed PCB concentrations of 0.04 and 0.05 ug/m^3. The airborne PCDFs were generally non-detected except for 3 of 16 samples that contained tetra- and penta-CDFs. The airborne PCDDs were all non-detected, except for the hepta- and octa-CDDs. The maximum concentration calculated for the airborne 2,3,7,8-TCDD equivalents was 0.34 pg/m^3, which is below the guideline of 2 pg/m^3.

Based upon the sampling results obtained from the two selected office buildings in Boston, it is concluded that the concentrations of PCBs, and PCDFs and PCDDs (converted to 2,3,7,8-TCDD equivalents) that are present in office air and on workspace surfaces as normal background contamination in these buildings are below the guidelines used for cleanup of the Staniford Street Building. It is also concluded that the AHUs contain surface concentrations of PCBs, and to a lesser extent 2,3,7,8-TCDD equivalents in excess of the guideline values.

KEYWORDS: SIC 9199 (Office Building), polychlorinated biphenyls, PCBs, polychlorinated dibenzofurans, PCDFs, polychlorinated dibenzo-p-dioxins, PCDDs, background, air, surface, TCDD-equivalents.

II. INTRODUCTION

On August 8, 1986, the National Institute for Occupational Safety and Health (NIOSH) was requested by Charles River Park Properties to conduct a study to determine the background concentrations of polychlorinated biphenyls (PCBs), polychlorinated dibenzofurans (PCDFs), and polychlorinated dibenzo-p-dioxins (PCDDs) in office buildings in Boston, Massachusetts. The objective of the study was to determine how the environmental criteria selected as guidelines for clean-up of the 50 Staniford Street Office Building compared to normal levels of background contamination that exist in other similar buildings in Boston; the Staniford Street Office Building experienced a transformer fire in October 1981.

On October 17-20, 1986, NIOSH with assistance from the Commonwealth of Massachusetts Department of Labor and Industries, Division of Occupational Hygiene, and SOS International, Environmental Engineering Division conducted a study to determine the background concentrations of PCBs, PCDFs, and PCDDs in two office buildings in Boston, Massachusetts.

III. BACKGROUND

A. Staniford Street Office Building Transformer Incident

On October 25, 1981, a fire occurred in an electrical transformer located in the upper basement of the 50 Staniford Street Office Building in Boston, Massachusetts. The transformer contained a coolant liquid consisting of Aroclor 1254 (a commercial mixture of poychlorinated biphenyls with approximately 54% chlorine by weight). The resultant combustion soot containing polychlorinated biphenyls (PCBs) and pyrolysis products including polychlorinated dibenzofurans (PCDFs) and polychlorinated dibenzo-p-dioxins (PCDDs) was transported by both mechanical and natural ventilation throughout the upper basement, and possibly other areas of the building. A contractor removed the heavy soot deposits in the upper basement area; painted the wall, ceiling and floor surfaces; and replaced the contaminated ventilation ducts.

Testing conducted in June, September and October of 1985 by private consultants [1,2] showed that the upper basement was still contaminated with PCBs, PCDFs, and PCDDs; maximum air and surface concentrations were present in the restricted access areas including the transformer vault and switchgear rooms. The testing also showed that floors one through four were contaminated with low concentrations of PCBs and, to a lesser extent PCDFs and PCDDs. Floors one through four were cleaned between November 1985 and January 1986, and the upper basement between January and December 1986.

NIOSH was requested by Charles River Park Properties (the building property management company) to design and implement a Final Test Plan to verify that the 50 Staniford Street Office Building had been cleaned to acceptable guidelines. The guidelines selected by the NIOSH investigators for the building were the same as those recommended by the Governor appointed Advisory Panel for certification of the New Mexico State Highway Department (NMSHD) Building in Santa Fe, New Mexico [3]; the NMSHD Building experienced an electrical transformer malfunction on June 17, 1985 [4]. In addition, Charles River Park Properties requested that NIOSH conduct a study to determine how these criteria levels compared to normal concentrations of background contamination that exist in other similar buildings in Boston, Massachusetts.

B. Clean-up Criteria

The clean-up criteria established by the New Mexico Advisory Panel were based on the maximum levels of PCBs, PCDFs, and PCDDs that would not result in a significant human health risk if a person were exposed to these levels for a working lifetime of 30 years. The guidelines for PCDFs and PCDDs were intended to maintain the risk of developing cancer below one in one million for a person spending a working lifetime (30 years) in the building. The guidelines for PCBs took into account the usual presence of detectable background levels of PCBs in air [5] and on surfaces [6] and were intended to guide the cleanup within a safe margin of this background level.

The surface and air guidelines recommended by the Panel are shown below:

	AIR	SURFACE
PCBs	0.5 ug/m^3	50 ug/m^2
2,3,7,8-TCDD Equivalents	2 pg/m^3	1 ng/m^2

Units: ug/m^3 = micrograms of PCB per cubic meter of air.
pg/m^3 = picograms of TCDD Equivalents per cubic meter of air.
ug/m^2 = micrograms of PCB per square meter of surface.
ng/m^2 = nanograms of TCDD Equivalents per square meter of surface.

The potential toxicity of the PCDF and PCDD mixtures was assessed based upon the calculated concentration of 2,3,7,8-tetrachlorodibenzo-p-dioxin equivalents (TCDD-equivalents). This procedure, first proposed by the New York State Department of Health [7], permits calculation of the amount of 2,3,7,8-TCDD that would have to be present to exhibit the same toxicity as the measured quantities of each of the various PCDFs and PCDDs that are present, and the summation of these calculated amounts of 2,3,7,8-TCDD equivalents is an estimate of the total TCDD-equivalent toxicity of the mixture. This procedure assigned toxicity weighting factors equal to the relative toxicity of the various PCDFs and PCDDs chlorinated in the 2,3,7,8-positions as compared to the toxicity of 2,3,7,8-tetrachlorodibenzo-p-dioxin. The U.S. EPA reviewed the available data on toxicity of these chemicals, and has recommended toxicity equivalence factors (TEFs) for calculating the 2,3,7,8-TCDD equivalence of a mixture of PCDDs and PCDFs [8]. The TEFs used to calculate the 2,3,7,8-TCDD equivalents are listed below:

PCDDs	TEF	PCDFs	TEF
2,3,7,8-TCDD	1	2,3,7,8-TCDF	0.1
other TCDDS	0.01	other TCDFs	0.001
Total PeCDDS	0.5	Total PeCDFs	0.1
Total HxCDDs	0.04	Total HxCDFs	0.01
Total HpCDDs	0.001	Total HpCDFs	0.001
OCDD	0	OCDF	0

IV. STUDY DESIGN AND METHODS

A. Study Design

The objective of the study was to determine the air and surface concentrations of PCBs, PCDFs, and PCDDs present as background contamination in office buildings in Boston, and compare these data to the criteria (see Part III, Section B) selected as guidelines for clean-up of the 50 Staniford Street Office Building in Boston.

Two buildings were selected for testing. The buildings were constructed in the mid-1960's, and had no history of experiencing an electrical transformer fire or failure. Building Number One consists of twin, 24-story office towers and a low-rise, five-story office tower. The twin-towers are connected by a common elevator core, and the low-rise section is connected by a corridor at the first floor lobby and second floor levels. (The testing was limited to the twin towers.) The air in the twin towers is conditioned (cooled or heated) and circulated throughout the building by 11 separate air handling units (AHUs) located in the basement and roof penthouse mechanical equipment rooms. Building Number Two consists of a single 22-story office tower. The building's air is conditioned and circulated throughout the building by 17 separate AHUs located in the basement, first, second, and twenty-third floor mechanical equipment rooms.

The buildings were tested for surface and air concentrations of PCBs, as well as PCDFs and PCDDs (2,3,7,8-tetra CDF and CDD isomers, and total tetra- through octa-chlorinated homologs). The buildings were tested with the heating, ventilation, and air-conditioning (HVAC) system operating under normal occupancy conditions. The fresh-air intake plenums were sampled to determine the concentration of these contaminants in the ambient air entering the buildings.

The frequency of the air and surface samples collected by building is summarized below:

	Air		Surface	
	PCB	PCDF/PCDD	PCB	PCDF/PCDD
Building One	12	6	112	14
Building Two	12	6	112	14
Ambient Air	4	4	-	-
Field Blanks	6	2	18	2
Total	36	18	242	30

The PCB samples were obtained on both building surfaces (floors, walls, elevated horizontal, and high skin contact surfaces) and interior air handling unit (AHU) surfaces. The PCDF and PCDD samples were limited to elevated horizontal and high skin contact surfaces, and interior AHU surfaces. Elevated horizontal surfaces are those surfaces at a height of greater than six-feet above the floor. Typical elevated horizontal surfaces included tops of storage cabinets and bookshelves. High skin contact surfaces are those with which a person would probably have frequent and/or prolonged direct dermal contact. Typical high skin contact surfaces include desks, tables, counters, file cabinets, and miscellaneous work surfaces. The interior AHU surfaces included the floor of the fan's air-intake plenum and fan housing.

The frequency of the samples collected by type of surface is presented below:

Building	Type of Surface	PCB	PCDF/PCDD
One	Wall	12	-
	Floor	12	-
	Elevated Horizontal	41	6
	High Skin Contact	36	6
	Air Handling Unit	11	2
Two	Wall	12	-
	Floor	12	-
	Elevated Horizontal	37	6
	High Skin Contact	36	6
	Air Handling Unit	15	2

B. Sampling and Analytical Methods

a. Air Sampling - PCBs, PCDFs, and PCDDs

Air samples for PCBs were collected using a modification of a florisil stick procedure developed by the New York State Department of Health. The New York State Florisil (NYSF) stick procedure was modified by trapping airborne particulates on a 47-mm, 0.3 um pore size glass fiber filter before collecting the vapor phase on the florisil. This modification is consistent with NIOSH method 5503 [9].

The NYSF stick is a glass tube 9.5 inches long by 0.375 inches outside diameter. The tube contains two sections (front and back) of 400 mg of 30/60 mesh florisil adsorbent. The front and back are separated by two plugs of glass wool. The two-stage sampling device was attached to a 1.5 cfm rotary vane pump operating at 110 VAC line power. The air samples were collected for approximately a 50-hour period at a flow rate of 1.0 L/min using an "in-line" calibrated rotameter and a precision flow control valve. The samplers were inspected approximately every six hours and flow rates recorded and adjusted as necessary.

Air samples for PCDFs and PCDDs were collected using a high volume sampling device developed by the New York State Health Department (NYSDH) [10].
The high volume sampler is a two-stage sampling device. The first stage is a 47-mm diameter, 0.3 u

pore size glass fiber filter. The second stage is a cartridge of 8 gms of silica gel adsorbent. The silica gel cartridge was spiked with a 2.5 ng each of 2,3,7,8-tetrachlorodibenzo-p-dioxin-$^{13}C_{12}$ and 2,3,7,8-tetrachlorodibenzofuran-$^{13}C_{12}$ before sampling for quantification and to account for any retention losses during sampling. The sampler was attached to a 1.5 cubic feet per minute (cfm) rotary can vacuum pump operated on 110 VAC line power. The air sample was collected for approximately a 50-hour period at a flow rate of 20 liters per minute (L/min) to achieve an air volume of approximately 57.6 cubic meters of air. The air flow rate through the samples was regulated to 20 L/min using an "in line" calibrated rotameter and a precision flow control valve. The samplers were inspected approximately every six hours and flow rates recorded and adjusted as necessary.

b. Surface Sampling - PCBs, PCDFs, and PCDDs

A wet-wipe protocol was used to assess the surface concentrations of PCBs, PCDFs, and PCDDs.

The surface wipe samples were collected using 3" x 3" soxhlet extracted cotton gauze pads. The sampling procedure consisted of marking off a surface into 0.25 m^2 areas using a galvanized steel template or a metal tape measure. Each 0.25 m^2 area was wiped with a 3" x 3" gauze pad which had been wetted with 8-ml of pesticide grade hexane. The wet wipe sample pad was held with a glove hand; a non-linear polyethylene, unplasticized type glove was changed with each sample. The surface was wiped in two directions (the second direction was performed at a 90° angle to the first direction). Each gauze pad was used to wipe only one 0.25 m^2 area. The gauze pad sample was then placed in glass sample container equipped with a Telflon-lined lid.

Each PCB wipe sample consisted of a single sample from an area of 0.25 m^2. Each PCDF and PCDD wipe sample consisted of a composite of four 0.25 m^2 wipe samples for a total area of 1.0 m^2. The four PCDF and PCDD gauze pads were composited and treated as a single sample to attain an acceptable detection limit.

c. PCB Analysis - Air and Surface

The glass fiber filters were placed in an Erlemeyer flask and extracted with 20-ml of hexane on a wrist action shaker for 30-minutes. The 20-ml of hexane used to extract the filter was then passed through the front portion of the florisil stick into a centrifuge tube. The back portion of the florisil stick was eluted with an additional 20-mls of hexane. Both the front- and back-portion extracts were concentrated to 1-ml using a gentle stream of nitrogen. This 1-ml extract was then vialed and stored for analysis.

The wipe samples were extracted on an automatic wrist action shaker for 30 minutes. Forty milliliters of a 15 percent methylene chloride/85 percent hexane mixture was used as the extraction solvent. The extract was then decanted into a Kuderna-Danish concentrator. The extraction vessels were washed with two 40-ml portions of the extraction solvent and the washings combined with the initial extract in the Kuderna-Danish concentrator. The volume was reduced by distillation using a three ball Snyder column to less than 5-mls.

The 5-ml extract was cleaned by performing a liquid-liquid extraction using an equal portion of concentrated sulfuric acid. 1-ml of the acid cleaned extract was taken for processing through a micro

Florisil column. The micro Florisil column was prepared by packing a 10-ml serological pipette with 2-gms of Florisil. The column was pre-eluted with 5-mls of hexane. The 1-ml aliquot of the acid cleaned extract was quantitatively transferred to the column. Prior to the exposure of the column to air, 20-mls of hexane was added to the column. The eluate was collected in conical centrifuge tube and concentrated under a gentle stream of purified nitrogen to 1-ml. The extract was then vialed and stored for analysis.

The samples were analyzed using packed column gas chromatography-electron capture detection. The chromatograms were interpreted by visually comparing them to Aroclor standards. Quantitation was performed by summing the peak heights of the five major peaks of the standards and comparing those sums of the same peaks in the sample. The air samples did not contain clearly recognizable Aroclor patterns; thus, were quantitated using the Webb and McCall procedure [11].

Quality assurance consisted of the analysis of method standards, analytical replicates, and field blanks. The method standards were prepared by spiking a clean cotton gauze pad or an unused florisil stick with a known amount of a PCB standard. Analytical replicates are the analysis of a second aliquot of the sample extract. Field blanks are samples handled exactly the same as the field samples, except that no air was drawn through the sampler or a surface was not wiped with the cotton gauze pad. None of the field blanks showed detectable concentrations of PCBs at a detection limit of <0.02 ug/m^3 and <1 ug/m^2 for air and surface samples, respectively. The results of the other quality assurance checks are summarized below:

	No. of Samples	Mean	Std. Dev.	Range
	Method Standards			Percent Recovery
Surface	36	102	23	53-155
Air	9	84	8	76-96
	Replicate Analysis			Relative Percent Deviation
Surface	25	5.8	4.9	0-16
Air	3	11	9	5-22

d. PCDF and PCDD - Surface and Air Analysis [12]

1. Sample Extraction and Analyte Enrichment

The surface wipe samples were transferred to Soxhlet extraction thimbles and spiked with 5 ng each of 2,3,7,8-tetrachlorodibenzo-p-dioxin-$^{13}C_{12}$ (2,3,7,8-tetra-CDD-$^{13}C^{12}$), 1,2,3,7,8-pentachlorodibenzo-p-dioxin-$^{13}C_{12}$ (1,2,3,7,8-penta-CDD-$^{13}C_{12}$), 1,2,3,6,7,8-hexachlorodibenzo-p-dioxin-$^{13}C_{12}$ (1,2,3,6,7,8-hexa-CDD-$^{13}C_{12}$), 1,2,3,4,6,7,8-heptachlorodibenzo-p-dioxin-$^{13}C_{12}$ (1,2,3,4,6,7,8-hepta-CDD-$^{13}C_{12}$), octachlorodibenzo-p-dioxin-$^{13}C_{12}$ (octa-CDD-$^{13}C_{12}$), 2,3,7,8-tetrachlorodibenzofuran-$^{13}C_{12}$ (2,3,7,8-tetra-CDF-$^{13}C_{12}$), 1,2,3,7,8-pentachlorodibenzofuran-$^{13}C_{12}$ (1,2,3,7,8-penta-CDF-$^{13}C_{12}$), 1,2,3,4,7,8-hexachlorodibenzofuran-$^{13}C_{12}$ (1,2,3,4,7,8-hexa-CDF-$^{13}C_{12}$), and 1,2,3,4,7,8-heptachlorodibenzofuran-$^{13}C_{12}$ (hepta-CDF-$^{13}C_{12}$). Benzene was added to the extractors and the samples were extracted for 20 hours.

The silica gel cartridge and the particulate filter from each PCDD/PCDF air sampler were transferred to Soxhlet extractors and extracted for 18 hours with approximately 250 ml of benzene as the solvent. Two isotopicallly labelled internal standards, 2.5 ng each of 2,3,7,8,-tetra-CDD-$^{13}C_{12}$ and

2,3,7,8-tetra-CDF-$^{13}C_{12}$, had been spiked into the silica gel cartridges prior to sampling. Five additional internal standards including 5 ng each of the above penta-CDD-$^{13}C_{12}$, hexa-CDD-$^{13}C_{12}$, octa-CDD-$^{13}C_{12}$, penta-CDF-$^{13}C_{12}$, and hexa-CDF-$^{13}C_{12}$ standards were also spiked into each sample before extraction.

The benzene extracts were concentrated to approximately 4 ml with 3-stage Snyder columns. The benzene extracts were transferred to multilayered silica gel columns containing sodium sulfate, activated silica gel, 44 percent concentrated sulfuric acid on silica gel, and 33 percent 1M sodium hydroxide on silica gel. The purpose of these columns was to remove acidic and basic compounds and easily oxidized materials from the extracts. The silica gel support provided a large surface area for contact with the sample extracts, thus improving the cleanup efficiency. The PCDD/PCDF isomers were eluted from the columns with 70 ml of hexane and the entire eluates, including the original extract volume, were collected. The benzene/hexane eluates were concentrated with a gentle stream of nitrogen gas and solvent-exchanged into hexane. The hexane solutions were chromatographed through columns containing approximately 5 g of activated basic alumina with hexane/methylene chloride (97:3, v/v), and hexane/methylene chloride (1:1, v/v) as elution solvents. The 1:1 hexane/methylene chloride eluates were collected, concentrated to near dryness, and dissolved in 20 ul of n-decane containing 5 ng of an absolute recovery standard, 1,2,3,4-tetra-CDD-$^{13}C_{12}$. All solutions were stored at 0°C and protected for light until analyzed.

2. Analysis

The extracts were analyzed and quantified for PCDD/PCDF by combined capillary column gas chromatography/high resolution mass spectrometry (HRGC/HRMS). The HRGC/HRMS system consists of a Carlo Erba Model 4160 gas chromatograph interfaced directly into the ion source of a VG Model 7070 high resolution mass spectrometer. The chromatographic column was a 60 m DB-5 fused silica column. Helium was used as the carrier gas at a flow velocity of 30 cm/sec. The mass spectrometer was operated in the electron impact (EI) ionization mode at a mass resolution of 9,000-12,000 (M/WM, 10% valley definition). All HRGC/HRMS data were acquired by multiple-ion-detection (MID) with a VG Model 11-250J Data System.

3. Quality Assurance

The operation of the HRGC/HRMS was evaluated each day by analyzing standard mixtures of PCDD/PCDF isomers. These mixtures consisted of 2,3,7,8-tetra-CDD, 2,3,7,8-tetra-CDF, 2,3,7,8-tetra-CDD$^{13}C_{12}$, and 2,3,7,8-tetra-CDF-$^{13}C_{12}$ to evaluate accuracy of quantification, mixtures of selected PCDD/PCDF isomers to evaluate the stability of the chromatographic elution windows, and tetra-CDD isomer mixtures to evaluate isomer resolution. Each day the mass spectrometer was calibrated from m/z 293 to m/z 516 using perfluorokerosene (PFK) as reference. Mass accuracy and shape for each subsequent run was checked by observing and centroiding reference masses that correspond to the mass range of each MID group. Centroid adjustments are stored by the computer along with the original calibration. A PFK "lock mass" was included in each MID group to insure mass accuracy. Native spike and laboratory method blank samples were processed during the extraction and cleanup of the samples. The native spike sample was used to evaluate the accuracy of quantification, while the laboratory method blank samples were used to demonstrate freedom from contamination. All method blank analyses were free of PCDD/PCDF contamination, except for trace levels of octa-CDD and octa-CDF, which were observed in one method blank. The observed levels were less than the desired detection limit for these congener classes and should therefore not adversely affect the analytical results. Recovery of the analyses from the native spike samples ranged from 86-104 percent, which is within the expected range of variation.

4. Recovery of Internal Standards

Recoveries of the internal standards, 2,3,7,8-tetra-CDD-$^{13}C_{12}$, 1,2,3,7,8-penta-CDD-$^{13}C_{12}$, 1,2,3,6,7,8-hexa-CDD-$^{13}C_{12}$, 1,2,3,4,6,7,8-hepta-CDD-$^{13}C_{12}$, octa-CDD-$^{13}C_{12}$, 2,3,7,8-tetra-CDF-$^{13}C_{12}$, 1,2,3,7,8-penta-CDF-$^{13}C_{12}$, 1,2,3,4,7,8-hexa-CDF-$^{13}C_{12}$, and 1,2,3,4,6,7,8-hepta-CDF-$^{13}C_{12}$ were calculated by comparison to the external standard, 1,2,3,4-tetra-CDD-$^{13}C_{12}$, which was added following extraction. Relative response factors were determined from triplicate analyses of a standard mixture containing the eight isotopically labelled standards. The equation used to calculate the recoveries was:

$$\text{Recovery (\%)} = \frac{\text{Ais x Qrs x 100}}{\text{Ars x Qis x Rf}}$$

Where:

Ais = Sum of integrated areas for internal standard;
Qrs = Quantity of recovery standard in ng;
Ars = Sum of integrated areas for recovery standard;
Qis = Quantity of internal standard in ng; and
Rf = Response factor.

5. Quantification

The tetra, penta, hexa, and hepta PCDD/PCDF isomers were quantified by comparing the sum of the two ions monitored for each class to the sum of the two ions monitored for the corresponding isotopically labelled internal standard. The octa-CDD-$^{13}C_{12}$ was used to quantify the octachloro-PCDD/PCDF congener classes. In the case of the air samples, where there was no heptachloro-CDD/CDF-$^{13}C_{12}$ added as an internal standard, the octa-CDD-$^{13}C_{12}$ was also used to quantify the heptachloro- PCDD/PCDF congener classes. Experimental relative response factors (RRF) were calculated from multiple analyses of a mixture which contained representatives of the tetrachloro- through octachloro- PCDD/PCDF congener classes. These response factors were included in all calculations used to quantify the data. The response factors were calculated by comparing the sum of the two ions monitored for each congener class to the sum of the two ions monitored for the corresponding internal standard. The averaged experimental response factors were:

Congener Class	Air Samples	Surface Wipes
	Averaged RRF	
Tetra-CDD	2.15	2.15
Penta-CDD	1.10	1.10
Hexa-CDD	0.836	0.836
Hepta-CDD	1.34	0.854
Octa-CDD	0.595	0.595
Tetra-CDF	1.03	1.03
Penta-CDF	1.35	1.35
Hexa-CDF	1.00	1.00
Hepta-CDF	2.15	1.12
Octa-CDF	1.27	1.27

The formula used for quantifying the PCDD/PCDF isomers was:

$$\text{Quantity/sample} = \frac{Ac \times Qis}{Ais \times Rf}$$

Where:

Quantity = Total quantity of target isomer or congener class;
AC = Sum of integrated areas for the target isomer or congener class;
Qis = Quantity of internal standard;
Ais = Total integrated areas for the internal standard; and
Rf = Response factor.

Each pair of resolved peaks in the selected-ion-current chromatograms was evaluated manually to determine if it met the criteria for a PCDD or PCDF isomer. By examining each pair of peaks separately, quantitative accuracy was improved over what is obtained when all of the peaks in a selected chromatographic window are averaged. When averaged data are used, it is possible for pairs of peaks with high and low chlorine isotope ratios to produce averaged data that meets the isotope ratio criterion. For example, two pairs of peaks having chlorine isotope ratios of 0.56 and 0.96, both outside of the acceptable range, would have an average ratio of 0.76.

The criteria that were used to identify PCDD and PCDF isomers were:

(1) Simultaneous responses at both ion masses;
(2) Chlorine isotope ratio within ± 15% of the theoretical value;
(3) Chromatographic retention times within windows determined from analyses of standard mixtures;
(4) Signal-to-noise ratio equal to or greater than 2.5 to 1.

The 2,3,7,8-tetra-CDD/CDF isomers and octa-CDD included the additional criterion that they coeluted within ± 2 seconds of their isotopically labelled analogs.

A limit of detection (LOD) was calculated for samples in which isomers of a particular chlorine congener class were not detected. The formula used for calculating the LOD was:

$$\text{LOD/sample} = \frac{Hc \times Qis \times 2.5}{His \times Rf}$$

Where:

LOD = Single isomer limits of detection for a congener class;
Hc = Height of congener class isomer;
Qis = Quantity of internal standard;
His = Peak height of internal standard;
Rf = Response factor.

e. Sample Chain-of-Custody

Sample Chain-of-Custody procedures were an integral activity of both sampling and analytical activities. Chain-of-Custody procedures provided documentation of samples through all phases of activities from the time the sampling devices were prepared to be sent to the field through reporting of the analytical results. Sample Chain-of-Custody was initiated by the sampling personnel upon receipt of the sampling devices. Each sampling device was assigned a unique identification number.

The chain-of-custody procedures were in accordance with those specified in NIOSH's manual of Standard Operating Procedures for Industrial Hugiene Sampling and Chemical Analyses, SOP No. 019, December 19. 1984.

V. RESULTS AND DISCUSSION

A. Surface Concentrations of PCBs

A total of 224 surface wipe samples were collected for the analysis of PCBs. Figure 1 shows that approximately 5% (11/224) of the samples were non-detected at a detection limit of <1 ug/m^2; 85% (190/224) ranged from 1 to 49 ug/m^2; 5% (11/224) ranged from 50 to 99 ug/m^2; and 5% (12/224) exceeded 100 ug/m^2. Of these 224 samples, 112 samples were collected in Building One (Table 1) and 112 samples were collected in Building Two (Table 2). Figure 2 shows that the concentration frequency distributions are comparable for each building, with the maximum number of samples (100/112 and 90/112, respectively) showing concentrations ranging from 1 to 49 ug/m^2.

Table 3 summarizes the analyses of the 224 samples by location of the surface for each building. The data are grouped as building surfaces (floors, walls, and elevated horizontal and high skin contact surfaces) and interior air-handling unit surfaces. The concentrations on building surfaces in Building One ranged from non-detected

(<1 ug/m^2) to 69 ug/m^2 (n = 101, geometric mean = 11 ug/m^2) with one value exceeding 50 ug/m^2. This sample (69 ug/m^2) was obtained on an elevated horizontal surface. The concentrations in Building Two ranged from non-detected (<1 ug/m^2) to 110 ug/m^2 (n = 97, geometric mean = 5.6 ug/m^2) with five sample values exceeding 50 ug/m^2. These samples ranging from 63 to 110 ug/m^2 were obtained on elevated horizontal surfaces. The data for each building was log transformed and analyzed using a one-sample 2-tailed t-test to compare the measured log mean surface concentration to the log of the guideline value (50 ug/m^2). The null hypotheses was that the log mean measured concentration, u, equalled the log of the guideline value of 50 ug/m^2, u_o, i.e., H_o: $u = u_o$. In both cases, the measured mean log concentration of PCBs on building surfaces was significantly less than ($p < 0.05$, t = -2.35 and t = -2.51, respectively) the log of the guideline value.

The interior AHU surface samples in Building One ranged from 22 to 470 ug/m^2 (n = 11, geometric mean = 129 ug/m^2). Nine of the 11 samples showed concentrations above 50 ug/m^2; these nine sample concentrations ranged from 60 to 470 ug/m^2. The concentrations in Building Two ranged from 14 to 150 ug/m^2 (n = 15, geometric mean = 47 ug/m^2). Eight of the 15 samples showed concentrations above 50 ug/m^2; these eight sample concentrations ranged from 53 to 150 ug/m^2. The data were log transformed and analyzed using a one-sample 2-tailed t-test as described above. In both cases, the measured mean log concentration of PCBs on interior AHU surfaces was not significantly different ($p < 0.05$, t = 1.0 and -0.091, respectively) from the log of the guideline value.

B. Surface Concentrations of PCDFs and PCDDs

A total of 28 surface wipe samples were collected for analysis of tetra- through octa-chlorinated dibenzofuran (PCDF) and dibenzo-p-dioxin (PCDD) homologs, and the respective 2,3,7,8-tetra CDF and CDD isomers (Table 4). (Two quality control "field blank" samples also were included.) Twenty-four of the 28 samples were collected on building surfaces (12 samples in each building); and four samples were collected on interior AHU surfaces (two samples in each building).

Table 5 presents the grouped data for the PCDF and PCDD concentrations on building surfaces. The surface concentrations of total PCDFs (tetra- through octa- CDF homologs) ranged from 0.48 to 5.4 ng/m^2 (arithmetic mean = 1.7 ng/m^2). The concentrations of 2,3,7,8-tetra CDF ranged from non-detected (<0.08 ng/m^2) to 0.40 ng/m^2 (arithmetic mean = 0.18 ng/m^2). The surface concentrations of total PCDDs (hexa- through octa-CDD homologs) ranged from 2.8 to 146 ng/m^2 (arithmetic mean = 26 ng/m^2). The 2,3,7,8-TCDD isomer or tetra- and penta-CDDs were not present above the detection limit in any of the samples. The calculated surface concentrations of total 2,3,7,8-TCDD equivalents (Table 6) ranged from 0.02 to 0.17 ng/m^2 (n = 24, arithmetic mean = 0.05 ng/m^2). All of the samples showed concentrations below the guideline value of 1 ng/m^2 2,3,7,8-TCDD equivalents.

The distribution of PCDF and PCDD homologs for the wipe samples obtained on building surfaces is shown in Figure 3. The PCDF distribution shows the presence of both the lower- and higher chlorinated homologs with the maximum concentrations represented by the hepta- and octa-CDFs. The hepta- and octa-CDFs represented approximately 32% and 30%, respectively, of the total PCDFs present. The PCDD distribution shows an absence of the lower chlorinated homologs and a predominance of octa-CDD. The octa-CDD homolog represented approximatelty 86% of the PCDDs present.

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. The concentrations of PCBs, PCDFs, and PCDDs were log transformed and used in linear regression analysis. The correlation coefficients (Table 7) were statistically significantly different from zero ($p < 0.02$) in both cases. Thus, a significant relationship between concentrations of PCBs and concentrations of PCDFs and PCDDs on the building surfaces existed in these buildings.

Table 8 presents the grouped data for the PCDF and PCDD concentrations on interior AHU surfaces. The surface concentrations of total PCDFs (tetra- through octa-CDF homologs) ranged from 6.5 to 53 ng/m^2 (n = 4, arithmetic mean = 28 ng/m^2). The 2,3,7,8-TCDF isomer was present above the detection limit in all of the samples at concentrations ranging 0.46 to 1.9 ng/m^2. The surface concentrations of total PCDDs (penta- through octa-CDDs) ranged from 69 to 421 ng/m^2 (n = 4, arithmetic mean = 173 ng/m^2). The 2,3,7,8-TCDD isomer or tetra-CDDs were not present above the detection limit in any of the samples. The calculated surface concentrations of total 2,3,7,8-TCDD equivalents (Table 6) ranged from 0.31 to 2.3 ng/m^2, with one value exceeding the 1 ng/m^2 2,3,7,8-TCDD equivalents guideline.
The distribution of PCDF and PCDD homologs for these AHU wipe samples are shown in Figure 4. The PCDF and PCDD homolog distributions obtained for the AHU samples are quite similar to those obtained for the building surface samples (Figure 3). In both cases, the higher chlorinated CDFs and CDDs represent the predominant homolog concentration.

The four PCDF and PCDD samples were collected at locations paired to the collection of PCB samples to determine the existence of a statistical relationship. The concentrations of PCBs, PCDFs, and PCDDs were log transformed and used in linear regression analysis. The correlation coefficients (Table 7) were not statistically significantly different from zero ($p > 0.10$). Thus, a significant relationship between the concentrations of PCBs and concentrations of PCDFs and PCDDs on the interior AHU surfaces was not demonstrated. There was not a large enough sample to demonstrate a statistically significant correlation. The sample size would have to be increased to ten paired observations in order for a correlation coefficient of 0.63 to be statistically significant ($p < 0.05$).

C. Airborne Concentrations of PCBs

A total of 27 air samples were collected for the analysis of PCBs (Tables 9 and 10) in October 1986. Twenty-four of these samples were collected in the occupied workspaces of Buildings One and Two; 12 samples were collected in each building. Three of the 27 samples were collected at the buildings fresh-air intake plenums to determine the concentrations of PCBs entering the buildings through the ambient air. All of the 24 samples collected in the occupied workspace of the buildings showed detectable concentrations of PCBs ranging from 0.06 to 0.31 ug/m^3 (arithmetic mean = 0.17 ug/m^3), which are below the guideline value of 0.5 ug/m^3. Two of the three ambient air samples showed detectable concentrations at 0.04 and 0.05 ug/m^3; the third sample was non-detected at a detection limit of <0.02 ug/m^3. The six field blanks were all non-detected at a detection limit of <0.06 ug per sample, which is equivalent to approximately <0.02 ug/m^3 assuming an air volume of 3295 liters.

To confirm these findings of detectable PCB air concentrations in all of the samples obtained in the occupied workspace of the buildings, Building One was re-tested in December 1986 (Table 11). The PCB samples were collected using the same New York State Florisil Stick (NYSFS) procedure, as well as by NIOSH

Method 5503 [9]. Method 5503 involves a two-stage sampling device consisting of a 13-mm glass fiber particulate filter preceeded by 150-mg of florisil adsorbent (100 mg front and 50 mg back sections). Both the NYSFS and NIOSH Method samplers operated for approximately 48-hours at a flow rate of approximately 0.8 L/min. The 150-mg florisil tube and 13-mm glass fiber filters were changed at approximately 24-hours. The two 150-mg florisil tubes and two 13-mm glass fiber filters were then composited by the laboratory chemists as a single sample. A total of 13-paired samples were collected at the same locations that were tested in October 1986 (Table 11). This included 12 occupied workspace samples and one ambient air intake sample. The PCB concentrations measured using the NYSFS procedure ranged from 0.13 to 0.33 ug/m^3 (arithmetic mean = 0.23 ug/m^3), and those by the NIOSH Method 5503 ranged from 0.19 to 0.31 ug/m^3 (arithmetic mean = 0.22 ug/m^3). The PCB concentrations in the ambient air samples were 0.04 ug/m^3 and 0.03 ug/m^3, respectively. Comparison of the PCB concentrations at the 13 paired locations showed that there was not a statistically significant difference ($p > 0.10$, $t = 0.72$) between the concentrations measured by these methods. Comparison of the airborne concentrations measured in October 1986 using the NYSFS procedure to those measured in December 1986 using the same procedure, showed that there was not a statistically significant difference ($p > 0.10$, $t = -0.88$) between the air concentrations. Therefore, it was concluded that the PCB concentrations originally measured in October 1986 were correct.

D. Airborne Concentrations of PCDFs and PCDDs

A total of 16 air samples were collected for the analysis of tetra- through octa-chlorinated dibenzo-p-dioxin (PCDD) and dibenzofuran (PCDF) homologs, and the respective 2,3,7,8-tetra CDD and CDF isomers (Table 12). (The analysis of two quality control "field blank" samples also are included.) Twelve of the 16 samples were collected in the occupied workspace of the two buildings; and four samples were collected at the fresh-air intake plenums of the buildings.

The PCDD homolog distributions (Table 12) are quite similar to those shown for the wipe samples obtained on building surfaces (Figure 3) and interior air-handling unit surfaces (Figure 4). In both the air and surface wipe samples there is an absence of the lower chlorinated CDDs, a presence of hepta-CDDs, and a predominance of octa-CDD. The concentrations of total PCDDs (hepta- and octa-CDDs) ranged from 3.6 to 7.1 pg/m^3 (arithmetic mean = 5.4 pg/m^3) in workspace air, and ranged from 3.5 to 7.2 pg/m^3 (arithmetic mean = 5.1 pg/m^3) in ambient air. Octa-CDD represented approximately 83 and 79% of PCDDs present, respectively. The PCDFs were generally non-detected, except for 3 of 16 samples that showed detectable concentrations of tetra- and penta-CDFs. Two of these samples (one workspace and one ambient air) contained detectable concentrations of 2,3,7,8-TCDF (1.4 and 0.83 pg/m^3, respectively). The calculated concentration of total 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, which are below the guideline of 2 pg/m^3.

VI. CONCLUSIONS

A study was conducted to determine the background concentrations of polychlorinated biphenyls (PCBs), polychorinated dibenzofurans (PCDFs), and polychlorinated dibenzo-p-dioxins (PCDDs) in air and on surfaces in two commercial office buildings in Boston, Massachusetts. The buildings selected for testing had no history of experiencing an electrical transformer fire or failure. Measurable air and surface concentrations of these contaminants were present in both buildings. Comparison of the data to the guidelines selected for cleanup of the 50 Staniford Street Office Building shows that the concentrations of PCBs, and PCDFs and PCDDs (converted to 2,3,7,8-TCDD equivalents) present in air and on workspace surfaces as normal background contamination in these buildings are below the respective guideline values. However, the air-handling units were found to contain surface concentrations of PCBs, and to a lesser extent 2,3,7,8-TCDD equivalents in excess of the guideline values.

The higher concentrations of PCBs, PCDFs, and PCDDs were present on interior air-handling unit surfaces and elevated horizontal surfaces than on high skin contact surfaces. These surfaces with the highest concentrations are less likely to be contacted on a frequent and prolonged bases.

A statistically significant correlation between workspace surface concentrations of PCBs and workspace surface concentrations of PCDFs and PCDDs was demonstrated. Therefore, PCBs can be used in these buildings as surrogate to predict the corresponding concentration of PCDFs and PCDDs.

The air and surface concentrations of PCDDs were consistently higher than the PCDFs. The 2,3,7,8-TCDD isomer was non-detected in all samples, where the 2,3,7,8-TCDF isomer was frequently present in surface samples.

The concentrations of PCBs, PCDFs, and PCDDs measured in these buildings may be indicative of the concentrations present in similar buildings in other large urban areas.

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IX. DISTRIBUTION AND AVAILABILITY OF REPORT

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1. Building Superintendent, Building One, Boston, Massachusettes
2. Building Superintendent, Building Two, Boston, Massachusettes
3. NIOSH Boston Region
4. OSHA Region I

For the purpose of informing affected employees, copies of this report shall be posted by the employer in a prominent place accessible to the employees for a period of 30 calendar days.

Table 1
Concentrations of Polychlorinated Biphenyls on Workplace and Interior Air-Handling Unit Surfaces
Office Building Number One
Boston, Massachusetts
October 18-19, 1986

Sample Number	Sample Location/Description	Concentration[b] ug/m^2
	FLOOR TWENTY-FOUR:	
001	Room 2407 desk top	6
002[a]	Room 2407 bookcase top	11
003	Room 2403 table top	9
004	Room 2403 table top	11
005[a]	Room 2403 cabinet top	12
006[a]	Room 2406 bookcase top	16
007	Room 2407 wall	3
008	Lobby vinyl tile floor	47
009	Conference room table top	18
010[a]	Room 2411 cabinet top	9
011	Room 2411 desk top	20
012[a]	Room 2411 cabinet top	69
013	Field blank	ND[c]
014	Ceramic tile floor	10
015	Room 2403 desk top	43
016	Lobby wall	ND
017[a]	Room 2403 cabinet top	20
118[a]	Room 2403 cabinet top	12
119[a]	Room 2403 cabinet top	13
120[a]	Room 2403 cabinet top	26
	FLOOR EIGHTEEN:	
018[a]	Room 1804 bookcase top	8
019	Room 1804 table top	19
020	Room 1804 desk top	7
021[a]	Room 1804 cabinet top	15
022	Lobby vinyl tile floor	40
023	Room 1803 desk top	22
024	Field blank	ND
025[a]	Room 1803 bookshelf top	19
026	Room 1803 wall	4
027	Ceramic tile floor	6
028[a]	Room 1800 cabinet top	33
029	Room 1800 table top	11
030	Room 1800 desk top	12
031[a]	Room 1800 cabinet top	18
032	Room 1800 wall	ND
033	Room 1800 desk top	31
034[a]	Room 1800 bookcase top	7
121[a]	Room 1800 cabinet top	12
122[a]	Room 1800 cabinet top	48
247	Field blank	ND
	FLOOR FOURTEEN:	
035	Painted concrete floor	36
036	Field blank	ND
037[a]	Room 1401 cabinet top	16
038	Room 1401 desk top	21

Table 1 (continued)

Sample Number	Sample Location/Description	Concentration ug/m^2
	FLOOR FOURTEEN continued:	
039[a]	Room 1401 cabinet top	19
040	Room 1401 desk top	14
041	Room 1401 wall	4
042	Room 1401 table top	11
043[a]	Room 1401 cabinet top	11
044	Ceramic tile floor	12
045	Room 1409 desk top	33
046[a]	Room 1409 cabinet top	8
047[a]	Room 1409 cabinet top	23
048	Field blank	ND
049	Room 1409 desk top	7
050	Room 1409 wall	14
051[a]	Room 1409 bookcase top	4
052	Room 1409 desk top	19
	FLOOR ELEVEN:	
053	Vinyl tile floor	35
054	Room 1105 table top	19
055[a]	Room 1105 cabinet top	8
056	Room 1105 table top	7
057	Room 1105 wall	4
058[a]	Room 1105 cabinet top	8
059	Room 1105 desk top	12
060	Field blank	ND
061[a]	Room 1100 cabinet top	11
062	Painted concrete floor	29
063	Room 1100 table top	21
064	Room 1100 desk top	8
065[a]	Room 1100 cabinet top	4
066[a]	Room 1100 cabinet top	8
067	Room 1100 desk top	2
068[a]	Room 1101 cabinet top	11
069	Room 1101 wall	2
	FLOOR SEVEN:	
070	Vinyl tile floor	39
071	Room 707 desk top	3
072	Field blank	ND
073	Room 707 desk top	8
074[a]	Room 707 bookcase top	14
075[a]	Room 707 bookcase top	21
076	Room 707 file cabinet	40
077[a]	Room 707 bookcase top	11
078	Room 707 wall	2
079	Room 710 desk top	12
080[a]	Room 710 cabinet top	12
081[a]	Room 710 cabinet top	28
082	Vinyl tile floor	27
083	Room 710 table top	5
084	Field blank	ND
085[a]	Room 710 cabinet top	12
086	Room 710 desk top	4
087	Room 710 wall	2

Table 1 (continued)

Sample Number	Sample Location/Description	Concentration ug/m^2
	FLOOR THREE:	
088	Room 300 desk top	8
089	Room 300 wall	3
090[a]	Room 300 cabinet top	3
091[a]	Room 300 cabinet top	13
092	Room 300 desk top	7
093	Room 300 desk top	15
094[a]	Room 300 cabinet top	10
095	Room 312 desk top	10
096	Field blank	ND
097[a]	Room 312 bookcase top	9
098	Room 312 desk top	17
099	Room 312 wall	5
100[a]	Room 312 cabinet top	28
101	Ceramic tile floor	8
102	Painted concrete floor	16
013	Room 308 desk top	25
104[a]	Room 308 cabinet top	11
105	AHU[d] S-1: fan housing	140
106	AHU I: fan housing	38
107	AHU H: fan housing	22
108	Field blank	ND[b]
109	AHU S-2: plenum floor	60
110	AHU G: plenum floor	280
111	AHU E: plenum floor	120
112	AHU F: plenum floor	270
113	AHU J: plenum floor	470
114	AHU D: fan housing	110
115	AHU B: plenum floor	260
116	AHU S-5: plenum floor	210
117	Field blank	ND

[a] Denotes an elevated horizontal surface; height of greater than six-feet above floor

[b] PCB identified as a mixture of Aroclors 1254 and 1260.

[c] Denotes non-detected. The limit of detection is 1 ug/m^2.

[d] Denotes air-handling unit.

Table 2
Concentrations of Polychlorinated Biphenyls on Workplace and Interior Air-Handling Unit Surfaces
Office Building Number Two
Boston, Massachusetts
October 18-19, 1986

Sample Number	Sample Location/Description	Concentration[b] ug/m^2
	FLOOR TWENTY-ONE:	
123	Room 2103 desk top	2
124[a]	Room 2103 bookcase top	7
125[a]	Room 2103 bookcase top	19
126	Room 2103 vinyl tile floor	8
127	Room 2103 desk top	3
128	Room 2103 wall	ND[c]
129[a]	Room 2105 bookcase top	23
130	Conference room table top	6
131[a]	Room 2105 cabinet top	33
132	Room 2105 desk top	ND
133[a]	Room 2110 bookcase top	7
134	Field blank	ND
135	Room 2110 desk top	5
136	Room 2108 wall	ND
137	Ceramic tile floor	4
138	Room 2106 desk top	3
139[a]	Room 2103 cabinet top	15
232[a]	Room 2100 cabinet top	10
	FLOOR EIGHTEEN:	
234[a]	Room 1809 bookcase top	7
140	Desk top	4
141	Vinyl tile floor	8
142	Table top	3
143[a]	Bookcase top	10
144[a]	Cabinet top	70
145	Desk top	2
146	Field blank	ND
147[a]	Bookcase top	10
148	Desk top	4
149	Wall	ND
150[a]	Cabinet top	26
151	Table top	3
152	Desk top	2
153[a]	Bookcase top	22
154[a]	Bookcase top	8
155	Wall	ND
156	Ceramic tile floor	3
	FLOOR FIFTEEN:	
157	Painted concrete floor	4
158	Field blank	ND
159	Desk top	3
160	Table top	4
161[a]	Bookcase top	5
162[a]	Cabinet top	3
163	Wall	ND
164	Table top	2

Table 2 (continued)

Sample Number	Sample Location/Description	Concentration ug/m^2
	FLOOR FIFTEEN Continued:	
165	Table top	4
166[a]	Cabinet top	4
167[a]	Cabinet top	15
168[a]	Cabinet top	14
169	Desk top	4
170	Field blank	ND
171	Room 1511 desk top	3
172[a]	Room 1511 cabinet top	4
173	Room 1511 wall	4
174	Vinyl tile floor	5
	FLOOR TEN:	
175	Courtroom E table top	13
176	Courtroom C table top	21
177	Desk to	6
178[a]	Cabinet top	73
179	Desk top	10
180[a]	Bookcase top	40
181	Table top	3
246	Field blank	ND
182[a]	Cabinet top	2
183	Table top	10
184[a]	Cabinet top	3
185[a]	Cabinet top	63
186[a]	Bookcase top	3
187	Ceramic tile floor	4
188	Room 1010 vinyl tile floor	29
189	Room 1010 wall	ND
190	Room 1000 wall	10
	FLOOR TWO:	
191[a]	West exit revolving door top	99
192	Ceramic tile floor	46
193	Field blank	ND
194	Table top	17
195[a]	East exit door top	110
196[a]	Cabinet top	14
197	Desk top	7
198	Desk top	3
199[a]	Bookcase	4
200	Ceramic tile floor	12
201	Wall	2
202	Table top	14
204	Table top	4
205	Field blank	ND
206	Table top	5
207	Wall	ND
208[a]	Partition wall top	2

Table 2 (continued)

Sample Number	Sample Location/Description	Concentration ug/m^2
	FLOOR SIX:	
209	Table top	5
210	Wall	ND
211	Vinyl tile floor	14
212[a]	Bookcase top	25
213	Table top	4
214[a]	Cabinet top	9
215	Desk top	4
216	Field blank	ND
217[a]	Bookcase top	16
218	Ceramic tile floor	5
219	Table top	3
220[a]	Cabinet top	3
221	Wall	1
222	Table top	18
223[a]	Cabinet top	12
224	Desk top	4
225[a]	Bookcase top	4
226	AHU[d] S-3: plenum floor	120
227	AHU S-4: plenum floor	150
228	AHU S-5: plenum floor	85
229	AHU S-6: fan housing	72
230	AHU S-7: plenum floor	26
231	Field blank	ND[b]
233	Field blank	ND
235	AHU S-14: fan housing	97
236	AHU S-16: fan housing	140
237	AHU S-11: plenum floor	19
238	AHU S-12: plenum floor	14
239	AHU S-9: plenum floor	35
240	AHU S-10: plenum floor	19
241	AHU S-8: fan housing	76
242	AHU S-1: plenum floor	18
243	AHU S-2: fan housing	53
244	AHU S-17: fan housing	46
245	AHU S-13: fan housing	25
246	Field blank	ND

[a] Denotes an elevated horizontal surface; height of greater than six-feet above the floor.

[b] PCB identified as a mixture of Aroclors 1254 and 1260.

[c] Denotes non-detected. The limit of detection is 1 ug/m^2.

[d] Air-Handling Unit.

Table 3

Background Concentrations of Polychlorinated Biphenyls on Surfaces in Two Office Buildings in Boston, Massachusetts

October 18-19, 1986

		PCB Concentration ug/m^2				
			Geometric	Geometric		
Building	Location of Surface	n/N*	Mean[a]	Mean[a]	Std. Dev.	Range
One	High Skin Contact	36/36	15	12.0	1.9	2 - 43
	Elevated Horizontal	41/41	16	13.2	1.8	3 - 69
	Wall	10/12	4	2.6	2.5	ND (1)[b] - 14
	Floor	12/12	25	20.9	2.1	6 - 47
	Overall	99/101	15	10.9	2.5	ND(1) - 69
	Air Handling Unit	11/11	180	129	2.6	22 - 470
Two	High Skin Contact	35/36	6	4.4	2.1	ND(1) - 21
	Elevated Horizontal	37/37	22	12.3	2.9	2 - 110
	Wall	4/12	1.8	0.93	2.8	ND(1) - 10
	Floor	12/12	12	7.9	2.3	3 - 46
	Overall	88/97	12	5.7	3.4	ND(1) - 110
	Air Handling Unit	15/15	63	46.8	2.3	14 - 150

*n/N is the number of samples above the detection limit / total number of samples collected.

[a] Mean calculated with non-detected values treated as one-half the detection limit.

[b] Denotes non-detected. Value in parentheses is the limit of detection.

Table 4
Surface Concentrations of Polychlorinated Dibenzofurans (PCDFs) and Polychlorinated Dibenzo-p-Dioxins (PCDDs) in Two Office Buildings in Boston, Massachusetts
October 18-19, 1986

		PCDFs ng/m^2						PCDDs ng/m^2					
Sample Number	Sample Location	2,3,7,8-Tetra -CDF	Total Tetra -CDF	Total Penta -CDF	Total Hexa -CDF	Total Hepta -CDF	Octa -CDF	2,3,7,8-Tetra -CDD	Total Tetra -CDD	Total Penta -CDD	Total Hexa -CDD	Total Hepta -CDD	Octa -CDD
	BUILDING ONE:												
301	RM 2407 Bookcase[a]	(0.08)[b]	(0.08)	(0.02)	(0.01)	0.37	0.33	(0.04)	(0.04)	(0.15)	0.14	2.60	14.0
302	RM 2411 Table	(0.21)	(0.21)	(0.15)	0.04	0.12	0.23	(0.18)	(0.18)	(0.22)	0.10	1.70	5.50
303	RM 1804 Table	(0.39)	(0.39)	(0.15)	(0.08)	0.34	0.36	(0.28)	(0.28)	(0.24)	(0.21)	0.74	8.30
304	RM 1800 Cabinet[a]	0.17	0.24	0.12	0.40	1.80	1.90	(0.03)	(0.03)	0.19	0.91	7.60	45.0
305	RM 1401 Cabinet[a]	(0.16)	(0.16)	(0.06)	0.17	0.40	0.41	(0.04)	(0.04)	(0.12)	0.20	3.20	15.0
306	RM 1409 Desk	0.32	0.53	0.03	0.04	0.34	0.32	(0.11)	(0.11)	(0.10)	0.22	1.20	6.20
308	RM 1105 Table	0.16	0.30	0.12	0.22	0.82	0.45	(0.02)	(0.02)	(0.03)	0.38	2.0	8.40
309	RM 1100 Cabinet[a]	0.04	0.08	0.04	0.15	0.10	0.11	(0.01)	(0.01)	(0.02)	0.09	0.56	2.10
310	RM 707 Bookcase[a]	0.11	0.22	0.12	0.24	0.52	0.46	(0.02)	(0.02)	(0.04)	0.40	3.80	18.0
311	RM 710 Table	0.10	0.15	0.02	0.06	0.18	0.32	(0.02)	(0.02)	(0.04)	0.08	1.10	9.60
312	RM 300 Desk	0.11	0.16	(0.01)	0.06	0.33	0.19	(0.02)	(0.02)	(0.05)	0.11	3.10	39.0
313	RM 312 Bookcase[a]	0.07	0.09	0.05	0.14	0.34	0.16	(0.02)	(0.02)	(0.12)	(0.10)	2.20	9.30
314	AHU G at Fan	1.40	2.70	1.80	9.90	30.0	8.50	(0.27)	(0.27)	0.36	4.60	23.0	100.
315	AHU B at Fan	0.46	0.81	0.56	2.70	7.10	3.10	(0.08)	(0.08)	(0.11)	2.10	12.0	58.0
307	Field blank	(0.03)	(0.03)	(0.01)	(0.30)	(0.08)	0.14	(0.02)	(0.02)	(0.04)	(0.02)	(0.41)	0.42
	BUILDING TWO:												
316	RM 2103 Bookcase[a]	0.22	0.58	0.37	0.75	1.70	2.0	(0.02)	(0.02)	(0.11)	1.10	15.0	130.
317	FL 21 Desk	0.28	0.40	0.03	(0.02)	0.11	0.20	(0.05)	(0.05)	(0.06)	0.22	0.79	5.0
318	FL 18 Bookcase[a]	(0.67)	(0.67)	(0.10)	(0.04)	(0.09)	0.19	(0.15)	(0.15)	(0.09)	(0.08)	1.40	13.0
319	FL 18 Table	0.40	0.58	(0.02)	0.15	0.22	0.35	(0.04)	(0.04)	(0.06)	0.64	1.60	12.0
320	FL 15 Table	0.24	0.35	0.05	0.08	0.31	0.38	(0.04)	(0.04)	(0.04)	0.19	1.30	7.60
321	FL 15 Cabinet[a]	0.06	0.10	0.03	(0.02)	0.18	0.15	(0.03)	(0.03)	(0.04)	(0.02)	0.77	5.90
322	FL 10 Table	0.34	0.72	0.14	0.10	0.14	0.15	(0.02)	(0.02)	(0.03)	0.42	2.10	12.0
323	FL 10 Bookcase[a]	0.37	0.79	0.41	0.48	1.70	1.40	(0.04)	(0.04)	(0.08)	1.10	12.0	81.0
324	FL 2 W Exit[a]	0.29	0.84	1.0	1.20	0.96	0.34	(0.04)	(0.04)	(0.08)	0.22	2.10	11.0
325	FL 2 Table	0.12	0.22	0.03	(0.02)	0.12	0.11	(0.02)	(0.02)	(0.05)	0.14	0.46	3.50
327	FL 6 Table	0.11	0.18	(0.01)	0.13	0.26	0.13	(0.04)	(0.04)	(0.05)	0.20	1.0	7.70
328	FL 6 Bookcase[a]	0.13	0.33	0.28	0.52	1.60	1.30	(0.02)	(0.02)	(0.07)	1.10	10.0	66.0
329	AHU S6 at Fan	1.90	8.30	5.40	7.0	12.0	7.0	(0.09)	(0.09)	2.0	9.70	89.0	320.
330	AHU S11 at Fan	0.37	1.40	1.48	1.40	1.31	0.92	(0.02)	(0.02)	0.10	1.30	7.70	60.0
326	Field blank	(0.04)	(0.04)	(0.01)	(0.01)	(0.06)	0.11	(0.03)	(0.03)	(0.03)	(0.03)	0.31	0.42

[a] Elevated horizontal surface; height above the floor is greater than six-feet.

[b] Value in parentheses is the limit of detection.

Table 5
Concentrations of PCDFs and PCDDs on Building Surfaces in Two Office Buildings in Boston, Massachusetts
October 18-19, 1986

	n/N*	Concentration ng/m^2 Mean**	Range
2,3,7,8-TCDF	19/24	0.18	(0.04)[a] - 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	-	1.7	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	-	26	2.8 - 146

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

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

[a] Value in parentheses is the limit of detection.

Table 6

Surface Concentrations of 2,3,7,8-TCDD Equivalents in Two Office Buildings in Boston, Massachusetts

October 18-19, 1986

Sample Number	Sample Location	2,3,7,8-TCDD Equivalents ng/m^2
	BUILDING ONE:	
301	RM 2407 Bookcase	0.02
302	RM 2411 Table	0.02
303	RM 1804 Table	0.03
304	RM 1800 Cabinet	0.17
305	RM 1401 Cabinet	0.04
306	RM 1409 Desk	0.05
308	RM 1105 Table	0.03
309	RM 1100 Cabinet	0.03
310	RM 707 Bookcase	0.01
311	RM 710 Table	0.01
312	RM 300 Desk	0.02
313	RM 312 Bookcase	0.01
314	AHU G at Fan	0.83
315	AHU B at Fan	0.26
	BUILDING TWO:	
316	RM 2103 Bookcase	0.13
317	FL 21 Desk	0.04
318	FL 18 Bookcase	0.04
319	FL 18 Table	0.07
320	FL 15 Table	0.04
321	FL 15 Cabinet	0.01
322	FL 10 Table	0.07
323	FL 10 Bookcase	0.14
324	FL 2 W Exit	0.15
325	FL 2 Table	0.02
327	FL 6 Table	0.02
328	FL 6 Bookcase	0.10
329	AHU S6 at Fan	2.3
330	AHU S11 at Fan	0.31

Table 7

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

	Workspace Surfaces*			Interior AHU** Surfaces		
	N	Corr. Coeff.	P	N	Corr. Coeff.	P
PCDFs	24	0.49	<0.02	4	0.63	>0.10
PCDDs	24	0.48	<0.02	4	0.03	>0.10

*Tables, desks, counters, storage cabinet and book shelves.
**Air-Handling Unit fan air intake plenum.

Table 8
Concentrations of PCDFs and PCDDs on Interior Air-Handling Unit Surfaces in Two Office Buildings in Boston, Massachusetts
October 18-19, 1986

	n/N*	Concentration ng/m^2 Mean**	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)[a]
TCDDs	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

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

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

[a] Value in parentheses is the limit of detection.

Table 9

Airborne Concentrations of Polychlorinated Biphenyls
Office Building Number One
Boston, Massachusetts

October 18-19, 1986

Sample Number	Sample Location	Sample Volume Liters	Concentration[a] ug/m^3
402	Floor 24: Room 2407	3385	0.14
413	Floor 24: Room 2400	3317	0.15
410	Floor 18: Room 1804	3301	0.24
412	Floor 18: Room 1800	3177	0.23
405	Floor 14: Room 1401	3359	0.31
404	Floor 14: Room 1409	3274	0.23
407	Floor 11: Room 1102	3210	0.18
406	Floor 11: Room 1109	3372	0.23
408	Floor 7: Room 702	3294	0.31
414	Floor 7: Room 710	3297	0.17
411	Floor 3: Room 300	3348	0.19
409	Floor 3: Room 312	3195	0.18
403	Ambient Air-Intake	3573	0.05
415	Field blank	0	ND[b]
416	Field blank	0	ND
417	Field blank	0	ND

[a] The PCBs present did not conform to any specific Aroclor pattern.

[b] Denotes non-detected. The limit of detection is <0.06 ug/sample, which is equivalent to <0.02 ug/m^3 assuming an air volume of 3315 liters.

Table 10

Airborne Concentrations of Polychlorinated Biphenyls
Office Building Number Two
Boston, Massachusetts

October 18-19, 1987

Sample Number	Sample Location	Sample Volume Liters	Concentration[a] ug/m^3
420	Floor 21: Room 2109	3301	0.12
421	Floor 21: Room 2103	3293	0.09
422	Floor 18: Room 1805	3284	0.07
423	Floor 18: Room 1800	3267	0.22
424	Floor 15: Room 1500	3458	0.06
425	Floor 15: Room 1511	3249	0.11
426	Floor 10: Room HRC	3243	0.20
427	Floor 10: Room 1000	3242	0.14
428	Floor 6: Room 607N	3239	0.16
429	Floor 6: 604S	3236	0.11
430	Floor 2: Lobby	3229	0.11
431	Floor 2: Room T13A	3228	0.10
418	Ambient Air Intake	3576	0.04
419	Ambient Air Intake	3509	ND
432	Field blank	0	ND[b]
433	Field blank	0	ND
434	Field blank	0	ND

[a] The PCBs present did not conform to any specific aroclor pattern.

[b] Denotes non-detected. The limit of detection is <0.06 ug/sample, which is equivalent to 0.02 ug/m^3 assuming an air volume of 3295 liters

Table 11

Airborne Concentrations of Polychlorinated Biphenyls:
Comparison of NIOSH Method 5503 (modified) to NYSDH* Method
Office Building Number One
Boston, Massachusetts

December 1986

Sample Number	Sample Location	Sample Volume - Liters		Concentration ug/m^3	
		NYSDH	NIOSH	NYSDH	NIOSH
005/006	Room 2400	2455	2454	0.21	0.22
007/008	Room 2407	2416	2418	0.13	0.19
009/010	Room 1800	2418	2421	0.19	0.19
011/012	Room 1804	2422	2390	0.29	0.31
001/002	Room 1401	2385	2385	0.20	0.21
003/004	Room 1409	2387	2322	0.19	0.20
013/014	Room 1102	2385	2386	0.24	0.21
015/016	Room 1109	2380	2348	0.25	0.21
017/018	Room 702	2343	2376	0.26	0.22
019/020	Room 710	2409	2339	0.22	0.23
021/022	Room 300	2330	2392	0.33	0.25
023/024	Room 312	2393	2320	0.25	0.24
029/030	Ambient Air Intake	2285	2285	0.04	0.03
037/033	Field blank	0	0	ND**	ND
038/034	Field blank	0	0	ND	ND
039/035	Field blank	0	0	ND	ND
040/036	Field blank	0	0	ND	ND

* Denotes New York State Department of Health Method

** Denotes non-detected. The limit of detection is <0.06 ug per sample, which is equivalent to approximately <0.02 ug/m^3 assuming an air volume os 2584 liters.

Table 12
Airborne Concentrations of Polychlorinated Dibenzofurans (PCDFs) and Polychlorinated Dibenzo-p-Dioxins (PCDDs) in Two Office Buildings and Ambient Air in Boston, Massachusetts
October 18-19, 1986

		PCDFs pg/m^3						PCDDs pg/m^3					
Sample Number	Sample Location	2378-Tetra -CDF	Total Tetra -CDF	Total Penta -CDF	Total Hexa -CDF	Total Hepta -CDF	Octa -CDF	2378 Tetra -CDD	Total Tetra -CDD	Total Penta -CDD	Total Hexa -CDD	Total Hepta -CDD	Octa -CDD
	BUIDLING ONE:												
502	Room 2407	(1.5)[a]	(1.5)	(0.21)	(0.21)	(0.60)	(0.55)	(0.48)	(0.48)	(0.65)	(0.46)	(1.2)	4.0
508	Room 1804	(1.6)	(1.6)	(0.12)	(0.12)	(0.63)	(0.76)	(1.4)	(1.4)	(1.1)	(0.60)	(0.88)	3.2
504	Room 1401	(0.85)	(0.85)	(0.20)	(0.18)	(0.78)	0.60	(0.65)	(0.65)	(0.64)	(0.45)	2.0	5.1
505	Room 1109	(1.1)	(1.1)	(0.28)	(0.20)	(1.1)	(0.99)	(0.54)	(0.54)	(0.63)	(0.58)	0.82	4.6
507	Room 702	(0.82)	(0.82)	(0.17)	(0.16)	(0.76)	(0.83)	(0.57)	(0.57)	(0.56)	(0.25)	1.2	4.3
506	Room 302	(0.37)	0.92	0.38	(0.18)	(0.53)	(1.0)	(1.2)	(1.2)	(0.48)	(0.31)	0.66	7.6
509	Field blank	(0.67)	(0.67)	(0.12)	(0.13)	(0.39)	(0.59)	(0.57)	(0.57)	(0.19)	(0.28)	(0.77)	(1.5)
	BUILDING TWO:												
512	Room 2109	(1.2)	(1.2)	(0.26)	(0.16)	(0.89)	(1.1)	(0.32)	(0.32)	(0.50)	(0.50)	(0.70)	5.54
513	Room 1805	(1.4)	(1.4)	(0.52)	(0.35)	(0.86)	(2.2)	(0.52)	(0.52)	(0.86)	(0.95)	(1.7)	5.0
514	Room 1500	(0.64)	(0.64)	(0.42)	(0.09)	(0.96)	0.54	(0.66)	(0.66)	(0.74)	(0.58)	0.86	5.1
515	FL 10 RMC	(0.90)	(0.90)	(0.28)	(0.15)	(0.64)	(1.3)	(0.40)	(0.40)	(0.80)	(0.48)	(0.95)	5.1
516	Room 607	1.40	6.20	1.90	0.36	(0.78)	(0.96)	(0.43)	(0.43)	(0.59)	(0.43)	1.6	4.5
517	FL 2 Looby	(1.50)	(1.50)	(0.29)	(0.28)	(1.5)	(1.8)	(0.71)	(0.71)	(0.96)	(0.70)	(1.8)	3.5
518	Field blank	(1.4)	(1.4)	(0.36)	(0.22)	(0.58)	(1.1)	(0.72)	(0.72)	(0.79)	(0.30)	(0.93)	(5.8)
501	Ambient Air	0.83	4.40	1.20	(0.14)	(0.53)	(0.66)	(0.40)	(0.40)	(0.55)	(0.27)	1.6	5.6
503	Ambient Air	(0.72)	(0.72)	(0.23)	(0.21)	(0.51)	(0.51)	(0.46)	(0.46)	(0.60)	(0.36)	1.3	4.4
510	Ambient Air	(1.5)	(1.5)	(0.30)	(0.11)	(0.76)	(0.55)	(0.57)	(0.57)	(0.51)	(0.28)	(1.2)	3.5
511	Ambient Air	(1.0)	(1.0)	(0.57)	(0.29)	(1.5)	(2.8)	(0.44)	(0.44)	(1.6)	(0.51)	(1.6)	(5.5)

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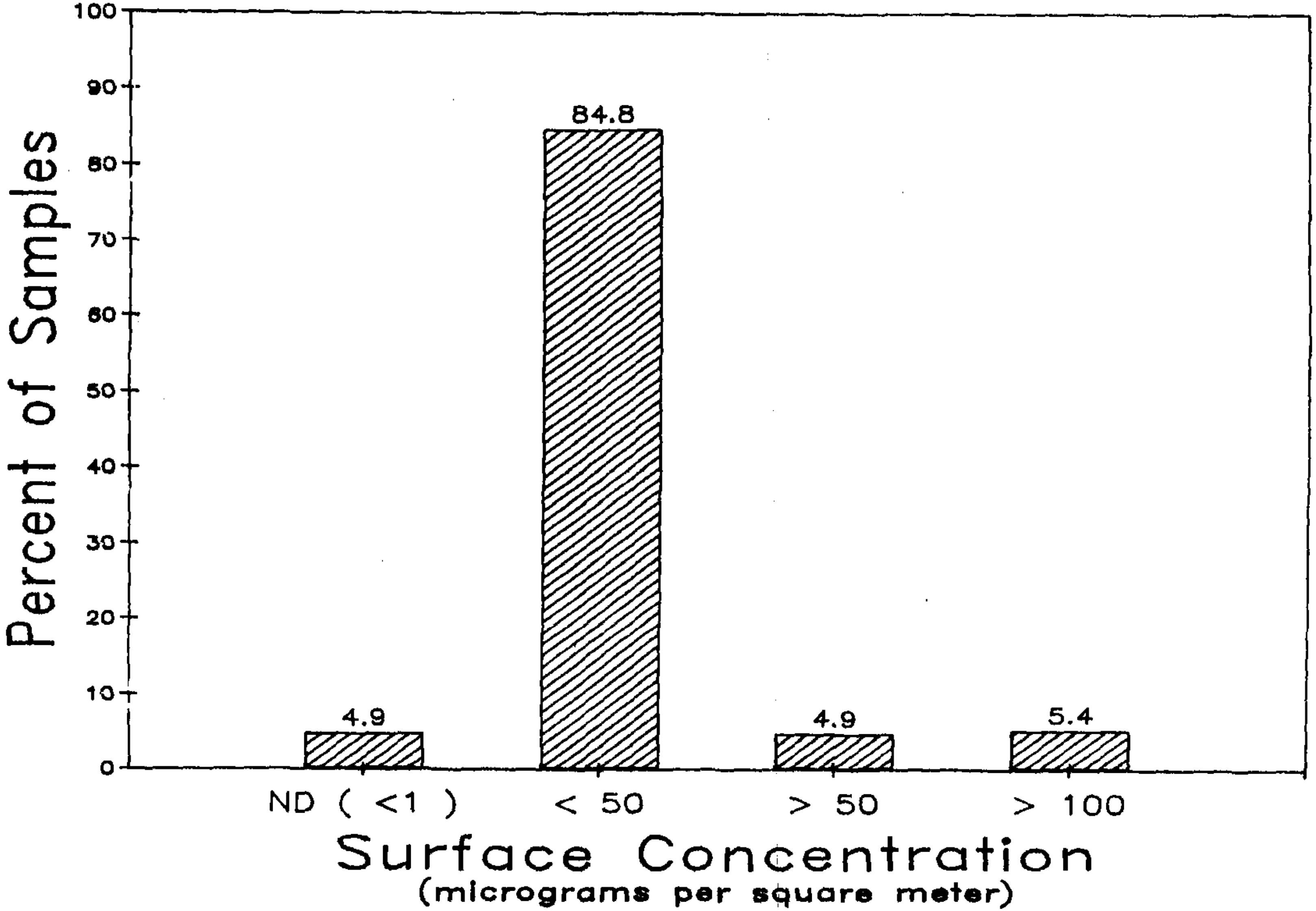
[a] Value in parentheses is the limit of detection.

FIGURE 1

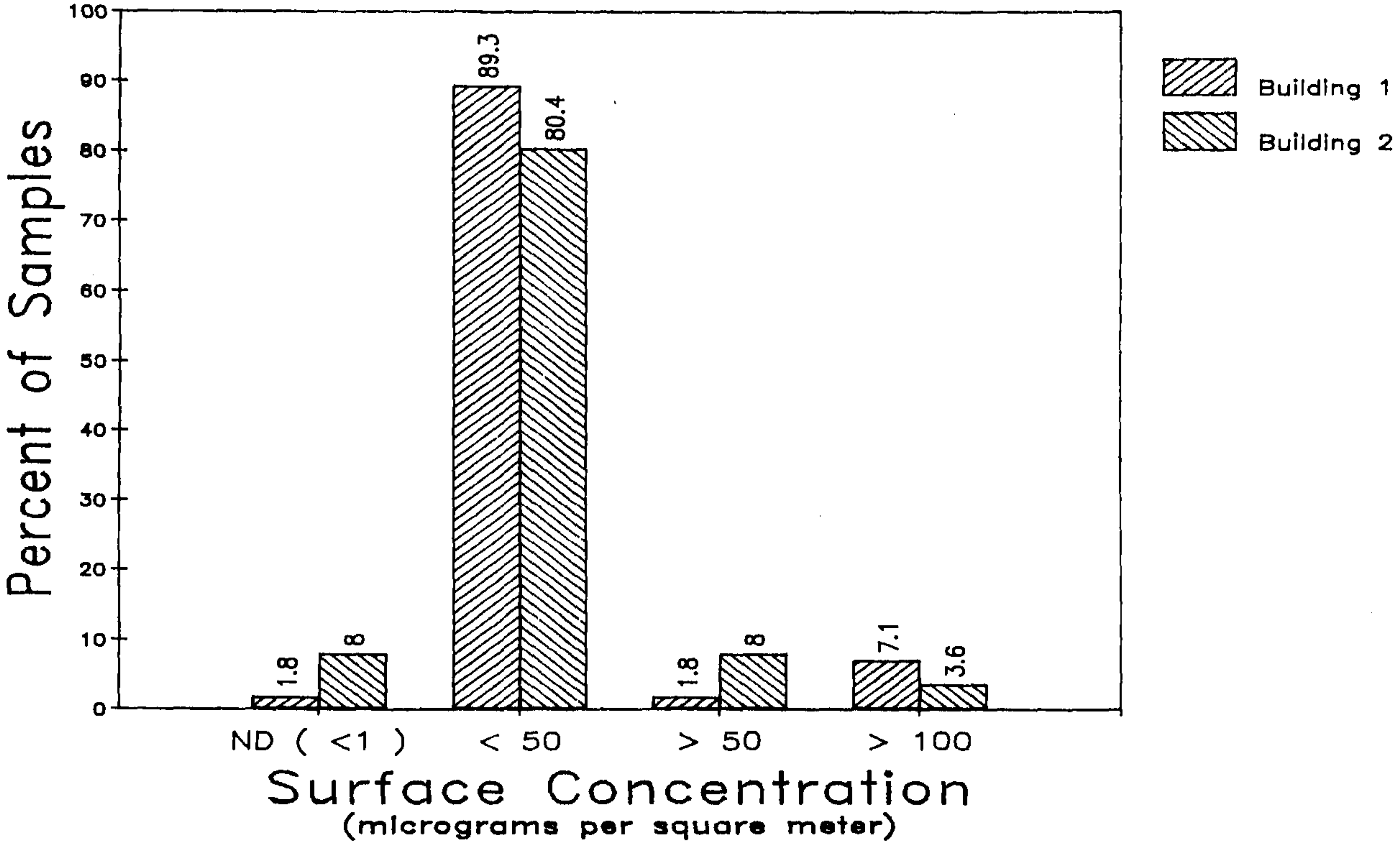
PCB surface concentration frequency distribution in two office buildings in Boston, MA.



224 samples taken

FIGURE 2

PCB surface concentration frequency distribution in office buildings one and two in Boston, MA.



224 samples taken

FIGURE 3

PCDF and PCDD homolog distributions for wipe samples obtained on building surfaces in two office buildings in Boston, MA.

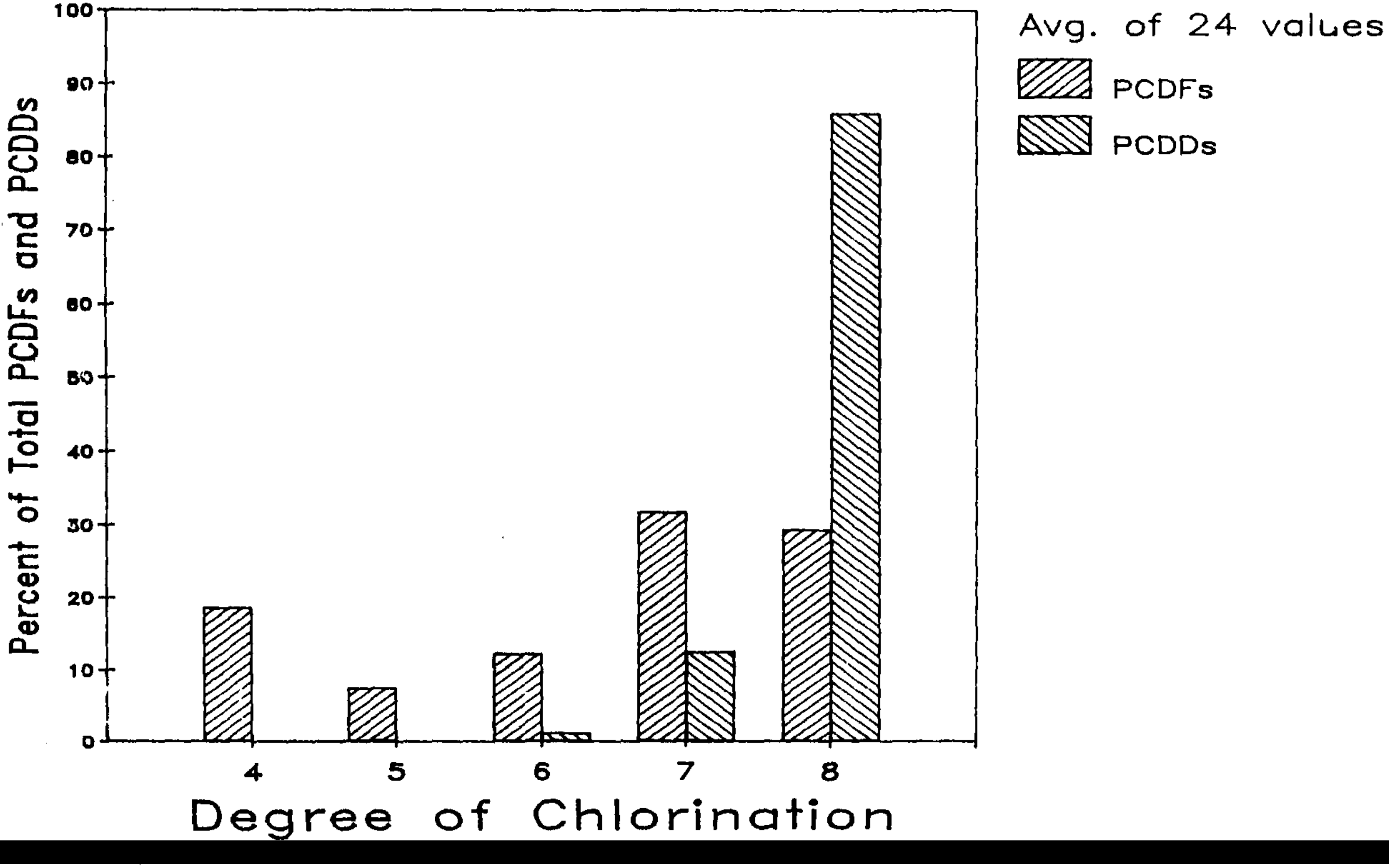


FIGURE 4

PCDF and PCDD homolog distributions for wipe samples obtained on interior air-handling unit surfaces in two office buildings in Boston, MA.