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COMMERCIAL OFFICE BUILDINGS
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NIOSH INVESTIGATOR:
John R. Kominsky, M.Sc., CIH

I. SUMMARY

On June 17, 1985, a 500 KVA transformer located in the New Mexico State Highway Department (NMSHD) General Office Building overheated and vented a vaporous-liquid aerosol containing polychlorinated biphenyls (PCBs), polychlorinated dibenzofurans (PCDFs), and polychlorinated dibenzo-p-dioxins (PCDDs). The building was decontaminated according to reoccupancy criteria developed by the Governor's Appointed Advisory Panel. Due to the ubiquity of PCBs, PCDFs, and PCDDs in the environment, a study was conducted to determine how these cleanup criteria compared to normal levels of background contamination that exist in other similar buildings in Santa Fe. Three office buildings were tested for air and surface concentrations of PCBs, as well as PCDFs and PCDDs (tetra- through octa-chlorinated homologs and the respective 2,3,7,8-tetra isomers). The fresh-air intake plenums were sampled to determine the ambient air concentrations of these contaminants entering the buildings. The surfaces tested for PCBs, PCDFs, and PCDDs were limited to high skin contact (HSC) surfaces; those surfaces such as desks, tables and counters which are repeatedly contacted by the building's occupants. The interior surfaces of the fresh-air intake plenums were tested for PCBs; these surfaces were limited to the floor and face of the air intake louvers.

The concentrations of PCBs on HSC surfaces ranged from non-detected (1.0 ug/m^2) to 5.9 ug/m^2 ($n = 37$), and those in the air intake plenums ranged from non-detected (1.0 ug/m^2) to 34 ug/m^2 ($n = 6$). The surface concentrations of PCDFs and PCDDs (converted to 2,3,7,8-tetrachlorodibenzo-p-dioxin equivalents) ranged from 0.04 to 0.42 ng/m^2 ($n = 12$). The Advisory Panel's PCB and TCDD-equivalents surface guidelines are 50 ug/m^2 and 1 ng/m^2 , respectively. The building air concentrations of PCBs ranged from non-detected (0.03 ug/m^3) to 0.18 ug/m^3 ($n = 21$), and those for 2,3,7,8-TCDD equivalents ranged from 0.15 to 1.5 pg/m^3 ($n = 9$). The Panel's PCB and TCDD equivalents air guidelines are 0.5 ug/m^3 and 2 pg/m^3 , respectively. The ambient air did not contain detectable concentrations of PCBs (detection limit = 0.03 ug/m^3 , $n = 4$); the TCDD equivalents ranged from 0.01 to 0.21 pg/m^3 ($n = 4$). A statistically significant correlation between the concentrations of PCBs and TCDD equivalents on surfaces and in air was not demonstrated ($p > 0.10$).

Based on the sampling results obtained from three selected office buildings in Santa Fe, the NIOSH investigator concluded that the air and surface concentrations of PCBs, and PCDFs and PCDDs (converted to 2,3,7,8-TCDD equivalents) that are present as normal background contamination in office buildings in Santa Fe are below the reoccupancy guidelines established for the New Mexico State Highway Department Building.

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

II. INTRODUCTION

On June 17, 1985, an electrical malfunction occurred in a 500 KVA power transformer located in the basement of the New Mexico State Highway Department General Office Building in Santa Fe, New Mexico [1]. The transformer overheated and vented a vaporous-liquid aerosol containing polychlorinated biphenyls (PCBs) and pyrolysis products including polychlorinated dibenzofurans and, to a lesser extent polychlorinated dibenzo-p-dioxins (PCDDs) throughout the building. The building was decontaminated according to reoccupancy criteria developed by the Governor's Expert Advisory Panel.

In addition to establishing absolute cleanup criteria, the Governor's Advisory Panel requested a study to determine how these criteria levels compared to normal levels of background contamination that exist in other similar buildings in Santa Fe, New Mexico. On November 1-3, 1985, the National Institute for Occupational Safety and Health (NIOSH), with assistance from the State of New Mexico, Environmental Improvement Division and SOS International, Environmental Engineering Division, conducted a study to determine the background concentrations of PCBs, PCDFs and PCDDs in air and on surfaces in commercial buildings in Santa Fe.

III. BACKGROUND

On July 16, 1985, the Governor of New Mexico appointed Expert Advisory Panel convened to develop air and surface cleanup guidelines for the New Mexico State Highway Department General Office Building in Santa Fe [2]. The Panel consisted of representatives of the National Institute for Occupational Safety and Health (NIOSH), U.S. Environmental Protection Agency (EPA), Workers Institute for Safety and Health (WISH), and four members of New Mexico's scientific community.

The reoccupancy criteria established by the 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 [3] and on surfaces [4] and were intended to guide the cleanup within a safe margin of this background level.

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

	<u>AIR</u>	<u>SURFACE</u>
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/m³ = micrograms of PCB per cubic meter of air.
pg/m³ = picograms of TCDD Equivalents per cubic meter of air.

ug/m² = micrograms of PCB per square meter of surface.

ng/m² = nanograms of TCDD Equivalents per square meter of surface.

*The observed surface and airborne concentrations of PCDFs and PCDDs (including penta through hepta chloro isomer groups and 2,3,7,8-tetra isomers) were converted to 2,3,7,8-tetrachlorodibenzo-p-dioxin equivalents (TCDD Equivalents).

In 1982, the New York State Department of Health [5] developed the concept of 2,3,7,8-TCDD Equivalents for estimating the total toxicity of a mixture of PCDFs and PCDDs as part of the development of reoccupancy criteria for the Binghamton State Office Building [6]; the building had experienced a PCB transformer fire in 1981. This procedure 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 other 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 TCDD equivalent toxicity of the mixture. The procedure assumes certain ratios of toxicities (termed weighting factors) between 2,3,7,8-TCDD and the other PCDFs and PCDDs [5]. The same weighting factors, with the exception of those for the hexa- and heptachlorodibenzofuran homologs, were used by the New Mexico Advisory Panel [7].

The following equation was used to calculate the TCDD Equivalents:

$$[2,3,7,8\text{-TCDD}] + 0.5 [\text{Penta CDDs}] + 0.02 [\text{Hexa CDDs}] + 0.33 [2,3,7,8\text{-TCDF}] + 0.17 [\text{Penta CDFs}] + 0.005 [\text{Hexa CDFs}] + 0.0005 [\text{Hepta CDFs}].$$

IV. STUDY DESIGN

The objective of the study was to determine the air and surface concentrations of PCBs, PCDFs, and PCDDs in commercial office buildings in Santa Fe, New Mexico. The buildings selected for testing were similar to the New Mexico State Highway Department General Office Building in both architectural design and age (constructed prior to 1970). The buildings had no reported history of experiencing an electrical transformer fire or failure.

Three commercial office buildings were tested for air and surface concentrations of PCBs as well as PCDFs and PCDDs (tetra- through octa-chlorinated homologs and 2,3,7,8-tetra isomers). 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 concentrations of these contaminants in the ambient air entering the buildings.

The surfaces tested for both PCBs, and PCDFs and PCDDs were limited to high skin contact surfaces. High skin contact surfaces are those which are repeatedly contacted, often for relatively long periods of time, by the building occupants. In this study, these surfaces were limited to include desks, tables and counters. The interior surfaces of the fresh-air intake plenums were tested for PCBs. The surfaces tested were limited to the floor of the plenum and the face of the air-intake louvers.

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

Building	<u>Surface</u>		<u>Air</u>	
	PCB	PCDF/PCDD	PCB	PCDF/PCDD
1	8	3	5	2
2	17	4	8	3
3	18	5	8	4
Ambient Air	-	-	3	4
Total	43	12	24	13

The PCDF and PCDD air and surfaces samples were collected at locations paired to the collection of PCB air and surface samples to determine the existence of a statistical relationship.

V. SAMPLING AND ANALYTICAL METHOLOGIES

A. Air Sampling - PCDFs, PCDDs, and PCBs

Air samples for PCDFs and PCDDs were collected using a high volume sampling device developed by the New York State Health Department (NYSDH) and previously used in evaluating the Binghamton State Office Building [8].

The high volume sampler is a two-stage sampling device. The first stage is a 47-mm diameter, 0.3 μ 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- $^{13}\text{C}_{12}$ and 2,3,7,8-tetrachlorodibenzofuran- $^{13}\text{C}_{12}$ 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 vane vacuum pump operated on 110 VAC line power. The air sample was collected for approximately a 48-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 four hours and flow rates recorded and adjusted as necessary.

Air samples for PCBs were collected using a modification of a florasil 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 μ m pore size glass fiber filter before collecting the vapor phase on the florasil. 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 florasil adsorbent. The front and back are separated by two plugs of glass wool. The front section of each tube is spiked with 0.1 μ g p,p'-DDE as an internal standard for measurement of recovery. 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 48-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 four hours and flow rates recorded and adjusted as necessary.

B. Surface Sampling - PCDFs, PCDDs, and PCBs

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

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 Teflon-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. PCDF and PCDD Analysis - Surface and Air [14]

The silica gel cartridge and the particulate filter from each PCDD and PCDF air sampler were Soxhlet extracted for 18 hours using approximately 250 mL of benzene and concentrated to 10 mL using a 3-stage Snyder column. The silica cartridges had been spiked with 2.5 ng each of 2,3,7,8-tetrachlorodibenzo-p-dioxin- $^{13}\text{C}_{12}$ (2,3,7,8-TCDD- $^{13}\text{C}_{12}$) and 2,3,7,8-tetrachlorodibenzofuran- $^{13}\text{C}_{12}$ (2,3,7,8-TCDF- $^{13}\text{C}_{12}$) prior to sampling. Before extracting, 5 ng of octachlorodibenzo-p-dioxin $^{13}\text{C}_{12}$ (OCDD- $^{13}\text{D}_{12}$) was spiked into each sample. The benzene extracts were concentrated to approximately 10 mL using a 3-stage Snyder column.

The wipe samples were transferred to Soxhlet thimbles and spiked with 10 ng each of

2,3,7,8-TCDD- $^{13}\text{C}_{12}$, 2,3,7,8-TCDF- $^{13}\text{C}_{12}$ and OCDD- $^{13}\text{C}_{12}$. All samples were Soxhlet extracted for 18 hours using benzene and concentrated to approximately 10 mL using a 3 stage Snyder column.

The benzene extracts from the air and wipe samples were transferred to multilayered columns containing activated silica gel, 44 percent concentrated sulfuric acid on silica gel, and 33 percent 1M sodium hydroxide on silica gel. The columns were rinsed with 70 mL of hexane and the entire eluates were collected. The purpose of these columns was to remove acidic and basic compounds from the extracts as well as oxidizable materials.

The benzene/hexane eluates were concentrated using a gentle stream of nitrogen gas and solvent exchanged into hexane. The hexane solutions were chromatographed through columns containing approximately 5 gm of activated basic alumina using hexane/methylene chloride (97:3, v/v), and hexane/methylene chloride eluates were collected, concentrated to near dryness, and dissolved in 20 μL of n-decane containing 5 ng of an absolute recovery standard, 1,2,3,4-TCDD- $^{13}\text{C}_{12}$. All solutions were stored at 0°C and protected from light until analyzed.

The extracts were analyzed and quantified for PCDD and PCDF using combined capillary column gas chromatography/high resolution mass spectrometry (HRGC/HRMS). The HRGC/HRMS consisted of a Carlo Erba Model 4160 gas chromatograph interfaced directly into the ion source of a VG Model 7070 mass spectrometer. The chromatographic column was a 60 M DB- fused silica column using helium carrier gas at a flow velocity of 25 cm/sec. The mass spectrometer was operated in the electron impact (EI) ionization mode at a mass resolution of 9000-12000 (M/WM, 10% valley definition). All HRGC/HRMS data were acquired by multiple-ion-detection using a VG Model 2035 Data System.

The operation of the HRGC/HRMS was evaluated each day by analyzing standard mixtures of PCDD and PCDF isomers. These consisted of 2,3,7,8-TCDF, 2,3,7,8-TCDD, 2,3,7,8-TCDF $^{13}\text{C}_{12}$, and 2,3,7,8-TCDD- $^{13}\text{C}_{12}$ mixtures to evaluate the accuracy of quantification, mixtures of selected PCDD and CDF isomers to evaluate the stability of the chromatographic elution windows, and TCDD isomer mixtures to evaluate isomer resolution. The mass accuracy of the MID unit was evaluated at least every four hours by focusing selected ion masses from perfluorokerosene (PFK) and correcting the slope to account for minor variations. Mass focus stability was assured by the use of a reference PFK "lock mass" to correct for any mass focus drift.

Native, field blank, and lab blank samples were processed during the extraction and cleanup of the samples. The isomer quantification for the native spiked samples ranged from 66 to 180% of the native spiked samples. The method blanks, were in general, free of contamination with the exception of low levels of heptachloro and octachloro isomers.

The recoveries of the internal standards, 2,3,7,8-TCDF-¹³C₁₂, 2,3,7,8-TCDD-¹³C₁₂, and OCDD-¹³C₁₂ were calculated by comparison to the external standard, 1,2,3,4-TCDD-¹³C₁₂, which was added following extraction. Relative response factors were calculated from triplicate analysis of a standard mixture containing the four labelled internal standards.

The PCDF and PCDD 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 internal standard. The 2,3,7,8-TCDF-¹³C₁₂ was used to quantify the TCDF isomers, while the 2,3,7,8-TCDD-¹³C₁₂ was used to quantify the TCDD isomers and the pentachloro and hexachloro PCDD and PCDF isomers. The OCDD-¹³C₁₂ was used to quantify the heptachloro and octachloro PCDD and PCDF isomers. Experimental relative response factors were calculated from analysis of a mixture which contained representatives of the tetrachloro- through octachloro-PCDD and PCDF congener classes. Since the mixture did not contain a heptachloro-CDD isomer, the heptachloro-CDF was used for calculating the relative response factor for the heptachloro PCDD and PCDF isomers. The response factors were included in all calculations used to quantify the data. The response factors were calculated using the sum of the two ions monitored for each class of isomers compared to the sum of the two ions monitored for the corresponding internal standard. The experimental response factors were:

Tetra-CDD	0.976	Tetra-CDF	1.04
Penta-CDD	1.19	Penta-CDD	0.509
Hexa-CDD	1.17	Hexa-CDF	0.636
Hepta-CDD	2.93	Hepta-CDF	2.93
Octa-CDD	1.08	Octa-CDF	1.12

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

$$\text{Quantity/sample} = \frac{\text{Areas of Quant. Masses} \times \text{Quantity of Internal Standard}}{\text{Areas of Int. Std. Masses} \times \text{Response Factor}}$$

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

- (1) Simultaneous response at both ion masses
- (2) Chlorine isotope ratio within $\pm 15\%$ of the theoretical value
- (3) 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-TCDF/TCDD and OCDD isomers included the additional criterion that they coeluted within ± 1 second of their isotopically labeled analogs. A limit of detection was calculated for samples in which a particular chlorination class was not detected. The formula was used:

$$\text{Limit of Detect./sample} = \frac{\text{Hts. of Quant. Mass.} \times \text{Quant. Int. Std.} \times 2.5}{\text{Hts. of Int. Std. Masses} \times \text{Response Factor}}$$

D. PCB Analysis - Surface and Air [15]

The wipe samples were extracted using the following procedures. Forty ml of 85:15 hexane/methylene chloride were added to each sample container. The samples were shaken on a wrist action shaker for 30 minutes to extract the PCBs. The extract was then transferred quantitatively to a 250 ml Kuderna-Danish flask with three 40 ml rinses. The extract was concentrated to between 5 and 10 ml on a hot water bath. The extract was then quantitatively transferred to a 15 ml centrifuge tube with rinsing, and it was concentrated to 2.5 ml using a gentle flow of sulfuric acid. Five ml of concentrated sulfuric acid were added to the extract and mixed with a vortex mixer. The layers were allowed to separate (centrifuged if necessary) and the hexane layer (top layer) was removed with a pipet. One ml of the extract was put in an inject vial, and the remainder of the extract was put in a vial for storage.

If the initial analysis of the sample indicated a need for additional cleanup, a micro florisil column cleanup was performed. Two grams of florisil were packed in a polypropylene column, and a small amount of sodium sulfate was put on top of the column. The column was preeluted with hexane. One ml of the sample extract was placed on top of the column and allowed to pass into the sodium sulfate layer. The column was then eluted with 20 ml of hexane. The eluant was concentrated to 1 ml and was vialled for analysis.

The procedure for extracting the air samples was as follows. If the sample included a glass fiber filter, the filter was placed in a erlenmeyer flask and was extracted with 20 ml of hexane on a wrist shaker for 30 minutes. The two stage florisil stick was then scored and broken in half. 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. If there was no filter, 20 ml of clean hexane was passed through the front portion of the florisil stick. The sample was then concentrated to a final volume of 1 ml using a gentle stream of nitrogen. This 1 ml extract was then vialled for analysis.

The back portion of the stick was extracted by passing 20 ml of hexane through the stick into a centrifuge tube. The extract was then concentrated to a final volume of 1 ml using a gentle stream of nitrogen and vialled for analysis.

If sample cleanup was necessary, a portion of the extract was cleaned using the procedures used for the wipe samples (acid cleanup and micro florisil cleanup).

A reagent blank and a method standard were included with every set of extractions. The reagent blank was prepared by adding the appropriate solvents to an extraction vessel and performing the entire extraction and analysis procedure on the resulting extract. The method standards was prepared by taking either a clean wipe pad or an unused florisil stick and spiking it with a known amount of a PCB standard. These two quality control samples served as a check on laboratory contamination and analytical accuracy.

The samples were analyzed by gas chromatography with electron capture detection. The analytical sequence was as follows. For the initial analysis of all the samples, standards of Aroclors 1016, 1221, 1232, 1242, 1248, 1254, and 1260 were analyzed prior to the analysis of samples. Three point curves were also typically run for Aroclors 1242, 1254, and 1260. After analysis of the standard, the samples and quality control check were run. Finally, a check standard was analyzed at the conclusion of the sequence.

The initial analysis demonstrated that many of the standards in the initial sequence were not necessary. Thus, for subsequent analyses, only the standards of interest were run. This always included Aroclor 1260, and sometimes included Aroclors 1242 and 1254.

The chromatograms were interpreted by visually comparing them to the Aroclor standards. In cases where there was a clear match between the sample and a specific Aroclor, the Aroclor was identified and the results were calculated by direct comparisons of 4 or 5 peaks with the standard. In cases where there was not a clear match, we either used the Webb and McCall procedure or the direct comparison method, depending on which we thought was more appropriate.

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 Hygiene Sampling and Chemical Analyses, SOP No. 019, December 19, 1984.

VI. RESULTS AND DISCUSSION

A. Airborne Concentrations of PCBs

A total of 24 air samples were collected for analysis of PCBs (Table 1). Three of these samples were collected in the buildings fresh-air intake plenums to determine the concentration of PCBs entering the buildings through the ambient air; and 21 samples were collected in the occupied workspace of the buildings. In buildings one and two, none of the samples (0/5 and 0/8, respectively) showed concentrations above the detection limit. In the third building, four of eight samples showed concentrations above the detection limit (0.03 ug/m^3). The four samples above the detection limit ranged from 0.10 to 0.18 ug/m^3 (arithmetic mean = 0.14 ug/m^3). All concentration are below the reoccupancy criteria of 0.50 ug/m^3 . The ambient air samples did not show detectable concentrations of PCBs at a detection limit of 0.03 ug/m^3 . The field blanks ($n = 4$) were all non-detected at a detection limit of 0.03 ug/m^3 .

B. Airborne Concentrations of PCDDs and PCDFs

A total of 13 air samples were collected for tetra- through octa-chlorinated PCDF and PCDD homologs and the respective 2,3,7,8-tetra isomers (Table 2). Four of these samples were collected in the buildings fresh-air intake plenums, and nine samples were collected in the occupied workspace of the buildings. The grouped data for nine samples obtained in the occupied spaces are presented in Table 3. The concentrations of PCDFs in the building air ranged from non-detected (0.49 pg/m^3) to 162 pg/m^3 (arithmetic mean = 22 pg/m^3). The 2,3,7,8-TCDF isomer was present above the detection limit in two of the nine samples at a concentration of 1.0 pg/m^3 in each sample. The corresponding concentrations of PCDDs ranged 2.4 to 221 pg/m^3 (arithmetic mean = 96 pg/m^3). The 2,3,7,8-TCDD isomer was not present above the detection limit (0.09 to 0.49 pg/m^3) in any of the samples. The grouped data for the ambient air samples is presented in Table 4. The concentration of PCDFs ranged from non-detected (0.65 pg/m^3) to 4.5 pg/m^3 (arithmetic mean = 3.2 pg/m^3), and those for PCDDs ranged for 19 to 193 pg/m^3 (arithmetic mean = 132 pg/m^3). The respective 2,3,7,8-tetra isomers were not detected (0.11 to 0.18 pg/m^3 and 0.06 to 0.19 pg/m^3 , respectively) in any of the samples.

The calculated TCDD-Equivalents for the interior building samples ranged from 0.15 to 1.5 pg/m^3 (arithmetic mean = 0.50 pg/m^3), and that for the ambient air intake samples ranged from 0.01 to 0.21 pg/m^3 (arithmetic mean = 0.14 pg/m^3). All of these samples showed concentrations below the 2.0 pg/m^3 reoccupancy guideline.

The PCDD and PCDF homolog profiles (tetra- through octa-chlorinated dibenzodioxins and dibenzofurans) for the building air and ambient air samples are presented in Figures 1 and 2, respectively. The tetra- through octa-chlorinated homologs are presented as the percent of the total PCDDs and PCDFs. The hepta- and octachlorinated homologs predominated in both of the PCDD and PCDF profiles. The similarities of the homolog profiles of interior building air and ambient air suggest a common source: atmospheric transport of combustion particulates [12-13].

The nine PCDF and PCDD samples were collected at locations paired to the collection of PCBs to determine the existence of a statistical relationship. The concentrations of PCBs, PCDDs, PCDFs, and TCDD-Equivalents were log transformed and used in linear regression analysis. The correlation coefficients (Table 5) were not statistically significantly different from zero ($p > 0.10$) in any case. Thus, as significant relationship between airborne concentrations of PCBs and concentrations of PCDFs, PCDDs, or TCDD-Equivalents did not exist in these buildings.

C. Surface Concentrations of PCBs

The PCB analyses of 37 samples collected on high skin contact surfaces (desks, tables and counters) in three office buildings are presented in Table 6. The analyses are summarized by building in Table 7. In building one, none (0/6) of the surface samples exceeded the detection limit (1.0 ug/m^2). In buildings two and three, 13/15 and 2/16 samples, respectively, exceeded the same detection limit. Overall, the surface concentrations ranged from non-detected (1.0 ug/m^2) to 5.9 ug/m^2 (arithmetic mean = 1.3 ug/m^2). The samples (15/37) with concentrations above the detection limit ranged from 1.2 to 5.9 ug/m^2 (arithmetic mean = 2.5 ug/m^2). The PCB was identified as Aroclor 1260 in building three. (Aroclors 1242, 1254 and 1260 are commercial mixtures of PCBs with approximately 42, 54 and 60 weight percent chlorine, respectively.)

The PCB analyses of six surface wipe samples collected from the interior of the air-handling units (AHUs) of the three buildings is presented in Table 8. The samples were collected in the fresh-air intake plenums of the AHUs. The three samples collected on the floor of the AHUs showed concentrations ranging from 3.3 to 34 $\mu\text{g}/\text{m}^2$ (arithmetic mean = 14 $\mu\text{g}/\text{m}^2$). The three samples collected from the face of the fresh-air intake louvers ranged from non-detected (1.0 $\mu\text{g}/\text{m}^2$) to 11 $\mu\text{g}/\text{m}^2$ (arithmetic mean = 5.8 $\mu\text{g}/\text{m}^2$). Overall, the surface concentrations ranged from non-detected (1.0 $\mu\text{g}/\text{m}^2$) to 34 $\mu\text{g}/\text{m}^2$ (arithmetic mean 9.9 $\mu\text{g}/\text{m}^2$). The PCB was identified as Aroclors 1254 and 1260.

The surface concentrations of PCBs measured were all below the 50 $\mu\text{g}/\text{m}^2$ guideline value. The higher levels were present on surfaces in the air intake plenums which are less frequently cleaned, as well as, less likely to be contacted on a frequent and prolonged basis.

D. Surface Concentrations of PCDFs and PCDDs

The samples collected on high skin contact surfaces and analyzed for tetra- through octa-chlorinated PCDF and PCDD homologs and the respective 2,3,7,8-tetra isomers are presented in Table 9. (Two quality control "field blank" samples also are included.) The grouped data is presented in Table 10. The surface concentrations of PCDFs ranged from 0.35 to 4.3 ng/m^2 , (arithmetic mean = 1.4 ng/m^2). The 2,3,7,8-TCDF isomer was present above the detection limit in all of the samples (range = 0.02 - 0.76 ng/m^2 , arithmetic mean = 0.29 ng/m^2); the field blanks did not show detectable levels (detection limit 0.01 ng/m^2). The surface concentrations of PCDDs ranged from 1.9 to 24 ng/m^2 (arithmetic mean = 8.5 ng/m^2). The 2,3,7,8-TCDD isomer was not present above the detection limit (0.02 ng/m^3) in any of the samples. The calculated concentrations of TCDD-Equivalents for these 12 samples ranged from 0.04 to 0.42 ng/m^2 (arithmetic mean = 0.15 ng/m^2), which were all below the skin contact guideline of 1 ng/m^2 .

The PCDD and PCDF homolog profiles (tetra- through octa-chlorinated dibenzo-p-dioxins and dibenzofurans) are presented in Figure 3. The tetra- through octa-chlorinated homologs are presented as the percent of the total PCDDs and PCDFs. The PCDD profile shows a predominance of the higher chlorinated homologs with the maximum concentrations represented by the octachlorodibenzodioxins. The PCDD profile is similar to that previously shown for the ambient and building air samples, and is also similar to that found in commercial grade pentachlorophenol [10-11]; PCDDs are manufacturing contaminants of chlorinated phenols [11]. Pentachlorophenol and its sodium salt have varied uses as fungicides and biocides, with the majority used as a wood preservative [11]. The PCDF homolog profile shows that the tetra- through octa-CDFs are more evenly distributed with the maximum concentrations represented by the tetra-CDFs.

The twelve PCDF and PCDD samples were collected at locations paired to the collection of PCB samples to determine the existence of a statistical relationship. The surface concentrations of PCBs, PCDFs, PCDDs, and TCDD-Equivalents were log transformed and used in linear regression analysis. The correlation coefficients (Table 5) were not statistically significantly different from zero ($p > 0.10$) in any case. Thus, a significant relationship between the surface concentrations of PCBs and concentrations of PCDFs, PCDDs, or TCDD-equivalents was not demonstrated in these buildings.

VII. CONCLUSION

A study was conducted to determine the background concentrations of polychlorinated biphenyls (PCBs), polychlorinated dibenzofurans (PCDFs) and polychlorinated dibenzo-p-dioxins (PCDDs) in air and on surfaces in three commercial office buildings in Santa Fe, New Mexico. The buildings selected for testing were similar to the New Mexico State Highway Department Building in both architectural design and age, and had no history of experiencing an electrical transformer fire or failure. Measurable air and surface concentrations of these contaminants were present in the buildings. Comparison of the data to the cleanup guidelines developed by the Governor's Advisory Panel for the New Mexico State Highway Department Building shows that the levels of PCBs, and PCDFs and PCDDs (converted to 2,3,7,8-TCDD equivalents) present as normal contamination office buildings in Santa Fe are below the values used as reoccupancy guidelines.

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

The similarities of the PCDD and PCDF homolog profiles of the building air and ambient air suggest a common source: atmospheric transport of combustion particulates.

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IX. AUTHORSHIP AND ACKNOWLEDGEMENTS

Report Prepared by:

John R. Kominsky, M.Sc., CIH
Hazard Evaluations and Technical
Assistance Branch
Division of Surveillance, Hazard
Evaluations, and Field Studies

Evaluation Conducted by:

John R. Kominsky, M.Sc., CIH
Hazard Evaluations and Technical
Assistance Branch
Division of Surveillance, Hazard
Evaluations, and Field Studies
Warren T. Slade, CIH
Bureau of Health and Safety
Environmental Improvement Division
State of New Mexico
Santa Fe, New Mexico

Robert Mooring
Environment Engineering Division
SOS International
South San Francisco, California

Originating Office:

Hazard Evaluations and Technical
Assistance Branch
Division of Surveillance, Hazard
Evaluations, and Field Studies

Laboratory Support:

Staff Chemists
Versar Incorporated
Springfield, Virginia

Staff Chemists
Battelle-Columbus Laboratories
Columbus, Ohio

Report Typed By:

Kym Smith
Clerk-Typist

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2. Chief Highway Administration, New Mexico State Highway Department, Santa Fe, NM.
3. Chief, Bureau Health and Safety, Environmental Improvement Division, State of New Mexico.
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5. NIOSH Region

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

Airborne Concentrations of PCBs in Office Buildings
and Ambient Air in Santa Fe, New Mexico

Building	Aroclor	n/N*	Concentration - $\mu\text{g}/\text{m}^3$	
			Mean**	Range
1	-	0/5	0.02	(0.03) ^a
2	-	0/8	0.02	(0.03)
3	1254/1260	4/8	0.08	(0.03)-0.18
Total	1254/1260	4/21	0.04 (0.14)	(0.03)-0.18
Ambient Air	-	0/3	0.02	(0.03)

* 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 2

Airborne Concentrations of Polychlorinated Dibenzofurans (PCDFs) and Polychlorinated Dibenzo-p-dioxins (PCDDs)
in Office Buildings and Ambient AirSanta Fe, New Mexico
November 1985

Building	Concentrations of PCDFs - pg/m ³						Concentrations of PCDDs - pg/m ³					
	2378 TCDF	TCDF	PeCDF	HxCDF	HpCDF	OCDF	2378 TCDD	TCDD	PeCDD	HxCDD	HpCDD	OCDD
1	(0.11)*	(0.11)	0.23	0.044	1.3	1.7	(0.13)	(0.13)	(0.25)	(0.61)	16	110
1	1.0	5.0	0.43	0.60	2.1	2.6	(0.21)	(0.21)	(0.26)	1.5	26	160
2	(0.18)	(0.18)	(0.078)	0.34	0.86	0.66	(0.095)	(0.095)	(0.18)	0.82	4.5	8.3
2	(0.98)	(0.98)	4.1	14	53	92	(0.49)	(0.49)	(1.2)	(0.88)	50	170
2	(0.19)	(0.19)	(0.30)	(0.17)	1.8	(0.78)	(0.34)	(0.34)	(0.35)	(0.29)	17	120
3	1.0	3.6	0.29	(0.063)	(0.15)	(0.43)	(0.19)	(0.19)	(0.34)	(0.23)	(0.13)	2.0
3	(0.21)	(0.21)	(0.14)	(0.050)	(0.17)	(0.38)	(0.18)	(0.18)	(0.33)	(0.23)	1.0	3.9
3	(0.59)	(0.59)	(0.25)	(0.17)	(0.70)	(1.4)	(0.43)	(0.43)	(0.59)	(0.42)	1.8	5.6
3	(0.42)	(0.42)	(0.29)	(0.11)	1.4	3.0	(0.36)	(0.36)	(0.79)	(0.36)	18	140
Ambient Air	(0.10)	(0.10)	(0.28)	(0.036)	(0.22)	(0.58)	(0.090)	(0.090)	(0.14)	(0.23)	4.8	14
"	(0.11)	(0.11)	(0.077)	0.27	1.5	2.6	(0.061)	(0.061)	(0.12)	0.72	22	170
"	(0.17)	(0.17)	(0.27)	(0.16)	1.1	1.7	(0.13)	(0.13)	(0.39)	(0.16)	14	140
"	(0.17)	(0.17)	(0.21)	(0.10)	1.6	2.7	(0.19)	(0.19)	(0.17)	(0.27)	20	170
Blank	(0.13)	(0.13)	(0.081)	(0.063)	(0.46)	(0.28)	(0.12)	(0.12)	(0.13)	(0.13)	0.51	0.38

* Value in parentheses is the limit of detection.

Table 3

Airborne Concentrations of PCDFs and PCDDs
in Three Office Buildings in Santa Fe, New Mexico

	n/N*	Concentration - $\mu\text{g}/\text{m}^3$	
		Mean**	Range
2378 TCDF	2/9	0.37	(0.11) ^a - 1.0
TCDFs	2/9	1.1	(0.11) - 5.0
PeCDFs	4/9	0.62	(0.08) - 4.1
HxCDFs	4/9	1.7	(0.05) - 14
HpCDFs	6/9	6.8	(0.15) - 53
OCDFs	5/9	11	(0.38) - 92
Total PCDFs		22	(0.49) - 162
2378 TCDD	0/9	0.13	(0.09) - 0.49
TCDDs	0/9	0.14	(0.09) - 0.49
PeCDDs	0/9	0.24	(0.18) - 1.2
HxCDDs	2/9	0.46	(0.23) - 1.5
HpCDDs	8/9	15	(0.13) - 26
OCDDs	9/9	80	2.0 - 170
Total PCDDs		96	2.4 - 221

* 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 4

Ambient Air Concentrations of PCDFs and PCDDs
in Santa Fe, New Mexico

	n/N*	Concentration - $\mu\text{g}/\text{m}^3$	
		Mean*	Range**
2378 TCDF	0/4	0.08	(0.11 - 0.18) ^a
TCDFs	0/4	0.08	(0.11 - 0.18)
PeCDFs	0/4	0.11	(0.07 - 0.28)
HxCDFs	1/4	0.10	(0.03 - 0.27)
HpCDFs	3/4	1.1	(0.22)- 1.6
OCDFs	3/4	1.8	(0.58)- 2.7
Total PCDFs		3.2	(0.65)- 4.5
2378 TCDD	0/4	0.06	(0.06 - 0.19)
TCDDs	0/4	0.06	(0.06 - 0.19)
PeCDDs	0/4	0.11	(0.12 - 0.39)
HxCDDs	1/4	0.30	(0.16 - 0.72)
HpCDDs	4/4	15	4.8 - 22
OCDDs	4/4	116	14 - 170
Total PCDDs		132	19 - 193

* 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 5

Correlation Between PCBs and PCDFs, PCDDs, and TCDD-Equivalents in Air and on High Skin Contact Surfaces in Office Buildings in Santa Fe, New Mexico

	Surfaces			Air		
	N	Corr. Coeff.	P	N	Corr. Coeff.	P
PCDFs	12	0.31	>0.1	9	-0.09	>0.1
PCDDs	12	0.43	>0.1	9	-0.34	>0.1
TCDD-Equivalent	12	0.42	>0.1	9	+0.31	>0.1

Table 6
 Levels of Polychlorinated Biphenyls (PCBs) on High Skin Contact Surfaces
 in Office Buildings
 Santa Fe, New Mexico - November 1985

<u>Sample Location/Description</u>		<u>Aroclor</u>	<u>Level-ug/m²</u>
BUILDING ONE			
Floor one:	desk	-	ND (1.0)*
"	field blank	-	ND (1.0)
Ground:	desk	-	ND (1.0)
"	"	-	ND (1.0)
"	"	-	ND (1.0)
"	"	-	ND (1.0)
"	field blank	-	ND (1.0)
BUILDING TWO			
Floor two:	counter	1260	2.7
"	desk	1260	2.2
"	table	1260	2.1
"	desk	-	ND (1.0)
"	"	1260	2.2
Floor one:	desk	1260	3.8
"	"	1260	3.8
"	"	1260	2.2
"	table	1260	1.2
"	desk	1260	1.7
Ground:	desk	-	ND (1.0)
"	"	1260	3.4
"	table	1260	5.9
"	"	1260	2.0
"	counter	1260	1.4
BUILDING THREE			
Floor four:	field blank	-	ND (1.0)
"	table	1254	1.6
"	"	-	ND (1.0)
Floor three:	desk	-	ND (1.0)
"	"	-	ND (1.0)
"	"	-	ND (1.0)
"	table	-	ND (1.0)
Floor two:	desk	-	ND (1.0)
"	"	-	ND (1.0)
"	"	-	ND (1.0)
"	"	1242	1.6
Floor one:	desk	-	ND (1.0)
"	table	-	ND (1.0)
"	"	-	ND (1.0)
"	"	-	ND (1.0)
"	field blank	-	ND (1.0)
Ground:	table	-	ND (1.0)
"	"	-	ND (1.0)

* ND denotes non-detected. Value parentheses is the limit of detection.

Table 7

Concentrations of PCBs on High Skin Contact Surfaces in
Office Buildings in Santa Fe, New Mexico

Building	Aroclor	n/N*	Concentration - $\mu\text{g}/\text{m}^2$	
			Mean**	Range
1	-	0/6	0.5	(1.0) ^a
2	1260	13/15	2.4	(1.0) - 5.9
3	1242/1254	2/16	0.63	(1.0) - 1.6
Total	-	15/37	1.3	(1.0) - 5.9

* 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 8

Surface Concentrations of PCBs in Fresh-Air Intake Plenums
in Office Buildings in Santa Fe, New Mexico

Sample Location/Description	Aroclor	Conc. - ug/m ²
BLDG 1: floor of air intake plenum	1254/1260	34
" face of fresh air intake louvers	1260	11
BLDG 2: floor of air intake plenum	1254	3.3
" face of fresh air intake louver	1260	6.0
" field blank	-	(1.0) ^a
BLDG 3: floor of air intake plenum	1260	4.8
" face of fresh air intake louver	-	(1.0)
" field blank	-	(1.0)

* MD denotes non-detected. Value in parentheses is the limit of detection.

Table 9
 Concentrations of Polychlorinated Dibenzofurans (PCDFs) and Polychlorinated Dibenzo-p-dioxins (PCDDs)
 on High Skin Contact Surfaces in Office Buildings

Santa Fe, New Mexico
 November 1985

BUILDING	Concentrations of PCDFs - ng/m ²						Concentrations of PCDDs - ng/m ²					
	2378 TCDF	TCDF	PeCDF	HxCDF	HpCDF	OCDF	2378 TCDD	TCDD	PeCDD	HxCDD	HpCDD	OCDD
1	0.079	0.13	0.035	0.063	0.047	0.14	(0.011)	(0.011)	(0.016)	(0.039)	0.28	2.5
1	0.47	0.95	0.29	0.17	0.37	0.36	(0.042)	(0.042)	(0.043)	0.21	0.88	5.0
1	0.38	0.61	0.046	0.15	0.095	0.16	(0.01)	(0.01)	(0.023)	0.15	0.63	4.4
2	0.76	1.6	0.34	0.56	0.52	0.55	(0.028)	(0.028)	(0.013)	4.3	5.2	14
2	0.17	0.24	0.088	0.35	0.42	0.27	(0.039)	(0.029)	(0.039)	0.86	3.2	8.9
2	0.61	1.0	(0.030)	0.22	0.35	0.27	(0.013)	(0.013)	(0.062)	1.0	2.2	6.9
2	0.18	0.25	0.10	0.19	0.36	0.27	(0.055)	(0.055)	(0.069)	0.44	1.3	3.7
3	0.024	0.32	0.019	0.064	0.042	(0.34)	(0.098)	(0.098)	(0.11)	0.18	0.36	2.0
3	0.12	0.17	(0.012)	(0.010)	0.069	0.10	(0.019)	(0.019)	(0.033)	0.094	0.23	1.6
3	0.20	0.35	0.049	0.060	0.15	0.24	(0.02)	(0.02)	(0.039)	0.38	4.4	13
3	0.37	0.60	(0.005)	0.15	0.84	1.6	(0.038)	(0.038)	(0.024)	0.58	1.3	6.2
3	0.11	0.13	0.035	0.063	0.047	0.14	(0.011)	(0.011)	(0.016)	(0.039)	0.28	2.5
Blank	(0.013)*	(0.013)	(0.011)	(0.005)	(0.022)	(0.043)	(0.014)	(0.014)	(0.025)	(0.009)	(0.007)	0.069
Blank	(0.016)	(0.016)	0.10	0.015	0.062	(0.030)	(0.026)	(0.026)	(0.032)	(0.016)	0.058	0.18

* Value in parentheses is the limit of detection.

Table 10

Concentrations of PCDFs and PCDDs on High Skin Contact Surfaces
in Three Office Buildings in Santa Fe, New Mexico

	n/N*	Concentrations - $\mu\text{g}/\text{m}^2$		
		Mean**	Range	
2378-TCDF	12/12	0.29	0.02	- 0.76
TCDFs	12/12	0.53	0.13	- 1.6
PeCDFs	9/12	0.08	(0.01) ^a	- 0.34
HxCDFs	11/12	0.17	(0.01)	- 0.56
HpCDFs	12/12	0.27	(0.02)	- 0.84
OCDFs	11/12	0.36	0.10	- 1.6
Total PCDFs		1.4	0.35	- 4.3
2378-TCDD	0/12	0.02	(0.01	- 0.10)
TCDDs	0/12	0.02	(0.01	- 0.10)
PeCDDs	0/12	0.02	(0.01	- 0.11)
HxCDDs	10/12	0.70	(0.04)	- 4.3
HpCDDs	12/12	1.7	0.23	- 5.3
OCDDs	12/12	6.0	1.6	- 14
Total PCDDs		8.5	1.9	- 24

* 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.

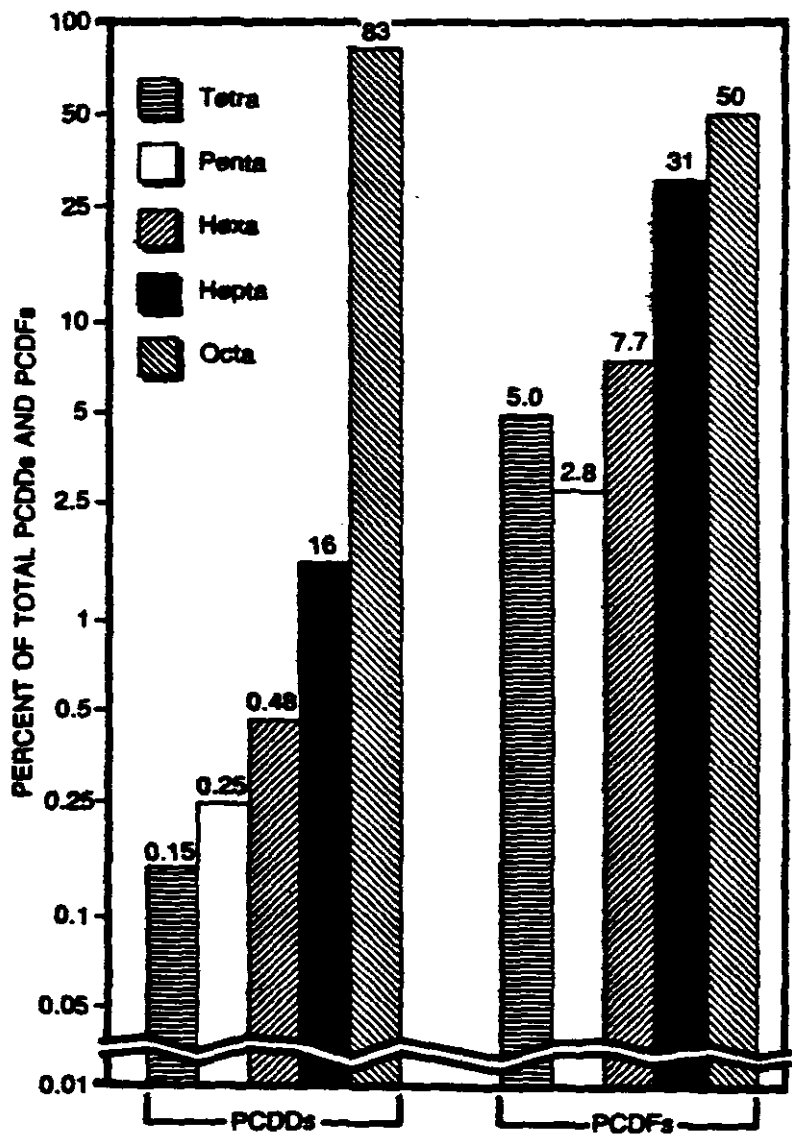


Figure 1: Tetra- through octa-chlorinated dibenzo-p-dioxin (PCDD) and dibenzofuran (PCDF) homolog profiles for air samples in three office buildings in Santa Fe, NM.

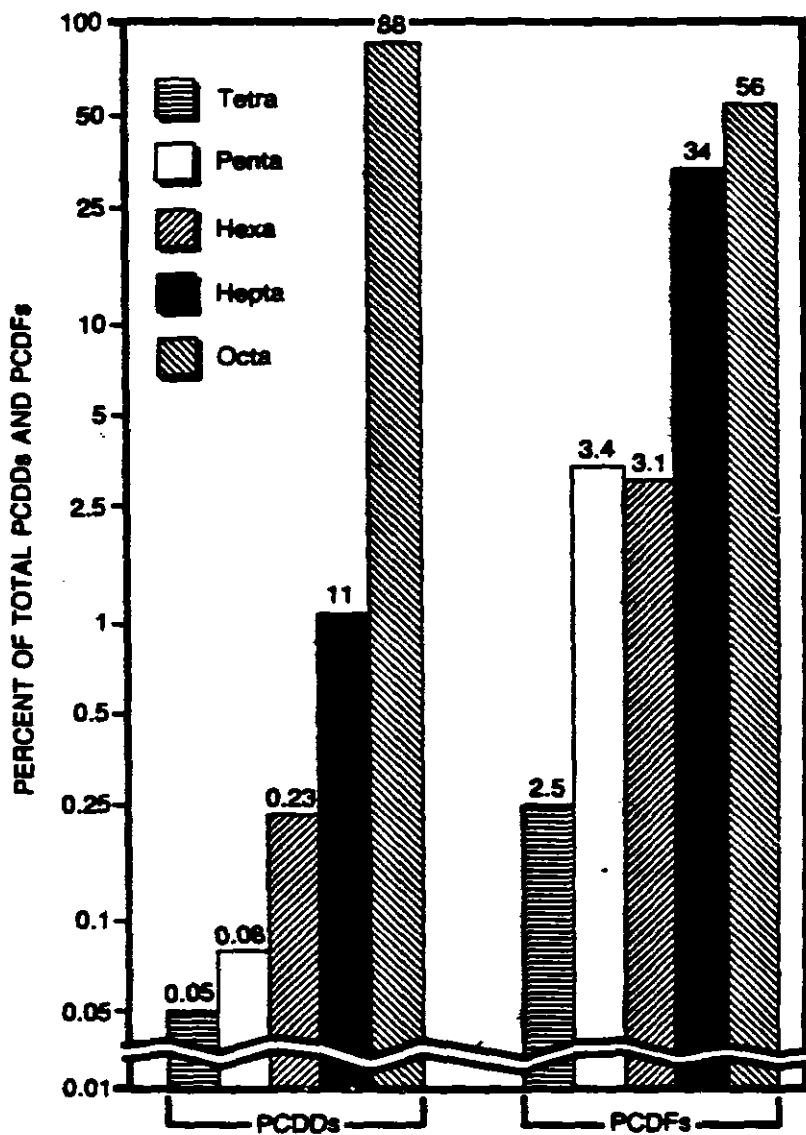


Figure 2: Tetra- through octa-chlorinated dibenzo-p-dioxin (PCDD) and dibenzofuran (PCDF) homolog profiles in ambient air samples obtained in Santa Fe, NM.

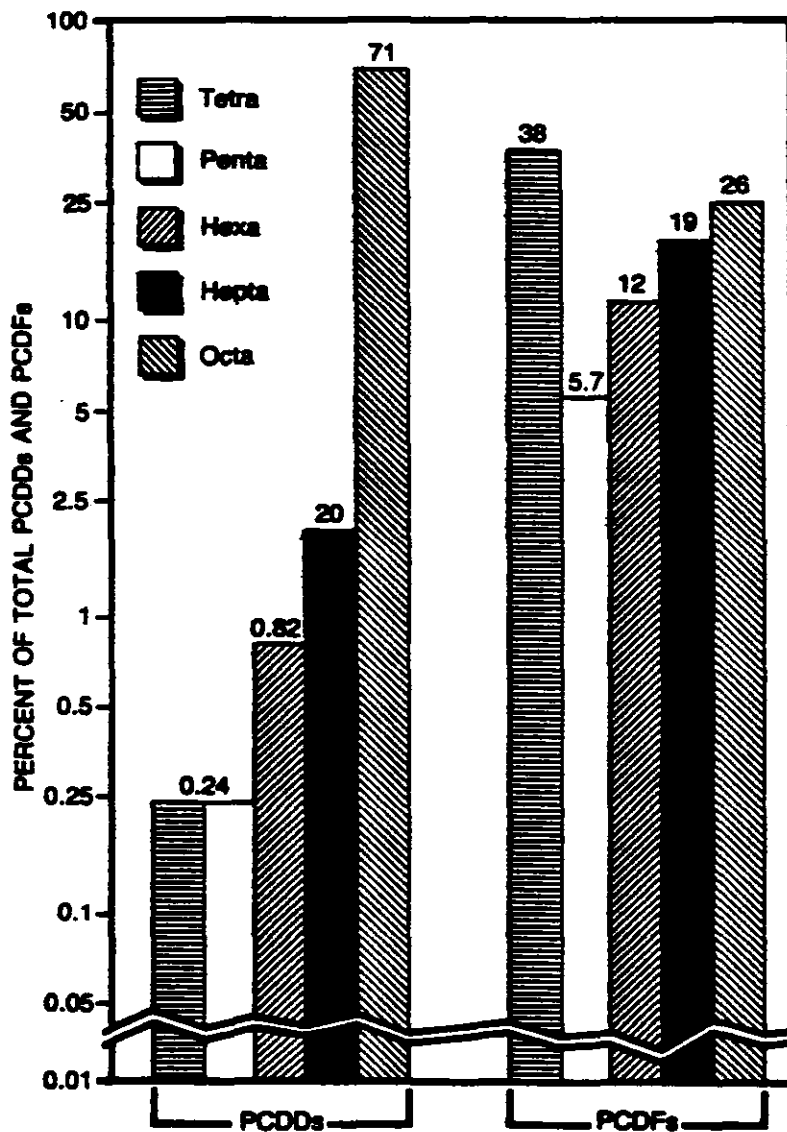


Figure 3: Tetra- through octa-chlorinated dibenzo-p-dioxin (PCDD) and dibenzofuran (PCDF) homolog profiles for wipe samples obtained on high skin contact surfaces in three office buildings in Santa Fe, NM.