

**RESULTS OF MONITORING FOR PCDDs and PCDFs IN AMBIENT AIR
AT MCMURDO STATION, ANTARCTICA**

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Interagency Agreement No. DPP-9102787
with
U.S. Department of Energy
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Idaho Falls, ID 83402

Project Officer

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ABSTRACT

This report presents the results of ambient air monitoring for polychlorinated dibenzo-p-dioxins (PCDDs) and polychlorinated dibenzofurans (PCDFs) performed during the 1992-1993 austral summer in the vicinity of McMurdo Station, Antarctica. Fifteen air samples were collected from four different locations for determination of the presence and concentration of PCDD/PCDF compounds. General Metal Works Inc. PS-1 air samplers equipped with polyurethane foam (PUF) with a sample flow rate of approximately 0.27 m³/min. were used to collect air samples. Sampling site selection, sampling procedures, and quality assurance procedures used were consistent with U.S. Environmental Protection Agency guidance for local ambient air quality networks. PCDD/PCDF compounds were not detected at the predominantly upwind location and at a more remote site on Black Island. Trace levels of only a few PCDD/PCDF congeners were detected sporadically at a location approximately 500 meters downwind of the station. The most frequent, most varied, and highest levels of PCDDs/PCDFs were measured at a "downtown" location, where concentrations of total PCDDs ranged from 0.27 to 1.80 pg/m³ and total PCDFs from less than 0.1 to 2.77 pg/m³. Results from the remote Black Island site indicate that the background Antarctic air is still "free" of PCDD/PCDF compounds (not detectable at current method detection limits). The initial baseline effort demonstrated that site selection and sampling equipment performance were satisfactory, provided useful data for assessing the impact of McMurdo operations on the local ambient air quality, and provided baseline data for assessing the Antarctica continental air quality.

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Results of Monitoring for PCDDs and PCDFs in Ambient Air at McMurdo Station, Antarctica

Introduction

McMurdo Station (77°51' South 166°40' East) is the largest human community in Antarctica. It is a coastal station constructed on low ash and volcanic hills at the southern tip of Ross Island. McMurdo serves as the primary logistics and staging facility for airborne resupply of inland research stations and supports a wide variety of scientific research sponsored by the United States National Science Foundation's Antarctic Program. The austral winter (March-September) population in 1992 was 257, and the austral summer (October-February) population exceeded 1,100. The station consists of over 100 structures, and numerous equipment laydown and storage areas. A nearby skiway airport and sea-ice runway serve fixed wing aircraft for flights to the Antarctic mainland, as well as flights to and from New Zealand. Emissions of atmospheric pollutants at or near McMurdo result from a variety of sources, including: boilers, furnaces, space heaters, electric generators, motor vehicle engines, incinerators, fugitive dust, petroleum storage tank vapors, aircraft operations, and ships. The major fixed air emission source is believed to be the electric generation plant. Tables 1 and 2 summarize the major source categories and estimated air pollutant/products of combustion emissions at McMurdo.

A report on the National Science Foundation (NSF) implementation of a strategy to comply with environmental law in Antarctica (NSF 1989) established the need to assess the environmental impact of air emissions at McMurdo Station and other U.S. Stations. In addition, the recent Protocol on Environmental Protection to the Antarctic Treaty (NSF 1991) and implementation of interim incineration during the 1992-1993 austral summer season of selected solid wastes at McMurdo further underlined the need to implement an ambient air monitoring network. Incineration at McMurdo ceased on March 22, 1993. In 1992 an ambient air monitoring plan for McMurdo was prepared that established the objectives of the monitoring effort as: (1) to determine the highest concentrations of pollutants expected to occur in the area covered by the network, (2) to determine representative concentrations of selected air pollutants in areas of high population density (3) to determine the impact on ambient pollution levels of significant sources or source categories, and (4) to determine background levels of selected air pollutants (Lugar, 1992).

The objectives and performance criteria established for the monitoring network were consistent with the intent of United States Environmental Protection Agency's (EPA) State and Local Air Monitoring Stations (SLAMS) objectives and network design (40CFR58, Appendix D). Quality assurance and quality control aspects of the PCDD/PCDF monitoring effort were generally consistent with EPA sampling procedures (EPA 1986) and the EPA Quality Assurance Handbook (EPA 1977). Co-location of samplers was not feasible during this initial baseline effort due to the limited number of samplers and the relatively short summer season. A variety of air pollutants, including many for which the EPA has

Table 1. Comparison of Sources of Products of Combustion at McMurdo Station¹ (metric tons per year)

	Electric Generation	Water Distribution	Space Heating	Surface Vehicles	Waste Incineration ²	TOTAL
CO ₂	12341	6743	2023	2862	201	24170
H ₂ O	4114	2620	786	1124	188	8832
SO ₂	7.8	4.3	1.3	0.064	0.086	13.6
NO _x	50.6	4.2	1.3	6.9	0.12	63.1
Part./HC	4.81	1.2	0.64	5.08	0.0068	11.7
HCl	<0.45	<0.23	<0.045	<0.0045	0.04	<0.77

¹ data based on emission factor estimates, not on actual monitoring data

² after scrubber (estimated)

Adopted from: Pearson 1991.

Table 2. Estimated Annual Air Pollutant Emissions at McMurdo Station

Source Category	Annual Emission Basis		Pollutant Emission Rate (tons ^a /yr)					
	Units	Quantity	SO ₂	NO ₂	PM-10	HC	CO	
Aircraft Operations								
LC-130 and C-130	LTOs ^b	328	0.6	2.9	0.4	8.9	14.0	
C-141	LTOs	25	0.004	0.2	0.01	1.8	2.2	
C-5B	LTOs	5 ^c	0.001	0.1	neg.	0.2	0.5	
Subtotal			0.7	3.2	0.4	11	17	
Internal combustion engines								
Diesel (stationary and mobile)	1000 gal ^d	1500	23.0	350.0	25.0	28.0	77.0	
Gasoline (mobile)	1000 gal	150	0.4	7.7	0.5	15.0 ^e	300.0	
External combustion								
Boilers, furnaces, etc.	1000 gal	1300	4.6	13.0	1.6 ^f	1.6 ^f	3.3	
Open burning (landfill)	DISCONTINUED		0	0	0	0	0	
Storage tanks (evaporation)								
JP-8						0.2		
Gasoline						7.2		
TOTAL McMurdo			29	374	28	63	398	

^a One ton equals 0.907 metric tons. English units are used in this table because regulatory emission limits and U.S. EPA emission factors are given in English units.
^b Landing take-off cycles.
^c Only two C-5B flights to McMurdo were reported for the 1989-90 summer season, but up to five flights per season would be typical.
^d One gallon equals 3.785 liters.
^e Sum of exhaust, evaporative, and crankcase emissions.
^f Used emission factors from residential furnaces.

Source: NSF 1991.

established National Ambient Air Quality Standards (NAAQS), were selected for monitoring. One pollutant of concern selected for monitoring for which there are no NAAQS was dioxin/furan compounds (PCDDs and PCDFs). Utilizing historical wind data, a local sampling network consisting of three locations was selected for the collection of samples. The locations were selected after field reconnaissance. They were based on 1) objectives outlined in the monitoring plan, 2) the availability of electrical power, and 3) operational support requirements and location of major emission sources. The three local sites selected were: 1) 8-Site for the predominantly upwind location, 2) Hut Point for the predominantly downwind site, and 3) Central McMurdo, near building 155, as the "worst case urban" location (See Figure 1). Black Island, a remote location approximately 33 kilometers south-southwest of McMurdo, was selected to provide background or "control" data, and the sample collected from there was considered representative of the continental air quality.

Methods

Samples were collected in accordance with EPA Reference Method T09, Method for the Determination of Polychlorinated Dibenzo-p-Dioxins (PCDDs) in Ambient Air Using High-Resolution Gas Chromatography/High-Resolution Mass Spectrometry (HRGC/HRMS). Samples were collected using a General Metal Works Model PS-1 PUF Sampler with a flowrate of approximately 0.27 m³/min. The method consists of sampling ambient air via an inlet glass fiber filter followed by a glass cartridge filled with a polyurethane foam (PUF) plug. Flow calibration curves were prepared for each sampler prior to the collection of the first sample and following the collection of the last sample. An elapsed time indicator on the sampler provided a record of sampling time. The PUF plugs were cleaned and then spiked with known amount of ¹³C₁₂-1,2,3,4-TCDD by the EPA Environmental Chemistry Laboratory (ECL) at Stennis Space Center, Mississippi. Following sample collection, the filters and PUF plugs were extracted by the same laboratory, and the extracts then analyzed by the EPA Atmospheric Research and Exposure Assessment Laboratory (AREAL) in Research Triangle Park, North Carolina. Field blanks, laboratory method blanks, and fortified laboratory method blanks (laboratory spikes) were utilized for quality assurance purposes.

Between 12NOV92 and 24JAN93, 14 air samples were collected at the three local McMurdo sample sites. During the week of 11NOV92, a single sample was collected from Black Island. Because this was the first known attempt to measure PCDD/PCDF compounds in the Antarctic ambient air, and no information was available on existing concentrations, the total elapsed sample times, and associated sample volumes, were varied between 24 and 48 hours (392 m³ and 778 m³, respectively) for the local McMurdo samples. The Black Island elapsed sampling time was approximately 166 hours (2586 m³) due to the anticipated pristine air quality at that location. The glass fiber filters and associated PUF plugs were retrieved as soon as possible after the conclusion of the sampling, wrapped in aluminum foil and placed in a resealable plastic bag to minimize exposure to the ambient air and light. The samples were stored at room temperature at McMurdo until a sufficient number of samples had accumulated to warrant shipment to the analytical laboratory. Two shipments

were made during the course of this work to the EPA ECL in Mississippi for sample preparation prior to analysis.

The analytical procedures used (Harless, 1992 and the revised EPA Reference Method T09) are similar to those in EPA Method 8290. A brief description is provided here. Sample preparations were performed on a set of 12 samples which consisted of 9 test samples, field blank, method blank, and a fortified method blank. Each respective glass fiber filter and PUF were combined, spiked with nine $^{13}\text{C}_{12}$ -labeled PCDD/PCDF internal standards and then Soxhlet extracted with benzene for sixteen hours. Each extract was then subjected to an acid base clean-up procedure followed by clean-up on micro columns of silica gel, alumina, and carbon. Each extract was concentrated to 0.5 mL. An aliquot of the recovery standard containing 0.5 ng $^{37}\text{Cl}_4$ -2,3,7,8-TCDD was then spiked to each extract. The extracts were concentrated to 30 μl , quantitatively transferred to respective 2 mm i.d. X 75 mm glass tubes, and fire sealed for shipment to EPA AREAL at Research Triangle Park, North Carolina for analysis.

A Finnigan MAT 90 HRGC-HRMS system operating in the electron impact ionization and multiple ion detection mode at 7000 to 10000 mass resolution was used for the analysis of samples. Chromatographic resolution of components was accomplished using a 30 m DB-5 fused silica capillary column and/or a 60 m SP-2331 fused silica capillary column for resolution of 2,3,7,8-substituted congeners, isomer specific analysis. The peak areas of the exact masses of the molecular ion clusters of the labeled and unlabeled PCDDs and PCDFs and respective response factors were used for quantification purposes. The $^{37}\text{Cl}_4$ -2,3,7,8-TCDD spiked to the sample extract prior to final concentration, was used to determine the method efficiency, recovery of the nine $^{13}\text{C}_{12}$ -labeled internal standards. The recovery of the $^{13}\text{C}_{12}$ -1,2,3,4-TCDD that was spiked to the PS-1 filter prior to ambient air sampling was used to determine the PS-1 air sampler collection and retention efficiency for the sampling period. The nine labeled PCDD and PCDF internal standards and respective response factors were used for quantification of unlabeled PCDDs and PCDFs and for determination of method detection limits (MDLs). For example, the $^{13}\text{C}_{12}$ -2,3,7,8-TCDD was used to quantify the 2,3,7,8-TCDD isomer and all other TCDD isomers present or to determine the MDLs. The $^{13}\text{C}_{12}$ -OCDD was used in a similar manner for OCDD and OCDF.

The data achieved for a set of samples was evaluated using defined analytical criteria and QA/QC criteria and requirements. The acceptance criteria for data include: acceptable chlorine isotope ratios, retention time, signal to noise ratio, PS-1 collection and retention efficiency, method efficiency, accuracy and precision achieved for laboratory method spike or control sample, method blank free of significant PCDD and PCDF contamination, analysis that confirmed the absence of chlorinated diphenylethers.

Results

PCDD/PCDF concentrations in ambient air at McMurdo were reliably measured using the stated methods and equipment. All results generated for each set of the test samples and QA/QC samples met the acceptance criteria. One sample

was lost during extraction. Eight out of a total of 14 samples successfully analyzed indicated the presence of a few PCDD/PCDF compounds in the sub pg/m^3 range. All PCDD/PCDF congeners were detectable in one of the samples. Table 3 provides a summary for all samples collected; the values reported have been blank-corrected. Table 3 also includes total PCDD and total PCDF values, Toxicity Equivalent Factors (TEFs) and associated 2,3,7,8-TCDD Equivalent Concentrations (TEQs). PCDD/PCDFs were detected in ambient air only at the central McMurdo and Hut Point locations. The average TEQ concentration for the five samples collected at the central McMurdo location was $0.0153 \text{ pg}/\text{m}^3$. For comparison purposes, this level is well below the State of Connecticut ambient air PCDDs/PCDFs standard of $1.0 \text{ pg}/\text{m}^3$ expressed as 2,3,7,8-TCDD equivalents. The results from the predominantly upwind 8-Site location and remote Black Island indicate no detectable PCDD/PCDF compounds present.

The few congeners detected in the Hut Point and central McMurdo samples were at concentrations very near the method detection limit, with the exception of one sample from the central McMurdo site collected on 28-30DEC92. This sample contained a notable variety of PCDD/PCDF congeners at levels well above the detection limits, and provides reliable evidence that PCDD/PCDF compounds were present in the ambient air. The total PCDD and PCDF concentrations of this sample were $1.8 \text{ pg}/\text{m}^3$ and $2.77 \text{ pg}/\text{m}^3$, respectively. These concentrations are comparable to levels measured by other researchers in suburban and urban areas (See Table 4). The average total PCDD/PCDF level based on five samples collected at central McMurdo during the 1992-1993 austral summer were more typical of a "cleaner" suburban area, and the average concentrations at Hut Point were comparable to rural concentrations in the United States (See Table 4).

To normalize concentrations and toxicity of the various PCDD/PCDF congeners, TEFs are used to calculate Toxicity Equivalents (TEQs), which represent the equivalent concentration of 2,3,7,8-TCDD. Total TEQ values for each of the eight samples with detectable quantities of PCDD/PCDFs are displayed graphically on Figure 2. TEQ values ranged from $0.00056 \text{ pg}/\text{m}^3$ to $0.07442 \text{ pg}/\text{m}^3$ for central McMurdo, and from zero (none detected) to $0.00216 \text{ pg}/\text{m}^3$ at Hut Point. For comparison purposes, these values are well below the 2-year average 2,3,7,8-TCDD equivalent concentration of total PCDD/PCDF measured in ambient air at Rutland, Vermont. (EPA, 1991)

Graphical profiles of PCDD/PCDF congeners were produced from the data to compare patterns between samples and potential sources (See Figures 3 through 11). Four of the five samples from the central McMurdo location demonstrated very similar profiles of HpCDDs and OCDDs as the only homologues present in the samples. The Hut Point samples that contained detectable quantities of PCDD/PCDF also indicated the presence of these same two homologues at lower concentrations. The Hut Point sample collected on 23-24JAN93 exhibited an elevated level of octa-chlorodibenzofuran (OCDF).

The 28-30DEC92 central McMurdo sample was notable not only in the elevated concentrations of PCDD/PCDF (relative to all other samples,) but also in the greater variety of congeners present. The exact source or sources of PCDDs/PCDFs detected during this sampling period cannot be definitively determined; however, the interim incinerator is one potential source.

Table 3. Summary of PUF dioxin/furan ambient air samples from McMurdo, Antarctica

DATE	TOTAL SAMPLE TIME (hr.)	LOCATION	SAMPLE ID/ LAB ID	SAMPLE VOLUME std m ³	AVG. DAILY WIND DIRECTION/SPEED (degrees @ knots)	PCDD/PCDF CONCENTRATION ^a (pg/m ³)	TEF ^b	TEQ ^c	BLANK CONC ^d (pg/m ³)
12-14NOV92	41.5	Hut Point	HPD01/F-878	671.5	260 @ 07/245 @ 06	ND ^e		0	
13-14NOV92	24.2	Central McMurdo	MCD01/F-879	391.8	260 @ 07/245 @ 06	HpCDDs (TOTAL) 1,2,3,4,6,7,8-HpCDD OCDD TOTAL PCDD: 0.34	0.04 0.04 0.30 0.34	0.0004 0.0003 TOTAL 0.0007	0.12 0.06 0.34
11-17NOV92	165.8	Black Island	BID01/F-880	2,586	NA ^f	ND ^e		0	
21-22NOV92	47.7	Hut Point	HPD02/F-881	744.3	120 @ 11/250 @ 06	ND ^e		0	
21-22NOV92	48.1	Central McMurdo	MCD02/F-882	778.4	120 @ 11/250 @ 06	HpCDDs (TOTAL) 1,2,3,4,6,7,8-HpCDD OCDD TOTAL PCDD: 0.30	0.04 0.03 0.26 0.30	0.0003 0.00026 TOTAL 0.00056	0.12 0.06 0.34
21-22NOV92	47.3	8-Site	TSD01/NA	794.1	120 @ 11/250 @ 06	sample lost during extraction		NA	
28-30DEC92	47.7	Hut Point	HPD03/F-908	743.3	260 @ 13/290 @ 09	HpCDDs (TOTAL) 1,2,3,4,6,7,8-HpCDD OCDD TOTAL PCDD: 0.08	0.05 0.02 0.03 0.08	0.0002 0.00003 TOTAL 0.00023	0.05 0.03 0.10

Table 3. - continued

DATE	TOTAL SAMPLE TIME (hr.)	LOCATION	SAMPLE ID/ LAB ID	SAMPLE VOLUME std m ³	AVG. DAILY WIND DIRECTION/SPEED (degrees @ knots)	PCDD/PCDF CONCENTRATION ^a (pg/m ³)	TEF ^b	TEQ ^c	BLANK CONC ^d (pg/m ³)
28-30DEC92	47.7	Central McMurdo	MCD03/F-901	744.3	260 @ 13/290 @ 09	TCDDs (TOTAL) 0.48 PeCDDs (TOTAL) 0.42 HxCDDs (TOTAL) 0.41 1,2,3,6,7,8-HxCDD 0.04 1,2,3,7,8,9-HxCDD 0.04 HpCDDs (TOTAL) 0.18 1,2,3,4,6,7,8-HpCDD 0.10 OCDD 0.31 TCDFs (TOTAL) 1.51 2,3,7,8-TCDF 0.11 PeCDF (TOTAL) 0.90 1,2,3,7,8-PeCDF 0.07 2,3,4,7,8-PeCDF 0.08 HxCDFs (TOTAL) 0.23 1,2,3,4,7,8-HxCDF 0.05 1,2,3,6,7,8-HxCDF 0.05 HpCDFs (TOTAL) 0.12 1,2,3,4,6,7,8-HpCDF 0.09 OCDF 0.01 TOTAL PCDD: 1.80 TOTAL PCDF: 2.77	0.10 0.10 0.01 0.00001 0.11 0.05 0.5 0.1 0.1 0.01 0.0001	0.004 0.004 0.001 0.00001 0.011 0.0035 0.04 0.005 0.005 0.0009 0.00001 TOTAL 0.07442	ND(0.01) ND(0.02) ND(0.03) ND(0.03) ND(0.03) 0.05 0.03 0.10 ND(0.03) ND(0.03) ND(0.009) ND(0.009) ND(0.009) ND(0.01) ND(0.01) ND(0.01) ND(0.02) ND(0.02) 0.03
28-30DEC92	48.1	8-Site	TSD02/F-906	778.7	260 @ 13/290 @ 09	ND ^e		0	
20-22JAN93	48.4	Hut Point	HP004/F-910	783.4	030 @ 18/310 @ 10	HpCDD (TOTAL) 0.06 1,2,3,4,6,7,8-HpCDD 0.03 OCDD 0.10 TOTAL PCDD: 0.16	0.01 0.001	0.0003 0.0001 TOTAL 0.0004	0.05 0.03 0.10
20-22JAN93	48.4	Central McMurdo	MCD04/F-907	813.3	030 @ 18/310 @ 10	HpCDDs (TOTAL) 0.08 1,2,3,4,6,7,8-HpCDD 0.03 OCDD 0.28 TOTAL PCDD: 0.36	0.01 0.001	0.0003 0.00028 TOTAL 0.00058	0.05 0.03 0.10
20-22JAN93	47.9	8-Site	TSD03/F-909	804.9	030 @ 18/310 @ 10	ND ^e		0	

Table 3. - continued

DATE	TOTAL SAMPLE TIME (hr.)	LOCATION	SAMPLE ID/ LAB ID	SAMPLE VOLUME std m ³	AVG. DAILY WIND DIRECTION/SPEED (degrees @ knots)	PCDD/PCDF CONCENTRATION ^a (pg/m ³)	TEF ^b	TEQ ^c	BLANK CONC ₃ (pg/m ³)
23-24JAN93	23.1	Hut Point	HPD05/F-899	373.7	090 @ 07	HpCDDs (TOTAL) 0.01 OCDD 0.05 HpCDFs (TOTAL) 0.25 1,2,3,4,6,7,8-HpCDF 0.14 OCDF 0.71 TOTAL PCDD: 0.06 TOTAL PCDF: 0.96	0.001 0.01 0.001	0.00005 0.0014 0.00071 TOTAL 0.00216	0.05 0.10 0.02 0.02 0.03
23-24JAN93	24.4	Central McMurdo	MCD05/F-902	398.8	090 @ 07	HpCDDs (TOTAL) 0.07 1,2,3,4,6,7,8-HpCDD 0.02 OCDD 0.20 OCDF 0.01 TOTAL PCDD: 0.27 TOTAL PCDF: 0.01	0.01 0.001 0.001	0.0002 0.0002 0.00001 TOTAL 0.00041	0.05 0.03 0.10 0.03
23-24JAN93	23.9	8-Site	TSD04/F-900	387.7	090 @ 07	ND ^e		0	

- a. Values reported are corrected for method or field blank concentrations.
- b. Toxicity Equivalent Factor (TEF). Reference: U.S. EPA (EPA/625/3-89/016) March 1989.
- c. Toxicity Equivalent (TEQ) is the equivalent concentration of 2,3,7,8-TCDD.
- d. Method or field blank concentrations used to correct sample results. Two sets of samples and corresponding blanks.
- e. Not Detected (ND) indicates compound was not detected or was detected at or below associated maximum blank concentrations.
- f. Not Available or Not Applicable (NA)

Table. 4 Comparison of Antarctica ambient air concentration of PCDD/PCDF with those of other locations. Antarctic results are in boldface type.

Location/Type	Total PCDF (pg/m ³)	Total PCDD (pg/m ³)
Industrial (Hamburg, Germany) ^a	15	13
Auto-tunnel (Hamburg, Germany) ^b	13	16
Industrial ^c	10	9
Urban ^d	8.8	8.6
Urban & industrial (Nordhein-Westfalen, Germany) ^e	5.5	3.2
Urban (Indianapolis, Indiana USA) ^f	2.6	2.5
Suburban (Hamburg, Germany) ^g	0.74	1.8
Suburban (Bloomington, Indiana USA) ^h	0.63	1.2
Suburban ⁱ	0.50	1.0
Suburban (Research Triangle Park, North Carolina USA) ^j	1.10	0.56
Rural (Trout Lake, Wisconsin USA) ^k	0.18	0.24
Central McMurdo, Antarctica ^l	0.56	0.61
Hut Point, Antarctica ^m	0.19	0.06
8-Site Antarctica ⁿ	ND	ND
Black Island, Antarctica ^o	ND	ND

a Average of sites 6 and 7 from Tables 2-7 in Rappe *et al.* (1988).

b Average of site 8 from Tables 2-7 in Rappe *et al.* (1988).

c Average of CAM site from Table 2 in Smith *et al.* (1988).

d Determined from Figure 4 in Nakano *et al.* (1987).

e From Table 9 in Buck and Kirschmer (1986).

f From Table 5-4 in Hites. (1991).

g Average of sites 1 and 2 from Tables 2-7 in Rappe *et al.* (1988).

h From Table 5-4 in Hites. (1991).

i Average of HRB site from Table 2 in Smith *et al.* (1988).

j From Table 6 in Harless, *et al.* (1992).

k From Table 5-4 in Hites. (1991).

l Average of five samples, total PCDF detected in only two samples.

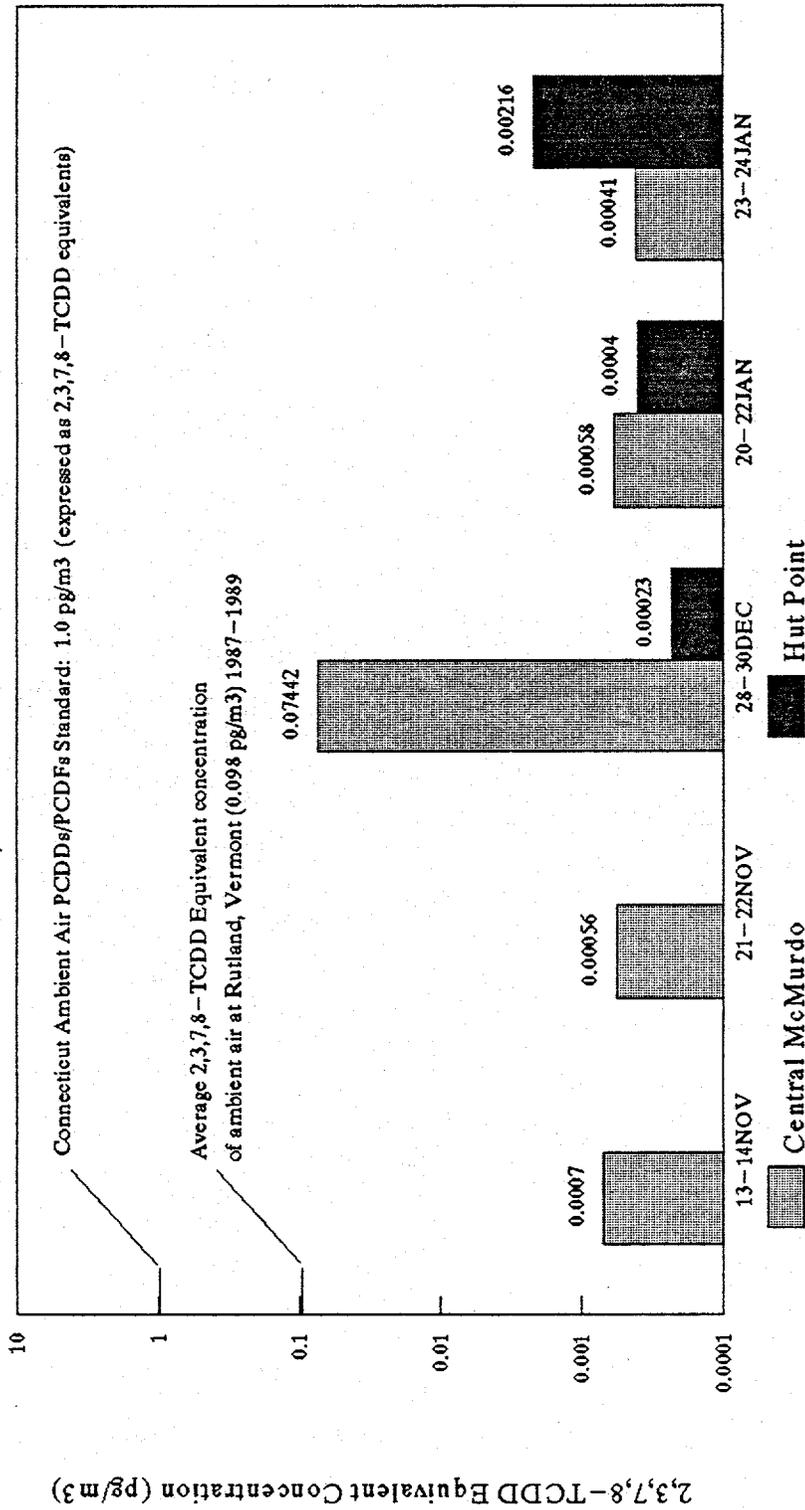
m Average of five samples, total PCDF detected in only one sample, total PCDD detected in only three samples.

n Not detected in three samples analyzed, detection limit dependent on analytical batch, specific congeners.

o Not detected in single sample, detection limit dependent on analytical batch and specific congeners.

Adopted from Table 5-4, p. 59, in Hites (1991).

Figure 2. Concentration of Dioxin/Furans in Ambient Air
McMurdo, Antarctica 1992 – 1993 Austral Summer



Note: Average 2,3,7,8-TCDD Equivalent concentration for Rutland, Vermont derived from Table 3-5, of EPA 600-8-91/007 (EPA 1991)

Figure 3. Ambient Air Dioxin/Furan Congener Profiles
Central McMurdo (MCD01) 13-14NOV92

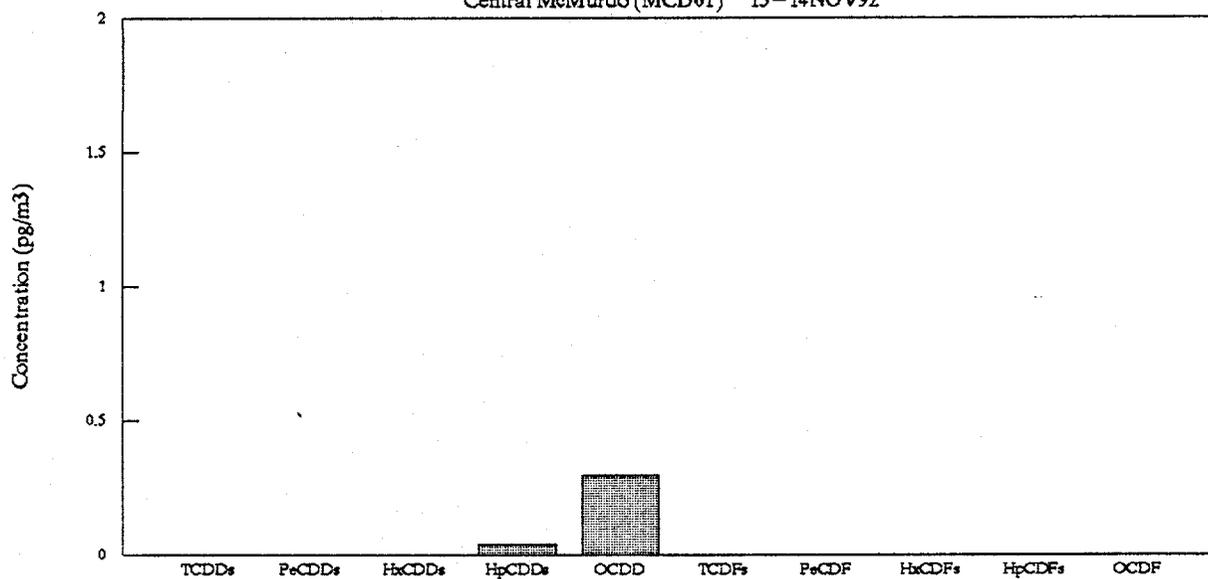


Figure 4. Ambient Air Dioxin/Furan Congener Profiles
Central McMurdo (MCD02) 21-22NOV92

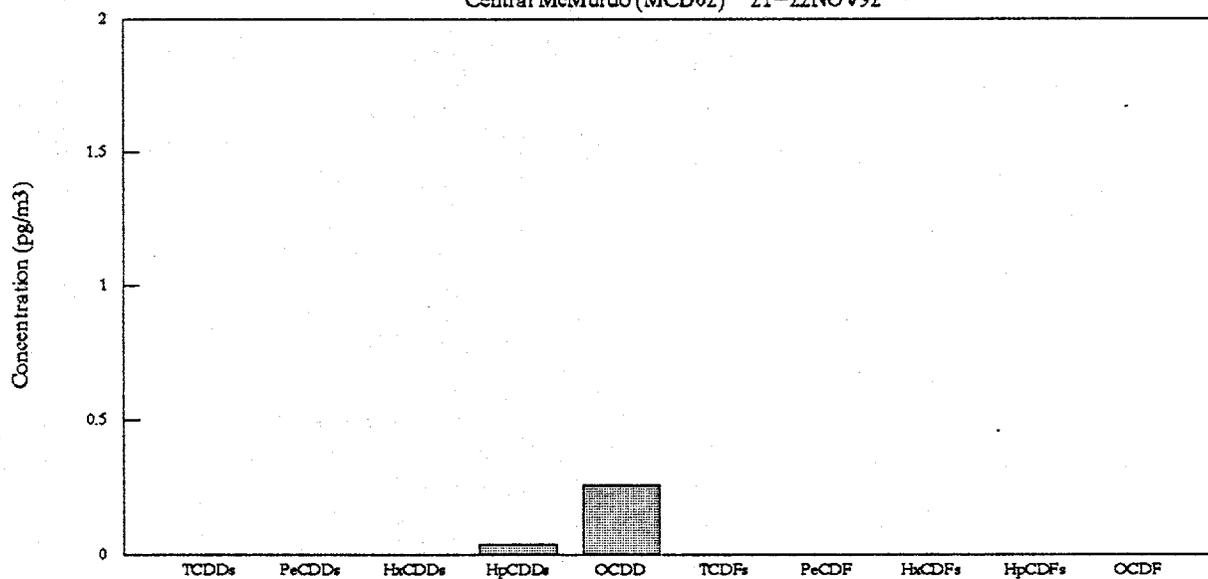


Figure 5. Ambient Air Dioxin/Furan Congener Profiles
Central McMurdo (MCD03) 28-30DEC92

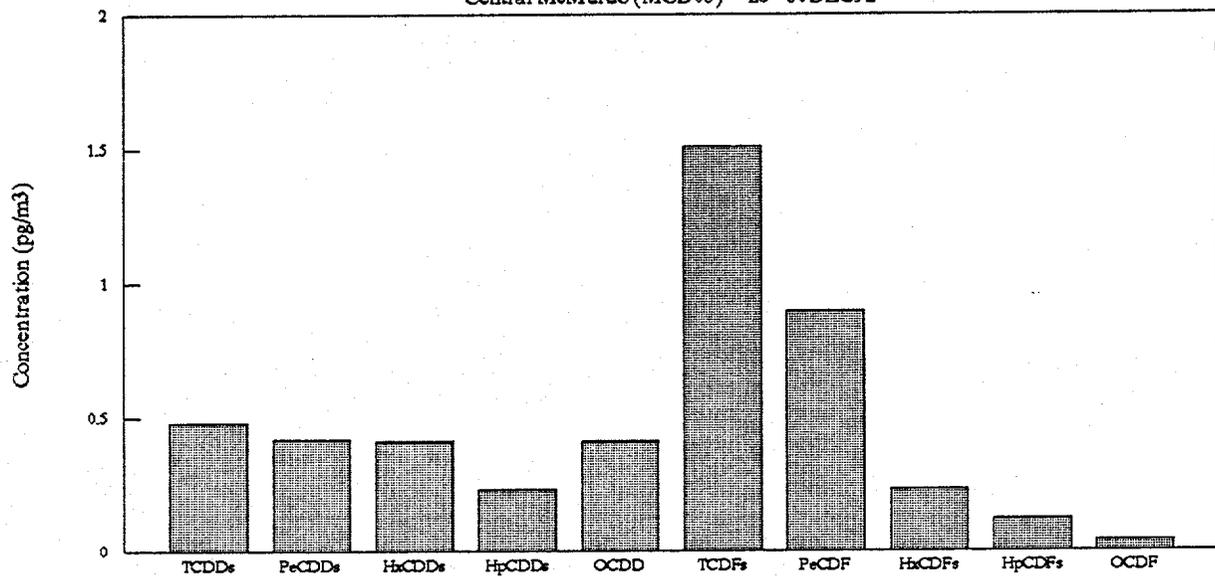


Figure 6. Ambient Air Dioxin/Furan Congener Profiles
Central McMurdo (MCD04) 20-22JAN93

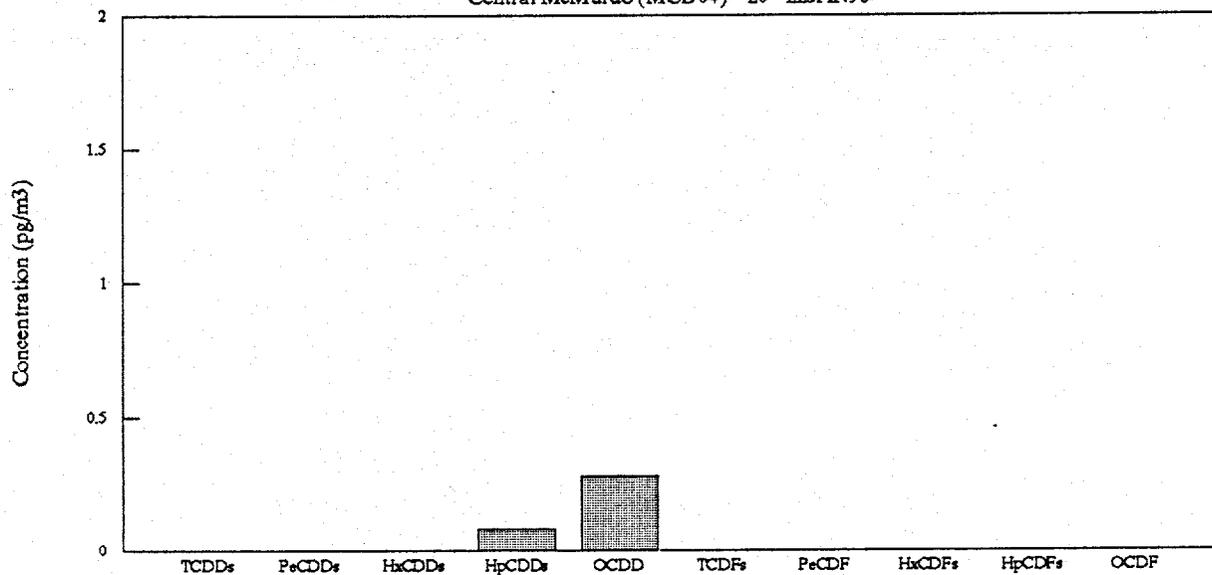


Figure 7. Ambient Air Dioxin/Furan Congener Profiles
Central McMurdo (MCD05), 23-24 JAN 93

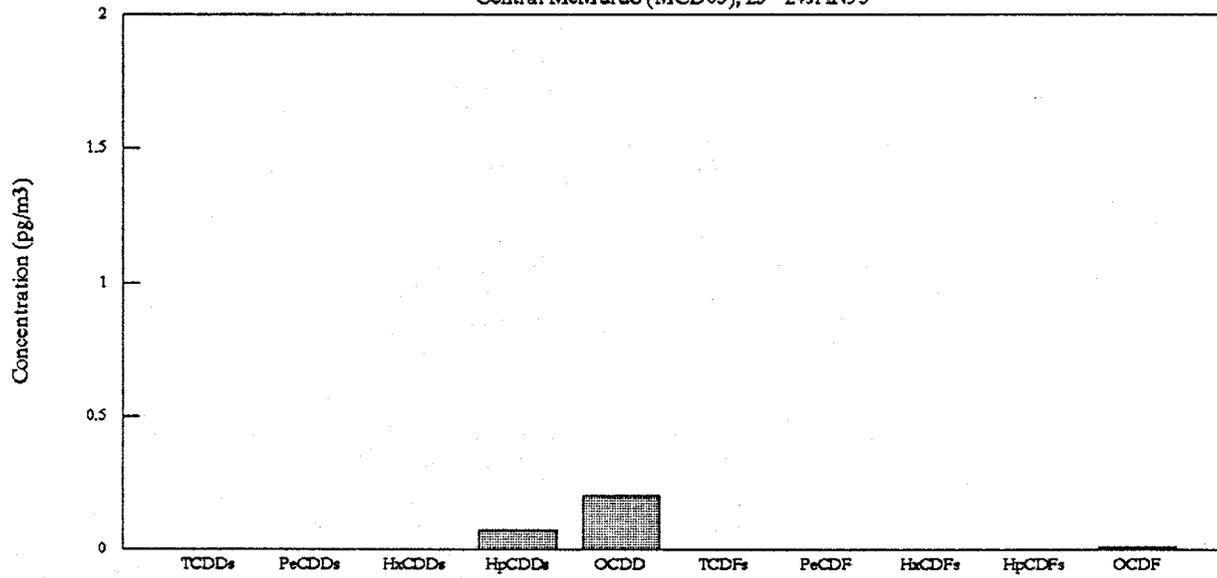


Figure 8. Ambient Air Dioxin/Furan Congener Profiles
Hut Point (HPD01), 12-14NOV92

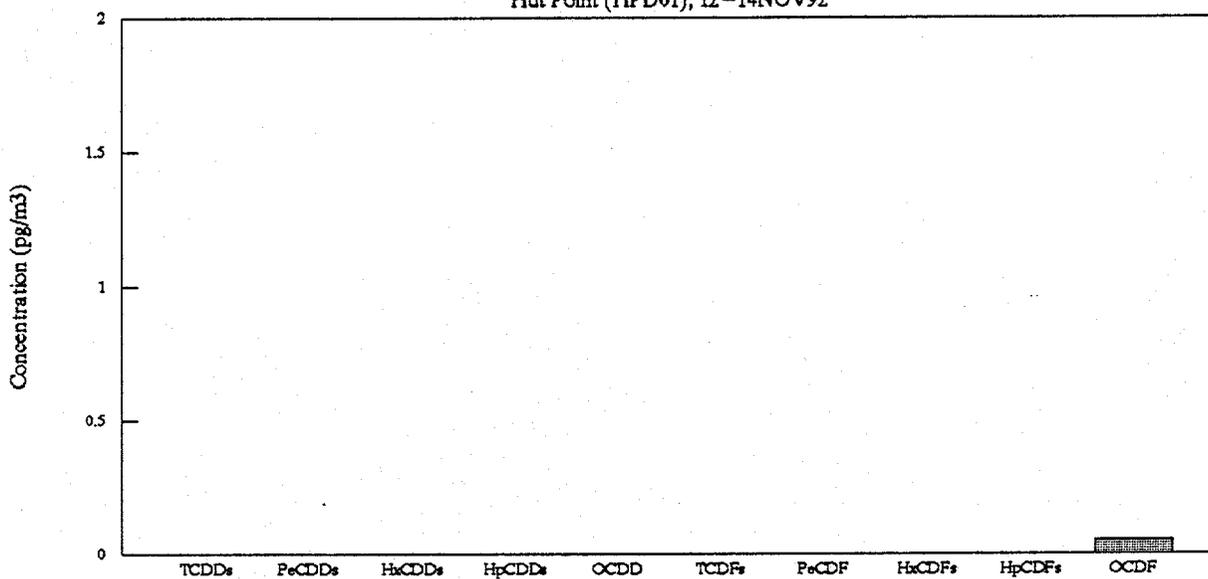


Figure 9. Ambient Air Dioxin/Furan Congener Profiles
Hut Point (HPD03), 28-30DEC92

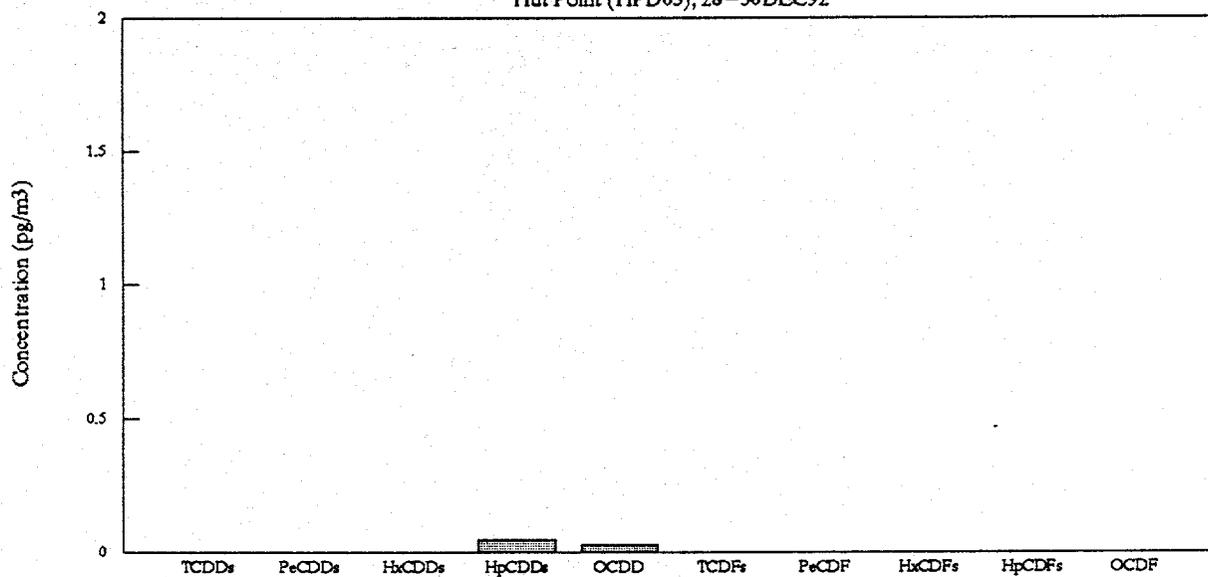


Figure 10. Ambient Air Dioxin/Furan Congener Profiles
Hut Point (HPD04), 20-22JAN93

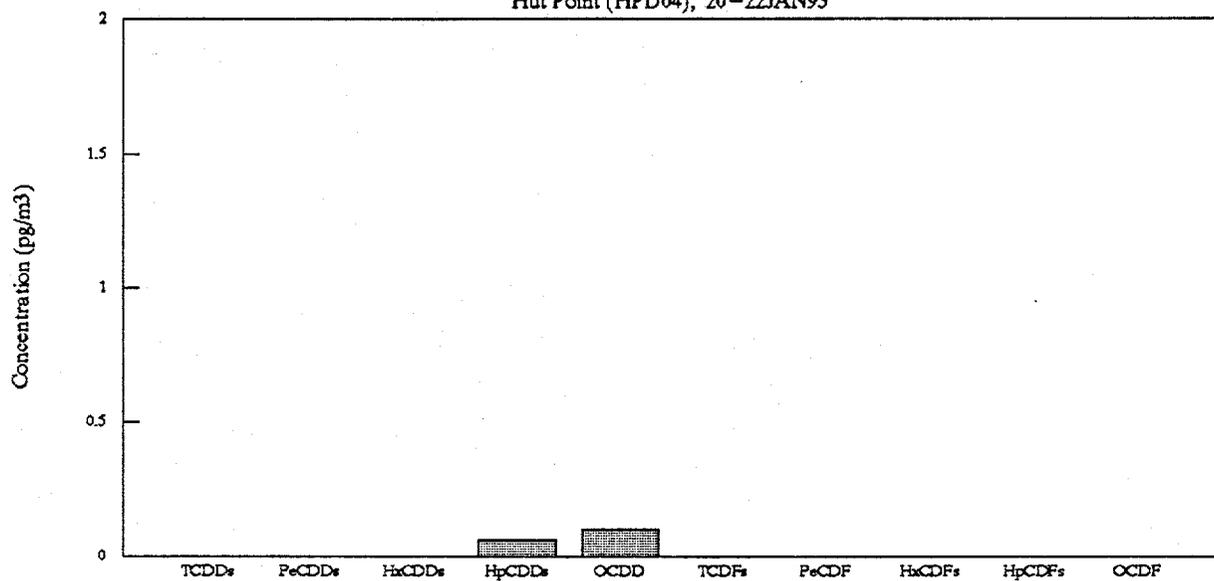


Figure 11. Ambient Air Dioxin/Furan Congener Profiles
Hut Point (HPD05), 23-24JAN93

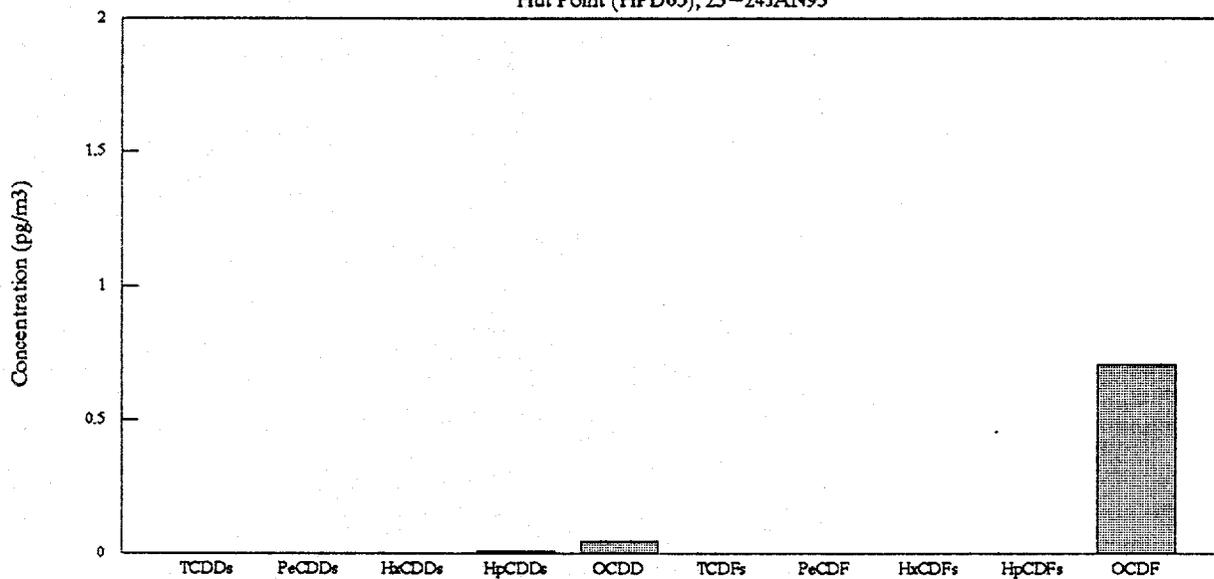


Figure 12. Interim Incinerator Emission PCDD/PCDF Profile
McMurdo, Antarctica Run 1, December 5, 1992

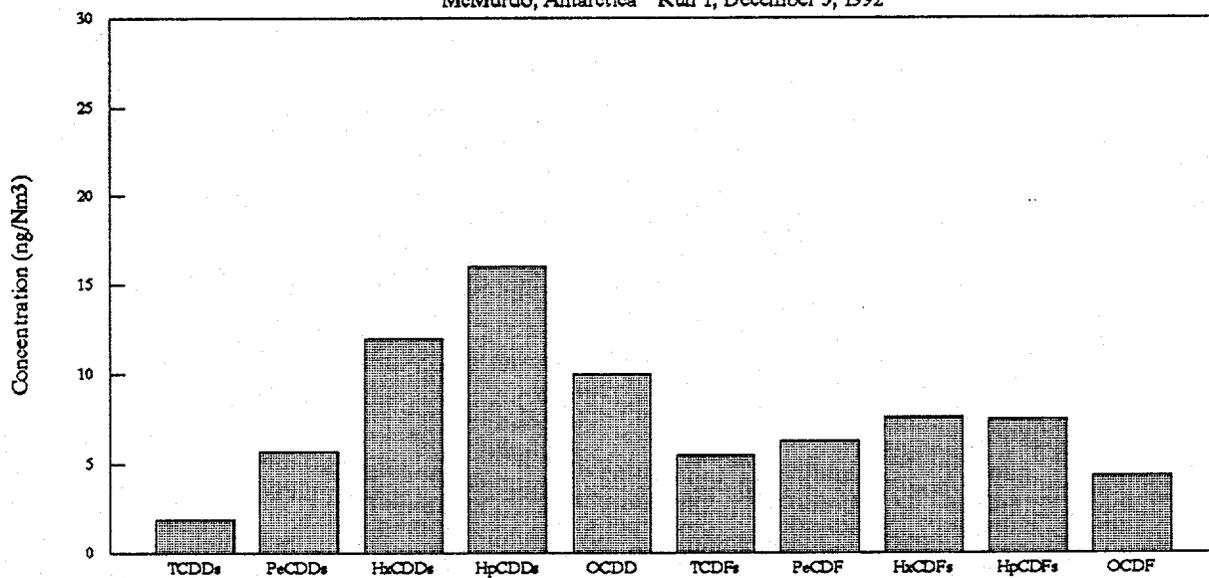


Figure 13. Interim Incinerator Emission PCDD/PCDF Profile
McMurdo, Antarctica Run 2, December 5, 1992

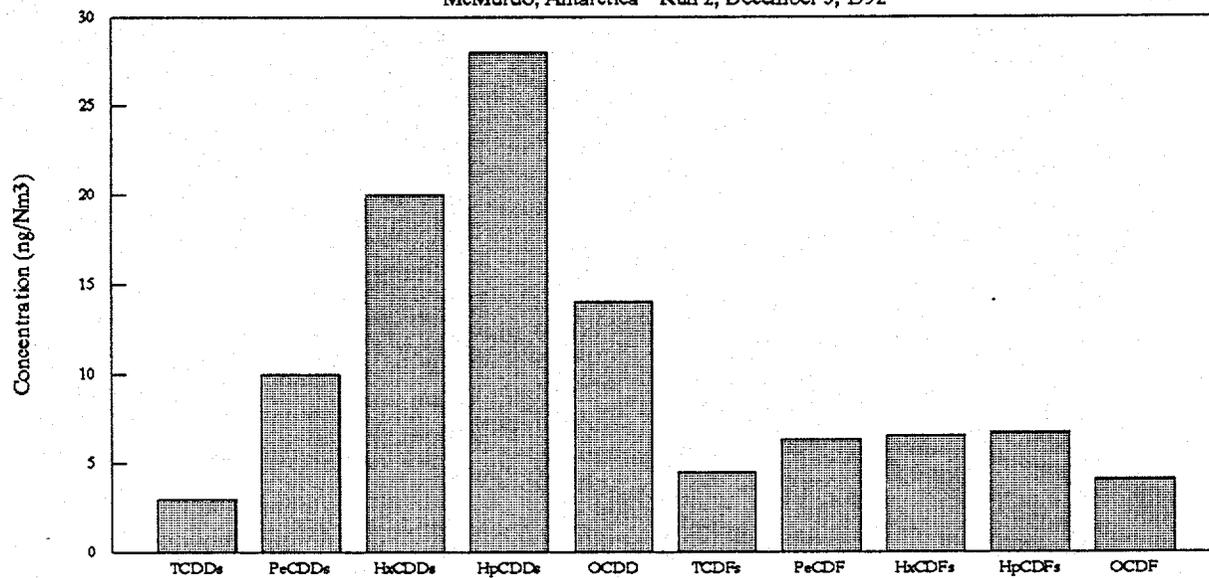
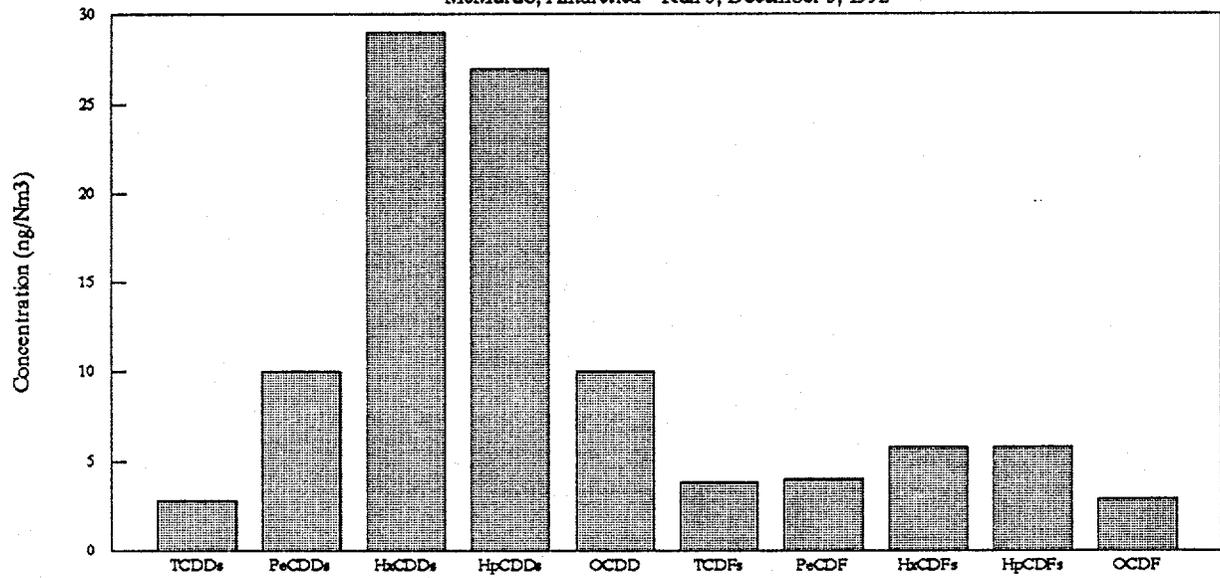


Figure 14. Interim Incinerator Emission PCDD/PCDF Profile
McMurdo, Antarctica Run 3, December 5, 1992



Operating logs indicate the interim incinerator was in operation during most of the sampling period on 28-30DEC92, and the predominant wind direction during the sampling period would have favored the transport of incinerator emissions toward the central McMurdo sampler.

Profiles of PCDD/PCDF congeners measured in the interim incinerator stack gas on 05DEC92 (Figures 12 through 14) were compared to ambient air PCDD/PCDF profiles (Figures 3 through 11) in an attempt to match ambient profiles with profiles from this potential source. The interim incinerator is the only potential McMurdo source that has had its air emissions characterized for PCDDs/PCDFs (Andrews, 1993). No meaningful correlation could be ascertained from this comparison; it is important to note that the three stack tests all occurred on the same day not concurrent with the ambient air sampling. Varied waste input, and changing operating conditions of the incinerator can create different PCDD/PCDF profiles, therefore a reliable conclusion to the comparison of the ambient air profiles and stack emission profiles is not possible, and the exact source of the detected PCDDs/PCDFs cannot be definitively determined from the available data.

Although the total number of samples per location was relatively small, the data do indicate the highest frequency of occurrence and greatest concentration of PCDDs/PCDFs in the ambient air was evident at the "downtown" McMurdo location. The impact of McMurdo operations on ambient air quality at Hut Point in terms of PCDDs/PCDFs was less frequent and at concentrations near the detection limit. PCDD/PCDF concentrations, if present, were below the detection limit at 8-Site, implying that emissions from the New Zealand Scott Base are either not transported to the 8-Site, or any emitted PCDDs/PCDFs are diluted to below the detection limit, or there simply are no PCDDs/PCDFs emitted. The remote Black Island sample permitted exceptionally lower detection limits, and the results indicate that the background Antarctic air is still "free" of PCDD/PCDF compounds (not detectable at current method detection limits).

Acknowledgements

This work was funded by the National Science Foundation Office of Polar Programs through Interagency Agreement # DPP-9102787 with the Department of Energy Idaho Field Office. The author gratefully acknowledges the project direction and technical support provided by Dr. Sydney Draggan; Dr. Jane Dionne, Alan Crockett, and Dr. Robert Harless; the logistics, construction, and laboratory support provided by Antarctic Support Associates personnel Dennis Tupick, John and Laurie Sherve, and Dr. Steve Kottmeier; and sample collection assistance provided by Jarvis Belinne. The author thanks Dr. Aubry DuPuy and Danny McDaniel at the U.S. EPA Environmental Chemistry Laboratory at the Stennis Space Center, Mississippi, for their support in sample cartridge preparation and sample extraction, and Dr. Robert Lewis and Dr. Robert Harless of the U.S. EPA Atmospheric Research and Exposure Assessment Laboratory at Research Triangle Park, North Carolina, for sample analysis and analytical data reporting.

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APPENDIX A

Raw PCDD/PCDF Analytical Results



UNITED STATES ENVIRONMENTAL PROTECTION AGENCY
ATMOSPHERIC RESEARCH AND EXPOSURE ASSESSMENT LABORATORY
RESEARCH TRIANGLE PARK
NORTH CAROLINA 27711

April 6, 1993

Dr. Sidney Draggan
Division of Polar Programs
Office of the Environment
National Science Foundation
1800 G Street, NW
Washington, DC 20550

Dear Dr. Draggan:

The analysis of ambient air samples from the Antarctica for polychlorinated dibenzo-p-dioxins (PCDDs) and polychlorinated dibenzofurans (PCDFs) is now complete. Background information is summarized. Polyurethane foam (PUF) plugs provided by Robert Lugar, Idaho National Engineering Laboratory (INEL) were subjected to an extraction and cleanup procedure at the US Environmental Protection Agency, Environmental Chemistry Laboratory (US EPA-ECL), Stennis Space center, Mississippi. The seventeen PUFs were then fortified with 800 pg each of $^{13}\text{C}_{12}$ -1,2,3,4-TCDD and shipped to Antarctica for sampling purposes. Ambient air sampling in Antarctica was conducted by Robert Lugar and his colleagues from INEL. After sampling, the PUFs and filters were shipped back to the US EPA-ECL for sample preparation. The extracts from the sample preparations were then shipped to this laboratory for analysis. High resolution gas chromatography-high resolution mass spectrometry (HRGC-HRMS) analyses were performed on the extracts using a Finnegan MAT 90 HRGC-HRMS system. The analytical procedures used were similar to EPA Method 8290 and 1613.

Analytical results generated for the two shipments of samples from Antarctica are shown in Tables 1 through 5. The QA/QC sample results shown in Table 2 are used in evaluation of results for test samples shown in Table 1, the first shipment. One test sample in this set was lost during extraction. The QA/QC sample results in Table 4 are used in evaluation of test sample results shown in Tables 3 and 5. These results for the test samples and QA/QC samples satisfies our data quality requirements for efficiency, accuracy, identification criteria, etc. The trace levels of PCDDs and PCDFs detected in the method blanks and field blanks are similar to those always detected (method background levels) and do not distract from the significance of results for the test samples.

In general, the extracts were very clean and the results indicate the ambient air in Antarctica is much cleaner than the ambient air in the USA, as it should be. However, the input of trace levels of PCDDs and PCDFs to the atmosphere is apparent in several of the samples, F-879, F-882, F-899 and especially F-901. The profiles of PCDDs and PCDFs and the isomer patterns in sample F-901 clearly indicate they came from a combustion source(s). Three of these positive samples are from the same site, MCD. The results are very interesting. I suggest the sampling, sample sites and analytical results be discussed in detail by the participants.

Please call me at (919) 541-2248 if you have any questions.

Sincerely,



Robert Harless
Research Chemist

Enclosures

cc: W. McClenny (MD-44)
R. Lewis (MD-44)
A. Dupuy (ECL-MS)
D. McDaniel (ECL-MS)
Robert Lugar (INEL) ✓

TABLE 1. Analytical Results for PCDDs and PCDFs in Ambient Air Samples from Antarctica

IDENTIFICATION*	F-878	F-879	F-880	F-881	F-882
PS-1 AIR SAMPLER EFFICIENCY (% RECOVERY)					
¹³ C ₁₂ -1,2,3,4-TCDD	106	97	95	96	99
METHOD EFFICIENCY (% RECOVERY)					
¹³ C ₁₂ -2,3,7,8-TCDF	86	82	81	83	87
¹³ C ₁₂ -2,3,7,8-TCDD	79	90	87	85	90
¹³ C ₁₂ -1,2,3,7,8-PeCDF	91	86	81	82	87
¹³ C ₁₂ -1,2,3,7,8-PeCDD	88	86	78	81	86
¹³ C ₁₂ -1,2,3,4,7,8-HxCDF	89	83	80	84	87
¹³ C ₁₂ -1,2,3,6,7,8-HxCDD	87	83	79	80	86
¹³ C ₁₂ -1,2,3,4,6,7,8-HpCDF	79	76	69	66	77
¹³ C ₁₂ -1,2,3,4,6,7,8-HpCDD	81	82	75	75	84
¹³ C ₁₂ -OCDD	73	82	70	73	74
CONCENTRATIONS DETECTED OR MLD (pg/m ³)					
TCDDs (TOTAL)	ND(0.01)	ND(0.04)	ND(0.003)	ND(0.006)	ND(0.009)
2,3,7,8-TCDD	ND(0.01)	ND(0.04)	ND(0.003)	ND(0.006)	ND(0.009)
PeCDDs (TOTAL)	ND(0.01)	ND(0.01)	ND(0.002)	ND(0.01)	ND(0.01)
1,2,3,7,8-PeCDD	ND(0.01)	ND(0.01)	ND(0.002)	ND(0.01)	ND(0.004)
HxCDDs (TOTAL)	ND(0.06)	ND(0.08)	0.008	0.03	0.07
1,2,3,4,7,8-HxCDD	ND(0.03)	ND(0.02)	ND(0.002)	ND(0.005)	ND(0.01)
1,2,3,6,7,8-HxCDD	ND(0.03)	ND(0.02)	ND(0.002)	ND(0.005)	ND(0.01)
1,2,3,7,8,9-HxCDD	ND(0.03)	ND(0.02)	ND(0.002)	ND(0.005)	ND(0.01)
HpCDDs (TOTAL)	0.09	0.16	0.015	0.07	0.16
1,2,3,4,6,7,8-HpCDD	0.04	0.10	0.008	0.03	0.09
OCDD	0.23	0.64	0.046	0.20	0.60
TCDFs (TOTAL)	ND(0.02)	ND(0.02)	ND(0.004)	ND(0.009)	ND(0.01)
2,3,7,8-TCDF	ND(0.02)	ND(0.02)	ND(0.004)	ND(0.009)	ND(0.01)
PeCDFs (TOTAL)	ND(0.01)	ND(0.007)	ND(0.002)	ND(0.01)	ND(0.01)
1,2,3,7,8-PeCDF	ND(0.01)	ND(0.007)	ND(0.002)	ND(0.01)	ND(0.01)
2,3,4,7,8-PeCDF	ND(0.01)	ND(0.007)	ND(0.002)	ND(0.01)	ND(0.01)
HxCDFs (TOTAL)	ND(0.02)	ND(0.01)	ND(0.003)	ND(0.02)	ND(0.01)
1,2,3,4,7,8-HxCDF	ND(0.02)	ND(0.01)	ND(0.003)	ND(0.008)	ND(0.01)
1,2,3,6,7,8-HxCDF	ND(0.02)	ND(0.01)	ND(0.003)	ND(0.008)	ND(0.01)
1,2,3,7,8,9-HxCDF	ND(0.02)	ND(0.01)	ND(0.003)	ND(0.008)	ND(0.01)
2,3,4,6,7,8-HxCDF	ND(0.02)	ND(0.01)	ND(0.003)	ND(0.008)	ND(0.01)
HpCDFs (TOTAL)	0.05	0.04	0.004	0.03	0.05
1,2,3,4,6,7,8-HpCDF	0.03	0.02	0.003	0.02	0.03
1,2,3,4,7,8,9-HpCDF	ND(0.006)	ND(0.02)	ND(0.008)	ND(0.008)	ND(0.002)
OCDF	0.10	0.04	0.005	0.03	0.04

ND = Not detected at specified minimum limit of detection (MLD).

TOTAL = All congeners, including the 2,3,7,8-substituted congeners.

*F-878 = HPD01, Antarctica air, 671.5 m³. F-881 = HPD02, Antarctica air, 744.3 m³.

F-879 = MCD01, Antarctica air, 391.8 m³. F-882 = MCD02, Antarctica air, 778.4 m³.

F-880 = BID01, Antarctica air, 2,586 m³.

TABLE 2. Analytical Results for PCDDs and PCDFs in Ambient Air Samples from Antarctica
(QA/QC Samples)

IDENTIFICATION*	F-883	F-892	F-893
PS-1 AIR SAMPLER EFFICIENCY (% RECOVERY)			
¹³ C ₁₂ -1,2,3,4-TCDD	106	89	96
METHOD EFFICIENCY (% RECOVERY)			
¹³ C ₁₂ -2,3,7,8-TCDF	81	73	84
¹³ C ₁₂ -2,3,7,8-TCDD	80	85	88
¹³ C ₁₂ -1,2,3,7,8-PeCDF	83	73	85
¹³ C ₁₂ -1,2,3,7,8-PeCDD	79	70	85
¹³ C ₁₂ -1,2,3,4,7,8-HxCDF	81	71	83
¹³ C ₁₂ -1,2,3,6,7,8-HxCDD	78	69	72
¹³ C ₁₂ -1,2,3,4,6,7,8-HpCDF	71	62	72
¹³ C ₁₂ -1,2,3,4,6,7,8-HpCDD	72	74	75
¹³ C ₁₂ -OCDD	70	59	70
CONCENTRATIONS DETECTED OR MLD (pg/m ³)			
TCDDs (TOTAL)	ND(0.03)	ND(0.02)	1.53
2,3,7,8-TCDD	ND(0.03)	ND(0.02)	0.68
PeCDDs (TOTAL)	ND(0.02)	ND(0.03)	1.89
1,2,3,7,8-PeCDD	ND(0.02)	ND(0.03)	0.65
HxCDDs (TOTAL)	0.06	0.12	3.25
1,2,3,4,7,8-HxCDD	ND(0.02)	ND(0.03)	0.65
1,2,3,6,7,8-HxCDD	ND(0.02)	ND(0.03)	0.65
1,2,3,7,8,9-HxCDD	ND(0.02)	ND(0.03)	0.72
HpCDDs (TOTAL)	0.12	0.12	1.87
1,2,3,4,6,7,8-HpCDD	0.05	0.06	1.25
OCDD	0.31	0.34	1.64
TCDFs (TOTAL)	ND(0.02)	ND(0.05)	1.53
2,3,7,8-TCDF	ND(0.02)	ND(0.05)	0.63
PeCDFs (TOTAL)	ND(0.02)	ND(0.03)	2.29
1,2,3,7,8-PeCDF	ND(0.02)	ND(0.03)	0.62
2,3,4,7,8-PeCDF	ND(0.02)	ND(0.03)	0.64
HxCDFs (TOTAL)	ND(0.02)	ND(0.03)	3.60
1,2,3,4,7,8-HxCDF	ND(0.02)	ND(0.03)	0.65
1,2,3,6,7,8-HxCDF	ND(0.02)	ND(0.03)	0.65
1,2,3,7,8,9-HxCDF	ND(0.02)	ND(0.03)	0.57
2,3,4,6,7,8-HxCDF	ND(0.02)	ND(0.03)	0.59
HpCDFs (TOTAL)	ND(0.03)	ND(0.05)	2.40
1,2,3,4,6,7,8-HpCDF	ND(0.03)	ND(0.02)	1.15
1,2,3,4,7,8,9-HpCDF	ND(0.03)	ND(0.02)	1.25
OCDF	0.04	0.05	1.38

ND = Not detected at specified minimum limit of detection (MLD).

Note: Please refer to text for discussion and qualification that must accompany the results.

Total = All congeners, including the 2,3,7,8-substituted congeners.

*F-883 = BIF01, Antarctica air, field blank.^a

F-892 = Laboratory method blank.^a

F-893 = Laboratory fortified method blank.^a

^a = 400 m³ air used for calculation of concentrations.

TABLE 3. Analytical Results for PCDDs and PCDFs in Ambient Air Samples from Antarctica

IDENTIFICATION*	F-899	F-900	F-901	F-902
PS-1 AIR SAMPLER EFFICIENCY (% RECOVERY)				
¹³ C ₁₂ -1,2,3,4-TCDD	97	93	93	94
METHOD EFFICIENCY (% RECOVERY)				
¹³ C ₁₂ -2,3,7,8-TCDF	91	90	85	86
¹³ C ₁₂ -2,3,7,8-TCDD	97	101	103	102
¹³ C ₁₂ -1,2,3,7,8-PeCDF	90	91	89	90
¹³ C ₁₂ -1,2,3,7,8-PeCDD	85	90	88	92
¹³ C ₁₂ -1,2,3,4,7,8-HxCDF	85	98	88	89
¹³ C ₁₂ -1,2,3,6,7,8-HxCDD	83	90	85	89
¹³ C ₁₂ -1,2,3,4,6,7,8-HpCDF	76	85	84	79
¹³ C ₁₂ -1,2,3,4,6,7,8-HpCDD	78	89	88	89
¹³ C ₁₂ -OCDD	72	85	89	82
CONCENTRATIONS DETECTED OR MLD (pg/m ³)				
TCDDs (TOTAL)	ND(0.01)	ND(0.02)	0.48	ND(0.02)
2,3,7,8-TCDD	ND(0.01)	ND(0.02)	0.01	ND(0.02)
PeCDDs (TOTAL)	ND(0.02)	ND(0.01)	0.42	ND(0.02)
1,2,3,7,8-PeCDD	ND(0.02)	ND(0.01)	0.02	ND(0.02)
HxCDDs (TOTAL)	ND(0.02)	ND(0.03)	0.41	ND(0.08)
1,2,3,4,7,8-HxCDD	ND(0.02)	ND(0.03)	0.02	ND(0.02)
1,2,3,6,7,8-HxCDD	ND(0.02)	ND(0.03)	0.04	ND(0.02)
1,2,3,7,8,9-HxCDD	ND(0.02)	ND(0.03)	0.04	ND(0.02)
HpCDDs (TOTAL)	0.06	0.04	0.23	0.12
1,2,3,4,6,7,8-HpCDD	0.03	0.02	0.13	0.05
OCDD	0.15	0.09	0.41	0.30
TCDFs (TOTAL)	ND(0.02)	ND(0.02)	1.51	ND(0.04)
2,3,7,8-TCDF	ND(0.02)	ND(0.02)	0.11	ND(0.04)
PeCDFs (TOTAL)	ND(0.08)	ND(0.02)	0.90	ND(0.02)
1,2,3,7,8-PeCDF	ND(0.008)	ND(0.02)	0.07	ND(0.02)
2,3,4,7,8-PeCDF	ND(0.008)	ND(0.02)	0.08	ND(0.02)
HxCDFs (TOTAL)	ND(0.02)	ND(0.03)	0.23	ND(0.01)
1,2,3,4,7,8-HxCDF	ND(0.02)	ND(0.03)	0.05	ND(0.01)
1,2,3,6,7,8-HxCDF	ND(0.02)	ND(0.03)	0.05	ND(0.01)
1,2,3,7,8,9-HxCDF	ND(0.02)	ND(0.03)	ND(0.008)	ND(0.01)
2,3,4,6,7,8-HxCDF	ND(0.02)	ND(0.03)	ND(0.008)	ND(0.01)
HpCDFs (TOTAL)	0.25	ND(0.01)	0.12	ND(0.02)
1,2,3,4,6,7,8-HpCDF	0.14	ND(0.01)	0.09	ND(0.02)
1,2,3,4,7,8,9-HpCDF	ND(0.02)	ND(0.01)	ND(0.009)	ND(0.02)
OCDF	0.74	0.03	0.04	0.04

ND = Not detected at specified minimum limit of detection (MLD).
 (TOTAL) = All congeners, including the 2,3,7,8-substituted congeners.
 *F-899 = HPD05, Antarctica air, 373.7 m³
 F-900 = TSD04, Antarctica air, 387.7 m³
 F-901 = MCD03, Antarctica air, 744.3 m³
 F-902 = MCD05, Antarctica air, 398.8 m³

TABLE 4. Analytical Results for PCDDs and PCDFs in Ambient Air Samples from Antarctica

IDENTIFICATION*	F-903	F-904	F-905
PS-1 AIR SAMPLER EFFICIENCY (% RECOVERY)			
¹³ C ₁₂ -1,2,3,4-TCDD	93	88	85
METHOD EFFICIENCY (% RECOVERY)			
¹³ C ₁₂ -2,3,7,8-TCDF	88	82	84
¹³ C ₁₂ -2,3,7,8-TCDD	103	104	100
¹³ C ₁₂ -1,2,3,7,8-PeCDF	84	87	88
¹³ C ₁₂ -1,2,3,7,8-PeCDD	82	86	87
¹³ C ₁₂ -1,2,3,4,7,8-HxCDF	80	92	86
¹³ C ₁₂ -1,2,3,6,7,8-HxCDD	78	89	83
¹³ C ₁₂ -1,2,3,4,6,7,8-HpCDF	72	85	75
¹³ C ₁₂ -1,2,3,4,6,7,8-HpCDD	72	91	79
¹³ C ₁₂ -OCDD	71	89	72
CONCENTRATIONS DETECTED OR MLD (pg/m ³)			
TCDDs (TOTAL)	ND(0.005)	1.55	ND(0.01)
2,3,7,8-TCDD	ND(0.005)	0.63	ND(0.01)
PeCDDs (TOTAL)	ND(0.01)	1.96	ND(0.02)
1,2,3,7,8-PeCDD	ND(0.01)	0.64	ND(0.02)
HxCDDs (TOTAL)	ND(0.01)	2.99	ND(0.03)
1,2,3,4,7,8-HxCDD	ND(0.01)	0.64	ND(0.03)
1,2,3,6,7,8-HxCDD	ND(0.01)	0.64	ND(0.03)
1,2,3,7,8,9-HxCDD	ND(0.01)	0.63	ND(0.03)
HpCDDs (TOTAL)	0.02	1.66	0.05
1,2,3,4,6,7,8-HpCDD	0.01	1.15	0.03
OCDD	0.07	1.15	0.10
TCDFs (TOTAL)	ND(0.02)	1.55	ND(0.03)
2,3,7,8-TCDF	ND(0.02)	0.66	ND(0.03)
PeCDFs (TOTAL)	ND(0.006)	2.30	ND(0.009)
1,2,3,7,8-PeCDF	ND(0.006)	0.65	ND(0.009)
2,3,4,7,8-PeCDF	ND(0.006)	0.64	ND(0.009)
HxCDFs (TOTAL)	ND(0.007)	3.51	ND(0.01)
1,2,3,4,7,8-HxCDF	ND(0.007)	0.66	ND(0.01)
1,2,3,6,7,8-HxCDF	ND(0.007)	0.65	ND(0.01)
1,2,3,7,8,9-HxCDF	ND(0.007)	0.58	ND(0.01)
2,3,4,6,7,8-HxCDF	ND(0.007)	0.58	ND(0.01)
HpCDFs (TOTAL)	ND(0.01)	2.34	ND(0.02)
1,2,3,4,6,7,8-HpCDF	ND(0.01)	1.08	ND(0.02)
1,2,3,4,7,8,9-HpCDF	ND(0.01)	1.26	ND(0.02)
OCDF	0.02	1.15	0.03

- ND = Not detected at specified minimum limit of detection (MLD).
 TOTAL = All congeners, including the 2,3,7,8-substituted congeners.
 *F-903 = Laboratory method blank.^a
 F-904 = Laboratory fortified method blank.^a
 F-905 = Field blank.^a
^a = 400 m³ air used for calculation of concentrations.

TABLE 5. Analytical Results for PCDDs and PCDFs in Ambient Air Samples from Antarctica

IDENTIFICATION*	F-906	F-907	F-908	F-909	F-910
PS-1 AIR SAMPLER EFFICIENCY (% RECOVERY)					
¹³ C ₁₂ -1,2,3,4-TCDD	88	102	104	95	89
METHOD EFFICIENCY (% RECOVERY)					
¹³ C ₁₂ -2,3,7,8-TCDF	86	86	74	89	90
¹³ C ₁₂ -2,3,7,8-TCDD	102	91	76	103	108
¹³ C ₁₂ -1,2,3,7,8-PeCDF	89	87	73	94	96
¹³ C ₁₂ -1,2,3,7,8-PeCDD	89	86	70	92	93
¹³ C ₁₂ -1,2,3,4,7,8-HxCDF	94	90	75	90	97
¹³ C ₁₂ -1,2,3,6,7,8-HxCDD	89	93	71	91	96
¹³ C ₁₂ -1,2,3,4,6,7,8-HpCDF	86	84	67	83	95
¹³ C ₁₂ -1,2,3,4,6,7,8-HpCDD	89	89	73	88	95
¹³ C ₁₂ -OCDD	83	93	69	82	89
CONCENTRATIONS DETECTED OR MLD (pg/m ³)					
TCDDs (TOTAL)	ND(0.006)	ND(0.03)	ND(0.02)	ND(0.01)	ND(0.02)
2,3,7,8-TCDD	ND(0.006)	ND(0.03)	ND(0.02)	ND(0.01)	ND(0.02)
PeCDDs (TOTAL)	ND(0.005)	ND(0.02)	ND(0.01)	ND(0.01)	ND(0.01)
1,2,3,7,8-PeCDD	ND(0.005)	ND(0.02)	ND(0.01)	ND(0.01)	ND(0.01)
HxCDDs (TOTAL)	ND(0.02)	ND(0.03)	ND(0.009)	ND(0.01)	ND(0.06)
1,2,3,4,7,8-HxCDD	ND(0.02)	ND(0.03)	ND(0.009)	ND(0.01)	ND(0.01)
1,2,3,6,7,8-HxCDD	ND(0.02)	ND(0.03)	ND(0.009)	ND(0.01)	ND(0.01)
1,2,3,7,8,9-HxCDD	ND(0.02)	ND(0.03)	ND(0.009)	ND(0.01)	ND(0.01)
HpCDDs (TOTAL)	0.03	0.13	0.10	ND(0.03)	0.11
1,2,3,4,6,7,8-HpCDD	0.01	0.06	0.05	ND(0.01)	0.06
OCDD	0.05	0.38	0.13	0.05	0.20
TCDFs (TOTAL)	ND(0.02)	ND(0.02)	ND(0.02)	ND(0.01)	ND(0.01)
2,3,7,8-TCDF	ND(0.02)	ND(0.02)	ND(0.02)	ND(0.01)	ND(0.01)
PeCDFs (TOTAL)	ND(0.007)	ND(0.01)	ND(0.01)	ND(0.01)	ND(0.01)
1,2,3,7,8-PeCDF	ND(0.007)	ND(0.01)	ND(0.01)	ND(0.01)	ND(0.01)
2,3,4,7,8-PeCDF	ND(0.007)	ND(0.001)	ND(0.01)	ND(0.01)	ND(0.01)
HxCDFs (TOTAL)	ND(0.009)	ND(0.02)	ND(0.02)	ND(0.01)	ND(0.01)
1,2,3,4,7,8-HxCDF	ND(0.009)	ND(0.02)	ND(0.02)	ND(0.01)	ND(0.01)
1,2,3,6,7,8-HxCDF	ND(0.009)	ND(0.02)	ND(0.02)	ND(0.01)	ND(0.01)
1,2,3,7,8,9-HxCDF	ND(0.009)	ND(0.02)	ND(0.02)	ND(0.01)	ND(0.01)
2,3,4,6,7,8-HxCDF	ND(0.009)	ND(0.02)	ND(0.02)	ND(0.01)	ND(0.01)
HpCDFs (TOTAL)	ND(0.009)	ND(0.01)	0.01	ND(0.01)	0.01
1,2,3,4,6,7,8-HpCDF	ND(0.009)	ND(0.01)	0.01	ND(0.01)	0.01
1,2,3,4,7,8,9-HpCDF	ND(0.009)	ND(0.01)	ND(0.01)	ND(0.01)	ND(0.01)
OCDF	ND(0.02)	ND(0.03)	0.02	ND(0.03)	ND(0.02)

ND = Not detected at specified minimum limit of detection (MLD).

(TOTAL) = All congeners, including the 2,3,7,8-substituted congeners.

*F-906 = TSD02, Antarctica air, 778.7 m³

F-909 = TSD03, Antarctica air, 804.9 m³

F-907 = MCD04, Antarctica air, 813.3 m³

F-910 = HPD04, Antarctica air, 783.4 m³

F-908 = HPD03, Antarctica air, 743.3 m³