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RESULTS OF PM_{10} AND TSP MONITORING AT MCMURDO STATION, ANTARCTICA

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ABSTRACT

This report presents the results of ambient air monitoring of particulate matter performed during the 1992-1993 austral summer in the vicinity of McMurdo Station, Antarctica. Thirty three 24-hour samples were collected from three locations for determination of the concentration of particulate matter less that 10 micrometers (PM_{10}), and seven samples collected for determination of total suspended particulate matter (TSP) concentration. Critical flow high volume air samplers with a sample flow rate of approximately 1.1 m^3/min. were used to collect the particulate matter on quartz fiber filters for subsequent gravimetric analysis. 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. Mean austral summer PM_{10} levels in the McMurdo locale were 3 $\mu g/m^3$ at the predominantly upwind location, 9 $\mu g/m^3$ at a location approximately 500 meters downwind of the station, and 16 $\mu g/m^3$ at a "downtown" location. All PM_{10} results were below the U.S. National Ambient Air Quality Standard. TSP results at all locations were greater than PM_{10} concentrations; ranging from 8 $\mu g/m^3$ at the upwind location to a maximum measurement of 276 $\mu g/m^3$ at the "downtown" location. The initial baseline effort demonstrated that site selection and sampling equipment performance were satisfactory, and provided useful data for assessing the impact of McMurdo operations on the local ambient air quality.

RESULTS OF PM_{10} AND TSP MONITORING 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. 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 Antarctica 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, incinerator, 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 U.S. EPA State and Local Air Monitoring Stations (SLAMS) objectives and network design (40CFR58, Appendix D). Quality assurance and quality control aspects of the particulate monitoring effort were generally consistent with U.S. EPA sampling procedures (40CFR50, Appendix B and Appendix J), and the U.S EPA Quality Assurance Handbook (US EPA 1977). Collocation of particulate 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 U.S. EPA has established National Ambient Air Quality Standards, were selected for monitoring. Particulate matter with a diameter less than or equal to 10 micrometers (PM_{10}) and total suspended particulate matter (TSP) were selected for monitoring particulate air pollution. Utilizing historical wind data, a sampling network consisting of three locations was selected for the collection of PM_{10} and TSP samples. The locations were selected after field reconnaissance and were based on the objectives outlined in the monitoring plan, as well as

Table 1. Comparison of Sources of Products of Combustion at McMurdo Station (thousands of pounds per year)

Compound Discharged	Electric Generation	Water Distribution	Space Heating	Surface Vehicles	Waste Incineration[1]	TOTAL
CO_2	27207	14867	4460	6311	444	53291
H_2O	9069	5775	1732	2478	414	19468
SO_2	17.1	9.5	2.9	0.14	0.19	29.8
NO_x	111.6	9.3	2.8	15.2	0.27	39.2
Part./HC	10.6	2.6	1.4	11.2	0.015	25.1
HCl	< 1.0	< 0.5	< 0.1	< 0.01	0.088	< 1.6

1. After scrubber

Source: Pearson 1991.

Table 2. Estimated Annual Air Pollutant Emissions at McMurdo Station

	Annual Emission Basis		Pollutant Emission Rate (tons[a]/yr)				
Source Category	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.

the availability of electrical power and other operational support, and location of major emission sources. The three sites selected were: 8-Site for the predominantly upwind location, Hut Point for the predominantly downwind site, and Central McMurdo, near building 155, as the "worst case urban" location (See Figure 1). The monitoring plan called for 24-hour PM_{10} samples to be collected concurrently at all three sites every 6 days, followed by conversion of the high volume sampler inlet to the TSP mode and the collection of a 24-hour TSP sample.

Methods

PM_{10} (particulate matter $\leq$ 10 micrometers in diameter) samples were collected in accordance with U.S. EPA Reference Method for the Determination of Particulate Matter as PM_{10} (40CFR50, Appendix J). A Wedding & Associates, Inc. PM_{10} critical flow high volume sampler (EPA Designation Number RFPS-1087-062) was used. Particulate matter was collected for a 24 hour period on 8"x 10" quartz fiber filters at a flowrate of approximately 1.13 m^3/min. Filters were weighed using a Sartorius analytical balance. Flow calibration was performed prior to each sample collection using the manufacturer's recommended single-point flow rate audit procedure. Using this procedure in conjunction with the critical flow device, the volumetric flow rate of the system was known to within 0.75%. A mechanical timer and elapsed time indicator on the sampler provided a record of total elapsed sampling time.

TSP samples were collected after the PM_{10} inlet assembly was removed from the sampler and replaced with the TSP filter holder assembly and gabled roof. The use of a single high volume sampler unit with the capability for conversion from PM_{10} to TSP mode was originally planned in order to reduce sampling equipment costs, and was expected to be easily implemented as part of the routine monitoring tasks. However, this conversion proved to be more difficult and time consuming than originally thought, especially when performing the conversion alone and outdoors in cold, windy conditions. As a result of the difficulty and time consumption involved in routinely performing the conversions from PM_{10} to TSP mode, TSP sampling was assigned a lower priority than other air quality measurements, and subsequently a total of only seven TSP samples were collected during the 1992-1993 austral summer.

PM_{10} sampling was initiated on 13NOV92 and conducted through 15FEB93. A total of 33 samples were collected over this time period (11 per site), representing a sampling completeness of 65% (51 planned). The reduced data completeness occurred primarily during November and December, and is attributed to problems with the availability and reliability of the analytical balance and associated filter weight measurements, unscheduled power outages, and absence of the environmental health technician for training in the U.S.

Results

PM_{10} levels at McMurdo were reliably measured using the stated methods and equipment. A summary of the data collected during the 1992-1993 austral summer season is provided in Table 3 and Figures 2 and 3. PM_{10} concentrations ranged from below the detection limit of 2.2 $\mu g/m^3$ measured at 8-Site, to a maximum concentration of 37.5 $\mu g/m^3$ measured at the Central McMurdo site. All

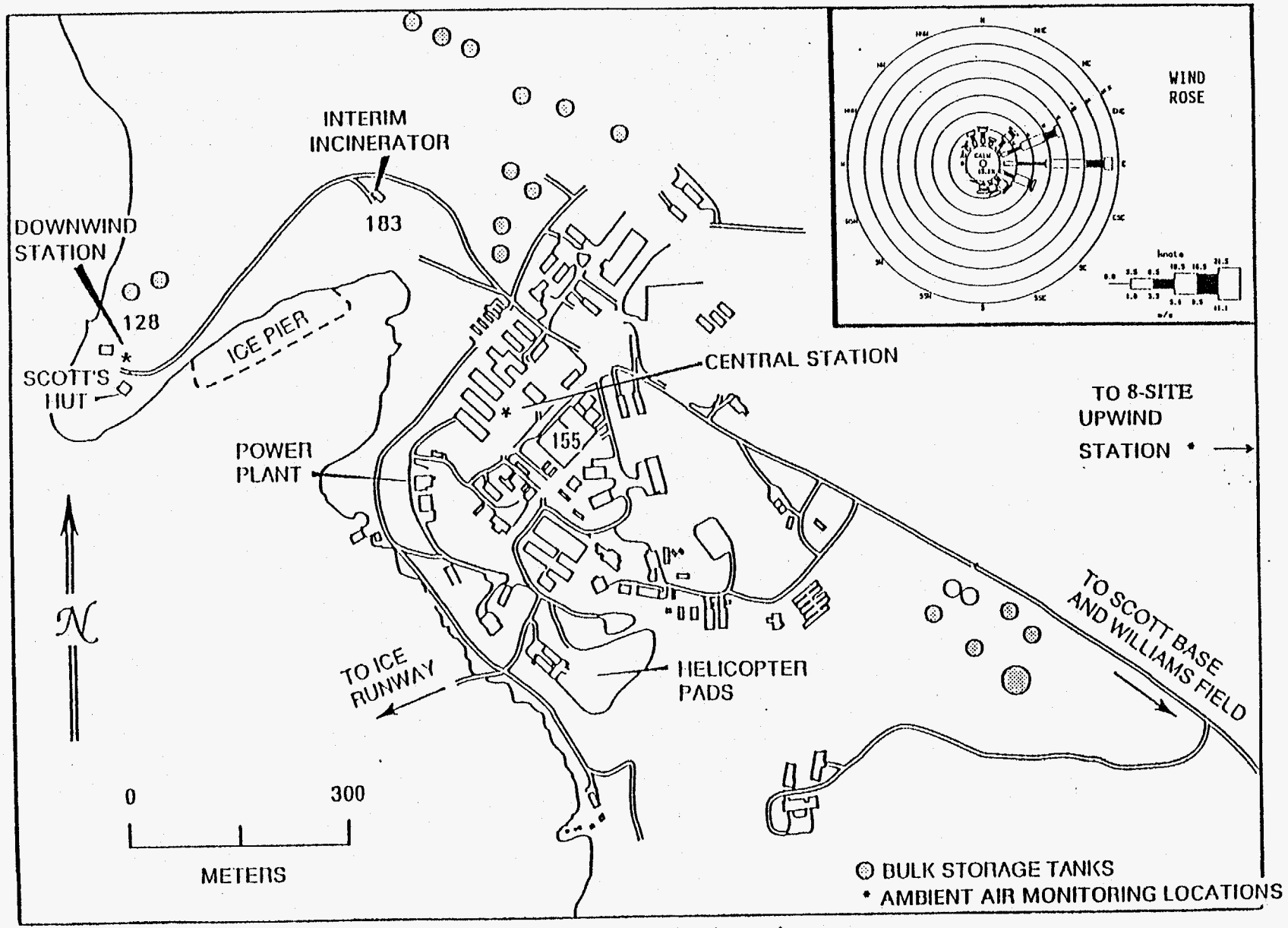


Figure 1. Map of Ambient Air Monitoring Stations at McMurdo, Antarctica.

Table 3. PM_{10} Ambient Air Concentration Data Summary

DATE	FILTER#	LOCATION	RESULTS*
13 NOV 92	MC 01	CENTRAL MCMURDO	23.0 $\mu g/m^3$
13 NOV 92	HP 01	HUT POINT	7.8 $\mu g/m^3$
18 NOV 92	TS 01	8 - SITE	REJECTED1
18 NOV 92	MC 02	CENTRAL MCMURDO	REJECTED1
18 NOV 92	HP 02	HUT POINT	REJECTED1
21 NOV 92	TS 02	8 - SITE	6.7 $\mu g/m^3$
21 NOV 92	MC 03	CENTRAL MCMURDO	37.5 $\mu g/m^3$
21 NOV 92	HP 03	HUT POINT	REJECTED2
27 NOV 92	TS 03	8 - SITE	6.0 $\mu g/m^3$
28 NOV 92	MC 04	CENTRAL MCMURDO	18.0 $\mu g/m^3$
27 NOV 92	HP 04	HUT POINT	12.4 $\mu g/m^3$
03 DEC 92	TS 04	8 - SITE	3.3 $\mu g/m^3$
03 DEC 92	MC 05	CENTRAL MCMURDO	19.9 $\mu g/m^3$
03 DEC 92	HP 05	HUT POINT	23.2 $\mu g/m^3$
09 JAN 93	TS 07	8 - SITE	< 2.2 $\mu g/m^3$
09 JAN 93	MC 08	CENTRAL MCMURDO	5.5 $\mu g/m^3$
09 JAN 93	HP 08	HUT POINT	3.3 $\mu g/m^3$
15 JAN 93	TS 08	8 - SITE	< 2.2 $\mu g/m^3$
15 JAN 93	MC 09	CENTRAL MCMURDO	8.7 $\mu g/m^3$
15 JAN 93	HP 09	HUT POINT	4.8 $\mu g/m^3$
21 JAN 93	TS 09	8 - SITE	< 2.2 $\mu g/m^3$
21 JAN 93	HP 10	HUT POINT	11.8 $\mu g/m^3$
23 JAN 93	TSM 01	8 - SITE	2.1 $\mu g/m^3$
23 JAN 93	MC 10	CENTRAL MCMURDO	9.9 $\mu g/m^3$
23 JAN 93	HP 11	HUT POINT	6.0 $\mu g/m^3$
25 JAN 93	TSM 02	8 - SITE	2.2 $\mu g/m^3$
25 JAN 93	MC 11	CENTRAL MCMURDO	15.1 $\mu g/m^3$
25 JAN 93	HP 12	HUT POINT	2.7 $\mu g/m^3$
03 FEB 93	TS 10	8 - SITE	3.8 $\mu g/m^3$
03 FEB 93	MC 12	CENTRAL MCMURDO	10.9 $\mu g/m^3$
03 FEB 93	HP 13	HUT POINT	7.6 $\mu g/m^3$
09 FEB 93	TS 11	8 - SITE	5.4 $\mu g/m^3$
09 FEB 93	MC 13	CENTRAL MCMURDO	21.6 $\mu g/m^3$
09 FEB 93	HP 14	HUT POINT	15.5 $\mu g/m^3$
15 FEB 93	TS 12	8 - SITE	3.3 $\mu g/m^3$
15 FEB 93	MC 14	CENTRAL MCMURDO	8.9 $\mu g/m^3$
15 FEB 93	HP 15	HUT POINT	8.3 $\mu g/m^3$

* Improved weighing methods increased accuracy and reliability after 01JAN93

1. Rejected: balance inadvertently removed from the CSEC laboratory
2. Rejected: weight measurements erroneous

Figure 2.

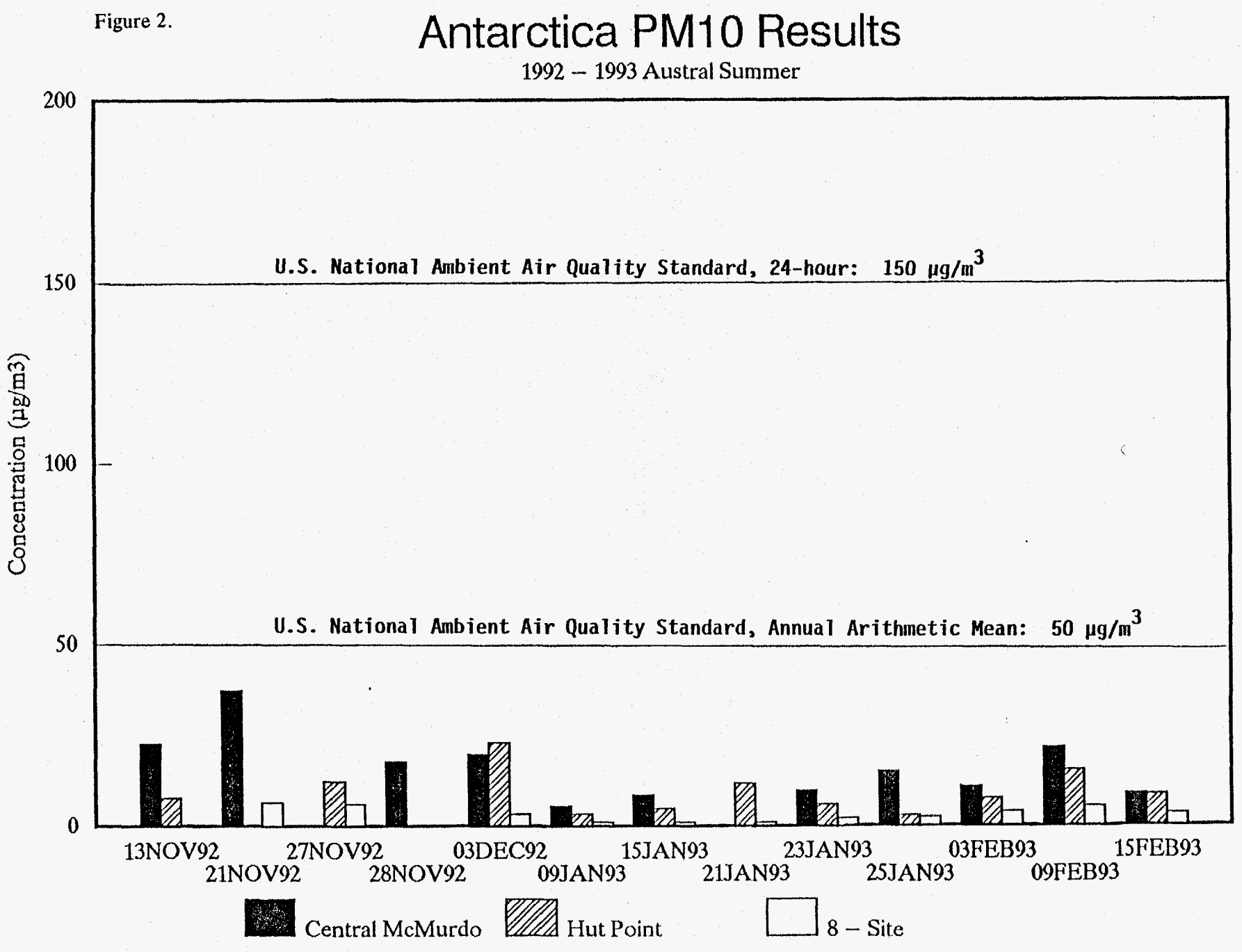
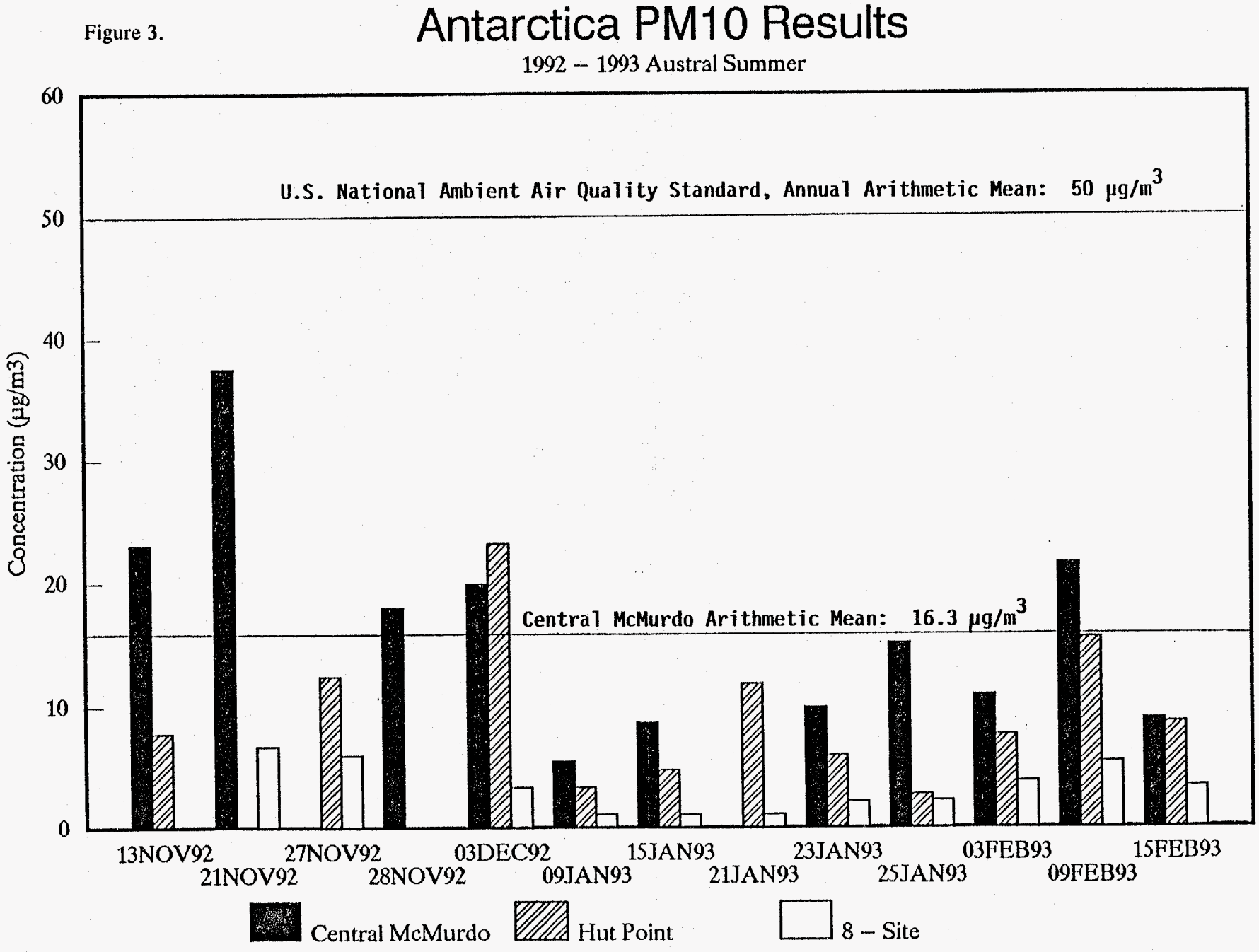

Antarctica PM10 Results
1992 – 1993 Austral Summer
200
150
100
50
0
Concentration (µg/m3)
U.S. National Ambient Air Quality Standard, 24-hour: 150 µg/m3
U.S. National Ambient Air Quality Standard, Annual Arithmetic Mean: 50 µg/m3
13NOV92
21NOV92
27NOV92
28NOV92
03DEC92
09JAN93
15JAN93
21JAN93
23JAN93
25JAN93
03FEB93
09FEB93
15FEB93
Central McMurdo
Hut Point
8 – Site

Figure 3.


Antarctica PM10 Results
1992 – 1993 Austral Summer
U.S. National Ambient Air Quality Standard, Annual Arithmetic Mean: 50 µg/m3
Central McMurdo Arithmetic Mean: 16.3 µg/m3
Concentration (µg/m3)
60
50
40
30
20
10
0
13NOV92
21NOV92
27NOV92
28NOV92
03DEC92
09JAN93
15JAN93
21JAN93
23JAN93
25JAN93
03FEB93
09FEB93
15FEB93
Central McMurdo
Hut Point
8 – Site

measurements were below the U.S. National Ambient Air Quality Standards for PM_{10} of 50 $\mu g/m^3$ (annual arithmetic mean) and 150 $\mu g/m^3$ (24 hour maximum).

A strong correlation between PM_{10} concentration and location was observed and validates the selection of the locations of the monitoring sites. The Central McMurdo location exhibited the highest PM_{10} levels with a seasonal mean of 16.3 $\mu g/^3$ followed by lower concentrations at Hut Point. The lowest PM_{10} concentrations were observed at 8-Site. Based on PM_{10} data compiled from selected U.S. cities, the summer seasonal PM_{10} levels measured at Central McMurdo were comparable to concentrations found in Santa Fe, New Mexico (see Figure 4) (U.S. EPA 1992).

Table 4 and Figure 5 summarize the TSP data. TSP levels ranged from 6.1 $\mu g/m^3$ at 8-Site to a maximum of 675.5 $\mu g/m^3$ measured at the Central McMurdo site. From 1971 to 1987, TSP was used by the U.S. EPA as the indicator for particulate matter pollution. In 1987, PM_{10} replaced TSP as the regulatory indicator for particulate air pollution. As expected, TSP concentrations measured at all three monitoring locations were higher than PM_{10} levels. Due to the very limited TSP data set, a reliable conclusion cannot be ascertained regarding mean TSP levels, however, all three TSP values measured at the Central McMurdo location were above the obsolete TSP NAAQS of: annual geometric mean not to exceed 75 $\mu g/m^3$. If a more complete data set had been obtained, the single measurement of 676.5 $\mu g/m^3$ at Central McMurdo may have exceeded the obsolete TSP 24-hour NAAQS of: 260 $\mu g/m^3$ not to be exceeded more than once per year. TSP concentrations at Hut Point were below the obsolete NAAQS values, as was the single measurement of TSP at 8-Site. The elevated TSP levels relative to PM_{10} concentrations at the Central McMurdo locations is most likely explained by the resuspension of larger particulate matter from the nearby roadway by vehicular traffic and wind.

Note that both the TSP and PM_{10} data collected after 01JAN93 is more reliable than prior data due to improvements to the filter weighing procedure and analytical balance environment.

Although the particulate data set for the austral summer season was smaller than originally planned, the monitoring effort did prove useful in assessing the sampler performance, determining the range of particulate concentrations present, and in providing useful data for assessing the impact of McMurdo operations on the local air quality.

Figure 4.

Mean PM10 Results for McMurdo, Antarctica and Selected U.S. Cities
McMurdo (1992–1993 austral summer), U.S. Cities (1991)

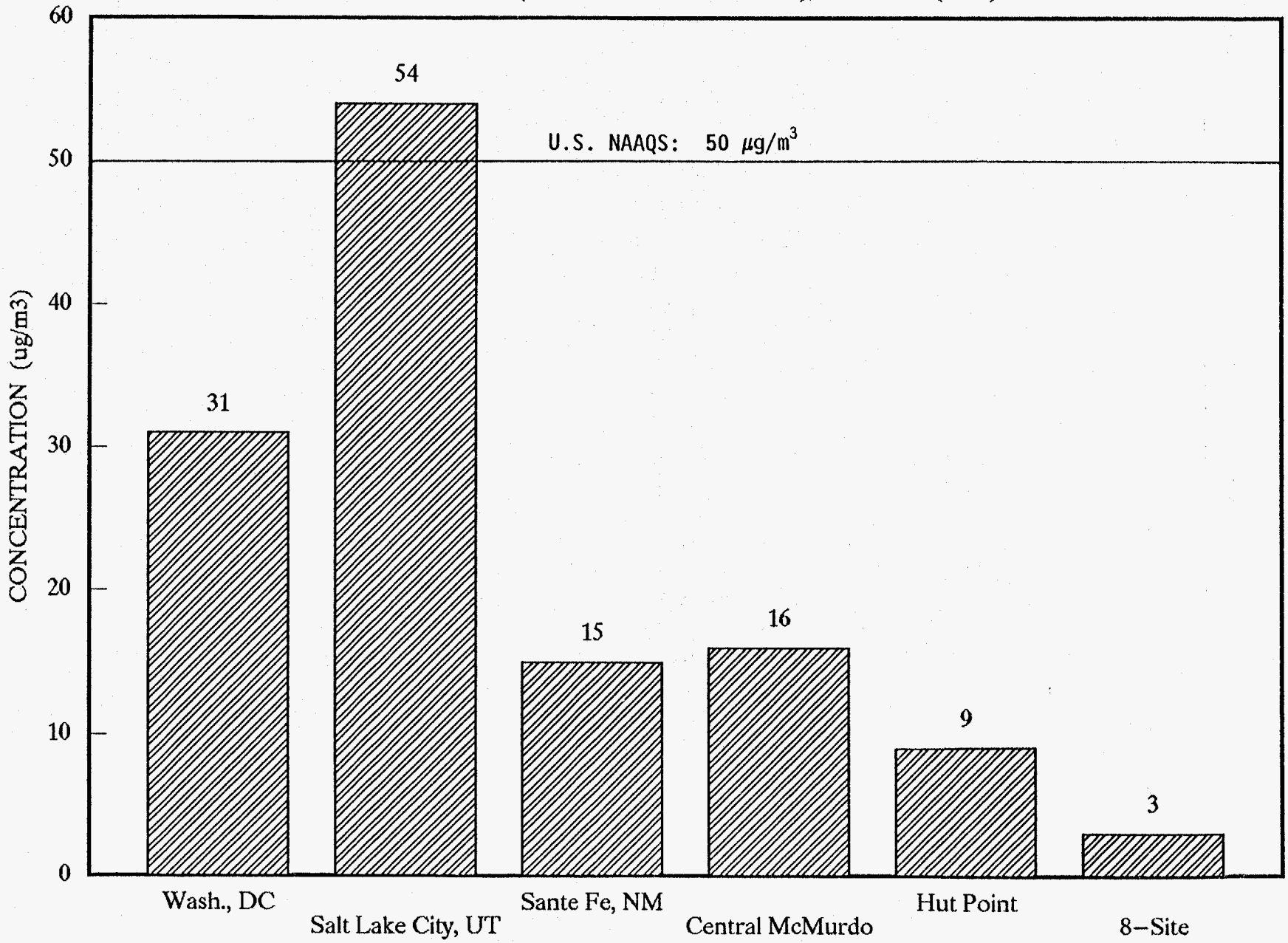
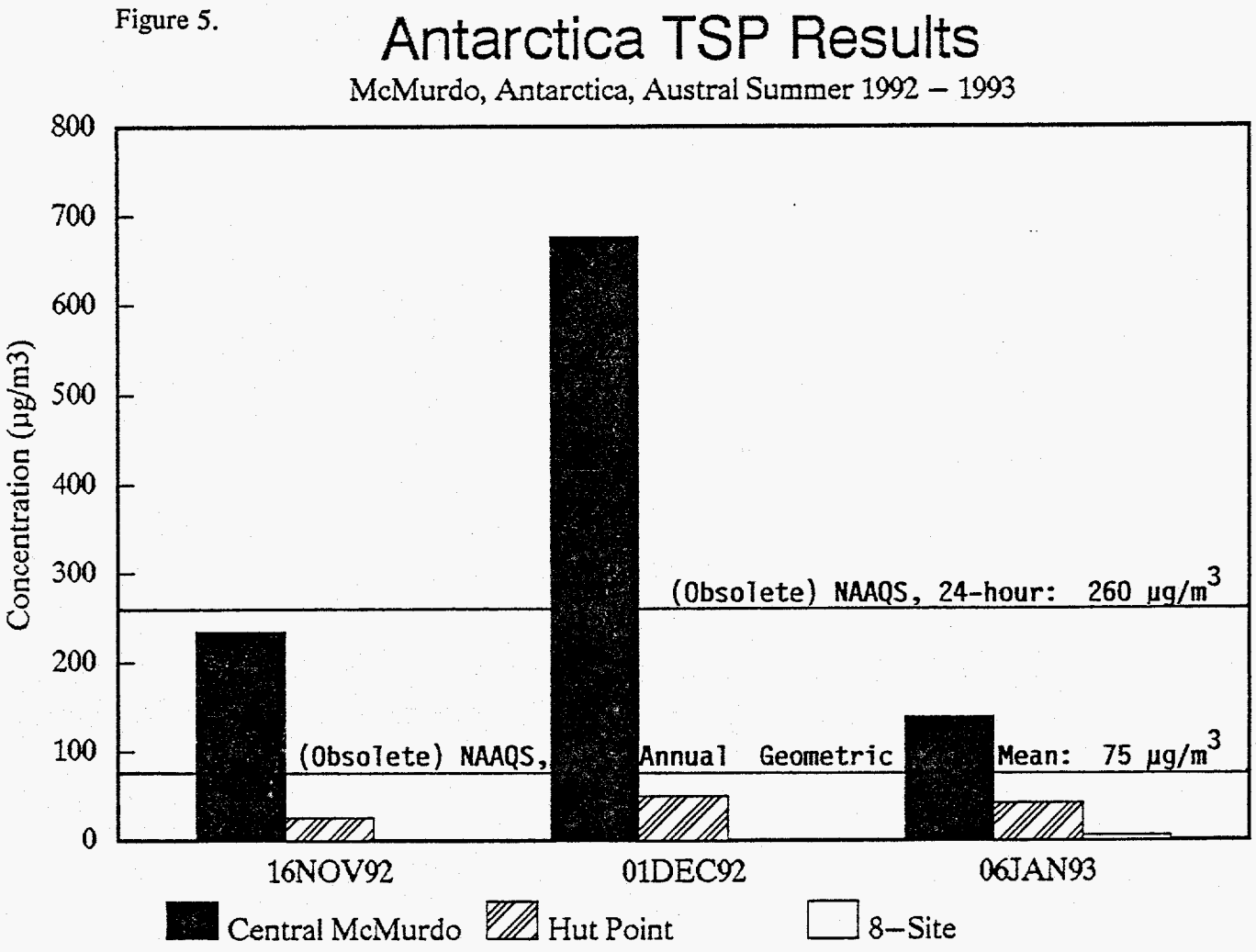


Table 4. TSP Ambient Air Concentration Data Summary, McMurdo, Antarctica, Austral Summer 1992-1993

DATE	FILTER #	LOCATION	RESULTS*
16 NOV 92	MCM 01	CENTRAL MCMURDO	234.0 $\mu g/m^3$
16 NOV 92	HPM 01	HUT POINT	26.5 $\mu g/m^3$
01 DEC 92	MCM 02	CENTRAL MCMURDO	676.5 $\mu g/m^3$
01 DEC 92	HPM 02	HUT POINT	49.7 $\mu g/m^3$
06 JAN 93	MC 07	CENTRAL MCMURDO	138.1 $\mu g/m^3$
06 JAN 93	HP 07	HUT POINT	42.3 $\mu g/m^3$
06 JAN 93	TS 06	8 - SITE	6.1 $\mu g/m^3$

* Improved weighing methods increased accuracy and reliability after 01JAN93.

Figure 5.


Antarctica TSP Results
McMurdo, Antarctica, Austral Summer 1992 – 1993
Concentration (µg/m3)
800
700
600
500
400
300
200
100
0
(Obsolete) NAAQS, 24-hour: 260 µg/m3
(Obsolete) NAAQS, Annual Geometric Mean: 75 µg/m3
16NOV92
01DEC92
06JAN93
Central McMurdo
Hut Point
8–Site

References

Code of Federal Regulations, 40CFR58, Appendix D, "Network Design for State and Local Air Monitoring Stations (SLAMS) and National Air Monitoring Stations (NAMS)," July 1989.

Code of Federal Regulations, 40CFR50, Appendix B, "Reference Method for the Determination of Suspended Particulate Matter in the Atmosphere (High-Volume Method)," and Appendix J, "Reference Method for the Determination of Particulate Matter as PM_{10} in the Atmosphere," Office of the Federal Register, July 1991.

Lugar, Robert M., 1992. *FY-1993 Ambient Air Monitoring Plan for McMurdo Station, Antarctica.* Prepared for National Science Foundation Division of Polar Programs. EG&G Idaho, Idaho Falls, ID 83415-1406. September 1992.

National Science Foundation, 1989. *Implementation of the National Science Foundation's Strategy for Compliance with Environmental Law in Antarctica.* National Science Foundation, Washington, D.C. 19 pp. 1989.

National Science Foundation, 1991. *Supplemental Environmental Impact Statement for the United States Antarctic Program.* National Science Foundation, Washington, D.C. October 1991.

Pearson, C.V., 1991. *Technology Assessment: Evaluation and Design of a High Temperature Incinerator for Treatment of Solid Wastes at McMurdo Station, Ross Island, Antarctica.* Part II: Reference System Description for the Interim Incinerator Facility. Argonne National Laboratory, Argonne, IL. June 1991.

United States Environmental Protection Agency, 1977. *Quality Assurance Handbook for Air Pollution Measurement Systems, Volume II - Ambient Air Specific Methods.* Research Triangle Park, NC. EPA-600/4-77-027a, May 1977.

United States Environmental Protection Agency, 1992. *National Air Quality Trends and Emissions Trends Report, 1991.* U.S. EPA Office of Air Quality Planning and Standards, Research Triangle Park, NC. 450-R-92-001, October 1992.