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Regional Air Pollution Study High Volume Filter Measurements of Suspended Particulate Matter

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High Volume Filter Measurement of Suspended Particulate Matter

ABSTRACT

High volume air samplers have been used for many years for collection of suspended particulate matter, thus becoming established as an EPA reference method. For this reason, ten RAMS stations located in various environments were equipped with high volume air samplers during the RAPS program. Preweighed, quality controlled filters were used to collect particulate samples every third day at these sites. Samples were transported to a chemical laboratory where total suspended particulates (TSP) were determined and wet chemical analyses performed for sulfates ($SO_4^=$) and nitrates (NO_3^-). A total of 2,358 filter samples were collected and analyzed. All data obtained were reported in micrograms meter^{-3}.

The concentration data for the three parameters studied appeared to vary both seasonally and between stations. To further examine the variability, the annual mean for each parameter was computed and plotted for each sampling station. The geometric mean for TSP ranged from 33.0 to 90.9 micrograms meter^{-3}, $SO_4^=$ ranged from 7.0 to 12.7 micrograms meter^{-3} and NO_3^- from 2.3 to 3.8 micrograms meter^{-3}. Each year was divided into quarters for each sampling station and the quarterly mean computed and plotted. A one way analysis of variance technique was used to test the significance of the variations in concentration. The results of the analysis of variance did indeed show a statistically significant difference in concentration between stations and also between quarters or seasons of the year.

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1.0 INTRODUCTION AND SUMMARY

An important element of the Regional Air Pollution Study (RAPS) conducted in the St. Louis area was the characterization of the urban aerosol. A series of experiments, measurement and analyses of suspended particulates were conducted to determine the character of aerosols in the St. Louis region in terms of their chemical and physical properties and their probable origins and evolution. Measurements of suspended particulates were made in either real time or as aerosol samples which were collected for subsequent chemical analysis using various traditional laboratory techniques. High volume sampler measurements, the subject of this task order, were to be used primarily for comparison with historical data and with other techniques for measurement of atmospheric aerosols, and to broadly characterize the distribution of total suspended particulates (TSP), sulfates ($SO_4^=$), and nitrates (NO_3^-) in the St. Louis region.

Two high volume samplers were installed at each of the following RAMS stations: 103, 105, 106, 108, 112, 115, 118, 120, 122, and 124. The samplers were equipped with constant flow controllers (Sierra Model 310B) to insure a constant air flow through the filter regardless of filter loading within limits of the sampler's capabilities. However, the constant flow section was not connected during the first year of operation, but was connected for the remainder of the sampling period and the percentage of recoverable valid data was vastly increased. For accurate and reliable flow data, the setpoint output voltage from the constant flow controller should be periodically checked with a calibrating device, preferably the top loading orifice calibrator.

High volume filters were Government Furnished Equipment (GFE) and were inspected, numbered and weighed before and after each sample collection, utilizing the Community Health Air Monitoring Program (CHAMP) procedures. Filters were stored in an environment of 23°C and 40% relative humidity except during filter transit and while installed in the sampler.

One filter sample was collected every third day including weekends and holidays at each of the ten RAMS stations in synchronism with the National Air Surveillance Network (NASN) schedule. The period of sampling was from midnight to midnight. The RAMS data acquisition and control system was used to initiate and terminate sampling. Flow rate measurements from each operating sampler flow transducer were recorded by the RAMS data acquisition system. During scheduled visits to each station for sample collection, new filters were installed, flow rates verified, sampler system inspection made, and preventative maintenance performed where required.

All collected samples with associated documentation were packaged in accordance with the CHAMP sample handling and shipping procedures and mailed to the Rockwell International Air Monitoring Center (RIAMC) Analytical Chemistry Laboratory in Newbury Park, California, for analysis. The results of the analyses for TSP, $SO_4^=$, and NO_3^- were compiled in SAROAD format and placed on magnetic tape for inclusion into the RAPS data bank.

A comprehensive quality assurance plan was submitted and approved by the EPA Task Coordinator. As part of quality assurance, the following guidelines were established with the recommendation that data exceeding these limits be considered for further investigation.

$$20 < TSP < 200$$
$$4 < SO_4^= < 50 \qquad \text{values in } \mu g/m^3$$
$$1 < NO_3^- < 10$$

Monthly progress reports were submitted which included descriptions of quality assurance activities, sample status, operational performance of each station, reasons for sampler failure, major problems and planned corrective action and plans for future activities. Under Task Order No. 51 (Contract DU-68-02-1081), the twenty high volume samplers of the Regional Air Monitoring System (RAMS) were operated and maintained from 14 January 1975 to 15 August 1975. The operation and maintenance of these twenty high volume samplers were then continued under Task Order No. 101 from 16 August 1975 to 31 March 1977. During that period, 2,358 filters were collected out of a possible 2,456 for a capture rate of 96 percent. Samples were inspected after collection and validated. A sample could be invalidated because of questionable

flow rate data, site computer malfunction, bird excrement and scratches, sampling time outside the prescribed limits (23-25 hours), mechanical damage to filter and waterspots caused by flowing rain or snow. Some samples were included in the Particulate Data Summary although they were outside the sample time limits because of the useful information they might contain. These samples are identified in the Particulate Data Summary. Eighty-eight percent of the samples analyzed were reported. For completeness, the summaries of data contained in this report include the data resulting from Task Order No. 51 as well as Task Order No. 101.

Cursory data analysis showed that two stations exceeded the National Ambient Air Quality Standards. Graphical presentation of the data and rudimentary statistical tests also revealed significant variations between stations and seasonal patterns.

2.0 NETWORK OPERATIONS

Prior to initiating formal work on Task Order No. 51, the predecessor to this task order, the installation of two each Sierra Model 305, high volume samplers with flow controllers and computer tie-in control, was accomplished at ten RAMS sites. This effort was performed by a change order to the basic RAMS contract. Samplers were installed at RAMS sites 103, 105, 106, 108, 112, 115, 118, 120, 122, and 124. Installations were completed in late January 1975. The flow controller portion of the mass flow controller was not connected to the motor. The motor was controlled with a manually operated motor controller separate and apart from the Sierra 310B constant flow device. The manual controller was set so that the flow through a clean filter was approximately 1.13 m^3/min. The first two weeks of February 1975 were used to operate the samplers for systems checkout, equipment burn-in and operator training. Operations under Task Order No. 51 were continued under Task Order No. 101 beginning 16 August 1975 and terminating 31 March 1977. Beginning 12 February 1975, samples were collected every third day at ten stations; on 13 March 1975, the schedule was altered to coincide with the federal, state and city schedule (NASN schedule). The filters collected for the month of February were not analyzed because old filters from a previous task were used. The new batch of filters had not been received from the EPA soon enough to complete the pre-weighing and shipment to St. Louis by 12 February 1975.

2.1 PERSONNEL ACQUISITION AND TRAINING

Implementation of the support services required by Task Order No. 51 was performed by two full-time technicians who also supported two other field sampling task orders. At the time work began on this task order, the required skilled personnel were available from other programs being phased out. Both operators had previous experience operating high volume samplers. Since the RAMS computer system was used to control operation of the high volume samplers and flow data acquisition, additional training was required in this area.

Also, new solid state automatic flow controllers were used with the high volume samplers thereby requiring more operator training.

2.2 HIGH VOLUME SAMPLER NETWORK

An all metal filter holder was used in the installation and removal of the samples. The exposed filter was removed inside the shelter and the appropriate entires made on the Daily Hi-Vol Data Record (Figure 1), and the Total Particulate Raw Data Card (Figure 2). The exposed filter was placed in a manila folder and put into an envelope along with the Data Record Cards. The collected samples were later returned to the RAPS office where they were recorded in a high volume sampler record book. On 19 January 1976, a new system for recording filter data was initiated. The new system incorporated the Particulate Raw Data Record and the manila folder into one unit. The combined folder and Raw Data Record consisted of the folder with three copies of the Raw Data Record attached to the folder. When data were recorded on the first sheet, it was transferred to the other sheets and the folder. When the exposed filters were analyzed, three copies of the Raw Data Record were returned to the RAPS St. Louis facility for their records.

Prior to April 1976, flow rate data were not sent with the exposed filters. The filters were analyzed at the chemistry lab in California after which the raw analyses were sent back to the St. Louis facility where the flow rate data were merged with the raw analyses in the RAMS computer. The output from the RAMS computer resulted in a printout of concentrations and a magnetic tape in SAROAD format. During the month of March 1976, a new method for reporting filter data and filter validation was conceived. The new reporting system resulted in the printout and magnetic tape being produced at the time the filter analyses were performed. This was accomplished because all the necessary information was placed on the new Total Suspended Particulates form. The printout of high volume data for each site contained the following information:

EPA (DL:) 202

DAILY HI-VOL DATA RECORD

City & State _____

Year 19 __ __ Site Number _____ _____ _____ _____

Type of Sampler: Regular _____

Other _____

Sampler Serial Number _____ _____ _____ _____ _____

Filter Number _____ _____ _____ _____ _____

	mo.	day	hr	min	CFM
Time Start	_____	_____	_____	_____	_____
Time Stop	_____	_____	_____	_____	_____

FOR LAB USE ONLY

(__ __) CFM

(__ __) CFM

Total Minutes Sampled _____ _____ _____ _____

FIELD NOTES:

_____

_____

_____

SIGNATURES:

Sample On: _____

Sample Off: _____

For lab use only:

PARTICULATE DATA

Gross Wgt.-Filter _____ _____ . _____ ___ ___ (grams)

Tare Wgt.-Filter _____ _____ . ___ ___ ___ ___ (grams)

Particulate Wgt. _____ _____ . ___ ___ ___ ___ (grams)

ORGANIC DATA

Tube & Sample _____ _____ . ___ ___ ___ ___ (grams)

Tube Tare Wgt. _____ _____ . ___ ___ ___ ___ (grams)

Wgt. of Extract _____ _____ . ___ ___ ___ ___ (grams)

Total Wgt. (9 x 2) _____ _____ . ___ ___ ___ ___ (grams)

CUT

FIGURE 1. DAILY HI-VOL DATA RECORD

TOTAL SUSPENDED PARTICULATES

FMT.	2	1	(1-2)	NOTE: X 0 - COMPUTER		* 0-REG.	CITY:
SITE			(3-6)	1 - MANUAL		1-DUP.	JULIAN STOP DATE:
	DATE YR	MO	DAY	TIME	FLOW (m^3/m)		METER FLOW OBSERVED
START						(7-19)	START _____ (m^3/m)
STOP						(20-32)	STOP _____ (m^3/m)
							FIELD COMMENTS:
X	*	STAT-US CODE	MOTOR SERIAL NO.	FILTER NO.		(33-47)	
							ON BY:
FLOWMETER SERIAL NO.			ANALYSIS DATE YR	MO	DAY	(48-58)	OFF BY:
							LAB. COMMENTS:

LAB. ANALYSIS	C.C.	TYPE OF ANALYSIS	
	(59-63)	SAMP. + TARE WT. (mg.)	
	(64-68)	TARE WT. (mg.)	
	(69-73)	NO_x WT. (mg.)	VALIDATION CODE
	(74-78)	SO_x WT. (mg.)	0 0 (79-80)

ANALYZED BY:

EPA(DUR)328

FIGURE 2. TOTAL PARTICULATE RAW DATA CARD

1. Julian date - start and stop
2. Start time - stop time
3. Filter number
4. Start weight - stop weight (of filter)
5. Flow in cubic meters
6. A four digit code, having the following meaning

FIELD		CODE	MEANING
Raw data card	SAROAD		
33	70	0	Flow controlled operation
		1	Manually set operation
34	71	0	Normal operation--24 hour data
		1	Interrupted operation--less than 24 hours
		2	Interpolated data; 24 hour operation, but some computer entries missing
35-36	72-73	00	Normal 24 hour operation
		XX	Hours of operation, if code in field 34 and 71 is 1
		XX	Interpolated hours, if code in field 34 and 71 is 2

7. Total suspended particulates (TSP) in mg on filter; concentration in µg/ml; airborne concentration in µg/m^3.
8. Sulfate - same units
9. Nitrate - same units
10. Comments

The constant flow circuit of the controller was connected before the start of sampling scheduled for 19 January 1976. The controls were set to yield flows of approximately 1.27 m^3/min. at all stations except to sampler No. 2 at RAMS site 118. The output voltage at 1.27 m^3/min. was at the upper limit of 5 volts that could be measured by the station's data acquisition system. The flow for sampler No. 2 at RAMS site 118 was set for approximately 0.91 m^3/min.

Programs were written for the RAMS data acquisition system to convert the average total flows which were in cfm to cubic meters. With the addition of this information on the flow data printout sheets all manual computations were eliminated. The flows were entered on the raw data cards sent to the chemistry lab. The flow data printout information seemed to indicate that the constant flow controllers maintained a constant flow through the filters for all practical purposes.

In March 1976 a protective device was designed to keep birds from using the high volume shelter as a nesting and roosting site. Sparrows seemed to give the most trouble. No trouble was experienced with the birds in populated areas. Several methods had been tried in the past to protect the samplers, including toy snakes. The snakes were successful for only a short time until the birds would actually physically remove them or build nests beside them. The newly designed device consisted of an aluminum frame with a 15.9 mm mesh plastic net material draped over the frame. This device proved to be the only means for effectively protecting the samplers from the birds.

During the month of August 1976 extra high volume filters were sampled by running the spare sampler on four consecutive sampling days with the regular sampler. At the end of the sample period the extra high volume filters were treated with NH_3. Before the filters were removed the sampler was turned on and approximately 150 cc of NH_3 was released over the filter. These filters and five blanks were given to the EPA Task Coordinator to be analyzed at Research Triangle Park.

Occasionally flow data would be lost in the data acquisition for no apparent reason. Careful investigation by RAMS personnel indicated losses usually occurred when the minicomputer malfunctioned and had to be reprogrammed. The high volume sampler would continue to run after the computer malfunctioned but if for some reason it had to be reprogrammed the sampler motor would be stopped and would not start again until it received a command from the computer. Two "start" commands were available to the operator, (1) an abbreviated command, requiring few instructions and (2) a longer command requiring about twice as many instructions. It was discovered that when the abbreviated command was used the data loss would sometimes occur, though not always, but would never occur when the longer command was used. When this glitch was

identified, the longer command was the only one used to restart a sampler.

RAMS site 124 was deactivated in February 1977. The remaining network continued to operate normally until the close of business on 31 March 1977, after which time the samplers were removed from the shelter roofs and stored inside the shelters.

During the period of performance of the sampling network 2,358 filters were collected out of a possible 2,456 for collection efficiency of 96%. The collection efficiency by station is presented in Table 1. Tables 2 and 3 present a compilation of the most prevalent sampler and non-sampler related malfunctions experienced during the life of the network.

2.3 EQUIPMENT MAINTENANCE

During scheduled visits to each station for sample collection, sampler systems were inspected and preventative maintenance performed as required. Motor brush replacement proved to be the biggest maintenance item. A table was constructed for each sampler indicating all maintenance required. The table was used to project the expected date of brush replacement. It proved to be superior to the usual practice of changing brushes after a fixed number of hours of operation because each sampler motor exhibited its own peculiar characteristics. During preventative maintenance periods, it became apparent that periodic checks for leaks should be performed. Leaks in the system will give a false flow output voltage reading because the feedback circuit controlling the flow would compensate for the leak. The output voltage was a function of the sample flow through the filter.

For the lifetime of the sampling network, seventy-five sets of motor brushes, five solid state a.c. relays, and two sampler motors were replaced and ten constant flow controllers were repaired at the Rockwell International Air Monitoring Center in St. Louis.

2.4 SAMPLE ANALYSIS

Total suspended particulates were determined gravimetrically from the weights of the glass fiber filters before and after sampling on a Mettler H20 analytical balance. Gnats and/or other insects embedded in the particulate matter were removed with Teflon-tipped tweezers, being careful not to