Bench Marking Survey of State Air Pollution Control Agencies on the Resources Required to Conduct Air Quality Monitoring Programs

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ABSTRACT

This paper reports on a bench marking survey conducted of nine state air pollution control agencies on the resources required to conduct their air quality monitoring programs. The paper is directed to managers and personnel operating government air quality monitoring programs.

While private industry frequently uses bench marking surveys to compare their costs and performance with other companies and industries, this methodology is rarely used to help air pollution control agencies assess their cost effectiveness in achieving their goals.

The survey consisted of seven questions focusing on operations for the year 1999:

1. Number of monitors operated and sampling frequency

2. Frequency of scheduled and unscheduled site visits by monitor type

3. Frequency of calibrations and quality control performance checks

4. Travel distance and travel time to monitor sites

5. Type of calibrators used for continuous gas analyzers

6. Resources required to operate and maintain, quality assure and process data from the monitoring program

7. Ideas the state agency has implemented or is considering implementing for improving the efficiency and effectiveness of the state air quality monitoring program

Survey responses are summarized and analyzed to compare resources devoted in terms of number of equivalent continuous air quality monitor-years of operation per equivalent full time person-year. Because some state agencies outsource their laboratory analyses, all responses were adjusted to exclude the equivalent full time person-years devoted to laboratory analyses.

The monitoring conducted by each state in 1999 including the new $PM_{2.5}$ air quality monitoring initiated by states in that year was translated into the number of equivalent continuous SO_2 air quality monitor-years of operation. This was done using Enviroplan's experience since 1974 with over a hundred air quality monitoring networks in operation and maintenance, quality assurance and data processing including operating a large state $PM_{2.5}$ monitoring program. Our data base of direct labor hours required to operate each type monitor was applied to the number, period and sampling frequency actually used in 1999 for each monitor type to determine the number of equivalent continuous SO_2 air quality monitor-years of operation.

Survey results show a wide variation in the resources used by the nine states with the least efficient state requiring four times the resources of the most efficient state in conducting the required air quality monitoring.

The average resources required vary from 0.59 equivalent continuous SO_2 air quality monitors operated per full time person to 2.40 equivalent continuous SO_2 air quality monitors operated per full time person with an average of 1.54 equivalent continuous SO_2 air quality monitors operated per full time person. Ideas offered by state agencies for improving the cost effectiveness of their monitoring programs are discussed. Observations and conclusions with associated limitations of the survey are presented.

INTRODUCTION

About 5,000 air quality monitors at about 3,000 monitoring sites currently are operated by state and local air pollution control agencies in the United States to satisfy the requirements of the Clean Air Act and state and local air pollution monitoring requirements. U.S. EPA and state and local governments spend about $150 million per year to carry out these monitoring requirements. Performance requirements for this monitoring are codified in several federal regulations and guidelines [(1), (2), (3), (4), (5), (6)] as well as in state and local government rules.

To date, we know of no studies that have been conducted to compare the resources required by different state government agencies to satisfy these requirements and the different approaches taken by these agencies.

The purpose of this study was to conduct a survey of several state air pollution control agencies to compare the resources each requires to carry out its air quality monitoring requirements and the approaches taken to do this.

The body of this paper is organized into four main sections: 1) survey design, 2) results, 3) discussion of results, and 4) conclusions.

SURVEY DESIGN

Nine state air pollution control agencies agreed to participate in this survey. All are located in the eastern half of the U.S. including the New England, Mid-Atlantic, Midwest and Southeast regions.

The survey consisted of seven questions. The first five questions dealt with the scope of air quality monitoring conducted with emphasis on questions that affect the resources required to operate an air quality monitoring program. The sixth question requested information on the specific resources required to operate the state's air quality monitoring program with separate requests for resource requirements for each of 13 parts of the monitoring program. The last question gave the state agency the opportunity to discuss ideas the agency has implemented or is considering implementing for improving the efficiency and effectiveness of its air quality monitoring program.

The survey was mailed to the manager in charge of the air pollution control division in each of the state environmental agencies. The survey requested responses for operations in the year 1999. We assured prospective survey participants that only the statistical results of the survey would be reported and that individual state names corresponding to each response would not be disclosed.

RESULTS

Question 1 requested the number of monitors of each type operated in 1999, the average number of operating months and the sampling frequency. Responses are given in Table 1 and are based on all nine agencies responding.

A total of 935 air quality monitors were operated in the nine states in 1999 consisting of eight types of continuous monitors and eight types of episodic samplers. The largest number of continuous monitors were operated for ozone (O_3) with an average of 16.4 monitors per state. The largest number of episodic monitors were for PM-10 with an average of 16.6 monitors per state. In addition, there were an average of 13.4 meteorological monitoring stations per state with an average of 4.5 meteorological parameters per monitoring station.

Question 2 requested the frequency of scheduled and unscheduled site visits. Responses are given in Table 2 and are based on eight agencies responding.

The frequency of scheduled site visits for continuous monitors ranged from once every five days to once every 11.3 days depending on the monitor type with an average (not weighted by the number of monitors of each type) of once every 8.4 days. The frequency of scheduled site visits for episodic monitors ranged from once every 4.3 days to once every 8.3 days depending on the monitor type with an average of once every 6.2 days.

The frequency of unscheduled site visits for continuous monitors ranged from once every 3.5 days (for VOC-automated GC monitors) to once every 60 days with an average of once every 26.4 days. The frequency of unscheduled site visits for episodic monitors ranged from once every 12.3 days to once every 32 days depending on the monitor type with an average of once every 26.9 days.

Table 1. Scope of air quality monitoring operations by state agencies.

Question 1: Number of Monitors Operated in Calendar Year 1999 and Sampling Frequency					
Parameter	Number of Monitors per State Responding			Average #	Sampling Frequency
	Avg.	Min.	Max.		
O3	16.4	1.0	47.0	8.4	Continuous
SO2	7.6	1.0	35.0	12.0	Continuous
CO	5.4	0.0	18.0	10.7	Continuous
NOx	3.9	1.0	12.0	11.4	Continuous
NOy	3.0	0.0	14.0	8.2	Continuous
PM10 continuous	1.5	0.0	7.0	12.0	Continuous
PM2.5 continuous	1.3	0.0	4.0	12.0	Continuous
VOC-automated GC	1.2	0.0	4.0	6.4	Continuous
PM10	16.6	2.0	58.0	12.0	6.0
PM2.5 only	22.1	9.0	36.0	11.6	2.9
PM2.5 speciated	4.0	0.0	9.0	12.0	3.7
Lead	4.9	0.0	20.0	12.0	5.8
PUF	4.0	0.0	16.0	6.0	12.0
Metals	4.2	0.0	16.0	6.0	12.0
VOC-canister	5.8	0.0	16.0	9.0	7.3
Carbonyl	2.0	0.0	4.0	9.0	8.0
Total number of air quality monitors	935				
Average number of air quality monitors per state agency	103.9				
Average number meteorological stations per state agency	13.4			4.5	Continuous
Average number parameters per meteorological station	4.5				

Table 2. Frequency of scheduled and unscheduled site visits.

Question 2: Frequency of Scheduled and Unscheduled Site Visits in 1999 (once per specified number of days)		
Parameter	Frequency of Scheduled Site Visits	Frequency of Unscheduled Site Visits
O3	8.8	18.7
SO2	8.8	33.0
CO	8.0	33.0
NOx	7.9	28.7
NOy	7.9	13.0
PM10 continuous	9.8	60.0
PM2.5 continuous	11.3	21.0
VOC-automated GC	5.0	3.5
PM10	5.8	32.0
PM2.5 only	4.3	12.3
PM2.5 speciated	4.6	-
Lead	5.7	30.0
PUF	-	-
Metals	7.0	-
VOC-canister	8.3	30.0
Carbonyl	8.0	30.0
Meteorological parameters	119.0	60.0
Average for continuous monitors	8.4	26.4
Average for episodic monitors	6.2	26.9

Question 3 requested the average number of calibrations and quality control performance checks in 1999 per analyzer. Responses are given in Table 3 and are based on eight agencies responding.

Table 3. Average number of calibration and quality control performance checks.

Question 3: Average Number of Calibrations and Quality Control Performance Checks in 1999 per Analyzer					
Parameter	Frequency of calibrations (specify number of times per year scheduled				Specify which
	A. Level 1	B. Level 2	C. Precision	D. Multipoint	
O3	17.7	15.8	10.2	0.7	A,B,C
SO2	74.4	13.0	16.5	1.7	A,C
CO	81.1	2.5	21.1	1.5	A,B,C
NOx	57.6	27.3	22.7	1.7	A,B,C
NOy	101.5	0.0	23.3	3.3	A,C
PM10 continuous	N/A	N/A	N/A		
PM2.5 continuous	N/A	N/A	N/A	1.5	
VOC-automated GC	12.5	0.0	12.5		N/A
PM10	N/A	N/A	N/A	0.4	
PM2.5 only	N/A	N/A	N/A	0.1	
PM2.5 speciated	N/A	N/A	N/A		
Lead	N/A	N/A	N/A		
PUF	N/A	N/A	N/A		
Metals	N/A	N/A	N/A		
VOC-canister	N/A	N/A	N/A		
Carbonyl	N/A	N/A	N/A		
Average for	57.5	14.6	17.7	1.7	

An average of 57.5 Level 1 zero/span calibrations were performed per continuous monitor. An average of 14.6 Level 2 zero/span calibrations were performed for the O_3, SO_2, CO and NO_x monitors. An average of 17.7 precision checks were performed per continuous monitor and an average of 1.7 multipoint calibrations were performed per continuous monitor in 1999. For five of the continuous monitor types, one or more states used automated calibration and/or precision checks.

Question 4 requested for each monitor site the travel distance to the site and the travel time to the site. Responses are given in Table 4 and are based on three agencies responding.

Table 4. Average travel distance and time to air quality monitor sites.

Question 4: Site ID, Parameters Measured, Travel Distance and Travel Time in 1999		
	Travel distance to site (miles) (a)	Travel time to site (minutes) (b)
Average	66.0	97.4

While only three states responded to this question, the average travel distance and time indicate a significant amount of resources are expended in travel to and from each monitor site.

Question 5 requested information on the number of calibrators used and number of calibrations/certifications per calibrator performed in 1999. Responses are given in Table 5 and are based on seven agencies responding.

Table 5. Calibrators used for continuous gas analyzers.

Question 5: Calibrators Used for Continuous Gas Analyzers in 1999				
	Permeation Tube	Dynamic Gas Dilution Calibrators with Mass	O3 Transfer Standards	O3 Primary Standards
# of calibrators	1.7	4.1	6.8	2.0
Average # of calibrations/ certifications per calibrator performed per year	11.6	6.4	13.0	4.4

Table 5 indicates that dynamic gas dilution calibrators with mass flow controllers are used more than twice as often as permeation tube calibrators based on the product of the number of calibrators of each type times the average number of calibrations/ certifications per calibrator performed per year. Also, O_3 transfer standards are used far more often than O_3 primary standards in conducting these calibrations and certifications.

Question 6 requested information on the resources required to operate the state air quality monitoring program. Responses are given in Table 6 and are based on all nine agencies responding.

The number of equivalent full time personnel used to operate the state air quality monitoring programs range from 7.5 to 55.7 persons with an average of 25.0 persons per state agency. The 25^{th}, 50^{th} and 75^{th} percentile of the number of equivalent full-time persons used are also given, e.g. 25% of the state agencies responding used 15 or less equivalent full time persons to operate their monitoring programs.

Table 6. Resources required to operate the state air quality monitoring program.

Question 6: Resources Required in 1999 to Maintain, Quality Assure and Process State Air Quality Monitoring Network Data Specified in Responses to Above Tables						
Task	Number of Equivalent Full Time Personnel in 1999					
	Minimum	25%	50%	Average	75%	Maximum
1. Site Operation and Maintenance for Continuous Analyzers including Travel to and from Sites	1.5	3.3	5.0	6.0	6.8	14.6
2. Site Operation and Maintenance for PM2.5 Samplers including Travel to and from Sites	2.0	2.3	4.5	5.2	7.5	10.2
3. Site Operation and Maintenance for All Other Episodic Samplers including Travel to and from Sites	0.5	0.7	1.0	2.7	4.0	8.1
4. Equipment Repair (if not done by site operator)	1.0	1.8	2.0	2.8	3.1	6.3
5. Calibrations/QC Performance Checks (if not done by site operator)	2.0	2.3	2.5	2.5	2.8	3.0
6. Data Review and Analysis	0.2	1.1	2.3	2.3	3.0	5.2
7. Data Validation and Reporting	0.0	0.8	1.0	1.0	1.1	1.5
8. QA Audits	0.2	1.0	1.5	1.6	2.4	3.0
9. Standards Calibration	0.1	0.3	0.5	0.5	0.8	1.0
10. Laboratory Sample Preparation and Analysis - PM2.5 (a)	0.3	1.6	2.5	2.1	3.0	3.0
11. Laboratory Sample Preparation and Analysis - other episodic samplers	0.1	0.8	1.5	1.9	2.6	4.4
12. Program Management	1.0	1.3	2.5	2.7	3.8	5.0
13. Other (specify)	0.5	0.9	1.3	1.3	1.6	2.0
Total Number Equivalent Full Time Personnel per Year	7.5	15.0	24.0	25.0	27.0	55.7

Also presented in this table are the equivalent full time persons used to carry out each of the 13 functions into which monitoring program operation was divided in the survey. The largest personnel requirements, on average, were for the site operation and maintenance for continuous analyzers including travel to and from sites. This function accounted for 24% of the total resources required on average. The second largest personnel requirements were for site operation and maintenance for $PM_{2.5}$ monitors including travel to and from the sites. This function required 21% of the total resources required. For two of the nine states responding, the labor for laboratory preparation and analysis of the samples for the episodic samplers including the $PM_{2.5}$ samplers were excluded from the equivalent full time personnel reported. This omission, however, should not make a significant difference in the overall reported results.

Question 7 requested information on the ideas each agency has implemented or is considering implementing for improving the efficiency and effectiveness of its air quality monitoring program. Responses are given in Table 7 and are based on all nine agencies responding.

Table 7. Ideas the state air pollution control agencies have implemented or are considering implementing for improving the efficiency and effectiveness of their air quality monitoring programs.

Question 7: Ideas Your Agency Has Implemented or is Considering Implementing for Improving the Efficiency and		
Idea	Implemented	Benefit Achieved (Expected)
Assign specific $PM_{2.5}$ filters to specific sites for	Yes	Allows for more efficient handling of data
Interface balance for weighing $PM_{2.5}$ filters to	Yes	Eliminates transcription errors.
Convert older air monitoring data into a format,	Pending	Quick access to older data.
Update analyzers, calibrators and other	Pending	Less time involved in station precision checks,
Upgrade equipment shelters so that less time	Pending	Less roof tarring, etc.
Automate quality control checks on continuous	Yes	Reduced field operator work load.
Automate calibrations on continuous monitors.	No	Reduce field operator work load.
Automate data down load from non-continuous	No	Reduce field operator work load.
Have operators use electronic field lab books.	Yes	Improved quality control operations. Reduced
Restructure laboratory responsibilities.	No	Improve data quality and more efficient use of
Install programmable multi-point ozone	Yes	Saves travel costs.
Install modems at all $PM_{2.5}$ sites.	Yes	Saved travel costs and improved ability to obtain
Obtain commercial software for the particulate	No	Saves staff time to create and up-date our own
Outsource special monitoring projects.	No	Expected to offset personnel shortage and also
Connect via modem data logger for more rapid	Yes	
Automate calibration capabilities for the	Yes	Decreased travel and staff time and increased

As shown in Table 7, sixteen ideas were provided of which eight have been implemented to date.

DISCUSSION OF RESULTS

To make meaningful comparisons of the cost effectiveness of the different state monitoring programs, it is necessary to translate each state's monitoring program into a single output measure that can be compared to the equivalent number of full time persons required to operate each monitoring program.

The output measure selected was the number of equivalent continuous SO_2 air quality monitors operating for 12 months.

To represent a state's air quality monitoring program in terms of this output measure, we used Enviroplan's experience since 1974 in operating over a hundred air quality monitoring networks including a large state PM 2.5 and air toxics monitoring program and our data base of direct labor hours required to operate each type monitor for a 12 month period for various sampling frequencies.

Table 8 presents the hours per year of direct labor based on Enviroplan's experience to operate one air quality monitor of each type for 12 months. For episodic samplers, the hours are based on the designated sampling frequency given in the table. These direct labor hours per monitor are based on the assumption that the travel time to each monitor is 1.5 hours (which is close to the average reported in Table 5) except for $PM_{2.5}$ samplers where the estimated travel time is one hour in view of the greater number of these type monitors and monitor sites than any other type monitor in the state programs.

The ratio of the number of direct labor hours per year for each monitor type to the 291 hours per year required to operate one continuous SO_2 monitor was calculated. This ratio gives the number of continuous SO_2 monitors operating for 12 months that are equivalent (in direct labor) to operating one monitor of each type at the designated sampling frequency for 12 months. These results are given in Table 8.

The equivalency relationships in Table 8 with their designated sampling frequencies for episodic samplers were applied in each state to the information in Table 1 to calculate the equivalent number of continuous SO_2 monitors operated in each state. The equivalency relationships in Table 8 were scaled by the average number of months per year and actual average sampling frequency that the monitors of each type operated.

Results of this analysis are given in Table 9 for each of the nine states designated by a letter code. This table presents the equivalent number of continuous SO2 monitors operated for a 12 month period, the equivalent number of full time persons used to operate the monitoring program as reported in the survey and the equivalent number of continuous SO_2 monitors operating for 12 months per equivalent full time person.

Table 8. Hours per year of direct labor based on Enviroplan experience to operate one air quality monitor of each type for 12 mo nths per year

Monitor	Type	Sample Frequency (once/specified # days)	Labor Hours/Yr	Equivalent # of Continuous SO2 monitors per Monitor Operating 12 Months at Designated Sampling Frequency
O3	continuous		291	1.00
SO2	continuous		291	1.00
CO	continuous		291	1.00
NOx	continuous		327	1.12
NOy	continuous		327	1.12
PM10	continuous		313	1.08
PM2.5	continuous		313	1.08
VOC-			327	1.12
PM10	episodic	6.0	58	0.20
PM2.5 only	episodic	2.9		
Variable per sampler with once per 3 day sampling			274	0.94
Fixed per			34	0.12
PM2.5	episodic	3.7		
Variable per sampler with once per 3 day sampling			274	0.94
Fixed per			34	0.12
Lead	episodic	5.8	60	0.21
PUF	episodic	12.0	63	0.22
Metals	episodic	12.0	29	0.10
VOC-canister	episodic	7.3	48	0.16
Carbonyl	episodic	8.0	45	0.15
	# of sites	Average # parameters per site		
Meteorological	13.4	4.5	201	0.69

Table 9. Comparison of resources required to operate nine state air quality monitoring programs.

State	Equivalent Number of Continuous SO2 Monitors	Equivalent Number of Full Time Persons Used to Operate Monitoring Program	Equivalent Number SO2 Monitors Operating for 12 Months per Full Time Person
A	17.23	15.00	1.15
B	10.43	9.80	1.06
C	45.18	18.80	2.40
D	22.48	24.00	0.94
E	52.78	24.00	2.20
F	40.97	31.00	1.32
G	16.97	7.50	2.26
H	101.55	51.70	1.96
I	12.30	21.00	0.59
Average	35.54	22.53	1.54

Results show a wide variation in the resources used by the nine states with the least efficient state requiring four times the resources of the most efficient state in conducting the required air quality monitoring. The average resources required vary from 0.59 equivalent continuous SO_2 air quality monitors operated per full time person to 2.40 equivalent continuous SO_2 air quality monitors operated per full time person with an average of 1.54 equivalent continuous SO_2 air quality monitors operated per full time person.

CONCLUSIONS

State air pollution control agencies use widely different numbers of persons to operate the same equivalent number of air quality monitors. Part of these differences are due to different procedures states may follow to comply with the federal and state requirements, differences in the travel times to the monitor sites, and differences in the degree of automation of calibration and precision checks for continuous monitors, among other factors.

These state agencies also have developed and implemented many ideas for improving the cost effectiveness of their monitoring programs as indicated by the survey responses in Table 7.

This bench marking survey gives state agencies the opportunity to compare their cost effectiveness with other states and to share ideas on how to further improve the cost effectiveness of their air quality monitoring programs. Such surveys may offer similar benefits in other parts of state air pollution control agency operations.

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KEY WORDS

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