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Project Summary

Investigation of Filter Media for Use in the Determination of Mass Concentrations of Ambient Particulate Matter

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Quartz and Teflon® filter media were evaluated under controlled use conditions to determine their suitability for ambient particulate measurements. Weighing tests and handling tests were conducted in a laboratory environment. A field comparison test in which samples were collected on glass, quartz, and Teflon® filters was conducted at a typical air quality monitoring site.

An analysis of weight changes observed during repeated weighings of 8 x 10 inch and 102 mm glass, quartz, and Teflon® filters showed no evidence of systematic weight loss during the weighing process. Weight losses were observed for both glass and quartz filters during filter mounting and handling tests, but the estimated errors in corresponding mass concentration measurements due to such weight losses were always less than 3 $\mu g/m^3$. Teflon® filters generally gained weight during these tests.

Total suspended particulate, nitrate, and sulfate concentrations measured during the field comparison test using quartz and Teflon® filters on high-volume samplers were lower than those measured using glass filters. Observed differences could be explained reasonably well by artifact effects and the aforementioned handling effects. Teflon® filters showed a tendency to clog at ambient total suspended particulate concentrations around 75 $\mu g/m^3$.

This Project Summary was developed by EPA's Environmental Monitoring Systems Laboratory, Research Triangle Park, NC, to announce key findings of the research project that is fully documented in a separate report of the same title (see Project Report ordering information at back).

Introduction

The most widely used methods for measuring the mass concentration of particulate matter in the atmosphere involve aerosol collection on a filter substrate and subsequent gravimetric mass determination. The current EPA reference method for determination of suspended particulates in the atmosphere (TSP) uses the high-volume sampler and a glass fiber filter for sample collection. A major disadvantage of glass fiber filters is their inability to provide a chemically inert collection surface. Consequently, artifact formation resulting from gas-to-particle conversions on the filter surface often represents a significant interference in the desired mass concentration measurement. Sulfate and nitrate artifacts, formed by the oxidation of acidic gases (i.e., SO_2, NO_2) and retention of nitric acid on the surface of these alkaline glass fiber filters, have been demonstrated by several investigators in both laboratory and field studies. Estimates of the most probable combined errors from sulfate and nitrate artifacts range from about 7 $\mu g/m^3$ (typical sampling locations) to as high as 11 $\mu g/m^3$ (Los Angeles Basin) for a 24-hour sampling period.

Over the past few years size-specific particulate samplers have been used to

collect air quality data in support of anticipated revisions in the national ambient air quality standards (NAAQS) for particulate matter. These samplers include the conventional high-volume sampler equipped with size-selective inlets designed to collect particles in the $\leq$ 15 μm and $\leq$ 10 μm size ranges. Although glass fiber filters continue to be used with these samplers, it is clearly evident that mass concentration errors resulting from artifact formation pose a more significant problem for the size-specific measurements than for TSP since less mass is collected in the $\leq 15\,\mu$m or $\leq 10\,\mu$m size ranges.

Consideration of available alternative filter media for these samplers indicates that quartz filters may exhibit less artifact interference. However, their use in routine sampling will depend on whether they are sufficiently rugged to withstand the normal handling operations encountered in a typical air monitoring application. Quartz filters are known to be extremely fragile and may be prone to fiber loss during weighing, handling, and sampling.

Teflon,® used as the filter substrate in low-volume (dichotomous) samplers and the recently developed medium-volume (4 cfm) samplers, is another alternative filter medium. Positive sulfate and nitrate artifact formation is not a problem with Teflon® filters; however, loss of particulate nitrate by dissociation or chemical reaction has been reported. Physical loss of particles after sample collection and static charge interferences in the weighing process can be problems. Teflon® filters are also prone to more rapid clogging as mass loadings increase.

Commercially available quartz and Teflon® filters were evaluated under carefully controlled laboratory and field conditions to determine the suitability of these filters for particulate mass concentration measurements. Tests included weighability and handleability tests, as well as a field comparison test in which TSP samples were collected on glass, quartz, and Teflon® filters over a 12-day period.

Procedure

The filters selected for evaluation were Gelman microquartz fiber filters (1979 and 1981 production), Whatman quartz microfibre filters (QM-A), Pallflex tissuquartz filters (2500 QAST), and Membrana/Ghia Zefluor™ membrane filters (P5PI). Schleicher and Schuell glass fiber filters (1981 production) were also included for comparative purposes.

Ten 8 x 10 inch filters of each type were subjected to repeated weighings to determine whether significant weight losses occurred during the weighing process. Filters were conditioned and then weighed once each day for six days in a climate controlled weighing room ($\leq$ 50% RH, T = 22° $\pm$ 3° C). Ten additional filters of each type were also subjected to a handling test to determine the magnitude of weight losses due to placement on a sampler. In this test the filters were conditioned and then weighed twice before and twice after placement on a high-volume sampler. All filter loading, unloading, and other handling operations were designed to simulate the normal handling that filters undergo during typical air monitoring applications. Particle free air was drawn through each filter for 5 minutes during this test. Similar handling tests were also conducted using 102 mm circular filters and a medium-volume (4 cfm) sampler.

A field comparison test using the six types of filters was conducted at a typical urban-commercial-industrial air monitoring site in Durham, North Carolina. The six filter types were systematically alternated among six high-volume samplers so that each filter type was used twice with each sampler over 12 sampling days. Total suspended particulate (TSP) measurements were obtained each day for each filter type. Sulfate and nitrate analyses were performed on all collected samples.

Results and Discussion

The average weight changes between successive weighings (over six weighings) of 8 x 10 inch filters and the standard deviations of the weight changes are given in Table 1. The average weight changes over the six weighings are given in the bottom row of the table.

The magnitude of the changes in weight for all filter types were similar except for the Gelman(81) quartz filters, which exhibited much more dramatic effects than the other filters. A strong correlation (r^2 = 0.88) was obtained between the average weights of the ten Gelman(81) quartz filters and the relative humidity in the weighing room.

An analysis of covariance that included humidity as a factor showed no evidence of systematic weight losses during the weighing process for any of the filters tested. It was concluded that some random effect associated with each weighing session was the major component of the observed variation in the data over the six weighing sessions. The results with the Gelman(81) filters suggest that closer control of relative humidity in the filter conditioning and weighing environment might be advantageous for some quartz filters, but further investigation is recommended.

The average weight changes between successive weighings before and after mounting of the filters on a high-volume sampler and the average weight changes due to handling and mounting on the sampler are tabulated in Table 2. During this filter mounting test the sampler was turned on and allowed to sample clean air for 5 minutes. It was assumed that the major loss of fiber material from the filters would occur during this sampler start-up period.

The weight changes between two successive weighings before (W2-W1) and after (W4-W3) mounting of the filters on the sampler and the filter-to-filter variabilities were similar (except for the

Table 1. Weight Changes (mg) Between Successive Weighings (8 x 10 inch Filters)

		S&S Glass	Gelman(79) Quartz	Gelman(81) Quartz	Whatman Quartz	Pallflex Quartz	Ghia Teflon®
W2-W1:*	Avg.	+0.31	-0.03	+1.88	+0.08	+0.26	-0.26
	S.D.	0.19	0.22	0.36	0.36	0.15	0.35
W3-W2:	Avg.	-0.06	+0.14	+0.05	-0.49	-0.18	+0.24
	S.D.	0.11	0.16	0.29	0.43	0.25	0.16
W4-W3:	Avg.	+0.13	-0.10	-0.98	-0.12	-0.23	+0.19
	S.D.	0.12	0.18	0.47	0.13	0.15	0.22
W5-W4:	Avg.	-0.43	-0.67	-1.67	-0.43	+0.14	+0.14
	S.D.	0.15	0.22	0.27	0.16	0.24	0.20
W6-W5:	Avg.	+0.33	-0.13	+0.81	+0.06	-0.05	-0.02
	S.D.	0.13	0.17	0.38	0.12	0.12	0.18
W6-W1:	Avg.	+0.30	-0.79	+0.10	-0.90	-0.06	+0.29
	S.D.	0.17	0.22	0.54	0.29	0.18	0.39

**W1 indicates the first weighing and so on.*

Ghia Teflon® filters) to the results obtained in the earlier weighing tests. The weight changes (W3-W2) due to handling and mounting on the sampler (with clean air flow for 5 minutes) were substantially higher for the quartz filters than for the S&S glass filters. The Ghia Teflon® filters gained weight (+ 0.50 mg) with a high filter-to-filter variability. An analysis of variance revealed that mounting was a significant effect for all filter types except the Ghia Teflon.®

The average of the first two weighings and the average of the last two weighings were used to estimate the weight changes due to mounting the filters. These estimates appear in Table 3 with estimates of the corresponding errors in mass concentration measurements. The estimated errors in mass concentration for quartz filters were less than the estimated errors due to artifact formation on glass filters for most sampling locations.

The results of mounting tests for the 102 mm filters were comparable to those obtained for the 8 x 10 inch filters after adjustment for filter size and sampler flowrates. Once again, the Ghia Teflon® filters showed a slight weight gain equivalent to 0.2 $\mu g/m^3$.

The measured TSP concentrations for the 12-day field comparison test when all six types of filters were used for sampling are given in Table 4. Each day the highest TSP concentration was obtained with the S&S glass filters, except for day 2 when the Whatman quartz gave the highest value. The Whatman filters contain a small amount (5 percent) of borosilicate glass, added during the filter manufacturing process. This small amount of glass can apparently cause an increase in artifact formation over what would be expected from filters containing only quartz. Sulfate and nitrate measurements (not shown) were higher for the S&S and Whatman filters than for the quartz or Teflon® filters. On two of the days (days 5 and 6) clogging of the Ghia Teflon® filters resulted in a significant drop in the sampler flow rates. Since the TSP concentrations were only 65 to 75 $\mu g/m^3$ on these days, these results suggest that 3.0 μm pore size Teflon® might not be suitable for use on high-volume samplers because of potential overloading problems.

Table 2. Weight Changes (mg) Between Successive Weighings and Before and After Mounting on Sampler (8 x 10 inch Filters)

		S&S Glass	Gelman(79) Quartz	Gelman(81) Quartz	Whatman Quartz	Pallflex Quartz	Ghia Teflon®
W2-W1:*	Avg.	-0.16	-0.36	-1.13	-0.10	+0.08	-1.26
	S.D.	0.09	0.09	0.56	0.08	0.12	2.11
W4-W3:	Avg.	-0.32	-0.29	-0.31	-0.20	-0.19	+0.16
	S.D.	0.12	0.16	0.40	0.11	0.11	0.16
W3-W2:	Avg.	-0.57	-3.19	-4.31	-2.28	-1.08	+0.50
	S.D.	0.22	0.97	0.92	0.73	0.40	1.74

*W1 indicates the first weighing and so on.

Table 3. Weight Changes (mg) Due to Mounting on Sampler (8 x 10 inch Filters)

Filter Type	Wt. Changes (mg)	Corresponding Error in Mass Concentration ($\mu g/m^3$)*
S&S Glass	-0.82	-0.5
Gelman(79) Quartz	-3.51	-2.0
Gelman(81) Quartz	-5.03	-2.8
Whatman Quartz	-2.43	-1.4
Pallflex Quartz	-1.14	-0.6
Ghia Teflon®	+0.054†	+0.03†

*Assuming 24-hour high-volume sample (1800 m^3 sample volume).
†Weight gain observed.

Table 4. TSP Concentrations ($\mu g/m^3$) Measured with High-Volume Samplers Using Glass, Quartz, and Teflon® Filters

Day No.	S&S Glass	Gelman(79) Quartz	Gelman(81) Quartz	Whatman Quartz	Pallflex Quartz	Ghia Teflon®
1	43.60	34.59	38.64	41.46	36.16	37.84
2	46.38	43.42	41.92	50.60	45.54	44.11
3	95.60	83.75	82.63	87.69	82.84	84.37
4	76.02	63.94	66.42	68.27	60.00	65.71
5	89.11	74.57	86.88	85.46	76.67	72.49*
6	79.92	65.31	58.07	76.87	68.24	67.40*
7	76.51	60.12	71.49	68.85	63.22	63.80
8	36.71	26.94	25.63	32.80	29.02	26.26
9	39.44	33.88	30.39	37.82	30.29	32.57
10	42.82	33.09	34.86	37.64	33.66	34.11
11	36.11	25.55	27.01	31.89	26.10	26.38
12	29.52	23.63	26.47	28.84	24.06	24.09
Avg.	57.64	47.40	49.20	54.02	47.98	48.26

*Plugging of Teflon® filter resulted in significant drop in flowrate.

Conclusions and Recommendations

1. An analysis of the weight changes observed during repeated weighings of 8 x 10 inch and 102 mm glass, quartz, and Teflon® filters showed no evidence of systematic weight loss during the weighing process for any of the filters tested.

2. Weight losses due to mounting of the 8 x 10 inch and 102 mm filters on particle samplers were observed for both glass and quartz filters. An analysis of the test data revealed that mounting was a significant effect for all filter types tested except the Ghia Teflon®. The estimated errors in corresponding mass concentration measurements were less than 3 $\mu g/m^3$.

3. Ambient TSP, sulfate, and nitrate concentrations measured using quartz and Teflon® filters on high-volume samplers were lower than those measured using glass fiber filters. The observed differences in TSP measurements could be explained in part by the increased artifact nitrate and sulfate on filters containing glass fibers (S&S glass and Whatman quartz).

4. The humidity in the filter conditioning and weighing environment has an apparent effect on filter weights, more so for the quartz filters than for the glass filters. The correlation between filter weight and humidity for the Gelman(81) quartz filters suggests that closer control of humidity during conditioning and weighing might be advantageous for this, and perhaps other quartz filters, but further investigation is recommended.

5. The Ghia Teflon® filters exhibited a tendency to gain weight upon repeated weighings, even after mounting on the samplers. Although the observed weight

gains were small over the time periods involved in this study, this phenomenon warrants further investigation. The 8 x 10 inch Ghia Teflon® filters also had a tendency to clog during ambient sampling at TSP concentrations around 65 to 75 $\mu g/m^3$.

6. Based on the results of this study, the use of 8 x 10 inch and 102 mm quartz filters as collection substrates on high- and medium-volume particle samplers appears to be feasible. Special care during weighing, handling, and mounting operations is necessary when using quartz filters. The use of filter cassette holders, designed to facilitate installation of filters at field sites, is recommended.

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The complete report, entitled "Investigation of Filter Media for Use in the Determination of Mass Concentrations of Ambient Particulate Matter," (Order No. PB 84-199 876; Cost: $8.50, subject to change) will be available only from:

National Technical Information Service
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