Fractionating Particulate Studies in Indianapolis, Indiana II. Comparative Studies of Ambient Particulate Sampling Methods

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Introduction

In a two-year comparative study of cascade impactor and hi-vol particulate sampling in Indianapolis, Indiana we observed significantly higher total suspended particulate (TSP) values on cascade impactor samples (1). Geometric means were twice those of the hi-vol and greatly exceeded the annual National Ambient Air Quality Standards (NAAQS) for particulates. In that study the hi-vol particulate sampling method was apparently less efficient in particle collection than the cascade impactor. Those results were significant in that the hi-vol is the USEPA reference method for the particulate air quality standard.

Recently USEPA has taken preliminary steps to revise the NAAQS for particulates to include an inhalable particulate standard to more accurately assess the health consequences of ambient particulate concentrations (2, 4). An inhalable particulate standard will require a reference sampling method which fractionates particles into discrete aerodynamic size ranges so that the inhalable (<15 micrometers) and respirable fractions (<2.5 micrometers) can be determined. Several fractionating sampling methods are currently available including cascade and virtual impactors. At the present time the virtual impactor is perceived to be the leading candidate for the inhalable particulate reference sampling method (4). The cascade and virtual impactors differ somewhat in design and particle fractionating ability. The virtual impactor separates particles into 2 fractions, those less than 2.5 micrometers and those between 2.5 and 15 micrometers. The cascade impactor separates particles into 5 fractions with no definite upper cutoff limit. Because of the differences observed between hi-vol and cascade impactor values in a previous study and the projected use of virtual impactors as an inhalable particulate reference method concurrent hi-vol, cascade impactor and virtual impactor studies were carried out to compare the performance of these sampling methods under similar atmospheric conditions.

Methods

Concurrent hi-vol, cascade and virtual impactor sampling was conducted in downtown Indianapolis, Indiana during a two-week period. Particulate samples were collected for each instrument on 7 sampling days during late May and early June of 1979. Samples were collected for 24 hours. Filters from all instruments were collected within 5 minutes of sample completion. All filters were dessicated in a conditioned environment for 24 hours for pre- and post-sampling weighing of filters.

The cascade impactor (Anderson Model 2000) collected ambient particulates into five aerodynamic particle diameter size ranges. The effective lower cutoff diameters for the flow rate employed, 0.57 m^3/min, were 5.5, 2.4, 1.75, and 0.93 micrometers for the four impactor stages; particles less than 0.93 micrometers were collected by a backup filter. The inhalable fraction <15 micrometers, was determined graphically using the method of Regan *et al.* (3). Perforated Gelman type A glass fiber filters were used in the first four stages; a Gelman type A, 20 x 25 centimeter glass fiber filter was used as a backup.

The virtual impactor (Sierra Series 244 Dichotomous Sampler) separated particles into two aerodynamic size ranges <2.5 micrometers and 2.5 to 15 micrometers. Thirty-seven millimeter glass fiber membrane filters were utilized to collect particles from both stages. The flow rate for the small particle fraction, <2.5 micrometers, was 0.1 m^3/hr (CMH) and 0.9 CMH for the larger particle fraction, 2.5 to 15 micrometers.

The hi-vol was operated at a flow rate of 1.13-1.70 m^3/min using a Gelman type A, 20 x 25 centimeter glass fiber filter.

A quality assurance check was conducted on all instruments before and after each sampling period.

All samplers were located approximately 15 meters above ground level on top of the Indiana State Board of Health building in downtown Indianapolis. The area around the sampling site is characterized by commercial and residential buildings. Major industrial sources are located 0.7 kilometers to the west and 3 kilometers to the southeast.

Differences between geometric means for TSP, inhalable and respirable fractions were evaluated by a two-way analysis of variance, Duncan's multiple range test and a paired Student's t-test. An alpha level of 0.05 was accepted as significant. The degree of correlation between sampling methods was determined by simple linear regression analysis.

Results

The mass concentrations ($\mu g/m^3$) of total suspended particulates (TSP), inhalable (<15 micrometers) and respirable (<2.5 micrometers) particulate fractions sampled with concurrently operated hi-vol, virtual and cascade impactor sampling instruments were compared. Geometric means for these data are summarized in Table 1. Significant differences between sampling methods were observed. TSP values measured on the cascade impactor were significantly higher (71% higher) than hi-vol TSP and virtual impactor inhalable patriculate values (15% higher). The virtual impactor inhalable values were also significantly higher

TABLE 1. *Geometric means ($\mu g/m^3$) and standard deviations for TSP, inhalable (<15 micrometers) and respirable (<2.5 micrometers) fraction data for concurrent hi-vol, virtual and cascade impactor particulate sampling.*

Sampling Method	TSP	Inhalable Fraction	Respirable Fraction
hi-vol	88.66 ± 1.34	----	----
virtual impactor	----	131.87 ± 1.26	74.47 ± 1.51
cascade impactor	151.41 ± 1.39	129.45*	87.10 ± 1.51

* Calculated

(49%) than hi-vol TSP. No significant differences between inhalable or respirable fractions were observed for virtual and cascade impactors.

Correlation coefficients were calculated to determine the degree of association between sampling methods. These comparisons are summarized in Table 2. Since the geometric mean for the cascade impactor inhalable fraction was calculated, correlation coefficients between inhalable fractions are not presented in Table 2. Differences between geometric means as seen in Table 1 are slight and a high correlation coefficient would have been expected. A high degree of correlation (+.94) between hi-vol TSP and cascade impactor TSP values was observed even though cascade impactor TSP values were significantly higher (71%). A high degree of correlation (+.85) was also observed between virtual and cascade impactor respirable fractions. Little or no correlation was osberved between hi-vol TSP and virtual impactor inhalable particulates. This was also true of cascade impactor TSP and virtual impactor inhalable particulates.

TABLE 2. *Coefficient of correlation between particulate sampling methods.*

	Correlation coefficient
hi-vol TSP vs. virtual impactor inhalable	+.26
hi-vol TSP vs. cascade impactor TSP	+.94
virtual impactor inhalable vs. cascade impactor TSP	+.31
virtual impactor respirable vs. cascade impactor respirable	+.85

Discussion

The large differences observed between cascade impactor and hi-vol TSP values are in agreement with our previous study. Results presented here provide some insight as to why these differences may exist. Several observations are important in explaining this result. These include: (1) the high degree of correlation between hi-vol and cascade impactor TSP measurements, (2) the apparent lack of correlation between cascade impactor TSP and virtual impactor inhalable particulates and (3) the equivalent inhalable particulate levels for cascade and virtual impactors.

Differences between cascade impactor TSP and virtual impactor particulate values can be almost entirely explained by the collection ability of cascade impactors for particles with aerodynamic diameters greater than 15 micrometers. Graphical analysis of cascade impactor data indicates that 15% of particulate mass is in excess of 15 micrometers, corresponding exactly with the difference in mass concentration between cascade impactor TSP and virtual impactor inhalable particulates. It is therefore apparent that the low degree of correlation between cascade impactor TSP and virtual impactor inhalable particulate values are due to day to day fluctuations in particulates larger than 15 micrometers. This is corroborated by the lower geometric standard deviations for virtual impactor inhalable fraction data. Since hi-vol and cascade impactors both have the capability to collect particulates in excess of 15 micrometers, it appears that the high correlation between hi-vol and cascade impactor TSP values are also due to the day to day fluctuations in large particulates. From these obervations the authors are inclined to conclude that differences observed in hi-vol and cascade impactor TSP are due to differential abilities of these two methods to collect small particles, possibly those that are less than 1 micrometer. Less efficient collection of submicron particles may be due in part to the high flow rates used in hi-vol operation. Under higher flow rates or airstream velocity very small, presumably submicron particles would be expected to squeeze between filter fibers; the higher the flow rate the greater the loss of submicron particles. The higher collection efficiency of submicron particles on the cascade impactor may be further augmented by the catalytic oxidation of sulfur oxides and nitrogen oxides to sulfates and nitrates on collected submicron particles.

Graphical analysis of cascade impactor data resulted in calculated inhalable particulate values equal to those measured by the virtual impactor method. This indicates that the cascade impactor can be used as an equivalent method for inhalable particulate measurement.

Literature Cited

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