STANDARD REFERENCE METHOD FOR THE MEASUREMENT OF SUSPENDED PARTICULATES IN THE ATMOSPHERE

(HIGH VOLUME METHOD)

Air Pollution Control Directorate

Environmental Protection Service

Report EPS 1-AP-73-2

January 1973

REPRINT

TABLE OF CONTENTS

1. SCOPE

The method is applicable to the measurement of the complete range of concentrations of airborne suspended particulates over designated time intervals. The size of the sample taken allows other analyses to be carried out later.

2. FIELD OF APPLICATION

This method is applicable to the measurement of the mass concentration of suspended particulates in ambient air. When the sampler is operated at an average flow rate of 1.70 cubic metres per minute for 24 hours, an adequate sample will be obtained even in an atmosphere having concentrations of suspended particulates as low as 1 microgram per cubic metre. If particulate levels are unusually high, a satisfactory sample may be obtained in 6 to 8 hours time or even less. For the determination of the mean concentrations of suspended particulates in ambient air, a standard sampling period of 24 hours is recommended.

3. PRINCIPLE

3.1 Air is drawn into a covered housing and through a filter by means of a high flowrate blower at nominal flow rates from 1.13 to 1.70 cubic metres per minute. This allows suspended particulates having diameters of less than 100 μm, Stokes equivalent, to pass to the filter surface. See Figure 1. Particles within the size range of 100 to 0.1 μm are ordinarily collected on glass fibre filters. The mass concentration of suspended particulates in the ambient air, expressed in micrograms per cubic metre, is calculated by measuring the mass of collected particulates and the volume of air sampled.

3.2 The weight is determined to the nearest milligram, the flow rates are measured to the nearest 0.03 cubic metre per minute, the times are determined to the nearest 2 minutes and the mass concentrations are calculated and recorded to the nearest microgram per cubic metre.

4. INTERFERENCES

4.1 Particulate matter that is oily, such as wood smoke or photochemical smog, may block the filter and cause a rapid decrease in airflow at a nonuniform rate. Dense fog or high humidity can cause the filter to become too wet and severely reduce the airflow through the filter.

4.2 Glass fibre filters are comparatively insensitive to changes in relative humidity, but collected particulates can be hygroscopic (12.2).

4.3 Whenever the concentration of particulates is abnormally high, there may be loss of particulates, because of the weak adhesion of the particles to the filter.

5. REAGENTS

Filter media. Glass fibre filters having a collection efficiency of at least 99% for particles of 0.3 μm diameter, as measured by the DOP* test, are suitable for the quantitative measurement of concentrations of suspended particulates, although some other medium, such as paper, may be desirable for certain analyses (12.5). If a more detailed analysis is contemplated, care must be exercised to use filters that contain low background concentrations of the pollutant being measured. Careful quality control is required to determine background levels of these pollutants.

*Based upon the use of monodisperse dioctyl phthalate aerosol as the size calibrating medium.

6. APPARATUS

6.1 Sampling.

6.1.1 Sampler. The sampler is composed of three parts: (i) the face plate, gasket and retaining ring, (ii) the filter adapter assembly, and (iii) the motor-fan unit. The sampler must be capable of drawing ambient air through a portion of a clean glass fibre filter, 406.5 square centimeters in area, at a flow rate between 1.13 and 1.70 cubic metres per minute. The motor must be able to operate continuously per 24 hour periods with input voltages ranging from 110 to 120 volts, 50-60 Hz and must have third wire safety ground. The housing for the motor unit may be of any convenient construction as long as the assembly remains airtight and leak free. The life of the sampler motor can be extended by lowering the voltage by about 10 percent by means of a small "buck or boost" transformer between the sampler and power outlet.

6.1.2 Sampler shelters. It is important that the sampler be properly installed in a suitable shelter. The shelter is subjected to extremes of temperature, humidity and all types of air pollutants. For these reasons, the materials of the shelter must be chosen carefully. Properly painted exterior plywood or heavy gauge aluminum serves well. The shelter must be provided with a roof so that the filter is protected from precipitation and debris. The internal arrangement and configuration of a suitable shelter with a gable roof is shown in Figure 1. The area of clearance between the main housing and the roof at its closest point should be 580.5 ± 195.5 square centimetres. The main housing should be rectangular, with dimensions of about 29 x 36 centimetres.

6.1.3 Rotameter. Marked in arbitrary units, frequently 0 to 70 and capable of being calibrated. Other devices, of at least comparable accuracy, may be used.

6.1.4 Orifice calibration unit. This consists of a metal tube 7.6 cm internal diameter and 15.9 cm in length, provided with a static pressure tap 5.1 cm from one end. See Figure 2. The tube end nearest the pressure tap is flanged to about 10.8 cm in external diameter with a male thread of the same size as the inlet end of the high volume air sampler. A single metal plate, 9.2 cm in diameter and 0.24 cm thick, having a central orifice 2.9 cm in diameter, is held in place at the air inlet end with a female threaded ring. The other end of the tube is flanged to hold a loose female threaded coupling which screws on to the inlet of the sampler. An 18-hole metal plate, an integral part of the unit, is positioned between the orifice and sampler to simulate the resistance of a clean glass fibre filter. An orifice calibration unit is shown in Figure 2.

6.1.5 Differential manometer. Capable of measuring to at least 40 cm of water.

6.1.6 Positive displacement meter. Calibrated in cubic metres or cubic feet, to be used as a primary standard.

6.1.7 Barometer. Capable of measuring atmospheric pressure to the nearest millimetre of mercury.

6.2 Analysis.

6.2.1 Filter conditioning equipment. Balance room or desiccator maintained at 20 to 30°C with less than 50% relative humidity.

6.2.2 Analytical balance. Equipped with a weighing chamber designed to handle unfolded filters, in size 20.3 x 25.4 cm. The balance should have a sensitivity of 0.1 milligram.

6.2.3 Light source. A table of the type used to view X-ray films is convenient.

6.2.4 Numbering device. Capable of printing identification numbers on the edge of the filters.

7. SAMPLING AND SAMPLES

7.1 Filter preparation. Expose each filter to the light source and inspect for pinholes, particles or other imperfections. Filters having visible defects should not be used. A small brush is useful for removing loose particles. Equilibrate the filters in the filter conditioning environment for 24 hours. Weigh the filters to the nearest milligram and record the tare weight and filter identification number. Do not bend or fold the filter before collection of the sample.

7.2 Sample collection. Open the shelter, loosen the wing nuts and remove the retaining ring from the filter holder. Install a weighed and numbered glass fibre filter in position with the rough side up, replace the retaining ring without disturbing the filter and fasten securely. Undertightening will allow air leakage, over-tightening will damage the sponge rubber gasket. During inclement weather, the sampler may be removed to a protected area for filter change. Close the roof of the shelter, run the sampler for about 5 minutes, connect the rotameter to the nipple on the back of the sampler and take the reading of the rotameter float with the rotameter in a vertical position. Estimate the reading to the nearest whole number. If the ball is fluctuating too rapidly, tilt the rotameter and slowly straighten it until the ball gives a constant reading. Disconnect the rotameter from the nipple and record the initial rota-meter reading and the starting time and date on the filter folder. The rotameter should never be connected to the sampler except when the flow is being measured. Sample for 24 hours, from midnight to midnight standard time and take a final rotameter reading at the end of the sampling period. Record the final rotameter reading and ending time and date on the filter holder. Remove the filter retainer as described above and carefully remove the filter from the folder, touching only the outer edges. Fold the filter lengthwise so that only surfaces with collected particulates are in contact and place in a manila envelope. Record on the envelope, the filter number, location and any other factors such as meteorological conditions or razing of nearby buildings etc. that might affect the final results. If the sample is defective, discard it at this time. In order to obtain a valid sample, the high volume sampler must be operated with the same rotameter and tubing that were used during its calibration.

7.3 Analysis. Equilibrate the exposed filters for 24 hours in the conditioning environment and then weigh again. After having been weighed the filters can be used later for detailed chemical analyses.

8. PROCEDURE

8.1 Calibration.

8.2 Purpose. Since only a small portion of the total air sampled passes through the rotameter during measurement, the rotameter must be calibrated against actual air flow with the orifice calibration unit. Before the orifice calibration unit can be used to calibrate the rotameter, the orifice calibration unit itself must be calibrated against the positive displacement primary standard.

8.3 Orifice calibration unit. Attach the orifice calibration unit to the intake end of the positive displacement primary standard and attach a high volume blower unit to the exhaust end of the primary standard. Connect one end of a differential manometer to the differential pressure tap of the orifice calibration unit and leave the other end open to the atmosphere. Operate the high volume motor-blower unit so that a series of different, but constant airflows, usually six, are obtained for definite time periods. Record the reading of the differential manometer at each airflow. The different constant airflows are obtained by placing a series of load plates, one at a time, between the calibration unit and the primary standard. Placing the orifice before the inlet reduces the pressure at the inlet of the primary standard below atmosphere. A correction must be made, therefore, for the increase in volume caused by this decreased inlet pressure. Attach one end of a second differential manometer to the inlet pressure tap of the primary standard and leave the other end of the manometer open to the atmosphere. During each of the constant airflow measurements made above, measure the true inlet pressure of the primary standard with this second differential manometer. Measure the atmospheric pressure and temperature. Correct the measured air volume to true air volume as directed in

Section 9.1.2, then obtain the true airflow rate, Q, as directed in Section 9.1.4. Plot the differential manometer readings of the orifice unit versus Q.

8.3.1 High volume sampler. Assemble a high volume sampler with a clean filter in place and run for at least 5 minutes. Attach a rotameter, read the float, adjust so that the float gives a reading of 65 and seal the adjusting mechanism so that it cannot be changed easily. Shut off the motor, remove the filter and attach the orifice calibration unit in its place. Operate the high volume sampler at a series of different but constant airflows, usually six. Take the readings of the differential manometer from the orifice calibration unit and record the readings of the rotameter for each flow rate. Measure the pressure and temperature of the ambient atmosphere. Convert the differential manometer readings to cubic metres per minute, Q, then plot rotameter readings against Q.

9. EXPRESSION OF RESULTS

9.1 Calculations.

9.1.1 Calibration of orifice.

9.1.2 True air volume.

Calculate the air volume measured by the positive displacement primary standard, thus:

$$V_a = \frac{(P_a - P_m)}{P_a} \cdot V_M$$

where V_a = true volume of air at atmosphere temperature, in cubic metres

P_a = barometric pressure, in millimetres of mercury

P_m = drop in pressure at inlet to reference orifice, in millimetres of mercury

V_M = volume measured using the standard orifice, in cubic metres.

9.1.3 Conversion factors.

Inches of mercury x 25.4 = millimetres of mercury

Inches of water x 73.48×10^{-3} = inches of mercury

Cubic feet of air x 0.0284 = cubic metres of air.

9.1.4 True flow rate

$$Q = \frac{V_a}{T}$$

where Q = flow rate of air, in cubic metres per minute

T = duration of sampling, in minutes.

9.2 Sample volume.

9.2.1 Volume conversion. Convert the initial and final rotameter readings to true airflow rate, Q, using the calibration curve established in accordance with Section 8.3.

9.2.2 Calculation of volume of air sampled.

$$V = \frac{Q_1 + Q_2}{2} \cdot T$$

where V = air volume sampled, m^3

Q_1 = initial airflow rate, m^3/min

Q_2 = final airflow rate, m^3/min

T = sampling time, in minutes.

9.2.3 Corrections for pressure or temperature. If the pressure or temperature, during calibration of high volume sampler, is substantially different from the pressure or temperature during orifice calibration, a correction of the flow rate, Q, may be required. If the pressures differ by no more than 15 percent and the temperatures, in °C, differ by no more than 100 percent, the error in the uncorrected flow rate will be no more than 15 percent. If necessary, obtain the corrected flow rate as directed below. This correction applies only to orifice meters having a constant overflow coefficient. The coefficient for the calibrating orifice described in 6.1.4 has been shown experimentally to be constant over the normal operating range of the high volume sampler, of 0.6 to 2.2 cubic metres per minute. Calculate corrected flow rate according to the formula:

$$Q_2 = Q_1 \left[\frac{T_2 \ P_1}{T_1 \ P_2}\right]^{\frac{1}{2}}$$

where Q_2 = corrected flow rate, m^3/min

Q_1 = flow rate during high volume calibration, m^3/min

T_1 = absolute temperature during orifice unit calibration, °K or °R

P_1 = barometric pressure during orifice unit calibration, in mm Hg

T_2 = absolute temperature during high volume calibration, °K or °R

P_2 = barometric pressure during high volume calibration, in mm Hg.

9.3 Calculation of mass concentration of suspended particulates.

$$S.P. = \frac{(W_2 - W_1) \cdot 10^6}{V}$$

where S.P. = mass concentration of suspended particulates in $\mu g/m^3$

W = initial weight of filter, in grams

W = final weight of filter, in grams

V = air volume sampled, in cubic metres

10^6 = conversion factor from grams to micrograms.

Weights are determined to the nearest 0.1 milligram, airflow rates are determined to the nearest 0.03 cubic metres per minute, times are recorded to the nearest 2 minutes, and mass concentrations are reported to the nearest microgram per cubic metre.

10. PRECISION, ACCURACY AND STABILITY

10.1 Based upon collaborative testing, the relative standard deviation for single analyst variation, or repeatability of the method, is 3.0 percent. The corresponding value for multilaboratory variation, or reproducibility of the method, is 3.7 percent (12.3).

10.2 The accuracy with which the sampler measures the true average concentration depends upon the constancy of the rate of airflow through the sampler. The airflow rate is affected by the concentration and the nature of the dust in the atmosphere. Under these conditions, the error in the measured average concentration may be in excess of ± 50 percent of the true average concentration, depending upon the amount of reduction of airflow rate and on the variation of the mass concentration of dust with time during the 24-hour sampling period (12.4).

11. NOTES ON PROCEDURE

11.1 Maintenance.

11.1.1 Sampler motor. Replace brushes before they are worn to the point where motor damage can occur.

11.1.2 Sealing gasket. Replace when the margins of samples are no longer sharp. The gasket may be sealed to the retaining plate with rubber cement or double-sided adhesive tape.

11.1.3 Rotameter. Clean as required, using alcohol.

11.2 Other equipment. A modification of the high volume sampler incorporating a method for recording the actual airflow over the entire sampling period has been described and is acceptable for measuring the concentration of suspended particulates (12.6). This modification consists of an exhaust orifice meter assembly connected through a transducer to a system for continuously recording airflow on a circular chart. The volume of air sampled is calculated by the following equation:

$$V = Q \cdot T$$

where Q = average sampling rate, m^3/min

T = sampling time, in minutes

The average sampling rate, Q, is determined from the recorder chart by estimation, if the flow rate does not vary more than 0.11 cubic metres per minute during the sampling period. If the flow rate does vary more than 0.11 cubic metres per minute during the sampling period, read the flow rate from the chart at 2 hour intervals and take the average.

12. REFERENCES

12.1 Robson, C.D., and Foster, K.E. "Evaluation of Air Particulate Sampling Equipment." Am. Ind. Hyg. Assoc. J. 24, 404 (1962).

12.2 Tierney, G.P., and Conner, W.D. "Hygroscopic Effects on Weight Determinations of Particulates

Collected on Glass-Fiber Filters." Am. Ind. Hyg. Assoc. J. 28, 363 (1967).

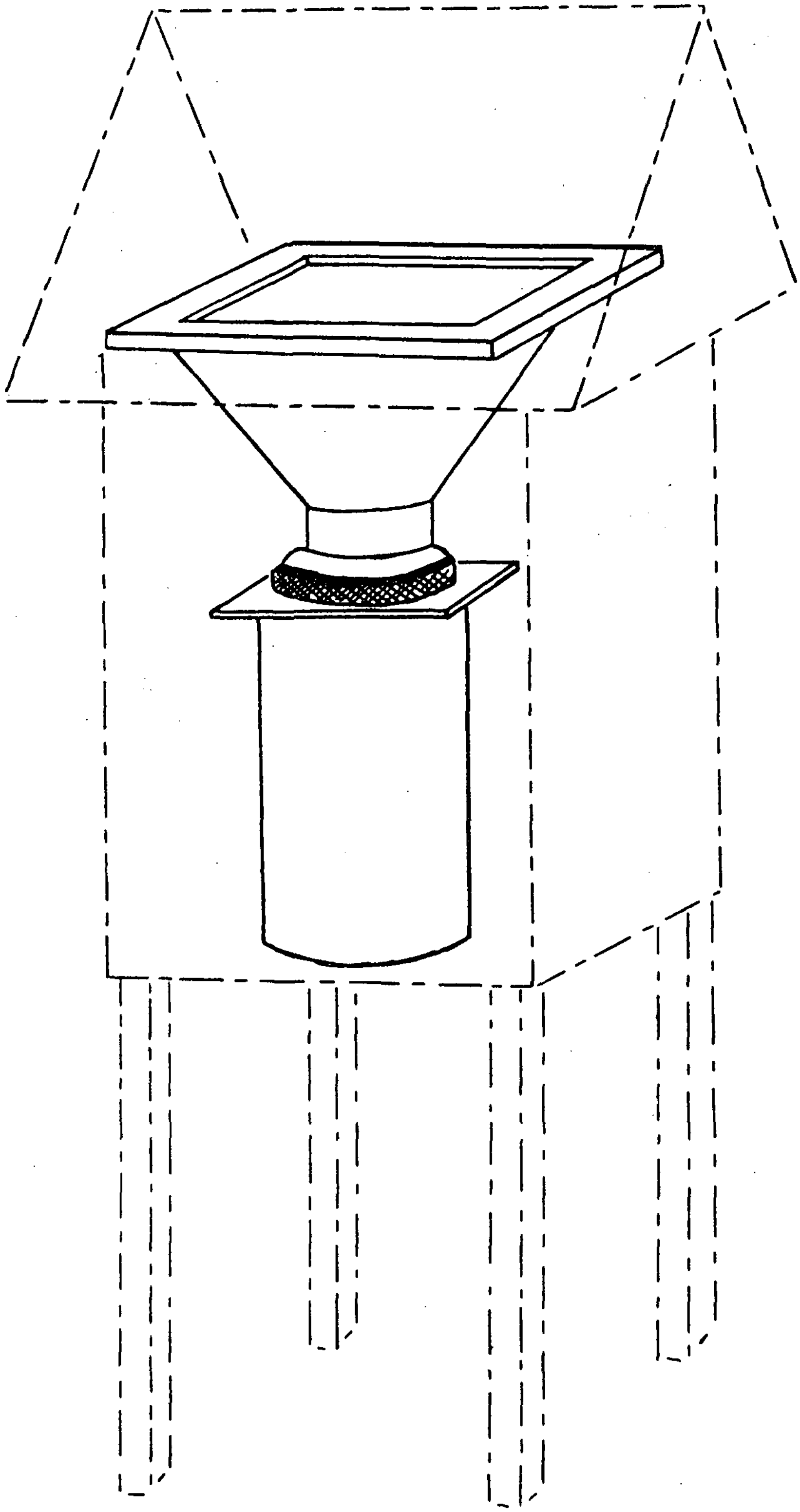
12.3 Unpublished data based on a collaborative test involving 12 participants, conducted under the direction of the Methods Standardization Services Section of the National Air Pollution Control Administration. October (1970).

12.4 Harrison, W.K., Nader, J.S., and Fugman, F.S. "Constant Flow Regulators for High-Volume Air Sampler." Am. Ind. Hyg. Assoc. J. 21, 114-120 (1960).

12.5 Pate, J.B., and Tabor, E.C. "Analytical Aspects of the Use of Glass-Fiber Filters for the Collection and Analysis of Atmospheric Particulate Matter." Am. Ind. Hyg. Assoc. J. 23, 144-150 (1962).

12.6 Henderson, J.S. Eighth Conference on Methods in Air Pollution and Industrial Hygiene Studies. Oakland, California (1967).

FIG. 1



SAMPLER AND SHELTER

FIG. 2

ORIFICE CALIBRATION UNIT