Sampling Efficiency of Aerosol Samplers for Large Wind-Borne Particles - A Preliminary Report

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SAMPLING EFFICIENCY OF AEROSOL SAMPLERS FOR LARGE WIND-BORNE PARTICLES—A PRELIMINARY REPORT

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Abstract—The feasibility of assessing the sampling efficiency of aerosol samplers for large wind-borne particles in the open air was determined in a pilot study. The experiments with 17 μm diameter monodisperse aerosols show the low sampling efficiency of widely used instruments such as the EPA high volume sampler and LIB sampler for a coarse aerosol. A new developed tunnel sampler shows a high sampling efficiency for this aerosol relative to the Rotorod as a reference sampler. Additional experiments with different aerosol sizes and under varying meteorological situations are planned.

During the last decade much research effort was devoted to assess the large particle sampling efficiency of aerosol samplers and specially designed inlets. Wind-tunnel experiments to develop sampling theory were performed by Raynor (1970), Belyaev and Levin (1974), Davies and Subari (1978), Lundgren et al. (1978), Zebel (1979), Durham and Lundgren (1980), Tufto and Willeke (1981), Jayasekera and Davies (1980) and Davies and Subari (1982). Wind-tunnel research on commercial instruments or prototypes was performed by Sehmel (1970), Pattenden and Wiffen (1977), McFarland et al. (1977), Wedding et al. (1977), Ogden et al. (1978), Wedding et al. (1980), and Liu and Pui (1981).

Comparisons of sampling instruments using pre-existing aerosol in the open air were made by Friedrichs and Grover (1977), Baiulescu and Marinescu (1979), and Laskus et al. (1980).

The only test of commercially available aerosol samplers in the open air with monodisperse aerosols, was conducted by May et al. (1976). They used sampling instruments important at that time. Sampling instruments widely used nowadays such as the EPA high volume sampler, LIB sampler (Landesanstalt Immissionsschutz Essen, BRD), a 47 mm filter holder and virtual impactor inlet were not tested and were not all available at that time.

Field tests of aerosol sampling instruments with well defined test aerosols are very important since the intensity and structure of turbulence in the open air are thought to differ from those in wind-tunnels, due to limitations of the latter in size, and to wall effects.

Large particle sampling characteristics are important because:

1. The proposed inspirability curve for aerosols by ISO-TC 146 (1981) extends to 180 μm diameter.
2. Models for dispersion and deposition of aerosols should be validated by measurements of total suspended particles (TSP).
3. Source strengths of fugitive dust sources can only be estimated by TSP measurements.

In 1978 the Dutch Study Group on Aerosols initiated a research project on the sampling efficiency of aerosol samplers under field conditions in which the Air Pollution Department of the Agricultural University Wageningen, the Atomic Research Establishment, Mol (Belgium), the Netherlands Energy Research Centre, Petten, the Prince Maurits Laboratories TNO, Rijswijk, and the Institute for Environmental and Occupational Hygiene TNO, Delft, participated. The experimental set-up consisted of an emission line, perpendicular to the wind direction, consisting of three spinning-top generators (May, 1966) producing monodisperse dioctylphthalate (DOP) aerosols and three SF6 tracer gas emission units. The aerosol sampling line (Fig. 1) was located parallel to the emission line at a distance
Fig. 1. Diagram of instrument arrangement. (1) Background measurement Rotorod, gas-bulb, (2) (3) (4) meteorological towers, (5) SF₆ gas reservoir, (6) field laboratory, (7)-(9) emission of DEHS and SF₆, (10) high volume sampler + Rotorod + gas, (11) tunnel sampler vertical + Rotorod + gas, (12) tunnel sampler horizontal + Rotorod + gas, (13) dichotomous sampler inlet + Rotorod + gas, (14) LIB sampler + Rotorod + gas, (15) air compressor, and (16) 220 VAC generator.

30 m downwind. Several samplers were placed there at 2 m intervals with a gas-bulb for sampling the tracer gas next to each sampler. Hour-averaged samples of the, non-water-soluble, tracer were obtained by draining the water from the gas-bulbs through capillaries under constant pressure (Fig. 2). Each experiment lasted 1 hr and was followed by changing filters and gas-bulbs; subsequently the DOP was washed off the filters with tetrachloroethane. During the experiments the wind velocity at three heights (2, 4 and 10 m), the temperature profile and the cloud coverage were measured. Analysis was performed by gas chromatography in the laboratory. Reference aerosol samples in the sampling line were taken using 0.15 m diameter sharp edged tubes fitted with small filter holders facing the wind. At the back of the tubes a damping screen was placed together with a fan (Fig. 3). The intake velocity of the large tube was 9 m/sec; the filter holder sampled isokinetically. Relative dilution factors were obtained dividing the SF₆ concentration at a sampler by the SF₆ concentration at the reference point (Fig. 1). The ambient DOP concentration at a sampler was calculated by multiplication of the DOP concentration at the reference point with the relative dilution factor. The sampling efficiency of the sampler is obtained dividing the measured DOP concentration by the ambient DOP concentration.

The 1978 experiments were only partially successful due to technical and analytical problems.

In 1981 the experiments were repeated by the Air Pollution Department of the Agricultural University Wageningen. The set-up was the same, except that di-ethylhexylsebacate (DEHS) was used instead of DOP and extraction was done with ethylalcohol. This time a Rotorod sampler was placed next to each instrument together with the gas-bulb. In this way an aerosol concentration profile along the sampling line was obtained, together with a gas concentration profile.
The Rotorod was used as a reference sampler, because this instrument has no entrance errors and a sampling efficiency of 93% for 20 μm diameter particles (May, 1976).

The sampling efficiency of the other instruments was calculated with

\[
E = \left\{ \left[ \frac{n}{\sum \frac{C_r}{C_i + C_r}} \right]^{-1} \right\} \times 100\% 
\]

where \( n \) is the number of experiments, \( C_r \) the reference DEHS concentration (Rotorod) and \( C_i \) the DEHS concentration measured with the instrument.
Results for a particle diameter of 17 $\mu$m and atmospheric stability class D (Pasquill, 1974) are given below:

<table>
<thead>
<tr>
<th>Instrument</th>
<th>Efficiency ($%$)</th>
<th>$\sigma$ ($%$)</th>
</tr>
</thead>
<tbody>
<tr>
<td>EPA high volume sampler</td>
<td>33</td>
<td>7</td>
</tr>
<tr>
<td>0.15 m$^3$/h. tunnel sampler</td>
<td>94</td>
<td>27 $n = 6$</td>
</tr>
<tr>
<td>LIB sampler (Essen)</td>
<td>39</td>
<td>12</td>
</tr>
</tbody>
</table>

Comparison of measured $SF_6$ profiles and DEHS profiles showed differences of 20$\%$ at most. This difference can mainly be attributed to the error in DEHS analysis of 10$\%$ and to the variable source strength of the spinning-top generator. The standard deviation of the mean for the tunnel sampler is relatively high because of measured concentrations just above the analytical detection limit.

Further experiments with several particle sizes of liquid and solid aerosols are planned under varying meteorological conditions. The number of tested instruments will increase.

For comparison of these field experiments with results obtained in wind-tunnel studies sharp edged thin walled nozzles will be tested as well. In the absence of an absolute method of determining the aerosol concentration in the open air, the Rotorod sampler has been calibrated and tested for use as a reference instrument.

REFERENCES