**Appendix B**

During aerosol collection with the HVS-TPS, a fraction of the airborne particles is deposited by settling and thus not collected. This fraction can be significant as particle size enlarges. One should keep in mind that aerosol is also collected by the vacuum bag extraction apparatus; therefore, this fraction is not measured by the HVS samplers.

These loss fractions for the HVS samplers can be evaluated using the “closed box” method.

If we assume spherical particles of density ρp and diameter dp, the collected mass of aerosol during the HVS-TPS aerosol sampling time Δt can be written:

, (B1)

where QHVS represents the total sampling flowrate of the five HVS.

Equation B1 supposes that particles are collected with an intrinsic sampling efficiency of the HVS equal to 100 % for all particle sizes.

Using the expression given by equation A3 for and integrating equation B1 between 0 and , gives:

, (B2)

where C0 is the initial aerosol concentration in the tent and τ the characteristic evolution time of the aerosol concentration.

In addition, since the aerosol concentration is homogeneous at any time, the mass of particle in the experimental enclosure at t = 0 can be expressed:

, (B3)

where V is the tent volume.

One should notice that this modelling supposes that the whole mass of aerosol to be measured is produced instantaneously inside the tent at t = 0 ; this consideration is roughly acceptable as the time duration of concrete milling during a trial is less than 10 min and therefore less that the characteristic evolution time of the aerosol concentration inside the tent.

Combining equations B2 and B3 gives:

. (B4)

If the sampling time, Δt, is large compared to the characteristic time, τ, eq. B4 can be simplified to express the initial mass of aerosol inside the tent, m0, according to the effectively collected mass, m(Δt), as:

. (B5)

It can be noticed that in absence of particle settling and vacuum aspiration, which indicates that all the airborne particles present inside the tent at t = 0 have been collected.

Thus, a multiplying coefficient α must be applied to the collected mass of aerosol to accurately evaluate the ARF. This coefficient takes account for the fraction of aerosol not collected by the HVS due to particle settling and due to aspiration by the vacuum bag filter; it is expressed:

. (B6)

The particle settling velocity in the Stokes regime is:

, (B7)

where da is the aerodynamic particle diameter,  = 1000 kg.m-3 the reference particle density for the aerodynamic diameter, Cu the Cunningham slip correction factor (Cu ≈ 1 for particle diameters above 3 µm), η the dynamic viscosity of air (1.81×10-5 Pa.s at 20°C) and g the acceleration of gravity.

Considering the experimental tent floor deposition area, Sd = 26 m2, a particle aerodynamic diameter equal to 4.3 µm (median value measured by the ACI) and a gravitational acceleration g = 9.81 m.s-2, the multiplying coefficient α is estimated at 1.59, which corresponds to an aerosol collection yield of 63 % during experiment.

In order to validate the multiplying coefficient calculation defined from the “closed box” modelling, the HVS collection yield was assessed experimentally by dispersing a calibrated mass of aerosol in the experimental tent and collecting them on the HVS filters.

For that purpose, we used and aerosol generator (TSI-TOPAS, model 3410 U) fed with an aluminum oxide powder (DURMAX, SPM 95). The SPM 95 powder is chosen as it exhibits relatively high particle aerodynamic diameter to assess settling losses.

Aerosol generator Model 3410 U uses a rotating stainless steel ring supporting powder deposit, which is use to feed a dispersion nozzle supplied with compressed air. It allows controlling in a stable and repeatable manner the particle dispersion mass flowrate by adjusting the rotation speed of the dosing ring.

It has therefore been necessary to determine in a first place the dependence between the powder mass rate and the operating parameters of the generator. The calibration of the powder mass rate was performed by filter sampling and weighing over a defined time interval (see dedicated experimental set-up Figure B1). The generator flowrate is set at 2 m3.h-1 and the dosing ring has a thickness of 3 mm. The powder sample was dried overnight in oven and the room temperature and relative humidity during the test were 19°C and 48 % respectively. The powder was dispersed and the aerosol collected on a cellulose filter in a sampling duct connected to a pump. The pump aspiration was adjusted to a flowrate that was slightly higher than the volumic flowrate of the generator to avoid flowrate sampling ratio correction to obtain particle mass rate directly from the filter weighing. This was checked using a pressure drop sensor and adjusting the pump flowrate to obtain an under pressure configuration (). This monitoring also guarantees that the sampling flowrate remains higher than the aerosol generator volumic flowrate taking account clogging of the collection filter.

The collected mass on the filters during a sampling time of 3 min and for 5 trials are presented in Table B1.

Table B1 - Aerosol mass collected on the calibration filters from the dispersion of SPM 95 power

|  |  |  |  |
| --- | --- | --- | --- |
| Trial (sampling time) | Initial | Final | Δm (mg) |
| 1 (3min) | 145.60 | 156.30 | 10.70 |
| 2 (3min) | 145.10 | 156.80 | 11.70 |
| 3 (3min) | 145.00 | 156.50 | 11.50 |
| 4 (3min) | 145.70 | 156.90 | 11.20 |
| 5 (3min) | 145.40 | 156.80 | 11.40 |
| Mean |  |  | 11.45 |
| COV |  |  | 1.3 % |

The mean value of the collected mass during the time interval of 3 min is 11.45 mg, corresponding to an aerosol mass rate of 229 mg.h-1. The COV of 1.3 % shows the very good repeatability of the dosing and confirms the capability of the aerosol generator to deliver calibrated mass of aerosol from the SPM 95 powder.

|  |
| --- |
|  |
| Figure B 1 - Experimental setup for the mass flowrate calibration of the aerosol generator 3410U |

After the mass rate calibration, the generator was cleaned up and filled with a new dried SPM 95 powder sample that was aerosolized right away in the experimental tent for duration of 1 hour and a half and collected on the HVS-TPS filters. At the same time, the aerosol particle size distribution was evaluated by ACI sampling (Figure B2). No additional flowrate from vacuum bag filter extraction was used for that experiment.

One should notice that the theoretical derivation of the α coefficient was done considering aerosol sampling during a concentration decrease process, with no source term and starting from an initial concentration (eq. A3). The same coefficient is obtained between the aerosol mass dispersed and the aerosol mass sampled during an increase in concentration from a zero initial value assuming constant generation mass rate and sampling time higher than characteristic aerosol evolution time τ. This assumption is demonstrated hereinafter.

The aerosol mass collected by the HVS is defined by eq. B1. The evolution of aerosol mass concentration (Cm) during the aerosol generation process and sampling with HVS is given by:

, (B8)

where q is the aerosol mass rate dispersed in the tent from the aerosol generator, V the volume of the tent and τ the characteristic aerosol evolution time defined by . Combining equations B1 and B8 and integrating between 0 and gives:

. (B9)

The mass of aerosol dispersed inside the tent during is expressed simply as : , therefore when , eq. B9 is rewritten as:

. (B10)

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| --- |
|  |
| Figure B 2 - Experimental setup for the in-situ evaluation of the HVS-TPS collection yield by aerosolized SPM 95 powder |

The collected mass on the five HVS-TPS filters for two trials are presented in table B2. The aerosol size distribution was partly out the size range of the ACI, nevertheless, aerodynamic median diameter is estimated from an extrapolation of the data assuming a log normal particle size distribution. The MMAD (Mass Median Aerodynamic Diameter) obtained is 11 µm, this value is consistent with measurement done with the same powder reference in other sampling configuration[[1]](#footnote-1).

The collected mass of aerosol on the 5 HVS filters for the two trials are respectively 212 mg and 209 mg. Taking into account a mass of aerosol dispersed during 1 h 30 min, equal to 344 mg, this correspond to experimental α values of 1.62 and 1.64, respectively; corresponding collection yield are 62 % and 61 %.

The calculated value of α using equation B6, considering an aerodynamic diameter of 11 µm is α = 1.75 corresponding to a collection yield of 57 %.

The experimental collection yield measurement validates the multiplying coefficient approximation by the “closed box” method with a discrepancy below 10 %.

Table B2 - Aerosol mass collected on the HVS-TPS filters from the dispersion of SPM 95 powder

|  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- |
|  | Trial 1 | | | Trial 2 | | |
|  | Initial (g) | Final (g) | Δm (mg) | Initial (g) | Final (g) | Δm (mg) |
| HVS 1 | 87.4903 | 87.537 | 46.7 | 87.4707 | 87.5143 | 43.6 |
| HVS 2 | 87.5003 | 87.5405 | 40.2 | 87.4872 | 87.5248 | 37.6 |
| HVS 3 | 85.8651 | 85.9058 | 40.7 | 85.8461 | 85.8829 | 36.8 |
| HVS 4 | 85.8834 | 85.9079 | 24.5 | 85.8700 | 85.9060 | 36.0 |
| HVS 5 | 87.4700 | 87.5300 | 60.0 | 87.4849 | 87.5400 | 55.1 |
| Total (1h30min) |  |  | 212.1 |  |  | 209.1 |
| Collection yield (%) |  |  | 62 |  |  | 61 |
| α |  |  | 1.62 |  |  | 1.64 |

1. Witschger O., Grinshpun S.A., Fauvel S. et Basso G. (2004) Performance of personal inhalable aerosol sampler in very slowly moving air when facing the aerosol source. *Ann. Occup. Hyg*. **48**, 351-368. [↑](#footnote-ref-1)