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Technical note

Evaluation of the particle infiltration efficiency of three passive samplers and the PS-1 active air sampler

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HIGHLIGHTS

- The particle infiltration efficiencies (PIEs) of 4 common air samplers were evaluated.
- Online spectrophotometer was used to measure PIEs for ambient 250–4140 nm particles.
- GAPS, Lancaster, and Hi-Vol acquired representative ambient particle samples.
- A low PIE of 54 ± 8.0% was determined for the MONET passive sampler.

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ABSTRACT

The particle infiltration efficiencies (PIE) of three passive and one active air samplers were evaluated under field conditions. A wide-range particle spectrometer operating in the 250–4140 nm range was used to acquire highly temporally resolved particle-number and size distributions for the different samplers compared to ambient air. Overall, three of the four evaluated samplers were able to acquire a representative sample of ambient particles with PIEs of 91.5 ± 13.7% for the GAPS Network sampler, 103 ± 15.5% for the Lancaster University sampler, and 89.6 ± 13.4% for a conventional PS-1 high-volume active air sampler (Hi-Vol). Significantly ($p = 0.05$) lower PIE of 54 ± 8.0% was acquired for the passive sampler used under the MONET program. These findings inform the comparability and use of passive and active samplers for measuring particle-associated priority chemicals in air.

1. Introduction

Passive air samplers are widely used for studying persistent organic pollutants (POPs) in air (Bogdal et al., 2013; Harner et al., 2006; Pozo et al., 2009). The appeal of the samplers is that they are inexpensive, do not require electricity and are small enough to be transported and deployed almost anywhere. These samplers consist of a sampling chamber and a sorbing medium. The most commonly used passive sampler for studies of POPs is a double-dome stainless steel shelter housing a polyurethane foam (PUF) disk (Harner et al., 2004; Jaward et al., 2004; Shoeib and Harner, 2002). The chamber protects the sampler from precipitation, sunlight and dampens the wind-effect on the sampling rate (Petrich et al., 2013; Thomas et al., 2006; Tuduri et al., 2006). Several regional- and global-scale air monitoring programs employ the PUF disk sampler using slightly different chamber configurations. These include the Global Atmospheric Passive Sampling (GAPS) Network (Bogdal et al., 2013; Pozo et al., 2009, 2006), the MOnitoring NETwork (MONET) operated in Europe and Africa by RECETOX, Masaryk University (Bohlin et al., 2014; Klánová et al., 2008), and various regional international studies using the Lancaster University sampler design (LANCS) (Jaward et al., 2004; Li et al., 2011). Increasingly, data from these programs are being combined into larger data sets for model application and validation and for risk assessment and risk management. Therefore, comparability among the different passive sampler designs and their comparability with conventional high-volume active air samplers are of key importance (UNEP, 2011).

While originally targeting mainly gas-phase compounds, PUF disk passive air samplers are increasingly being applied to assess

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mixed-phase or entirely particle-associated chemicals e.g. polycyclic aromatic compounds (Harner et al., 2013), polychlorinated dibenzodioxins and furans (PCDD/Fs) (Cortés et al., 2014) and high molecular weight, halogenated flame retardants (Bohlin et al., 2014). A compilation of field-based calibration studies of the PUF disk samplers has shown that sampling rates are typically in the range 4 ± 2 m^3 day^{-1} for both gas- and particle-phase compounds (Harner et al., 2014). However, discrepancies do exist and there is some debate regarding particle sampling efficiencies of the different passive sampler designs relative to typical high volume samplers (Bohlin et al., 2014; Klánová et al., 2008). It has been speculated that the double-dome sampling chamber may discriminate against larger particles (relative to an active high-volume sampler such PS-1), and that the manner in which the sampler is attached (i.e. fixed vs hanging) may also play a role (Bohlin et al., 2014; Klánová et al., 2008). Degrendele et al. (2014) have shown that most of the chemical burden (e.g. PAHs, PCDD/Fs) of the particle-phase is associated with the smaller particles (<1 μm) due to their larger total surface area for sorption.

In this work, we evaluate the ability of the different passive and active air samplers to acquire a representative ambient particle sample. This was accomplished by using an online particle spectrophotometer to measure the number concentration and size distributions of particles inside and outside of samplers, with high time resolution. The comparison of measured particle distributions will provide insight to the comparability of the passive and active samplers for measurements of particle-associated chemicals in air.

2. Methods

Three passive (GAPS network sampler (GAPS), Lancaster sampler (LANCS), and MOnitoring NETwork (MONET) sampler) and one active PS-1 (Hi-Vol) offline samplers were evaluated at the Downsview field site (43.780°, −79.468°) located in the north part of the city of Toronto, Ontario, Canada, during November of 2014 (Fig. S1). The three passive samplers were installed onto a chain-linked fence ~1.5 m above ground, which is their standard sampling configuration (Fig. 1; see also Figs. S2 and S3). PUF disks were removed from the samplers to facilitate the characterization of the chambers, installation of the particle spectrometer sample inlet, and to prevent measurement bias from deposition of particles on PUF filters located inside of sampling domes just above the spectrometer sampling inlet (see below). One new hole was drilled in the middle of the bottom plate of each sampler to accommodate installation of a 2 inch long (0.25 inch OD) stainless steel tube through which the sampled air was extracted. Although all of the samplers contained several holes on the bottom plate, the new holes were drilled to ensure sampling from the middle of the sampler interior, where filters are located (when installed). The Hi-Vol sampler was placed onto a cart ~1 m above ground to provide sampling height similar to those of the three passive samplers (see Fig. S3). An existing hole on the side of the Hi-Vol was used to install sampling tubing to the interior ~6 inch from the sampling head that is located in the middle of the Hi-Vol's sampling compartment. The Hi-Vol pump was turned on during the experiment, with a glass fiber filter installed in the sampling head generating a sampling rate of ~250 L min^{-1}. This is in the typical operating range for PS-1 samplers. The Miniature Wide Range Aerosol Spectrometer (Mini-WRAS, Model 1.371, Grimm Aerosol Technik GmbH & CO, Ainring, Germany) was installed on a cart and placed directly below the three passive samplers and next to the Hi-Vol during sampling to minimize the length of sampling lines and potential particle losses from collisions with tubing walls. The inlet of the Mini-WRAS was connected to a Y-shaped fitting whose ends were each connected to a stainless steel ball valve. One of the valves was further connected to a stainless steel tee, from which connections were made to a HEPA filter (MODEL # 12144, Pall Life Sciences Corp., Port Washington, NY, USA) and the inside of a sampler. Similarly, the second valve was connected to a HEPA filter and the tubing leading to the area just outside of a sampler (generally < 12 inches away). Bypass HEPA filters were installed to split the total flow to the Mini-WRAS (~1.2 L min^{-1}) and reduce the sampling flow rate from a passive sampler to ~0.5 L min^{-1} thus minimizing the impact on the "passivity" of the evaluated samplers. A compilation of field-based calibration studies of the passive samplers has shown that sampling rates for the PUF disk substrate are typically in the range 4 ± 2 m^3 day^{-1} (Harner et al., 2014). However, actual airflow rates through the chamber itself are more than an order of magnitude greater based on the previous assessments of inside versus outside wind speeds (Tuduri et al., 2006). Hence, the additional flow of 0.72 m^3 day^{-1} due to Mini-WRAS sampling is expected to have a negligible impact on the particle infiltration efficiencies of the samplers. The HEPA filters were also used during the study for periodic "blank" measurements by the Mini-WRAS. The instrument

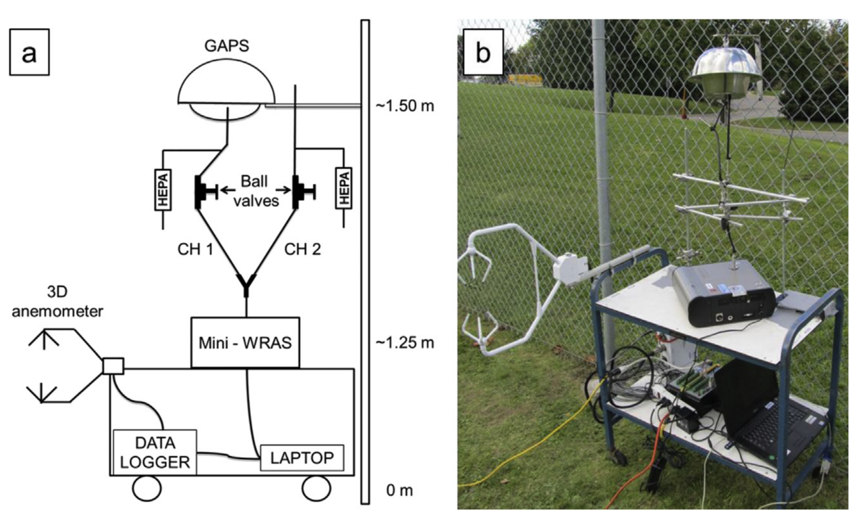

Fig. 1. Schematic (a) and photo (b) of the experimental set-up used to evaluate the ability of the different passive (GAPS, LANCS, MONET) and active air samplers (Hi-Vol) to acquire a representative ambient particle-phase sample (schematic not to scale). The example of a set-up used during the GAPS evaluation is shown, and s similar set-up was used for the evaluation of three other samplers.