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Validation of MicroAeth® as a Black Carbon Monitor for Fixed-Site Measurement and Optimization for Personal Exposure Characterization

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ABSTRACT

This paper reports on validation experiments with the recently developed microAeth®, a pocket-sized device which is able to obtain real-time and personal measurements of black carbon (BC) aerosol. High reproducibility was observed when comparing the results from six new individual units during fixed-site monitoring out of a window (relative standard deviation [RSD] = 8% ± 5%, N = 1442). The results obtained from the microAeth devices agreed with those obtained from a full size rack mounted Aethalometer, based on both the 1-minute data (R = 0.92, slope = 1.01 ± 0.01, N = 1380) and 24-h average data. The 24-h average of real time data obtained from the microAeths was comparable to the BC concentration obtained from 24-h integrated $PM_{2.5}$ filter deposits, as determined by multi-wavelength optical absorption (R = 0.98, slope = 0.92 ± 0.07, N = 12). Rapid environmental changes in relative humidity (RH) and temperature (T) can result in false positive and negative peaks in the real time BC concentrations, though averages > 1–2-hour are only minimally affected. An inlet with a diffusion drier based on Nafion® tubing was developed in order to use BC data with a high time resolution. The data shows that the diffusion drier greatly reduce the impacts from rapid changes in RH and T when the monitoring system is worn in close proximity to the body (e.g., in the vest pocket).

Keywords: Black carbon; MicroAeth; Personal exposure; Fixed-site monitoring; Humidity.

INTRODUCTION

Black carbon (BC), which is of increasing interest for its climatic, environmental, and widespread health effects (Hansen *et al.*, 2000; Andreae, 2001; Jacobson, 2001; Ostro *et al.*, 2007), mainly results from incomplete combustion of biomass and fossil fuels. Anthropogenic and natural sources of BC exist (Ogren and Charlson, 1983; Akhter *et al.*, 1985), and BC is often measured based on the optical absorption of specific wavelengths of light by particulates collected on a filter. Theoretically it is a similar metric to elemental carbon (EC), which is determined by a number of thermo-optical techniques; practically there are issues with both BC and EC techniques. For example, EC fraction of total carbon depends strongly on the details of the method chosen and the type of aerosol (Butterfield, 2010). In general, measured BC and EC are highly correlated but the slope of the correlation can vary by location, season, laboratories (Jeong *et al.*, 2004; Venkatachari *et al.*, 2006; Quincey *et al.*, 2009).

The ease, cost and direct significance to atmospheric properties of the particles have resulted in optical methods being more widely used. The full size rack-mounted Aethalometer® (Magee Scientific, Berkeley, CA) is the most common instrument for real-time BC measurement and was introduced by Hansen *et al.* (1984). This instrument has been validated by comparing with other BC and EC measurement methods (Allen *et al.*, 1999; Babich *et al.*, 2000). Further, the technology conducted by Aethalometer has advantages of high sensitivity and capability of short-term measurements, which provides the potential for real time personal BC monitoring.

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Personal monitoring is widely viewed as the gold standard for exposure assessment for air pollutants and has been shown to provide stronger statistical associations with health outcomes than fixed site monitoring and additional information about exposure patterns such as pathways of exposure (Chillrud *et al.*, 2004) or peak levels of exposure (Rabinovitch *et al.*, 2005; Brook *et al.*, 2011). However, conduction of personal monitoring in large-scale epidemiologic studies has been extremely limited to-date due to the fact that traditional personal monitors are often burdensome, noisy and expensive to carry out.

The microAeth is an instrument based on Aethalometer technology and designed specifically for the mobile mapping of BC distribution. It is lightweight, compact in size, and easy to operate; thus it has the potential to be used in epidemiological studies as both a personal and indoor air monitor. Like any real-time monitor, microAeth data can be highly variable or noisy, especially when the time step between measurements becomes shorter or the concentrations are very low, and as such it can be advantageous to carry out post-processing of the real-time data to average adjacent points to smooth out the noise from the real signal (Hagler *et al.*, 2011). However, the usage of the microAeth as a personal BC real-time monitor has not been validated in peer-reviewed literature by comparison to other methods and the issue of rapid changes in temperature and/or humidity has not been addressed. Such rapid changes in environmental conditions (RH and T) has been reported to cause problems among other optical instruments such as particle counters and nephelometers (Arnott *et al.*, 2003; Fischer and Koshland, 2007) and can result in a significant deviations in short-term BC determinations. Here we report on detailed tests of the performance of the microAeth in making BC measurements, the impact of rapid changes in RH and T, and provide recommendations for operation including optimization methods to overcome RH and T effects.

METHODS

The MicroAeth® Model AE51 (AethLabs, San Francisco, CA) measures BC air concentrations using light emitting diodes (LEDs) at 880 nm with two detectors, one for the sensing channel that monitors the spot on the filter where particulate matter is deposited and one for the reference channel that monitors a blank area of the filter with no active sampling. Up to six units were tested in our study. Each unit weighs about 250 g with a size of 11.7 cm L × 6.6 W × 3.8 D. Sampling parameters: whereas the pump samples continuously, the time interval for making readings on the units we used can be 1 s, 1 min, or 5 mins; the flow rate can be set at 50, 100, or 150 mL/min. The units tested initially had firmware/software (S0) that kept the LEDs and detectors on continuously. To extend the runtime on the internal rechargeable battery to more than 24-hrs, a firmware/software upgrade was made which turned the light source and detectors on and off to save on power and the testing reported here was done with version (S1). At 5 min intervals and a flow rate of 50 mL/min on a full charge, the S1 versions of the units last 27–30 hours. For each sampling event in New York City (NYC), a new, single filter made of T60 Teflon coated borosilicate glass fiber is used.

Reproducibility Tests for Fixed Site Monitoring

To evaluate and validate microAeth for use as fixed site monitor, side-by-side testing of several microAeth units and comparisons of the microAeth units with other established BC measurement methods, including a rack-mount Aethalometer and multi-wavelength optical measurements on integrated Teflon filters, were conducted. Of particular note the multi-wavelength optical measurement of BC is calibrated gravimetrically by collecting, weighing and then optically measuring $PM_{2.5}$ filters of kerosene soot and assuming that 100% of the mass is BC (Yan *et al.*, 2011); literature values consistently show values of 95% ± 5% (Lam *et al.*, 2012). This comparison testing was conducted from the window of a fifth floor apartment along the W168th street, NYC, which is situated at an intersection of a busy street with idling ambulances and a truck route with heavy traffic. However, the sampling window faced a courtyard rather than the street. Six microAeth units were inside the apartment; sampling tubing passed through a window board, and the sampling inlets were about 0.3 m from the outside wall. MicroAeths were set to acquire BC data for every 1 min at a flow rate of 100 mL/min and replace the filter for every 24 hrs.

In a separate experiment, four of six microAeth units were operated in turn along with a rack-mount Aethalometer® (AE22, Magee Scientific Co.) continuously measuring BC level every minute at the flow rate of 4.0 LPM and three integrated $PM_{2.5}$ samplers (KTL cyclones BGI, Inc.) collecting $PM_{2.5}$ on 37 mm Teflon membrane filters (Pall Corporation, Port Washington, NY) at flow rate of 4.0 LPM. This comparison test ran for four weeks with three consecutive 24-hr sampling periods every week. The full size Aethalometer used a web-reinforced quartz fiber filter tape (supplied by Magee Science Co.), allowing an automatic advance of the filter when the sampling spot became heavily loaded.

A multi-wavelength optical method has been established for measuring BC levels collected on $PM_{2.5}$ Teflon filters via optical equipment purchased from Ocean Optics (Dunedin, FL) including a balanced deuterium tungsten halogen light source (DH-2000-BAL), an integrating sphere (ISP-50-8-R) modified to have a reflective white bottom, a lab-made filter holder, and an Ocean Optics USB4000-VIS-NIR fiber-optic spectrometer (Yan *et al.*, 2011). Whereas the microAeth and full size Aethalometer measures the change in light attenuation between every time stamp (e.g., each min), from which the BC air concentration is calculated for that period of time, the multi-wavelength optical reflectance method determines the total BC mass loading on filters (based on an empirical gravimetric calibration) that occurred over the entire deployment period, which was 24 hrs in this experiment. For comparison, data retrieved from both microAeth and full size Aethalometer in the 24 hours period were integrated and the daily average BC level were compared to those measured by the multi-wavelength method. The high resolution temporal data from both microAeth and Aethalometer was compared with each other; data from a single random day was selected to better illustrate details.

Humidity Issue and Optimization for Personal Sampling

Duplicate personal sampling events were conducted to test the humidity impact on real-time BC readings made by microAeth as well as the role of different in-house designs of diffusion drier inlets on the humidity/temperature issues. Two microAeths were worn in a double lined vest where the inlet tubing passed up between the liner to the breathing zone and the person was primarily outdoors for about 3.5 hr and 1.5 hr on a sunny (relative humidity, RH = ~65%) day and a rainy (RH = ~100%) day, respectively. In both events, one unit was connected with only regular inlet tubing (Freelin-Wade Co., 1J-425-01) and the other was connected with inlet tubing that incorporated a short diffusion drier, based on Nafion® tubing (Perma Pure LLC, Toms River, NJ).

Nafion tubing allows water vapor but not larger molecules to pass through the tubing if there is a moisture gradient (either from vacuum or from use of a drying agent). In a series of experiments focused on testing the efficacy of a diffusion drier, the regular inlet tubing is in line with a piece of Nafion tubing; to create the moisture gradient, the exposed Nafion tubing is intimately surrounded by bags of pre-dried silica gel, which are then enclosed by a sealed plastic box. The plastic box is lightweight and doesn't require additional power. Two different drier sizes, were tested: a "short" version (with 2.7 cm of exposed Nafion tubing and 4 g of silica gel) and a "long" version (5.5 cm of exposed Nafion tubing and 6 g of silica gel).

Evaluation on Lifespan of Diffusion-drying Inlets for Personal Sampling

For the further application of the diffusion-drying inlets, the lifespan of the silica gel in both short and long diffusion drying inlets were evaluated. The RH and T were monitored inline before and after the diffusion driers by inline sensors (HOBO®, ONSET, H08-003-02, accuracy of RH ± 2%, T ± 0.5°C) while challenging the system to high RH conditions. A humidifier was used to adjust humidity inside of a plastic chamber (Rubbermaid ®, 53L). In the first part of this experiment (2nd to 17th hr), the humidifier was turned on for 15 min every two hours (long cycle) which raised RH in the chamber to 90%; and then the humidifier was turned off and RH levels in the chamber gradually decreased with the introduction of filtered (BC-free) room air (100 mL/min). The complete RH cycle (increasing and decreasing) was repeated 8 times. In the second part of this experiment (18th to 47th hr), the humidifier was kept on continuously to keep the RH near 100% and maintained at that level until the end of the experiment.

Impact of Temperature Changes

To test the impact of temperature change when the monitors were not worn, open tray testing was carried out on a sunny day. Instead of being worn in a vest, two microAethes were carried on an open tray, in and out of an air-conditioned building that was located at suburban area (with relatively low BC concentrations BC ≈ 0.5 μg/m^3) for three cycles. One unit was connected with a drying box and the other one was connected with regular tube. Given that HOBO sensors would block BC particles if placed inline, they were placed on the same tray. During the testing, the RH and T inside the building were 33.2 ± 4.3% and 26.5 ± 3.1°C, respectively; while RH and T outside the building were 36.3 ± 7.0% and 35.6 ± 4.3°C.

RESULTS AND DISCUSSION

Reproducibility Tests for Fixed Site Monitoring

The time series of the six microAeth units placed side by side (Fig. 1) demonstrates the excellent reproducibility of these new units during fixed-site monitoring. The mean RSD of 1-min averages among six units over 24-hr side-by-side sampling was 8% ± 5% (mean absolute standard deviations of 0.063 ± 0.034 μg/m^3). Within 1-h subsections of the lowest and highest BC levels, the mean RSD of 1-min BC across six units, were 12% ± 5% and 5% ± 1%, respectively (with corresponding mean absolute standard deviations of 0.049 ± 0.019 μg/m^3 and 0.106 ± 0.052 μg/m^3, respectively).

Beside the high reproducibility between microAeth units, microAeth BC data were consistent with data from a full-size Aethalometer (Fig. 2(a)). Selecting a representative 24-hr sampling period (N = 1380 points) as an example, their 1-minute data were highly correlated (R = 0.92; slope ± SE = 1.01 ± 0.01); their 24 hr BC average were even more highly correlated (R= 0.98 and slope ± SE = 1.04 ± 0.07, N = 12). Finally, the microAeth data averaged for 24 hr periods were also highly correlated (R= 0.98 and slope ± SE = 0.92 ± 0.07, N = 12) with optical analyses made on 24 hr PM$_{2.5}$ filters (as shown in Fig. 2(b)), which were run side by side with four microAeth units over 12 days.

The good agreement between data generated from microAeth units and data from these two widely used BC fixed-site monitors demonstrates that this model of microAeth has the ability to provide high quality fixed-site BC data. However, there are obvious limitations using the microAeth units as fixed-site monitors. For example, one has to manually replace the filter strips before optical saturation occurs. Guideline threshold values for light saturation for changing filters are based on the change in attenuation (ΔATN) since the beginning of a deployment, with different groups using values ranging from 75 to 125 ΔATN units. Data for 335 deployments of the microAeth as personal monitors for 24 hr periods in NYC showed a mean ΔATN ± 1 SD of 26.4 +/– 19.2, and the range was from 4.1 to 155. Therefore, in urban environments such as modern day NYC, a microAeth filter typically can go for one to a few days before needing to be changed due to saturation. Other locations with significantly less BC could go much longer on a single filter. However, in more contaminated environments, such as Beijing, the filter can be saturated in less than 12 hrs. Another limitation is that one has to recharge batteries daily or less, depending on the selection of duty cycles. However, one can run the microAeth off of line power via the USB charger, albeit this method introduces noise in the BC parameters (though

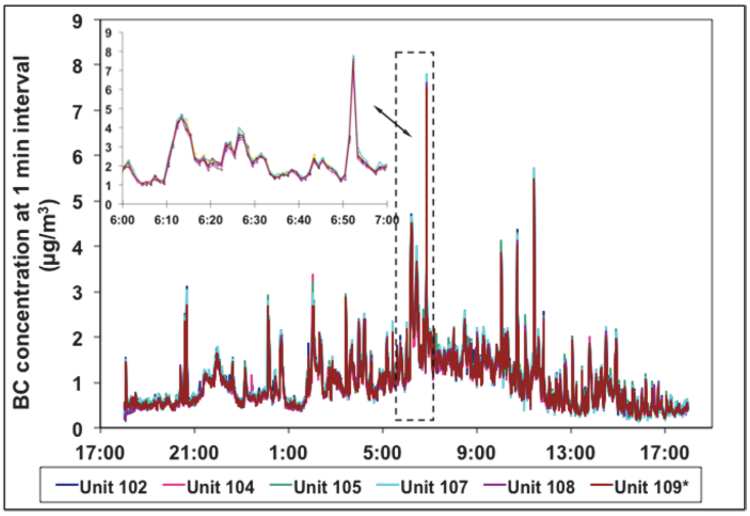

Fig. 1. Time series of six-microAeths fixed-site side-by-side sampling over 24 hrs (1-min interval). The left upper corner plot shows the BC levels between 6:00 am to 7:00 am. * Unit 109 data is corrected because its clock shifted 1 minute at 10:48 a.m. on Apr. 24.

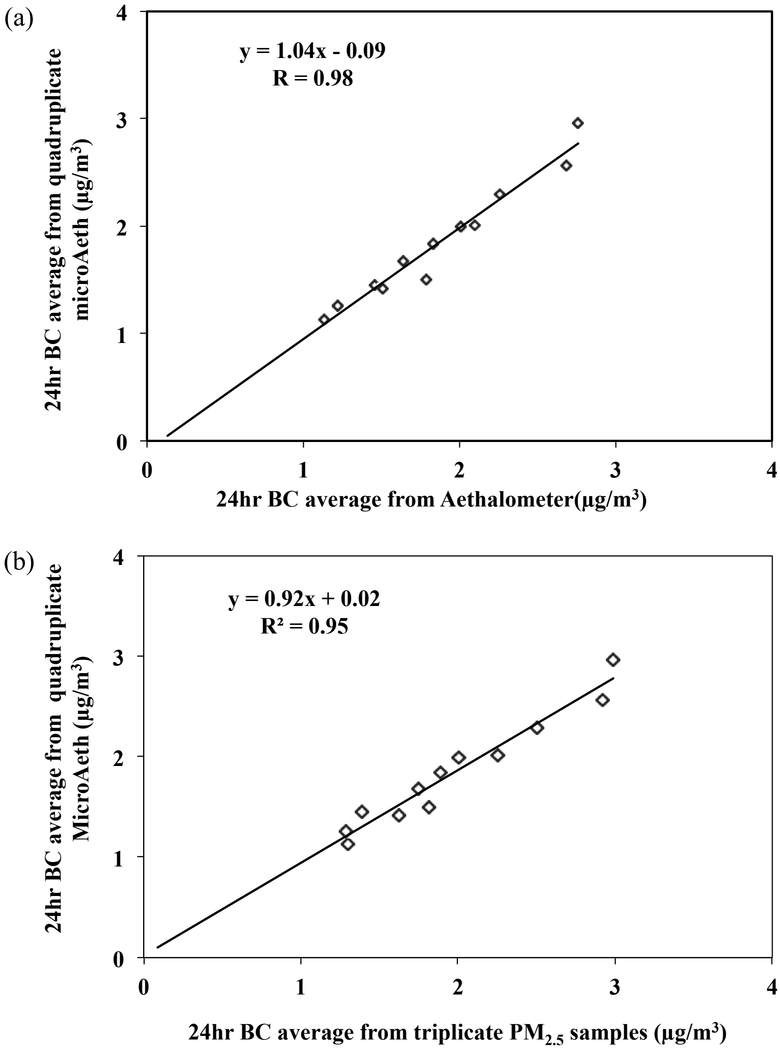

Fig. 2. (a) Comparison between 24 hr BC average from quadruplicate microAeth (y-axis) and 24 hr BC average from Aethalometer (x-axis); (b) Comparison between 24 hr BC average from quadruplicate microAeth (y-axis) and 24 hr BC average from triplicate $PM_{2.5}$ samples (x-axis).

that can easily be averaged out in post-processing). However, the miniature pump used in the microAeth has a nominal runtime of only 3000 hrs, which also excludes it from consideration as a monitor or a permanent fixed site location but still allows it to be used as a fixed site monitor in indoor and outdoor locations for non-permanent settings as long as one budgets for maintenance over the course of a study.

At the time of the tests above there was not a size selective inlet for $PM_{2.5}$ available for any of the flow-rates that the microAeth uses. As such, the particles entrained and deposited on the filter of the microAeth included all sizes of airborne particles. However, combustion particles are typically smaller than 2.5 µm. The excellent agreement between the microAeth data and the co-located samplers in an urban setting that did use size selective inlets with a $PM_{2.5}$ cut (Figs. 2(a), 2(b)) is consistent with the BC being in particles smaller than 2.5 µm. A $PM_{2.5}$ cyclone for 50 mL/min is now available from the manufacturer and is actually recommended both to keep large particles out of the monitor and for settings where coarse particles may confound using BC readings as a tracer of combustion sources (i.e., subway settings where abrasion of steel produces black iron oxides (Cai *et al.*, 2013)).

Humidity and Improvements in BC Data Using a Diffusion Drier Inlet System

Optical measurements can have more frequent humidity impacts during personal sampling compared to fixed site monitoring, since environmental humidity and temperature can vary dramatically as subjects move among different environments. To investigate how environmental conditions can impact microAeth BC measurements, an individual wore two microAeths on both a rainy day and a sunny (relatively dry) day. Both units were worn in a pocket of a vest with the inlet tubing passing up through the double lined vest, but one unit had a diffusion drier as part of the inlet tubing and the other had just "regular" tubing.

On the rainy day when RH was up to 97%–100% (T = 18.1 ± 1.3°C), the microAeth unit with only "regular" tubing exhibited large positive and negative excursions in the BC data (Fig. 3). In the largest excursion observed by this unit the BC concentration varied from 11.9 $\mu g/m^3$ to –17.2 $\mu g/m^3$ within 2 minutes. These observed changes in BC are consistent with high humidity and/or changes in humidity changes can severely affect real time data quality. However, there were no noticeable spikes in BC reading of the unit with an inlet that included a diffusion drier. During the two-hours of sampling on the rainy day deployment, roughly 40 minutes (~33%) of data points are influenced by +/– excursions in the data as compared to no data from the unit with the diffusion drier. The average % difference between 1 min measurements of the two units on the rainy day was 53% ± 238% (N = 100). However, the % difference of the 1 hr averages of two units on the rainy day deployment is ~1% or negligible, indicating that the positive excursions largely are balanced by negative excursions as long as the averaging time is long enough.

During sampling on a relatively dry sunny day when RH was around 65% (T = 13.3 ± 0.5°C), the two units with and without a diffusion drier gave very similar concentrations (average % difference ± 1SD of 1-min BC data was 5% ± 33%, N = 204) (Fig. 4), indicating that the diffusion drier does not remove BC particles significantly.

Optical instruments often have issues with high RH and condensation, which have been reported by earlier studies (Arnott *et al.*, 2003; Fischer and Koshland, 2007). The rapid increase in RH or very high RH can result in condensation of moisture onto surfaces of the collecting medium (especially hydrophilic filters) and/or optical components. Moisture has a strong ability to scatter light. When water vapors/droplets coat the sampling medium or optical components (e.g., light source and optical detectors), it can contribute to light attenuation (i.e., results in significant decrease on optical signal received by detectors) and result in faulty positive BC

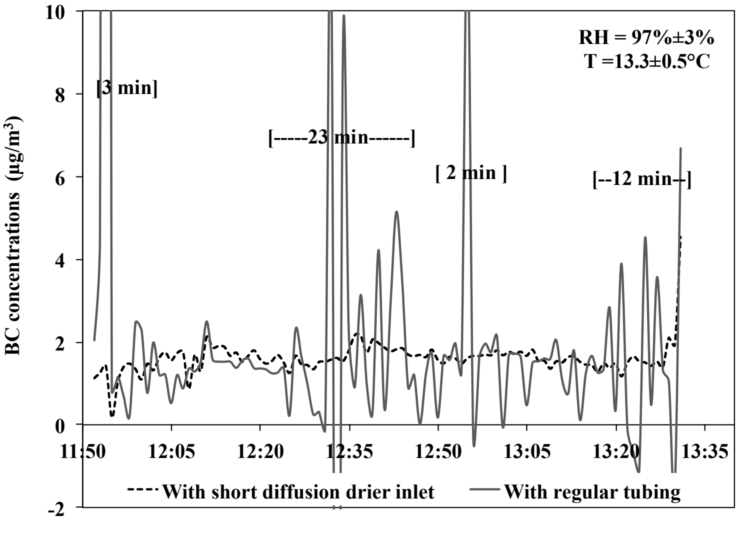

Fig. 3. Time series of duplicate personal sampling on a rainy day, where one microAeth unit was used with a short diffusion drier and the other without (regular tubing). The numbers in bracket [] represent the duration of in minutes of the questionable data.

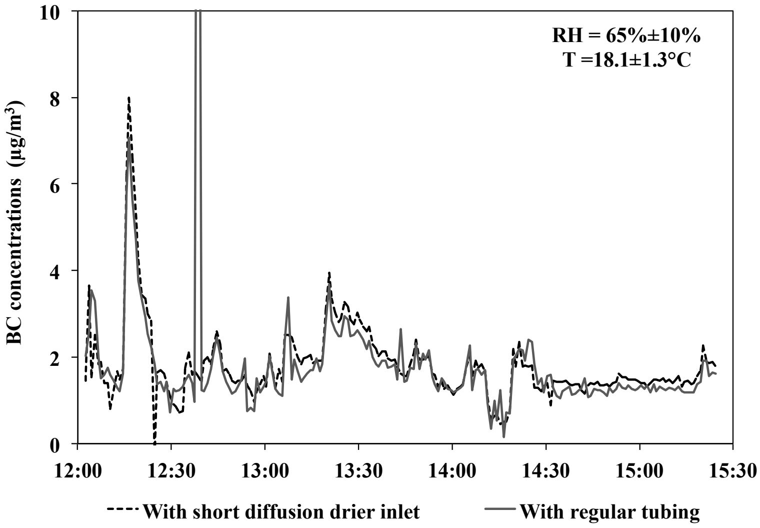

Fig. 4. Time series of duplicate personal sampling on a sunny day, where one microAeth unit was used with a short diffusion drier and the other without (regular tubing). The agreement of the data for the two different units indicates that the diffusion drier does not remove BC significantly.

readings. However, when evaporation of retained moisture occurs, the previous light attenuation contributed by water is reduced, which can cause negative excursions in BC since the calculation is based on successive differences of attenuation. Such a cycle of condensation and evaporation of moisture occurring in the optical pathway due to the abrupt changes in environmental conditions (RH and T), can explain why humidty changes can often cause positive or/and negative excursions/spikes in optical mearements and why one can follow the other closely in time.

Due to the design of the microAeth AE51, these issues are also impacted by the fact that the measurement is based on comparing changes of the active area of the filter where particles are deposited (and monitored by the sensing channel detector) to changes in an unused part of the filter that has no active flow (monitored by the reference channel detector) (Cai *et al.*, 2013). The reference channel is used to take into account temporal changes in the light source. Since the reference optical pathway does not have any active flow of incoming air, it is not as quickly affected by changes in RH and T as the sensing optical pathway. Moisture introduced with incoming air can impact the optical pathway of the sensing channel more quickly than the reference channel, which has to wait for diffusion/advection of moisture. The effectiveness of the diffusion drier is partially explained by reducing incoming moisture and thus lowering the dew point temperature and thus lowering chances of condensation and false excursions in BC readings.

Evaluation on Lifespan of Diffusion-drying Inlets

The lifespan of diffusion-driers were assessed by placing two microAeth units, one with a short diffusion drier (with 2.7 cm of exposed Nafion tubing and 4g of silica gel) and the other with a long diffusion drier (5.5 cm of exposed Nafion tubing and 6 g of silica gel) into a small environmental chamber. RH and T monitors were also placed in line before and after each diffusion drier to monitor the impact of the diffusion driers. The data collected allows one to estimate how long one can use the short and long diffusion driers before their capacity is consumed by absorbed water. As seen in Figs. 5 and 6, this small chamber experiment initially had pulses of humidity added to the chambers for 15 min of every 2 hr time period and then an extended period at 100% RH and 19.4°C. As expected, the long diffusion drier shows a higher efficiency/capacity in water removal than the short diffusion drier inlet. Since the driers work by diffusion caused by the gradient in humidity across the Nafion tubing, the driers are more effective at lowering RH when RH is at high levels and less effective at lower RH inside the chamber. The long drying setting reduces the RH in the air flow by about 40% at high chamber RH (90%) and about 20% at the minimum (60%) chamber RH settings, compared to 30% and 10% reductions, respectively, for the short diffusion driers. During the pulsed introduction of humidity, both diffusion driers appeared to be just as effective at lowering RH after 8 cycles as at the beginning; when constant 100 %RH levels are kept in the chamber, the effectiveness of the short diffusion drier decreases at a faster rate than the long drier. The rate of change in %RH were all within ± 2 %/min, though they did slightly increase as humidity increased (e.g., go from less than 1 %/min to more than 1 %/min).

Based on results of a large environmental chamber experiment reported in a separate publication (Cai *et al.*, 2013) and the rainy day deployment described sampling in this article, we believe that the diffusion drier inlet will be effective as long as it can control RH rate of change to be within ± 2.5 %/min, even in an environment with RH up to 90% and above. In the small chamber experiments above (Figs. 5 and 6), the short diffusion drier can keep the RH% of incoming air entering the microAeth below 85% and RH change rate within ± 1.0 %/min for 30 hours (pulsing time period +100% RH time period), while the long drier can last for more than 47 hours. Given that the vast

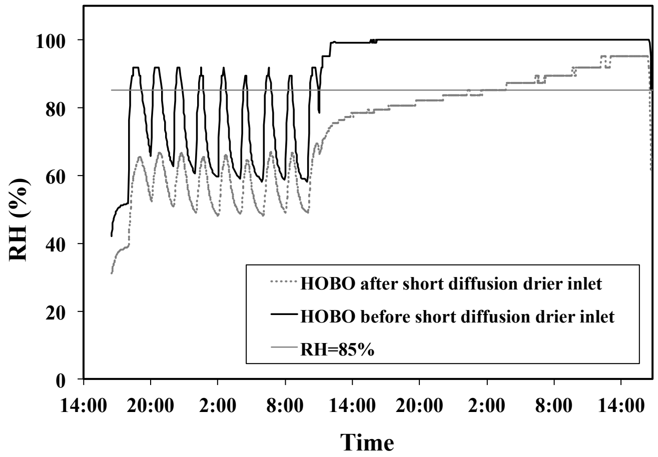

Fig. 5. Lifespan experiments of silica gel bags in the short drying inlet. Comparing the rate of change in the RH, one observes that the diffusion driers keep the rate of change to < 1% per min in pulse mode and < 2% per min in the 100 %RH mode.

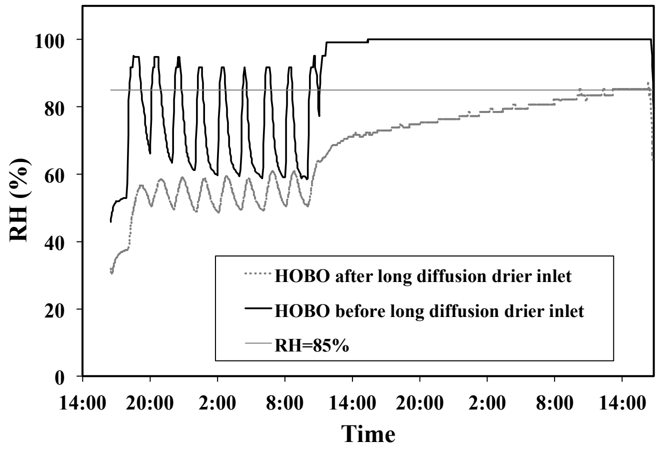

Fig. 6. Lifespan experiments of the long diffusion drier inlet. Comparing the rate of change in the RH, one observes that the diffusion driers keep the rate of change to < 1% per min in pulse mode and < 1% per min in the 100 %RH mode.

majority of people's time is spent indoors where relative humidity is rarely at such high levels for extended periods of time, the diffusion driers should last much longer than these estimated minimum time periods.

Loss of Temperature Buffering when not Wearing the Monitoring System

Fig. 7 demonstrated that when the units were not worn on a person, but instead placed on a tray and carried in and out of building from relatively low T and RH (inside) to relatively high T and slightly higher RH (outside), the diffusion driers were not effective at reducing the frequency and severity of BC data excursions (spikes). Both units with and without a diffusion drier had suspect BC readings and the direction of these suspect readings were in the opposite direction; condensation vs. evaporation on filter surfaces of either sensing or reference channels, most likely, are the cause. When walking out of air-conditioned building to the hot and more humid outside environment, the unit without the drier showed positive excursions, consistent with enhanced water condensation on sensing channel relative the reference channel, artificially increasing the BC reading; In contrast, the unit with the inline drier showed negative excursions, suggesting relative evaporation in the sensing channel vs. the reference channel. In such a case, the drier reduces RH in the incoming air passing through sensing channel, but the prior conditions of colder temperature is still surrounding reference channel and it is not being dried and thus humidity has some potential to condense when the reference spot on the filter starts feeling the higher moisture content of the outside air. Once liquid water coats a surface on the optical path differentially between the reference and sensing channel, incorrect BC readings occur.

In additional controlled experiments in a large environmental chamber reported in a separated publication (Cai *et al.*, 2013), such excursions were not observed when units with the diffusion drier were worn in a vest pocket and carried in and out of very different T and RH environments. HOBO Sensors placed in line with the microAeths showed much smaller temperature swings than that of the two rooms indicating that when the units were worn in a close proximity of body (e.g., in a vest pocket) the temperature seen by the microAeth is largely buffered or damped. Therefore, the diffusion drier system and the temperature buffering ability

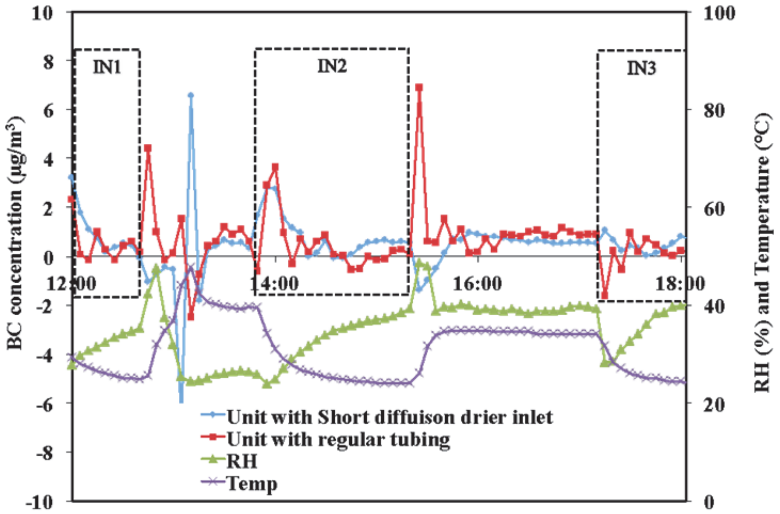

Fig. 7. Data collected while walking in and out of air-conditioned building with a HOBO and two microAeth units, one with a short diffusion drier and one without (regular tubing). All three instruments were placed on a tray and thus did not have the temperature buffering advantages of being worn on the body (see text).

of human body (analogous to an inlet heater) are two indispensable components that make the system work, especially when participants travel between the different micro-environments.

In general it is common knowledge that when one uses optical instruments outdoors for extended periods it is necessary to use heated enclosures and/or heated inlet systems to avoid condensation on instrument surfaces when temperatures may be below the dew point, especially in early morning hours. But for personal monitors e.g., microAeth, heated enclosures/inlets mean additional energy requirement, which will shorten the running time of units; in contrast, the diffusion drier and wearing the unit in a vest pocket are more favorable for the energy budget of the monitor.

SUMMARY AND RECOMMENDATIONS

This study evaluated several newly purchased microAeth AE51 monitors as fixed site and personal BC monitors. As fixed site monitors, the microAeth units showed high level of reproducibility and agreed well with other validated methods for both short time scales (min) to 24 hr time scales. Similar agreement between BC readings was possible when two units were used as duplicate personal monitors. However, when used as personal monitors, abrupt changes in temperature and/or relative humidity was found to be able to cause false temporary excursions in the BC readings. Notably, when the microAeth was worn in a vest and the used with diffusion drier inlets, based on Nafion tubing and silica gel, greatly decreased both the frequency and the magnitude of false BC events, resulting in excellent agreement of duplicate monitors. Two types of diffusion driers inlets (with 2.7 cm/5.5 cm of exposed Nafion tubing and 4 g/6 g of silica gel, respectively) were able to last for > 24 hr for the application of daily personal sampling. Of equal importance, based on comparison of co-located units, it appears that a diffusion drier system is not needed if one is going to average the data for long enough time periods (≥ 1 hr) since the impact of these false positive and negative excursions appear to cancel and thus become negligible.

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