Profiling Personal Air Pollutant Exposures Using a Wearable Non-Selective Passive Wristband

Elizabeth Z. Lin, Sarah Esenther, Fareeha Irfan, Massimiliano Mascelloni, Krystal J. Godri Pollitt

Environmental Health Sciences, School of Public Health and Health Sciences, University of Massachusetts Amherst

Overview

- Characterizing cumulative exposure to air pollutant mixtures is a critical step in understanding disease development. Overcoming this research challenge requires the creation of new technologies for capturing and analysing exposures.
- This work demonstrates the use of a novel wearable air pollutant monitor, the Fresh Air wristband, to passively sample nitrogen dioxide as well as non-polar compounds. A thin-film polydimethylsiloxane (**PDMS**) sorbent material is used to non-selectively absorb non-polar compounds. This sorbent is then analyzed off-line following the exposure assessment period using thermal desorption (**TD**)- gas chromatography (**GC**) time-of-flight mass spectrometry (**ToF-MS**).
- Presented results highlight the efficiency of the PDMS sorbent material to sample polycyclic aromatic hydrocarbons (**PAHs**) under controlled laboratory conditions as well as from ambient air.
- The Fresh Air wristband was tested as personal exposure assessment tool in a cohort of school-aged children over a 5-day period. The wristband was well received by the children. Children with asthma were found to have increased personal exposure to combustion derived PAHs and nitrogen dioxide compared to children without asthma.

Introduction

- One challenge in evaluating the effect of air pollutants on disease is routed the accuracy of personal exposure techniques. Organic air pollutants, such as PAHs, are released from various sources, including vehicle emissions, building materials, paints, cleaning products and air fresheners. PAH exposure is associated with respiratory and cardiovascular disease, cancer and adverse neurobehavioral outcomes.
- Current personal air pollutant monitoring systems include backpacks containing hand-held air monitors and filters/pumps. Pollutants sampled onto filters are typically solvent extracted and analyzed by GC-MS. This sample preparation approach is laborious, limiting the feasibility of evaluating personal exposure on a larger scale (**Figure 1A**).
- The size, weight and cost of these air sampling systems prevents use with vulnerable populations (*i.e.* pregnant women, infants). There has been limited development of analytical techniques to capture the cumulative exposure of individuals at critical windows of susceptibility to air pollutant mixtures (**Figure 1B**).
- New exposure assessment tools are required to study longitudinal environmental exposures.

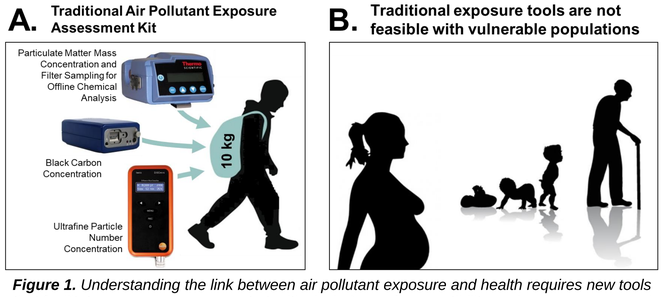

Figure 1. *Understanding the link between air pollutant exposure and health requires new tools that facilitate exposure assessment at critical windows of susceptibility such as pregnancy and childhood.*

Objective

Develop a light-weight wearable monitor to measured exposure to a broad panel of air pollutants.

ziyinglin@umass.edu

Methods

Passive Air Pollutant Sampling

- Solid phase micro-extraction PDMS fibres have been widely demonstrated to be an efficient technique for sampling a wide panel air pollutants. The fragile design and cost of this method have limited the application to personal exposure assessment. To make the design of the sampling device more robust, we coated a borosilicate glass rod with a thin film of PDMS (Dow Corning) (**Figure 2**).
- The capacity of the PDMS sorbent to absorb a range of non-polar compounds was tested through controlled laboratory exposures (**Figure 3**). PDMS sorbent bars were first cleaned by heating to 300 ºC under a flow of a high purity N_2 for 2 hours. Uptake on cleaned PDMS sorbent bars was evaluated using two approaches (direct infusion to a certified semi-volatile mixture and air loading) over multiple exposure periods. Retention of compounds to the sorbent material tested at different storage temperatures.

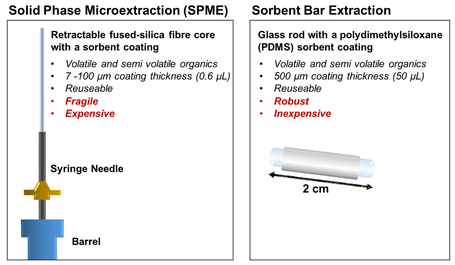

Figure 2. *Approaches for air pollutant sampling using PDMS as a sorbent material.*

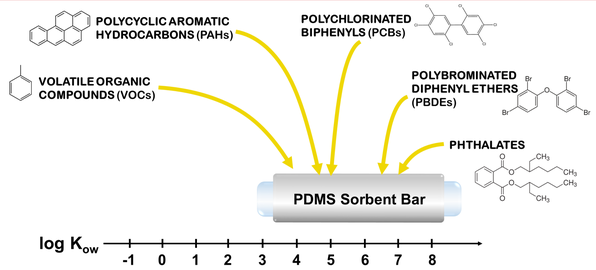

Figure 3. *The sorption properties of PDMS are proportional to the octanol water partitioning coefficient (log K_{ow}) of a compound.*

The Fresh Air Wristband

- The Fresh Air wristband was developed to profile personal organic air pollutant exposures. This sampling device consisted of a silicone wristband with a PTFE chamber which contained our fabricated non-polar sorbent bar. While the wristband was worn, pollutants were passively collected onto the sorbent bar (**Figure 4**).
- Follow the exposure assessment period, the sorbent bar was removed from the wristband and analyzed offline using TD (Gerstel)-GC (Agilent) coupled with a ToF-MS (Waters). The sorbent bars was heated to 250 ºC under a flow of He. Extracted compounds were cold trapped in split mode onto a glass wool liner cooled to -90 ºC prior to elution onto the GC. Analytes were separated with HP-5MS GC column (30m/0.25mm). The ToF-MS was operated in full span electron ionization mode (70 eV). Exposure concentrations were quantified using retention times and identifying ions.
- Nitrogen dioxide, a marker of tailpipe vehicle emissions, is also passively sampled with the Fresh Air wristband using a triethanolamine-coated pad (Ogawa). Nitrogen dioxide exposure concentrations were measured offline using colourmetric methods.

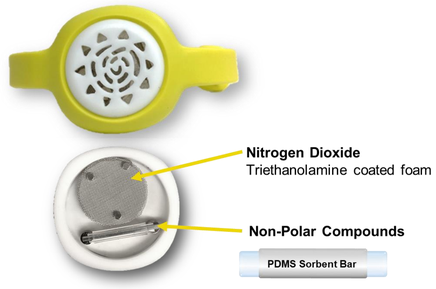

Figure 4. *Personal exposure to non-polar airborne chemicals and nitrogen dioxide can be assessed using passive sampling techniques with the Fresh Air wristband.*

Results

Capture and Repeatability

- Results for PAHs are highlighted.
- Linear uptake was found across a range of concentrations that were representative of ambient air levels (**Figure 5**).
- Low variation was observed across replicate sorbent bars that were directly infused with the PAH mixture or air loaded with PAHs in indoor cooking environment (**Figure 6**).

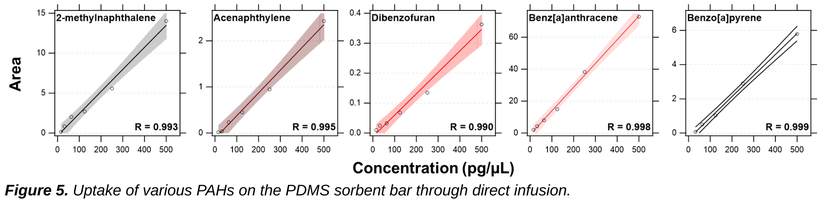

Figure 5. *Uptake of various PAHs on the PDMS sorbent bar through direct infusion.*

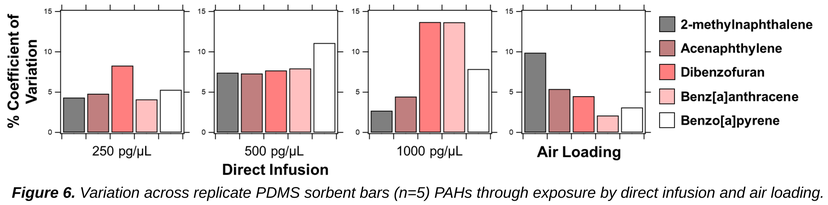

Figure 6. *Variation across replicate PDMS sorbent bars (n=5) PAHs through exposure by direct infusion and air loading.*

Results

Loading Duration and Storage

- PDMS sorbent bars were worn by individuals living in western MA. Following a 24 hour exposure period, PAHs were detectable on the PDMS sorbent bar (**Figure 7**).
- By comparing bars that were worn for 24 hours compared to 7 days by the same individual, lower molecular weight PAHs were closer to reaching equilibrium in the PDMS compared to heavier compounds (**Figure 8**).
- Lower molecular PAHs experienced losses during storage at room temperature compared to PDMS sorbent bars stored at 4 ºC (**Figure 9**).

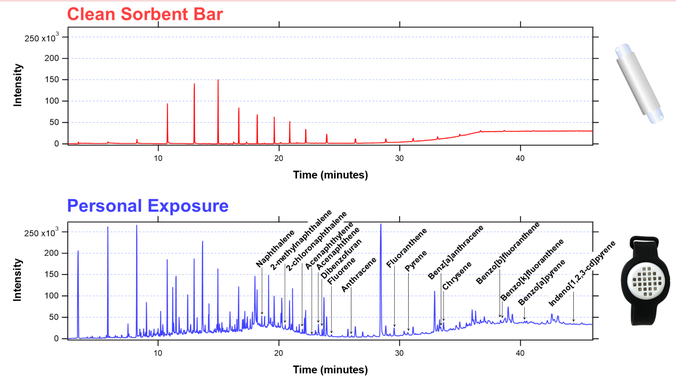

Figure 7. *GC-ToF MS total ion chromatograms of a clean PDMS sorbent bar (top) and a PDMS sorbent bar worn for 24 hours in the Fresh Air wristband (bottom). Observed peaks in the clean bar chromatogram were confirmed as siloxane. Peaks corresponded to PAHs are labeled for the personal exposure chromatogram.*

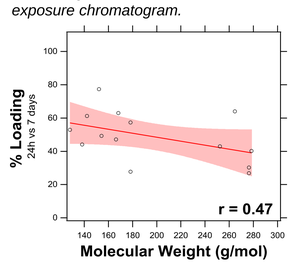

Figure 8. *Percent difference in PAH uptake on PDMS sorbent bars air loaded for 24 hours compared to 7 days.*

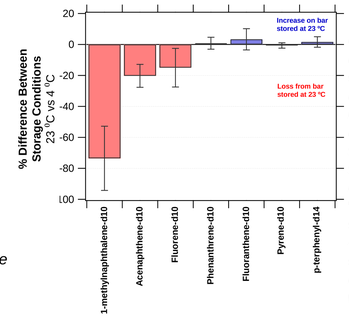

Figure 9. *Percent difference in PAH recovery on PDMS sorbent bars stored for 24 hours at 23 ºC compared to 4 ºC in order of increasing molecular weight.*

Application as a Personal Exposure Tool

- A cohort of children (n=36, aged 12-13 years) living in Springfield, MA which wore the Fresh Air wristband for 5 consecutive days.
- Children with asthma (n=12) were found to have elevated exposure to nitrogen dioxide and various combustion derived PAHs compared to children with no diagnosis of asthma **(Figure 10).**

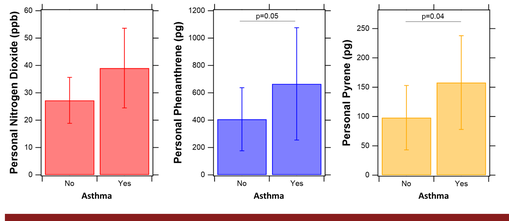

Figure 10. *Ambient air pollution is composed of many chemical compounds. Organic air pollutants include VOCs*

Conclusions

- A cost-effective wearable monitor was developed to enhance personal exposure assessment of sensitive population to air pollutant mixtures.
- Future work will focus on modifying the PDMS sorbent material to expand the sampling range to increasingly polar compounds.