Community-based environmental exposure assessment and personal monitoring

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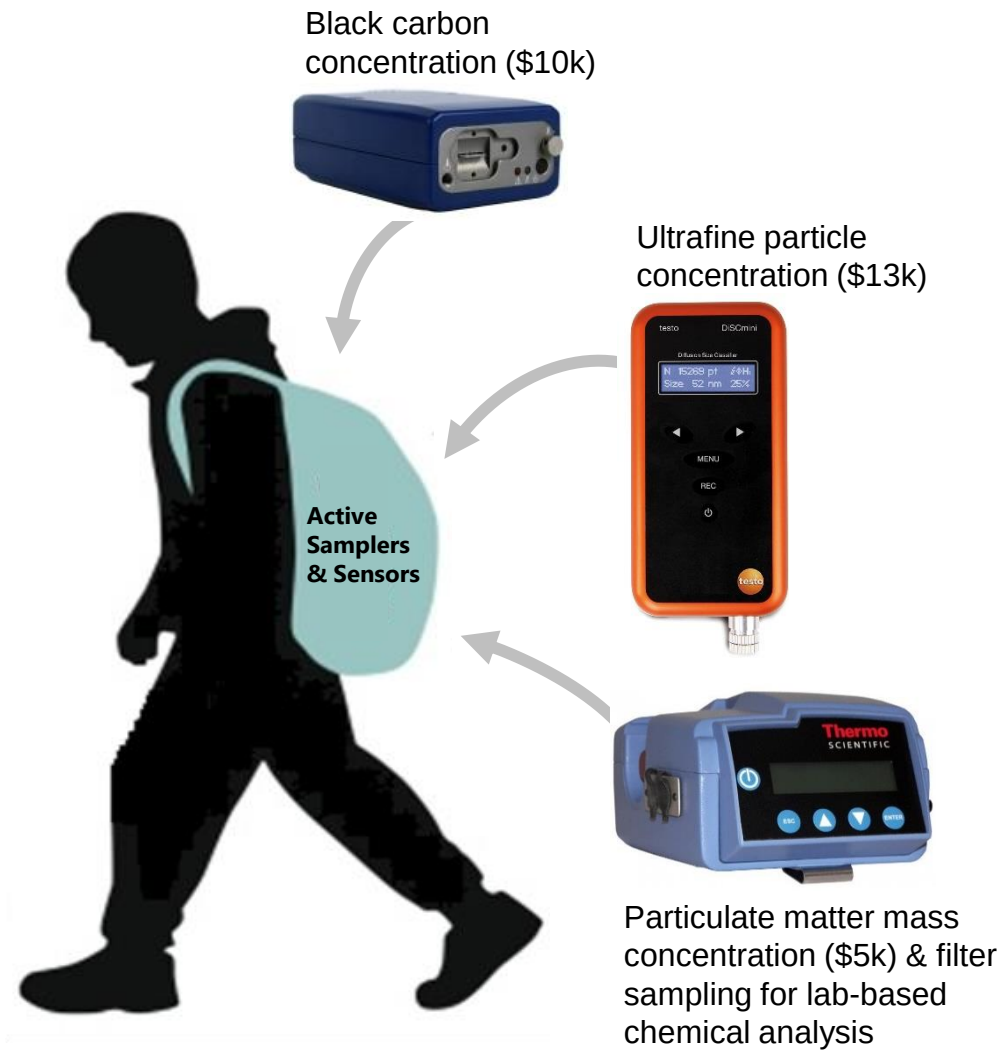
Exposure to air pollutants can be assessed using various tools

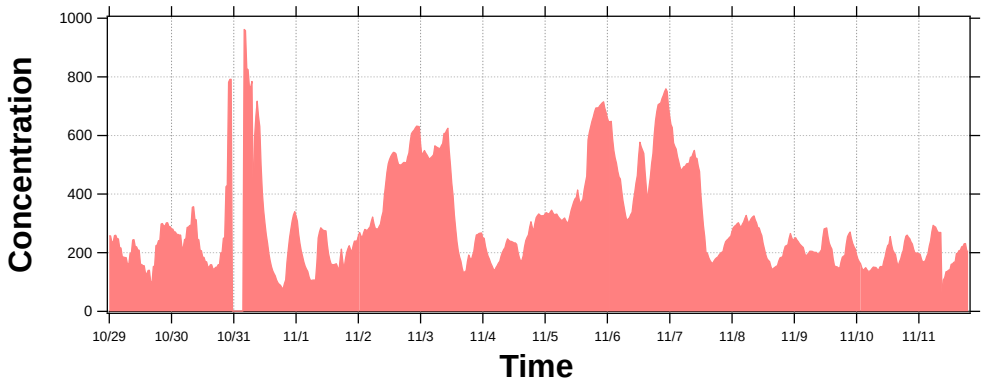
How can wearable monitors be adapted to support:

- Assessment of the cumulative impact of multiple pollutants
- Evaluation in overburdened communities
- Deployment in community-based studies

Challenges with available wearable technologies



High temporal resolution but one monitor = one air pollutant

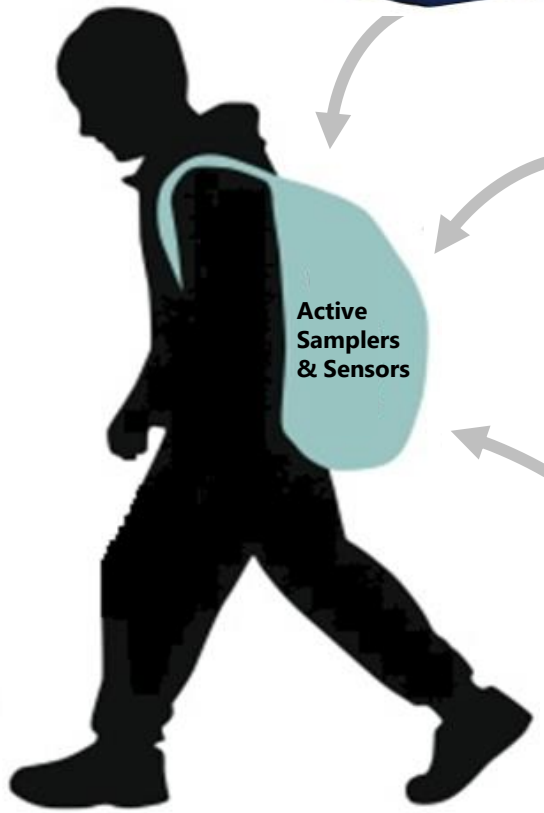


- Limited battery life
- Heavy
- High cost

Challenges with available technology

Black carbon concentration ($10k)

Ultrafine particle concentration ($13k)



Particulate matter mass concentration ($5k) & filter sampling for lab-based chemical analysis

Active Samplers

Active samplers contain three main components that increase their weight and cost.

Pump

Battery

Filter or sorbent material

Air pulled by a pump through a filter/sorbent or sensors

Taking a different approach to sampling air

Passive Samplers

Filter or Sorbent Material

Passive samplers are comprised of a filter or sorbent. Air pollutants are collected on these materials by diffusion; no air flow is required.

Eliminating the pump and battery of the active sampler improves the wearable across larger, more vulnerable populations.

Active Samplers

Active samplers contain three main components that increase their weight and cost.

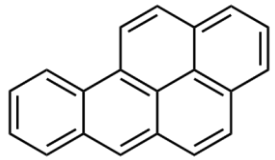
Pump

Battery

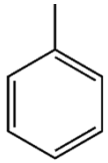
Filter or sorbent material

Air pulled by a pump through a filter/sorbent or sensors

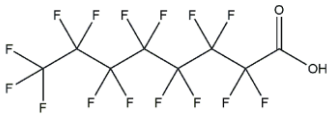
Passive sampling using silicone films



POLYCYCLIC AROMATIC HYDROCARBONS (PAHs)

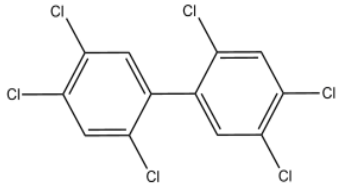


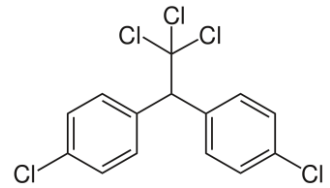
VOLATILE ORGANIC COMPOUNDS (VOCs)



PER-AND POLYFLUOROALKYL SUBSTANCES (PFAS)

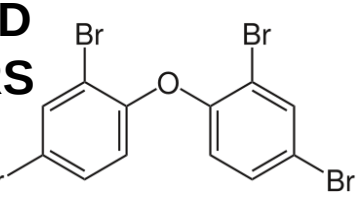
POLYCHLORINATED BIPHENYLS (PCBs)



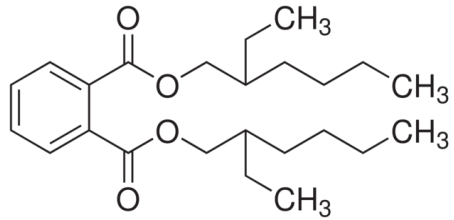


PESTICIDES

POLYBROMINATED DIPHENYL ETHERS (PBDEs)



PHTHALATES



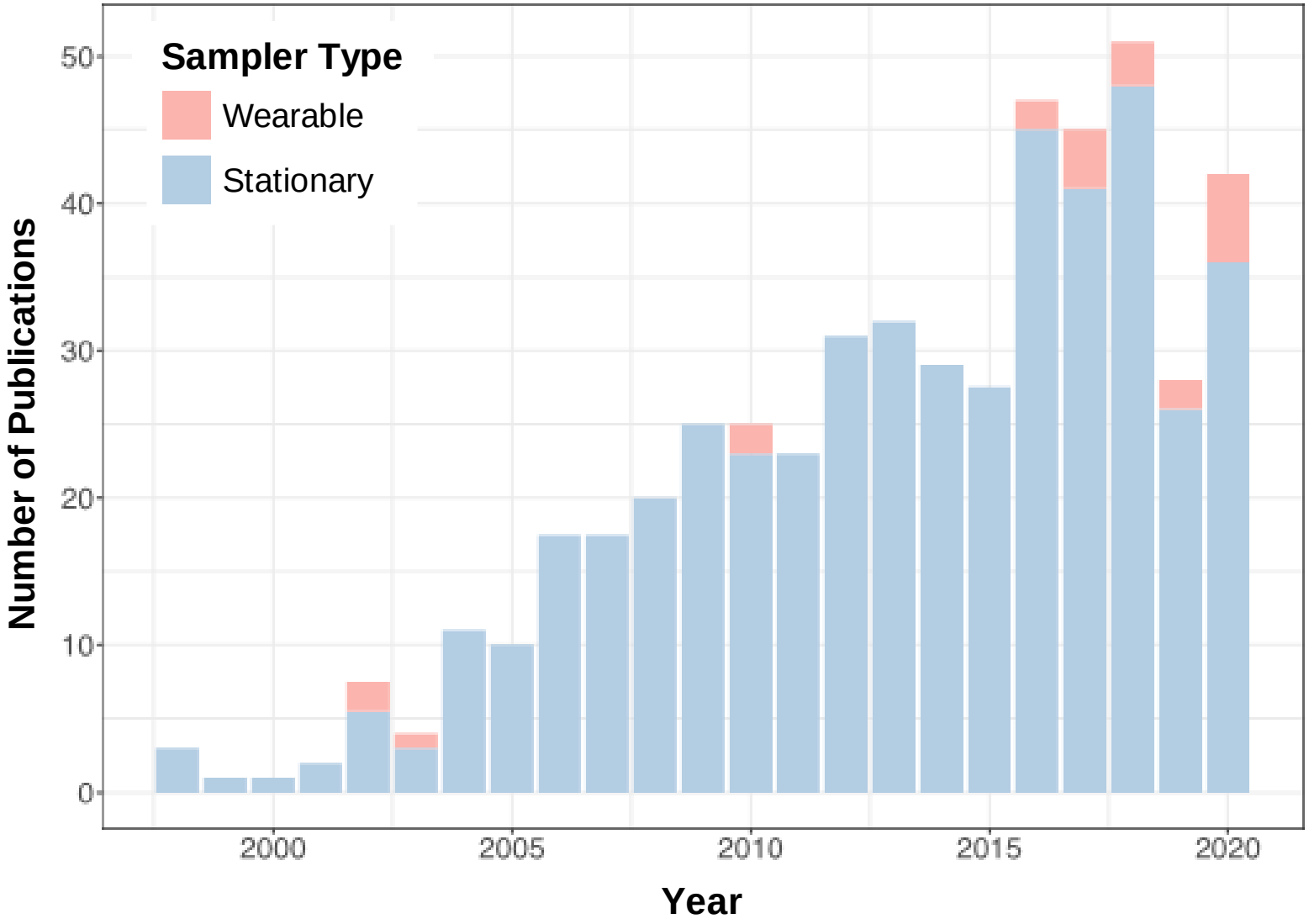
Sorption properties of PDMS are proportional to octanol air partitioning coefficient (log K_{oa})

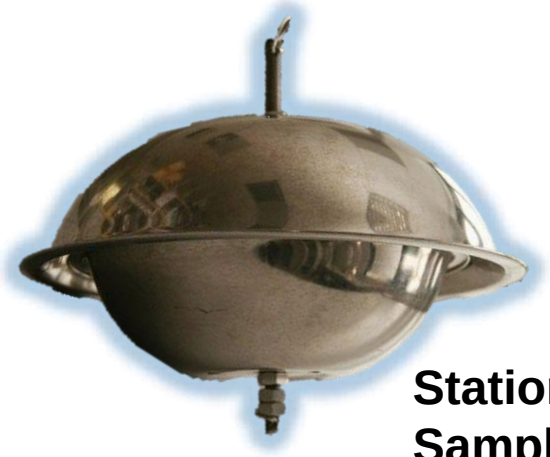
Polydimethylsiloxane (PDMS)

log K_{oa}

0 2 4 6 8 10 12 14

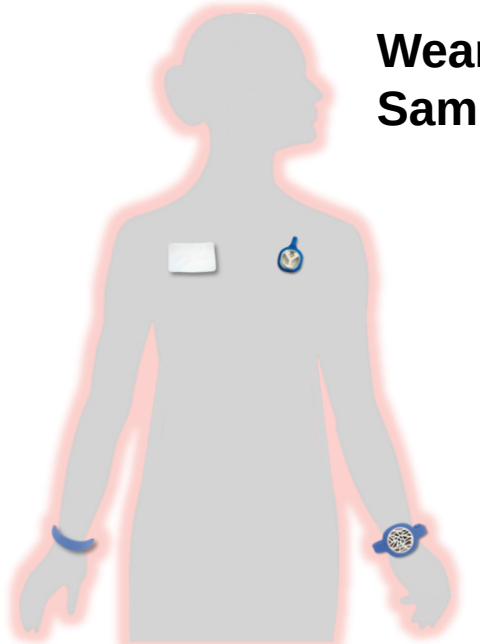
Passive samplers have a long history





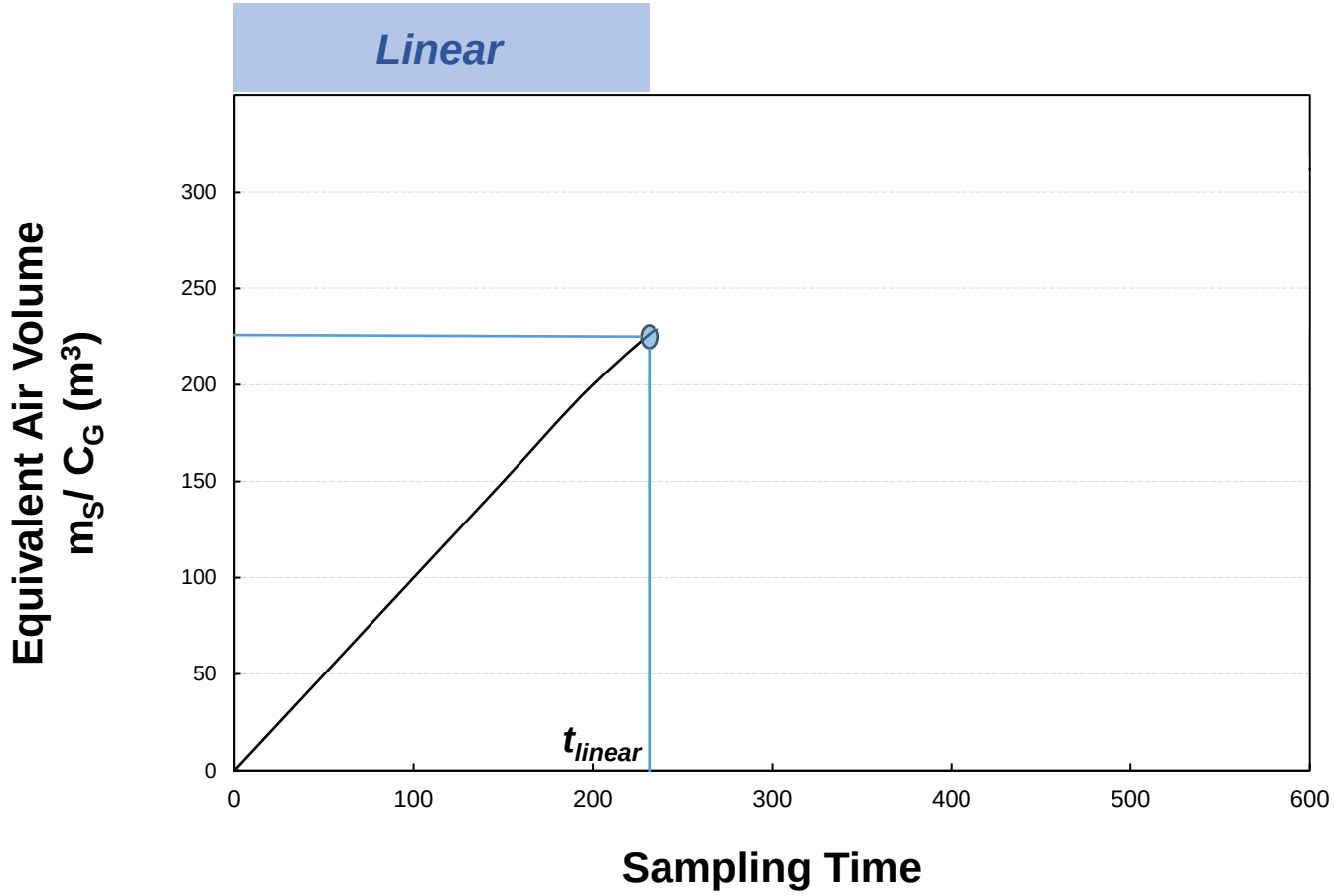
Stationary Samplers

Wearable Samplers



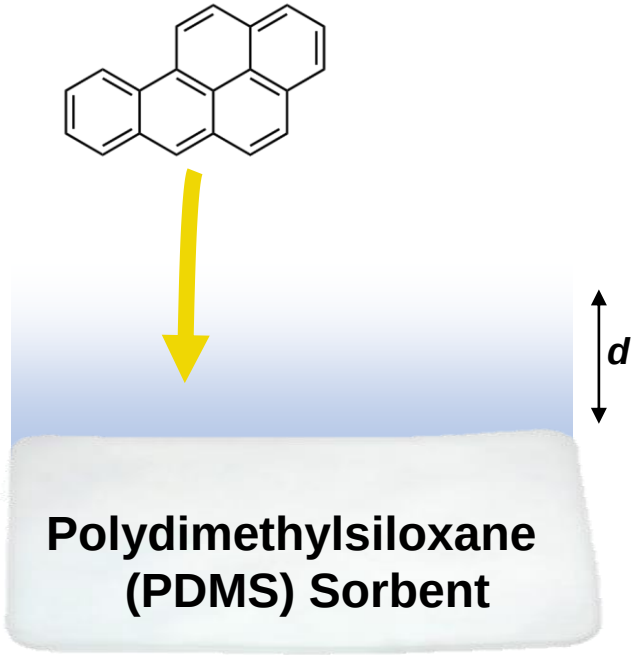
Okeme *et al.* (2023) *Current Enviro Health Reports*. 1-15.

Sampling Behaviour of Gas-Phase Contaminants by Passive Samplers

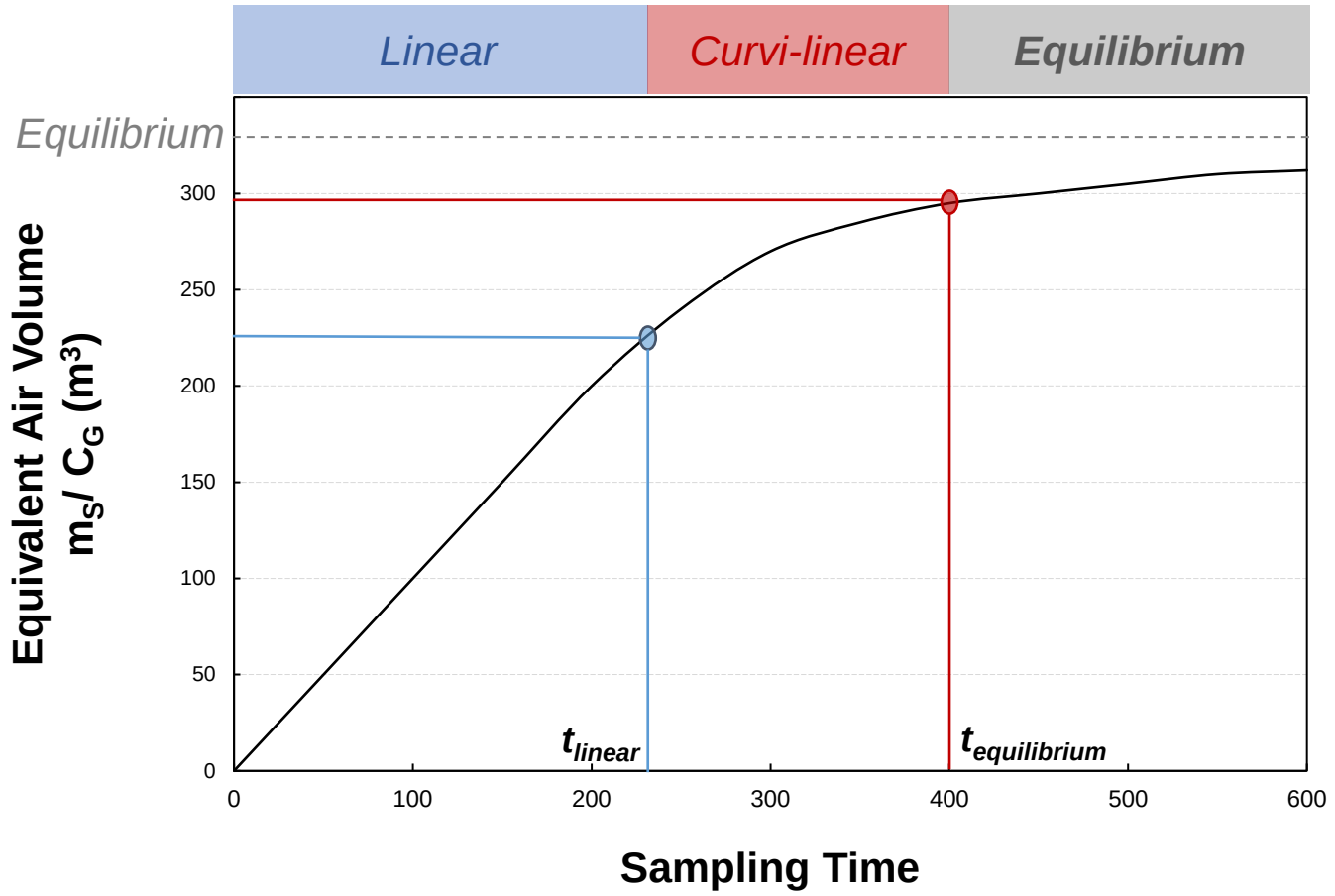


In the **linear phase**, chemical is taken up by a sorbent over time at a constant rate.

The uptake rate depends on the thickness of boundary layer (*d*) above the sorbent.

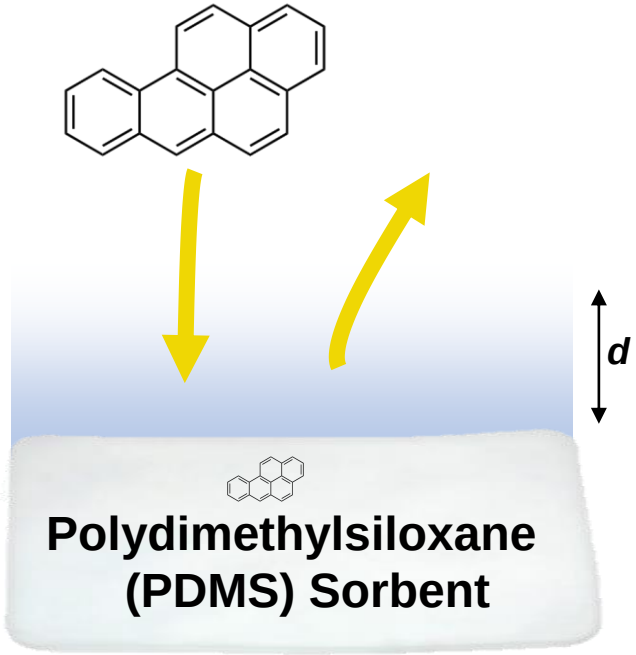


Sampling Behaviour of Gas-Phase Contaminants by Passive Samplers

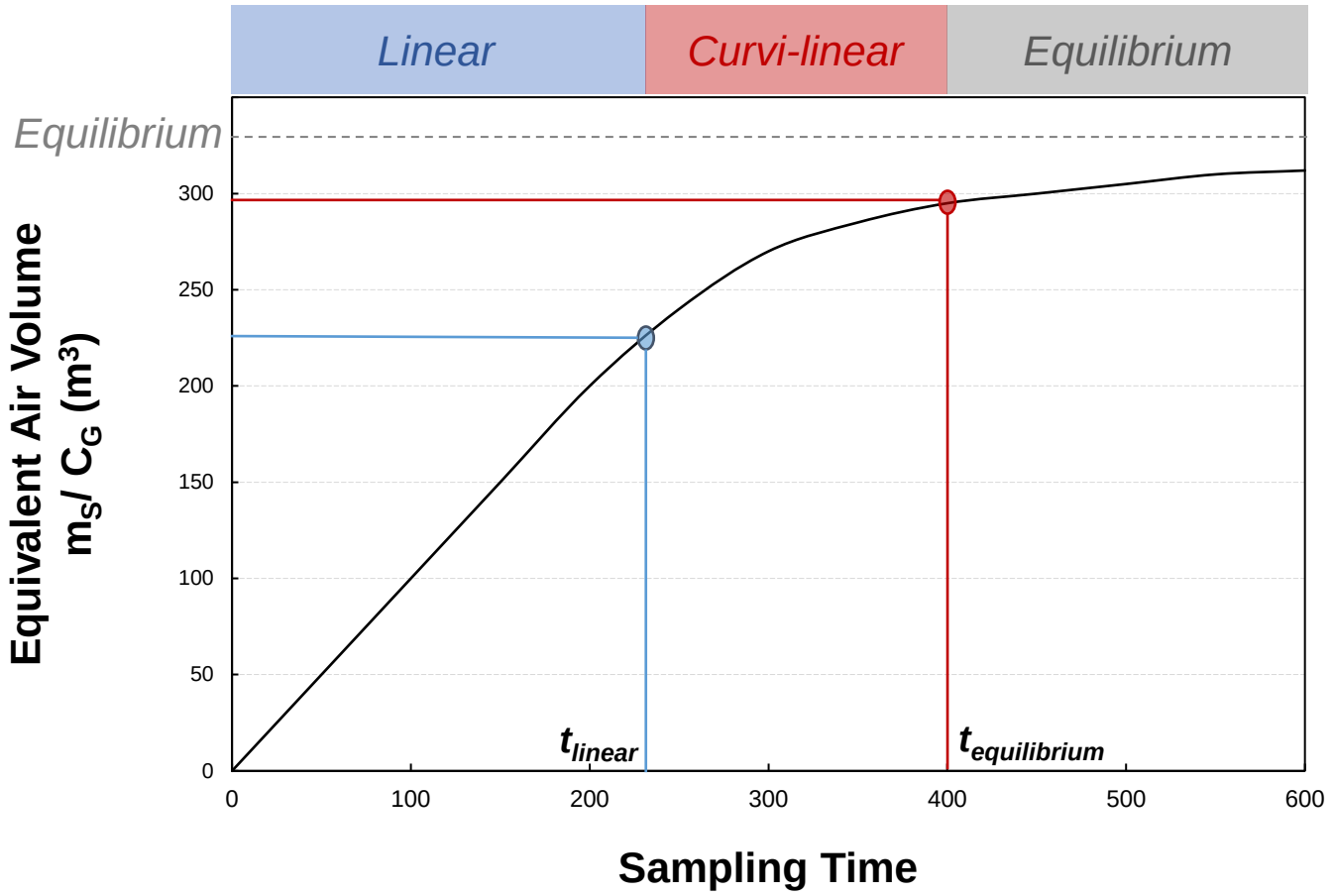


In the **equilibrium phase**, the uptake rate equals the loss rate.

This rate is controlled by the partitioning between the sorbent and air for the chemical.

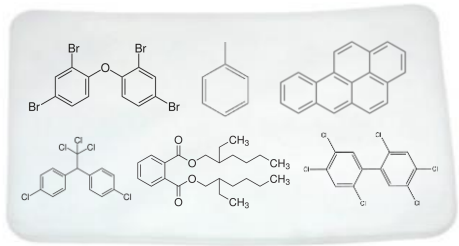


Sampling Behaviour of Gas-Phase Contaminants by Passive Samplers



Measurement of Contaminant Mass Loading
(pg/ sorbent mass)

Passive Sampler Sorbent

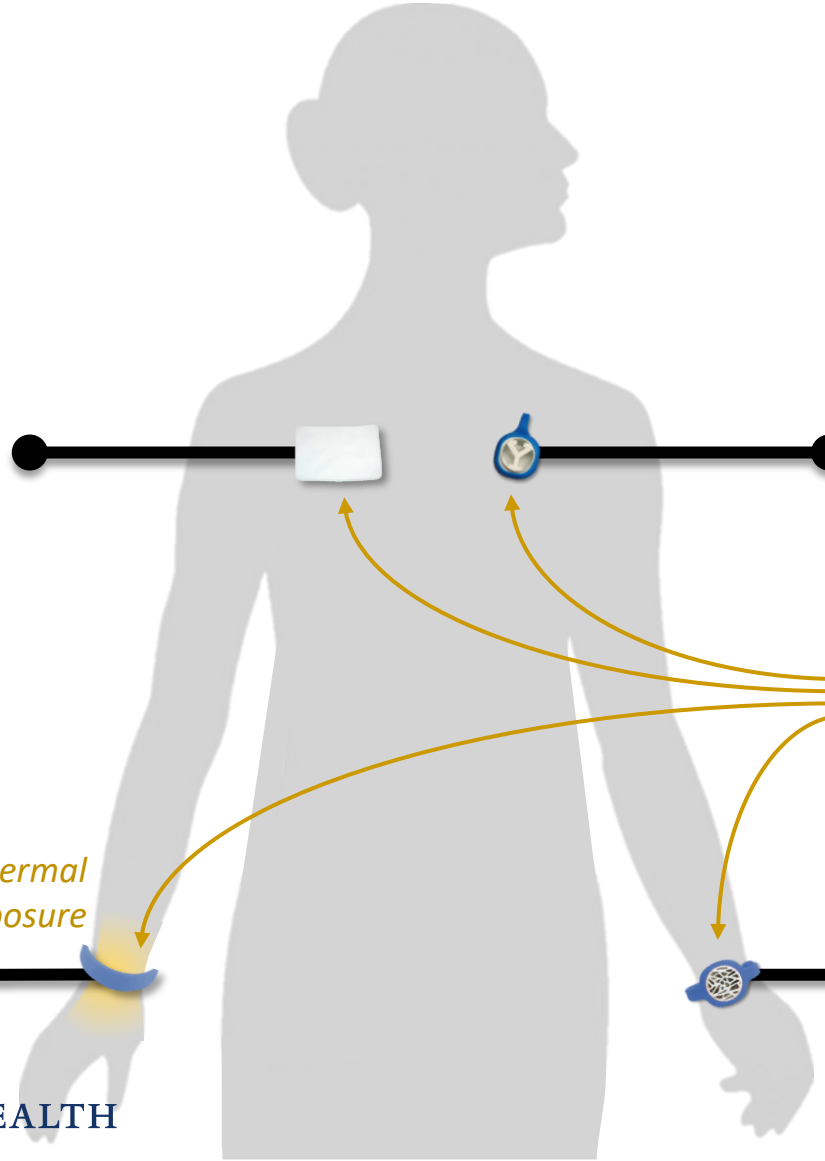


Conversion of Mass Loading to Air Concentration
(m^3/ day)

- **Linear**
  Uptake rate
- **Equilibrium**
  Equilibrium sorption coefficient

Contaminant Air Concentration
(pg/ m^3)

Wearable Passive Samplers



PDMS Badge/Brooch
Wang *et al.* 2019 Enviro. Int.

Fresh Air Clip
Angel *et al.* 2022 ES&T Letters
Lin *et al.* 2022 JESEE

Inhalation Exposure

Fresh Air Ankle band

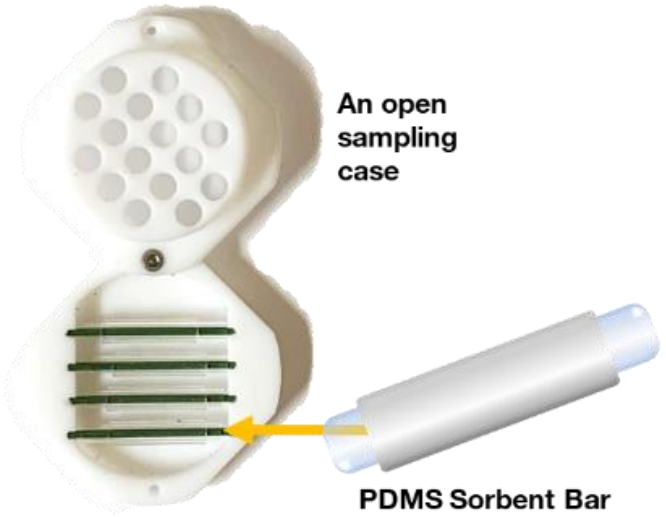
Dermal Exposure

Silicone Wristband
Anderson *et al.* 2017 JESEE
Hammel *et al.* 2016 ES&T

Fresh Air Wristband
Lin *et al.* 2020 ES&T Letters
Koelmel *et al.* 2021 Enviro Pol

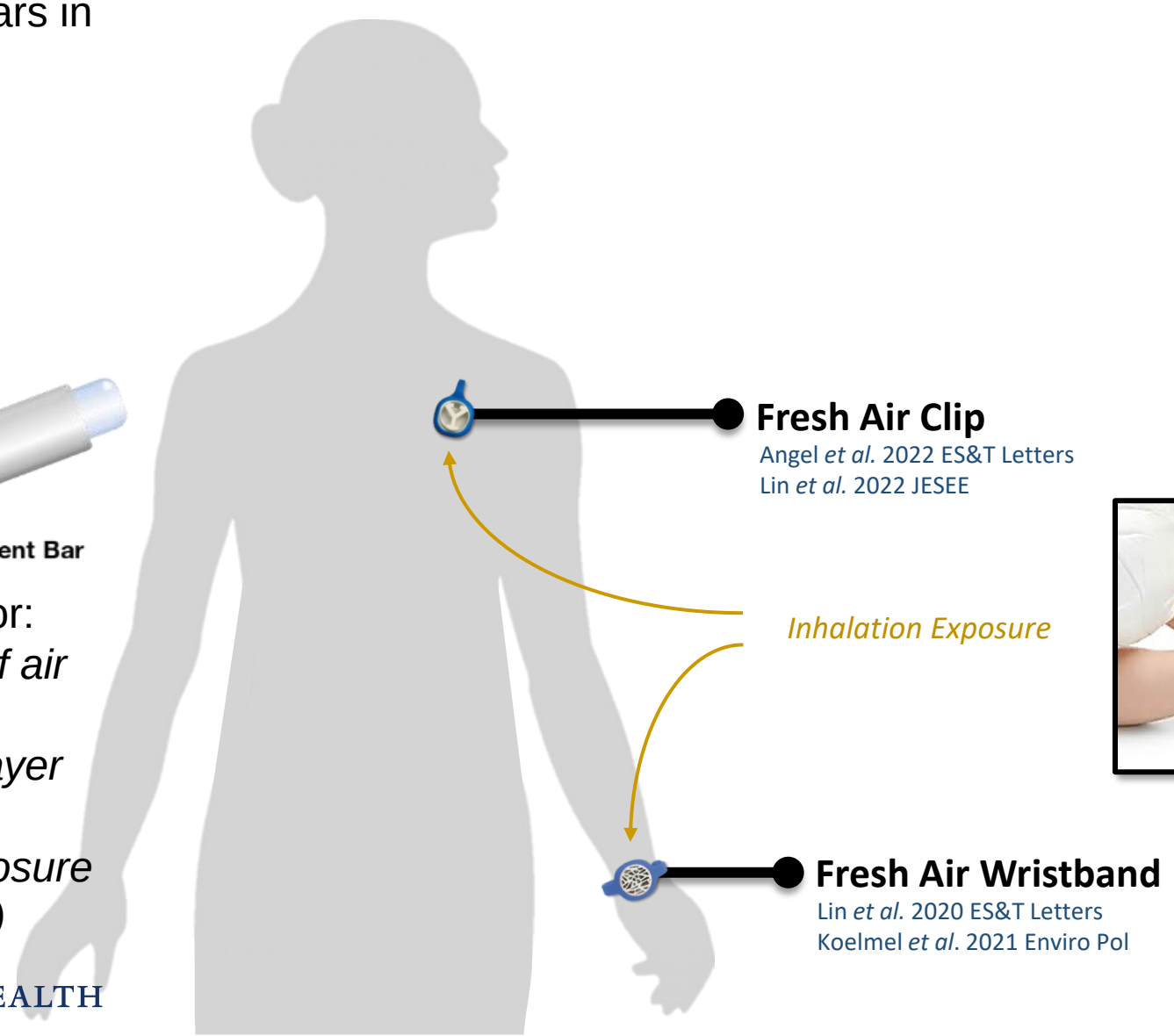
Wearable Passive Samplers

Fresh Air passive samplers mount PDMS sorbent bars in a perforated case.



Use of the case allows for:

1) *Exclusive sampling of air contaminants*
2) *Constant boundary layer over the sorbent*
3) *Quantification of exposure concentration (pg/m³)*



Fresh Air Clip

Angel *et al.* 2022 ES&T Letters
Lin *et al.* 2022 JESEE

Inhalation Exposure

Fresh Air Ankle band

Fresh Air Wristband

Lin *et al.* 2020 ES&T Letters
Koelmel *et al.* 2021 Enviro Pol

High Throughput Analysis for Chemical Assessment

1. Personal Sampling

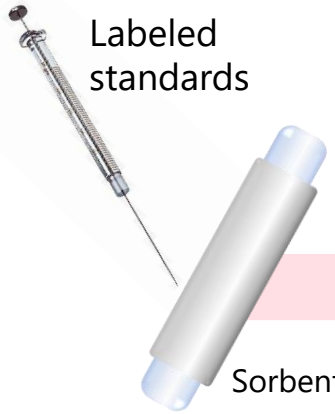
2. Sample preparation (thermal desorption)

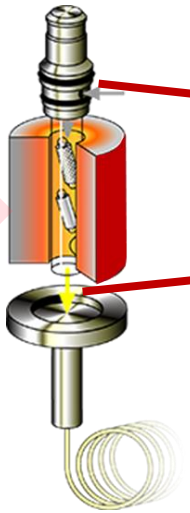
3. Separation by gas chromatography

4. Detection by high resolution Orbitrap mass spectrometry

5. Data processed for Exposure Assessment

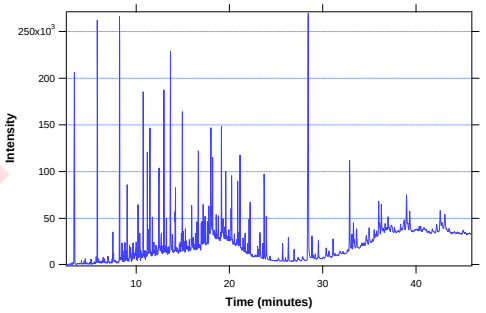
Wristband worn for 1-14 days





Thermal desorption (300 °C)

Q-Exactive GC Orbitrap MS



Lin *et al.* (2020) *ES&T Letters.* 7(5):308.

Thousands of Air Contaminants can be Detected

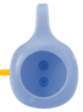
Koelmel *et al.* (2021) *ES&T*. 55(6):3796.

Air Sampling Kits for Personal and Community Exposure Assessment

Insulated Mailer Box
The kit is contained in an insulated shipping box.

Pre-Paid Shipping Label and Return Bag
Shipping label provided for participants to return the box to the study team.

Sample Jars
Six samplers are supplied in individual sealed jars. These samplers will be inserted by participants into clips or a band. A spare is provided in case of loss or damage. A blank is also included to monitor for contamination.

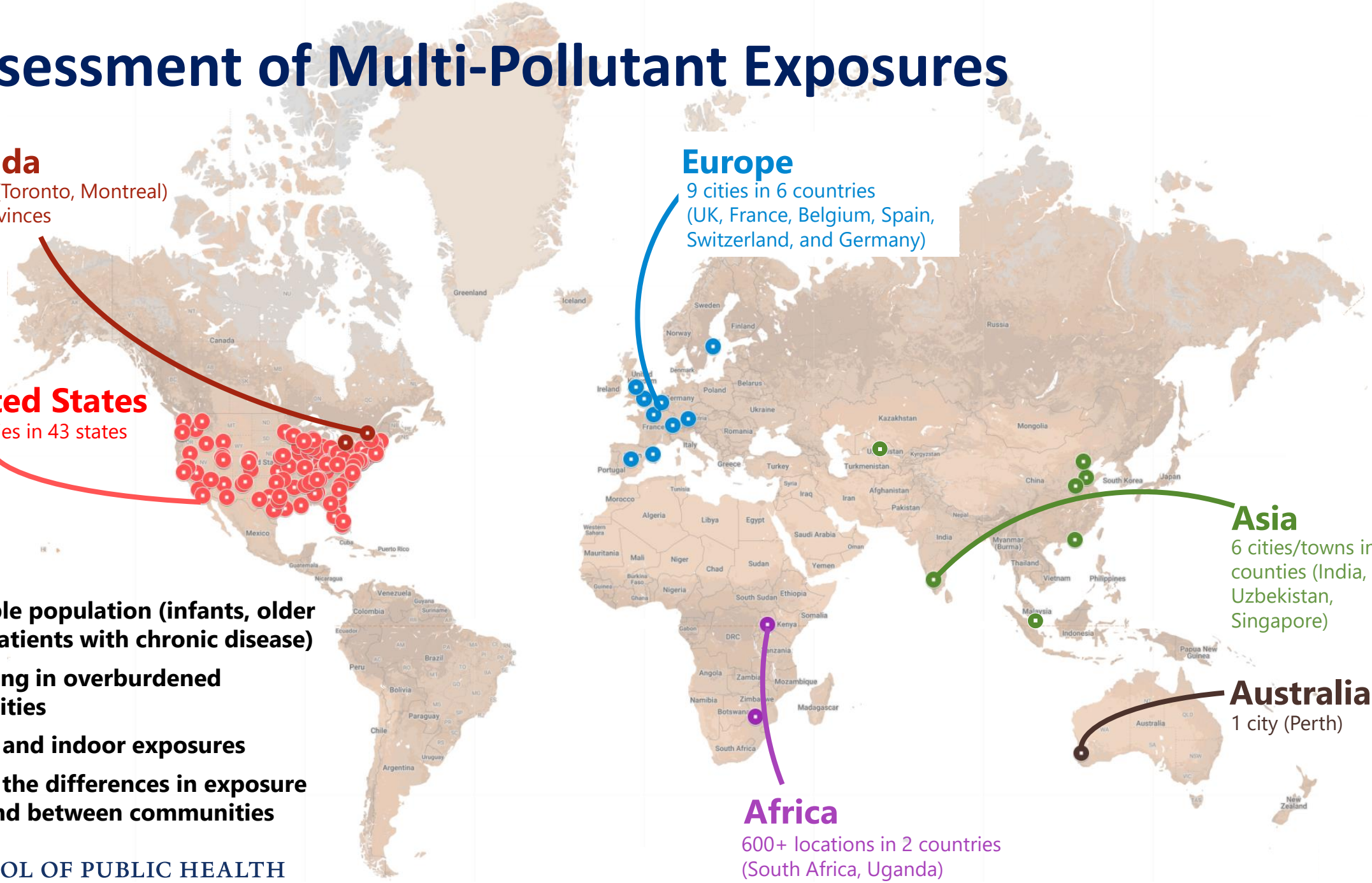


Clips
Four clips to hang samplers at fixed indoor and outdoor locations. One is provided as a back-up in case of damage/loss.

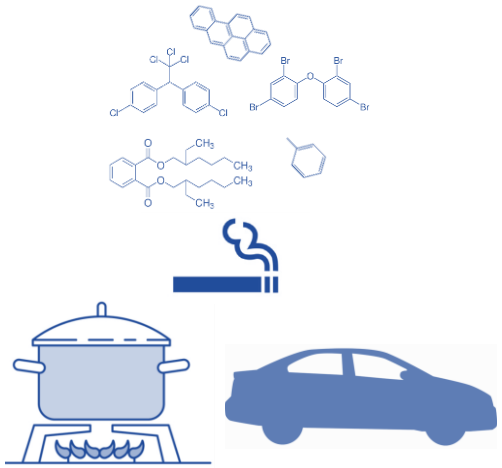
Wristband
Two (2) wristbands or ankle bands are supplied to wear. An extra band is provided in case of damage/loss.

Ice Packs
Four ice packs are included under the sample jars.

Assessment of Multi-Pollutant Exposures



- **Vulnerable population (infants, older adults, patients with chronic disease)**
- **Monitoring in overburdened communities**
- **Outdoor and indoor exposures**
- **Evaluate the differences in exposure within and between communities**



What is our **personal exposure** to air pollutants?

How do personal exposures vary over **time**?

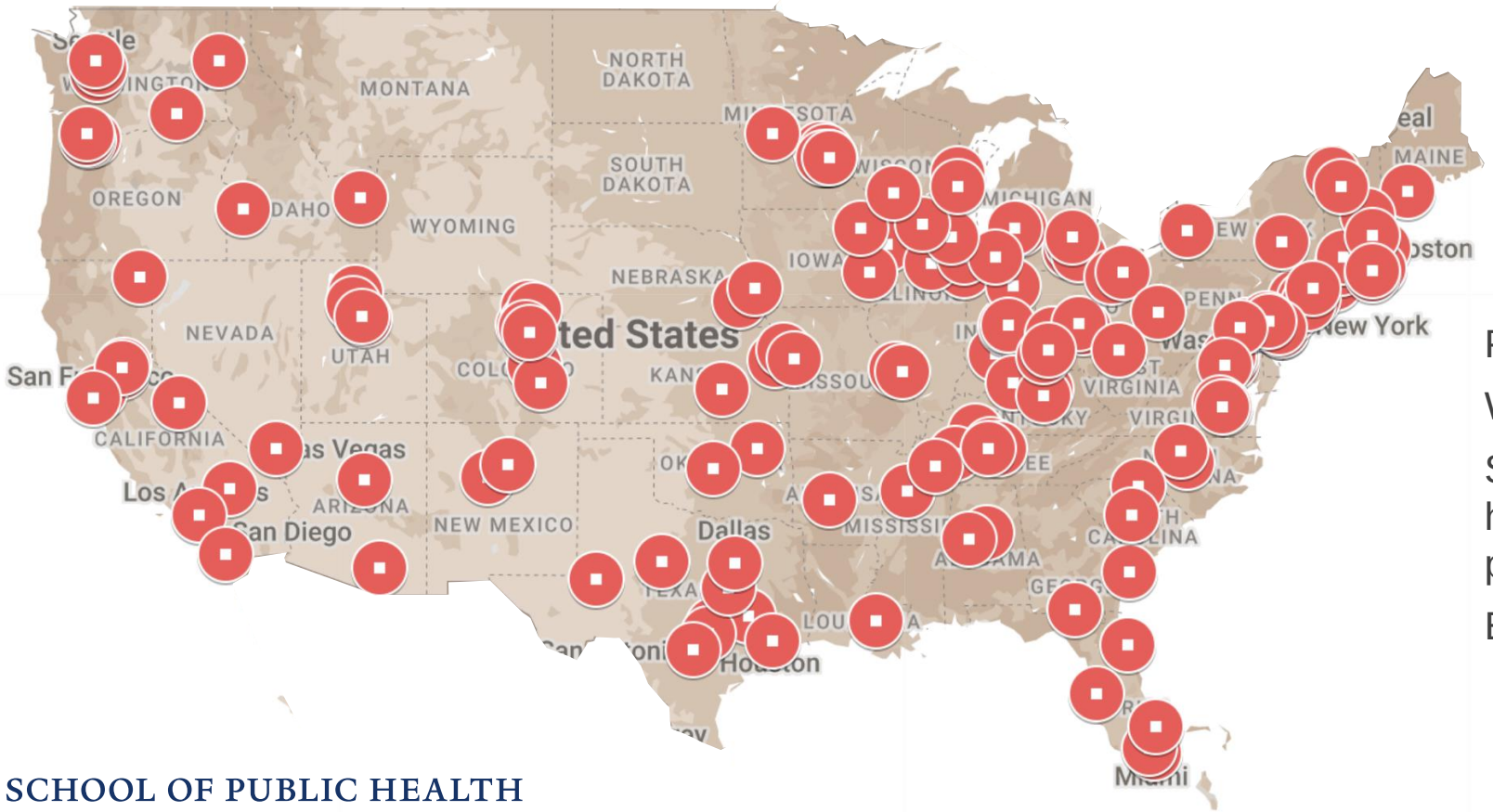
How do exposures vary across **communities**?

Monitoring personal airborne chemical exposures

PRESTO
BOSTON UNIVERSITY

Pregnancy Study Online (PRESTO), an internet-based preconception cohort study

- 139 female participants that were all trying to conceive
- Aged 21 to 45 years
- June to November 2021



Participants were from 39 states

Wristband worn for 5 days

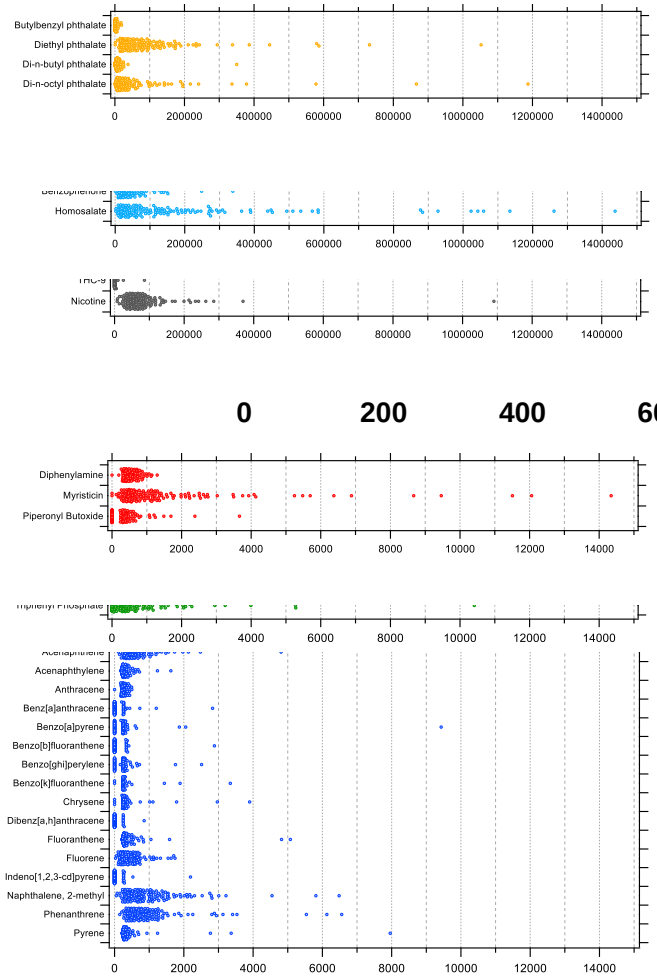
Self-reported questionnaire detailing household characteristics and activity patterns

Exposure report back to participants

Wide range of airborne exposures identified

490 unique chemical exposures identified

118 cosmetics
79 food-related
62 flavorants
35 pharmaceuticals
17 combustion products
15 pesticides
4 antimicrobials
3 smoking-related



Phthalates
77%
100%
100%
100%

Cosmetics
100%
100%

Smoking-related
15%
100%

Pesticides
99%
100%

Flame Retardants
56%
74%

Combustion -related
100%
100%
100%
100%
19%
60%
9%
100%
100%
6%
100%
100%
8%
100%
100%
100%

Detection Frequency

0 200 400 600 800 1000 1200 1400

0 2 4 6 8 10 12 14

Concentration (ng/m³)

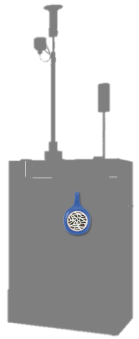
BOSTON UNIVERSITY

Yale SCHOOL OF PUBLIC HEALTH

Wristbands can be used to capture exposures over time…

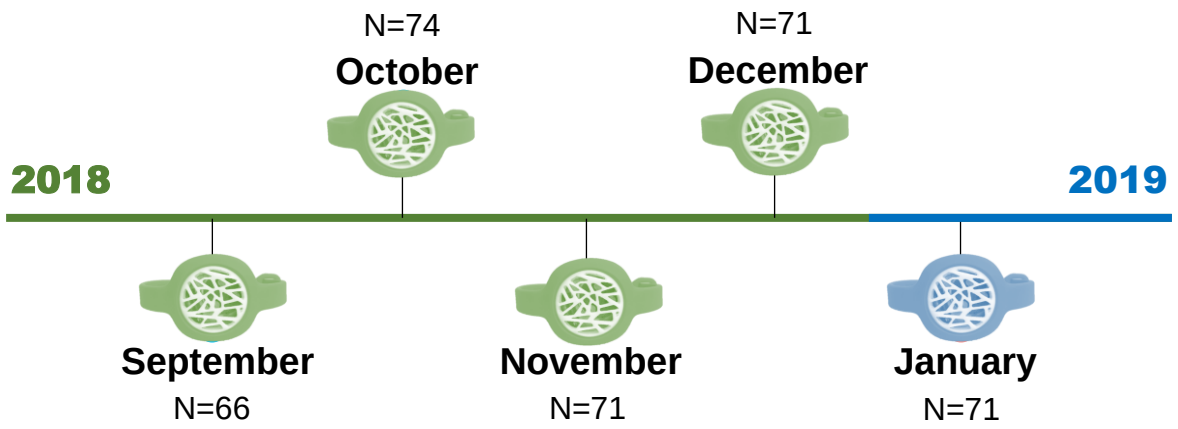
3 days

Personal Monitoring



3 days

Outdoor Monitoring



Parallel outdoor air sampling was conducted over the study period.

Jinan, China
Adults (60-69 years)

Biomarkers of **A**ir **P**ollutants **E**xposure (**China BAPE**) Study

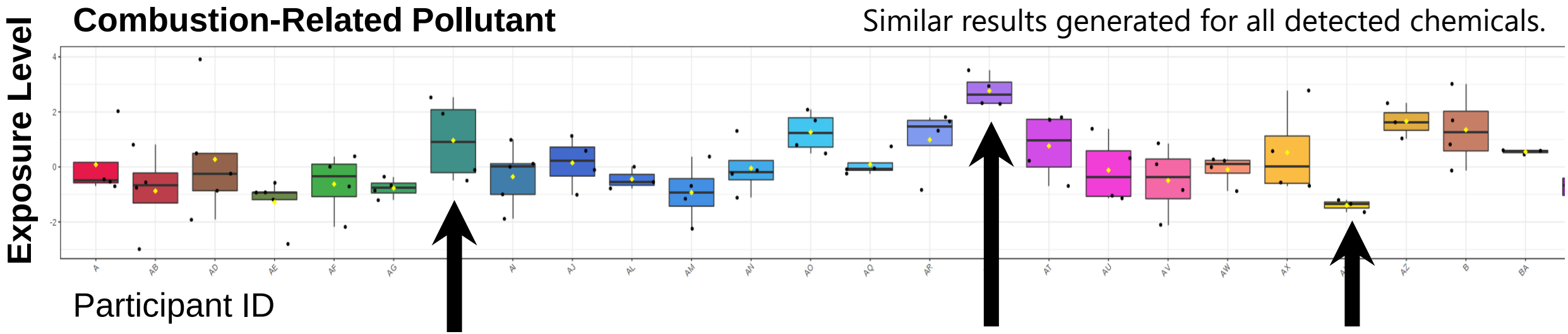
Guo *et al.* (2021) *Environment International*. 156:106709.
Koelmel *et al.* (2021) *Environmental Pollution.* 270:116228.
Shi *et al*. (2022) *Environment International*. 170:107614.

…to reveal unique exposure profiles

615 chemical exposures detected

Each bar shows 5 repeat exposures for one participant across 5 months.

Similar results generated for all detected chemicals.



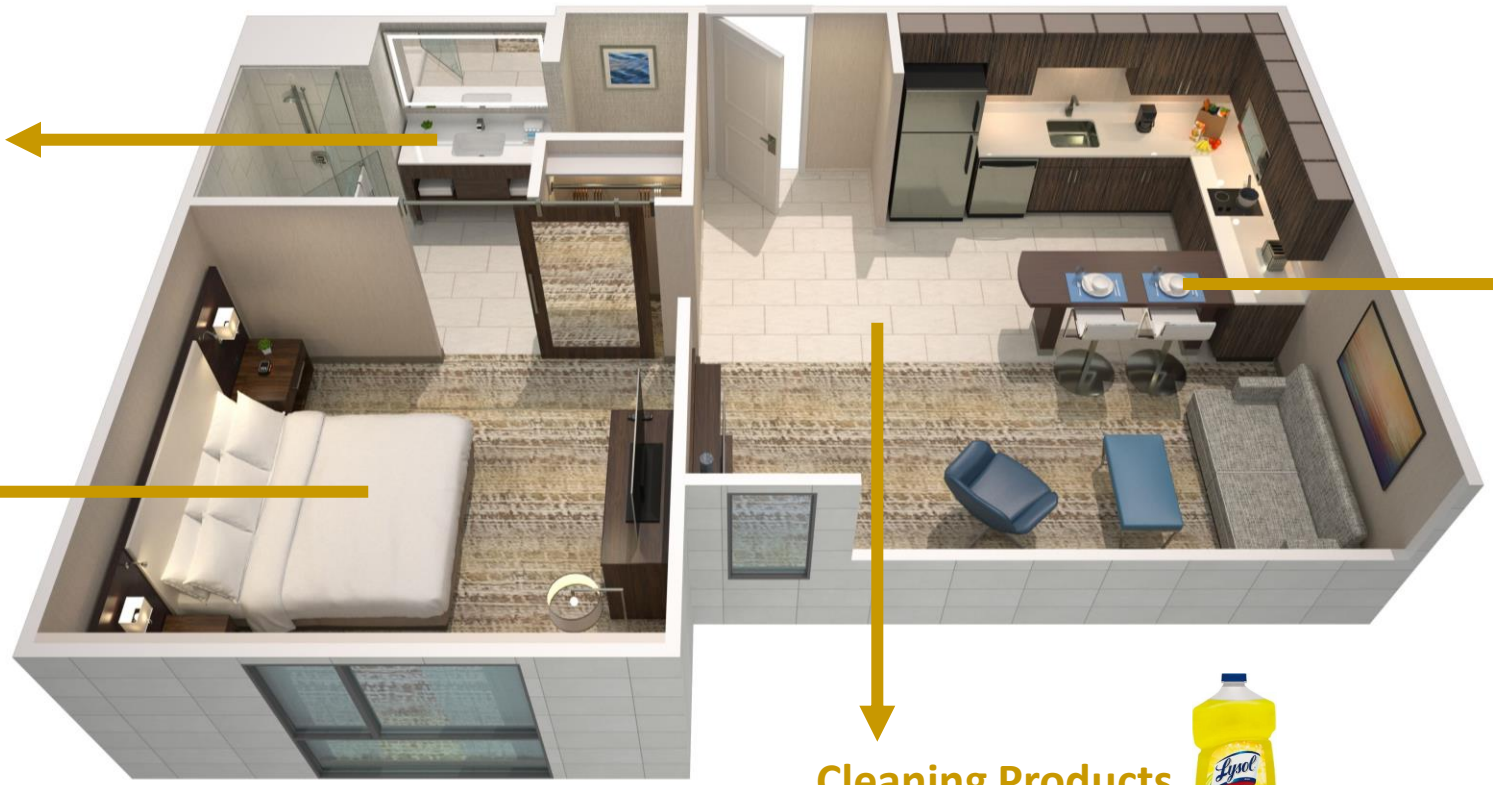
Participant with a range of exposures.

Participant with consistently HIGH exposure.

Participant with consistently LOW exposure.

Evaluation of personal exposures over time

Personal Care Products



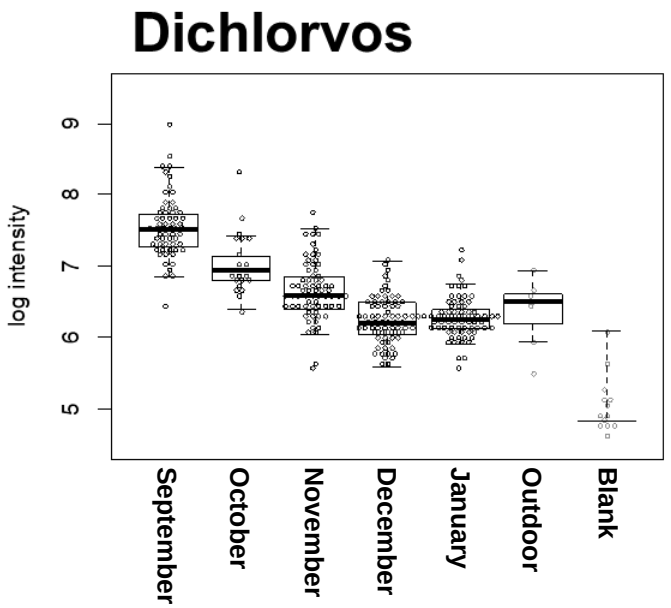
Food Preservatives

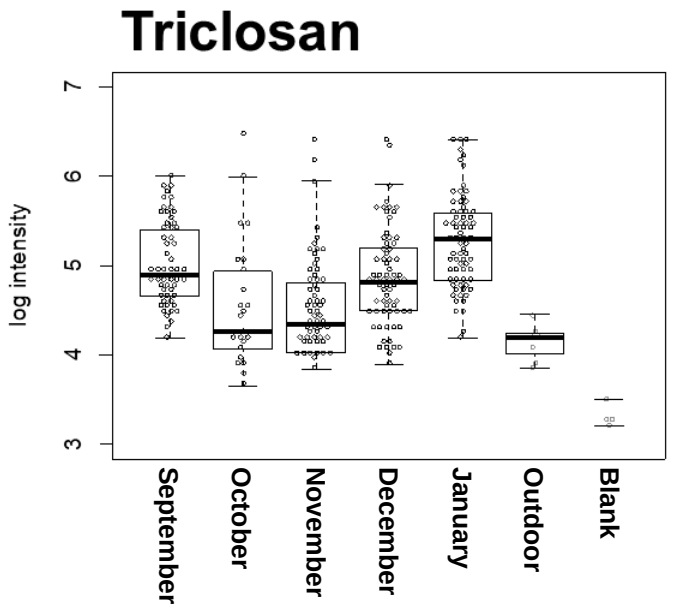
Pest Control

Cleaning Products

Seasonal Use

Insecticide



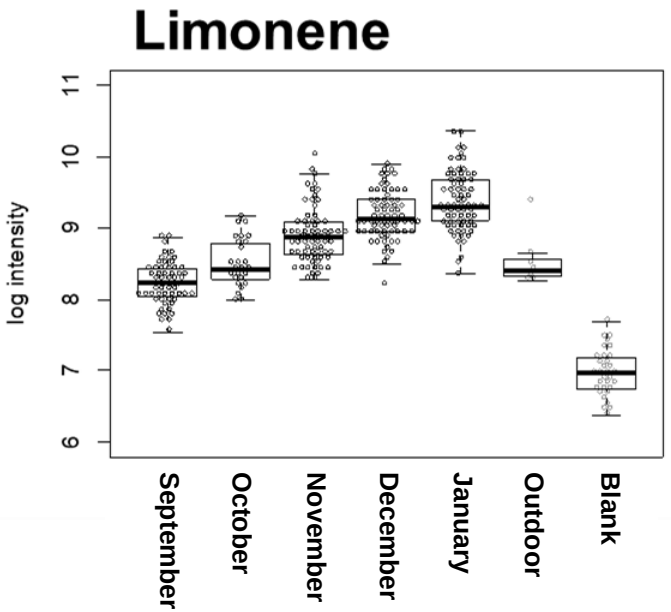


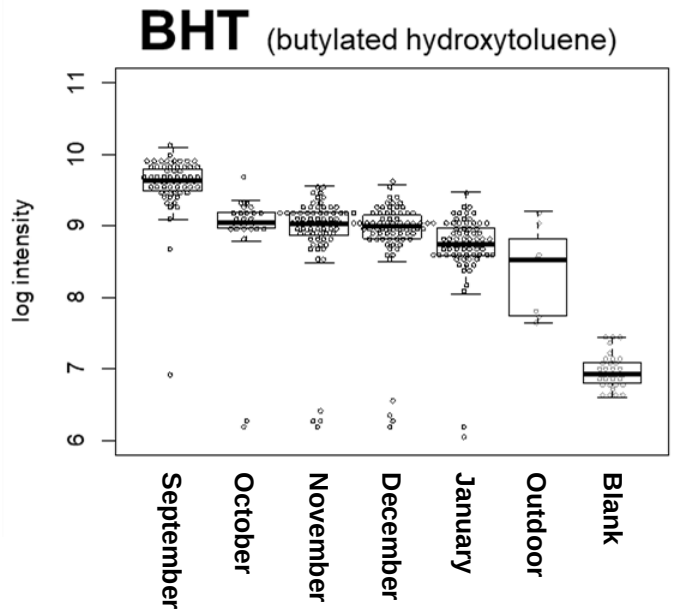
No temporal variance

Personal Care Products

Indoor sources

Food, cleaning products





Food preservative

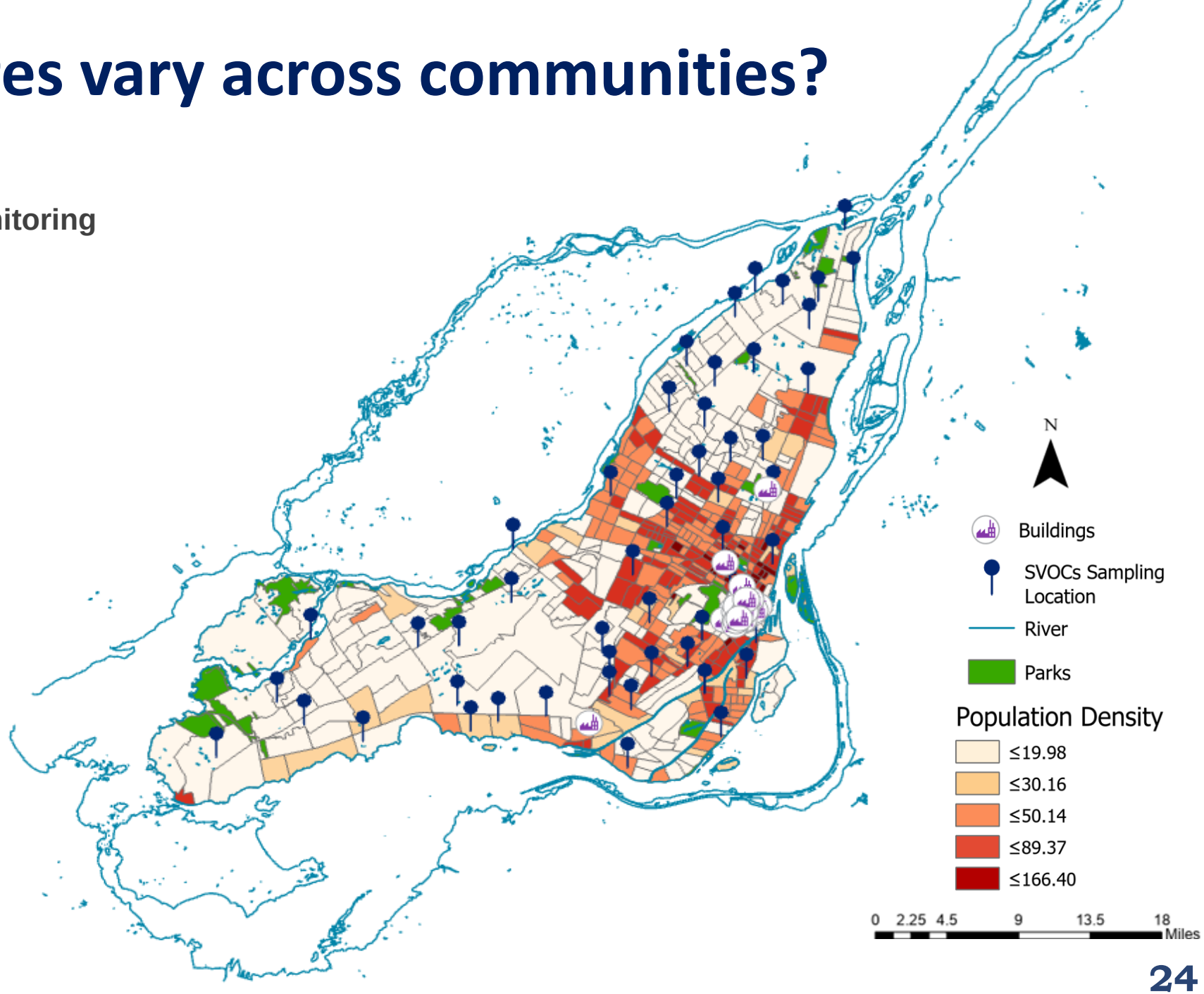
Koelmel *et al.* (2021) *Environmental Pollution.* 270:116228.

How do exposures vary across communities?

McGill

Community-based Stationary Monitoring

- Montreal, Canada
- 2-week exposure assessment
- 50 sites
- July 2021



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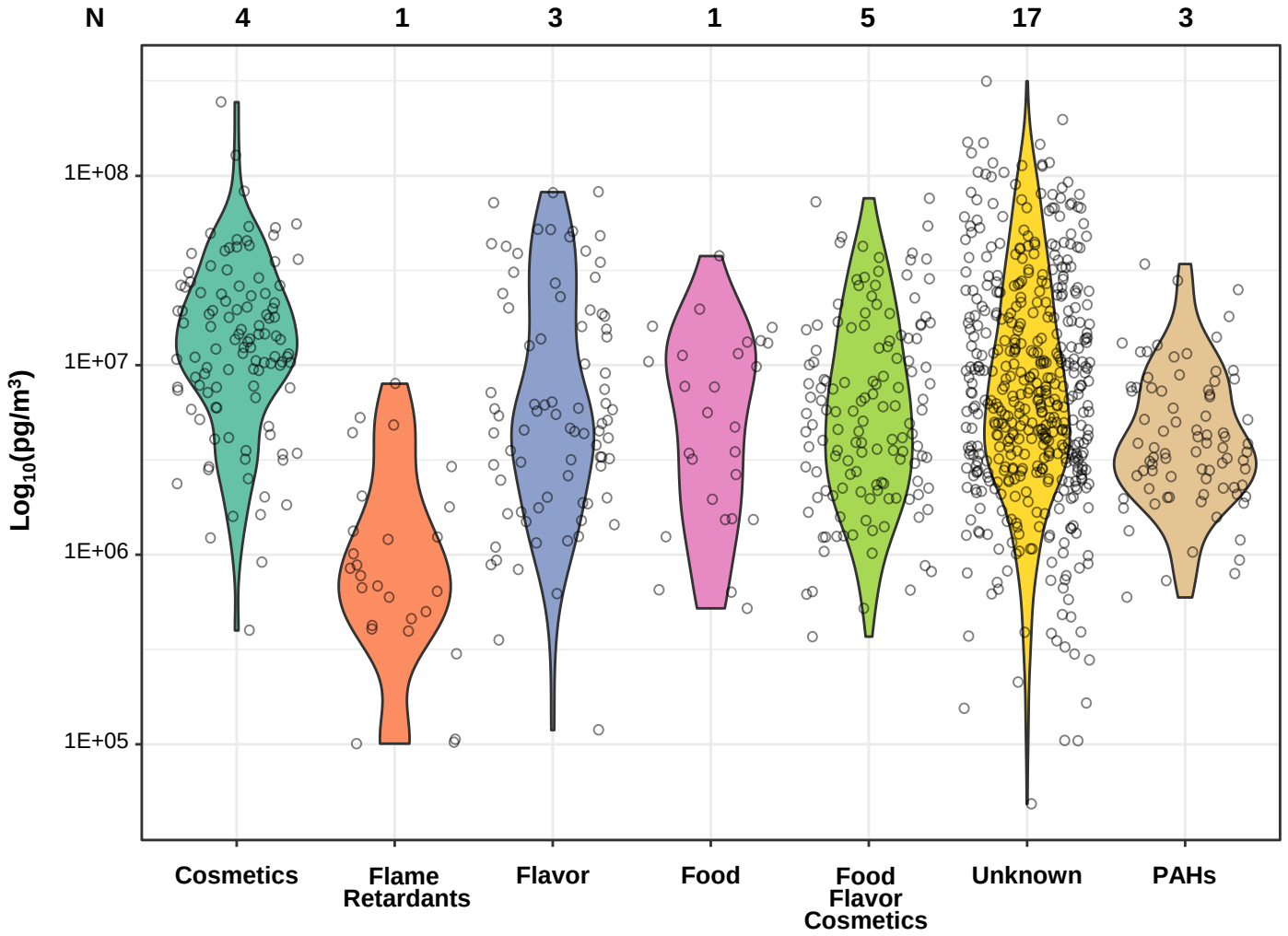
Diverse mixture of chemicals in outdoor air

McGill

Community-based Stationary Monitoring

- Montreal, Canada
- 2-week exposure assessment
- 50 sites
- July 2021

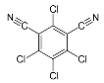
330 chemical exposures detected in outdoor air



165 chemicals with known chemical use categories

Spatial variation of airborne contaminants

Chlorothalonil

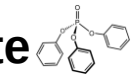


Pesticide

Agricultural and horticultural applications

Use was banned in Montreal as of Jan 1, 2022

Triphenyl phosphate



Organophosphate flame retardant

Fire Protection Fluid

Building materials

Electronics

Plasticizer

McGill

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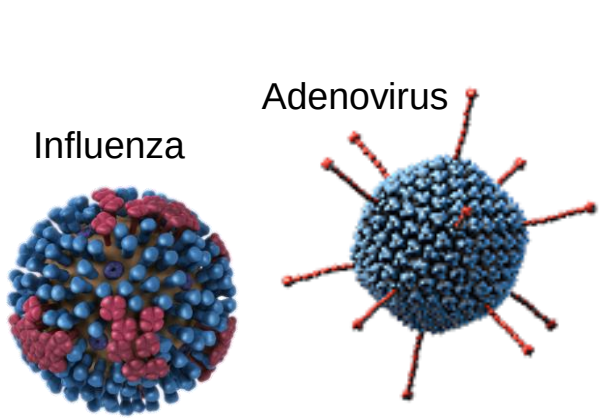
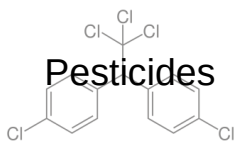
Wearable passive samplers as exposomic tools for comprehensive assessment of airborne chemicals *and* biological contaminants

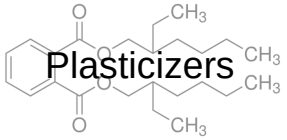


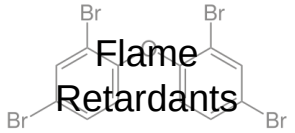
Respiratory Viruses

Fresh Air Samplers

Airborne Chemicals
Gases *and* Particles





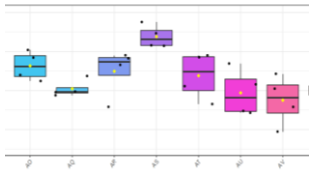


+ Metals
+ Microplastics

Summary

Wearable passive samplers are emerging tools for **personal exposure** assessment to air pollutants. These samplers enable detection of **multipollutant mixtures** (chemical, biological), which can include both known and previously unknown environmental contaminants.

Samplers can be deployed across large populations to assess exposures of **vulnerable populations** in **overburden communities** to capture dense snapshots of **outdoor and indoor** air pollutant exposures.



Integration of the air pollutant exposure data captured by these samplers with other omic data (e.g., metabolomic, lipidomic) presents exciting opportunities for investigating **disease risk factors**.

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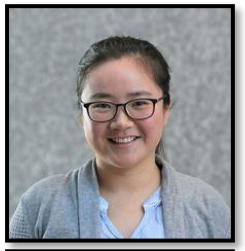

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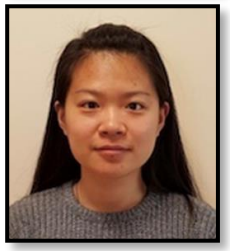

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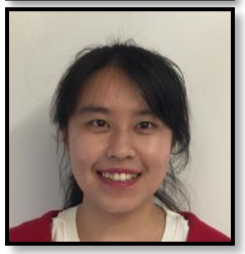

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