Airborne Microplastics and PFAS: Distribution and Partitioning in Northern New Jersey

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Outline

- **Introduction**
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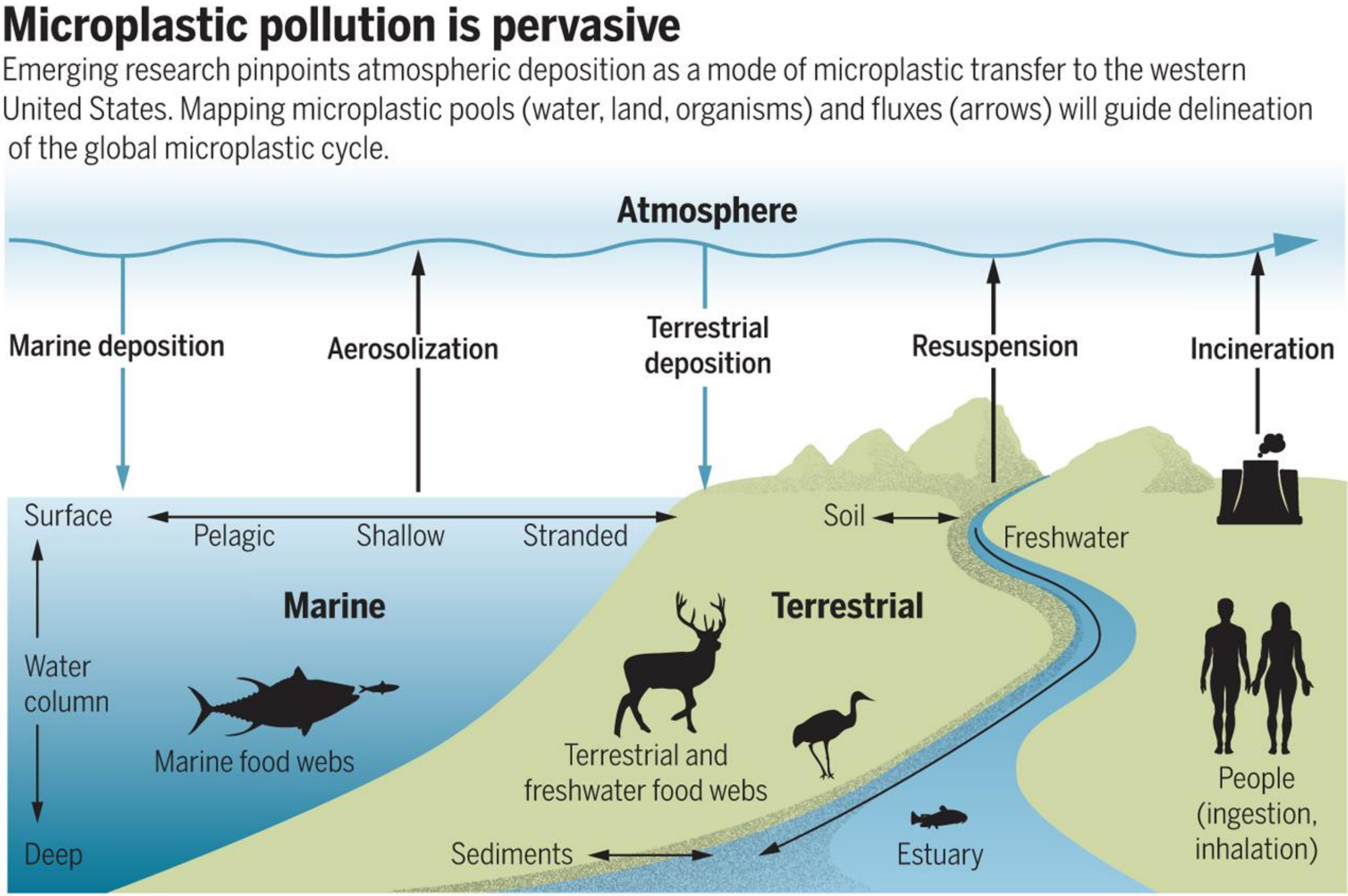
  - **Project #2:** Distributions and deposition rates of airborne PFAS in ambient air of Northern New Jersey
- **Conclusions, Challenges, and Perspectives**
- **Acknowledgement**

Introduction: Why Airborne Microplastics and PFAS Matter?



(Rochman and Hoellein, 2020)

- **Widespread distribution of emerging contaminants** becoming part of the global **geophysical–chemical cycles**.
- Long-range atmospheric transport leading to localized environmental contamination;
- Pose risks to ecosystems and potentially enter the food chain and inhaled or ingested by animals or human (Trowbridge et al., 2020).
- Potential carrier-pollutant interactions (Brahney et al., 2021).

Project #1: Characterization of Microplastics in Indoor and Ambient Air in Northern New Jersey

This study characterized the spatial distribution of airborne microplastics in indoor and ambient air in the Newark urban area. This research has been published on Environmental Research (Yao et al., 2022).

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Characterization of microplastics in indoor and ambient air in northern New Jersey

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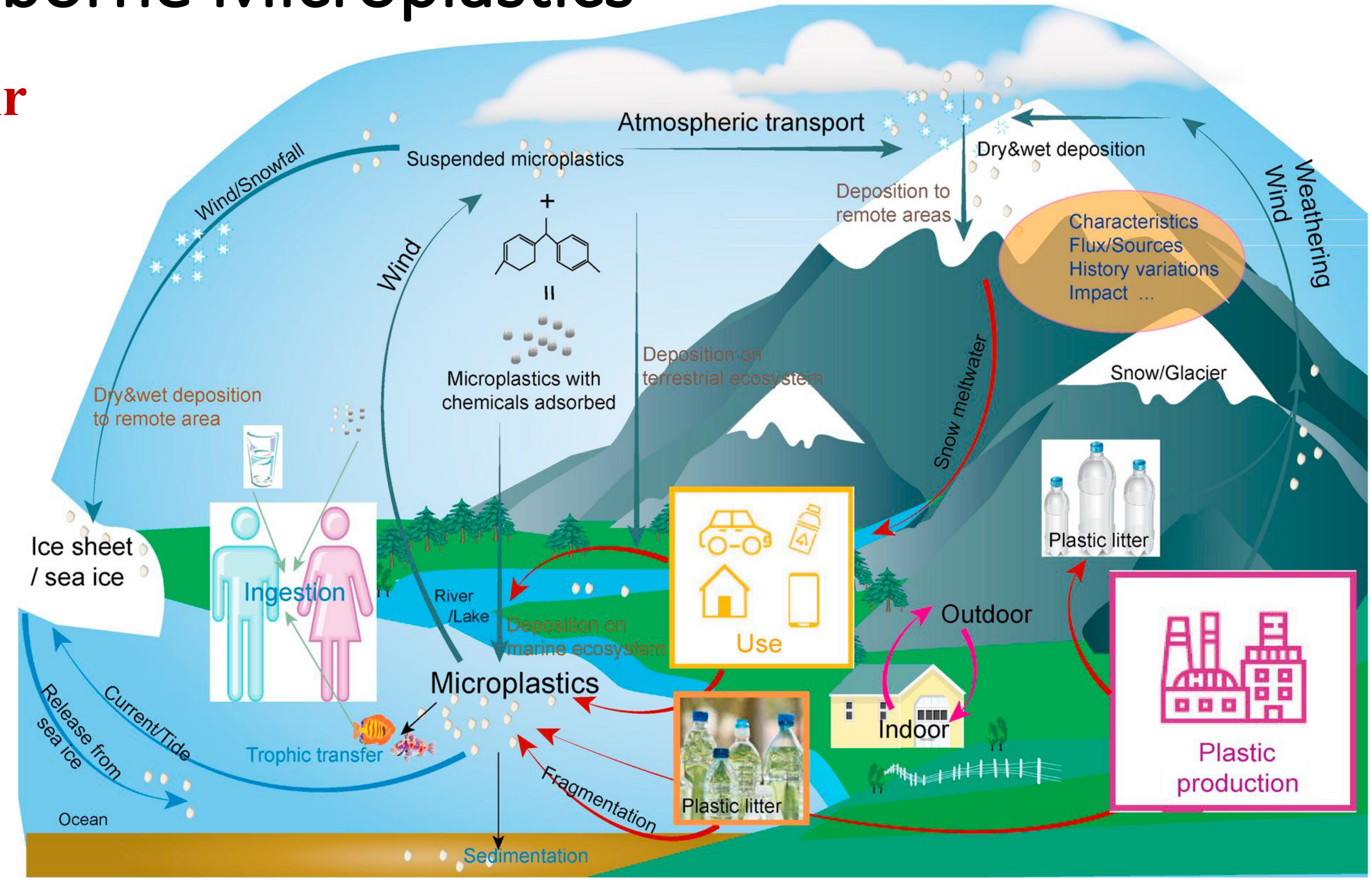
Background: Airborne Microplastics

- **Suspended in the air for nearly a week**
  (Brahney et al., 2021).

- The total global land-based emissions: 6.1×10^{17} particles per year

- Oceanic emissions 2.6×10^{16} particles per year

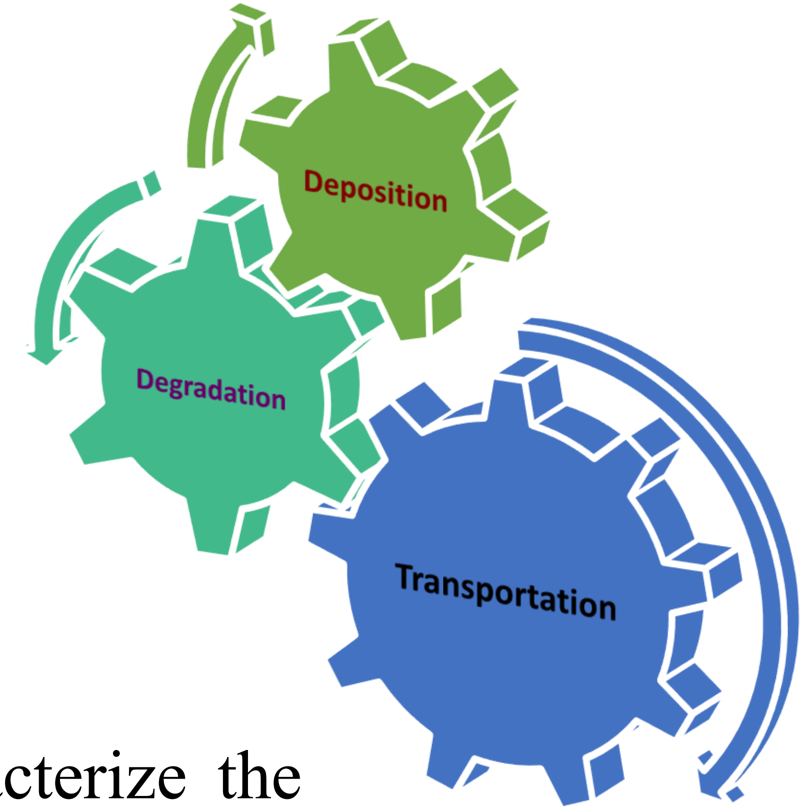
(Evangelou, I., Bucci, S. & Stohl, A., *Nature* **649**, 1186–1189, 2026)



Conceptual model of atmospheric microplastics in the environment (Zhang et al. 2020)

Questions I aimed to answer

1) What is the deposition rate of airborne MPs in indoor and outdoor ambient air in Northern New Jersey?
2) What kind of plastics are included in the airborne MPs in indoor and outdoor air?

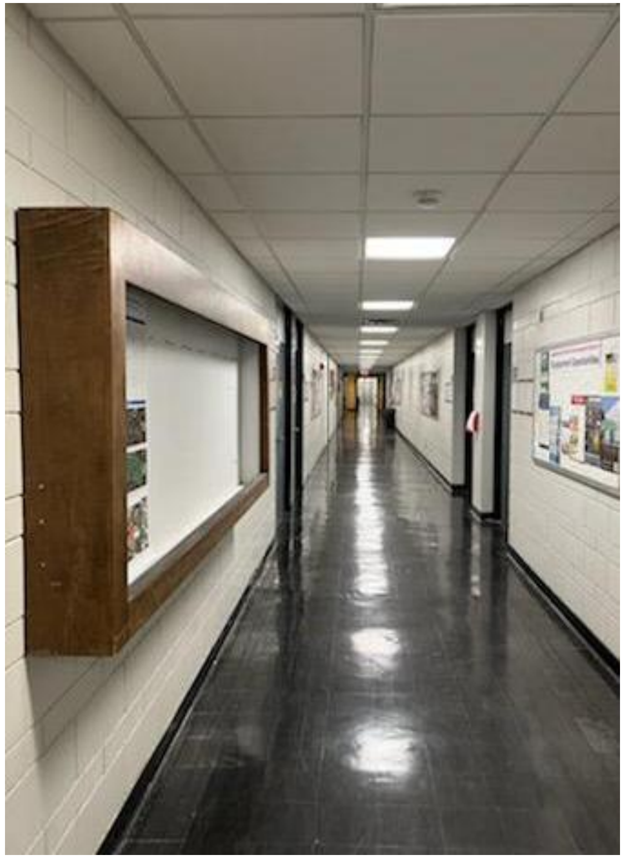


Results from this work can be used to characterize the properties of airborne MPs in urban environments and support future studies of airborne MPs degradation, transport and deposition, as well as their sources and potential health risks.

Methods and Materials
Indoor Fallout Sampling

- Sampling duration: 14 Days

Whatman quartz filter (2.2μm, 47mm) baked at 550 °C over night.



1) Hallway

2) Department Office

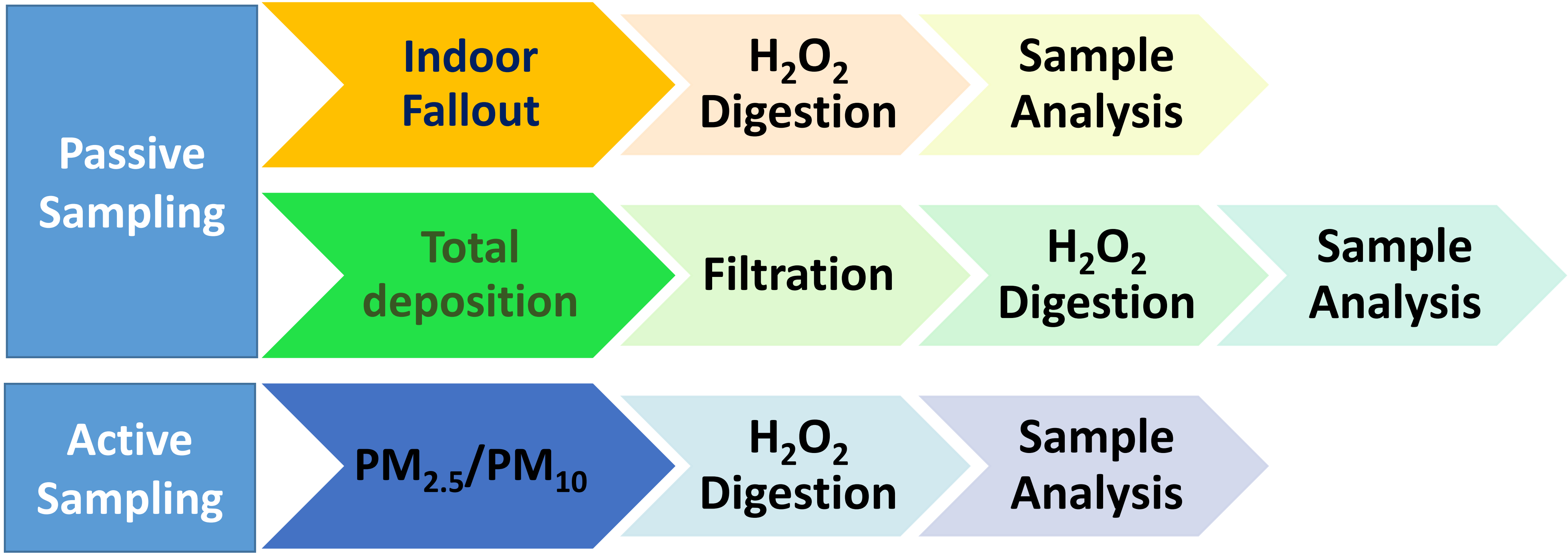
3) Classroom

4) Residential House

Outdoor Sampling

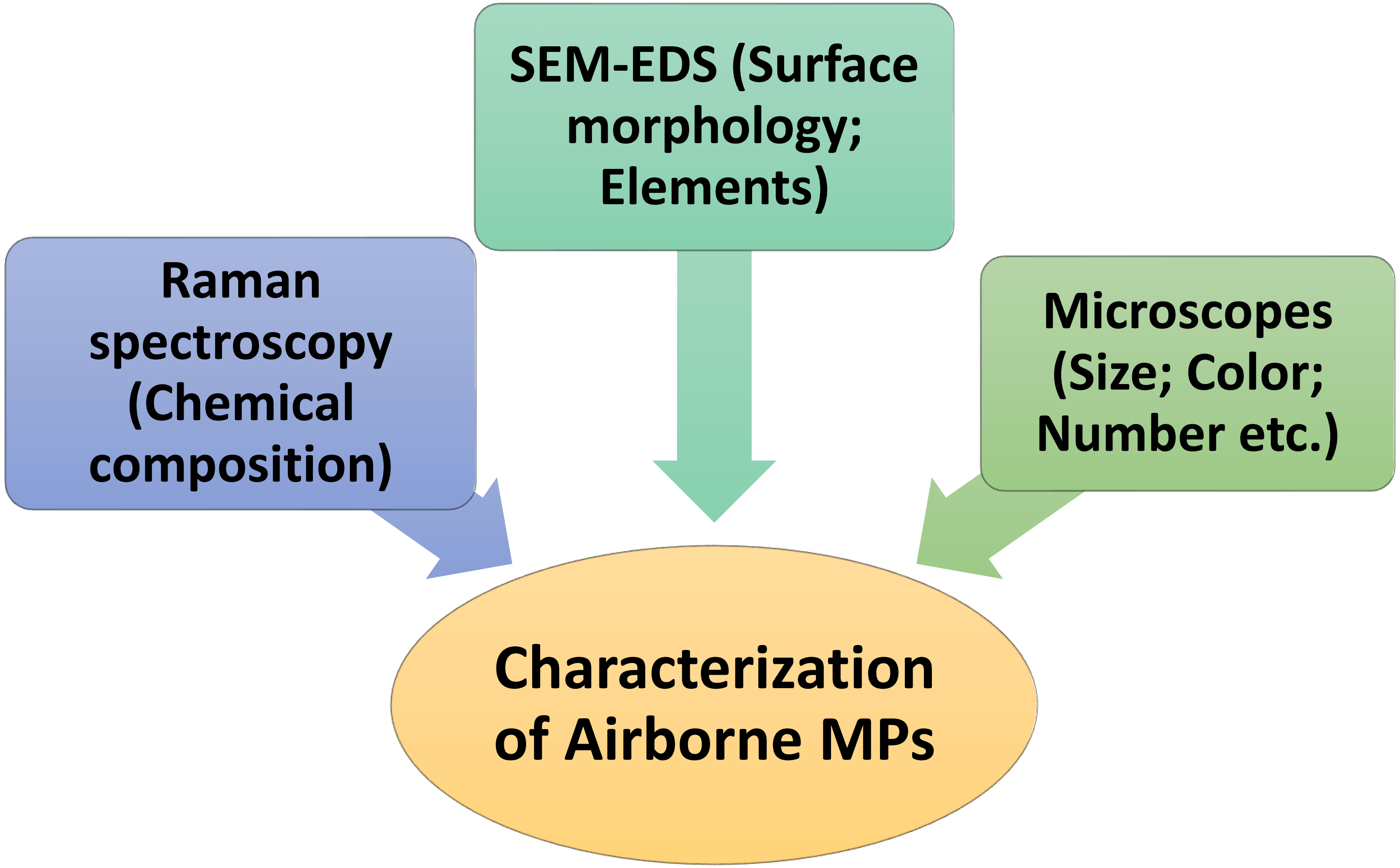
- 14 Days passive sampling on Bradley Hall roof for total deposition;
- 2 days for $PM_{2.5}$ and PM_{10} samples (Thermo Scientific™ Partisol™ 2000i-D)

Sample Preparation



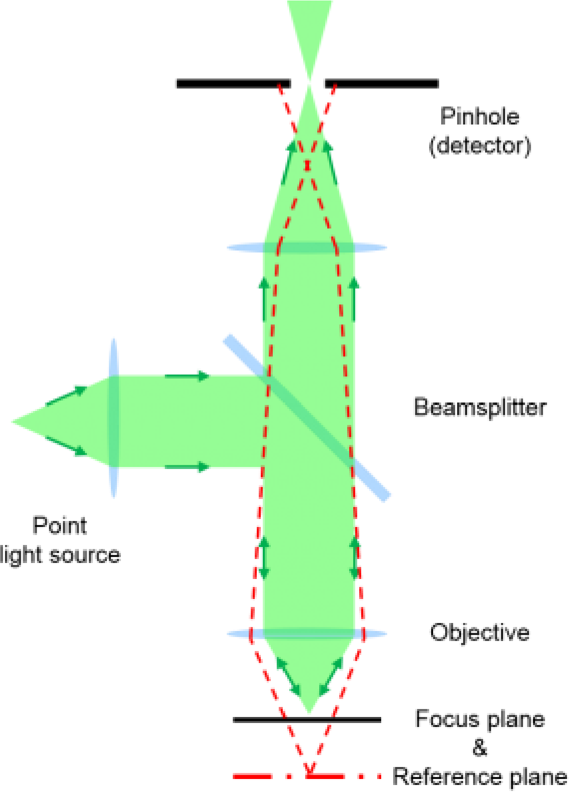
Digested with hydrogen peroxide (30% w/w) at room temperature for 24 hours to remove the interference of organic impurities.

Sample Analysis



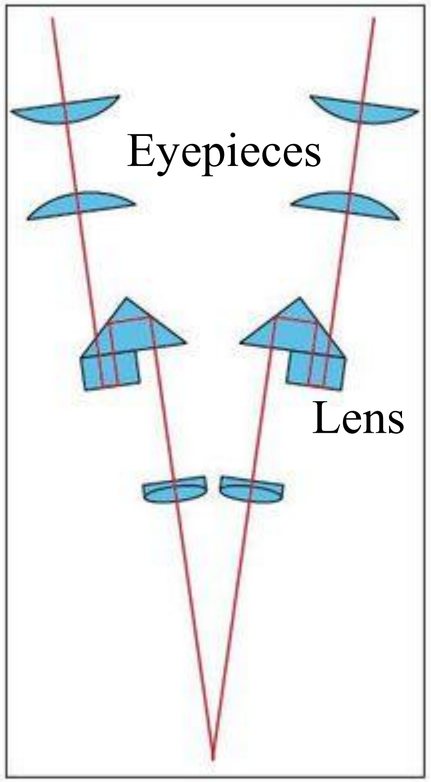
Microscopes

Confocal Microscope Principle



(Credit: WITec)

Stereo Microscope-Greenough Principle



(Credit: Leica Microsystems)

- Leica Zoom 2000 Stereo microscope for big particles
- A WITec Confocal Raman microscope alpha300 R for small particles

Raman Spectroscopy

WITec Raman Spectroscopy-
A Vibrational Spectroscopy

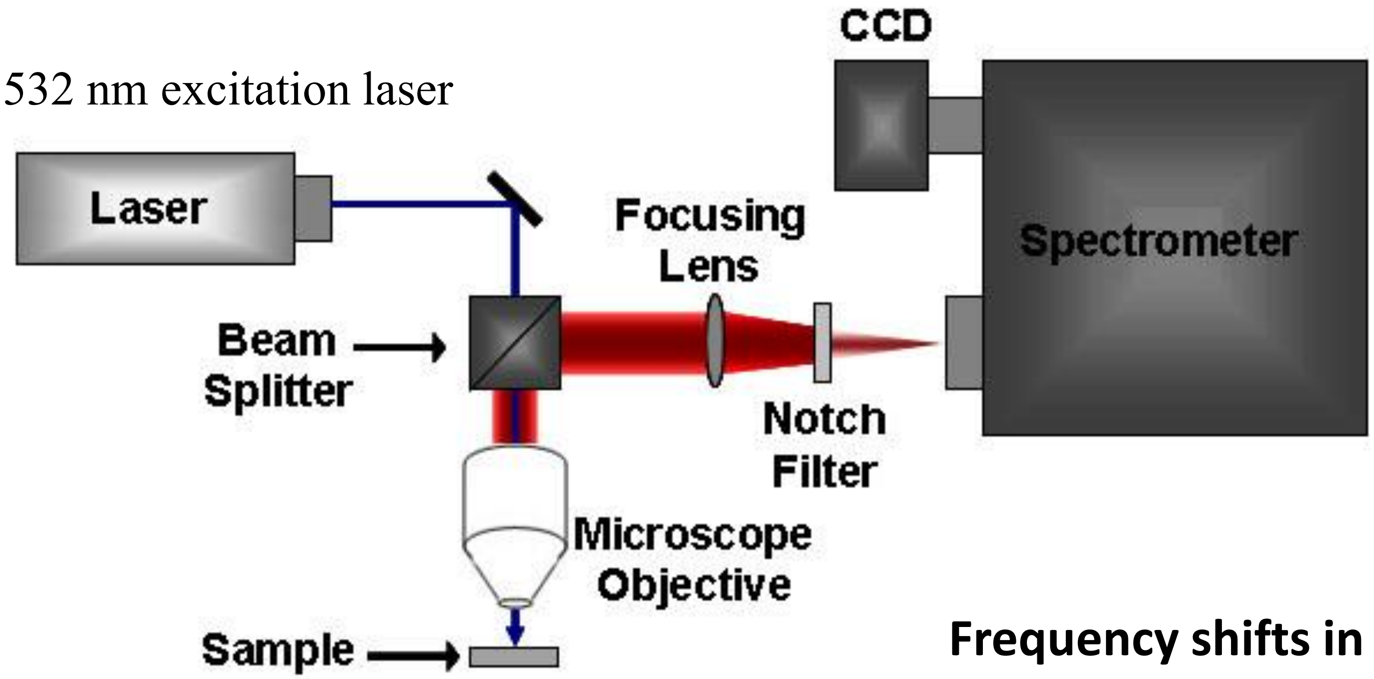
$$h\nu + E_i = h\nu' + E_f$$

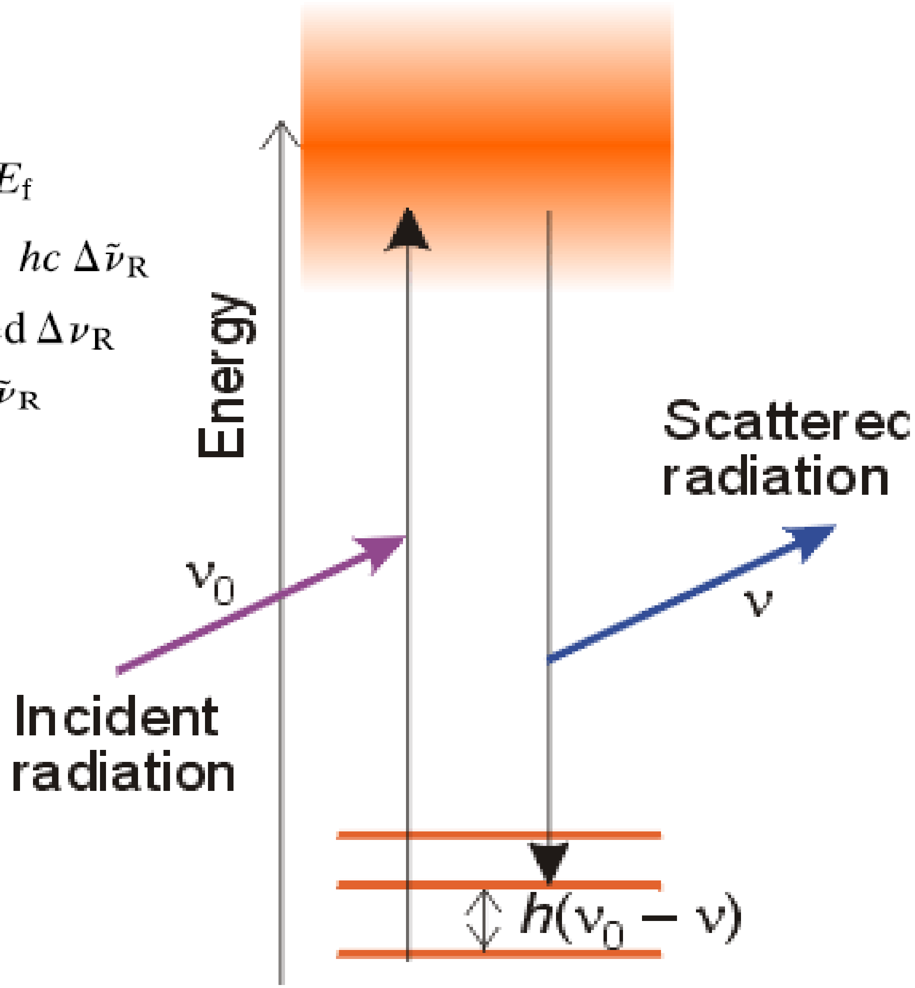
$$h(\nu' - \nu) = E_i - E_f = h\,\Delta\nu_R = hc\,\Delta\tilde{\nu}_R$$

shift in frequency is labeled $\Delta\nu_R$

shift in wave number is $\Delta\tilde{\nu}_R$

532 nm excitation laser



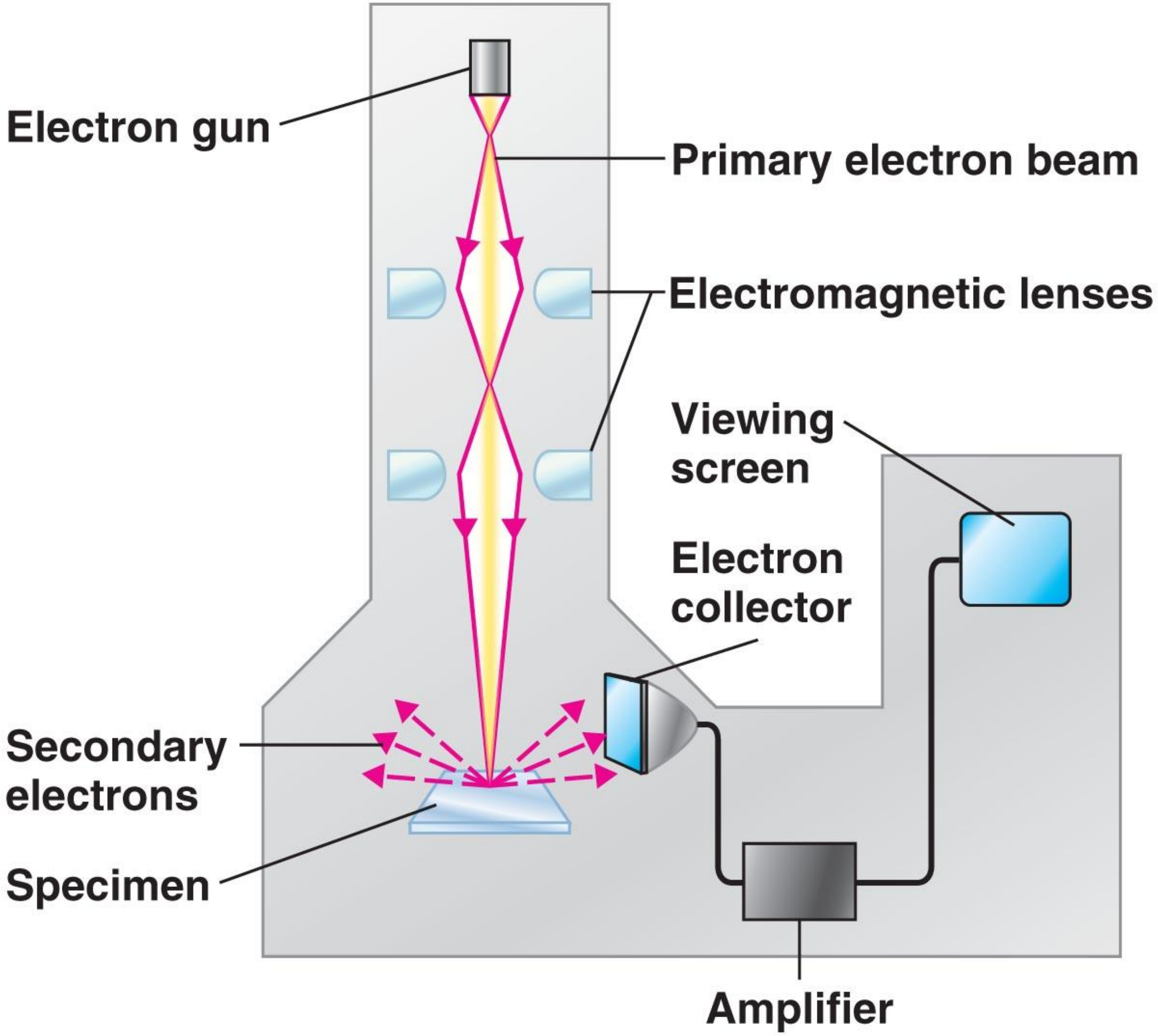


Frequency shifts in Raman spectroscopy reflect differences in vibrational energy levels, providing direct information about the vibrational states of molecules.

SEM-EDS

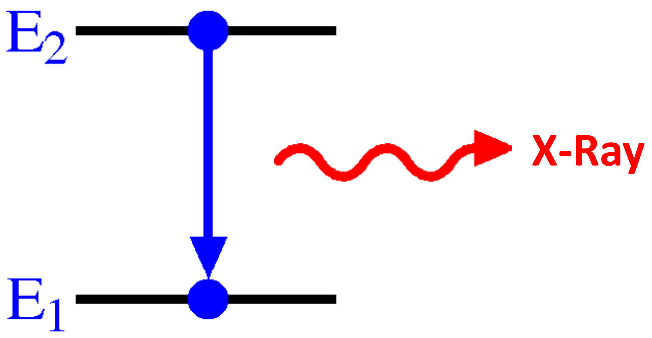
Scanning electron microscope (SEM) (Hitachi S-4800 SEM) was used for surface morphology analysis.

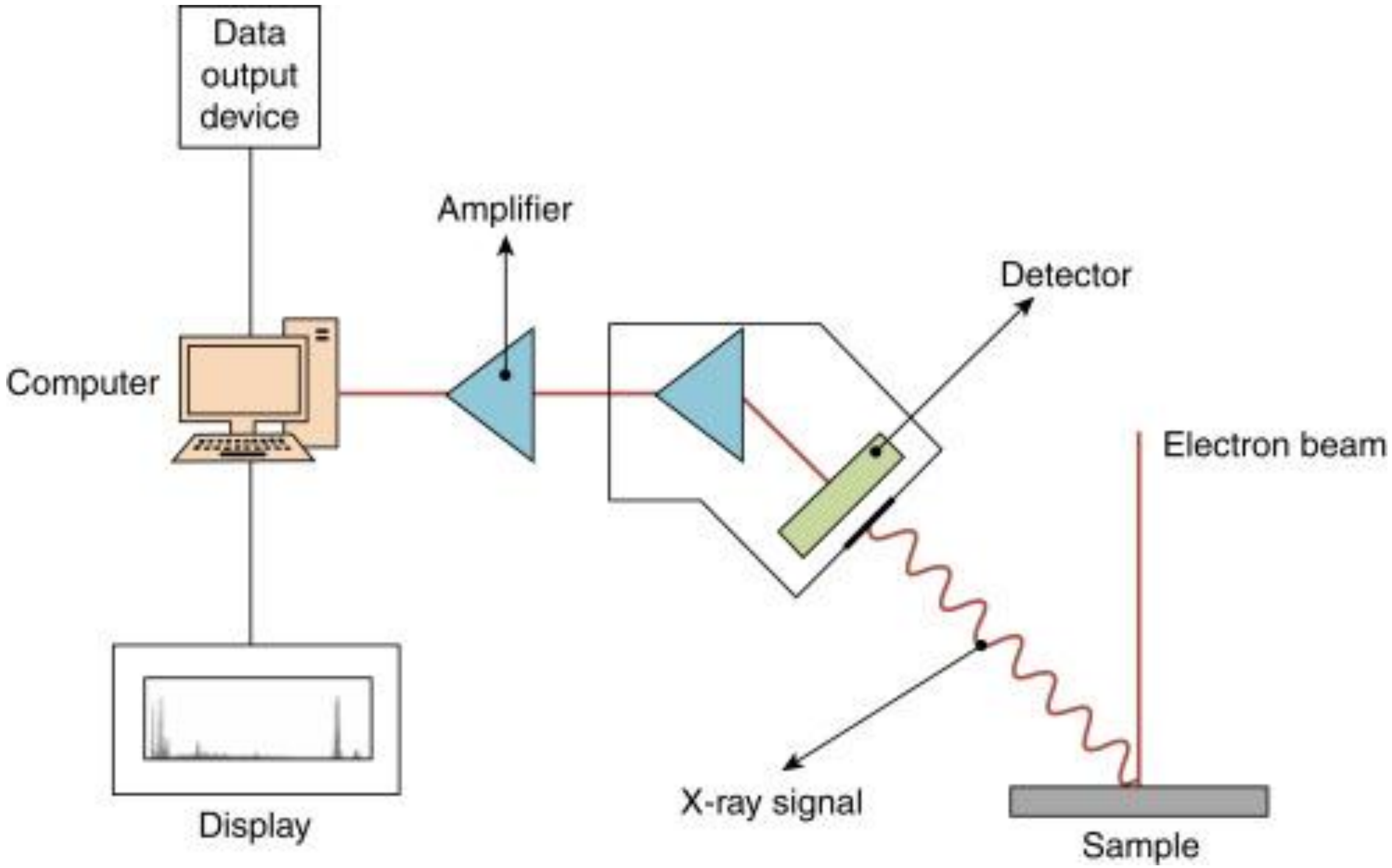
Before analysis, the samples were coated with Ir using a Ted Pella sputter coater (208 HR).



SEM-EDS

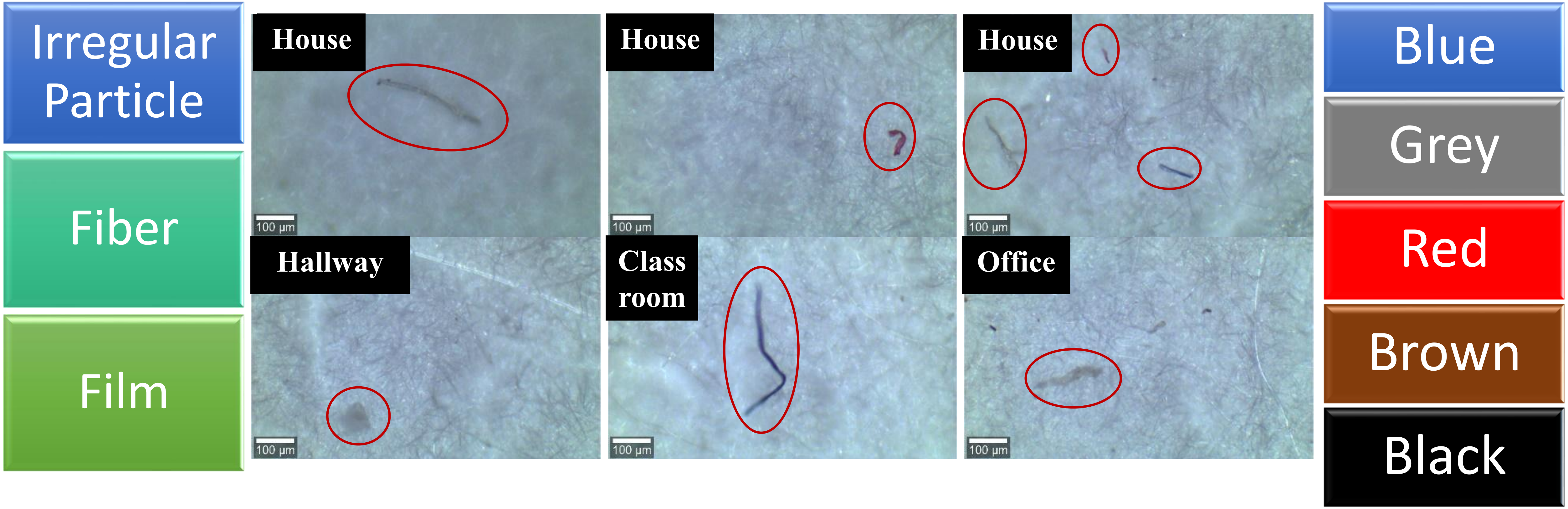
Energy dispersive X-Ray spectroscopy (EDAX EDS) was used for element identification.





(Colpan et al., 2018).

Results and Discussion
Indoor fallout samples



Distribution of indoor fallout samples

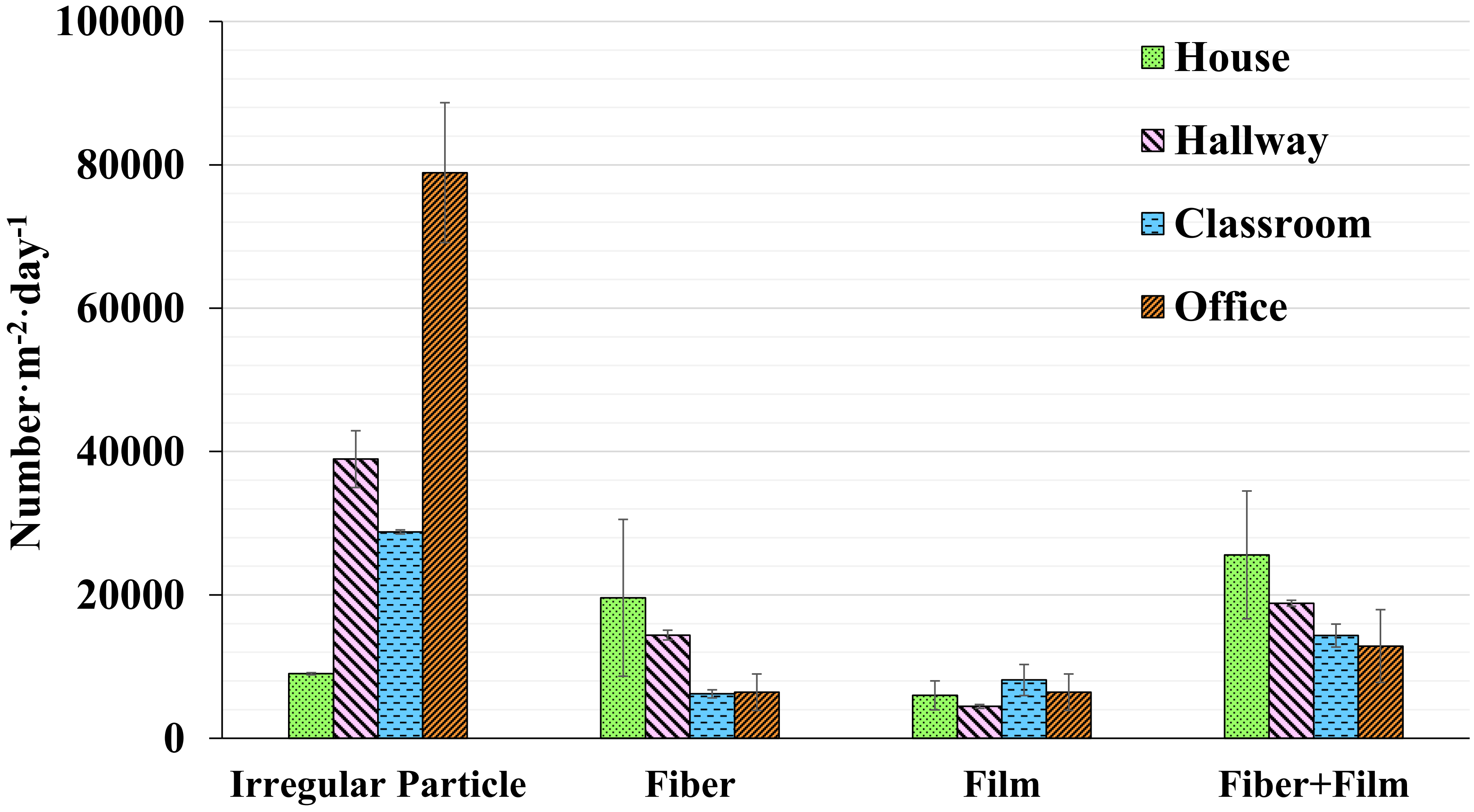


Figure 1. Indoor average deposition rates of irregular particles, fibers, and films per m^2 per day.

Key points:

- Irregular particles dominated the fallout samples
- Fibers accounted for most fallout samples in the single-family house (54%)
- House could be an important source of airborne MPs

Total atmospheric deposition

Dongguan, China <	Paris, France <	Western U.S. conservation areas <	**This Study, Newark NJ** <	Remote mountain catchment in France <	Central London
36 ± 7 per m^2 per day (Cai et al., 2017)	110 ± 96 per m^2 per day (Dris et al., 2016)	132 ± 6 MPs per m^2 per day (Brahney et al., 2020)	327 ± 19 per m^2 per day	366 MPs per m^2 per day (Allen et al., 2019)	575 to 1008 MPs per m^2 per day (Wright et al., 2020)

Our results are consistent with global studies, though variability reflects differences in urban density and emission sources.

Total atmospheric deposition

	This Study, Newark, NJ (per m^2 per day)		Remote mountain catchment in France (per m^2 per day) (Allen et al., 2019)
Fiber	139 ± 19	>	44
Film	114 ± 12	>	73
Fragment	74 ± 12	<	249
Total	327 ± 19	<	366

Opposite order in the remote mountain catchment indicate degradation or weathering of airborne plastics during the atmospheric transport.

Surface morphology and Element analysis

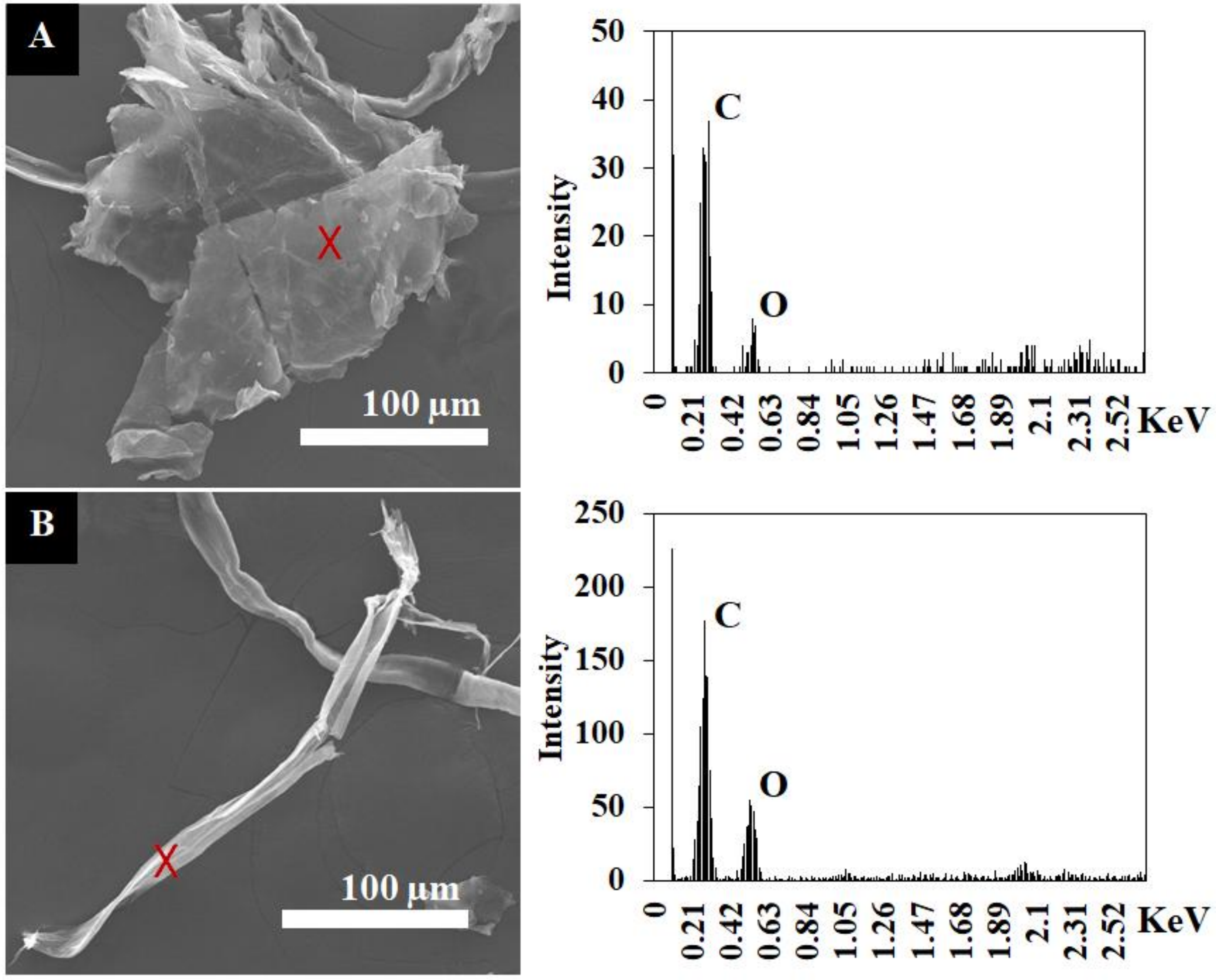


Figure 2. SEM micrographs of film or fiber or fragment collected from the indoor fallout samples

Indoor Fallout Samples

Most the indoor fibers and films were only composed of carbon and oxygen.

Wearing and peeling were observed on the surface and at the edge of the samples.

Surface morphology and Element analysis

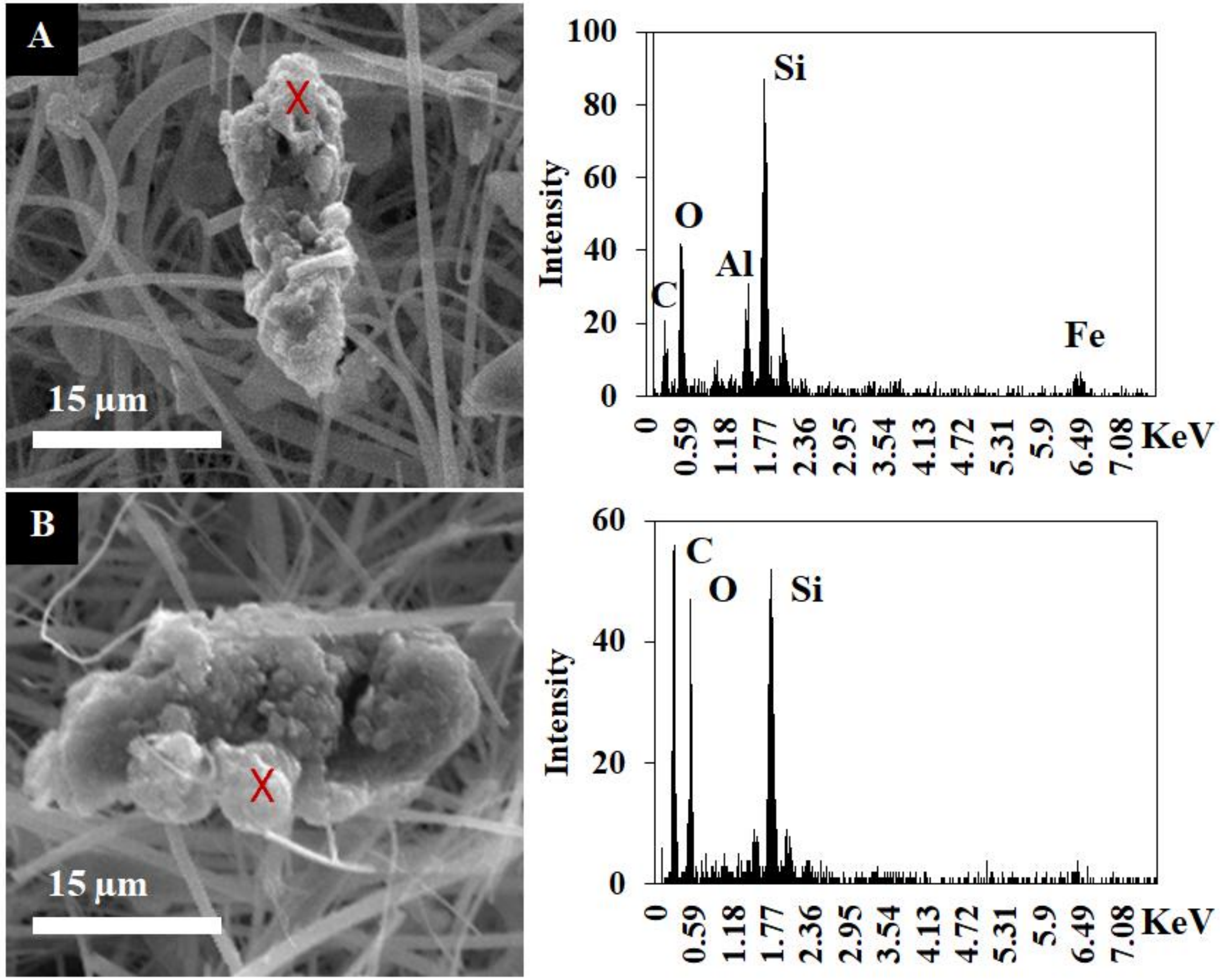


Figure 3. SEM micrographs of particles collected from total atmospheric deposition samples.

Total Deposition Samples

Ambient particles could have C, O, Al, Fe, Si, etc. on the surface.

The surface morphology of the particle suggests the presence of coagulation of several different particles.

The surface morphology of Figure 3A is similar with tire wear particles, a type of microplastics that is abundant in the ambient air and may contribute to global warming by its light-absorbing properties (Evangeliou et al., 2020; Knight et al., 2020).

Surface morphology and Element analysis: PM2.5/PM10

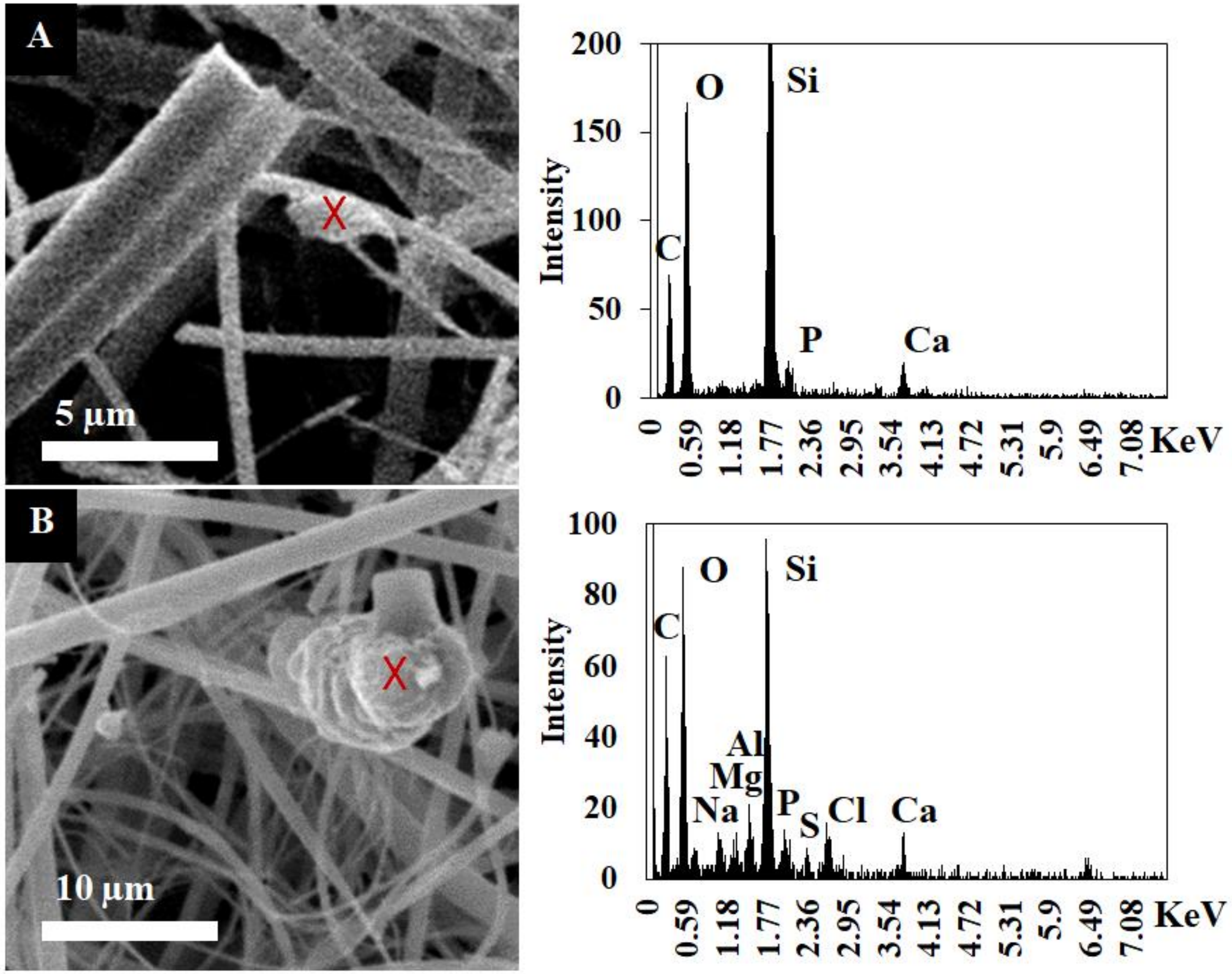


Figure 4. SEM micrographs of particles collected from $PM_{2.5}$ and PM_{10} samples.

Elements C, O, Si, Na, Al, Mg, P, Cl, Ca, and S were found in the carbon containing PM samples.

In the ambient environment, particulate matters with a variety of trace elements could attach to the surface of microplastics.

With UV radiation and mineral interactions in aerosols, the plastic aging could be accelerated by photodegradation (Naik et al., 2020; Song et al., 2017).

Plastic composition of MPs - indoor

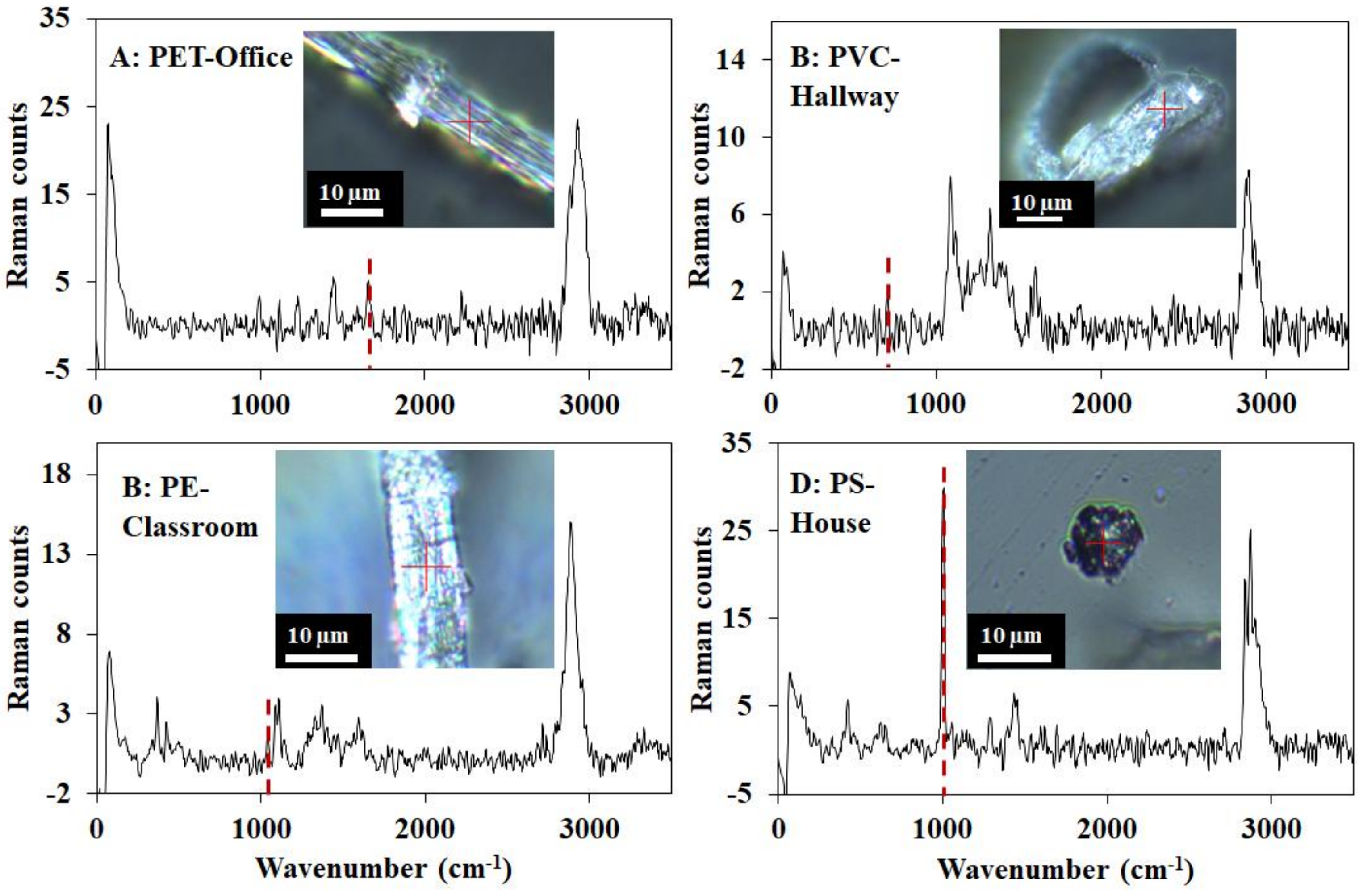


Figure 5. Confocal micrographs and Raman spectra of indoor airborne MPs

- PE: 40%
- PET: 26%
- PS: 20%
- PP: 7%
- PVC: 7%

PS, PE, PVC, PET, and PP were identified by their main peaks in the indoor samples.

PE fiber or fragment is the major plastic of the identified indoor MPs.

Plastic composition of MPs - Outdoor

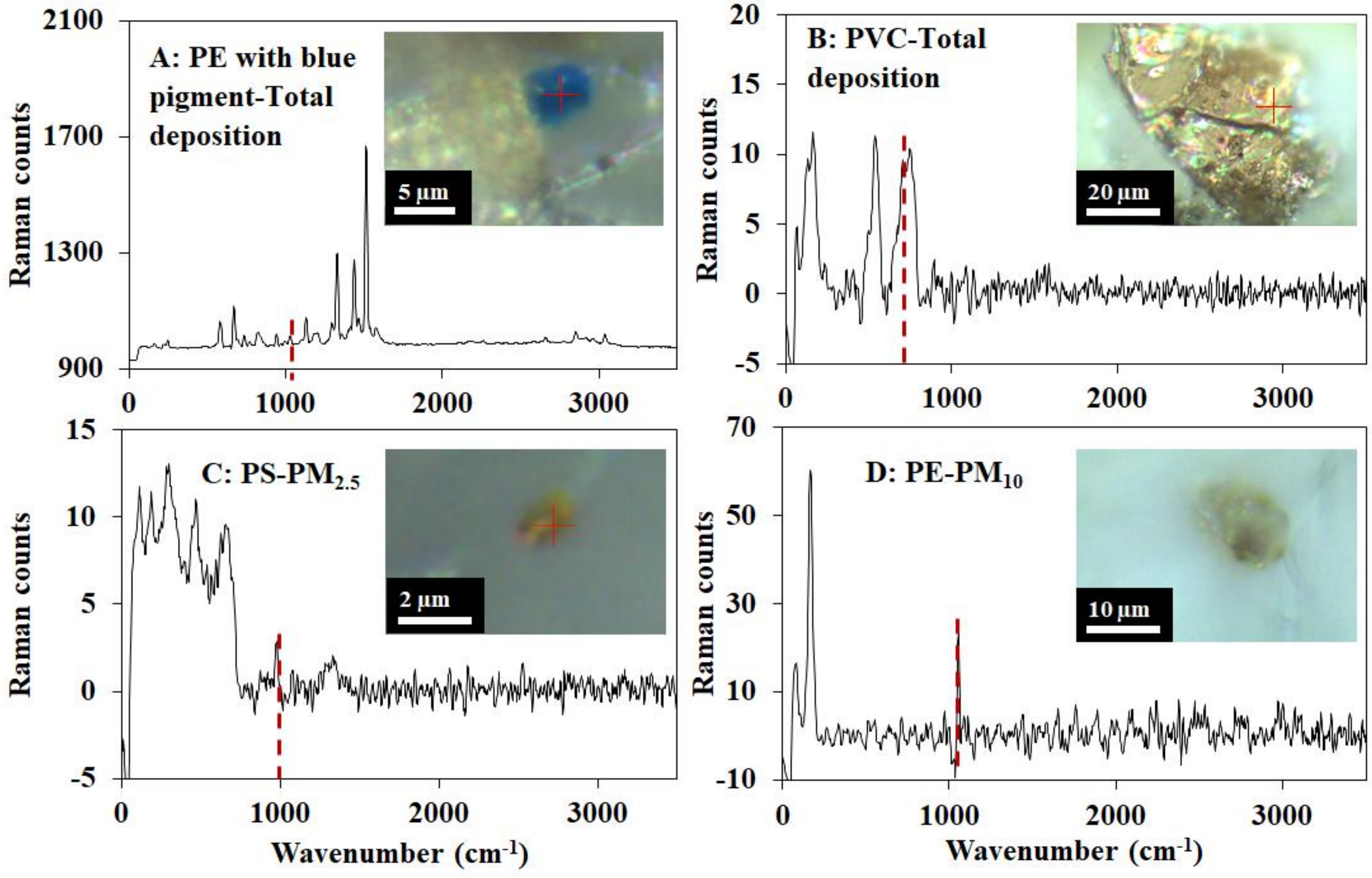


Figure 6. Confocal micrographs and Raman spectra of outdoor airborne MPs

PVC, PE, and PS were identified in the outdoor samples.

PVC fragment is the dominant plastic in the total deposition sample.

The Raman peaks of PVC were low in intensity and hard to be identified in PM_{10}/$PM_{2.5}$.

Project #1 Conclusions

1) **The deposition rates of MPs in indoor were 12.9 - 56.6 times higher than that in the ambient air.**
2) **The main indoor MPs are PE fibers or particles, and the main ambient MPs are PVC fragments.**
3) **The MPs with similar texture but different sizes were observed in the ambient samples, suggesting the degradation of MPs.**

Project #2: Distributions and Partitioning of Airborne PFAS in Urban Atmosphere of Northern New Jersey

This study investigated and characterized the distributions and partitioning of airborne PFAS in gas and particle phase, wet and total deposition in urban atmosphere. This research has been published on Science of the Total Environment (Yao et al., 2025).

Science of the Total Environment 970 (2025) 179037

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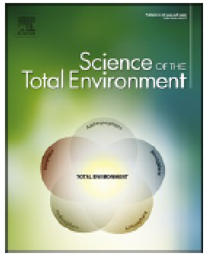
journal homepage: www.elsevier.com/locate/scitotenv



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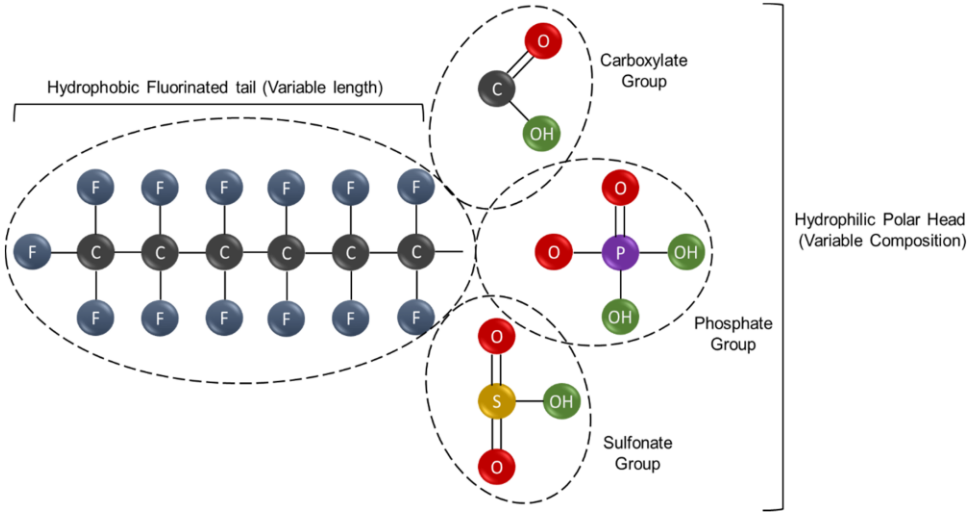
Distributions and partitioning of airborne Per- and Polyfluoroalkyl Substances (PFAS) in urban atmosphere of Northern New Jersey

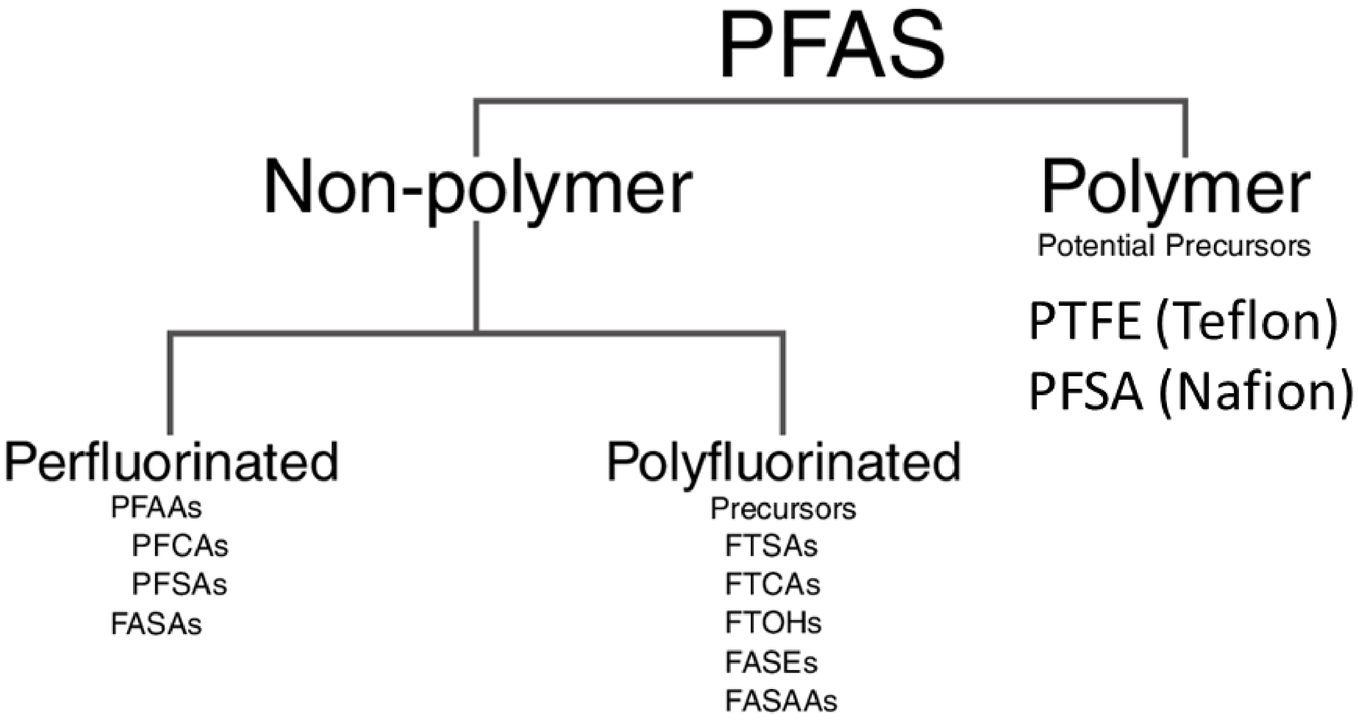
Ying Yao [a,b], Xinting Wang [a], Fangzhou Liu [c], Wen Zhang [c], Francisco J. Artigas [a,b], Yuan Gao [a,*]

Per- and polyfluoroalkyl substances (PFAS)

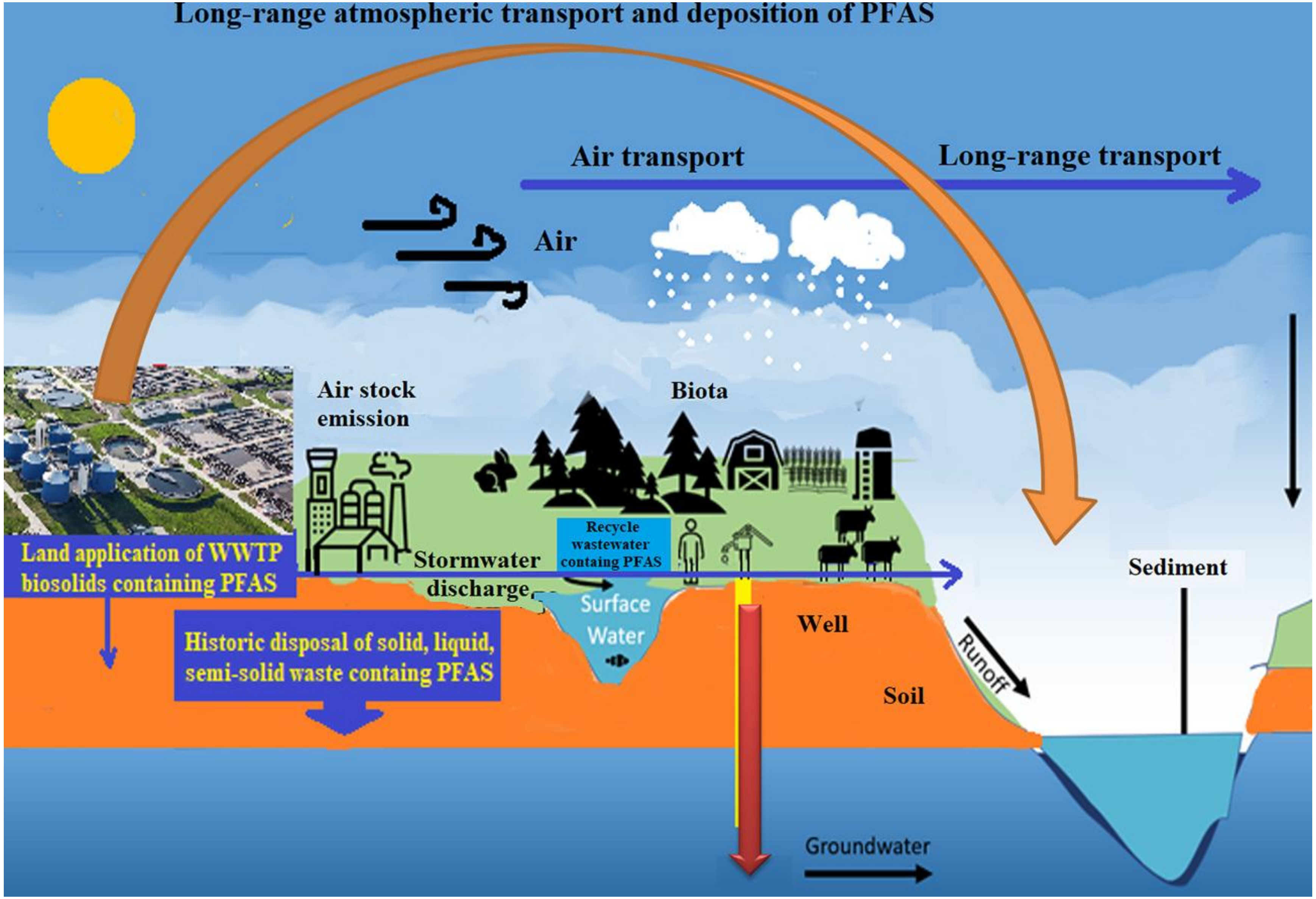
- A large group (over 5000) of synthetic compounds with a chain of fluorinated carbon (hydrophobic tail) and functional (hydrophilic) head that make many of them extremely persistent and mobile in the environment (Lindstrom et al. 2011, Buck et al. 2011).



PFAS Structure, *Source: Tyana Smith, Vibrant Wellness.*



Atmospheric transport is an important pathway

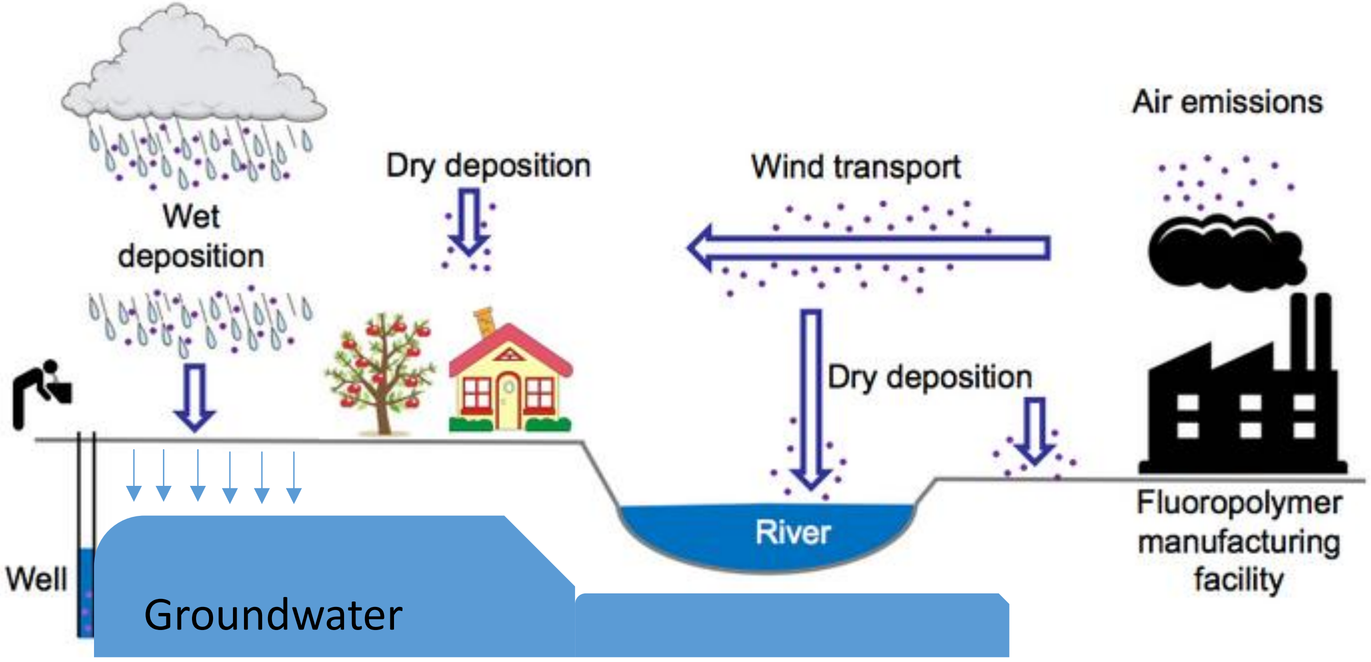


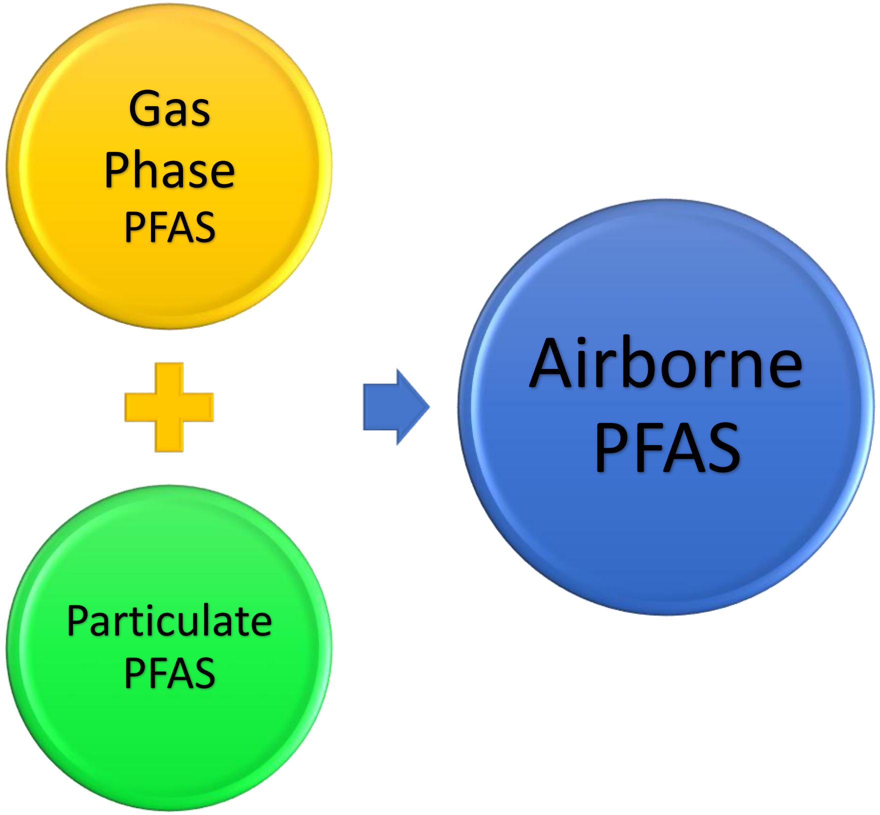
Kurwadkar, S., et al, Science of The Total Environment, 2022, 809, 151003.

- Long-range atmospheric transport leading to localized environmental contamination;
- Pose risks to ecosystems and potentially enter the food chain and inhaled or ingested by animals or human (Trowbridge et al., 2020).

Airborne PFAS

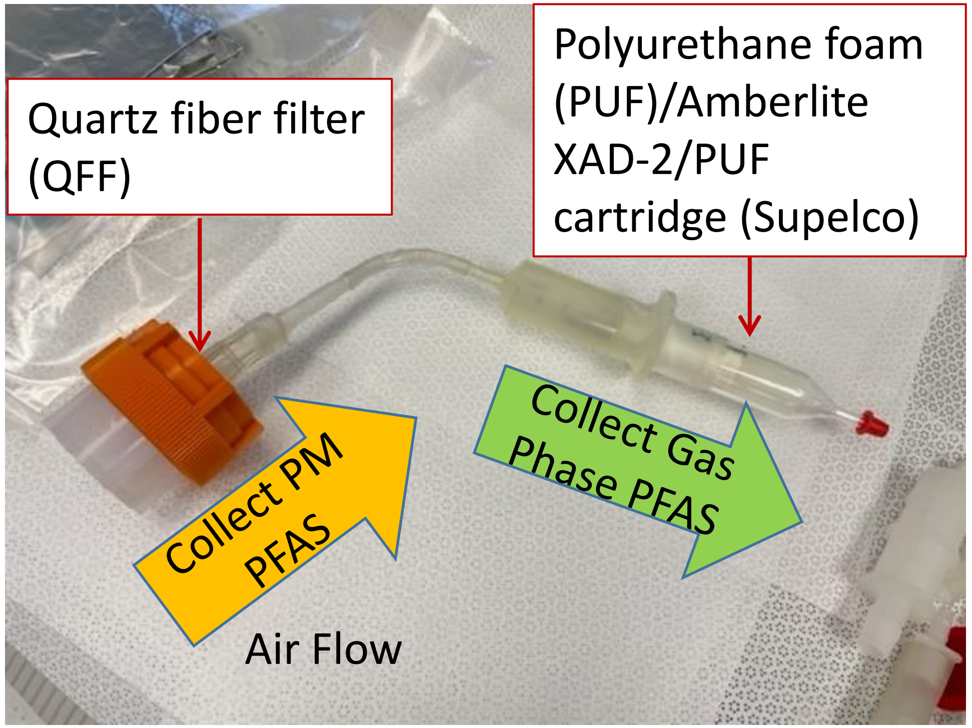
Airborne PFAS includes the PFAS in gas phase samples and the particulate matter samples.

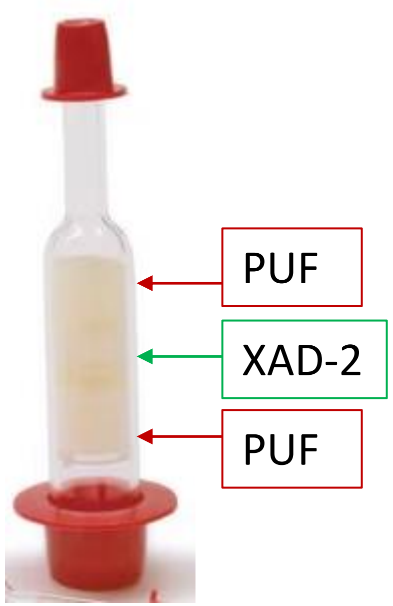




US EPA, 2020, https://www.epa.gov/sites/default/files/2020-10/documents/r1-pfas_webinar_day_2_session_5_phelps-murphy_final.pdf

Airborne PFAS Sampling





Aerosol Sampling Rate: 5 L/min;
Sampling period: 14 days per sample and total 5 samples in spring.

ADS/NTN Atmospheric Precipitation Sampler: Wet deposition sampling.
A 29 cm diameter HDPE bucket: Total deposition sampling.
Total 9 sampling events

PFAS Extraction Methods in the lab

- Particulate PFAS on Quartz fiber filter extracted by methanol (Wu et al., 2021)

Three times

Add 5 ml Methanol → Shake 20 min 200 rpm at 30 °C → Vortex for 30 s → Centrifuge for 15 min at 5000 rpm → Collect Supernatant

- Gas phase PFAS on PUF extracted by ethyl acetate (Jahnke et al., 2007)

Two times

Squeeze PUF into a PP syringe → Add 15 ml ethyl acetate → Elute about 1 drop/s → Collect extract

- Gas phase PFAS on XAD-2 extracted by ethyl acetate (Jahnke et al., 2007)

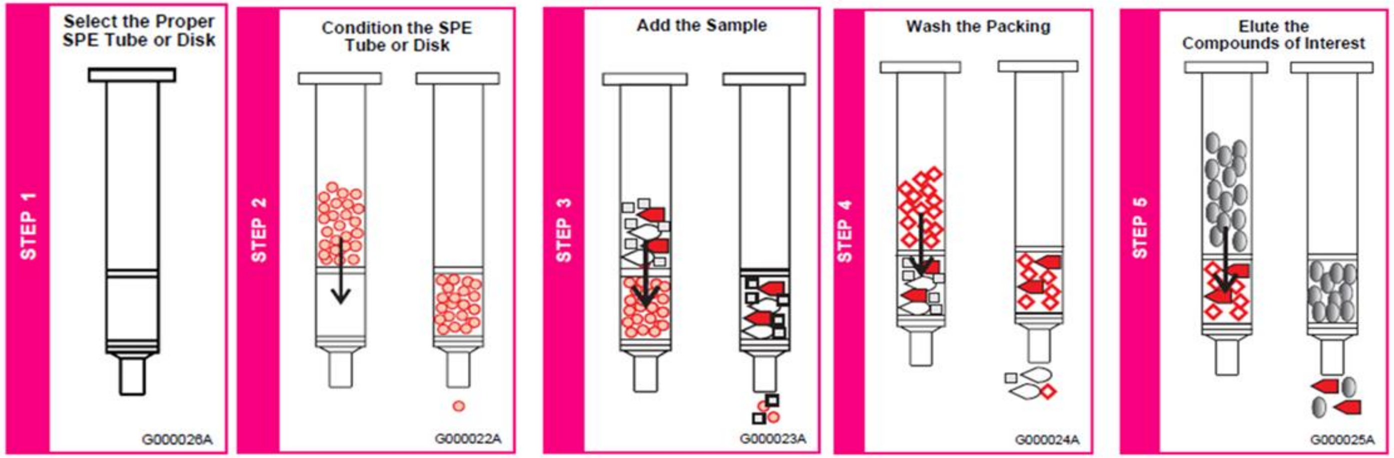
Three times

Put XAD-2 in 50 mL PP tube → Add 10 mL ethyl acetate → Shake 10 min 250 rpm at 40 ◦C → Centrifuge for 15 min at 5000 rpm → Collect Supernatant

100 µl of the 500 µg/L PFAS standard was spiked on the blank sample for quality control check.

PFAS Extraction Methods in the lab

Wet deposition and total deposition samples were directly extracted with Solid Phase Extraction cartridge (SPE) (Waters Oasis WAX 150 mg) methods.

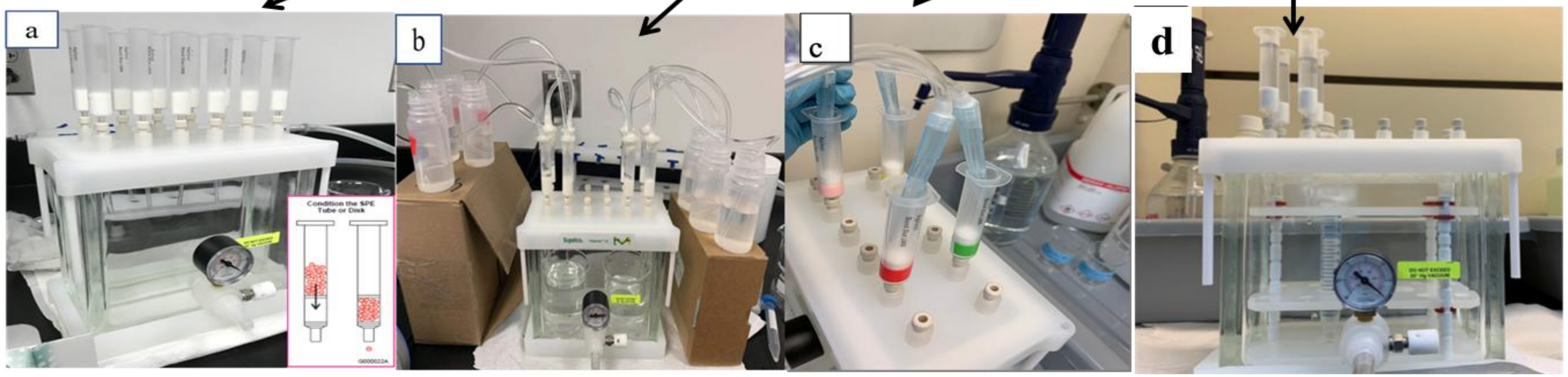


Condition the SPE cartriges using using 4 mL of 0.1% ammonium hydroxide in methanol, as well as 4 mL of 100% methanol and 4 mL of Milli-Q water

Samples are added to the cartridges at a low flow rate (e.g., 1-2 drop per second).

Wash the cartridge with 7.5-mL Milli-Q water twice. Air or nitrogen is purged through the cartridge for 5 minutes at a pressure of 30 kPa

Rinse the sample bottles (50-ml PP tubes) with 4-mL of methanol, which is then pipetted to the cartridges to elute the extracted PFAS by gravity

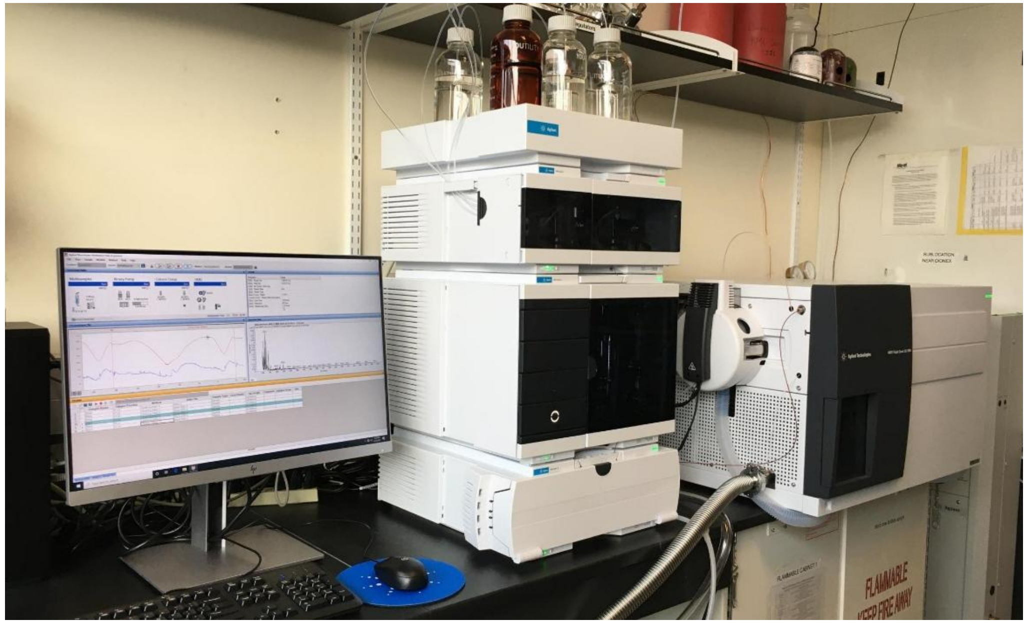


PFAS Analysis

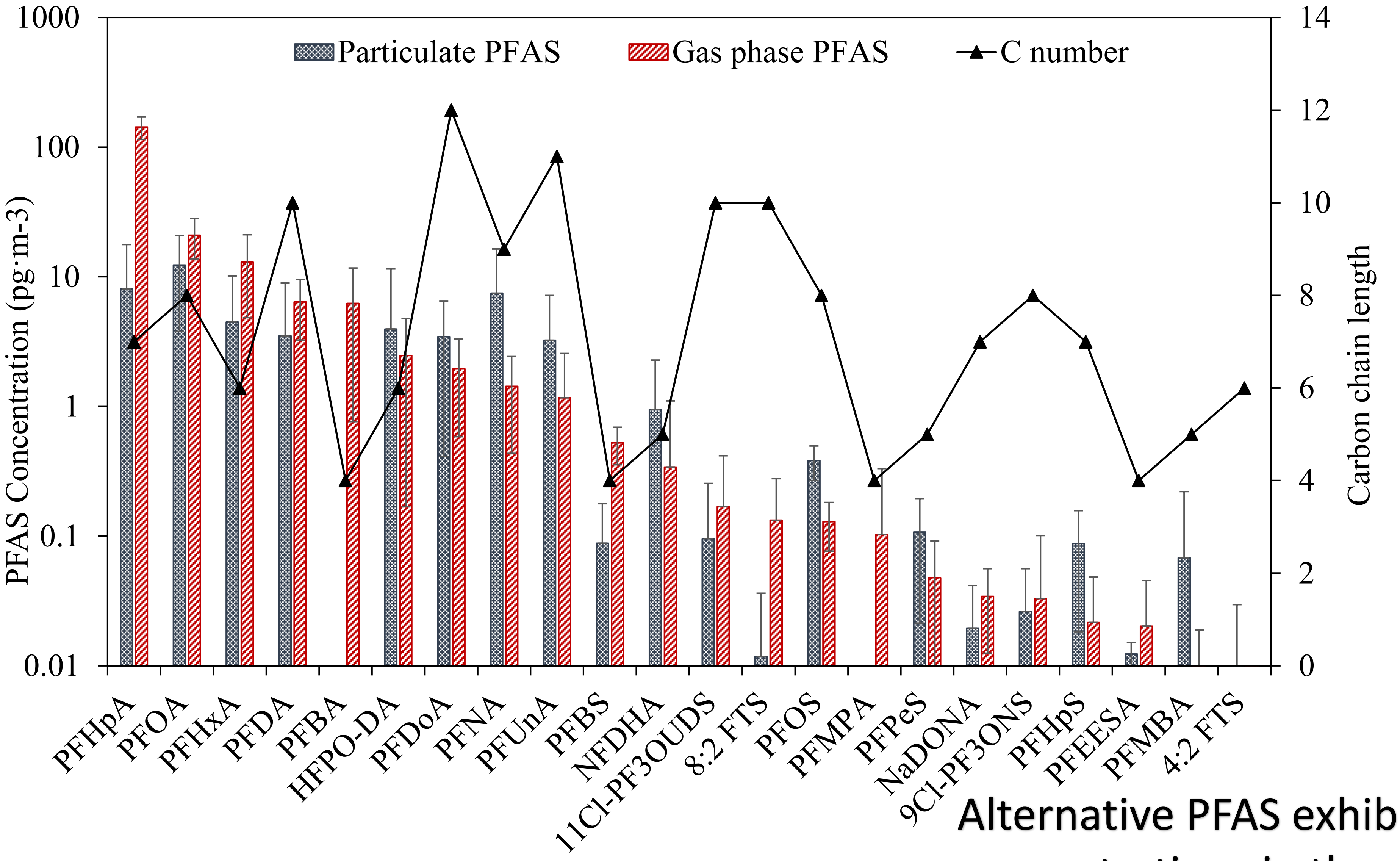
- Agilent 6470A triple quadrupole LC/QQQ-MS system with C_{18} column (Agilent poroshell 120 EC, 50 × 3 mm, 1.8 µm);
- Refer to EPA Method 537 and 533, and the mixture of PFAS EPA 533 standards (Wellington laboratories) were used.

24 PFAS compounds analysed (C4 to C12), including major groups:

> - Perfluoroalkyl carboxylic acids (PFCAs)
> - Perfluorosulfonic acids (PFSAs)
> - Popular alternative PFAS



Partitioning of PFAS in gas and particulate phases



Top 3 in gas:

PFHpA (Perfluoroheptanoic acid, $C_6F_{13}COOH$);
PFOA (Perfluorooctanoic acid, $C_7F_{15}COOH$);
PFHxA (Perfluorohexanoic acid, $C_5F_{11}COOH$)

Top 3 in particulates:

PFOA (Perfluorooctanoic acid, $C_7F_{15}COOH$);
PFHpA (Perfluoroheptanoic acid, $C_6F_{13}COOH$);
PFNA (Perfluorononanoic acid, $C_8F_{17}COOH$)

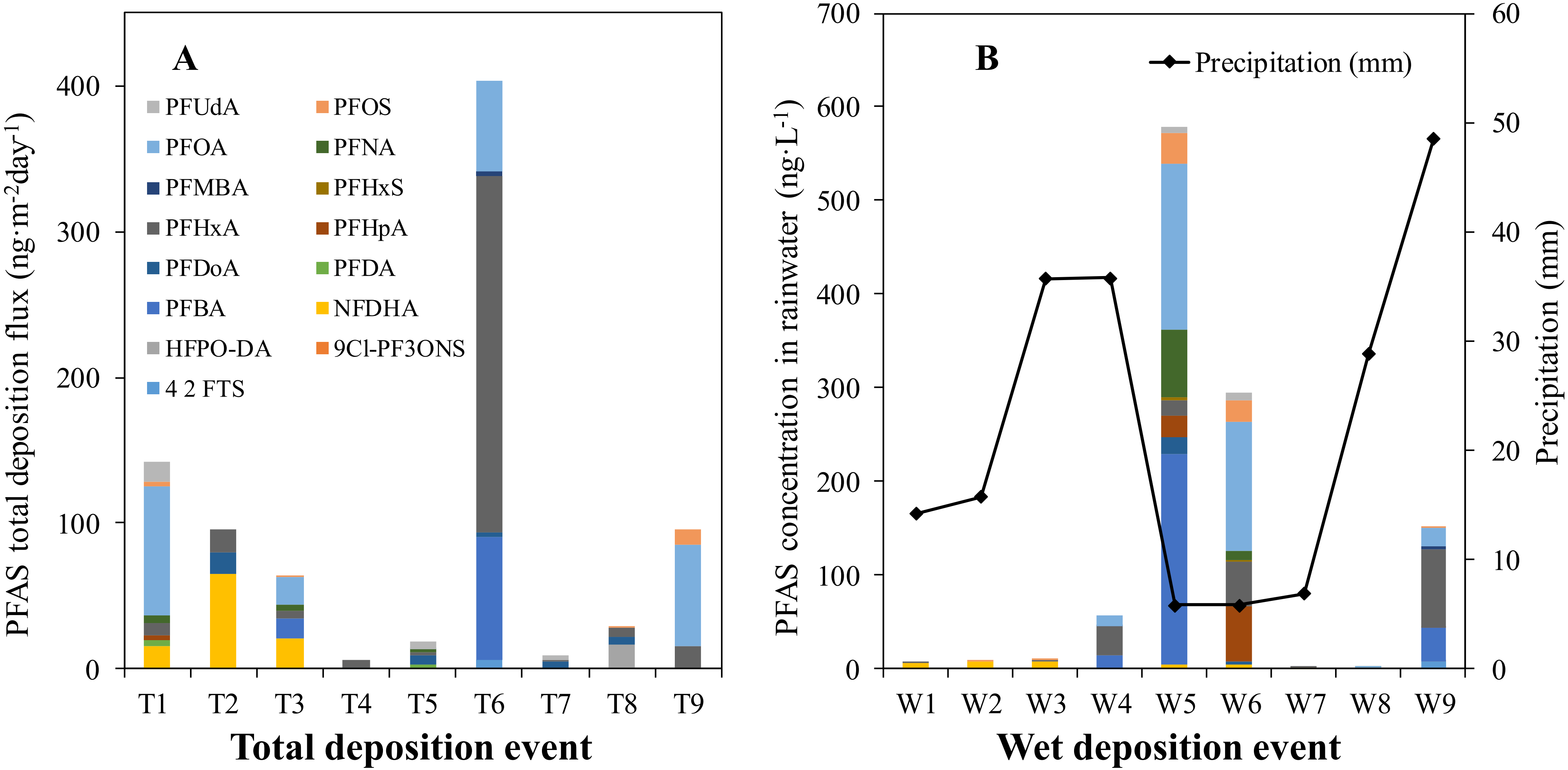
Alternative PFAS exhibit higher concentrations in the gas-phase samples.

Total PFAS in particulate and gas phase samples

Sampling period	Sampling period ID	Precipitation (mm)	Particle-phase PFAS ($pg\cdot m^{-3}$)	Gas-phase PFAS ($pg\cdot m^{-3}$)	Total deposition ($ng\cdot m^{-2}$)	Wet deposition ($ng\cdot m^{-2}$)
2/14-2/28	M1, M2	29.9	77.0	157.1	1804	176
2/28-3/14	M3, M4	71.5 (Snow)	17.3	144.0	493	2593
3/14-3/28	M5, M6	11.6	119.3	260.7	1026	5953
3/28-4/11	M7	6.9	11.7	223.1	127	16.4
4/11-4/25	M8, M9	77.4	16.2	203.7	866	8002
Average			48.3 ± 47.9	197.7 ± 47.9	863 ± 631	3348±3542

The lowest gas-phase PFAS concentrations were observed during 2/28–3/14, coinciding with a snowstorm, suggesting enhanced washout by snow.

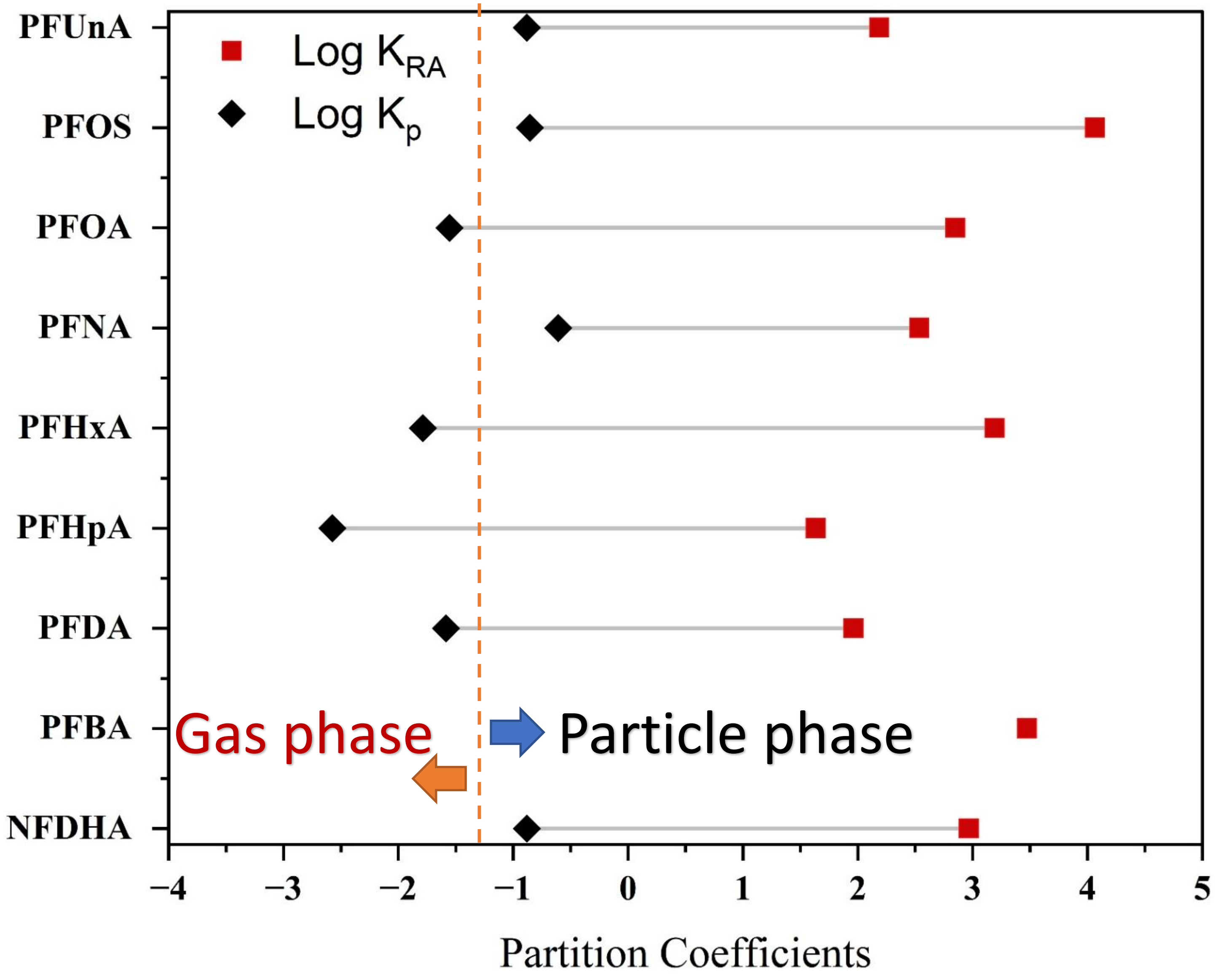
PFAS in wet deposition and total deposition samples



W5 and W6 were the two wet deposition events from 3/14 to 3/28/2023 which had the highest concentration of the PFAS in gas-phase and particulate samples.

(**A**) Total deposition fluxes of the analyzed PFAS in each sampling event; **(B)** Different PFAS concentrations (ng·L^{-1}) in different wet deposition samples with their corresponding precipitation rates (mm).

Partitioning characteristics of airborne PFAS

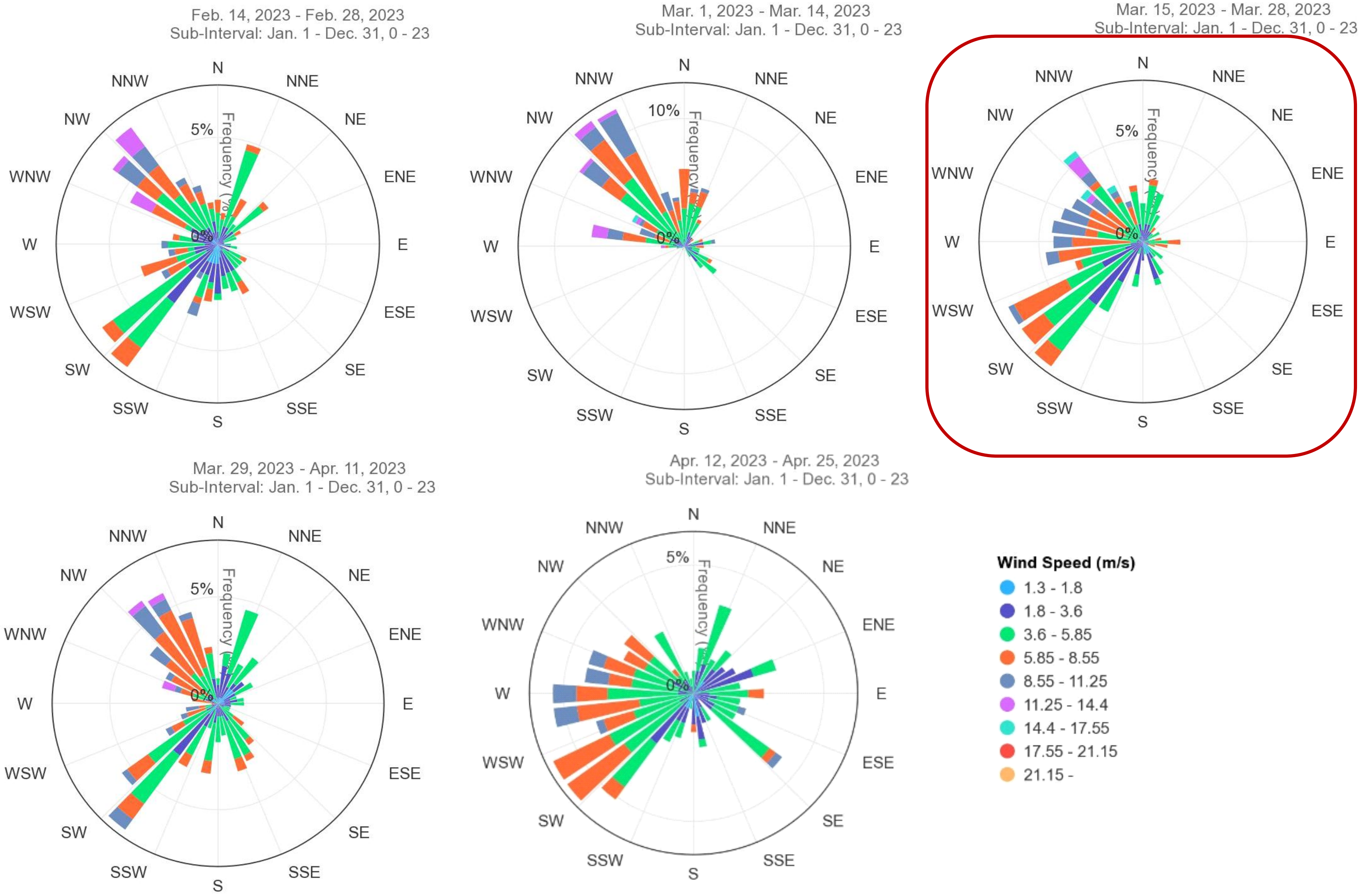


Rain-air partition coefficient, also called the water/air scavenging ratio or washout ratio, $K_{RA} = \frac{C_w}{C_{air,P}+C_{air,G}}$

The particle-air partition coefficient, $K_P = \frac{C_{air,P}/TSP}{C_{air,G}}$ (TSP ≈ 21 μg·m^{-3})

Some PFAS exhibit **higher concentrations in the gas phase** than in the particle phase and show **low washout ratios and particle–air partition coefficients**, including **PFOA, PFHpA, PFHxA, and PFDA.**

Wind roses during the study period

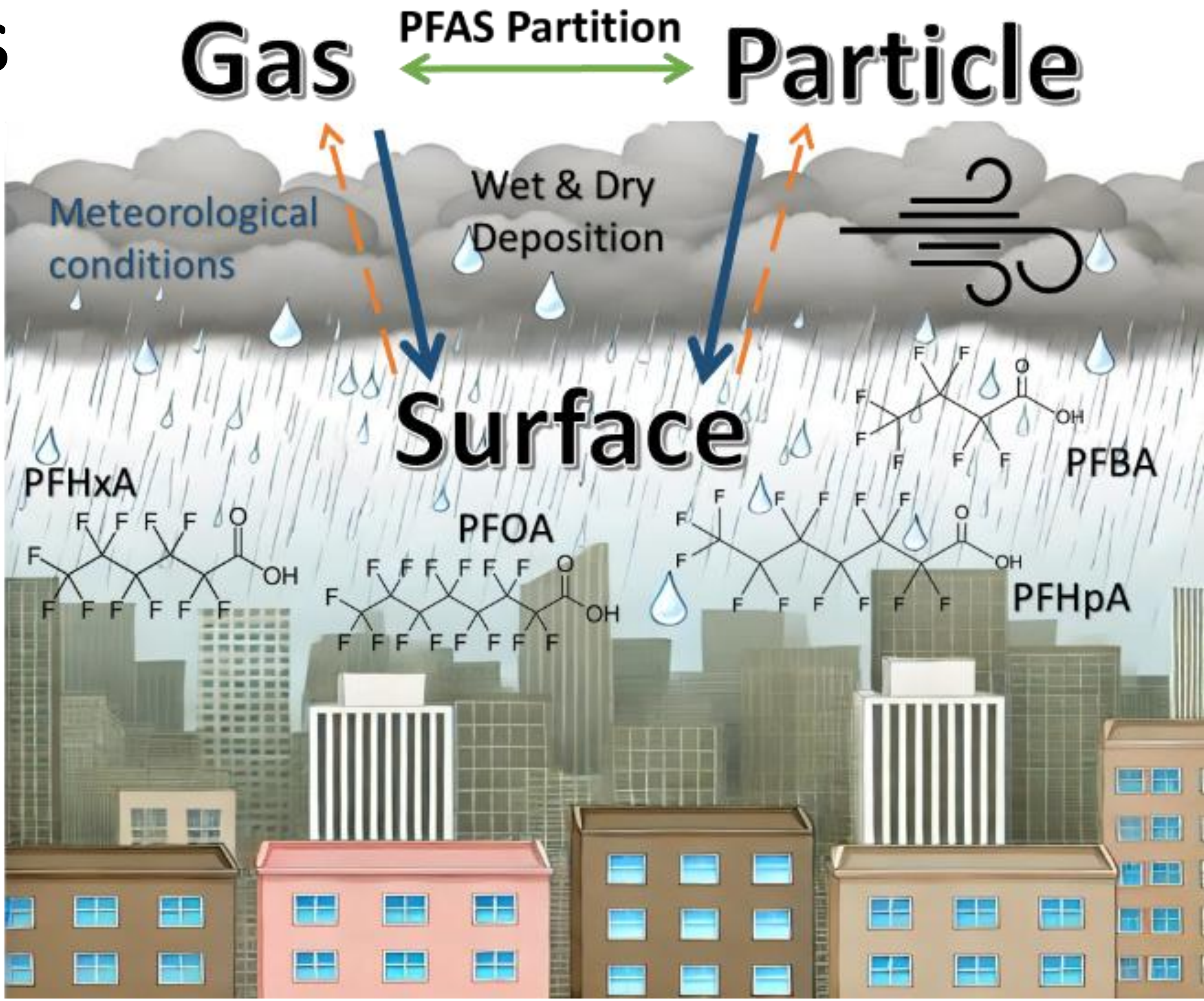


Emission sources of gas-phase PFAS in spring are probably from the southwest of NJ.

Source confirmation requires additional sampling and source-apportionment analysis.

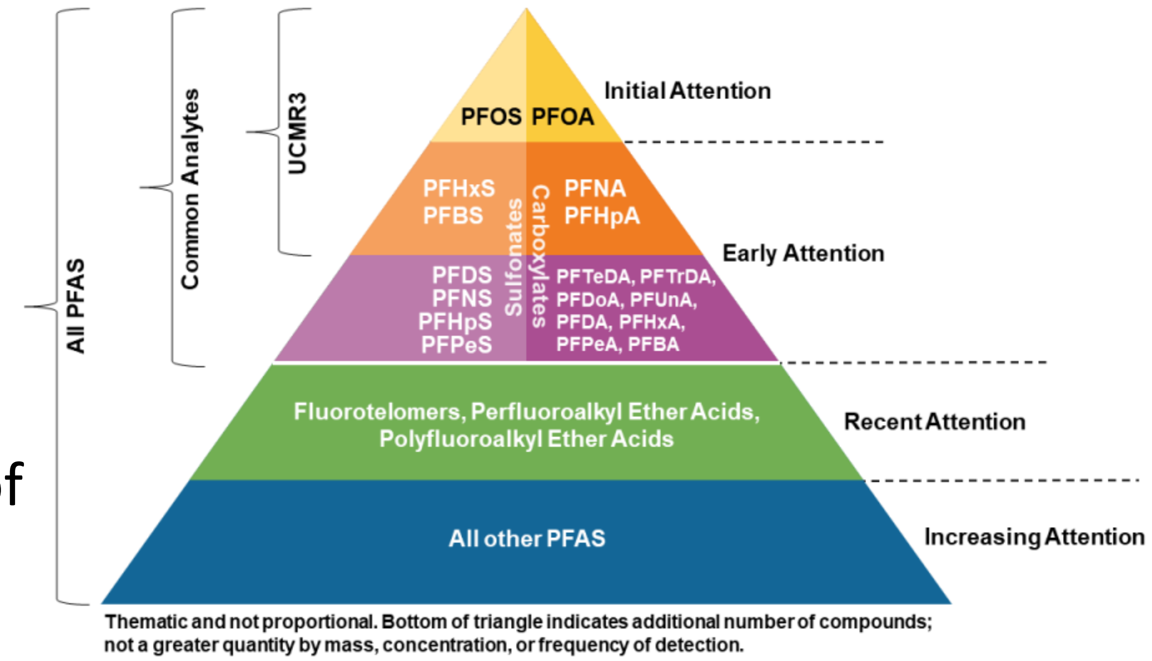
Project #2 Conclusions

- In urban aerosol of northern NJ, the average PFAS in gas phase is 197.7 ± 47.9 pg/m^{3}Air and in particulate phase is 48.3 ± 47.9 pg/m^{3}Air;
- Alternative PFAS have higher concentration than the regulated PFAS.
- Alternative PFAS exhibit low washout ratios and particle-air partition coefficients.



Challenges

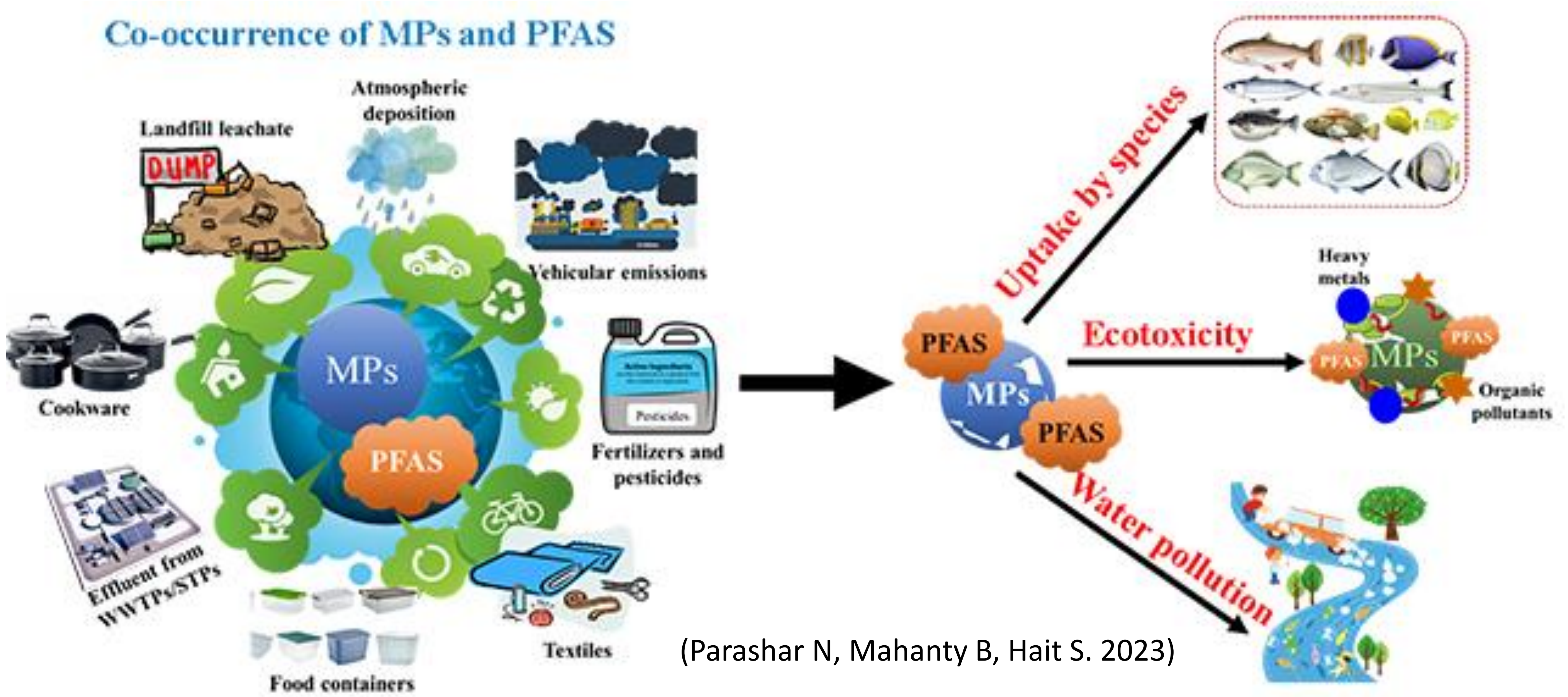
- Emission sources are diverse:
  - PFAS chemical manufacturers
  - PFAS used in commercial applications
  - PFAS emitted during thermal treatment of waste (e.g., municipal solid waste incineration)
  - Products of Incomplete Combustion (PICs)



Source: J. Hale, Kleinfelder. https://pfas-1.itrcweb.org/2-3-emerging-health-and-environmental-concerns/

- Validated source and ambient air methods for PFAS do not exist, some research methods are available
- Current emissions tests often target only a small number of PFAS compounds for analysis while significantly more may be present

Co-occurrence and Interactions of Airborne MPs and PFAS

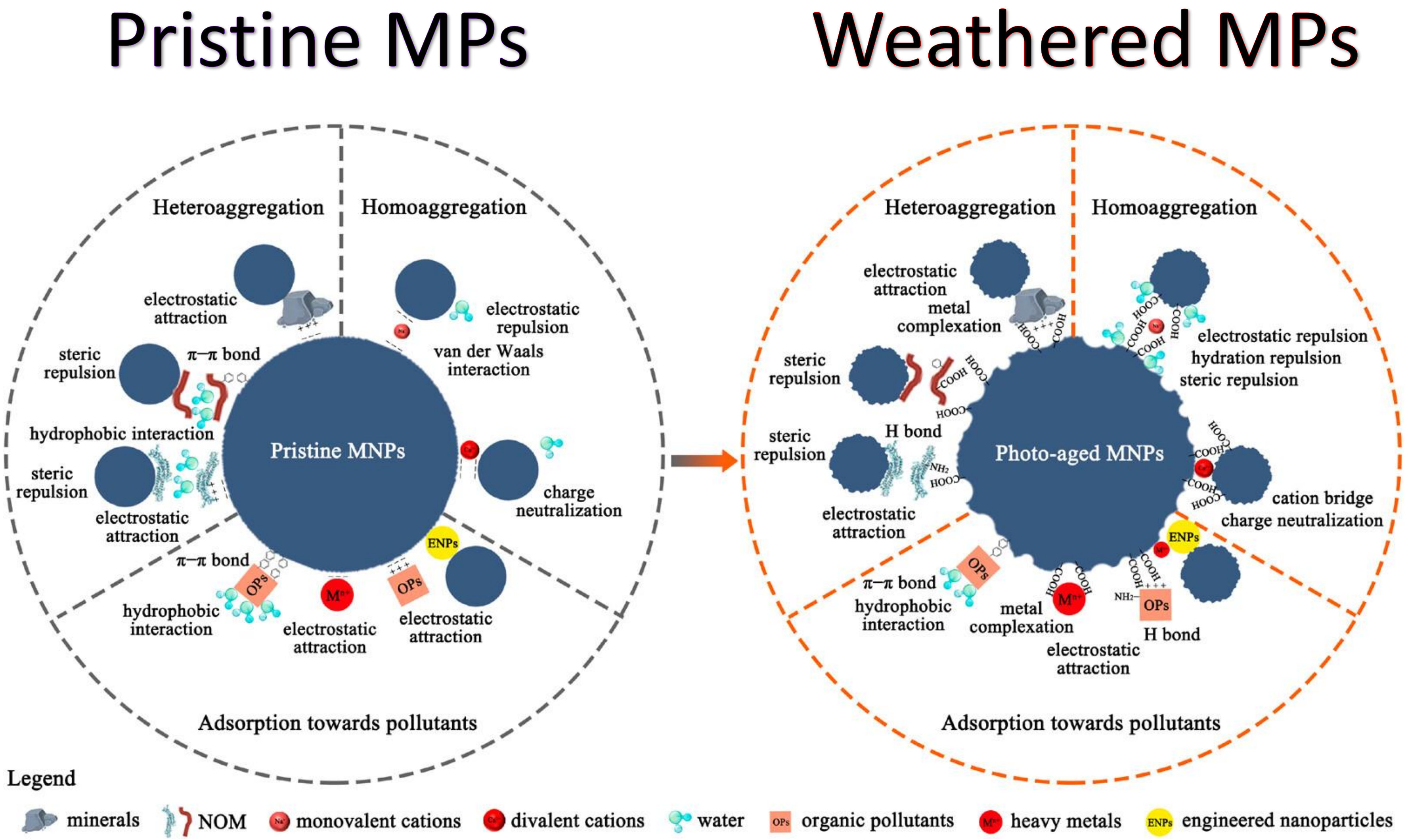


(Parashar N, Mahanty B, Hait S. 2023)

- MPs and PFAS can co-occur in multiple environmental compartments
- MPs may act as carriers or transport media for PFAS

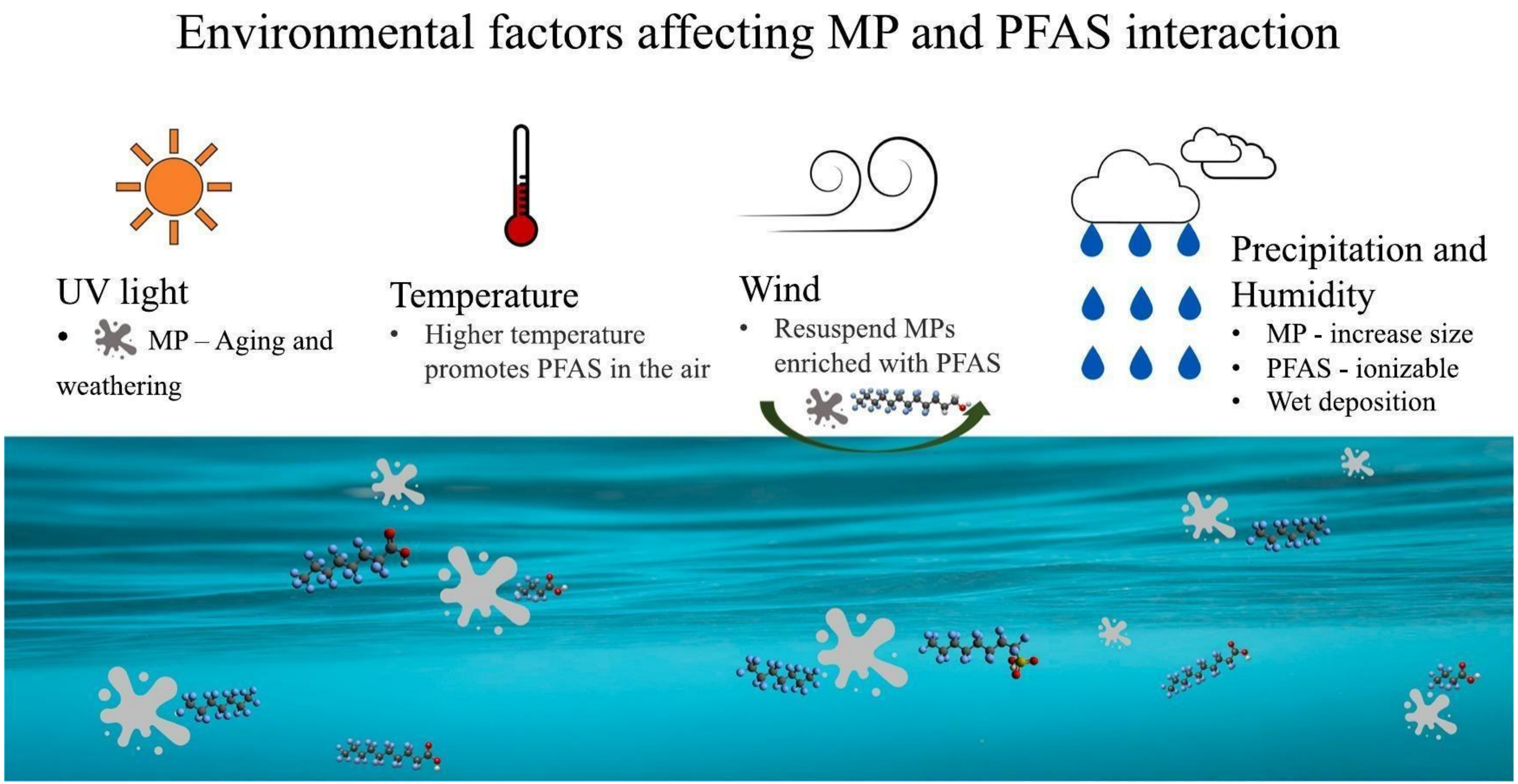
Microplastics could facilitate PFAS distribution

- Weathered MPs could behave differently.
- Atmospheric aging processes remain poorly understood, with most studies focusing on UV irradiation.



(Xu, Y., et al, *Environnemental Science & Technology* **2024** *58* (2), 991-1009

Research Gap



Yuxin Wang, Kelly D. Good, Science of The Total Environment, 2024, 954, 176247.

- Most studies focus on **water, sediment and soil**
- Limited understanding of **MPs-PFAS interactions,** particularly in the **atmosphere**

Future Perspectives

- Conduct long-term, multi-site monitoring to capture seasonal trends, regional differences, and emission sources
- Develop advanced analytical methods to detect and characterize nanoplastics, ultrafine particles, or total PFAS
- Investigate microplastic-PFAS interactions, particularly under atmospheric conditions, to better understand their co-transport, transformation, and health risks
- Simulate realistic atmospheric aging: thermal cycling, UV, oxidation, and biological effects

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Questions?


danke
謝謝
ngiyabonga
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спасибо
dank je
thank you
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tapadh leat
mauruuru
hvala
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