Classifying the Chemical and Biological Composition of Particles in Waterloo Region

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May 26th, 2026

Introduction and Motivation

Air Quality Team 2020-2022

ELSEVIER
Journal of Hazardous Materials
Volume 413, 5 July 2021, 125445

Research Paper

Rigorous quantification of statistical significance of the COVID-19 lockdown effect on air quality: The case from ground-based measurements in Ontario, Canada

Hind A. Al-Abadleh [a], Martin Lysy [b], Lucas Neil [c], Priyesh Patel [a], Wisam Mohammed [a], Yara Khalaf [a]

long-term pollutant trends from 2008 to 2019 to quantify the effect of COVID-19 lockdowns

(1) NO_2 reductions (11/16 Sites)

(2) O_3 and $PM_{2.5}$ reductions (3/16 sites)

- Third fastest-growing city in Canada
- Home to Canada's largest tech companies
- Welcomes 1000s of newcomers

Is one station sufficient ?

"We cannot manage what we cannot measure"

Introduction and Motivation

atmospher

Article

Air Quality Me… ito… Ca…
Multisensor M… tat…

Wisam Mohammed [1], Nico… Tow…
and Hind A. Al-Abadleh [1]


Dr. Nausheen Sadiq

Catharina Venter


Wisam Mohammed

4–30% … in AQHI … that reported by
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concentration of these pollutants.


Yara Khalaf

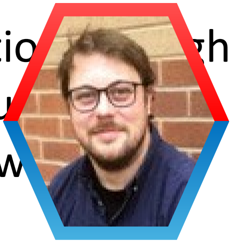

Dr. Hind Al-Abadleh

- Empowered over 250 students and teachers with critical knowledge a… po… pa… mitigation strategies, f… mental awareness.
- Bridged the gap between science and educatio… gh a real-time air quality dashboard, enabling stu… explore localized air quality data and engage w… actionable i…

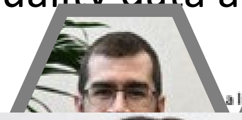

Wisam Mohammed

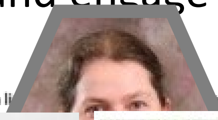

Hind Al-Abadleh


Priyesh Patel


Tom Townend


Adrian Adamescu





JOURNAL OF CHEMICAL EDUCATION

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Article

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The "Clean Air Outreach Project": A Paired Research and Outreach Program Looking at Air Quality Microenvironments around Elementary Schools

Yara Khalaf,[§] Carol Salama,[§] Brenda Kurorwaho,[§] Jessica C D'eon, and Hind A. Al-Abadleh*

ACS ES&T

pubs.acs.org/estair

**Dissolution of Selected Tr…
Aerosol Aging and Huma…
Ash**

Nausheen W. Sadiq,* Catharina Venter, Wisam Mohammed, Yara K…


Yara Khalaf


Carol Salamah


Brenda Kurorwaho


Dr. Jessica D'eon


Dr. Hind Al-Abadleh

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Main Research Question

What are the chemical, oxidative, and biological characteristics of atmospheric particles in Waterloo Region ?

Objectives

PM

BIOLOGICAL Quantification	Oxidative Potential	CHEMICAL Characterization
Airborne bacterial DNA signal 16S rRNA gene recovery	**Particle redox activity**	**Particle composition** Carbon and metal content

Knowledge Gap – From General Air Quality assessment to Detailed Composition in Mid-Sized Cities

What we know ?

Kitchener Ambient Air Monitoring Urban Site

Measure Pollutants:

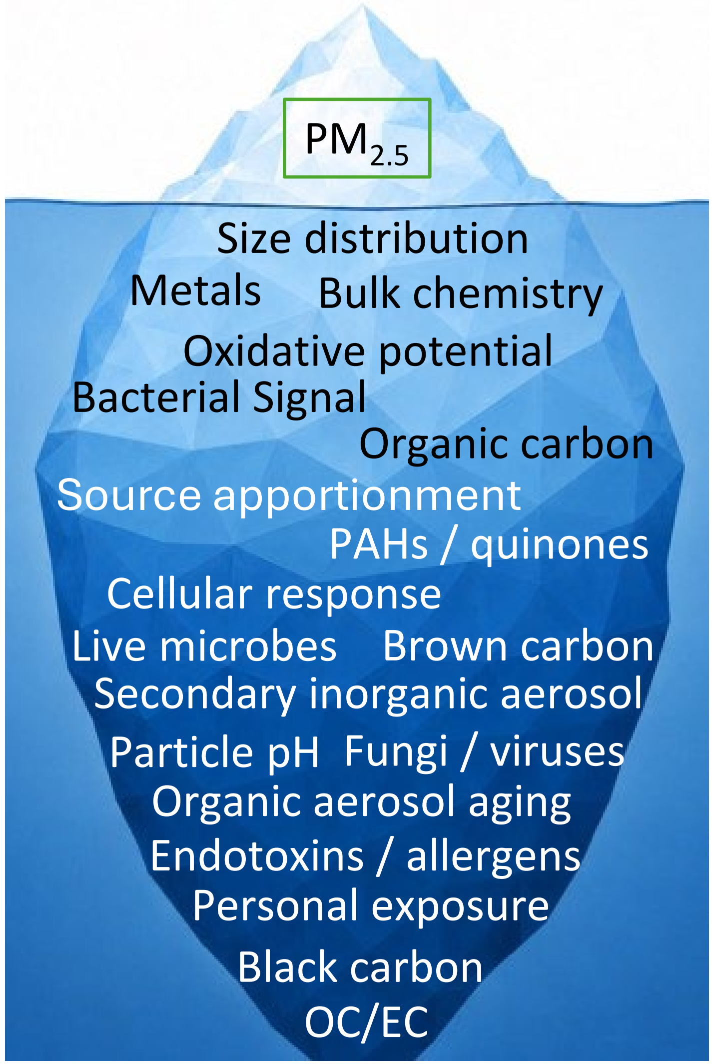
O_3 : Ozone (ppb)

$PM_{2.5}$ ($\mu g/m^3$): Fine Particulate Matter

NO_2 : Nitrogen Dioxide (ppb)

https://www.airqualityontario.com/history/station.php?stationid=26060

Knowledge gap: what $PM_{2.5}$ concentrations does not tell us ?

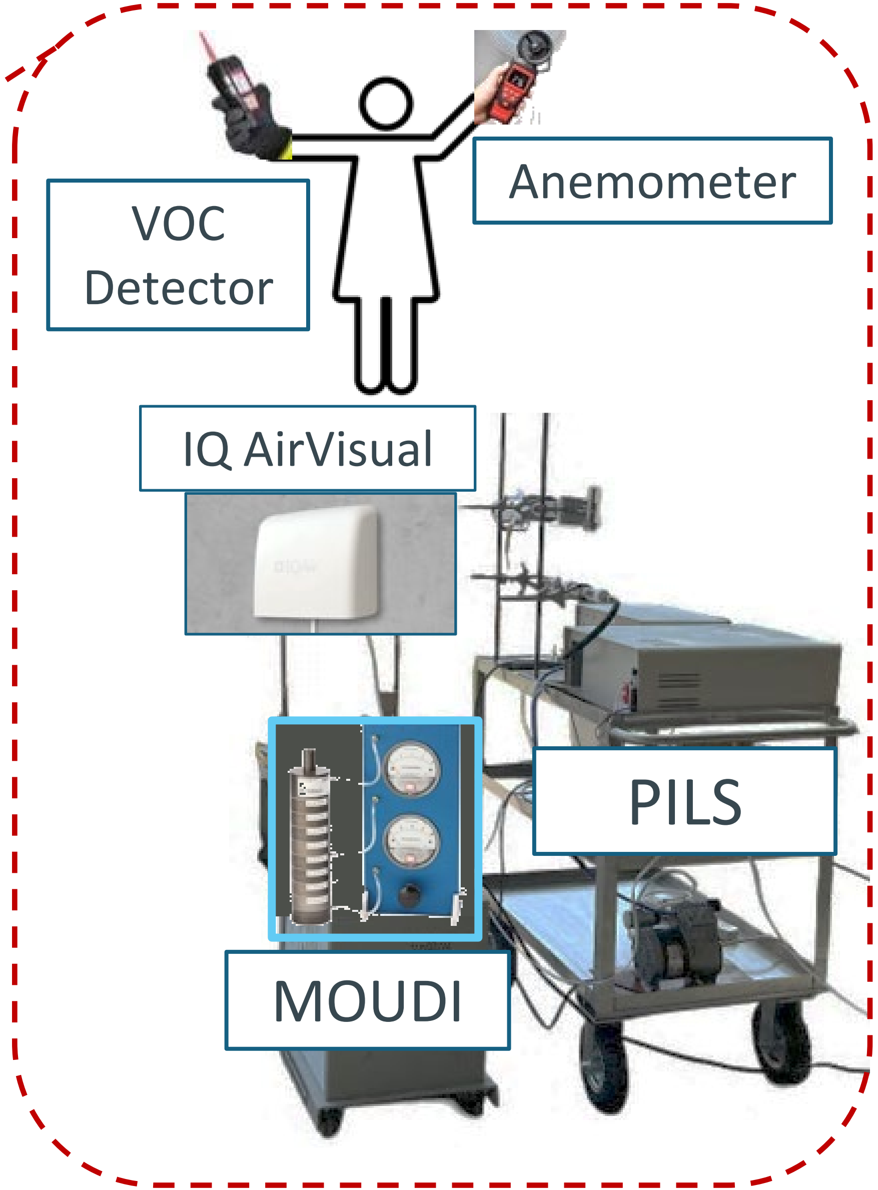


Knowledge Gap – From General Air Quality Assessment to Detailed Assessment in Mid-Sized Cities

This project as a response

King St N

Bricker Ave



Method Development

MOUDI — PILS — Filter Testing — Indoor Application — Extraction Workflow — DTT Setup — DTT Optimization — Chemical Analysis — Bioaerosol Workflow — Outdoor Deployment

Micro-Orifice Uniform Deposit Impactor

- Collects aerosols across aerodynamic size fractions
- Larger particles deposit on upper stages; smaller particles continue to lower stages
- Flow rate 30 L min^{-1}
- Provides stage-resolved filters for downstream chemical and biological analysis

https://tsi.com/products/cascade-impactors/non-rotating-moudi-impactors/moudi-impactors-100nr,-100s4,-110nr

Method Development

MOUDI | **PILS** | Filter Testing | Indoor Application | Extraction Workflow | DTT Setup | DTT Optimization | Chemical Analysis | Bioaerosol Workflow | Outdoor Deployment

Particle into Liquid Sampler

- Collects water-soluble aerosol into liquid
- Uses steam condensation to grow particles into droplets
- Generates liquid samples for TOC, soluble metals, DTT, and DNA
- Required field control of temperature, flow, flushing, and dilution
- Flow rate 15 L min^{-1}

https://www.brechtel.com/product/particle-into-liquid-sampler-pils/

Method Development

MOUDI · PILS · **Filter Testing** · Indoor Application · Extraction Workflow · DTT Setup · DTT Optimization · Chemical Analysis · Bioaerosol Workflow · Outdoor Deployment

Filter Selection and Gravimetric QA/QC

- Built a project specific gravimetric protocol for MOUDI field samples
- Tested multiple filters for mass stability, low static, mechanical integrity, and aqueous extraction
- Polytetrafluoroethylene (PTFE)

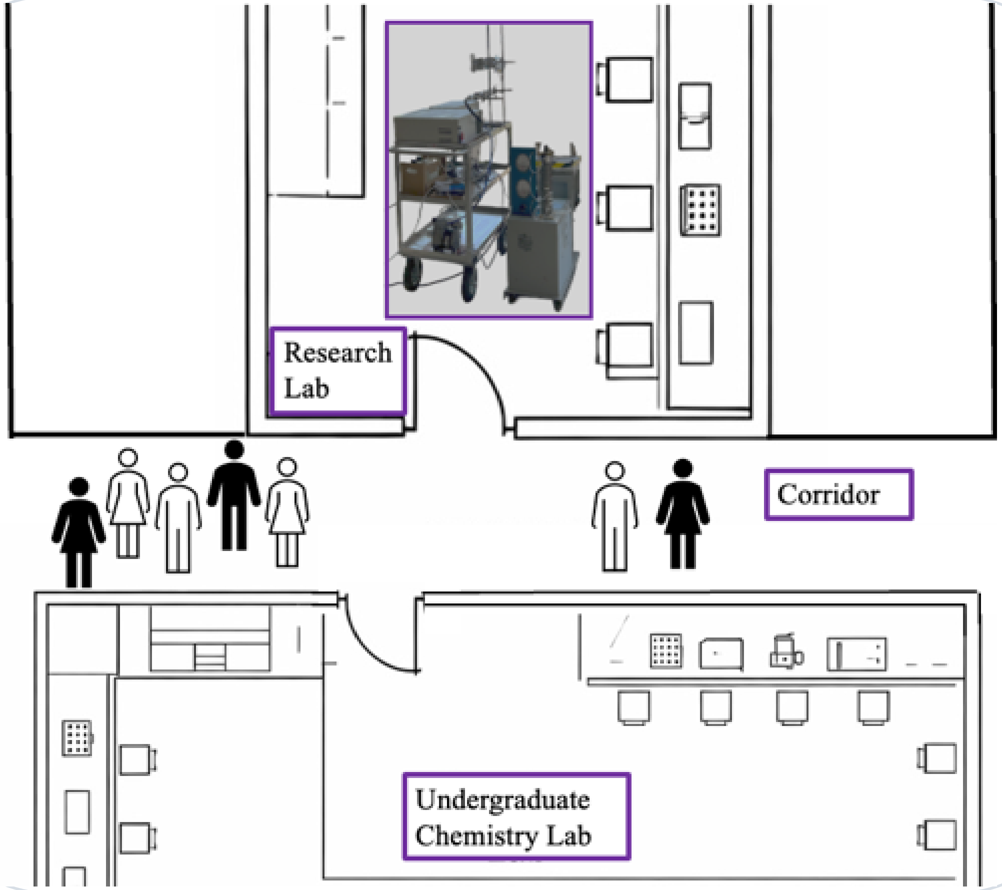
Hydrophobic PTFE provided the best balance and was selected as the primary MOUDI substrate.

Method Development

MOUDI · PILS · Filter Testing · **Indoor Application** · Extraction Workflow · DTT Setup · DTT Optimization · Chemical Analysis · Bioaerosol Workflow · Outdoor Deployment

Indoor Application

- Foundation stage before outdoor field sampling
- Tested MOUDI + PILS under laboratory conditions
- Compared high occupancy and low occupancy corridor periods
- Verified sampler operation, flow stability, and sample recovery
- Generated pilot samples for downstream analysis



Method Development

MOUDI – PILS – Gravimetrical Analysis – Indoor Application – **Extraction Workflow** – DTT Setup – DTT Optimization – Chemical Analysis – Bioaerosol Workflow – Outdoor Deployment

Extraction Workflow

- Converted collected MOUDI filter material into aqueous extracts
- Defined as an acid extractable aerosol fraction
- Enhances recovery of particle-bound metals and labile constituents

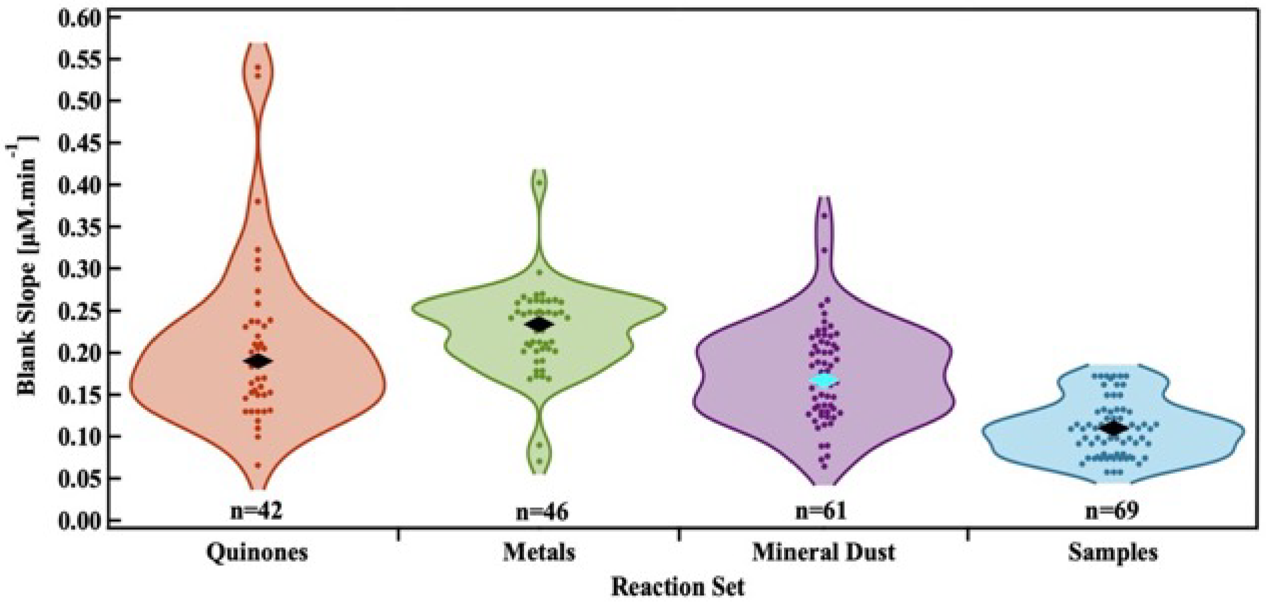
Method Development

PILS | Indoor Application | **DTT Setup** | Chemical Analysis | Outdoor Deployment

MOUDI | Filter Testing | Extraction Workflows | DTT Optimization | Bioaerosol Workflow

Dithiothreitol (DTT) assay setup

- Acellular assay for particle redox activity
- The method is sensitive to procedural techniques
- The outcomes depend on reaction initiation, the synchronized of stopping across reactions, and the consistency of the yellow color development
- Redox-active PM components accelerate DTT oxidation
- Blank slopes used as a diagnostic of assay stability



Particles → consume DTT → remaining DTT makes yellow color → measure oxidative potential

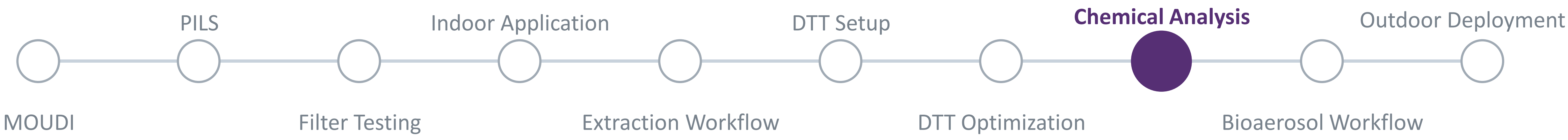
Method Development

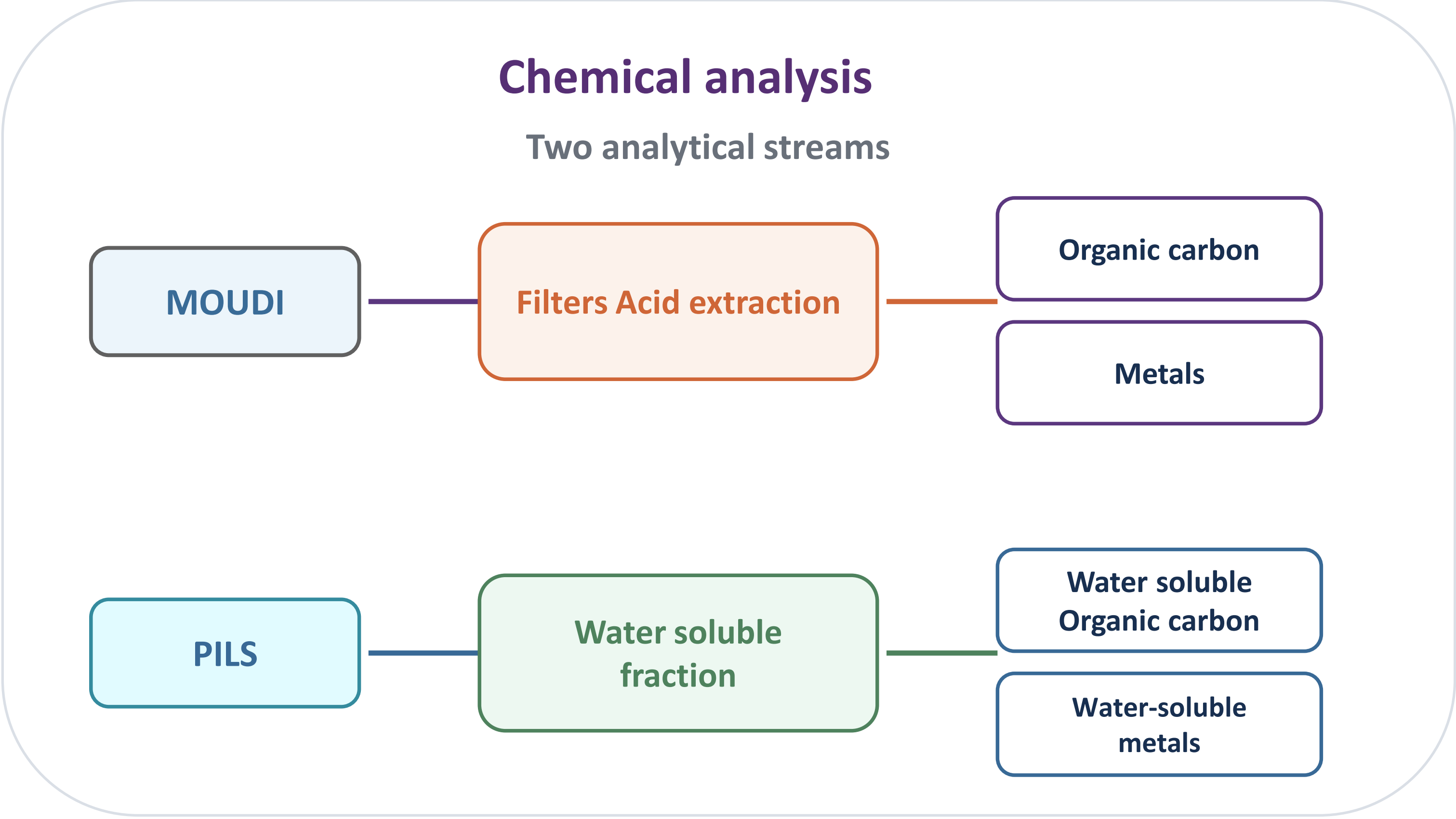
MOUDI — PILS — Filter Testing — Indoor Application — Extraction Workflow — DTT Setup — **DTT Optimization** — Chemical Analysis — Bioaerosol Workflow — Outdoor Deployment

DTT assay optimization

- Optimized conditions: 37°C, 100 µM DTT, water bath and stirring
- Measured activity was within the range reported in previous studies
- This supported applying the assay to atmospheric samples

Method Development



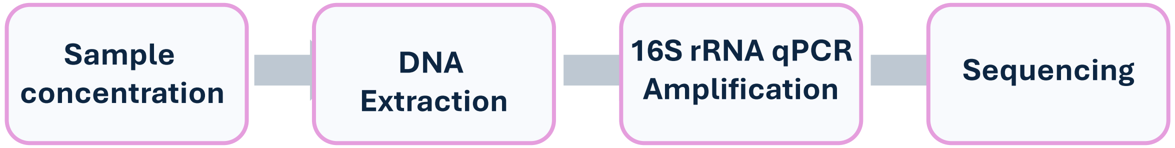


Method Development

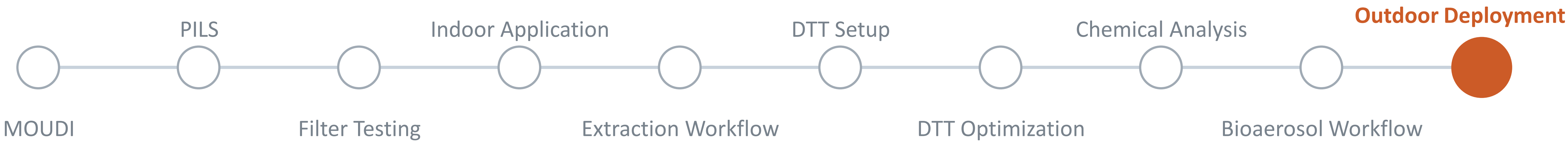
MOUDI — PILS — Filter Testing — Indoor Application — Extraction Workflow — DTT Setup — DTT Optimization — Chemical Analysis — **Bioaerosol Workflow** — Outdoor Deployment

Bioaerosol workflow

- Developed for ultra low-biomass atmospheric samples
- Concentrated samples before DNA extraction
- Quantified bacterial signal using 16S rRNA gene Quantitative Polymerase Chain Reaction (qPCR)
- Confirmed amplification with melt-curve / gel checks
- Contamination control
- DNA indicates biological material, not viability



Method Development



Preliminary Results

Examples of workflow outputs

Outdoor Campaigns Summary 2023 -2024

Summer 2023 Campaign Date	$PM_{2.5}$ Average µg/m^3
Aug 16th, 2023	47 .3
Aug 22nd, 2023	9.5
Aug 25th, 2023	9.2
Aug 28th ,2023	7.9
Sep 1st , 2023	6.8
Summer 2024 Campaign Date	**$PM_{2.5}$ Average µg/m^3**
May 30, 2024	2.5
June 19, 2024	17.4
July 4, 2024	4.7
July 8, 2024	7.9
July 25,2024	4.8
July 26, 2024	6.7
July 29, 2024	18
July 31, 2024	19
Aug 1, 2024	20
Aug 2, 2024	15.6
Aug 30, 2024	8.5
Sep 9th , 2024	7
Sep 10th 2024	7
Sep 13th ,2024	14
Sep 17th ,2024	14
Sep 18th , 2024	17
Sep 19th , 2024	16
Sep 20th , 2024	18

Fall 2023 Campaign Date	$PM_{2.5}$ Average µg/m^3
Oct 5th ,2023	11.3
Oct 6th ,2023	12.1
Fall 2024 Campaign Date	**$PM_{2.5}$ Average µg/m^3**
Oct 9th , 2024	1
Oct 10th , 2024	1
Oct 11th , 2024	6
Oct 15th , 2024	0.2
Oct 16th , 2024	0.3
Oct 17th , 2024	2
Oct 18th , 2024	11
Oct 21st ,2024	11
Oct 22nd , 2024	13
Oct 23rd , 2024	9
Oct 24th , 2024	2

Event based sampling captured a wide $PM_{2.5}$ range, from clean background days to elevated smoke/urban episodes.

Smoke and Transport Context for the August 16th, 2023 Field Campaign

firesmoke.ca
NASA FIRMS. 2023. Fire Information for Resource Management System (FIRMS): active fire detection data for North America. NASA Earth Science Data and Information System (ESDIS). Data subset used: active-fire detections for 16 August 2023 over Canada and the United States, downloaded as geospatial fire-point data and used for the August smoke-transport maps. Accessed May 3, 2026.
Stein, A. F., Draxler, R. R., Rolph, G. D., Stunder, B. J. B., Cohen, M. D., and Ngan, F. (2015). NOAA's HYSPLIT atmospheric transport and dispersion modeling system. Bulletin of the American Meteorological Society, 96, 2059–2077. doi:10.1175/BAMS-D-14-00110.1.
Rolph, G., Stein, A., and Stunder, B. (2017). Real-time Environmental Applications and Display sYstem: READY. Environmental Modelling & Software, 95, 210–228. doi:10.1016/j.envsoft.2017.06.025.
Statistics Canada. (2021). Boundary Files, Census year 2021 (Catalogue no. 92-160-X). Government of Canada.

2023 Campaigns: $PM_{2.5}$, PILS soluble carbon, and oxidative potential

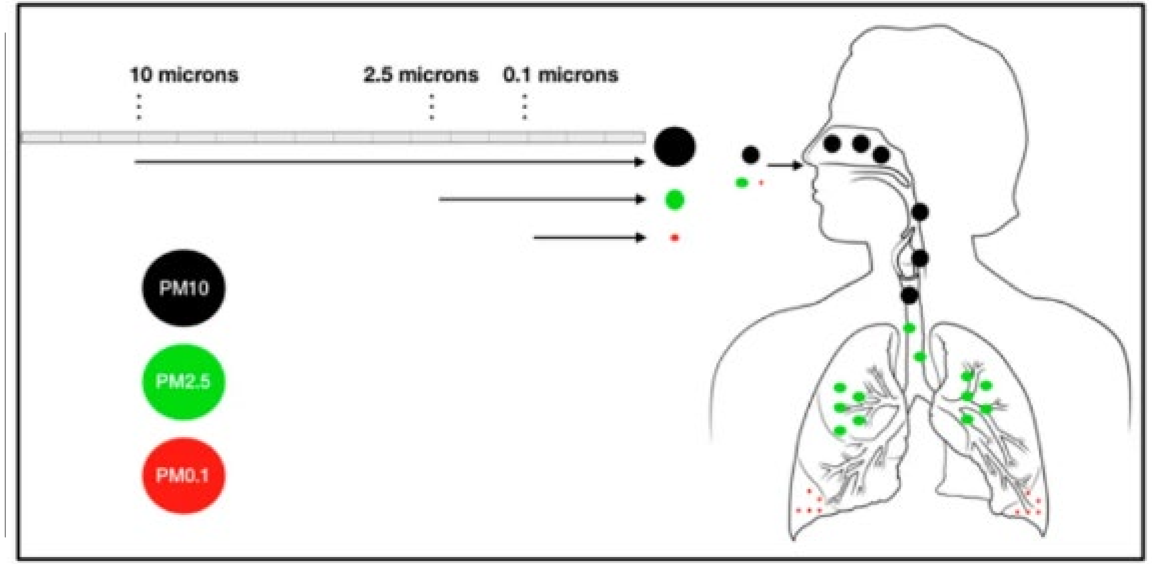
The highest $PM_{2.5}$ and soluble carbon event was not the strongest DTT response

2024 Campaigns: $PM_{2.5}$, PILS soluble carbon, metals and oxidative potential

Each sampling day carried a different chemical fingerprint

2023 MOUDI field example: size resolved carbon and oxidative potential

MOUDI analysis showed that organic carbon and oxidative potential can occupy different size resolved patterns



Lee, C. W., Vo, T. T. T., Wu, C. Z., Chi, M. C., Lin, C. M., Fang, M. L., & Lee, I. T. (2020). The Inducible Role of Ambient Particulate Matter in Cancer Progression via Oxidative Stress-Mediated Reactive Oxygen Species Pathways: A Recent Perception. *Cancers*, *12*(9), 2505. https://doi.org/10.3390/cancers12092505

2024 MOUDI field example: size-resolved particle mass

Seasonal median MOUDI gravimetric mass size distributions, expressed as dCm/dlogDa, for the summer and fall 2024 campaigns across the fine and ultrafine size range

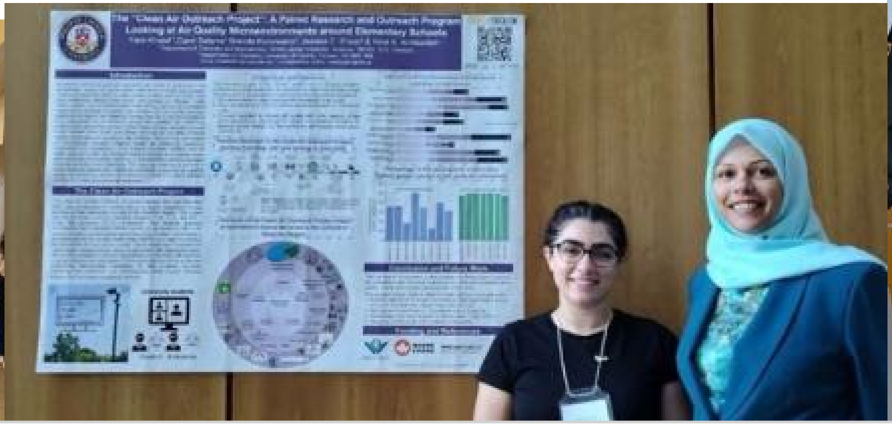
MOUDI measurements show how particle mass is distributed by size, providing information that bulk samples cannot resolve.

Bioaerosol Signal in Outdoor Aerosol

The bioaerosol workflow recovered measurable bacterial 16S rRNA gene signal from low biomass atmospheric samples, with higher recovery in 2024 PILS samples than in the earlier 2023 extracts.

Selected 2024 PILS samples: Shotgun metagenomic sequencing , taxonomic context

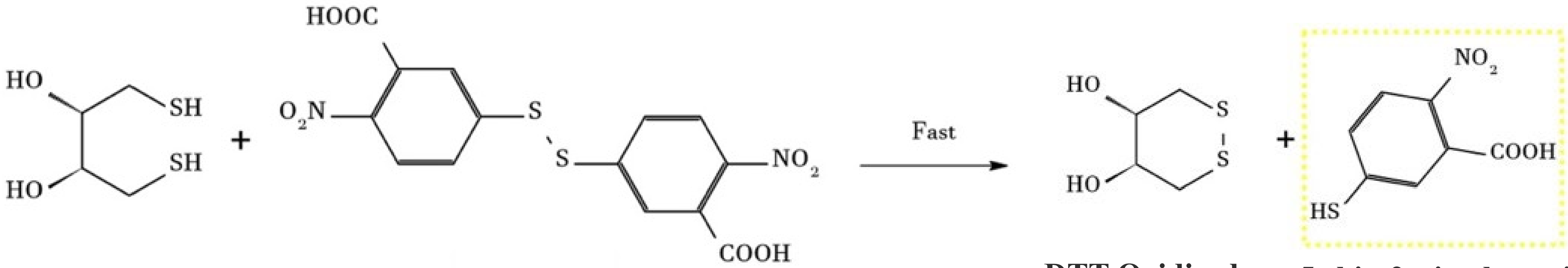
Bacterial family-level contrast between two sequenced September 2024 PILS aerosol DNA extracts



With gratitude to my professor and mentor Hind Al-Abadleh, whose guidance shaped this work.

Thank you

DTT setup



Dithiothreitol (DTT) Reduced

5,5′-Dithiobis(2-nitrobenzoic acid) (DTNB)

DTT Oxidized

5-thio-2-nitrobenzoic acid (TNB)

qPCR Protocol

Stage	Cycles	Temp (˚C)	Hold Time (s)	Ramp Rate (˚C s^{-1})
Initial denaturation / enzyme activation	1	95.0	120	1.6
Denaturation	40	95.0	15	1.6
Annealing/extension	40	60.0	60	1.6
Melt curve-denaturation	1	95.0	15	1.6
Melt curve-re-anneal	1	60.0	60	1.6
Melt curve-acquisition and Dissociation	1	95.0	15	0.075

Particulate Matter Composition