Jay G. Slowik :: Laboratory of Atmospheric Chemistry :: Paul Scherrer Institute

Advanced Source Apportionment and Aerosol Oxidation Potential
New Strategies for Improved Air Quality and Public Health

Better Air Quality Conference (BAQ 2023)
Manila, Philippines
November 15, 2023
Aerosol sources and health risks

Globally ~9 million premature deaths per year.

Measure particle composition
Source apportionment

Oxidation with $O_3$, $OH^·$, $NO_3^·$

Primary particles + gases

Oxidized gases

Secondary particles

NATURAL

ANTHROPOGENIC
Shortcomings in source apportionment

Huang et al., *Nature*, 2014

High-visibility study (>3500 citations) of extreme haze in China via source apportionment of collected filter samples

Highlighted role of secondary species in extreme haze
Shortcomings in source apportionment

Huang et al., *Nature*, 2014

Which source(s) control health risks?

What do these names mean?

How to relate to sources/processes?

Intense effort by leading researchers \(\Rightarrow\) results 1 YEAR after measurement

Too slow!

Fast response to acute events

Policy motivation, design, implementation
Shortcomings in source apportionment

Huang et al., *Nature*, 2014

Which source(s) control health risks?

What do these names mean?

How to relate to sources/processes?

Clean Air in China Project
- Advanced source apportionment of organic aerosol
- Link sources to reactive oxygen species (ROS)
- Develop real-time source apportionment model (DEZA PMF)

Intense effort by leading researchers → results 1 YEAR after measurement

Too slow!

Fast response to acute events
Policy motivation, design, implementation

November 15, 2023
Jay G. Slowik (jay.slowik@psi.ch)
Information on particulate air pollution sources available within minutes of the measurement.

Step 1: Measurements & standard analysis
Automated data processing
Chemical composition (no sources)

Manousakas et al., in prep
DEZA PMF: real-time source results

Information on particulate air pollution sources available within minutes of the measurement.

Manousakas et al., in prep
DEZA PMF: real-time source results

Information on particulate air pollution sources available within minutes of the measurement.

Step 3: Automated recombination of apportionment results
Complete source apportionment

Manousakas et al., in prep
Advanced source apportionment of secondary OA

**EESI-TOF:**
PSI-developed instrument
Molecular composition of organics

**AMS:**
Quantification of aerosol components
Limited chemical speciation of organics

**Better chemical resolution → improved source apportionment**

---

**Online method** (continuous field measurements)
Advantages:
- Fast time resolution (matches human activity)
- Daily cycles
- Avoid collection/storage artifacts

**Offline method** (bring filter extracts to lab)
Advantages:
- Long (year or more) time series
- Spatial coverage
- Can analyze historical samples

---

November 15, 2023
Jay G. Slowik (jay.slowik@psi.ch)
Source apportionment: added value from EESI

Primary Organic Aerosol:  
- Traffic  
- Cigarette smoke

Secondary Organic Aerosol (SOA)

OA Concentration ($\mu$g m$^{-3}$)

- $<5$
- $5-10$
- $15-30$
- $15-30$
- $>30$

Ep. 1  
Ep. 2  
Ep. 3

SOA dominates... progressively more so as pollution increases

Qi et al., in prep
Source apportionment: added value from EESI

Primary Organic Aerosol:

Secondary Organic Aerosol:

Secondary Composition

Traffic, Cigarette smoke, Cooking, Fresh biomass burning

Secondary Composition

Traffic, Aqueous SOA, Aqueous SOA (NH₃-Influenced)

Secondary Composition

Secondary/Aged biomass burning

Daytime oxidation, Nighttime oxidation

AMS only

Traffic-influenced

AMS + EESI-TOF

High pollution episodes

High pollution episodes

SOA dominates... progressively more so as pollution increases

Aqueous SOA and aged/secondary biomass burning are important

Traffic-derived SOA not dominant but does matter, especially under less polluted conditions.

Qi et al., in prep

November 15, 2023  Jay G. Slowik (jay.slowik@psi.ch)
Oxidative potential (OP)

Epidemiology vs. Toxicology

Acellular assays
- Expose known amount of anti-oxidant to aerosol
- Measure consumption of anti-oxidant with time

“Oxidative Potential ("OP")”
Related to health risk

ROS = reactive oxygen species

Bronchial cells

Lining fluid

Redox cycling

Oxidative stress

Cardio-vascular diseases

1. Cytokine signaling
2. Systemic inflammation
3. DNA alteration and protein deactivation

Similar to Alzheimer, autoimmune diseases...

Free radicals

Antioxidants

PM_{10}
PM_{2.5}
PM_{0.1}

PMs

ROS

RED

OX

O_2

O_2^-
Sources of oxidative potential (OP) in 6 Chinese cities

Chongqing (CHQ), Xi’an (XIA), Beijing (BEJ), Langfang (LGF), Shijiazhuang (SJZ), Wuhan (WHN)

PM$_{2.5}$ mass

OP-dominating sources are different from city to city:

- Dust: low toxicity but high mass → still the largest OP contributor in Xi’an (XIA) and Langfang (LGF).
- Non-exhaust traffic (e.g., brake wear) is important in Beijing (BEJ).
- Secondary organics (“OOAs”) and solid fuels are important at all sites.

Jay G. Slowik (jay.slowik@psi.ch)
Conclusions

- Newly developed model for real-time source apportionment (DEZA PMF).
  - Results available within minutes of measurement
  - Not available anywhere else in the world

- Successful apportionment of secondary organic aerosol in terms of real-world sources and processes.

- Quantitative links between sources of PM and their potential health effects.
Acknowledgements

• Thanks to co-authors!
  – Paul Scherrer Institute
    Prof. Dr. Andre Prevot
    Dr. Lu Qi
    Dr. Tianqu Cui
    Dr. Manousos Manousakas
    Rico K. Y. Cheung
    Dr. Robin L. Modini
    Dr. Kaspar R. Daellenbach
  – Institute of Earth Environment (IEE) and Institute of Atmospheric Physics (IAP)
    Prof. Junji Cao

• Project supported by:
  Swiss Agency for Development and Cooperation.