CHEMICAL SPECIATION OF PM$_{2.5}$ IN MAJOR CITIES WORLDWIDE

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SPARTAN Team
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AS3.21 (R. 2.91), Megacities session
**GLOBAL SIGNIFICANCE OF PM$_{2.5}$**

- **Dhaka**  > 50 μg m$^{-3}$
- **Beijing**  > 70 μg m$^{-3}$
- **Hanoi**  > 40 μg m$^{-3}$
- **Rehovot**  15-150 μg m$^{-3}$

- WHO target of PM$_{2.5}$ = 10 μg m$^{-3}$
- Adverse lung, cardiovascular effects
- 3 million* annual deaths worldwide (3% of all deaths)

NEED TO EVALUATE SATELLITE-DERIVED PM$_{2.5}$

PM$_{2.5,\text{surface}} = f(\text{AOD})$

= f(\text{AOD, RH, mixing, composition, diurnal, ...})

AOD = aerosol optical depth

van Donkelaar, et al ES&T 2016, 50, 3762
**SPARTAN = SURFACE PARTICULATE MATTER NETWORK**

SPARTAN Headquarters:
Dalhousie U, Halifax NS

**Urban Areas:**
- Beijing
- Kanpur
- Hanoi
- Buenos Aires
- Dhaka
- Manila
- Rehovot

Ongoing measurements of ground-level PM$_{2.5}$
colloqued with AOD measurements (sun photometer)

- Each site collocated with sun photometer
  (AERONET)

Sun Photometer: AOD at 550 nm

SPARTAN INSTRUMENTS

Each SPARTAN station includes two instruments:

Physical sampling: aerosol filters

Optical sampling: Nephelometer

Multi-day measurements per filter

*AirPhoton.com
FILTER WEIGHING

• Cleanroom facility (< 100 particles/cm³)
• Follows USEPA protocols:
  • T-range: 20 – 25 °C
  • RH-range = 30 – 40 %
• Daily mass calibrations
DECONSTRUCTING FILTER MASS

<table>
<thead>
<tr>
<th>Species</th>
<th>Rel. Composition</th>
</tr>
</thead>
<tbody>
<tr>
<td>Soil = {Mg, Al, Ti, Fe}</td>
<td>8 – 23%</td>
</tr>
<tr>
<td>Sea Salt = {Na}</td>
<td>1 – 10%</td>
</tr>
<tr>
<td>Trace Element Oxides = {V, Zn, As, Cd, Ba, Pb}</td>
<td>&lt; 1%</td>
</tr>
<tr>
<td>Ammonium nitrate = {NO}_3</td>
<td>2 – 10%</td>
</tr>
<tr>
<td>Ammonium sulfate = {SO}_4, NH}_4</td>
<td>5 – 26%</td>
</tr>
<tr>
<td>Effective Black Carbon = {Reflectance}</td>
<td>2 – 13%</td>
</tr>
</tbody>
</table>
Residue Matter (RM*) = Total Mass – [Inorg.] – [PBW]

Particle-bound water (PBW*) = f(RH)

*RM and PBW are indirectly measured

Trace Metals: Al, Mg, Ti, Fe, V, Cr, Mn, Zn, As, Ba, Pb
GLOBAL PM$_{2.5}$ COMPOSITION

PM$_{2.5}$

Site | Zn:Al
---|---
Hanoi | 2.7
Singapore | 1.6
Dhaka | 2.6
M. Cave | 0.1

ESTIMATING PARTICLE-BOUND WATER (PBW)

Hygroscopicity parameter (k-Kohler theory):

\[
\kappa_{m,tot} = \frac{1}{M} \sum_x m_x \kappa_{m,x}
\]

\[
f_m(RH) = 1 + \kappa_{m,tot} \frac{RH}{100 - RH}
\]

\[
PBW = M \times (f_m(35\%) - 1)
\]

1. Average k over PM components
2. Set RH to 35%
3. Add to water total mass

<table>
<thead>
<tr>
<th>Compound</th>
<th>K</th>
</tr>
</thead>
<tbody>
<tr>
<td>Crustal, BC, TEO</td>
<td>0</td>
</tr>
<tr>
<td>RM/OM</td>
<td>0.10</td>
</tr>
<tr>
<td>ASO_4</td>
<td>0.56</td>
</tr>
<tr>
<td>ANO_3</td>
<td>0.67</td>
</tr>
<tr>
<td>NaCl</td>
<td>1.12</td>
</tr>
</tbody>
</table>

Duplissy et al. ACP, 11, 1155-65, 2011
WATER-MASS CONTRIBUTION

$K_v$

PM$_{2.5}$

PBW (35% RH)

ANO$_x$, ASD$_x$, Sea Salt, EBC, TEO, Crustal, PBW

SPARTAN sites

Buenos Aires, ilorin, Pretoria, Dhaka, Singapore, Bandung, Manila
HOURLY PM$_{2.5}$ ESTIMATES

\[
PM_{2.5, \text{hourly,dry}} = \frac{\langle PM_{2.5, \text{dry}} \rangle}{\langle b_{sp}(RH)/f_v(RH) \rangle} \cdot \frac{b_{sp}(RH)}{f_v(RH)}
\]

Summer 2014 Beijing comparison of PM$_{2.5}$

- \( r^2_{\text{hourly}} = 0.67 \)
- \( n = 148 \)

TRACE ELEMENTS: CRUSTAL ENRICHMENT FACTORS

EF(X) = \frac{\left[ \frac{[X]}{[Al]} \right]_{PM2.5}}{\left[ \frac{[X]}{[Al]} \right]_{Crust.}}

-Snider et al, ACP in prep, 2016
CORRELATIONS OF SPECIES

All-site weighted average:

- Crustal Material
- Biomass burning
- Coal & industry
- Vehicle dust

Pearson Correlation (r)

Industrial, Road Dust
Biomass (Wood, Coal, Oil)
Natural Dust
SUMMARY

• Ongoing PM$_{2.5}$ and AOD measurements in urban areas:
  - hourly, seasonal, and multi-year time spans

• Characterizing PM$_{2.5}$ mass, composition at a single facility,
  using standardized methods

• Aerosol components show multi-site correlations, trends

• We encourage ideas for new partnerships. For more
  information, please visit spartan-network.org

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THANK YOU/DANKE SCHÖN

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