Preliminary Analyses of PM2.5 ACSM Measurements in Handan, China

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Background

• For many years Aerodyne had been developing a PM2.5 aerodynamic particle sampling lens (Xu et. al. 2016).

• By the spring of 2015, the PM2.5 lens had already gone through extensive lab tests.

• In May 2015, a Q-ACSM with a prototype PM2.5 lens and a prototype Particle Capture Vaporizer was ordered by Handix, with the intention to deploy the system in China to test its vitality in more polluted environment.

• In June 2016, the PM2.5 ACSM was delivered to Handix (Nanjing, China).

• Since then, the demo PM2.5 ACSM has been deployed in Nanjing (July – October, 2015), Handan (Dec. 2015 – Feb. 2016), Guangzhou (Oct-Nov. 2016) and PKU-Beijing (Nov. 2016 - now).
Why in Handan?

- Handan city, with a population of about 2 million, is located about 400 km southeast of Beijing.

- It is often listed as the top-10 most polluted cities in China.

- Most pollutants are from coal combustion by the steel and chemical plants, vehicle emissions, civilian heating, etc.
Sampling site

- The sampling site is on the rooftop of a 5-story building on the campus of Hebei University Of Engineering.

- It is near the edge of the city, about 450m away from a main highway.
Instruments and Collaborators

1. PM2.5-ACSM (Handix/Aerodyne)
2. Xact-625 (Handix/CES)
3. PM1.0-ACSM (Tsinghua University)
4. PAX (Tsinghua University)
5. SMPS (Tsinghua University)
6. MAAP (Tsinghua University)
7. BAM (Beta Attenuation Monitor) for PM1 mass loading (Academy of Environmental Sciences of Hebei Province)
8. PTR-MS (Academy of Environmental Sciences of Hebei Province)
9. ECOTECH Nephelometer (Academy of Environmental Sciences of Hebei Province)
10. TEOM (Tapered Element Oscillating Microbalance) for PM2.5 mass loading (Hebei University Of Engineering)
11. Personal Weather Station (Hebei University Of Engineering)
12. POPS (Handix)
13. APS (Tsinghua University)
Experiment Timeline

Dec. 4, 2015
- Personal Weather Station
- ACSM (PM1.0, PM2.5)
- TEOM PM2.5
- PAX, SMPS, M
- AAPDec.
- BAM, PM1.0, PTR-MS, ECOTECH NEPH

Dec. 4, 2015
- APS, POPES

Jan. 19, 2016
- 10:16 ECBC flow rate for ACSMs increased from 2LPM to 3LPM

Feb. 29, 2016
- Xact-625
Time Series of PM2.5-ACSM mass loading

Sampling flow rate was changed to 3LPM
Coefficient values ± one standard deviation

\[ a = 16.911 \pm 1.44 \]
\[ b = 0.793 \pm 0.010 \]
\[ r^2 = 0.827 \]
**Period 1**

- When flow rate was 2LPM before Jan. 16, 2016 10:16am;
Pie Chart

Total Mass: 277.57 μg/m³
- Org: 47.8%
- NH₄: 7.8%
- SO₄: 6.8%
- NO₃: 6.4%
- Chl: 10.6%
- BC: 20.6%
The graph shows the loading (µg/m³) over local time from 2015/12/26 to 2016/1/15. The following data lines are distinguished:

- Green line: ACSM chemical sum
- Red line: mass loading of (ACSM+PAX)
- Black line: PM2.5 by TEOM
- Blue line: PM1.0 by BAM

The graph indicates fluctuations in loading over time, with peaks and valleys correlating to specific local times.
Mass loading: PM2.5-ACSM vs TEOM(PM2.5)

Coefficient values ± one standard deviation:

\[ a = 12.662 \pm 2.588 \]
\[ b = 1.055 \pm 0.009 \]
\[ r^2 = 0.937 \]

Graph showing correlation between NR-PM2.5 and PM2.5, with coefficient values provided.
Mass loading: (ACSM + PAX) vs TEOM(PM2.5)

Coefficient values ± one standard deviation:

\[ a = 14.370 \pm 2.650 \]
\[ b = 1.128 \pm 0.009 \]
\[ r^2 = 0.943 \]
Paradox?

• that 89% of the non-refractory mass is detected with the new system, while was only 65% with the old system. (Xu et al. 2016)
Period 2

- When flow rate was changed to 3LPM on Jan. 16, 2016 10:16am, but before Festival;
Coefficient values ± one standard deviation

\[ a = 11.066 \pm 1.759 \]
\[ b = 0.947 \pm 0.012 \]
\[ r^2 = 0.937 \]
Period 3 - In the Festival Period

Difference:
dust cannot be vaporized by VapT=600°C, nor detected by PAX or Xact.
• Excluding dust in Pie;
• Still 14.29% of PM2.5 mass;
Mass loading : PM2.5-ACSM vs TEOM(PM2.5)
Mass loading: (ACSM + PAX + Xact) vs TEOM (PM2.5)
Summary

- For sampling flow rate of 2LPM and 3LPM, very good regression factors between mass loading of NR-PM2.5 and that of PM2.5;
- About half of PM2.5 mass cannot be detected by PM2.5-ACSM, PAX or Xact-625 in Spring Festival and Lantern Festival, which causes a bad regression.
- Higher slope (Period 1) caused by 1) loss of volatile/semi-volatile species due to the evaporation in TEOM, Or 2) shift of larger particles (Dp>2.5 μm) to the measurement size range (Dp0.1-2.5μm) of PM2.5-ACSM?
- Minimal loss of micron particles (Dp1.0-2.5μm)(Period 2&3) in bends of sampling tube to ACSM, when sampling flow rate increased to 3LPM, to some extent.
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