Chemical characteristics and sources of PM$_{2.5}$ during haze pollution events in Beijing

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Introduction

The orographic condition and surrounding of Beijing (Source: Google map)
Introduction

Methodology

• **Sampling methods**
  – **Sampling period:** 2013.04.10 – 2013.06.08
  – **Samplers:** 2 high volume samplers DHA-80 (500 l min⁻¹)
  – **Filters:** Quartz fiber filters (Ø 150 mm)
  – **Sampling time:** 24 h (00:00-24:00) (4 h during some haze episodes)

• **Meteorological parameters**
  ZBAA: T, RH, P, WD, WS
  IAP: Precipitation, MLH

• **Visibility**
  ZBAA
Methodology

• **Analytical methods**
  – Thermal/Optical Carbon Analyzer: EC/OC
  – Inductively Coupled Plasma Mass Spectrometry: K, Ca, Na, Mg, Al, Fe, V, Cr, Mn, Ni, Cu, Zn, As, Cd, Ba, Tl, and Pb
  – Ion Chromatography: Cl⁻, NO₃⁻, SO₄²⁻, NH₄⁺, K⁺, Mg²⁺, Ca²⁺
  – Gas Chromatography-Mass Spectrometry: 11 hopanes and 11 polycyclic aromatic hydrocarbons (PAHs)

**Hopanes:**
- \(18\alpha(H)-22,29,30\)-Trisnorneohopane (Ts)
- \(17\alpha(H)-22,29,30\)-Trisnorhopane (Tm)
- \(17\beta(H)-22,29,30\)-Trisnorhopane (27b)
- \(17\alpha(H)21\beta(H)-30\)-Norhopane (29ab)
- \(17\beta(H)21\alpha(H)-30\)-Norhopane (29ba)
- \(17\alpha(H)21\beta(H)\)-Hopane (30ab)
- \(17\beta(H)21\alpha(H)\)-Hopane (Moretan) (30ba)
- \(22S-17\alpha(H)21\beta(H)\)-Homohopane (31abS)
- \(22R-17\alpha(H)21\beta(H)\)-Homohopane (31abR)
- \(22S-17\alpha(H)21\beta(H)\)-Bishomohopane (32abS)
- \(22R-17\alpha(H)21\beta(H)\)-Bishomohopane (32abR)

**PAHs:**
- benz(a)anthracene (BAA)
- chrysene (CRY)
- benz(bk)fluoranthene (BBKF)
- benzo(e)pyrene (BEP)
- benzo(a)pyrene (BAP)
- perylene (PER)
- dibenz(a,h)anthracene (DAH)
- indeno(1,2,3,c,d) pyrene (IND)
- picene (PIC)
- benz(g,h,i)perylene (BGH)
- coronene (COR)
Results

Average: 89 µg m\(^{-3}\)

24 h PM\(_{2.5}\) threshold values:
- WHO: 25 µg m\(^{-3}\)
- US-EPA: 35 µg m\(^{-3}\)
- China (Grade II): 75 µg m\(^{-3}\)

Green: Clear days
- HP1: 164 µg m\(^{-3}\)
- HP2: 164 µg m\(^{-3}\)
- HP3: 125 µg m\(^{-3}\)
- Clear: 45 µg m\(^{-3}\)

Red: Heavy haze days
- HP1: 164 µg m\(^{-3}\)
- HP2: 164 µg m\(^{-3}\)
- HP3: 125 µg m\(^{-3}\)
- Clear: 45 µg m\(^{-3}\)
Variations of compounds

Mass concentration (µg C m⁻³)

Sampling Date

HP1
HP2
HP3

Mass concentration (µg m⁻³)

Sampling Date

NO₃⁻
SO₄²⁻
NH₄⁺
Variations of compounds

Mass concentration (µg m⁻³)

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Mass concentration (ng m⁻³)

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Variations of compounds

Mass concentration (ng m$^{-3}$)

Sampling date

Haze/Clear

2013.04.10-2013.06.08

2013.04.10-2013.05.31

Mass concentration ratio

Mass percentage ratio

Rongrong Shen
2014-04-28

EGU

Institute of Meteorology and Climate Research (IMK-IFU)
Variation of compounds mass percentages

HP1: NO$_3^-$
HP2 & HP3: SO$_4^{2-}$
Average mass balance

Haze: 146 µg m⁻³

Clear: 45 µg m⁻³

- NO₃⁻: 18.5%
- SO₄²⁻: 23.6%
- NH₄⁺: 14.6%
- OM: 17.0%
- EC: 3.5%
- Mineral: 10.0%
- Other: 12.1%
- Trace elements: 0.8%

- NO₃⁻: 6.9%
- SO₄²⁻: 8.8%
- NH₄⁺: 5.3%
- Other: 12.0%
- OM: 30.0%
- EC: 4.6%
- Mineral: 31.9%
- Trace elements: 0.5%
- Other: 12.1%
Meteorological influences

- T: no correlation
- RH: high RH enhances PM mass concentration
- WS: high wind speed increases dilution of pollutants
- MLH: low MLH reduces dilution of pollutants
- WD:

Haze days - stagnant weather conditions:
high relative humidity
low mixing layer height
Effect on visibility

Visibility correlates negative with anthropogenic compounds, especially \( \text{NO}_3^- \), \( \text{SO}_4^{2-} \), and \( \text{NH}_4^+ \)

\[ \text{PM}_{2.5}/\text{PM}_{10} \text{ from Tapered Element Oscillating Microbalance (TEOM) of IAP} \]

Haze: 0.68
Clear: 0.38
Source apportionment: PMF3.0

**HP 1**
- Industry: 41.7%
- Secondary inorganic ions: 39.7%
- Dust: 1.3%
- Fuel oil combustion: 0.1%
- Soil Dust: 1.3%
- Traffic: 17.1%

**HP 2**
- Industry: 9%
- Secondary inorganic ions: 55%
- Dust: 2%
- Fuel oil combustion: 16%
- Soil Dust: 8%
- Traffic: 20%

**HP 3**
- Industry: 4%
- Secondary inorganic ions: 66%
- Soil Dust: 2%
- Fuel oil combustion: 21%
- Traffic: 7%

**Measurements**
- HP 1: 04.21-04.23
  - 164 µg m⁻³
- HP 2: 05.05-05.08
  - 164 µg m⁻³
- HP 3: 06.02-06.08
  - 125 µg m⁻³
Cluster means - Standard
60 backward trajectories
GDAS Meteorological Data

Back trajectory – HYSPLIT 4 (NOAA)

Cluster 1: Long-rang N flow
Cluster 2: N flow
Cluster 3: Long-rang NW flow
Cluster 4: NW flow
Cluster 5: SE flow
Cluster 6: S flow

S flow: 43.8%
154 μg m⁻³
Fuel oil combustion 5%
Traffic 20%
Industry 27%
Secondary inorganic ions 44%
Soil Dust 4%

SE flow: 56.2%
126 μg m⁻³
Fuel oil combustion 8%
Traffic 8%
Industry 4%
Secondary inorganic ions 64%
Soil Dust 20%
(1) **Beijing**: electricity and heat production and supply industry, automotive manufacturing, electronic equipment manufacturing, pharmaceutical manufacturing, general equipment manufacturing, petroleum processing, coking

(2) **Tangshan**: iron and steel industry, coal mining (coking coal), petroleum products, cement and porcelain

(3) **Tianjin**: petrochemical, textiles, car manufacturing, mechanical industries and metalworking

(4) **Baoding**: the largest photosensitive materials and magnetic recording media manufacture, vehicle manufacturing and photovoltaic cells

(5) **Shijiazhuang**: pharmaceutical, textile, machinery and chemicals, building materials, light industry and electronics
Conclusion

1. Controlling the precursors of secondary inorganic ions becomes more and more important to increase the visibility

2. Sources of PM$_{2.5}$ during spring in Beijing: industry, secondary inorganic ions, traffic, soil dust and fuel oil combustion - supported by source apportionment from chemical speciation of PM$_{2.5}$

3. Improving air quality should not only consider Beijing but also the whole region, including Hebei province and Tianjin Municipality

4. Stagnant weather conditions are favorable for the formation of haze: low mixing layer height, low wind speed and high relative humidity
Outlook

- Source apportionment on the basis of high time resolution sampling results
- Source apportionment based on isotope analyses of carbon
- PM$_1$
- Health effect
- Emission reduction measures
Acknowledgements

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Thank you for your attention!