Air Pollution Control in China: Progress and Perspectives

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Outline

- Overview of air pollution in China
- Progress of air pollution control in China
  - Emission and control of transportation
  - Emission and control of coal combustion
  - Control of air pollution in megacities and regions
- Perspectives
Air pollution in China, 2015

Attainment of PM$_{10}$ and PM$_{2.5}$ in 338 cities
High percentage of secondary PM

Urban site_Tsinghua (1999~2010)

- PM$_{2.5}$ concentration range (μg m$^{-3}$):
  - 20~50
  - 50~80
  - 80~100
  - 100~120
  - 120~170
  - 170~360

- Percentage trace elements:
- crustal matter:
- EC:
- POA:
- SOA:
- NH$_4^+$:
- SO$_4^{2-}$:
- NO$_3^-$:
Overview of air pollution in China

Progress of air pollution control in China

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- Emission and control of coal combustion
- Control of air pollution in megacities and regions

Perspectives
In 2009, China became the largest market with the vehicle sales worldwide.

In 2013, China became the only country with sales of more than 20 million.


China will rank as the No. 1 country in vehicle population before 2025.
Vehicle emissions are concentrated in East China, especially in mega cities such as Beijing and Shanghai, due to much dense vehicle population and high travel mileage.

The vehicle emission density in East China in 2012 is 2.1 and 3.6 ton/km² for HC and NOₓ, respectively, several times higher than the average in China (0.4/0.8), EU-28 (0.2/0.7) and the U.S. (0.3/0.6).
Since mid-1990’s, studies on strategies for controlling vehicle emissions have been initiated in China.

- At national level, SEPA launched a first-ever comprehensive study in 1994, namely “China’s Strategies for Controlling Motor Vehicle Emissions” (supported by the World Bank).
  - More stringent emissions standards, such as Euro 1 and 2, were targeted for new vehicles.
  - Improvement of fuel quality (e.g., unleaded gasoline, lower sulfur in fuel) was emphasized to go with the same step while new emission standards were phasing in.
  - I/M program was evaluated, and enhanced I/M for typical cities, such as Beijing, was recommended.
  - Beijing, the No.1 city in automobile market in China, was suggested to play a key role in controlling vehicle emissions, just like the role of California to the U.S.
Beijing has been acting as the pioneer in controlling vehicle emissions in China since late 1990s

- Beijing is the pioneer in controlling vehicle emissions within China, which has compelled the progress of emission and fuel quality standards in the national wide.
- A “vehicle-fuel-road” integrated control framework has been developed within the past 15 years.
Beijing has been acting as the pioneer in controlling vehicle emissions in China since late 1990s.

- **Emission standards**
  - **Light-duty gasoline vehicles**
    - 1999/1-2002/12: China 1
    - 2003/1-2005/12: China 2
    - 2005/12-2008/2: China 3
    - 2008/3-2013/1: China 4
    - 2013/2-Beijing 5
  - **Heavy-duty diesel vehicles**
    - 2000/1-2002/12: China I
    - 2003/1-2005/12: China II
    - 2005/12-2008/6: China III
    - 2008/7- China IV \(^1, 2\)
    - 2013/2-Beijing IV \(^1\)

- **Improve gasoline quality**
  - Unleaded gasoline since 1998
    - 2003/1-2005/6: <500 ppm
    - 2005/6-2007/12: <150 ppm
    - 2008/1-2012/5: <50 ppm
    - 2013/2- <10 ppm

- **Improve diesel quality**
  - 2003/1-2005/6: <500 ppm
    - 2005/6-2007/12: <350 ppm
    - 2001/7-2012/5: <50 ppm
    - 2013/2- <10 ppm

- **I/M programs and in-use inspections**
  - 2001-2003: Transition
  - 2003- Full implementation of ASM and LugDown methods
  - 2013- On-road RS \(^3\)

- **Traffic restrictions on specific in-use fleets**
  - 1999: CNG public buses
  - 2003: Yellow-labelled vehicles; 2004: Freight trucks and motorcycles

- **Clean energy and new energy vehicles**
  - 2009: New energy vehicles promoted by the "Ten City & Thousand Units" program
  - 2012: LNG buses

- **Traffic management and economic measures**
  - 2008/10: Driving restriction on light-duty passenger cars
  - 2009: Subsidized scrappage of yellow-labelled vehicles
  - 2011-2012: License control
  - 2011: Expanded to older vehicles

- **Temporary measures for the Olympic Games**
  - Odd-even restrictions, ban on yellow-labelled vehicles, reducing use of government-owned vehicles

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\(^1\) only implemented for public fleets; \(^2\) for freight trucks and long-distance coaches, they complied with the China IV emission standard from July 2013 as required by the Ministry of Environmental Protection; \(^3\) remote sensing test
Thanks to the continuous control efforts, China’s vehicle emissions started to decline.

- Although vehicle population increased by over 500% during the past 15 years, the national vehicle emissions started to decline:
  - HC and CO: peak in 2006-2007
  - PM<sub>2.5</sub>: peak in 2010-2011
  - NO<sub>x</sub>: peak in 2013

- Vehicle-related emissions in Beijing started to decline much earlier than the national level: peak in 2000-2002.
The control experience in the U.S. already shows a win-win strategy between developing its economy and protecting the environment, and China is on the right way as the U.S. has done over the past.

In the next 20 years, China needs to push hard, to improve its fuel economy, to mitigate CO$_2$ and major air pollutant emissions (e.g., NO$_x$).
Major challenges and pathways towards future vehicle emission control in China

1) Real-world fuel economy and emission control for vehicles is now an international challenge, and enhancing compliance management and supervision becomes extremely important in China.

- Much higher on-road EC emissions were identified for those “Fake China III/IV” HDDVs with mechanical pump.
- On-road NO$_X$ emission control for HDDVs is not satisfactory both in China and Europe.
- The gap between the on-road fuel economy and certificated fuel economy for cars becomes larger in China, similar like other countries pointed by ICCT.
2) Launching the “National Clean Diesel Engine Campaign” to control both on-road and off-road diesel engines becomes very urgent.

- Require DPF on as many vehicles and engines ASAP.
- Require low sulfur fuels for both on and off road applications ASAP.
- Mandatory retirement combined with financial and market measures to encourage early elimination of old diesel engines and optimization of the fleet structure.
- Shore power facilities intensified and natural gas and other clean energy options favored.
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The trend of coal consumption in China

- 2015: 66%
- 2030: 50%
- 2050: 30%

The ratio of coal-based energy in general energy consumption:

- 2015: 66%
- 2030: 50%
- 2050: 30%
Tightened Emission Limit Standards

Evolution of emission standards of China’s coal-fired power plants

1996
SO₂: 1200-2100 mg/m³
NOx: 650-1000 mg/m³
PM: 200 mg/m³

2003
SO₂: 400-1200 mg/m³
NOx: 450-1000 mg/m³
PM: 50 mg/m³

2011
SO₂: 200 mg/m³
NOx: 100-200 mg/m³
PM: 30 mg/m³

2014
SO₂: 50 mg/m³
NOx: 100 mg/m³
PM: 20 mg/m³

PM 10: 10 mg/m³
SO₂: 35 mg/m³
NOx: 50 mg/m³
The advanced control technology

PM collection
- Compound electrostatic with fabric filter
- Low-temperature ESP
- Wet ESP

DeSOx
Enhanced FGD ways:
- Twin Tower
- Dual loop process
- High-efficiency absorber and absorbents

DeNOx
- Low NOx Combustion
- Selective Non-catalytic reduction (SNCR)
- Selective catalytic reduction (SCR)
Removal of NOx at widen temperature window

- Ceria enhance the redox property and broaden Temp. window
- Ceria improve N2 selectivity and suppress the N2O production.

Integrated control technology

To meet the ultra low emission standard, typically two ways.

1. SCR + FGC + LTESP + FGD + FGR

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<thead>
<tr>
<th>Parameter</th>
<th>Target Values</th>
<th>Notes</th>
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<tbody>
<tr>
<td>Dust (mg/m³)</td>
<td>≤ 20 (30)</td>
<td>≤ 5 (10)</td>
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<tr>
<td>SO₂ (mg/m³)</td>
<td>≤ 35 (35)</td>
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</tr>
<tr>
<td>NOₓ (mg/m³)</td>
<td>≤ 50 (50)</td>
<td>≤ 50 (50)</td>
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2. SCR + ESP + FGD + WESP

Removal of fine particulate, Mercury, and SO$_3$.

Dust removal efficiency ≥ 70%

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<th>≤ 20 (30)</th>
<th>≤ 5 (10)</th>
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<tr>
<td>Dust (mg/m$^3$)</td>
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<tr>
<td>SO$_2$ (mg/m$^3$)</td>
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<tr>
<td>NO$_x$ (mg/m$^3$)</td>
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The amount of pollutants decrease since 2011

The major air pollutants PM, SO$_2$, NOx all decreased, although the coal consumption in 2014 is three times of that in 2000.

The trend of coal consumption and inventory of air pollutants
In China’s residential sector, raw coal (~80% bituminous and ~20% anthracite) is often consumed in stoves with low efficiency. It’s primary PM$_{2.5}$ emission accounts for more than 50% of total emission from all coal consumption in China.

Control strategies:

- Switching to electricity and natural gas
- Replacing bituminous coal with anthracite
- Replacing raw coal (bituminous and anthracite) with processed coal (e.g., semi-coke, washed coal)
- Promoting better stoves (high energy efficiency and high combustion efficiency)

Li et al., *Scientific Reports*, 2016, 6: 19306
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Short-term air quality targets (2012~2017):

- PM$_{2.5}$ concentration declines by 25%
- PM$_{2.5}$ concentration declines by 20%
- PM$_{2.5}$ concentration declines by 15%
- PM$_{10}$ concentration down by 10%
- support Beijing-Tianjin-Hebei in realizing targets
Sino-US collaborations: Development of Air Benefit and Cost and Attainment Assessment System

ABaCAS: An integrated AQ Decision Support System

Developed for “Scientists” and “Policy Makers”
Sino-US collaborations: Development of Air Benefit and Cost and Attainment Assessment System

**RSM/CMAQ**
Provide Real-time Air Quality Response of Emissions Control

**CoST-CE**
Provide Emissions Control Cost Analysis and Estimate

**SMAT-CE**
Provide Attainment Test/Demo for PM2.5 & O3 Non-attainment Areas

**BenMAP-CE**
Provide Health Impacts and Economic Benefits Estimate
Pre-evaluation of the Action Plan in Jing-Jin-Ji

PM\textsubscript{2.5} concentration changes in BTH

The percentage change of PM\textsubscript{2.5}

Model Evaluation

-25.6% -18.7% -14.7%
Enhanced reduction scenario: PM$_{2.5}$ changes

**Emission changes**

Beijing
- PM$_{2.5}$ concentration changes:
  - 2013: 51%
  - 2017: 32%

Hebei
- PM$_{2.5}$ concentration changes:
  - 2013: 40%
  - 2017: 35%

Tianjin
- PM$_{2.5}$ concentration changes:
  - 2013: 47%
  - 2017: 35%

**PM$_{2.5}$ concentration changes**

**The percentage change**

- Beijing: -31.1%
- Tianjin: -25.9%
- Hebei: -25.5%
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by 2030, the emissions of SO$_2$, NO$_x$, PM$_{2.5}$ and VOCs in China should be reduced by 52%, 65%, 57%, and 39% compared with those of 2012. The emissions of NH$_3$ should decrease slightly.
We should intensify emission control in heavily polluted areas. For example, $\text{SO}_2$, $\text{NO}_x$, $\text{PM}_{2.5}$, $\text{VOC}$ and $\text{NH}_3$ emissions in the Beijing-Tianjin-Hebei Region in 2030 should be reduced by at least 59%, 72%, 70%, 44%, and 21% respectively.
Emission reductions for air quality attainment

Either ENE+EOP or MFR scenario need to be adopted to achieve the air quality target by 2030 in China.

1) Business as usual (BAU); 2) End-of-pipe control (EOP)
3) Alternative energy policy + End of pipe control, (ENE+EOP)
4) Maximum Feasible Reduction (MFR)
International collaborations shall be enhanced

- We share the same planet.

- China and the US represent the world’s largest economies, largest energy consumers, and largest emitters of carbon pollution.

- Addressing air pollution and climate change provides opportunities for innovation and to build the clean energy economy of the future—a future that’s safer and healthier for our children.

- Our collaboration and partnership are needed now more than ever.
Thank you for your attention!