Special Session: Sharing experience from the Republic of Korea in acid deposition and air quality management

Introduction: Sharing experience from the Republic of Korea (ROK) in acid deposition and air quality management, Dr. Imseok Chang, Senior Researcher, National Institute of Environmental Research (NIER), Republic of Korea

1. Connecting science and policies by KORUS-AQ, Dr. James Crawford, Senior Scientist for Atmospheric Chemistry at NASA Langley Research Center, USA

2. Korean government’s efforts to control particulate matter (PM) pollutions and current issues to improve domestic air quality, Dr. Chang-Sub Shim, Chief Research Fellow at Korea Environment Institute (KEI), Republic of Korea

3. Korea’s National Emission Inventory System and Improvement Efforts, Dr. Chul Yoo, Director, National Air Emission Inventory and Research Center, Republic of Korea
Science-based air quality management in Korea

Lim-Seok Chang
Environmental Satellite Center
National Institute of Environmental Research
## 1980s air quality in Korea

<table>
<thead>
<tr>
<th>Year</th>
<th>SO₂ (ppb)</th>
<th>CO (ppm)</th>
<th>TSP (㎍/㎥)</th>
<th>NO₂ (ppb)</th>
<th>O₃ (ppb)</th>
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</thead>
<tbody>
<tr>
<td>1986</td>
<td>54</td>
<td>3.0</td>
<td>183</td>
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<td>1987</td>
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<tr>
<td>1988</td>
<td>62</td>
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<td>33</td>
<td>9</td>
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<tr>
<td>1989</td>
<td>56</td>
<td>3.2</td>
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<tr>
<td>Annual Standard</td>
<td>30</td>
<td>25(1hr)</td>
<td>150</td>
<td>50</td>
<td>100(1hr)</td>
</tr>
</tbody>
</table>

**Annual Standard:**
- SO₂ (ppb): 30
- CO (ppm): 25 (1hr)
- TSP (㎍/㎥): 150
- NO₂ (ppb): 50
- O₃ (ppb): 100 (1hr)

Courtesy of Prof. Kim DongSul
Successfully mitigating SO$_2$, CO, Pb and TSP pollution
However, NO\textsubscript{2}, O\textsubscript{3}, and PM\textsubscript{2.5} pollution problem emerging

OECD ranks countries for PM2.5 pollution during 25 years

1990, 7\textsuperscript{th}  
2015, 2\textsuperscript{nd}

Source: Health Effects Institute
Acid rain is still on-going

Acid deposition monitoring network (41 stations)
Annual mean pH (2019): 5.4
Anion: $\text{NO}_3^- > \text{SO}_4^{2-} > \text{Cl}^-$
Cation: $\text{NH}_4^+ > \text{Na}^+ > \text{K}^+ > \text{Ca}^{2+} > \text{Mg}^{2+} > \text{H}^+$
How Korean government is managing \( PM_{2.5} \) pollution will be presented by Dr. Changsub Shim and Dir. Chul Yu.
Emergency PM2.5 reduction measures

Source: Markus Pesch

Concept for emergency measure

- Limit value
- Monitoring sites
- Urban areas
- Countryside
- Traffic, local sources
- Regional background
- Hemispheric/natural background
- Total urban contribution relevant for AQ LV compliance

Jungang daily (March.28)
Emergency PM2.5 reduction measures

**Power Generation**
- Shut-down of the decrepit coal-fired power plants (5 units) on a temporary basis in spring (Mar–June)

**Daily Surroundings**
- Intensive inspections on surrounding emission sources (construction sites and illegal incineration, etc.)

**Emergency Reduction Measures**
- Fine dust level going beyond certain levels
- Leave cars at home based on odd-even number plates
- Reduce usual operations

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Shut-down of the decrepit coal-fired power plants (5 units) on a temporary basis in spring (Mar–June)
Impact of emergency measures (seasonal measures, 19.12~`20.1)

Compared to Jan. 2019, PM2.5 in Backryungdo in Jan. 2020 decreased by 18% and PM2.5 in Seoul also decreased by 23%

Weather condition


'20. Jan. (20.1.1~4)
Three dimensional air quality monitoring system is needed.

Aircraft

O$_3$

NO$_2$

NO

OH

VOCs

HONO

hv

RO$_2$

HONO

OH

Secondary PM

NH$_4$NO$_3$

(NH$_4$)$_2$SO$_4$

Secondary OC

Primary PM, HAPs

SO$_2$

H$_2$SO$_4$

Primary PM, HAPs

Ground in-situ

Ship

Ground remote-sensing
How the multi-perspective observations are working will be presented by Dr. James Crawford
Real time monitoring of PM2.5 composition in ambient air

<table>
<thead>
<tr>
<th>Rack</th>
<th>Instruments</th>
<th>Chemical Species</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>PM2.5 chemical analyzer</td>
<td>PM1 (SO$_4^{2-}$, NO$_3^-$, Organic, NH$_4^+$, Cl$^-$)</td>
</tr>
<tr>
<td>2</td>
<td>PM2.5 monitor (BAM1020)</td>
<td>PM2.5 (Mass)</td>
</tr>
<tr>
<td>3</td>
<td>PM2.5 sampler (E-FRM)</td>
<td>PM2.5 (Mass, ion, carbon, metal)</td>
</tr>
</tbody>
</table>

10 super sites over all the country
Three dimensional air quality monitoring system in workplace

Remote sensing-based workplace monitoring

- **Fenceline monitoring**
  - SOF mobile lab
  - UV DOAS
  - UV-IR
  - PTR-TOF-MS
  - Oil refinery VOCs emission estimation

- **Remote sensing FTIR**
  - SOx, NOx concentration in stack plumes estimated by conversion technology

- **UV DOAS and hyperspectrometer**
  - Workplace operational monitoring

Fenceline monitoring (SOF mobile lab)

Fugitive leakage monitoring (drone, OGI camera)

Normal camera film

OGI camera film

Mobile monitoring

Operational remote sensing (UV DOAS)
GEMS monitors diurnal variation of air pollutants in Asia at near real time

Source: Prof. Jhoon Kim

Aug. 9, 2020
09:45
(Seoul Local Time)

Source: Prof. Hanlim Lee
“Scientific Technology can solve air pollution problem”
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KORUS-AQ: Connecting Science and Policy
James H Crawford, NASA Langley Research Center
KORUS-AQ science has resulted in 80+ publications across 23 scientific journals

Communicating Results

High-level findings supporting a Final Science Synthesis Report have been published in a special issue of Elementa.

These peer-reviewed results supplemented a Rapid Science Synthesis Report delivered to the Ministry of Environment one year after the field study.
Recommendation 1: Improving both PM$_{2.5}$ and ozone pollution relies on coordinated reductions in both NO$_x$ and VOCs, specifically higher (C$_7$+) aromatic compounds.

- Secondary aerosol account for 70-80% of PM$_{2.5}$
- Aerosol composition changes with meteorological conditions.
  - Aromatic compounds dominate organic aerosol production through photochemistry.
  - Frontal passages enhance both transported and local aerosol due to shallow boundary layer and faster heterogeneous production of secondary inorganic aerosol.
- Ozone production is more sensitive to aromatic compounds than all other anthropogenic VOCs combined.
- While ozone production is VOC-limited in urban areas, the regional extent of ozone production depends on NO$_x$ reductions.
- While emission reductions will immediately benefit PM$_{2.5}$, strategies to control ozone call for careful reduction in aromatic compounds along with NO$_x$ to limit short-term increases in urban ozone.
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### Pie Charts

- **Dynamic period (May 2-16)**
  - Organic: 29\%
  - Sulfate: 14\%
  - Nitrate: 18\%
  - Ammonium: 10\%
  - Black Carbon: 7\%

- **Stagnation period (May 17-22)**
  - Organic: 41\%
  - Sulfate: 14\%
  - Nitrate: 14\%
  - Ammonium: 13\%
  - Black Carbon: 8\%

- **Transport/Haze period (May 24-31)**
  - Organic: 21\%
  - Sulfate: 22\%
  - Nitrate: 15\%
  - Ammonium: 25\%

- **Blocking period (June 1-10)**
  - Organic: 29\%
  - Sulfate: 17\%
  - Nitrate: 8\%
  - Ammonium: 11\%
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Recommendation 2: Improved estimates place better bounds on current emissions, but specific sources for higher (C$_7^+$) aromatic compounds need to be targeted to enable effective control strategies.

- Models require accurate emissions in order to realistically simulate air quality and be useful for testing air quality control strategies.
- Initial model simulations compared to observations revealed large underestimations of NO$_x$ and aromatic compounds.
- Top-down satellite estimates corroborated the underestimation of NO$_x$ emissions.
- Aromatic emissions were improved through better speciation of VOC emissions.
- While the updated emissions dramatically improved model simulations, observation-based source apportionment points to diverse and broadly distributed sources of aromatic VOCs from both paint and non-paint solvent use that will be difficult to target without more detailed knowledge of their use and specific products to target.
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Recommendation 3: Large underestimates of VOC emissions from industrial point sources warrant continued scrutiny and verification.

- Direct sampling of point sources revealed good agreement for stack emissions of NO\textsubscript{x} and SO\textsubscript{2} from power plants and industrial sites, supporting the effectiveness of the continuous emissions monitoring system for these large sources.
- VOC emissions were shown to be underestimated by factors of 2.5 to 4 based on observations at the Daesan Chemical Facility, Korea’s largest industrial VOC source.
- VOC emissions carry additional health risks to workers and local communities as they carry multiple hazardous pollutants and their oxidation products.
- These VOC emissions are more difficult to monitor since they mainly occur as fugitive emissions that come from a multitude of facility components and activities such as storage tanks, transport pipelines throughout the complex and to/from nearby shipping sites, petroleum production and handling, as well as combustion and flaring operations.
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Recommendation 4: Model simulations of air quality require a hierarchy of models to obtain the best representation and understanding of uncertainties to support decision making.

- The KORUS-AQ team employed a hierarchy of models covering regional-to-global domains with various resolutions and complexity in their treatment of ozone and PM formation.
- The average of several different models, each with differing strengths and weaknesses, was generally better than any individual model at matching observations.
- The use of multiple models is needed to best identify drivers of air quality and place uncertainty bounds on quantitative assessments of conditions and strategies to mitigate poor air quality.
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Airborne and Satellite Investigation of Asian Air Quality (ASIA-AQ)

Purpose: Improve understanding of the factors controlling local air quality across Asia through multi-perspective observations and modeling.

Approach: Conduct airborne sampling across three to five locations in collaboration with local scientists, air quality agencies, and other relevant government partners.

Philosophy: Openly share data during all phases, conduct joint analysis with local scientists and air quality agencies, and report findings to local governments.
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https://espo.nasa.gov/asia-aq  James.H.Crawford@nasa.gov
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Efforts of Korean government to control PM pollutions and current issues for better air quality

Changsub Shim, Ph.D.
Chief Research Fellow
Korea Environment Institute
<table>
<thead>
<tr>
<th>Chapter</th>
<th>Title</th>
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<tbody>
<tr>
<td>1</td>
<td>Current Situation and characteristics of PM2.5</td>
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<tr>
<td>2</td>
<td>Recent government’s efforts to control PM2.5 (2015 ~ )</td>
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<td></td>
<td>Higher priorities of domestic PM controls</td>
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<td>3</td>
<td>Aspect of Emissions and PM contributions</td>
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<td>Aspect of Higher PM concentrations</td>
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<td>4</td>
<td>What do we need for better air quality? (PM)</td>
</tr>
<tr>
<td></td>
<td>Contribution of EANET data for air quality researches for Korea</td>
</tr>
</tbody>
</table>
1. Current status of Korean PM2.5

1) Annual PM2.5 concentrations of S. Korea

- National averaged PM2.5
  - ~ 10μg/m³ higher than national standard (15) until 2019
  - Improved since 2020 and need to careful monitor (effect of COVID19 + policy contributions)

- Seasonal pollution problems
  - Intensive policies and implications needed (November ~ March)
## 2. Recent efforts of Korean gov.

### 1) Getting Strict and Specific in PM policies

- **Major changes and events**
  - National PM2.5 monitoring only since 2015
  - Strengthen annual PM2.5 standard (15 $\mu$g/m$^3$, 2018)
  - Emergency reduction measures during severe PM2.5 events (2018)
  - Special law for PM control (2019): historic PM2.5 events
  - Comprehensive plans for national PM mitigation (2020 – 2024): first considering secondary PM productions
  - Measures for seasonal pollution problems (2019 -)
  - Designating 4 regions for mitigating air pollution emissions (Central government + **local government**) ➔ Setting total emissions caps for each region

### Chronicle of PM policies of S. Korea
3. Priorities in policies (based on science)

1) Regional Contributions to annual PM2.5 & Sector’s contributions

- Chung-Cheong needs regional priority for the policies
  - higher contributions of diverse industries
  - many large-scale power plants (coals)
  - many cities and traffics in transportation

- Many industrial complex and small but many factories
  - SMA (Seoul Metropolitan Area): difficulties in management
  - SMA: majority of population influenced by higher PM

- Important sectors (in annual concentration)
  - Industries (25%) ~ agricultural wastes (25%) > road vehicles (20%) > other transportation (13%) > power plants (7%)
3. Priorities in policies (based on science)

1) Considering population exposed to long-term higher PM2.5

- SMA and Chung-Cheong area have a large portion higher pM2.5
  - Vulnerable people (younger(<18) and elder(>65))
  - ~1/3 population is exposed to higher annual PM2.5(25 μg/m³)
  - Vulnerable population (~5.5 M)

Distributions of annual PM2.5(left) and vulnerable population number(right)
4. Role of ammonia for PM formation

1) Ammonia production is a key factor for PM control in Korea

- **Livestock waste**
  - more than 75% of total domestic NH3 emissions
  - Seldom considered as a key contributors of PM formation (in Korean policies)
  - Recently, satellite observation of atmospheric ammonia can help estimate ammonia emissions and its roles in pollution
  - 3 EANET sites in Korea can help long-term changes in concentrations and other data validation

Chemistry of PM formation (Stauffer, 2016)
5. Use of EANET NH3 and Satellite retrievals

1) ENAET sites and NH3 monthly variations

Monthly variations of NH3 and NH4 in Korea-Japan-China
6. Discussions

- Korea has enforced PM control policies since 2015 and now we are assessing the improvements
- Large population with relatively higher PM2.5, effective managements of ~ 60,000 plants and livestock waste are major challenges in Korean PM reduction policies
- Ammonia is one of the key species of PM pollution formation and EANET can contribute to assessing long-term variation of domestic ammonia concentrations
  - NH3 at agricultural area in Korea(lmsil, Jeju) has been increased.
  - EANET measurements are used to validate satellite NH3 products can assess NH3 emissions and identify regional controllers of PM formation!
감사합니다.

Thank you.
EANET AWARENESS WORKSHOP IN 2021
Acid Deposition Monitoring Network in East Asia

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1. CAPSS (Clean Air Policy Support System)

2. Result of Air pollutants emission in 2018
CAPSS (Clean Air Policy Support System)
Introduction

Korean National Emission Inventory, CAPSS (Clean Air Policy Support System)

Korean estimation system of national air pollutant emissions based on the emission inventories by using national, regional and local level of statistical data, complied by approximately 150 organizations since 1999

Goals of CAPSS

• To analyze emission trends and source contributions
• To provide a database for establishing policies for air quality measurement
• To evaluate the feasibility and effect of policies
• Air diffusion modeling, environmental impact assessment and studies
Clean Air Policy Support System

Air pollutant emission calculation system based on national emission source inventory

Provide high-quality basic data for the establishment and evaluation of air environment management policies, air quality forecasts, etc.
Classification of Emission Sources

**Laws & Regulations (basis)**
- Article 17 of the Special Act on Fine Dust Reduction and Management and Article 6 of the Enforcement Rule
- Article 17 of the CLEAN AIR CONSERVATION ACT (Surveys on Sources and Quantities of Emissions of Air Pollutants) and Article 16 of Enforcement Rule (Surveys on Sources and Quantities of Emissions by Emission Facilities)

**Calculation of Air Pollutant Emissions**
- Pollutants: 9 (CO, NOx, SOx, TSP, PM\(_{10}\), PM\(_{2.5}\), BC, VOCs, NH\(_3\))
- Inventory: 13 first-level categories,
  - 64 second-level categories
  - 355 third-level categories
- Spatial and Temporal Resolution: yearly/cities and provinces, City·county·district, 1km*1km

<table>
<thead>
<tr>
<th>Sector</th>
<th>Target Pollutant</th>
<th>SOx</th>
<th>NOx</th>
<th>TSP</th>
<th>PM(_{10})</th>
<th>PM(_{2.5})</th>
<th>CO</th>
<th>VOC</th>
<th>NH(_3)</th>
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<td>4. Industrial process</td>
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<td>5. Gas station</td>
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<td>6. Solvents use</td>
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<td>8. Non-road transport</td>
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<td>9. Waste</td>
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<td>10. Agriculture</td>
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<td>11. Others</td>
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<td>12. Fugitive Dust</td>
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<tr>
<td>13. Biomass burning</td>
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<td>●</td>
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<td>●</td>
</tr>
</tbody>
</table>
Emission Estimation Method

**Point Sources**

\[ \sum [\text{Activity Data} \times \text{EF} \times (1-\text{Control Facilities})] \]

- Activity data: Amounts of fuel consumption by the oil, coal and LPG at facility
- EF: Emissions Factor, by the facility using the oil, coal and LPG

**Mobile Sources**

(Road) \[ \sum (\text{Car population} \times \text{VKT} \times 365) \times \text{EF} \]

- Top down Method considering Car Fleet, Average Speed, Fuel type, Engine (Hot and cold start)

(Non-Road) \[ \sum \text{Activity Data} \times \text{EF} \]

- Activity data: Fuel Consumption, Chip Call, Aircraft LTO, Population
- Top down Method considering Engine Power, HRS

**Area Source**

\[ \sum [\text{Emission factor}\times\text{Activity data (ex. Number of fires etc.)}\times(1-\text{Reduction efficiency})] \]

- Method for calculating top-down emission considering various activity (crop cultivated area etc.)
Emission Factors

### Citation rate of emission factor

<table>
<thead>
<tr>
<th>Pollutant</th>
<th>Subtotal</th>
<th>In Korea</th>
<th>Foreign</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
<td>EPA</td>
</tr>
<tr>
<td>TSP</td>
<td>3,549</td>
<td>521</td>
<td>2,974</td>
</tr>
<tr>
<td>PM$_{10}$</td>
<td>3,840</td>
<td>570</td>
<td>3,247</td>
</tr>
<tr>
<td>PM$_{2.5}$</td>
<td>2,996</td>
<td>489</td>
<td>2,479</td>
</tr>
<tr>
<td>SO$_x$</td>
<td>3,409</td>
<td>1,263</td>
<td>1,943</td>
</tr>
<tr>
<td>NO$_x$</td>
<td>3,940</td>
<td>2,059</td>
<td>1,835</td>
</tr>
<tr>
<td>VOC</td>
<td>3,962</td>
<td>670</td>
<td>3,187</td>
</tr>
<tr>
<td>NH$_3$</td>
<td>3,825</td>
<td>272</td>
<td>3,344</td>
</tr>
<tr>
<td>CO</td>
<td>3,884</td>
<td>682</td>
<td>3,155</td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td><strong>29,405</strong></td>
<td><strong>6,526</strong></td>
<td><strong>22,164</strong></td>
</tr>
</tbody>
</table>

- Among about 30,000 emission factors, domestic (22.2%) and overseas (77.8%) have a high citation rate for overseas emission factors.
- The ratio of vehicles emission factor in Korea is 98%, which is higher than that of foreign countries.
Activity data

For calculating National Air Pollutants Emissions

Point Source

- Types I through III places of business (SEMS*)
- TMS** Data
- Types IV through V places of business (National Statistics)

<table>
<thead>
<tr>
<th>Fuel supply</th>
<th>(Coal, Petroleum, LPG, LNG...)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Manufacture</td>
<td>(Iron and steel, Petroleum, Chemical...)</td>
</tr>
<tr>
<td>Treatment of waste</td>
<td>(incineration and landfills)</td>
</tr>
<tr>
<td>Wastewater handling</td>
<td></td>
</tr>
</tbody>
</table>
| Sulfur content of fuel | ...

(75 related agencies)

Mobile Sources

(Road)

- Vehicle Populations,
- Vehicle Age distribution
- VKT (Vehicle Kilometer Traveled)
- VMT (Vehicle Miles of Travel)
- Road Type

<table>
<thead>
<tr>
<th>Equipment population</th>
<th>Ship call, Aircraft LTO</th>
</tr>
</thead>
</table>
| Fuel consumption, Engine power, Annual operating hours | ...

(40 related agencies)

Area Sources

Surface of building start
- Forest fire damage area
- Weather observation data

Charcoal kilns supply status
- Fire-burning stove & boiler supply status
- Fireplace supply status

Number of livestock (cow, chicken etc.)
- Fertilizer consumption
- Crop cultivated area, Farm population

(35 related agencies)

Activity data were determined using 300 sets of statistical data obtained from approximately 150 institutes

* SEMS: Stack Emission Management System
** TMS refers to a monitoring system that is meant to manage emissions by measuring air pollutants emitted from smoke stacks in real-time
Result of Air pollutants emission in 2018
2018 Activity Data

**Industry Source:** Approximately 60,000
- 1~3 Class industry: 4,039
- 4~5 Class industry: 52,221

**Vehicle:** 2.3 million

**Total VKT:** 3,277 hundred million km-vehicle

**Construction equipment:** 500,000
**Agricultural equipment:** 2,100,000

**Ocean Going Vessels:** 100,000 Call

**Aircraft:** 890,000 LTO

**Meat consumption:** 2,880,000 ton

**Livestock:** 200,000,000

**Agricultural Open burning:**
- Population ratio: 74.9%
- Forest fire area: 894 ha
Status of Air Pollutant Emission Ordinance

Result of Air pollutants emission in 2018

<table>
<thead>
<tr>
<th>Substance</th>
<th>2018 Emissions (Ton)</th>
</tr>
</thead>
<tbody>
<tr>
<td>PM-2.5</td>
<td>98,388</td>
</tr>
<tr>
<td>PM-10</td>
<td>232,993</td>
</tr>
<tr>
<td>SOx</td>
<td>300,979</td>
</tr>
<tr>
<td>NOx</td>
<td>1,153,265</td>
</tr>
<tr>
<td>VOCs</td>
<td>1,035,636</td>
</tr>
<tr>
<td>NH3</td>
<td>315,975</td>
</tr>
<tr>
<td>CO</td>
<td>808,801</td>
</tr>
</tbody>
</table>

Emission Contribution:
- CO: Biomass burning > Road transport > Non-road transport
- NOx: Road transport > Non-road transport > Manufacturing industry
- PM2.5: Manufacturing industry > Fugitive Dust > Non-road transport
- VOCs: Solvents use > Industrial process > Biomass burning
Air Pollutant Emission density of Local Authorities (Sigungu)

Result of Air pollutants emission in 2018

**< VOCs >**

- PM$_{2.5}$:
  - 0 - 1
  - 1 - 2
  - 2 - 3
  - 3 - 4
  - 4 - 5
  - 5 - 10
  - 10 - 110

- SO$_x$:
  - 0 - 2
  - 2 - 5
  - 5 - 10
  - 10 - 20
  - 20 - 30
  - 30 - 100
  - 100 - 600

- NO$_x$:
  - 0 - 10
  - 10 - 20
  - 20 - 30
  - 30 - 50
  - 50 - 100
  - 100 - 150
  - 150 - 700

- PM$_{2.5}$:
  - 0 - 15
  - 15 - 30
  - 30 - 50
  - 50 - 100
  - 100 - 150
  - 150 - 200
  - 200 - 1000

- NH$_3$:
  - 0 - 5
  - 5 - 10
  - 10 - 15
  - 15 - 20
  - 20 - 25
  - 25 - 30
  - 30 - 140
PM-2.5 Emission

Result of Air pollutants emission in 2018

Seoul metropolitan area
(17,162ton)

Non-metropolitan area
(81,226ton)

<table>
<thead>
<tr>
<th>Category</th>
<th>Energy production</th>
<th>industry</th>
<th>Road transport</th>
<th>Non-road transport</th>
<th>Miscellaneous</th>
<th>Air Conditioning</th>
</tr>
</thead>
<tbody>
<tr>
<td>Seoul</td>
<td>748</td>
<td>579</td>
<td>2945</td>
<td>4471</td>
<td>8000</td>
<td>419</td>
</tr>
<tr>
<td>Non-metropolitan</td>
<td>2531</td>
<td>5204</td>
<td>11511</td>
<td>21241</td>
<td>791</td>
<td></td>
</tr>
</tbody>
</table>

(ton, Primary Emission)
Comparison of year-on-year emission

**Emission decreases**

- CO: Automobile generation change
- NOx: Reinforcement of Emission Management
  ⇒ Old power plant shut down and seasonal management (March~June)
- SOx: Non-industrial combustion (fuel and anthracite) decreases
- VOCs: Paint supply and gasoline passenger car decreases

**Emission increases**

- PM$_{2.5}$: Anthracite iron supply and ship call increases
- PM$_{10}$: Anthracite iron supply increases
- NH$_3$: Low-NOx System fuel consumption increases
Thank You!
s7424yoo@korea.kr

Ministry of Environment (ME)
National Air Emission Inventory and Research Center (NAIR)
Special Session: Sharing experience from the Republic of Korea in acid deposition and air quality management

Questions & Answers