Air quality monitoring development and application in China

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2. National Air Quality Monitoring System
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4. Outlook
Precise Air Improvement based on big-data monitoring

- Major economic and social development decisions, as well as the construction and development of ecological civilization, require a correct assessment of the environmental quality.
- Developing various environmental protection and control plans, determining key areas, indicators, and measures for pollution prevention and control, requires the support of scientific environmental monitoring data.
- Accurate reduction and control of environmental pollution, ecological red line supervision, and early warning of resource and environmental carrying capacity require environmental monitoring to provide trend analysis, risk prediction, source analysis, and tracking.
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Improvement of PM$_{2.5}$ pollution in PRC

Class 2 limit of NAAQS: 35μg/m$^3$

WHO Standard: 25μg/m$^3$
National Air Monitoring Networks Development

- Expanding and establishing a multi-scale monitoring network that encompasses regional, city, county and township levels to effectively monitor air quality across various spatial scales
- Increasing the coverage of administrative divisions at the county level from 31.4% to 96.4%
- Supporting refined pollution control and tracking the sources of pollution for effective management

Source: CNEMC
Building an integrated urban-county-township air quality monitoring network-National

1,734 national monitoring stations for urban environmental quality in cities

- During the 14th Five-Year Plan period, the number of national monitoring stations for urban environmental quality increased to 1,734, resulting in a more balanced and rational distribution.

64 regional environmental air quality monitoring stations

- By the end of 2018, 64 regional stations were fully networked.
- Operation and maintenance tasks were entrusted to provincial stations.

16 national background air quality monitoring stations since 2008

- In 2021, monitoring of regional greenhouse gases was conducted at nine stations.

Source: CNEMC
Building an integrated urban-county-township air quality monitoring network - Local

- 10,588 local automatic monitoring stations for environmental air
  - 3503 county-level stations
  - 7085 township-level stations

- Three-levels monitoring network of cities-counties-townships, which effectively supports regional air pollution prevention and control

Source: CNEMC
Particle Composition and Photochemical Monitoring Network

PM:
- 166 cities with 194 automated monitoring stations connected to CNEMC
- Manual monitoring of PM composition has been carried out in 94 cities with 97 monitoring stations

PAMS:
- 167 cities have implemented automatic monitoring of VOCs and are all connected to CNEMC
- 308 cities have implemented NMHC automatic monitoring

✓ To monitor components in PM$_{2.5}$ and analyze the contribution of different pollution sources in each city
✓ Analyze the composition, active substances, photochemical intermediates, and influencing factors of VOCs
✓ Analyze causes of photochemical pollution in various cities

Source: CNEMC
1 Goal of Ambient Air Monitoring System
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Air Quality Improvement in Shanghai, PRC

- Change range (%)
  - 1992 - 2022

- Change range (\%)
  - GDP (/50)
  - Motor vehicle ownership (/50)
  - Energy consumption (/10)
  - Coal consumption
  - SO2
  - CO
  - TSP
  - PM10
  - PM2.5

- Change range:
  - GDP: 57 times
  - Vehicles: nearly 26 times
  - Energy consumption: 3.7 times
  - PM: -60\%
  - SO2: -87\%
  - CO: -74\%
  - TSP: -75\%
Fluctuation of $O_3$ in Shanghai, PRC

$O_3$: The concentration shows a **fluctuating and increasing** trend, increasing from 0.148mg/m$^3$ in 2012 to 0.180mg/m$^3$ in 2022.
Conventional network
19 national control and 54 district evaluation
6 Conventional + 5 meteorological parameters

Traffic network
7 transportation stations, port grid monitoring, and taxi mounted mobile monitoring
Conventional factors, benzene derivatives, NMHC, BC, etc

Industrial Zone network
74 automatic monitoring stations
More than 40 sets of VOCs component automatic monitoring equipment

Dust monitoring network
3600+ monitoring points
Covering construction sites, roads, docks, and mixing plants

Super Station network
1 key station+2 auxiliary stations

Photochemical monitoring network
Relying on conventional network and super station network
VOCs pilot monitoring

Source Apportionment Network
6 manual sampling points for PM$_{2.5}$ chemical components
Business monitoring
Ions, OC/EC, Elements, Organic Matter

Carbon monitoring network
8 greenhouse gas CO$_2$ monitoring stations

Ambient air monitoring systems in Shanghai
The number of national control evaluation points increased from 9 to 19 in the 14\textsuperscript{th} Five Year Plan period.

19 national stations + 35 district stations
Since 2013, automatic monitoring stations have been built in the key industrial parks. Over 40 sets of VOCs component automatic monitoring instruments are used, including automatic monitoring equipment covering GC-FID, GC-MS, and optical method equipment. Three types of monitoring stations, including park stations, boundary stations, and surrounding stations, are combined with mobile vehicles to achieve full coverage of industrial zone emission sources, boundaries, and surrounding residential areas.
During the “14th Five Year Plan period”, Shanghai will build a comprehensive traffic environment monitoring network

**Standard station:** Using conventional instruments for monitoring and evaluating the current traffic environment

**Micro station:** Fixed sensor monitoring for comprehensive monitoring of traffic pollution emissions and diffusion impacts

**Mobile monitoring:** Onboard small-sized sensor for real-time monitoring of road pollution conditions
Total 6400 online dust monitoring points in 2022. Among them, there are 5560 monitoring points for construction sites, 30 monitoring points for roads, 350 monitoring points for docks, and 470 monitoring points for mixing plants.
1 regional Dianshan Lake Core Station: Regional representativeness, supporting regional joint prevention and control, regional forecasting and early warning

2 auxiliary stations: A representative station in the urban area of a mega city

Dongtan auxiliary station: Large-scale long-distance cross regional transportation monitoring, supporting national level prevention and control policies

Super station network: 1 main and 3 auxiliary scientific network observation
Comprehensive Monitoring System for Major Event Support

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<td>3700 key sewage discharge units</td>
<td>Park coverage, 74 automatic stations</td>
<td>Nearly 10 sea area monitoring points</td>
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<td>Total platform</td>
<td>9 traffic stations, port grid, vehicle-mounted monitoring</td>
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<td>4000+ dust spots, 7000+ roads</td>
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1. Environmental quality Monitoring
   - Support accurate regional research and judgment
   - 421 national and provincial control points

2. Online monitoring of pollution sources
   - Support precise policy implementation
   - 3700 key sewage discharge units
   - Total platform

3. Super station component monitoring
   - Cause analysis, precise control
   - Regional evaluation, transmission analysis
   - 24 stations in shared area

4. Industrial area, transportation dust network
   - Source control and precise emission reduction in this city
   - Park coverage, 74 automatic stations
   - 9 traffic stations, port grid, vehicle-mounted monitoring
   - 4000+ dust spots, 7000+ roads

5. Navigation and UAV aerial survey
   - Spotting hot spots and enforcing the law by tapping acupoints
   - 8 aerial vehicles and 2 drones

6. Maritime monitoring
   - Support pollution transport analysis.
   - Nearly 10 sea area monitoring points
Overall framework of the Yangtze River Delta Regional Air Quality Forecasting Center

Ministry of Ecology and Environment
Environmental Monitoring Center

National Forecast and Warning Center

Ministry of Ecology and Environment Yangtze River Delta Regional Air Quality Forecast and Prediction Center

Visual consultation

Jiangsu Province Sub-Center
Zhejiang Province Sub-Center
Shanghai Municipality Sub-Center
Anhui Province Sub-Center
Jiangxi Province Sub-Center

Co-build, co-share, and serve
Visual consultation

City Forecast

System Platform
- Visualization Consultation System
- Emission Inventory System
- Data Sharing System
- Forecasting and Prediction System
- Information Service System
- Business Integration Platform
- High-Performance Computing Support

Organizational Structure
- Leadership Team
- Preparatory Team
- Forecasting Business Team
- Management Team
- Business Forecasting Team
- Technical Support Team
- Expert Committee

Technical Support: Yangtze River Delta Environmental Meteorological Forecast and Warning Center
Regional Air Quality Forecasting Platform for YRD

Real-time Concentration and Meteorological Observations

Satellite Retrieval

Fine-Grained Emission Inventory

Supercomputing Technology Assurance

Multi-Model Ensemble Forecast System

Model Source Apportionment

Superstation

Real-time Assimilation Ensemble Forecast

VS Comprehensive Source Apportionment
Key Technologies and Innovations

Centralized Supercomputing Support

Real-time Chemical Data Assimilation Technology

Machine Learning-Based Ensemble Forecasting Technology

Effectively promoted the improvement of air quality forecasting accuracy in Shanghai and the Yangtze River Delta region
Integration of Pollution Diagnosis Technologies

Superstation Fine Particle Generation Monitoring

PM$_{2.5}$ Superstation Observation and Online Comprehensive Source Apportionment

O$_3$ Vertical Distribution and Analysis of Its Active Components

Multi-Model Ensemble Forecast, Vertical Distribution, and Component Analysis

Integrate critical factors of PM$_{2.5}$ and O$_3$ pollution for assessment and prediction of control measures

Superstation Component Monitoring

Comprehensive Source Apportionment of PM$_{2.5}$

PM$_{2.5}$ and O$_3$ Numerical Forecast

Ozone Lidar Vertical Observation

OFP analysis (VOCs)

Integration of Pollution Diagnosis Technologies
Integration of Pollution Diagnosis Technologies

Scenario Simulation Effect Evaluation: Scenario simulations based on emission reduction plans yield concentrations closer to actual conditions, allowing assessment of pollution control measures by comparing with baseline emission inventory forecasts.

➢ Routine Business Forecast: Providing pollution trend analysis.
➢ Model Source Analysis: Identifying key areas and industries for pollution control.
➢ Backward Trajectories: Offering references for pollution transport ranges.

Regional Source Analysis

Key Industry Source Analysis

Pollution Air Mass Trajectories

On November 8, the orange warning was initiated, and Shanghai strengthened emergency emission reductions.

Influenced by the low-pressure trough, southeast wind

High-pressure front, northwest wind

Near the high-pressure center

PM$_2.5$ concentration (微克/立方米)
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Establishing a smart monitoring system based on sensing technology

**Socio-economic activity big data**

- Air quality, industrial monitoring
- Traffic monitoring, super station network
- Navigation monitoring, sea area monitoring
- Remote sensing monitoring, pollution sources

**Integrated atmospheric smart monitoring of environmental pollution sources on Earth, in the sky, and in space**

- Dynamic inventory, source profiles
- Meteorological monitoring and emission inventory

**Accurate forecasting and prediction**

- Data assimilation
- Model simulation
- Scientific mechanism

**Deep learning**

- Machine learning
- Knowledge graph

**Big data integration**

**Integrated platform - Smart Brain**

1. Smart screening of pollution hotspots, closed-loop precision control
2. Precision warning, assessment, and control of pollution events
3. Source attribution and scientific support for medium to long-term forecasting to inform policy
4. Closed-loop monitoring, control, and assessment, combining both short-term and long-term support for precise, science-based pollution control in accordance with the law.
Researching the establishment of the Shanghai Air Quality Health Index

Utilizing high-precision exposure assessment techniques and extensive epidemiological big data, we conduct health risk monitoring of key atmospheric environmental factors in Shanghai, exploring the research on the Shanghai Air Quality Health Index.

- **Health data**
  - Collect daily disease-specific mortality numbers from the Centers for Disease Control and Prevention (CDC).
  - Collect disease-specific resident healthcare utilization data from the Health Insurance Bureau, including outpatient, emergency room, and inpatient visits.
  - Disease classification coding using ICD-10, covering major cardiovascular and respiratory diseases.
  - Individual information, including age, gender, and education.

- **Exposure data**
  - Real-time atmospheric pollutant concentrations: PM$_{2.5}$, PM$_{10}$, O$_3$, SO$_2$, NO$_2$, CO.
  - Online monitoring data for PM$_{2.5}$ components’ concentrations.
  - Daily average temperature and relative humidity.

- **Establishing exposure-response curves for atmospheric pollution and resident health**
- **providing a more comprehensive reflection of air quality and its impact on health**

Conduct urban traffic environment monitoring and health impact assessment

Integrating the traffic environmental air quality monitoring network (standard stations, vehicle-mounted mobile and fixed micro stations)

Conducting health exposure assessment for traffic-related air pollution and establishing a Traffic Environmental Health Index
With a service-oriented approach, innovate public service models

- Promote the refinement of the time and spatial scales in air quality forecasting, enhance the accuracy of regional and urban forecasting products, continuously develop diverse urban and regional-level forecast service products.
- Expand the impact of forecast service products for better public service.
Thanks!

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