

**The Fifth Periodic Report
on the State of Atmospheric Environment in East Asia**

Executive Summary

December 2026

Preface

East Asian countries have experienced air pollution and acid deposition for several decades. These environmental pressures have resulted in various risks across the region, particularly in the context of rapid economic growth and increasing fossil fuel consumption. Air pollution and acid deposition can adversely affect human health, vegetation, wildlife, materials, and cultural heritage. Currently, East Asia is recognized as a global hotspot for both air pollution and atmospheric deposition.

The Acid Deposition Monitoring Network in East Asia (EANET) has gained international recognition for its success in promoting regional cooperation on air pollution and acid deposition monitoring in East Asia and facilitating inter-regional exchange on data measurement and assessments of the state of air quality and acid deposition.

EANET published scientific assessment reports, the *Periodic Report on the State of Acid Deposition in East Asia* (PRSad) in 2006, 2011, 2016, and 2021 based on EANET monitoring data for the periods of 2000-2004, 2005-2009, 2010-2014 and 2000-2019, respectively. The Twenty-fifth Session of the Scientific Advisory Committee (SAC25) discussed on the title of the Fifth Periodic Report and finally endorsed “*The Fifth Periodic Report on the State of Atmospheric Environment in East Asia* (hereafter PRSAE5)”.

PRSAE5 describes the outcomes of 25 years of EANET activities (2000-2024). The PRSAE5 is comprised of three parts; Part I: Regional Assessments, Part II: National Assessments, and Part III: Executive Summary. PRSAE5 Part I presents the main activities of EANET and provides an assessment of the state of air pollution and acid deposition focusing on the spatial distribution, trend analysis, and, possibly, impact assessment of air pollution and acid deposition in the region. The data from the 2000-2024 period was also utilized for evaluating the current status of the environment in the EANET region, to share the results of the past 25 years provided by EANET in its regular phase, and to scientifically evaluate the monitoring data generated. It includes quality assurance (QA) and quality control (QC), impacts on ecosystems in East Asia, a summary, conclusions, and recommendations.

To develop this report, a drafting committee comprising experts from EANET participating countries was established to lead the scientific evaluation of monitoring data and the achievements of EANET (2000-2024), implemented based on the Medium-Term Plans for EANET with the goals of producing a comprehensive assessment of air pollution and acid deposition, and further developing the EANET network. Part II is a compilation of National Assessments describing monitoring activities, atmospheric environment assessments, and control measures implemented at the national level in EANET participating countries. However, it must be noted that the contents of Part II are not covered in this executive summary.

This fifth report in the series represents a significant scientific achievement by EANET. Its publication owes much to the ongoing efforts of EANET participating countries and related collaboration coordinated by the network. The report is expected to promote a better understanding of air pollution and acid deposition issues in the region and marks an important step in the continuous development of EANET.

Summary for Policy Makers

Summary of Key Points

About the Fifth Periodic Report on the State of Atmospheric Environment in East Asia (PRSAE5)

EANET is an intergovernmental regional network established for promoting cooperation among countries in East Asia to address air pollution and acid deposition. It aims to create a common understanding of the state of air pollution and acid deposition in East Asia, provide useful inputs for decision making at local, national, and regional levels, prevent or reduce adverse impacts on the environment caused by air pollution and acid deposition, and contribute to cooperation on issues related to atmospheric environment among participating countries.

To assess the state of acid deposition and air pollution in the East Asia region, EANET published scientific assessment reports, the Periodic Report on the State of Acid Deposition in East Asia (PRSAD) every five years: PRSAD1 in 2006, PRSAD2 in 2011, PRSAD3 in 2016, and PRSAD4 in 2021. The Twenty-fifth Session of the Scientific Advisory Committee (SAC25) discussed on the title of the Fifth Periodic Report and finally endorsed “The Fifth Periodic Report on the State of Atmospheric Environment in East Asia (hereafter PRSAE5)”.

For the PRSAE5, the Network Center (NC) for EANET established the Drafting Committee (DC) to prepare the implementation plan and other related works. The PRSAE5 consists of 3 parts, namely, Part I: Regional Assessment Report, Part II: National Assessment Report, and Part III: Executive Summary. The PRSAE5 provides useful information to EANET participating countries to understand the state of air pollution and acid deposition in the East Asian region based on monitoring data.

Current status of EANET monitoring activities

EANET monitoring covers five environmental items, gas/aerosol concentration, wet/dry deposition, soil/vegetation, inland aquatic environment, and catchment scale monitoring. The monitoring activities have been conducted following a set of monitoring guidelines and technical manuals. Currently, gas/aerosol concentration and wet/dry deposition monitoring is being carried out at dozens of sites in the EANET network. Data and information for ecological impact studies are currently collected from more than dozens of inland aquatic monitoring sites and soil and forest vegetation monitoring sites. All the sites follow a standardized set of methodologies for site selection, sampling, and chemical analyses to ensure technical conformity within the network.

EANET monitoring sites are classified into two basic categories, namely, gas/aerosol concentration and wet/dry deposition monitoring sites (hereafter, atmospheric environment monitoring site) and ecological survey sites. The atmospheric environment monitoring sites are sites for the collection of fundamental data on the temporal and spatial distribution of gas/aerosol concentration and wet deposition, and they are further classified into three sub-categories: remote sites, rural sites, and urban sites, for specific objectives of the monitoring. Ecological survey sites are those that provide basic data for assessing the effects of acidification on terrestrial ecosystems, and they are further classified into two sub-categories: basic survey sites and ecosystem analysis sites.

The number of atmospheric environment monitoring sites in EANET has been increasing in the past 25 years. The number of the gas/aerosol monitoring sites was 51 in 2024 (Cambodia: 1, China: 5, Indonesia: 2, Japan: 12, Lao P.D.R: 1, Malaysia: 3, Mongolia: 3, Myanmar: 1, Philippines: 6, the Republic of Korea: 3, Russia: 3, Thailand: 6, Vietnam: 5), representing an 82%-increase from 2000. There are 20 urban sites, 15 rural sites, and 16 remote sites, including 35 sites using the filter pack method, 35 sites using the automatic method, and 2 sites using the passive sampler method. The number of the wet deposition monitoring sites was 57 in 2024 (Cambodia: 1, China: 10, Indonesia:

5, Japan: 12, Lao P.D.R: 1, Malaysia: 5, Mongolia: 2, Myanmar: 1, Philippines: 3, the Republic of Korea: 3, Russia: 3, Thailand: 4, Vietnam: 7), including 20 urban sites, 17 rural sites, and 20 remote sites. Total number of wet deposition sites represents a 42%-increase from 2000.

Since 2000, soil monitoring and vegetation monitoring have been conducted at 33 sites in 10 countries and 29 sites in 9 countries, respectively. The basic survey was principally carried out for the initial objectives (namely, the establishment of baseline data and early detection of possible impact) in participating countries in accordance with the technical manual of EANET. The vegetation monitoring includes conducting comprehensive forest survey, tree decline survey, and understory vegetation survey, but the content and frequency of surveys vary widely. The data on the inland aquatic environment are collected in 17 sites from 9 countries. In order to assess the possible impacts of atmospheric deposition on ecosystems, monitoring of soil, forest vegetation, and inland water, the integrated monitoring for catchment-scale analysis have been conducted in 4 sites in 3 countries since 2005.

Quality Assurance/Quality Control (QA/QC) of monitoring data is a crucial condition to ensure reliable and proven results of measurements, which is a solid base to create a common understanding of the status of the air pollution and acid deposition problems through EANET activities. QA/QC plays an important role in monitoring for gas/aerosol concentration, wet deposition, soil and vegetation, and inland water to ensure that the measurement is accurate, comparable, and of quantifiable quality. The EANET produced four QA/QC programs (Wet Deposition, Air Concentration, Soil and Vegetation, and Inland Aquatic Environment). Several documents regarding QA/QC have been developed by EANET to guide receiving reliable data that is comparable among the participating countries as well as with other monitoring networks outside of the East Asian region.

Data quality

Throughout the implementation of Inter-laboratory Comparison (ILC) project, the submitted data was evaluated by using the prepared values which were specified by the NC. Using this prepared value, a bias was observed in the statistical data. The possible likelihood value, which should be used for the evaluation, can be the median of all of the compiled data. The National Monitoring Plan (NMP) of each participating country was prepared after starting formal phase. The NMP should be reviewed every year and revised if necessary. When there is a revision in the monitoring activity, the NMP should be revised immediately and accordingly submitted to the NC. The Technical Mission has been conducted as one of the additional activities of EANET. It could be effective to build the acid deposition monitoring capacity in participating countries. The potential problems in the laboratories in charge of EANET monitoring in participating countries may not be able to be stimulated to maintain and improve their abilities and their data quality. Even in the laboratories, which have been already regarded as showing high potential, there might remain an unrevealed problem. It may be important to reconsider the modality of the Technical Mission. The following items should be focused on for the improvement of the quality of monitoring data in EANET: 1) Selection of the monitoring sites focusing on the site category; 2) Establishment of a common point of view on the methodology including sampling and measurement; 3) Implementation of the ILC project; 4) Implementation of the technical mission; 5) Establishment of quality management, and; 6) Reporting of the monitoring data.

Overview of the analysis of monitoring results

The long-term EANET observations provide an important basis for assessing the status and trends of the atmospheric environment in East Asia. The assessment indicates that air pollution has improved in some parts of East Asia, while important regional and local challenges remain. PM_{2.5} concentrations have decreased at many long-term sites in Japan, the Republic of Korea, Mongolia, Thailand, and Vietnam, partly reflecting reductions in emissions in China and associated decreases in long-range transport. SO₂ and NO_x concentrations have also decreased substantially at Chinese sites. These results indicate the

effectiveness of emission reduction measures in reducing particulate and acidic air pollution in Northeast Asia and their regional benefits.

In contrast, surface O₃ shows an emerging regional air quality concern. While springtime O₃ has decreased at some remote sites in Japan, likely reflecting reduced long-range transport from China, significant increases have been observed at urban sites in Thailand. This suggests increasing photochemical ozone production associated with NO_x and VOC emissions. Biomass burning in Southeast Asia and coal combustion in Mongolia also remain important sources of particulate matter. These findings indicate that the major characteristics of air pollution are changing across East Asia, from predominantly sulfur-related pollution toward more complex pollution involving PM_{2.5}, O₃, and their precursors.

The assessment of atmospheric deposition also indicates a changing regional environmental situation. Wet deposition of sulfur has generally decreased, particularly in Northeast Asia, consistent with reductions in SO₂ emissions. In contrast, nitrogen deposition shows more complex spatial patterns, and reduced nitrogen is now the dominant form of nitrogen deposition at most sites. High nitrogen deposition and exceedance of critical loads at many assessed sites indicate potential risks of nitrogen accumulation and eutrophication, particularly in parts of Southeast Asia. These findings highlight the growing importance of NH₃ and reactive nitrogen management.

EANET ecological monitoring has provided further evidence on the environmental consequences of atmospheric deposition. Although relationships between changes in atmospheric deposition and soil, forest, and inland-water responses have been observed at some sites, ecosystem responses are not uniform and are strongly influenced by meteorological, hydrological, geological, and biogeochemical processes. Continuing changes in climate may further modify these responses. Continued integrated monitoring is therefore essential for assessing both delayed ecosystem responses and emerging environmental risks.

Overall, the EANET assessment demonstrates that the atmospheric environment in East Asia has improved in some respects, particularly with regard to sulfur pollution and PM_{2.5} in several areas, but new and persistent challenges remain, including surface O₃, reactive nitrogen, NH₃ emissions, biomass burning, and ecosystem impacts. The long-term EANET monitoring network provides a unique scientific basis for identifying these regional changes, evaluating the effectiveness of emission control measures, and supporting evidence-based environmental policy. Future priorities should include maintaining and strengthening long-term monitoring; expanding PM_{2.5}, O₃, precursor, and reactive nitrogen observations; improving assessment of total deposition; promoting source apportionment and integrated modeling; and strengthening QA/QC, data harmonization, and regional collaboration.

Summary of State of Atmospheric Environment in East Asia

Gas and Aerosol Concentration in East Asia

EANET has conducted continuous monitoring at various sites across participating countries from 2000 to 2024, contributing to the establishment of a regional monitoring network and providing scientific evidence for atmospheric environmental management. As of 2024, 65 air concentration monitoring sites were operated under EANET, covering SO₂, NO, NO₂,

NO_x, PM₁₀/PM_{2.5}, O₃, HNO₃, HCl, NH₃, and particulate matter components.

PM₁₀ and PM_{2.5} concentrations showed clear spatial differences across the region, with the highest levels observed at urban sites in Mongolia and mainland Southeast Asia and the lowest at remote oceanic and high-altitude sites in Japan and the Philippines. PM_{2.5} showed significant decreasing trends at many long-term monitoring sites in Japan, the Republic of Korea, Mongolia, Thailand, and Vietnam. The declining trends in Northeast Asia may be partly attributable to stringent and sustained emission controls implemented in China. Biomass burning in Southeast Asia and coal combustion in Mongolia remain important sources of particulate matter.

Surface O₃ showed different trends across the region. Springtime O₃ decreased at remote sites in Japan, likely due to reduced long-range transport from China, whereas O₃ concentrations increased significantly at urban sites in Thailand, with annual trends ranging from +3 to +5 ppb yr⁻¹. This suggests that increasing NO_x and VOC emissions may be contributing to enhanced photochemical ozone production, highlighting an emerging air quality and public health concern in Southeast Asia. SO₂ and NO_x/NO₂ concentrations at Chinese sites also decreased substantially, while NH₃ increased at some agricultural sites, highlighting the growing importance of reactive nitrogen management.

Future priorities include maintaining and strengthening long-term monitoring, expanding PM_{2.5}, O₃, and precursor monitoring in areas with data gaps, strengthening reactive nitrogen monitoring, promoting source apportionment and integrated modelling, and enhancing QA/QC, data harmonization, and regional collaboration.

Wet and Dry Deposition of atmospheric substances

EANET has conducted continuous wet and dry deposition monitoring since 2000. As of 2024, 57 monitoring sites were operated under the network. Wet deposition of nss-SO₄²⁻ has generally decreased across East Asia, particularly in Northeast Asia, while Southeast Asia has shown more variable trends. The region with the highest sulfur deposition has shifted from China to Vietnam. Nitrogen deposition shows more complex spatial and temporal patterns, with NH₄⁺ generally exceeding NO₃⁻ deposition. Major nitrogen deposition regions during 2020–2024 included China, Malaysia, and Indonesia, while Vietnam emerged as a new high-deposition region.

Total nitrogen deposition estimated at sites with filter-pack data was generally highest in Southeast Asia, with values exceeding 30 kg N ha⁻¹ yr⁻¹ at some sites in Indonesia and Vietnam. Reduced nitrogen accounted for more than half of total nitrogen deposition at most sites, reflecting the increasing importance of NH₃ emissions. Critical loads for inland-water eutrophication were exceeded at 20 of 27 estimated sites, indicating risks of excessive nitrogen accumulation, particularly in urban areas of Vietnam and Indonesia.

Precipitation acidity has declined markedly in Northeast Asia, particularly in China and Japan, whereas Southeast Asia has shown greater year-to-year variability and susceptibility to episodic acidification. These findings highlight the need to strengthen NH₃ monitoring and long-term observations. Passive samplers offer a simpler and more cost-effective approach for obtaining spatial and long-term NH₃ data. Estimating total deposition remains important for assessing ecosystem impacts such as acidification and eutrophication, and a hybrid approach combining observations with chemical transport models should be

considered within EANET.

Impacts on Ecosystems in East Asia

EANET ecological monitoring over more than two decades has generated substantial datasets on soil, forest vegetation, and inland water, while catchment-scale analyses have clarified relationships among atmospheric deposition, soil, vegetation, and stream water. Soil responses to declining acidic deposition varied among sites, indicating that soil processes are influenced by multiple factors. Similarly, forest growth in China and Japan did not show a clear increase corresponding to the decline in sulfur deposition, with observed changes largely associated with human disturbance, climate fluctuations, and forest aging.

Inland water chemistry showed no clear regional evidence of widespread acidification, although decreases in sulfate concentrations were observed more frequently than increases, suggesting partial recovery from reduced sulfur deposition. Catchment-scale analyses also indicated that ecosystem responses to changes in atmospheric deposition are not always immediate or consistent. Forest catchments generally remained nitrogen sinks, although incomplete nitrogen retention may occur under relatively high DIN export.

Overall, ecosystem responses vary considerably among regions and are influenced by meteorological, hydrological, geological, and biogeochemical processes. Consequently, the impacts of nitrogen and sulfur deposition cannot be assessed uniformly based solely on deposition levels. In addition, rising CO₂ concentrations and temperatures and changing precipitation patterns may increasingly influence ecosystem responses. Continued monitoring of atmospheric deposition and ecosystems is therefore necessary to detect delayed recovery, acidification, and changes in nitrogen retention.

Key Messages to Policy Maker

EANET has built a strong foundation for regional cooperation over more than two decades. One of its greatest achievements is the development of reliable, consistent, and scientifically sound data on acid deposition across the region. Through common monitoring methods, technical guidelines, quality assurance and quality control, and cooperation among Participating Countries, EANET has created a trusted scientific platform that provides valuable information on changes in atmospheric conditions and environmental impacts.

There is an important opportunity to make greater use of this excellent scientific resource to support policy development and practical action. Air pollution in East Asia is becoming increasingly complex. Fine particulate matter, ozone, transboundary air pollution, and other atmospheric pollutants are closely connected with emissions, meteorological conditions, human activities, and regional transport. These challenges require stronger cooperation, better information, and a common understanding of the regional situation.

In this context, the expansion of EANET's scope provides an important opportunity to move from monitoring and understanding atmospheric conditions toward supporting policy and regional action.

Protecting and Strengthening EANET's Scientific Foundation

EANET's long-term monitoring data on air pollution and acid deposition is one of its most valuable assets. The data have been collected through a common regional framework and supported by scientific cooperation among Participating Countries. This provides an important basis for understanding long-term changes in air pollution/atmospheric deposition and environmental conditions in East Asia.

Such long-term scientific data should not be considered simply as historical information. They are a regional public good and an important foundation for future environmental policy. Maintaining the continuity, quality, and accessibility of these data should therefore remain a core priority for EANET.

At the same time, the region is facing new and emerging air pollution challenges. The expansion of EANET's scope to cover broader air pollution is therefore a timely development. By building on its existing scientific strength, EANET can progressively develop a broader regional knowledge base on the atmospheric environment. This approach allows EANET to maintain what it has already achieved while responding to the changing needs of the region.

Supporting Alternative Monitoring Technologies and Closing Data Gaps

Another important development is the increasing use of alternative air pollution monitoring technologies, including low-cost sensors (LCS). These technologies can provide opportunities to expand monitoring coverage, complement conventional monitoring stations, and provide more detailed information at local and community levels. However, low-cost sensors also present challenges related to data quality, calibration, location, environmental conditions, and data interpretation. This is why the development of appropriate technical guidance is important.

EANET's work in developing guidelines for alternative air pollution monitoring can provide a valuable regional reference for Participating Countries. It can help countries understand how these technologies can be used appropriately and how their data can complement existing monitoring networks. This should be seen as a way of strengthening the existing scientific monitoring system. Conventional monitoring provides high-quality reference data, while alternative technologies can help extend geographical coverage and provide more information where conventional monitoring is limited. Combining these approaches could help EANET close important monitoring and information gaps in the region.

Bridging Scientific Data with Policy Making

The next important step for EANET is to strengthen the connection between scientific information and policy making. Excellent scientific data have limited value if they remain only within technical reports or scientific discussions. Their greater value comes when they are translated into information that policy makers can understand and use.

EANET should therefore strengthen mechanisms for communicating scientific findings to policy makers in a clear and practical way. This could include regional assessments, policy briefs, thematic reports, data visualization, and targeted technical dialogues between scientists and policy makers. The objective is not to tell countries what policies they should adopt. Rather, EANET can provide a trusted and neutral scientific basis that helps

Participating Countries understand common problems, identify regional trends, and make informed decisions according to their national circumstances.

In this regard, EANET has a unique advantage. It is already a trusted regional network with established cooperation, scientific expertise, monitoring systems, and long-term relationships among Participating Countries. This trust is an important asset that should be used to strengthen the science-policy interface.

Moving from Regional Data to Regional Strategies and Measures

Air pollution, particularly transboundary air pollution, cannot be fully addressed through national action alone. Emissions generated in one area may affect air quality in another country. This creates a need for regional understanding and, where appropriate, regional cooperation.

EANET can contribute to this process by using its scientific data to identify regional trends, common challenges, information gaps, and areas where cooperation can provide greater benefits. For example, regional analysis could help identify priority pollution episodes, major transport pathways, seasonal patterns, and areas where additional monitoring or emission information is needed. Such information could then support discussions among Participating Countries on possible regional strategies and measures.

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EANET does not need to become a policy-making body. Its strength lies in providing the scientific evidence and regional knowledge that can support policy making. By maintaining this clear role, EANET can become an even stronger bridge between science and regional environmental cooperation.

Building a Stronger Regional Platform for the Future

Looking ahead, EANET should continue to develop as a regional platform that connects science, policy, and countries. Its future strength will come from combining its long-term scientific foundation with new forms of data, new monitoring technologies, and stronger communication with policy makers. The network can provide a platform where Participating Countries share data and knowledge, learn from each other, identify common challenges, and develop practical cooperation. It can also help connect national monitoring systems and initiatives with regional priorities, reducing duplication and making better use of existing resources.

Most importantly, EANET should ensure that its scientific excellence is fully utilized. The region already has a valuable foundation of long-term data, technical knowledge, institutional experience, and cooperation. This should not be left unused or disconnected from policy processes.

Conclusion

EANET has already demonstrated that regional cooperation can generate high-quality and trusted scientific information. Its long-term monitoring of air pollution and acid deposition is an excellent example of how countries can work together to build a common scientific foundation. The expansion of its scope now provides an opportunity to build on this success and respond to the broader air pollution challenges facing East Asia.

The policy recommendation is therefore clear: EANET should protect its scientific excellence while strengthening its role in translating data and knowledge into policy-relevant information and regional action.

By integrating a broader range of air pollution data, including emission inventories, meteorological and modelling analysis, conventional monitoring, and alternative technologies such as low-cost sensors and satellite observations, EANET can help close important information gaps in understanding the current state of the atmospheric environment across East Asia. By strengthening the science-policy interface, it can help Participating Countries make better-informed decisions. And by providing a trusted regional platform, it can support stronger cooperation and the development of regional strategies and measures to address shared air pollution challenges.

EANET has already built its foundation. The next step is to make full use of it. From trusted data to shared knowledge, from shared knowledge to informed policy, and from informed policy to regional action. EANET can continue to play a central role in building a cleaner and more sustainable future for East Asia.

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