Strategy Paper on Future Direction of Monitoring for Dry Deposition of the EANET (2021-2025)

[Draft]

Drafted by the Task Force on Monitoring for Dry Deposition of the EANET

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I. Introduction

1. The Task Force on Dry Deposition Monitoring for the Acid Deposition Monitoring Network in East Asia (EANET) was first established in 1998 by the Interim Scientific Advisory Group (ISAG) of the EANET to carry out the following functions:

   i) To prepare a draft Quality Assurance and Quality Control (QA/QC) program for the first priority chemicals and particles during the preparatory phase, for consideration and adoption by ISAG, and
   ii) To develop the Strategy Paper for Future Direction of Dry Deposition Monitoring of EANET, for consideration of ISAG.

2. On the recommendation of SAC, the Tenth Session of the Intergovernmental Meeting (IG10) in November 2008 agreed to change the name of the Task Force to "Task Force on Monitoring for Dry Deposition" and also agreed to the following new Terms of Reference (TOR) for the Task Force:

   i) To further develop and elaborate the strategy for dry deposition evaluation in the region
   ii) To discuss on future direction of dry deposition evaluation and provide guidance on relevant activities based on the strategy
   iii) To develop the Technical Manuals for Air Concentration Monitoring and Dry Deposition Flux Estimation

3. Since 2015, the Task Force has conducted activities under the following revised TOR of the Task Force adopted by the 15th Session of Scientific Advisory Committee (SAC15) in 2015.

   i) To further develop and elaborate the strategy for dry deposition evaluation in the region
   ii) To discuss on future direction of dry deposition evaluation and provide guidance on relevant activities based on the strategy
   iii) To improve the Technical Manuals for Air Concentration Monitoring and Dry Deposition Flux Estimation

4. Since the beginning of EANET, the Task Force has successfully produced four important documents as follows:

   i) *Strategy Paper for Future Direction of Dry Deposition Monitoring of EANET* endorsed by ISAG in September 1999

ii) *Strategy Paper for Future Direction of Dry Deposition Monitoring of EANET (Second Edition)* endorsed by the 5th Session of Scientific Advisory Committee (SAC5) of the EANET in September 2005

iii) *Strategy Paper on Future Direction of Monitoring for Dry Deposition of EANET (2011-2015)* endorsed by the 10th Session of Scientific Advisory Committee (SAC10) of the EANET in October 2010

iv) *Strategy Paper on Future Direction of Monitoring for Dry Deposition of EANET (2016-2020)* endorsed by the 15th Session of Scientific Advisory Committee (SAC15) of the EANET in October 2015

5. The *Strategy Paper for Future Direction of Dry Deposition Monitoring of EANET (Second Edition)* mentioned the step-wise approaches for dry deposition monitoring. As the first step, the priority chemical species that were identified in view of their serious impacts on the ecosystem and human health, should be monitored according to the standardized monitoring methodologies. The priority chemical species are shown as follows.

   Gaseous Species: SO_2, O_3, NO, NO_2, HNO_3, HCl, NH_3
   Particulate matters: PM_{10}, $PM_{2.5}$, Components in PM (SO_4^{2-}, NO_3^-, Cl^-, NH_4^+, Na^+, Mg^{2+}, K^+ and Ca^{2+})

6. Then, as the second step, the methodology for dry deposition monitoring is implemented on the research bases including setting up of direct measurement study, parameterization of deposition resistances, and development of the "Inferential Method". Consequently, the suitable site for estimating dry deposition flux should be selected among the air concentration monitoring sites.

7. As the third step for enhancement of dry deposition monitoring, consideration on feasibility of developed monitoring techniques, enhancement of spatial coverage for dry deposition flux estimation, promotion of an ozone and PM_{10}/$PM_{2.5}$ monitoring network and review of its current status in East Asia, develop the database for surface resistances of tropical and boreal regions, further elaborate QA/QC for air concentration monitoring have been implemented according to the *Strategy Paper on Future Direction of Monitoring for Dry Deposition of EANET (2016-2020)*.

II. Current status

8. Dry deposition is the process by which gases and particles are deposited directly onto the surface of the earth by gravitational settling and atmospheric diffusion. It is difficult to quantify the dry deposition amounts because of the dependency of deposition velocity on meteorological conditions, surface conditions, and chemical species. Direct measurement (e.g., Eddy correlation method) to determine the dry deposition amounts requires costly equipment. It is hard to conduct the direct measurement at many sampling sites simultaneously.

9. On the other hand, a number of preceding studies demonstrated that it is feasible for a routine monitoring activity to estimate the dry deposition amounts by coupling air concentration data with estimated deposition velocity by meteorological measurements. In this "Inferential Method", the dry deposition amount is estimated by routine atmospheric and meteorological monitoring data (Baumgardner et al., 2002, Flechard et al., 2011, Adon et al., 2013). Dry deposition flux of gaseous and particulate species is calculated by the product of air concentration and deposition velocity.

10. Expert groups established under the Task Force have drafted the relevant technical manuals; the *Technical Manual on Dry Deposition Flux Estimation in East Asia* adopted by the Tenth Session Scientific Advisory Committee (SAC10) in October, 2010, and the *Technical Manual for Air Concentration Monitoring in East Asia* adopted by the Thirteenth Session Scientific Advisory Committee (SAC13) in September, 2013. These manuals are to provide guidelines of dry deposition flux calculation in the EANET region using the site-specific meteorological and ambient concentration monitoring data and ambient air concentration monitoring to standardize the monitoring methodology, respectively.

11. The regular phase of the EANET activity has been operated since 2001. Regarding dry deposition monitoring, the atmospheric composition is measured with a filter-pack, a passive sampler and/or automatic monitors at 52 sites in 13 EANET participating countries as of 2018. These atmospheric composition data at EANET sites have been used for assessment of regional air quality, trend analysis of atmospheric composition, validation of atmospheric models (Chatani et al., 2014, Ban, et al., 2016, Li et al., 2016, Jeong et al., 2018, Okamoto et al., 2018, Taketani et al., 2018, Chen et al., 2019, Li et al., 2019, Itahashi et al., 2020, Takami et al., 2020). The EANET data has significantly contributed to the understanding of atmospheric processes in the region. Therefore, enhancement of dry deposition monitoring such as sustaining quality assurance/quality control (QA/QC) of air concentration monitoring, expansion of monitoring items and

sites, and data of high time resolution monitoring are important for satisfying the public demand.

12. As of 2018, calculation of dry deposition flux by the "Inferential Method" was implemented at 10 EANET stations in Japan. However, the number of available EANET sites for dry deposition flux estimation is limited because there are a limited number of the EANET sites where the hourly meteorological data are available.

III. Objectives

13. Considering the current status of monitoring for dry deposition in the EANET, the enhancement of air concentration monitoring at EANET sites, the further elaboration of dry deposition flux estimation and enhancement on data analysis combined with monitoring data, emission inventory and air quality model are most important issues for the upcoming years. The following future objectives should be achieved during 2021 and 2025.

    i) To provide more elaborated atmospheric monitoring and atmospheric deposition data including dry deposition flux for the assessment of the adverse effects on soil, vegetation, inland aquatic systems and human health
    ii) To enhance Quality Assurance and Quality Control (QA/QC) of atmospheric composition monitoring
    iii) To enhance data analysis of dry deposition and atmospheric composition by combining with atmospheric numerical models for regional assessment in East Asia

IV Activities to be implemented to achieve the objectives from 2021 to 2025

14. The Network Center (NC) for the EANET has encouraged and assisted the participating countries to conduct air concentration monitoring of the priority chemical species at EANET atmospheric monitoring sites. Moreover, the following items should be conducted in order to achieve the objectives shown in Chapter III. The time schedules of these activities from 2021 to 2025 as well as deliverables of each activity are summarized in the Table 1.

i) Further develop and elaborate air concentration monitoring methodology in East Asia

15. The *Technical Manual for Air Concentration Monitoring in East Asia* was adopted in 2013, and the national air monitoring at EANET sites should follow this manual. This standardization is important to provide the comparable and reliable dataset. Some requirements in the participating countries may not comply with those in this manual. For such a case, the requirements specified in each country can take precedence unless monitoring data are comparable with those in the other countries. The standardization and comparability should also consistent with those in other regional monitoring networks.

16. To attain the above objective, the current status on air concentration monitoring methodology in the participating countries should be reviewed. When some conditions in the participating countries will not comply with the EANET manuals, the data comparability should be investigated. Furthermore, the monitoring conditions described in the EANET manuals should be compared with those in other regional monitoring networks. This activity will be implemented by the NC and the Expert Group on Revisions of the Technical Manuals (EGRTM) and reviewed by the Task Force during 2021–2022. As the deliverable, the revised *Technical Manual for Air Concentration Monitoring in East Asia* will be published.

17. In order to develop an air concentration monitoring methodology which will fulfill the scopes of the EANET, a new monitoring methodology should be considered. For example, the conventional NOx analyzer cannot selectively detect NO_2. The alternative monitoring methods of NO_2 are recommended to install especially in remote sites where the concentrations of reactive nitrogen compounds other than NO_2 are significant.

18. Among the current monitoring methods, only filter pack monitoring is feasible for monitoring of aerosol compositions. Because there are usually diurnal variations of dry deposition velocity, hourly measurement of air concentration is preferable. However, the time resolution of filter pack is one or two weeks described in this manual. Therefore, the adoption of aerosol measurement with shorter time resolution could be desired. Size classified particulate matter monitoring is also important for elaboration of dry deposition flux estimation with particle size dependence and characterization of fine particulate matter.

19. In this context, the feasibility of developed monitoring techniques should be considered. The developed monitoring techniques such as noted in the previous paragraphs will be reviewed and the feasible way for monitoring at EANET stations will be considered. Because considerable amounts of costs and resources are necessary to conduct the

official method of air concentration monitoring in some countries, it is important to consider the use of low-cost air concentration monitors as an alternative option. This activity will be also implemented during 2021–2025. The outcomes of this activity will be included in the revised *Technical Manual for Air Concentration Monitoring in East Asia*.

ii) Further develop and elaborate dry deposition flux estimation methodology

20. The *Technical Manual on Dry Deposition Flux Estimation* was adopted in 2010, and dry deposition flux has been reported in the EANET data report since 2012. Attached to the technical manual, the NC developed a calculation tool to estimate dry deposition of selected parameters using the "Inferential Method" at EANET sites. The technical manual should be more user-friendly for relevant staffs in the participating countries, and the calculation tool should also include various types of deposition surfaces.

21. Hourly meteorological and air concentration data are necessary to calculate dry deposition flux because there is a diurnal variation of dry deposition fluxes of some species. However, there is the limited number of the dataset on hourly basis at EANET sites, which cause large uncertainty of dry deposition fluxes. It is necessary to encourage the participating countries to submit meteorological and air concentration data with short time resolution in EANET sites. Furthermore, a more simplified estimation methodology by using longer averaged data should be considered at the sites where short time resolution data are hard to be submitted.

22. Because the application of the "Inferential Method" in the East Asian region is underdeveloped, elaboration of the "Inferential Method" is indispensable. The NC will continue to collaborate with scientists from the participating countries to make direct measurements of dry deposition flux for other chemical species and under various types of environmental conditions to improve the current estimations of deposition velocities. By those basic researches, the parameterization to calculate dry deposition velocity should be updated based on the direct measurement studies in East Asia.

23. Available data set of hourly meteorological and air concentration data at EANET sites should be surveyed. Furthermore, a more simplified estimation methodology by using longer averaged data should be considered at the sites where short time resolution data are hard to be submitted. Moreover, the determination of seasonal category in the current technical manual is not suitable for the tropical region, which should be modified in the revised technical manual. The elaborated parameterization of dry

deposition velocity described in the previous and this paragraphs will be reviewed by the Task Force with the help of the EGRTM during 2021–2022. As the deliverable, the revised *Technical Manual on Dry Deposition Flux Estimation in East Asia* will be published.

iii) Enhancement of spatial coverage for dry deposition flux estimation

24. The present number of monitoring sites for air concentration is inadequate to represent the state of the atmospheric environment in the vast region of East Asia. Moreover, not all the current air concentration monitoring sites are measuring all the recommended priority chemical species for the EANET.

25. The participating countries should, therefore, make more effort to establish additional monitoring sites, particularly in the data-sparse areas, taking into consideration geographic, climate and ecological conditions.

26. In order to enhance the spatial coverage, the NC will continue to promote continuous measurements of air concentrations by encouraging the participating countries to use automatic real-time monitoring instruments as well as lower cost and highly accurate methodologies measuring average air concentrations in rural/remote areas such as filter packs, denuders or passive samplers, whichever is the most feasible for respective sites.

27. The NC in cooperation with the participating countries will continue to make an effort to expand the network of air concentration monitoring sites and encourage the monitoring of all priority chemical species in 2021–2025. As a result, it is expected to increase the number of stations providing dry deposition flux data in East Asia.

iv) Promotion of an ozone monitoring network for the review of its current status in East Asia

28. The measurement of surface ozone has been identified as one of the priority items in the EANET. However, there are a limited number of EANET sites at which ozone is measured by using automatic analyzers or passive samplers. Moreover, the sampling period varies in some countries. Recent satellite imageries indicate that ozone is a growing problem in East Asia. The insufficient number of ozone concentration data has made it difficult for the EANET to analyze the severity and extent of the ozone problem. Therefore, ozone monitoring network should be further promoted.

29. It has been suggested that high concentrations of ozone may be harmful to the growth of crops and trees. Several papers on the effects of ambient level ozone on Japanese, Chinese and Indian crops and a few studies on Southeast Asia showed that the exposure to ambient level ozone induces reduction in growth and yield. (Task Force on Research Coordination, 2015). Daily health effect of ozone in East Asia was considered to be comparable with western multi-city studies with some reservations, and the burden of disease for ozone in East Asia was considered substantial (Task Force on Research Coordination, 2015). Furthermore, ozone is expected to increase in East Asia in the future owing to the increase in NOx emissions, which implies increasing regional warming by ozone forcing (Task Force on Research Coordination, 2015). Various adverse effects of tropospheric ozone in East Asia have been pointed out, and thus the review of the state of ozone pollution and its adverse effect by using the accumulated ozone data in the participating countries is desirable.

30. To enhance number of ozone concentration data in East Asia, further efforts should be made to promote an ozone monitoring network. The NC will encourage the participating countries to establish more ozone concentration monitoring sites using national resources in 2021–2025. The NC will try to provide and install an ozone monitor in developing countries that do not have sufficient resources to acquire the monitor by the support of external funds. Additional monitoring of ozone may be carried out in the countries using passive samplers or low-cost ozone sensors, particularly in rural, remote and forest sites to supplement the network.

31. Each ozone monitor in the EANET shall be calibrated using an ozone calibrator traceable to the NIST (National Institute of Standards and Technology, U.S.A.) Standard Reference Photometer (SRP) at least once every two years according to *Technical Manual for Air Concentration Monitoring in East Asia*. However, the limited countries have the SRP used as the national standards. The NC will lend an ozone standard calibrator that is traceable to the SRP to the participating countries upon the request. As a result, it is expected to increase the number of stations in East Asia providing ozone data that are comparable to the other networks' data.

v) Promotion of a PM_{10}/$PM_{2.5}$ monitoring network for the review of their current status in East Asia

32. PM_{10} and $PM_{2.5}$ are designated as the priority chemical species for EANET dry deposition monitoring. The number of the stations providing PM_{10} and $PM_{2.5}$ has been increased in recent years. However, limited PM (particulate matter) concentration data

especially in developing countries is an obstacle to evaluate the potential air quality impacts originated from various sources and establish air quality standards of $PM_{2.5}$. Therefore, PM_{10}/$PM_{2.5}$ monitoring should be further promoted.

33. It is also important to review and provide information on the status and potential risk of PM because the importance of the adverse effects of PM has been recognized in EANET the participating countries as well as acidic substances. According to several investigations on the short-term effect of PM on human health in China, the Republic of Korea and Japan, the resulting increase in mortality rates varies with cities and countries (Task Force on Research Coordination, 2015). The effects of aerosols on climate change are dependent on the chemical compositions of aerosols. Typical scattering aerosols such as ammonium sulfate and nitrate result in significant surface cooling, whereas absorbing aerosols including black carbon and brown carbon aerosols cause atmospheric heating (Task Force on Research Coordination, 2015). These optical properties of aerosol will affect crop yields and tree growth both positively and negatively. The promotion of a PM_{10}/$PM_{2.5}$ monitoring and chemical characterization of PM in the participating countries will enable to provide sufficient data to evaluate the adverse effects.

34. The NC will encourage the participating countries to establish more PM mass concentration monitoring sites using national resources in 2021–2025. The NC will try to provide and install a PM monitor in developing countries that do not have sufficient resources to acquire the monitor by the support of external funds. Moreover, the operational cost of PM monitors is one of the difficulties for expansion of monitoring, and therefore the use of low-cost PM sensors will be considered as trial. As a result, it is expected to increase the number of stations the number of stations providing PM_{10} and $PM_{2.5}$ data in East Asia.

vi) Further elaborate QA/QC for air concentration monitoring

35. The *Technical Manual for Air Concentration Monitoring in East Asia* described QA/QC of air concentration monitoring covering overall procedures such as monitoring site, field and laboratory operations, data management, and determination of accuracy and precision, DQOs (Data Quality Objectives) of fundamental parameters. Also, the inter-laboratory comparison project on dry deposition has been implemented since 2005 in order to check the analytical validity of filter pack samples. The QA/QC in the EANET air concentration monitoring should be occasionally reviewed so that it will consider any new advances in the monitoring methodologies.

36. The QA/QC described in the EANET technical manuals should be occasionally reviewed, and some factors which are not consistent with other international networks should be elaborated in 2021–2025. The outcomes of this activity will be included in the revised *Technical Manual for Air Concentration Monitoring in East Asia*.

V. Capacity building of air concentration monitoring and dry deposition study

37. The NC will continue to support the participating countries to build capacity in air concentration monitoring activities. For example, the NC will make an effort to hold individual training courses/workshops/seminars for responsible persons of air concentration monitoring. The NC should also make full use of capacity building opportunities organized by international organizations such as the Clean Air Asia Center (CAA) with support from the Asian Development Bank, Japan International Cooperation Agency (JICA), Global Atmosphere Watch (GAW) Programme of the World Meteorological Organization (WMO) and so on.

38. It is important to expand contact information on experts of air concentration monitoring and dry deposition study in East Asia because the experts have a plenty of knowledge on regional studies. The NC will develop the list of national experts on the atmospheric environment especially in the fields of air quality and dry deposition in East Asia in order to keep them informed on recent developments in monitoring for dry deposition and related research activities in the participating countries.

VI. Collaboration with relevant networks/organizations

39. Collaboration with other networks and organizations is essential to address regional and global air pollution issues and also to ensure the sustainability and future development of the EANET. Till now, the EANET has continued to build and strengthen links with some international/domestic programs and initiatives such as the Cooperative Programme for Monitoring and Evaluation of the Long-Range Transmission of Air Pollutants in Europe (EMEP) under the Convention on Long-Range Transboundary Air Pollution (CLRTAP), WMO/GAW and National Atmospheric Deposition Program (NADP). The collaborative works to be implemented by the NC covers:

    i) Joint research studies on air concentration monitoring and dry deposition flux estimation in the EANET region involving researchers from the NC, researchers in the participating countries and interested external scientists.

ii) Sharing the monitoring data and metadata to assess regional and global impact on atmospheric environment and ecosystems.
iii) Coordinating investigations on global or inter-regional transport of air pollutant which threaten human health and ecosystems.
iv) Learning the good practices for addressing regional and transboundary air pollution problems, including the application of modeling and emission inventories, evaluation of long-term effects, control and mitigation measures, etc.

40. The EANET should continue to seek opportunities to inform and update the international and regional scientific programs and potential funding agencies on EANET activities, highlighting the significance and achievements since the start of its regular activities, and the need to continue efforts to promote a comprehensive approach to relevant environmental problems. The NC and relevant organizations in the participating countries will promote collaboration focusing on the following:

i) Seeking the ways to strengthen the existing cooperation with EMEP, WMO, the Regional Forum on Environment and Health developed jointly by World Health Organization (WHO) and Asia Pacific Clean Air Partnership (APCAP) under the United Nations Environment Programme (UNEP).
ii) Building partnerships and linkages with other programs in the region such as Deposition of Biogeochemically Important Trace Species of the International Geosphere-Biosphere Programme (IGBP-DEBITS), Malé Declaration in South Asia and ASEAN Haze Agreement.

41. Besides monitoring data analysis, atmospheric modeling is an essential tool for clarification of atmospheric processes and the identification of important air pollution sources. Enhancement on data analysis combined with monitoring data, emission inventory and air quality model will provide more reliable results because they compensate each other. The NC will communicate with modeling and emission inventory research communities such as Model Inter-Comparison Study for Asia (MICS-Asia) in order to discuss elaboration on atmospheric models and emission inventories by providing air concentration data at EANET sites. The output from the research communities will be reflected to the *5th Periodic Report on the State of Acid Deposition in East Asia* that will be prepared during 2025–2026.

Table 1 Time schedule of implementation of activity

Activity	2021	2022	2023	2024	2025	Deliverables
i-i) Review of the Technical Manual for Air Concentration Monitoring in East Asia	X	X				Revised Technical Manual for Air Concentration Monitoring in East Asia
i-ii) Consideration on feasibility of developed monitoring techniques	X	X	X	X	X	
ii) Further develop and elaborate dry deposition flux estimation methodology	X	X				Revised Technical Manual on Dry Deposition Flux Estimation in East Asia
iii) Enhancement of spatial coverage for dry deposition flux estimation	X	X	X	X	X	Increasing the number of stations providing dry deposition flux data in East Asia
iv) Promotion of an ozone monitoring network for the review of its current status in East Asia	X	X	X	X	X	Increasing the number of stations providing ozone data in East Asia
v) Promotion of a $PM_{10}/PM_{2.5}$ monitoring network for the review of their current status in East Asia	X	X	X	X	X	Increasing the number of stations providing $PM_{10}/PM_{2.5}$ data in East Asia
vi) Further elaborate QA/QC for air concentration monitoring	X	X	X	X	X	Revised Technical Manual for Air Concentration Monitoring in East Asia

Appendix

Members of the Task Force on Monitoring for Dry Deposition
(As of September, 2020)

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