Strategy Paper on Future Direction of Monitoring for Dry Deposition of the EANET (2016-2020)

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. The Task Force has successfully produced three 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

3. 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+})

4. 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.

5. 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:

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

6. In accordance with the TOR of the Task Force, the *Strategy Paper on Future Direction of Monitoring for Dry Deposition of EANET (2011-2015)* was developed during 2009-2010 and adopted by 10th Session of Scientific Advisory Committee (SAC10) of EANET in October, 2010. The *Strategy Paper (2011-2015)* further elaborates on the previous *Strategy Paper for Future Direction of Dry Deposition Monitoring of EANET (Second Edition)* and will serve as a guide for the Task Force and other related groups for planning and implementing future activities for improving the assessment of acid deposition and other priority chemical species of the EANET.

7. In the development of the *Strategy Paper (2011-2015)*, the Task Force was guided by the Medium Term Plan for EANET (2011-2015) adopted by the Twelfth Session of the Intergovernmental Meeting (IG12) in November 2010 and other recent developments within the EANET. The views of relevant bodies of the EANET were also taken into consideration in the development of the objectives for monitoring of dry deposition in the EANET.

II. Current status

8. Dry deposition is the process by which gases and particles are deposited directly onto the ground 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. Therefore, it is hard to conduct 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 (MACTEC, 2008). Dry deposition flux of gaseous and particulate species is calculated by the product of air concentration and deposition velocity.

10. 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 47 sites in 13 EANET participating countries as of 2015. 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 (Kuribayashi et al., 2012, Han et al., 2013, Itahashi et al., 2014, Kajino et al., 2012, Pozzer et al., 2012). The EANET data has significantly contributed to understanding of atmospheric processes in the region. Therefore, enhancement of dry deposition monitoring such as sustaining of 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.

11. The Expert Group on Preparation of the Technical Manual for Air Concentration Monitoring composed of relevant experts in this field was established under the Task Force in 2009. The Expert Group drafted the *Technical Manual for Air Concentration Monitoring in East Asia* that was adopted by the Thirteenth Session Scientific Advisory Committee (SAC13) in September, 2013. This manual is to provide guideline of air concentration monitoring based on identified monitoring methods and to standardize air concentration monitoring methodology.

12. The estimation of dry deposition is crucial to evaluate environmental impacts of total atmospheric deposition. Based on the verification of the Inferential method with direct measurement in East Asia (Takahashi et al., 2002, Matsuda et al., 2005, Matsuda et al., 2006), the Expert Group of Dry Deposition Flux Estimation established in 2007 had worked on preparing the *Technical Manual on Dry Deposition Flux Estimation in East Asia* adopted by the Tenth Session Scientific Advisory Committee (SAC10) in October, 2010. According to the Technical Manual, the NC will start to calculate dry deposition fluxes of available measurement species at EANET sites since 2012.

13. The *Strategy Paper for Future Direction of Dry Deposition Monitoring of EANET (Second Edition)* described a step-wise approach for dry deposition monitoring including:

Step 1: Implementation of air concentration monitoring for priority chemical species

Step 2: Intensive research on methodology for dry deposition monitoring

Step 3: Selection of specific monitoring sites suitable for dry deposition computation among the air concentration monitoring sites

Currently, the Step 1–3 has been carried out, but the problem of dry deposition estimation is that there are a limited number of the EANET sites where the hourly meteorological data are available.

III. Objectives

14. Considering the current status of monitoring for dry deposition in the EANET, the further elaboration of dry deposition flux estimation and the development of air concentration monitoring at EANET monitoring sites are most important issues. The following future objectives should be achieved in the upcoming years.
    i) To provide more elaborated atmospheric composition and dry deposition flux data for the assessment of the adverse effects on soil, inland aquatic systems, vegetation, and human health
    ii) To enhance Quality Assurance and Quality Control (QA/QC) of atmospheric composition monitoring
    iii) To provide spatially distributed atmospheric composition data for validation of atmospheric numerical model outputs and for assessment of regional air pollution

15. Furthermore, the following revised TOR for the Task Force was adopted by 15th Session of Scientific Advisory Committee (SAC15) of the EANET in October, 2015 in order to achieve the above objectives.
    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 revise Guidelines for Acid Deposition Monitoring in East Asia and to improve the Technical Manuals for Air Concentration Monitoring and Dry Deposition Flux Estimation

IV Activities to be implemented to achieve the objectives from 2016 to 2020

16. The Network Center (NC) for the EANET has carried out a number of activities to encourage and assist participating countries to conduct air concentration monitoring of all the priority chemical species in all EANET monitoring sites. Moreover, the following items should be conducted in order to achieve the objectives shown in Chapter III in the upcoming years. The time schedules of these activities from 2016 to 2020 are summarized in the Table 1.

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

17. 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 comparable and reliable dataset. Some requirements in participating countries may not comply with those in this manual. For such case, the requirements specific 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.

18. To attained the above objective, current status on air concentration monitoring methodology in EANET participating countries should be reviewed. When some conditions in participating countries will not comply with the EANET manuals, the data comparability should be investigated. Furthermore, the conditions described in the EANET manuals should be compared with those in other regional monitoring networks. This activity will be reviewed by the Task Force and the appropriate Expert Group during 2016–2017.

19. In order to develop air concentration monitoring methodology which will fulfill the scopes of the EANET, 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. 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, time resolution of filter pack is one or two

weeks described in this manual. Therefore, adoption of aerosol measurement with shorter time resolution could be desired.

20. In this context, the feasibility of developed monitoring techniques should be considered. The alternative monitoring methods of NO_2 such as a photodissociation convertor of NO_2, Cavity Ring-Down Spectroscopy (CRDS), Laser Induced fluorescence (LIF) and aerosol measurement with shorter time resolution such as Particle-Into-Liquid Sampler coupled with Ion Chromatograph (PILS-IC), Monitor for AeRosols and GAses (MARGA) a Gas-Particle Ion Chromatograph (GPIC), Gas and Aerosol Collector-Ion Chromatograph (GAC-IC) will be reviewed by long-term field observation researches. This activity will be also implemented during 2016–2020.

ii) Further elaborate and develop and elaborate dry deposition flux estimation methodology

21. 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 with 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 EANET participating countries, and the calculation tool should also include every type on deposition surfaces.

22. Hourly meteorological and air concentration data are necessary to calculate dry deposition flux because there is diurnal variation of dry deposition fluxes of some species. However, there is limited number of dataset of hourly data at EANET sites, which cause a large uncertainties of dry deposition fluxes. It is necessary to encourage EANET participating countries to submit meteorological and air concentration data with short time resolution in EANET sites. Furthermore, 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.

23. Because application of the Inferential method in 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.

24. Available data set of hourly meteorological and air concentration data at EANET sites should be surveyed. Furthermore, 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. The parameterization of dry deposition velocity will be reviewed by the Task Force with help of appropriate Expert Group during 2016–2017.

iii) Enhancement of spatial coverage for dry deposition flux estimation

25. 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.

26. 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.

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

28. The NC in cooperation with participating countries will continue to make effort to expand the network of air concentration monitoring sites and encourage the monitoring of all priority chemical species in 2016–2020.

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

29. 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 non-uniformity of the measurements has made it difficult for the EANET to analyze the severity and extent of the ozone problem.

30. It has been suggested that high concentrations of ozone may be harmful to the growth of trees and crops and specific visible injuries of plant leaves caused by ozone have been identified as indicators for observation of direct effects of this pollutant on plants. Review on the State of Air Pollution in East Asia (Task Force on Research Coordination, 2015) pointed that ozone is considered to be one of the environmental stresses relating to forest decline and tree dieback. However, very little information is available on the effects of ozone on tree species native to the other Asian countries Therefore, the accumulation of ozone data in forest areas of East Asian region should also be considered for future assessment of ozone impacts.

31. Further efforts should be made to promote an ozone monitoring network. This may be achieved by securing the necessary financial resources to purchase and install at least one set of automatic monitoring instruments in each country and a traveling standard for regular calibration of the network instruments, traceable to the NIST (National Institute of Standards and Technology, U.S.A.) Standard Reference Photometer (SRP). Additional monitoring of ozone may be carried out in the countries using passive samplers, particularly in rural and forest sites to supplement the network.

32. To strengthen the existing network, the NC will encourage participating countries to establish more surface ozone monitoring sites using national resources in 2016–2020. The NC will also try to provide and install an ozone monitor in developing countries which do not have sufficient resources to acquire an ozone monitor. Each ozone monitor in the EANET shall be calibrated using an ozone calibrator traceable to the NIST SRP at least once every two years according to *Technical Manual Technical Manual for Air Concentration Monitoring in East Asia*. The NC will lend an ozone secondary standard calibrator to participating countries upon the request.

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

33. Although PM_{10} and $PM_{2.5}$ has also been designated as the priority chemical species for EANET dry deposition monitoring, only several counties are implementing monitoring by automatic analyzers. Concentrations of secondary aerosol precursors are in high level in the region. Future trends of PM (particulate matter) mass concentrations must be monitored at many sites.

34. PM_{10}/$PM_{2.5}$ monitoring network should be promoted in East Asia. This activity may include acquiring financial support to purchase and install at least one set of automatic monitoring instruments for PM_{10} and $PM_{2.5}$ in each country following the specification described in the *Technical Manual for Air Concentration Monitoring in East Asia*.

35. It is also important to provide information on the status and potential of PM because the importance of the adverse effects of PM has been recognized in EANET participating countries as well as acidic substances. Review on the State of Air Pollution in East Asia (Task Force on Research Coordination, 2015) pointed that the short-term effect of PM on human health in East Asian countries, the resulting increase in mortality rates varies with cities and countries and also pointed that Possible impacts of particulate depositions on tree species have been reported in East Asia, as well as in Europe and North America. The promotion of a PM_{10}/$PM_{2.5}$ monitoring in the EANET will enable to provide sufficient data to evaluate adverse effects.

36. The NC will also encourage participating countries to establish more PM mass concentration monitoring sites using national resources in 2016–2020. The NC will also try to provide and install a PM monitor in developing countries which do not have sufficient resources to acquire a PM monitor by support of external funds such as Clean Air Asia (CAA).

vi) Develop the database for surface resistances of tropical and boreal regions

37. The *Technical Manual on Dry Deposition Flux Estimation in East Asia* defines 15 land use and 5 seasonal categories in order to identify surface resistance parameters such as the Roughness length "z_0"(m) and characteristic radius of plants "A" (mm). The adopted category was referred from Brook et al. (1999), which was originally reported in Wesely (1989) and generally applied for mid latitude region. In order to apply surface resistance in the whole EANET region, survey of surface resistance applied in tropical and boreal region is necessary. The

NC will develop the database for surface resistances of tropical and boreal regions by means of reviewing existing researches and with the aid of the relevant scientists.

38. The NC will review of existing researches of estimating dry deposition velocity in tropical and boreal regions in 2016–2020. Furthermore, in collaboration with the members of the Expert Group on Dry Deposition Flux Estimation, the NC will summarize the outcomes of dry deposition study in tropical region such as Thailand and boreal region such as northern Japan.

vii) Further elaborate QA/QC for air concentration monitoring

39. 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 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 advance in the monitoring methodologies.

40. 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 2016 and 2017. The QA/QC guidebook which covers general requirements of QA/QC for overall EANET monitoring will be developed by 2016.

V. Capacity building of dry deposition monitoring activities

41. The NC will continue to support participating countries to build capacity in dry deposition monitoring activities. For example, the NC will make an effort to hold individual training courses/workshops/seminars for responsible persons of dry deposition monitoring. The NC should also make full use of training courses organized by international cooperation organization such as Global Atmosphere Watch (GAW) programme of the World Meteorological Organization (WMO), Asia-Pacific Clean Air Partnership (APCAP) and Japan International Cooperation Agency (JICA).

42. Contact information on experts of air concentration monitoring and dry deposition study is not easily available in East Asia. The NC will compile a list of national experts on 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 dry deposition monitoring and related research activities in EANET participating countries.

VI. Collaboration with relevant networks/organizations

43. 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 programmes 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 and Clean Air Status and Trends Network (CASTNET). The collaborative works to be implemented by the NC covers:

- Joint research studies on air concentration monitoring and dry deposition flux estimation in EANET region involving researchers from the NC, participating countries and interested external scientists.
- Participating in activities organized by other international/regional initiatives.
- Coordinating investigations on global or inter-regional transport of air pollutant which threaten human health and ecosystems.
- Learning the good practices for addressing regional and transboundary air pollution problems, including application of modeling and emission inventories, evaluation of long-term effects, control and mitigation measures, etc.

44. 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. Future collaboration should focus 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 WHO and 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.

Table 1 Time schedule of implementation of activity

Activity	2016	2017	2018	2019	2020
i-i) Review of the Technical Manual for Air Concentration Monitoring in East Asia		X	X		
i-ii) Consideration on feasibility of developed monitoring techniques	X	X	X	X	X
ii) Further elaborate and develop and elaborate dry deposition flux estimation methodology		X	X		
iii) Enhancement of spatial coverage for dry deposition flux estimation	X	X	X	X	X
iv) Promotion of an ozone monitoring network and review of its current status in East Asia	X	X	X	X	X
v) Promotion of a $PM_{10}/PM_{2.5}$ monitoring network and review of their current status in East Asia	X	X	X	X	X
vi) Develop the database for surface resistances of tropical and boreal regions	X	X	X	X	X
vii) Further elaborate QA/QC for air concentration monitorin	X	X			

Appendix

Members of the Task Force on Monitoring for Dry Deposition
(As of October, 2010)

1.	Prof. Cho Seog-Yeon (Chair)	Inha University, Republic of Korea
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