The Fifth Session of the Scientific Advisory Committee
on Acid Deposition Monitoring Network in East Asia
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Discussion on Strategy Paper for Future Direction of Dry Deposition Monitoring of EANET

1. Background

The First Interim Scientific Advisory Group (ISAG) Meeting on EANET, held on 12-14 October 1998 in Yokohama, Japan intensively discussed the future strategy on dry deposition monitoring, and agreed on the identification of the priority chemical species. In this meeting (ISAG1), a Task Force on Dry Deposition Monitoring was established to develop a strategy paper for future direction of dry deposition monitoring of EANET and to prepare a draft QA/QC program for the first priority chemical species, which are measured by Automatic Monitors.

After ISAG1, the Task Force prepared those two documents. “Strategy paper for future direction of dry deposition monitoring of EANET (Strategy Paper)” was finally endorsed with some modifications by ISAG through the diplomatic channel in September 1999. In addition, “QA/QC program for the air concentration monitoring in East Asia” was finally endorsed with some modifications by the Science Advisory Committee (SAC) at its First Session held on 14-16 November 2001 in Chiang Mai, Thailand.

Since the Strategy Paper was prepared by reflecting the circumstances of dry deposition monitoring in the preparatory phase of EANET, there are pending issues to be discussed that were pointed out in those documents and/or in previous STM/SAC meetings. Moreover, Filter Pack Method is currently adopted in lots of countries in EANET based on “Technical Document for Filter Pack Method in East Asia” developed by the Task Force and was endorsed by SAC3, held on 24-26 November 2003 in Pattaya, Thailand. In this context, based on the discussion at STM5 held on 28-30 September 2004 in Niigata, Japan (STM5/8/1) and SAC4 held on 3-5 November 2004 in Siem Reap, Cambodia (SAC4/11/1), “Draft Revise Edition of Strategy Paper for Future Direction of Dry Deposition Monitoring of EANET” was prepared and distributed to members of Task Force on the Dry deposition Monitoring, National Focal Points, National Centers, SAC and Secretariat of EANET by Network Center (NC) in April 2005, as serving the Secretariat of Task Force on Dry Deposition Monitoring. Toward a revision of the Strategy Paper, several comments on the revision have been gathered so far.

In this document, the points of the revisions and the general comments on it are summarized.

2. The points on the revision of the Strategy Paper

"Issues to be discussed on Dry Deposition Monitoring of EANET" which were presented at STM5 (STM5/8/1) and SAC4 (SAC4/11/1) suggested the following issued to be discussed mainly: (1) Classification of priority chemical species, (2) Size of particulate matter to be monitored, (3) Quality assurance and quality control (QA/QC) for Ozone monitoring and Filter Pack Method.

Priority chemical species were defined in the Strategy Paper as follows:

First priority: SO_2, O_3, NO, NO_2 (urban), and particulate mass concentration (PM10)
Second priority: NO_2 (rural and remote), HNO_3, NH_3, particulate component (SO_4^{2-}, NO_3^-, NH_4^+, and Ca^{2+}).

This classification is originated in the feasibility of dry deposition monitoring in the preparatory phase of EANET. In the regular phase, the monitoring of the second priority chemical species except NO_2 (rural and remote) has been coming into wide use by filter pack methods. At STM3, it was suggested that chemical species determined as "second priority" in the Strategy Paper were equally important with "first priority" chemical species. Taking into account present situations, Priority chemical species are defined in the revised edition of the Strategy Paper as follows with notification for the monitoring methodology on NO_2 and PM2.5:

Priority chemical species: SO_2, O_3, NO, NO_2, HNO_3, HCl, NH_3, particulate component (SO_4^{2-}, NO_3^-, Cl^-, NH_4^+, Na^+ and Ca^{2+}), PM10, PM2.5

As for QA/QC, the inter-calibration of O_3 by means of traceability to the international standard of National Institute for Standard and Technology (NIST) is described in the revised edition. Moreover, survey of Filter Pack Method to verify the appropriateness for various situations like tropical forest is encouraged.

3. General comments on the revised edition of the Strategy Paper

Various comments and suggestions including specific aspects have been gathered from several countries. "Draft Revise Edition of Strategy Paper for Future Direction of Dry Deposition Monitoring of EANET" is attached as **Appendix 1** and some general comments on it are as follows:

General

(1) All of the discussion made at STM5 and SAC4 (**Appendix 2**) has been properly considered in the revised edition of the Strategy paper for Future Direction of Dry Deposition Monitoring of EANET. No particular comments for further revision.

(2) On page 10 (Step 3) there is a phrase: “The state of science is not yet such that we can defend a strict application of guidelines”. It is extremely important phrase! Unfortunately, it will be important in the near (and not near) future. Hence, we can write many such documents without any progress in practice.

(3) In the future plans, assessment of each participating country's capability and capacity is essential before implementation. This is to ensure that the formulated plan can be implemented effectively by the participating country.

Monitoring

(4) As stated in the report of SAC4 meeting, a study of PM10, PM2.5 and their components should be considered in special sites. Therefore, PM2.5 should not be listed together with other chemical species as a priority concerns in general or mandatory basis since the measurements of PM2.5 are still not much effective in the region.

(5) PM10 and PM2.5 data might be limited due to the designation of one-hour average values from these parameters as stated in section 3.3 (para4). The measurements should not be only limited to the real time automatic equipment for these pollutants. The measurement technology for these parameters should be opened to both manual and automatic techniques.

(6) Section 3.1, para 1, “The purposes of dry…” It could be extremely dangerous to use Na+ for estimation sea-salt contribution. Soils of the region (Chinese soils of its western part) can contain a lot of sodium (for example, see: Jie Xuan, 2005. Emission inventory of eight elements, Fe, Al, Mg, Mn, Na, Ca and Ti, in dust source region of East Asia. AE, 39, 5, 813-821). Under such conditions, sea-salt sulfate can be mistakenly overestimated.

(7) The paper suggested mandatory measurements of a number of variables and among them is biological species distribution. When applied to tropical ecosystems, this is very difficult to achieve as <u>tropical ecosystems are very diverse and endemic</u>. This will

entail a large number of monitoring sites to ensure representativeness.

(8) Monitoring sites: In dry deposition monitoring, priority should be given to selecting monitoring sites that make up the major areas of the region and surfaces that are sensitive to acid deposition.

Dry Deposition Velocity

(9) Section 2, para 6, "The collection on-site…" It is not clear, what on-site measurements can be used (in principal, even theoretically) to quantify Rb and Rc? How can Dry Deposition Inferential Method assess different resistances separately?

(10) Section 2, para 7, "Each of the resistances…" In addition to "diurnal cycle", there is seasonal cycle. It is very important for northern part of EANET region, where underlying surface changes its properties drastically from summer (vegetation) to winter (snow). The document does not concern this problem at all. Besides, properties of underlying surface according to dry deposition process can change significantly because of rain. Resistance for SO2 uptake by dry surface can be much higher that such resistance for wet surface after rain event.

(11) We should understand that applications of direct methods of dry deposition measurements are extremely expensive. They cannot be recommended as routine activities for all the stations of the network. Hence, measurements of airborne concentrations at many stations will be unclaimed (waste of money). Moreover, it is difficult to apply experience obtained at few stations of direct measurements to the other stations because of very different local conditions.

(12) Even if we measure dry deposition fluxes directly, the values can be representative for a small area around the station. Radius of representativeness can be of tens of kilometers (not more than a hundred). Hence, EANET region of huge territory will be covered with dry deposition assessment in few very local points.

(13) European and American experiences show that only modeling approach can provide dry deposition assessment for the region as a whole. In this case, the model (or models) should be verified on the basis of direct measurements of dry deposition fluxes, even if they are very scarce in space.

(14) As a temporary approach to step from measurements of concentrations in air (which themselves give no information on dry depositions) to REAL assessment of dry

deposition values, Russian / EMEP experience can be used. The approach is based on expert estimates of dry deposition velocities for each measured compound. The velocities are estimated by experts on monthly basis for each monitoring station, taking into account its local conditions and seasonal changes. Comparison of dry deposition values obtained in Russia for locations of EMEP stations with the EMEP modeling data shown that the difference could be not higher that 50% for a month, and not higher than 30% on annual basis. It is believed that appointed SAC and TF-on-DDM members (involving knowledge of national experts) could make expert estimates of DD velocities for all pollutants and for all EANET stations on monthly basis. Such a tentative measure could give a possibility to obtain dry deposition fluxes at stations, which already now measure pollutant concentrations in air.

(15) Deposition Velocity (Vd) for tropical rain forest is lacking as the residual resistance, Rc for tropical forest is unknown. Intensive research should therefore focus on dry deposition in tropical rain forest.

(16) The novel technology employing surrogate surface is now gaining more attention and worthwhile to be mentioned by appending the paragraph just after the first paragraph. As you may well aware, the direct measurement method using surrogate surfaces is easy to implement and maintain and moreover provides the actual amount deposited for the give types of surface.

Composition

(17) The unit of the air concentration should be specified as suggested in STM5 meeting. It should be listed together with the name of priority species in section 3.3.

(18) I/ II/ Page 4: Sub-headings 3.1, 3.2 and 3.3 seemed not consistent with "3. Priority chemical species ..." or the title of these sub-headings should be modified.

(19) II/ Page 8: "Along with the dry deposition fluxes, the air ..." should be: "Along with the dry deposition fluxes (F), the air ..." for clarity.

(20) II/ Page 9: Units should put to "wind speed; ... biological species distribution"

(21) Section 3.2, para 1, “From the viewpoint…” In the first phrase the word “concentration” should be removed. “Concentration” is not “substance”.

(22) Section 4.1, para 1, “The combination…” In point (iii): What is the meaning of “and

in the other regions"?

(23) It can be effective to express the need for expanding the measurement parameters. In this case, one or more sentences should be inserted in the introduction.

(24) The present strategy paper should fully devote to dry deposition monitoring excluding air quality monitoring because the different philosophy applies to these two monitoring. For example, the temporal resolution is very important in air quality monitoring but the spatial resolution is more important in dry deposition monitoring. This is main reason we have spent some time on passive samplers or filter pack methods for dry deposition monitoring.

Appendix 1

Strategy Paper for Future Direction of Dry Deposition Monitoring of EANET: Revised Edition (draft for SAC5)

1. Introduction

The First Interim Scientific Advisory Group (ISAG) Meeting on EANET, held on 12-14 October 1998 in Yokohama, Japan intensively discussed the future strategy on dry deposition monitoring, and agreed on the identification of the priority chemical species. For further elaboration of the strategy on dry deposition monitoring, it developed and approved a document titled "Future Direction of Dry Deposition Monitoring of EANET" (attached as Annex 1), and established a Task Force on Dry Deposition Monitoring (hereinafter referred to as the "Task Force"). The Terms of Reference of the Task Force are i) to prepare a draft QA/QC program for the first priority chemicals and particles during the preparatory phase, for consideration and adoption by ISAG, and ii) to develop a strategy paper for future direction of dry deposition monitoring of EANET, for consideration by ISAG.

After ISAG1, the Task Force prepared those two documents. "Strategy paper for future direction of dry deposition monitoring of EANET (Strategy Paper)" was finally endorsed with some modifications by ISAG through the diplomatic channel in September 1999. On the other hand, "QA/QC program for the air concentration monitoring in East Asia" was finally endorsed with some modifications by the Science Advisory Committee (SAC) at its First Session held on 14-16 November 2001 in Chiang Mai, Thailand.

The QA/QC program indicated that "Since more discussions are needed at the Task Force concerning QA/QC activities for other air concentration monitoring, such as filter packs, denuders, and passive samplers for the second priority chemicals, the QA/QC activities for these methods will be integrated in this program in the future, taking account of the progress of the discussions at the Task Force." In line with this suggestion of the QA/QC program and in response to request by the EANET participant countries using filter packs, "Technical Document for Filter Pack Method in East Asia" was developed by the Task Force. This technical document was finally endorsed by SAC3, held on 24-26 November 2003 in Pattaya, Thailand.

After the publications of those documents, SAC4 held on 3-5 November 2004 in

Siem Reap, Cambodia discussed some pending issues on dry deposition monitoring of EANET pointed out in those documents and/or in previous SAC meetings. It is important to clarify the pending issues like the expansion of measurement parameters considered by wide use of Filter Pack method in regular phase or their importance for evaluating atmospheric environment. In this context, this draft Revised Edition of the Strategy Paper was prepared mainly based on the outcomes at SAC4.

2. Status quo of dry deposition monitoring

To monitor dry deposition, one must either measure the dry deposition directly or measure air concentrations and calculate dry deposition by inferential methods. In some countries, it is feasible to apply direct measurement methodologies. For example, in the Netherlands and in the United Kingdom, eddy correlation methods have been employed at some selected locations and for some chemical species. However, most situations do not permit the routine application of such methods, because (i) the chemical sensors necessary are not yet suitable for routine unattended use, (ii) the cost involved is prohibitive, (iii) the requirement for skilled operators is unavoidable, and (iv) sites of suitable homogeneity are generally not available.

Consequently, most existing programs make use of an alternative approach, in which direct measurements are used to calibrate detailed relationships describing the factors that control dry deposition rates. These relationships are then used to infer dry deposition from measurements of key selected variables made at the sites in question. Such measurements are of air concentration of the chemicals of interest, and of variables known to be indicative of the processes controlling the exchange between the air and the underlying surface.

Measurements of air concentration are presently the easiest to make, in that the technology involved is well known. The options available are to use any of automatic real-time monitoring instruments, filter packs, denuders, or passive samplers. All available air sampling technologies appear to be somewhat imperfect. It appears unlikely that some specific standardized sampling methodology could suit all conditions.

The factors involved in calculating deposition velocity (Vd) are conveniently characterized in terms of resistances in a conceptual model analogous to an electrical resistance network, with individual resistances Ra, Rb and Rc corresponding to aerodynamic, boundary layer, and residual resistance. Vd is then computed as

$$Vd = 1/(Ra+Rb+Rc)$$

It should be noted that each of Ra, Rb and Rc is site-specific. In essence, dry deposition is a site-specific variable. For any location where dry deposition data are desired, it must first be decided precisely what surface is of major interest, and then instrumentation must be deployed so as to provide data relevant to that surface. It must also be noted that the surface-specific nature of dry deposition means that collection vessels and surrogate surfaces do not yield answers that are indicative of deposition to the biological surface that is generally of major interest.

The collection of on-site data indicative of the processes controlling local dry deposition is necessary. The focus of these measurements must be on quantifying each of Ra, Rb and Rc. The disciplinary skills required to assemble a coherent dry deposition sampling network program may include micrometeorology, plant physiology, and chemistry. Reference could be made for the Dry Deposition Inferential Method (DDIM) for details about Ra, Rb, and Rc.

Each of the resistances will display a strong diurnal cycle. Field experiments now available indicate that the quantification of Ra is fairly precise, at least for sites that are spatially homogeneous. Rb is less well understood, but the basic dependence on the leaf area index and the friction velocity (u*) impose a diurnal cycle that is expected in theory but difficult to detect in practice. Rc displays a strong diurnal cycledue to stomatally function and so on. In addition, each of resistances will also display a strong seasonal variation at some case such as snow covered field and rainy season. Some parameters such as Leaf Area Index could be useful to assess the seasonal variation.

The desired dry deposition estimate will require careful and thorough analysis of the meteorological, biological and surface data obtained at sampling sites. Once this process has yielded values of the dry deposition velocities that are needed, then they must be combined with the appropriate chemistry data to produce dry deposition rates. It must be anticipated that there will be need, as part of this process, to account for the effects of such factors as the diurnal cycles affecting Vd.

Several methods have been examined for determining dry deposition of gases such as SO_2, NO_2, HNO_3 and O_3 and of aerosol components such as SO_4^{2-} and NO_3^- to soil and vegetation (e.g. a red pine forest in Ohsiba Highland, Nagano, Japan; an agricultural area in Kyunggi, Republic of Korea). Details of the methods mentioned above are aerodynamics, gradient, and modified Bowen ratio to vegetation, and direct deposition to soil. A method was developed for determining total deposition of sulfur oxides to forest from the analysis of throughfall and stemflow. The method was applied to the deposition of SOx to a masson pine forest in Zhenwu Mountain, Chonqing, China and to a cedar forest in Gumma, Japan. Moreover gradient and modified Bowen ratio methods for SO_2 and O_3 have been examining in a teak forest, Lampang, Thailand under the Joint Research on Dry Deposition Flux between Network Center for EANET and National Center of Thailand (Pollution Control Department). The Dry Deposition Inferential Method was examined in some of those experiments. In this connection, this inferential method was applied to estimate dry deposition at Japanese EANET sites in the Comprehensive Summary Report on Acid Deposition Monitoring Survey, which is the assessment report of acid deposition during 20 years in Japan. In addition to these methods, the novel technology employing surrogate surface has been now gaining more attention because of its ease for implementation and maintenance.

3. <u>Priority chemical species for dry deposition monitoring in EANET</u>

3.1. Major chemical species for acid deposition monitoring

The purposes of dry deposition monitoring are (i) to provide data for the evaluation of total acid deposition on soil, vegetation etc. for the assessment of the adverse effects on specified ecosystems, (ii) to provide data for the evaluation of the regional budget of sulfur and nitrogen with the aid of numerical model. Although O_3 is not an acidic but rather an oxidizing species, it is known to be very harmful to plants. Its deposition rate on vegetation is large and is generally believed to affect ecosystems synergistically with acid deposition. Thus, it is highly recommended to evaluate O_3 deposition together with acid deposition. Moreover Na^+ in particles also concerns the regional budget of sulfur to estimate sea-salt or non-sea-salt sulfate. For these purposes, the concerned chemicals are primarily gaseous SO_2, NO, NO_2, O_3, HNO_3, HCl, NH_3, and the particulate SO_4^{2-}, NO_3^-, Cl^-, NH_4^+, Na^+ and Ca^{2+}.

Hourly data are expected where diurnal cycles in deposition velocity are to be monitored explicitly. However for evaluation of dry deposition, the sampling period of air concentrations could be longer than one day, e.g., a week for certain circumstances at monitoring site.

3.2. Major chemical species for air quality monitoring

From the viewpoint of air quality monitoring, major substances of concern are gaseous SO_2, NO/NO_2, O_3, and the particulate mass. Among these substances, SO_2, NO_2, O_3 and particulate matter (PM) are all well-known air pollutants from the viewpoint of health impacts etc. Although NO is not very harmful per se, it is a primary pollutant and it easily converts to NO_2 in the atmosphere. It is also a precursor of O_3. Thus, it is highly recommended to measure NO whenever feasible. For the measurement of PM, PM10 is important to detect total amounts of acid and base components in particles; PM2.5 is effective to define regional and hemispheric transport characteristics.

3.3. Priority chemical species in EANET

The priority chemical species for EANET dry deposition monitoring are recommended to be as follows:

SO_2, O_3, NO, NO_2, HNO_3, HCl, NH_3,
Particulate component (SO_4^{2-}, NO_3^-, Cl^-, NH_4^+, Na^+, and Ca^{2+}), PM10, PM2.5

SO_2, HNO_3, HCl, NH_3 and particulate components require the use of filter pack. Automatic instruments for SO_2 (UV fluorescence method), O_3 (UV photometric method) and NO (chemiluminescence detection method) are suitable to obtain one-hour averaged values of these species for air quality monitoring. Units of ppb for gas and $\mu g\ m^{-3}$ for particle can be used for data reporting. For calibration of the ozone monitoring equipment, traceability to the international standard of National Institute for Standard and Technology (NIST), USA should be considered. These one-hour averaged values can of course be used for the purpose of the evaluation of dry deposition after averaging over longer periods -- e.g. for one week.

It should be emphasized that commercial "NOx chemiluminescence instruments" with molybdenum converter should not be used for NO_2 measurement at rural and remote sites since its NOx mode responds not only to NO/NO_2 but also to HNO_3 and other organic nitrates unspecifically. The instruments could be used for NO/NOx* (NO, NO_2, PAN and partial HNO_3). Its use in urban sites near emission sources may be acceptable for NO_2 measurement since a major component of NOx would be NO_2 and NO in urban area. In remote and rural areas, passive sampler could be used to measure NO_2, unless advanced research-grade methods can be used. Passive sampler also could be used to measure O_3.

To obtain one-hour averaged values of PM10 and PM2.5, Tapered Element Oscillating Microbalance (TEOM) method or ß-ray method coupling with commercially-available impactors and cyclones are suitable.

4. Future strategy

4.1. Scope of future activities of the task force on dry deposition monitoring

The combination of research activities and routine monitoring, and step-wise expansion of dry deposition monitoring activities are required continued attention in East Asia. The continued activities of the Task Force on Dry Deposition Monitoring, with the scope of medium, long-term activities in this area, are requested. Terms of Reference (TOR) of the Task Force reorganized at ISAG2 held on 13-15 March 2000 in Jakarta, Indonesia includes (i) to further develop and elaborate a strategy for dry deposition monitoring in the region, as well as specific action plans, for consideration by SAC, (ii) to review and guide the relevant activities, based on the strategy and specific action plans finalized by SAC, and (iii) to communicate and coordinate with the activities of Global Atmosphere Watch (GAW) of the World Meteorological Organization (WMO) and in other regions. The new Task Force will consist of experts of the participating countries and other international organizations, and will review the steps outlined below.

4.2. Step-wise approaches for dry deposition monitoring

A step-wise approach has been proposed for developing dry deposition monitoring in the East Asian region, in combination with research and routine monitoring activities.

Step 1. Implement of concentration monitoring for Priority chemical species using the methods mentioned in the section 3.3 at Deposition monitoring sites

As described in the section 3, the actual measurement items can be decided by taking account of the presently available air quality monitoring and feasibility of additional monitoring activities as well. This monitoring might employ either of real-time monitors or integrating samplers (filter packs, denuders, or passive samplers, as may be determined appropriate).

It should be noted that air sampling technologies such as filter pack appear to be somewhat (if not greatly) susceptible to sampling problems when humidity is high. This could be a significant problem for operation in equatorial Asia. Thus, sampling technologies need to be carefully examined and tailored to conditions prevailing in the various countries of EANET. It appears unlikely that some specific standardized air sampling methodology will suit all conditions in the region. Further researches on the air sampling technologies such as filter packs are expected by NC and participating countries.

QA/QC activities such as inter-laboratory comparison of filter pack samples and inter-calibration of O_3 monitors should be encouraged.

Step 2. Intensive research on the methodology for dry deposition monitoring

(1) Setting up of special sites, where more direct measurements of dry deposition are initiated

In order to do direct measurement, these sites should be flat, and the surroundings should be uniform as far as a distance of 500 m in all upwind directions. Needless to say, the depositing species in question must have measurable concentrations around the sites. It is desirable to set up the sites on several different surfaces such as coniferous and decidous forests, cropland, rice field, etc. The special sites are expected to be set up firstly in some selected countries such as Japan and Republic of Korea, then gradually increased to include different surfaces typical in East Asia, for instance, arid regions and tropical forests. Since the operation of the special sites is expensive, an itinerant method may be considered. An appropriate policy is to include locations and organizations where there is an ongoing flux measurement capability ready for extension to dry deposition.

The first priority method to be employed at these sites is the modified Bowen ratio method, since this method is suited to a long-term automatic measurement and is relatively inexpensive. In addition, some experiences have been obtained in its application in South East Asia. As the measurement proceeds, other methods such as eddy correlation, eddy accumulation, relaxed eddy accumulation, etc. should be introduced for the comparative study on their applicability to each specific circumstance.

Along with the dry deposition fluxes (F), the air concentrations (C) of depositing species will be measured, permitting direct computation of the deposition velocity as $V_d = F/C$.

(2) Selection of schemes for calculating deposition resistances

The review should be done bearing in mind the various different surfaces typifying East Asia. As a result of this review, suitable schemes for use as starting points for inferring resistances will be selected, and the variables to be measured at all dry deposition field sites will be identified.

On the basis of the resultsof this review, several candidate schemes or formulations are to be selected by which the deposition resistances can be inferred from variables suitable for routine measurement. Measurement of the variables (meteorological, biological and surface) relates to the process controlling the exchange between the air and the underlying surface. The required variables should be decided later, but at least the following variables are expected to be measured:

wind speed [m s^{-1}];
wind direction;
temperature [degree];
humidity [%];
solar radiation with one hour resolution [W m^{-2}];
leaf area index [m^2 m^{-2}];
soil moisture [m^3 m^{-3}];
surface wetness (hourly data);
plant water stress; and
biological species distribution.

(3) Study on the methods for direct flux measurement

On the experience obtained at the special sites, the applicability and credibility of different methods should be examined to develop techniques more readily usable in many places in the region.

(4) Study on schemes for inferring Vd or resistances Ra, Rb and Rc

Ra : Field experiments now available indicate that the Ra can be quantified with adequate accuracy from local wind speed data and atmospheric stability which is derived from an indication of solar radiation and cloudiness.

Rb : This resistance depends on the friction velocity (u)*, which can be derived from the leaf area index and the wind velocity profile.

Rc : This is the most difficult of the three resistances to evaluate theoretically, since it depends on physical, chemical and biological interactions of the depositing substance with the surface. A reasonable approach is to evaluate it as a residual:

$$Rc = 1/Vd\text{ (field observed)} - (Ra + Rb)$$

then compare the value with that calculated by some existing model, and improve the model so that it is applicable to Asian conditions. For example, information is to be sought to obtain stomatal resistance expressions relevant to biological species of East Asia. It is helpful to this approach to measure and calculate the resistance for water vapor, since more information on the exchange between the air and the surface has been obtained for water vapor than for other substances.

(5) Others

A possibility should be explored to undertake a sub-program for developing chemical sensors of air concentrations suited for dry deposition monitoring. If any solid state sensor can be developed to a usable level, it would greatly improve the monitoring performance.

A possibility should be explored to establish a specialized central laboratory for dry deposition in the East Asian region, possibly within an existing organization in the region, in order to carry out and coordinate the above mentioned studies.

Step 3. Selection of specific monitoring sites suitable for dry deposition computation from among the concentration monitoring sites

These sites should satisfy the same geographical and surface conditions as those for the special site mentioned above. It should be noted that there must be some leniency permitted here. The state of science is not yet such that we can defend a strict application of guidelines. These sites should be instrumented with the sensors for site-specific properties necessary to quantify Vd (as mentioned in Step 2). Detailed records of these properties that control Vd must be maintained and sent to a central laboratory, where the information from the dry deposition monitoring sites is aggregated and used to assess Vd on a site-specific and time-changing basis. There will be need, as a part of this process, to account for the effects of such factors as the diurnal cycles affecting Vd.

A sub-program should be carried out for developing schemes for estimating dry deposition rates to a selected area of some special importance from the data obtained at several sites scattered in the area. These estimation methods are expected to cover the whole region in the future.

Step 4.

Annex 1

FUTURE DIRECTION OF DRY DEPOSITION MONITORING OF EANET

(Paper approved at the First ISAG Meeting)

The quality assurance/quality control (QA/QC) program for dry deposition monitoring will be prepared, taking into account the progress in the consideration on the technical manual for dry deposition monitoring. In this document, however, the future direction of dry deposition monitoring of EANET is discussed. During the preparatory phase, the QA/QC activities for dry deposition will be implemented, paralleling the QA/QC programs for wet deposition, where applicable.

1. Monitoring sites

Selection of sampling sites is a critical factor in the monitoring. The same sites used for wet deposition monitoring are recommended for dry deposition and/or air concentration monitoring. When dry deposition monitoring is difficult at the wet deposition monitoring site, a new but nearby sampling site should be selected by considering the site-selection constraints for measuring dry deposition, such as the uniformity of the ground surface, in addition to the criteria for wet deposition monitoring.

It should be noted that dry deposition is a surface-specific variable. For any location where dry deposition data are desired, it must first be decided precisely what kind of surface is of major interest, and then instrumentation must be deployed so as to provide data relevant to that surface.

2. Future direction

EANET requires dry deposition data, yet such data are very hard to obtain. In this respect, the Intergovernmental Meeting on EANET, held in March 1998, agreed that air concentrations monitoring is a step along the path leading to dry deposition evaluations. There are other good reasons to measure air concentrations - for basic air quality reasons, on the top of dry deposition evaluations. It should be noted that most items required for air concentrations monitoring also contribute to dry deposition monitoring.

Priority chemical species

First priority: NO_2 (urban), SO_2, O_3, and NO, and particle mass concentration;
Second priority: NO_2 (rural and remote), HNO_3, NH_3 and Particles (SO_4^{2-}, NO_3^-, NH_4^+, and Ca^{2+})

(Note) Measurement methods for NO_2 concentrations, particularly for remote and rural areas, NH_3 and HNO_3, need further elaboration

For particles, it is recommended to start with a 10 µm cut-off and add 2.5 µm as it becomes feasible. On the basis of discussions at the First ISAG Meeting, ISAG reaffirms that the start should be with air concentrations monitoring. In this connection, a QA/QC program for air concentrations monitoring should be developed.

The next step should be a move towards implementing the inferential approach, in which deposition velocity (Vd) is derived from on-site data.

A strategy should then be developed for future direction of dry deposition monitoring of EANET

Appendix 2

Outcomes of the discussion at STM5 and SAC4

Report of the Meeting (STM5)

IX. Consideration of improvement of the monitoring methodologies (Agenda Item 8)

NC reported the issues to be discussed on dry deposition monitoring. Major discussion on this topic included the following:

i. Priority chemical species

- It was suggested that Na^+ should be also included in the list of proposed priority chemical species because it could be used to calculate nss-SO_4^{2-} and nss-Ca^{2+} as the indicator of sea salts.
- Passive sampler could be applied to NO_2 monitoring in rural and remote areas.
- The availability to monitor proposed priority chemical species was clarified.
- It was introduced that the first session of WGFD held on 19-20 August 2004 emphasized the importance of extension of the monitoring activities for some air quality indicators such as ozone and sulfur dioxide.

ii. Size of particulate matter

- It was pointed out that fine particle sampling such as PM2.5 only was not suitable for acid deposition monitoring because PM2.5 was measured generally for the purpose of health problem. Acidic substances in coarse particles should not be ignored for acid deposition monitoring.

iii. QA/QC for dry deposition monitoring

- It was suggested that a secondary standard ozone generator calibrated by the Standard Reference Photometer could be used for circulation among EANET sites in order to implement inter-calibration for O_3 monitoring.

iv. Unit

- Merit and demerit were discussed to use each unit. The following were pointed out but need further discussion.
- As for gas, ppb is widely used and it doesn’t depend on temperature and pressure.
- As for particulate matter, generally its mass was measured after sampling therefore $\mu g/m^3$ is accustomed. PM could not use $nmol/m^3$ because of unknown

components.

- Molar unit is based on the SI (System International) unit. It could be applied to both gaseous and particulate components and to comparison with wet deposition components.

v. Filter pack method

- It was emphasized that flow rate of the 4-stage filter pack method could be increased to 2 L/min in the case of non detected concentrations according to the Technical Document for Filter Pack Method in East Asia.

Report of the Session (SAC4)

Agenda Item 11: Consideration of improvement of the monitoring methodologies

NC presented the paper "Issues to be discussed on Dry Deposition Monitoring of EANET". Major suggestions and proposals were done as follows:

- For calibration of the ozone monitoring equipment, traceability to the international standard, National Institute for Standard and Technology (NIST), should be considered.

- Although PM10 sampling is important to detect total amounts of acid and alkali components in aerosols, PM2.5 sampling is effective to define regional and hemispheric transport characteristics. A study on PM10, PM2.5 and their components in special sites should be considered.

- NC will prepare the revised Strategy Paper for Future Direction of Dry Deposition Monitoring of EANET taking into account the comments on the issues from the Fifth Senior Technical Managers' Meeting (STM5) and SAC4 participants to distribute it among the Task Force members for their consideration by March 2005. The revised Strategy Paper would be also circulated among SAC members for endorsement by the Fifth Session of SAC (SAC5), if possible.