Acid Deposition Monitoring Network
in East Asia (EANET)

Periodic Report on the State of Acid Deposition in East Asia

Part I: Regional Assessment

Cambodia China Indonesia Japan Lao P.D.R Malaysia Mongolia
Myanmar Philippines Republic of Korea Russia Thailand Viet Nam

Periodic Report
on the State of Acid Deposition in East Asia

Part I : Regional Assessment

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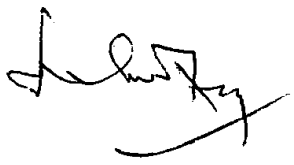
Foreword

Rapid population growth, industrial activities and high fuel consumption in the East Asian countries have created increasing threat of air pollution, which can cause damaging effects on the regional environment. Acid deposition is a significant regional environmental problem that has received much attention from scientists around the world as well as international organizations. In response to the growing concern on the adverse effects of acid deposition, countries in East Asia have established a coordinated monitoring network on acid deposition in the region using the knowledge and experiences from other similar regional and international networks.

The objectives of the Acid Deposition Monitoring Network in East Asia (EANET) are:
- To create a common understanding of the state of acid deposition problems in East Asia.
- To provide useful inputs for decision-makers at local, national, and regional levels, aimed at preventing or reducing adverse impacts on the environment caused by acid deposition.
- To contribute to cooperative efforts among participating countries on issues related to acid deposition.

The *Periodic Report on the State of Acid Deposition in East Asia*, which reports on the progress, achievements and key findings, is an initiative of the Scientific Advisory Committee (SAC) of EANET. The contributions from the SAC members, particularly the lead authors, to the Regional Assessment, and contributions from the authors of the National Assessments are all gratefully acknowledged. This Periodic Report is the first of a series that will be produced by EANET to report the results of assessments on the EANET data set using the most current methodologies.

The high quality dataset from EANET is increasingly used nationally, regional and internationally in research and in the formulation of policies and reduction measures to prevent and mitigate damage of acid rain and other air pollution to human health and the environment. It is hoped that the Periodic Report will promote better understanding of acid deposition issues in the region and mark an important step for further development of EANET.



Prof. Muhammad Bin Awang,
Chair, Scientific Advisory Committee of EANET

Overview of Report

The first ***Periodic Report on the State of Acid Deposition in East Asia*** was prepared with the goal to share the results of the first five years provided by the Acid Deposition Monitoring Network in East Asia (EANET) in its regular phase, as well as to evaluate scientifically the monitoring data generated. This relatively deep investigation of atmospheric deposition and its features in East Asia is accompanied by an overview of related EANET activities that could be useful to any international network with relatively wider goals and different capacities of countries involved. This first report is considered an important step on the path to generating a common understanding of the state of acid deposition, and it provides a valuable basis for further assessments of atmospheric pollution and deposition over the vast East Asian region, as the countries here pursue economic and social development.

The basic principles and history of EANET are described in this report in the context of international environmental policy and the experience of international networks in other regions where acid deposition and atmospheric pollution problems have already been experienced. This report includes an outline of the extensive process of discussion and preparation taken to properly organize the network. The current structure and institutional arrangements are presented, along with descriptions of the roles of the countries participating in the network, the Secretariat, and the Network Center (NC) for EANET, the scopes of their responsibilities, and the organizational links established. The outlines presented include summaries of the operation of 46 monitoring sites in 12 participating countries, the methodologies employed, the data flow, the management of EANET monitoring sites, and activities at the national level of participating countries.

The description of activities here focuses on quality assurance and quality control (QA/QC) of data and measurements taken, based on general procedures established in accordance with scientific knowledge and international standards in this field. The most fundamental matters include both the development of QA/QC programs, data quality objectives (DQOs), standard operating procedures (SOPs), and the assignment of responsibilities in obtaining and managing data. Improvements in measurements and analyses are described in an overview of long-term inter-laboratory comparison projects on monitoring wet deposition, soil, and inland aquatic environments, which have demonstrated a progress in the analytical practices of participating laboratories year-by-year. A number of problems remain unsolved, however, and they require more detailed investigation of the results achieved by the national centers and QA/QC managers together with NC. General principles on how to evaluate the measurements taken by the network are outlined here with a view to conducting more detailed studies in the future.

Regional geography and climatology are presented briefly for background, with a focus on the peculiarities of East Asia related to the spatial and temporal changes of atmospheric depositions. Natural differences between regions monitored appear in the variability of climatology and atmospheric parameters affecting acid deposition. General differences are also presented based on the analysis of meteorological data gathered at EANET monitoring sites over five years, as well annual variations in precipitation.

A scientific evaluation of recently obtained and recorded monitoring data for the period 2000–2004 is presented, with the main objective of identifying specific features and characteristics of the measurements. An analysis of data on air concentrations and wet deposition of acidic compounds is provided based on the latest knowledge in the field of atmospheric chemistry. The relationships between gaseous precursors and ions in aerosols are analyzed in different categories of monitoring sites, with a main focus on sulfur and nitrogen compounds, and it is shown that they make varying contributions of the target compounds to air pollution over the EANET region.

Evaluation of the monitoring results discloses some features that are characterized by both natural and anthropogenic effects. For instance, gaseous ammonia and ammonium aerosols appear to be the most dominant airborne species at all rural and remote sites, as well as appearing to be higher than concentrations of other acidified compounds in the atmosphere of urban sites. In contrast, sulfur dioxide and sulfate are dominant in remote areas compared to nitric acid and nitrate aerosol. These peculiarities reflect both the importance of agricultural and natural sources of reduced atmospheric nitrogen in most areas of East Asia, as well as the significance of airborne sulfur transport for remote territories. Further investigation of a possible cause of high concentration measurements at certain non-urban sites is proposed. At present, EANET air concentration (dry deposition) monitoring is not yet sufficient to be representative for the air quality evaluation in many urban areas.

Wet deposition measurements are analyzed from the perspective of acid-base chemistry—which is determined by the nature and proportions of acid ions and bases in aqueous solutions—with the understanding that pH is a secondary parameter defined by the quantities of different ions and their interaction. The presence of anions other than sulfate and nitrate (like weak organic acids) provides higher pH values than expected from the acid-base relations in lower latitudes in regions where the oxidation of organic materials in the air and precipitation are high. Extensive evaluations allow recognition of the stronger seasonal variations of precipitation acidity in mid-latitudes related both to the yellow-sand transport phenomenon in some areas and, probably, the long-range transport of sulfur and nitrogen compounds to remote places, but these require further study. Rather distinctive seasonal trends of anions in North East Asia are also exhibited, presumably due to increased fuel usage in winter. The range of average nitrate and non-sea salt sulfate concentrations found at many EANET sites, however, is comparable with their variations published by networks in other regions.

Specific scientific approaches are applied to evaluate the importance of different compounds on the chemical composition of precipitation throughout the EANET region. First of all, the wet deposition fluxes are calculated and investigated by comparing precipitation amounts. It was decided, however, that it is premature to draw any definite conclusions yet on trends in wet deposition, because only five year period datasets are available. Monitoring data over a longer period, as well as producing datasets on dry depositions, is required before data can be properly interpreted, along with more accurate projections of future trends.

The results of ecological monitoring in EANET countries up to now represent just the most basic data required for application and evaluation of the impact of acid deposition and other pollutants. The effects on soil, vegetation, and aquatic life in the EANET region are still inconclusive, although it was found that the monitoring data demonstrate higher values of sulfate and nitrate loadings from the atmosphere in some countries. Further studies are needed, especially with regard to sensitive ecological species and vulnerable ecosystems. The theoretical framework for investigation of the impact of acid deposition on ecosystems is provided here, regarding the development of observations and further studies with the main goal, among others, of finding possible solutions for the likely impacts on exposed ecosystems that acid deposition may cause.

The main achievements to date are summarized in this report, in order to review the experience gathered through the development of EANET on its regular basis, as well as some important steps taken from the start of network activities. It was realized early on that it is important to conduct capacity building activities for participating countries because of their varying availability of human and technical resources. Improved cooperative efforts are the result of intensive EANET training activities and collaboration with other capacity building programs. Joint research projects designed to support and develop monitoring methodologies and advanced methods are also overviewed in this report, as well as the efforts to promote public interest and the awareness of policy makers regarding EANET activities and the problems related to acid deposition.

Some important organizational initiatives and scientific studies on monitoring and atmospheric transport for EANET region – based on continuous measurements over at least a year or longer – are reviewed to show the variety of methodologies and approaches used for investigating atmospheric

pollution over the region, as well as to provide the perspectives of other regional activities and scientific knowledge that have been conducted and obtained outside of EANET. Also the review covers initiatives on emission inventories and modeling at the regional scale that target acid deposition and other regional air pollution in Northeast and Southeast Asia. In order to address the impacts on the environment, a review of ecological modeling and assessment studies for the region is also presented, including an introduction and discussion of applicable methodologies for this purpose. This knowledge and the advantages it provides should be carefully considered, especially when taking into account the fact that EANET development includes looking forward to employing more advanced and sophisticated methods in assessing and utilizing EANET own database, in developing transboundary models, and in building a common understanding of the impacts on the ecosystems within the East Asian regions.

Recommendations on future directions in research and studies are presented here, based on discussions on how to promote the further development of the EANET network. These are aimed at eliminating weak points in current monitoring and data evaluation, taking into account certain planning and coordinating efforts that have occurred within EANET during the last few years. It should be noted, however, in the context of existing international environmental policy and the experience of other networks, that the new activities are proposed and described as challenges for EANET in evaluating prospective directions in environmental assessment and other emerging issues.

National assessments of acid deposition, relevant monitoring, and related problems were provided by the National Focal Points (NFPs) on a voluntary basis and include national-wide and in-depth evaluation of certain topics. These reports observed in more detail the national data obtained from national monitoring network sites, some of which are not included in EANET network. Using the general format prepared by the Drafting Committee (DC), these contributions mostly describe the general behaviour of measured pollutants in air, precipitation, inland aquatic environments, and soil and vegetation as well as elaborating on data anomalies by analyzing any local influences and characteristics. Also, these assessments outline the extent of acid deposition in the respective countries and draw countermeasures taken. Most of these materials were presented at Scientific Workshops on Evaluation of the State of Acid Deposition in 2005 and 2006 for recommendations and comments from DC members, as well as to recognize the national achievements in these fields.

1. Basic Description of EANET Activities

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1.1 Introduction

The Acid Deposition Monitoring Network in East Asia (EANET) was established as a cooperative regional initiative to promote efforts for environmental sustainability and the protection of human health. EANET started its regular phase of operation on 1 January 2001, covering both the atmospheric and ecological environments by gathering measurements with the participation of ten countries: China, Indonesia, Japan, Malaysia, Mongolia, Philippines, Republic of Korea, Russia, Thailand, and Vietnam. EANET now includes thirteen countries after Cambodia, Lao People's Democratic Republic (PDR), and Myanmar joined in 2001, 2002, and 2005, respectively.

The European continent has long been covered by the Co-operative Programme for Monitoring and Evaluation of Long-range Transmission of Air Pollutants in Europe (EMEP), and the North American region is monitored by the National Atmospheric Deposition Program (NADP) and the Canadian Air Pollution Monitoring Network (CAPMoN). The World Meteorological Organization/Global Atmosphere Watch (WMO/GAW) has developed close collaboration with the regional and national networks on atmospheric chemistry monitoring and has invited EANET to take part in this global cooperative network. EANET has thus joined other bodies to play a key role in global and regional environmental scientific initiatives.

In this section, EANET activities are briefly described from the viewpoints of environmental science and international environmental policy making.

1.2 History of EANET

1.2.1 Background of EANET's establishment

a. Sweden's case study for the United Nation's Conference on the Human Environment

The issue of acid deposition played a key role in opening a new era of environmental study and protection. Acid deposition first surfaced as a contemporary environmental issue in Sweden, when a Swedish scientist, Svante Odén, published a pH contour map showing the acidity levels in his country for 1962 in the newspaper "*DAGENS NYHETER"*, on 24 October 1967, on the basis of long-term monitoring records of precipitation and freshwater measurements. A detailed scientific report was published the following year under the title (translated into English) *The Acidification of Air and Precipitation and its Consequences in the Natural Environment.* It should be noted that acidification of the atmosphere was also recognized and that the presence of emitted sulfur dioxide in the atmosphere was other aspects that attracted attention. The efforts of Scandinavian scientists and policy makers to cope with the impacts of what has since become known as "acid deposition" eventually resulted in the United Nations Conference on the Human Environment in 1972. Several countries established a governmental ministry or agency to deal with environmental issues in these years, including Sweden (1967), the United States (1970), the United Kingdom (1970), France (1970), Japan (1971), and Germany (1974).

b. Interests of the scientific community

Atmospheric chemistry has developed through the efforts mentioned above and progress made in Europe and North America. Atmospheric scientists from these regions also became interested on similar issues in East Asia. In 1989 the International Conference on Atmospheric Environmental Sciencewas held in Beijing, China, with the participation of leading scientists worldwide. In 1992, Henning Rodhe (Stockholm University, Sweden) and Greg Ayers (Commonwealth Scientific and Industrial Research Organization [CSIRO], Australia) invited Asian scientists interested in acid deposition to Singapore to inaugurate an international program called Chemistry and Acidity of Asian Precipitation (CAAP), which later developed into an extended program called Chemistry of Asian

Deposition (CAD). In 1994 the WMO held a workshop on acid deposition assessment in Bermuda to collect available data on wet and dry deposition at the national, regional, and global scales. The Fifth International Conference on Acid Deposition was held in Gotenborg, Sweden, in 1995, and one of the topics was "Acid Deposition in Non-European and Non-North American Region." These developments in the international scientific community focused considerable attention on East Asia, and motivated atmospheric scientists in the region to establish a network.

In 1992 the National Institute for Environmental Studies in Japan organized an international workshop on acid deposition in Kitakyushu, Japan. Professor Toshiichi Okita, the chair of the workshop, proposed that East Asia might follow the lead of EMEP and establish an international monitoring network in the region with the name of Asian Monitoring and Evaluation Programme. These activities of atmospheric chemists provided the scientifically-matured basis for a series of expert meetings (see Section 1.2.2) on acid deposition in East Asia from 1993 onward.

In summary, the above efforts of national and international players relating to scientific aspects of acid deposition led to the success of a series of expert meetings described below, and ultimately to the creation of a new international monitoring network—EANET.

c. International environment policy

One of the features of the acid deposition problem is the fact that the deposition of acidifying substances can affect areas that are hundreds or thousands of kilometers from the emission sources of precursor substances. Thus acid deposition is a regional problem not limited by national boundaries.

Acid deposition has become a policy issue, associated with international environmental problems. The East Asian region contains not only one-third of the world's population but is also experiencing remarkable economic growth. Because this growth is based on rapid industrialization, many countries in the region are facing threats from air pollution and acid deposition, which are becoming even more serious where much of energy production is based on sulfur-rich coal. In order to prevent acid deposition from becoming a more serious, widespread problem, it was imperative to initiate regional cooperation to undertake counter-measures.

Acid deposition is a global environmental issue, and international cooperation and collaboration is indispensable to finding solutions to the problem. In Europe, the Convention on Long-Range Transboundary Air Pollution (CLRTAP) was adopted in 1979, and a number of protocols on control or reduction of sulfur and nitrogen oxides emissions were adopted thereafter (Sliggers and Kakebeeke, 2004). These protocols initiated measures to reduce emissions of precursor substances of acid deposition. A multinational monitoring program, the European Monitoring and Evaluation Programme (EMEP), was launched in 1978. In North America, the United States initiated the 1980–1990 National Acid Precipitation Assessment Program (NAPAP), which resulted in a special section on acid rain in the 1990 Clean Air Act that was intended to reduce transboundary pollution to Canada.

Chapter 9 of Agenda 21, adopted at the United Nations Conference on the Environment and Development (UNCED), held in Rio de Janeiro in 1992, stated that "transboundary atmospheric pollution has adverse health impacts on humans and other detrimental environmental impacts, such as tree and forest loss and the acidification of water bodies" (UNCED 1992). It emphasizes the necessity of regional cooperation by pointing out that "programmes established in Europe and North America needed to be continued and enhanced, and their experience needs to be shared with other regions of the world."

Regional cooperation with research on and monitoring of acid deposition was first proposed at the Northeast Asian Conference on Environmental Cooperation, held in Japan in October 1992. The proposal was made again at the second conference (Korea, 1993), and at the third conference (Japan, 1994). At the Third Environmental Congress for Asia and the Pacific (ECO-ASIA), held in Japan in 1994, the participating environment ministers agreed on the need to establish new mechanisms to

facilitate regional cooperation on the environment and to address environmental problems common to the region.

After UNCED a basic consensus emerged in East Asia that the time had come to initiate regional and international cooperation on the issue of acid deposition before it became more serious.

It was in this context that the Environment Agency of Japan began advocating the establishment of the Acid Deposition Monitoring Network in East Asia, a network that would be dedicated to a common understanding of acid deposition in the region. The hope was that this common understanding would be mainly achieved by the implementation of acid deposition monitoring by each country in the region, as well as central compilation and analysis of monitoring data. The common understanding of acid deposition was expected to provide the basis for future cooperative measures to cope with the problem of acid deposition. Eventually, the Environment Agency of Japan held the Expert Meetings, starting in 1993, and invited all interested countries and international organizations to participate.

One of the most important commitments made at the World Summit on Sustainable Development (WSSD) in 2002 was the acceptance of the International Development Goals, which included the Millennium Development Goals, as well as the collective responsibility to advance and strengthen mutually reinforcing pillars of sustainable development at different levels (Agenda 21). Key points of activities in these fields were development of the *State of the Environment* (SoE) reports, as well as effective data collection and processing. Information needs to be gathered and institutional arrangements must be further developed, however, in order to enhance activities relating to regional assessments and early warning.

As a result of industrialization in recent decades, the East Asian region now faces increasing risks from problems related to excessive deposition of acidic substances, a situation similar to Europe and North America. Actual international actions to address this issue were seen as inadequate, however, in spite of the need for collaborative efforts in the region. This was pointed out in Agenda 21 (paragraph 9.26), adopted at UNCED in June 1992: “The programs (in Europe and North America) need to be continued and enhanced, and their experience needs to be shared with other regions of the world” (UNCED 1992).

The years of progress in discussions how to organize these activities finally culminated in the creation of EANET. The First Session of the Intergovernmental Meeting (IG1) of EANET, held in March 1998, made the important decision to start preparatory-phase activities of the network in April 1998. Regular-phase activities started in January 2001, after evaluation of the preparatory-phase activities at IG2.

The cooperative activities of countries participating in EANET are based on existing national monitoring plans, and include the monitoring of wet deposition, dry deposition, inland aquatic environments, soil and vegetation, in accordance with guidelines and other technical documents. QA/QC are important parts of the monitoring activities. Collected data are compiled by the EANET Network Center (NC), and these data become the basis for periodic reports on acid deposition in the East Asian region. As mentioned above, it is hoped that through these activities participating countries will ultimately share a common understanding regarding the status of acid deposition in the region, and that this understanding will provide the scientific basis for further steps to tackle the problems.

1.2.2 Expert Meetings: The way to establishing EANET

By the end of a series of four expert meetings between 1993 and 1997, participants from ten countries in East Asia and five international organizations agreed to establish an acid precipitation monitoring network and produced a preliminary outline of the network’s design.
Following is a chronology of the developments at each meeting.

(i) First Expert Meeting (26–28 October 1993, Toyama, Japan)

The first meeting was attended by 44 experts from ten countries (China, Indonesia, Japan, Korea, Malaysia, Mongolia, Philippines, Singapore, Russia, and Thailand) and three international organizations (EMEP, NAPAP, and the World Bank [WB]). Participants recognized that there was evidence of acidic precipitation in all countries in the region, and it was hoped that collaborative monitoring efforts might lead to the establishment of the Acid Deposition Monitoring Network in East Asia.

(ii) Second Expert Meeting (22–23 March 1994, Tokyo, Japan)
This meeting was attended by 64 experts from nine countries (the ten countries mentioned above minus Singapore) and four international organizations (EMEP, United Nations Environment Programme [UNEP], WB, and the Acid Rain Network in South, East and Southeast Asia [ARNSESEA]). A final version of *Guidelines for Monitoring Acid Deposition in East Asia Region* was adopted, along with recommendations to prepare a technical manual for monitoring and to establish a working group to begin drafting it. Also emphasized was the significance of dry deposition and the QA/QC program.

A paper titled "Conceptual Design of an Acid Deposition Monitoring Network in East Asia," prepared by the Environment Agency of Japan, was discussed and well received as a basis for further elaboration. After discussion of the most appropriate terminology to use to refer to the acidification of the environment, the term *acid deposition* was agreed on for use in the network instead of "acid precipitation" which had been originally proposed.

(iii) Third Expert Meeting (14–16 November 1995, Niigata, Japan)
Sixty-two experts from ten countries (Vietnam and the nine countries at the second meeting) and five international organizations (ARNSESEA, EMEP, UNEP/Regional Office for Asia and the Pacific [ROAP], WB, and CSIRO) attended the meeting. The focus of discussion was on two issues: (a) creation of the proposed acid deposition monitoring network in the region, and (b) enhancement and further development of the monitoring guidelines.

Participants agreed on the need to establish the network and adopted the *Conceptual Design of an Acid Deposition Monitoring Network in East Asia*. According to it, the central compilation and analysis of monitoring data would be implemented at a network center, likely to be established in Japan. In order to develop and enhance monitoring guidelines, it was proposed that working groups be formed to draft guidelines for the four respective fields of acid deposition monitoring: wet deposition, dry deposition, soil and vegetation, and inland aquatic environments. It was also agreed that the term *East Asia* would be used in a broad sense to include both Northeast Asia and Southeast Asia.

(iv) Fourth Expert Meeting (4–6 February 1997, Hiroshima, Japan)
Experts from the ten countries and six international organizations (EMEP, UNEP/International Environmental Technology Centre [IETC], WB, CSIRO, the Norwegian Institute for Air Research [NILU], and the US National Oceanic and Atmospheric Administration [NOAA]) discussed the Conceptual Design of an Acid Deposition Monitoring Network in East Asia" more in depth. They proposed that the objectives of the network should be (a) to create a common understanding of the state of acid deposition among countries and organizations of the East Asian region, and (b) to provide useful inputs for decision-makers at local, national, and regional levels to prevent or reduce the impacts of acid deposition on human health and the environment.

It was proposed that international working groups compile documents discussing how the network should address related scientific issues, including the development of emission inventories and numerical models of long-range transport of acidic substances and improvement of knowledge on the adverse impacts of acid deposition on the environment. The participants were urged to make significant efforts within their respective countries to realize the network's creation according to the following timeline:

1997	Establish a working group
1998	Hold the first intergovernmental meeting

1998–1999	Preparatory phase activities
2000	Hold the second intergovernmental meeting and begin full operation of the network

1.2.3 The start of EANET

(i) First Session of the Intergovernmental Meeting (March 1998)
The First Session of the Intergovernmental Meeting (IG1) on the Acid Deposition Monitoring Network in East Asia, held on 19–20 March 1998 in Yokohama, Japan, was attended by representatives of the following countries and international organizations: Indonesia, Japan, Malaysia, Mongolia, Philippines, Republic of Korea, Russia, Thailand, Vietnam, the United Nations Economics and Social Commission for Asia and the Pacific (ESCAP), and WMO. Representatives of China attended as observers.

The "Tentative Design of the Acid Deposition Monitoring Network in East Asia (EANET)" was developed (elaborated further at the Second Session of the Intergovernmental Meeting), and the document "Implementation of the Preparatory-phase Activities" was adopted. The major preparatory-phase activities and a tentative schedule of their deployment were agreed upon. Also suggested was the creation of a special scientific board to evaluate developments and the results of EANET activities.

(ii) Preparatory-phase activities (April 1998 – December 2000)
Preparatory-phase activities started in April 1998 on an interim basis over the territory of nine countries. In December 1998, China officially joined EANET after expressing its intent through diplomatic channels. The preparatory phase continued until December 2000 and resulted in the development of general EANET activities, including joint projects on the inter-calibration of laboratory analyses and data reporting. In order to make the required institutional arrangements, the function of interim secretariat was entrusted to the representative authority in Japan, while the Interim Scientific Advisory Group was incorporated to include atmospheric or ecological scientists from the participating countries together with established scientists on acid deposition outside the region. Periodic assessments of EANET achievements were done during this phase, with an emphasis on finding the best ways to develop joint monitoring and research, while taking into account the capabilities and other related features in participating countries.

(iii) Second Session of the Intergovernmental Meeting (October 2000)
The Second Session of the Intergovernmental Meeting (IG2), held on 24–25 October 2000 in Niigata, Japan, was attended by representatives of the following ten participating countries: China, Indonesia, Japan, Malaysia, Mongolia, Philippines, Republic of Korea, Russia, Thailand, and Vietnam. Also in attendance were experts and officials of the CLRTAP, ESCAP, UNEP, and WMO, a member of the Interim Scientific Advisory Group (ISAG), as well as officials of the government of Niigata Prefecture and other local governments in Japan.

It was concluded at IG2 that EANET's preparatory-phase activities had been successful, and the Joint Announcement on the Implementation of EANET was issued in order to start EANET activities on a regular basis from January 2001. The main technical documents were prepared for ongoing monitoring, and proposals were made to enhance results at the network level.

(iv) Regular phase of EANET activities (January 2001–present)
EANET commenced its activities on a regular basis in January 2001. Monitoring has been regularly conducted in ten countries since then (12 countries since 2002) using common approaches in data acquisition, compilation, and storage, as well as coordinated efforts in research and training. As was pointed out at IG2, further work is needed in a number of areas, such as improving capacity building activities and site selection methodology, increasing the number of monitoring sites, and improving monitoring methodology and QA/QC activities. Respective authorities in each participating country are expected to periodically review their national monitoring plan and develop their EANET activities using a step-by-step approach.

1.3 EANET's objectives and outlines of its institutional framework and activities

1.3.1 Objectives

After reviewing the achievements of the participating countries in developing the basis of EANET in the preparatory phase (establishment of monitoring sites, experience with laboratory analysis, QA/QC procedures, data exchange, etc.), the delegates at IG2 adopted both the Joint Announcement on the Implementation of EANET (EANET/IG 2/5/2) and the Commencement of EANET's Activities on a Regular Basis in January 2001. The objectives of EANET were described in these documents as follows:

- Create a common understanding of the state of acid deposition problems in East Asia.
- Provide useful inputs for decision-makers at local, national, and regional levels, aimed at preventing or reducing adverse impacts on the environment caused by acid deposition.
- Contribute to cooperative efforts among participating countries on issues related to acid deposition.

To achieve these objectives, EANET has since then conducted the following major activities:

a. Monitoring of acid deposition in the participating countries using common methodologies in four areas: wet deposition, dry deposition, soil/vegetation, and inland aquatic environments.
b. Compilation, evaluation, storage, and provision of the data obtained through monitoring.
c. Promotion of QA/QC activities to obtain high-quality monitoring data.
d. Capacity building of monitoring capabilities in participating countries including the implementation of training programs.
e. Promotion of research, studies, and public awareness activities related to acid deposition problems.

1.3.2 EANET institutional framework

1.3.2.1 Institutional arrangements

The Intergovernmental Meeting (IG), Scientific Advisory Committee (SAC), Secretariat, and Network Center (NC) are described in the "Tentative Design of the Acid Deposition Monitoring Network in East Asia (EANET)" (EANET/IG 2/5/3) as institutional bodies for implementing EANET activities on a regular basis (Figure 1.3.1).

The IG, composed of representatives of each participating country, is EANET's decision-making body, and it deals with matters related to management of the Network and implementation of the work program.

SAC is made up of scientific and technical experts from the participating countries, and it advises and assists the IG with various scientific and technical matters related to Network activities. The Task Force on Dry Deposition Monitoring, the Task Force on Soil and Vegetation Monitoring, and the Network of Soil and Vegetation Specialists were established under SAC supervision to assist in the development of a strategy and methodologies for the most important directions of monitoring.

The UNEP Regional Resource Center of Asia and the Pacific (RRC.AP) was designated as the Secretariat after discussions at IG3 in November 2001 on the arrangements necessary for establishing the Secretariat, with the assumption that it would begin functioning in January 2002. The Ministry of the Environment, Government of Japan, continued to serve as Interim Secretariat until UNEP took over as Secretariat in autumn 2002.

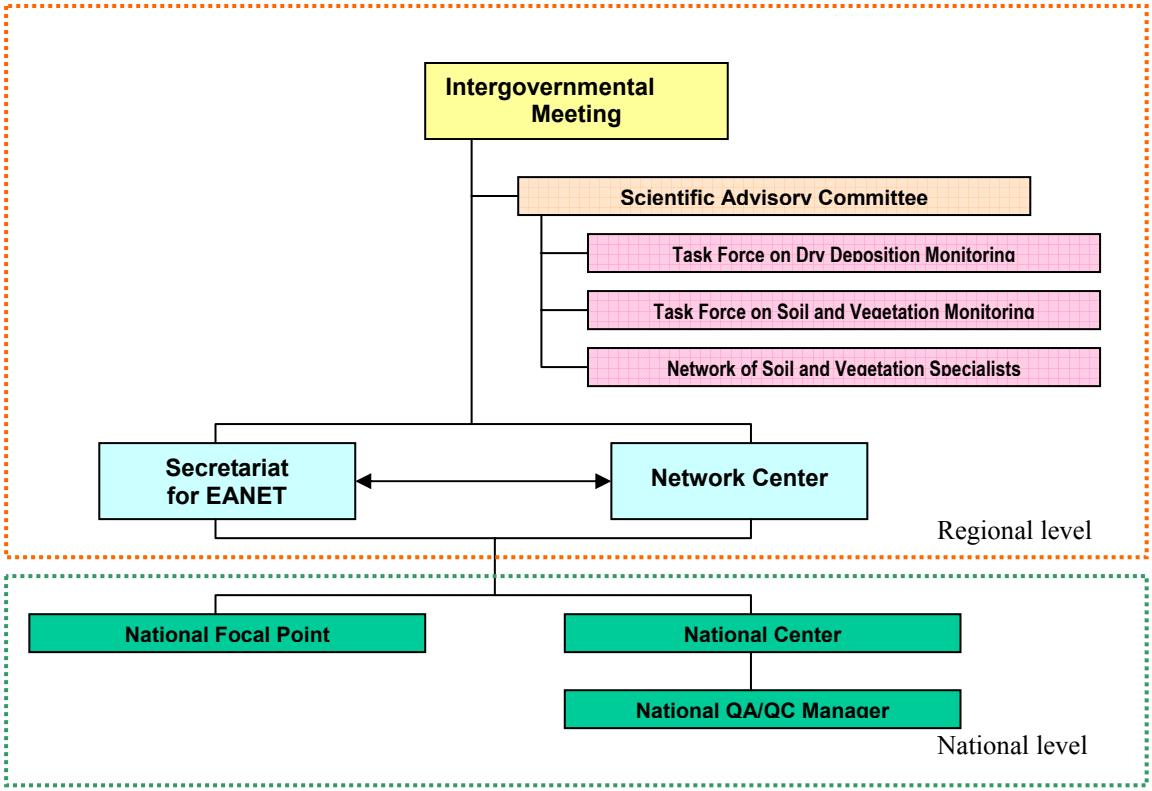

Figure 1.3.1 Institutional framework of EANET
Note: The UNEP Regional Resource Center of Asia and the Pacific (RRC.AP), located in Pathumthani, Thailand, was designated as the Secretariat of EANET. The Acid Deposition and Oxidant Research Center (ADORC), located in Niigata, Japan, was designated as the Network Center for EANET.

The Acid Deposition and Oxidant Research Center (ADORC) in Japan was designated as EANET's NC to carry out the following tasks under the guidance of the IG:

1. Centralized compilation, evaluation, and storage of monitoring data and related information
2. Preparation of data reports on acid deposition in East Asia
3. Dissemination of monitoring data and other relevant information
4. Provision of technical assistance to participating countries in implementing Network activities
5. Implementation and coordination of QA/QC activities
6. Development and implementation of education/training programs for those engaged in Network activities
7. Implementation of research on acid deposition
8. Provision of scientific and technical support for the IG, SAC, and other subsidiary bodies
9. Other tasks requested by the IG

1.3.2.2 Outline of EANET activities

The following is an outline of EANET activities:

1. Each participating country develops and implements its own national monitoring plan, which is then reviewed and revised based on the experience gained during the preparatory phase. Acid deposition monitoring is implemented in accordance with EANET monitoring guidelines, technical manuals, and other technical documents. Each participating country prepares and reports its monitoring data and other relevant information in accordance with specified procedures. Each country also designates a National Center to implement monitoring activities and report monitoring data.
2. The monitoring data and other information submitted by participating countries is compiled, evaluated, and stored by the NC. All participating countries can obtain the data and information

submitted to the NC by other participants (Figure 1.3.2).

3. In order to obtain high-quality monitoring data, the QA/QC programs are implemented in full collaboration with participating countries.
4. Periodic reports on the state of acid deposition in the East Asian region are produced and made available to the public.
5. The data and information compiled through the Network activities may be provided to individuals, organizations, and non-member countries in accordance with specified procedures.
6. Participating countries will promote the study of related scientific issues in order to improve understanding of the risks posed by acid deposition.
7. Other activities necessary to achieve the objectives of EANET can be implemented.

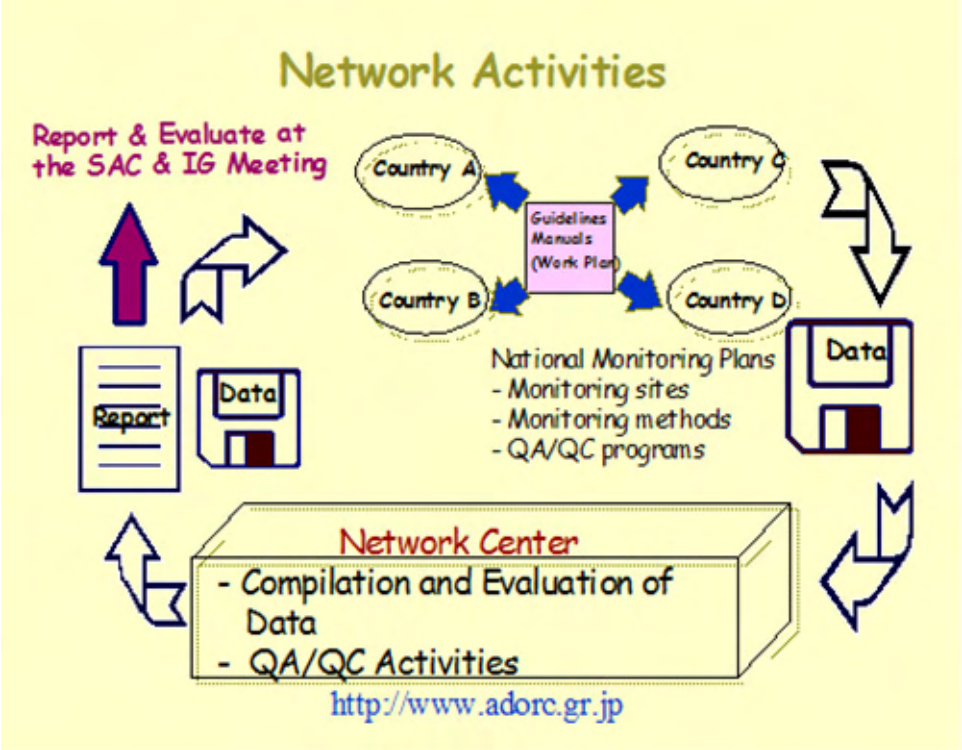

Figure 1.3.2 Principal flow of data exchange in EANET

1.3.3 Monitoring operations

1.3.3.1 Monitoring stations

The monitoring of acid deposition consists of measurements on wet deposition, dry deposition, inland aquatic environments, and soil and vegetation, and is carried out in accordance with EANET's monitoring guidelines, technical manuals, and other technical documents that were approved at the Second Interim Scientific Advisory Group Meeting (ISAG2). Participating countries are urged to improve their performance in monitoring acid deposition by making use of these documents, with modifications, if appropriate, to take into account their particular conditions or circumstances.

EANET monitoring sites are categorized under the following two classifications: (1) an acid deposition monitoring site or (2) an ecological survey site, following the criteria presented in Table 1.3.1.

Table 1.3.1 Classification of monitoring sites

Site category	Site classification	Main purposes and criteria for siting
Acid deposition monitoring - For monitoring wet deposition and air concentration (dry deposition)	Urban	- Assessment of the state of acid deposition in urban areas - Urbanized and industrial areas, and the areas immediately outside urban areas - Data can be used to evaluate the effects of acid deposition on buildings and historical monuments or human health
	Rural	- Assessment of the state of acid deposition in rural areas and/or hinterlands - Data can be used to evaluate acid deposition on agricultural crops, forests, and other features - More than 20 kilometers from large pollution sources like cities, power plants, or highways
	Remote	- Assessment of the state of acid deposition in remote areas - Data can be used to evaluate long-range transport and deposition models - More than 50 kilometers from large pollution sources like cities, power plants, or highways - More than 500 meters from main roads (more than 500 vehicles per day)
Ecological survey - For monitoring soil and vegetation and inland aquatic environments	Basic survey	- Accumulate basic data on soil, forest, and inland aquatic environments and disclose trends in their properties - Located in the vicinity of the acid deposition monitoring site
	Ecosystem analysis	- Assessment of acid deposition impacts on the whole ecosystem through application of terrestrial ecosystem analysis and/or catchment analysis - Areas sensitive to changes in atmospheric acidity and ecological conservation areas

In 2004, wet deposition monitoring was conducted at 46 stations (17 remote, 12 rural, 17 urban) in eleven participating countries (Figure 1.3.3, Table 1.3.2).

Instrumental monitoring and filter packs are the main methods used to monitor dry deposition (air concentration). Automatic instrumental monitoring for NO_x and SO_2 is done at 22 sites, 17 sites are equipped to monitor ozone concentration, and the filter pack method is used at 30 sites. Table 1.3.3 provides a list of monitoring sites and the methods used for sampling dry deposition at each site.

Ecological survey sites, established to monitor soil and vegetation and inland aquatic environments, are basically located in the vicinity of the acid deposition monitoring sites. According to the National Monitoring Plan of each participating country, 18 areas have been selected as soil and vegetation monitoring sites. Basically, it is recommended that two forest areas whose soils have different sensitivities to acid deposition should be selected in each area. A summary of the individual monitoring sites is listed in Table 1.3.4.

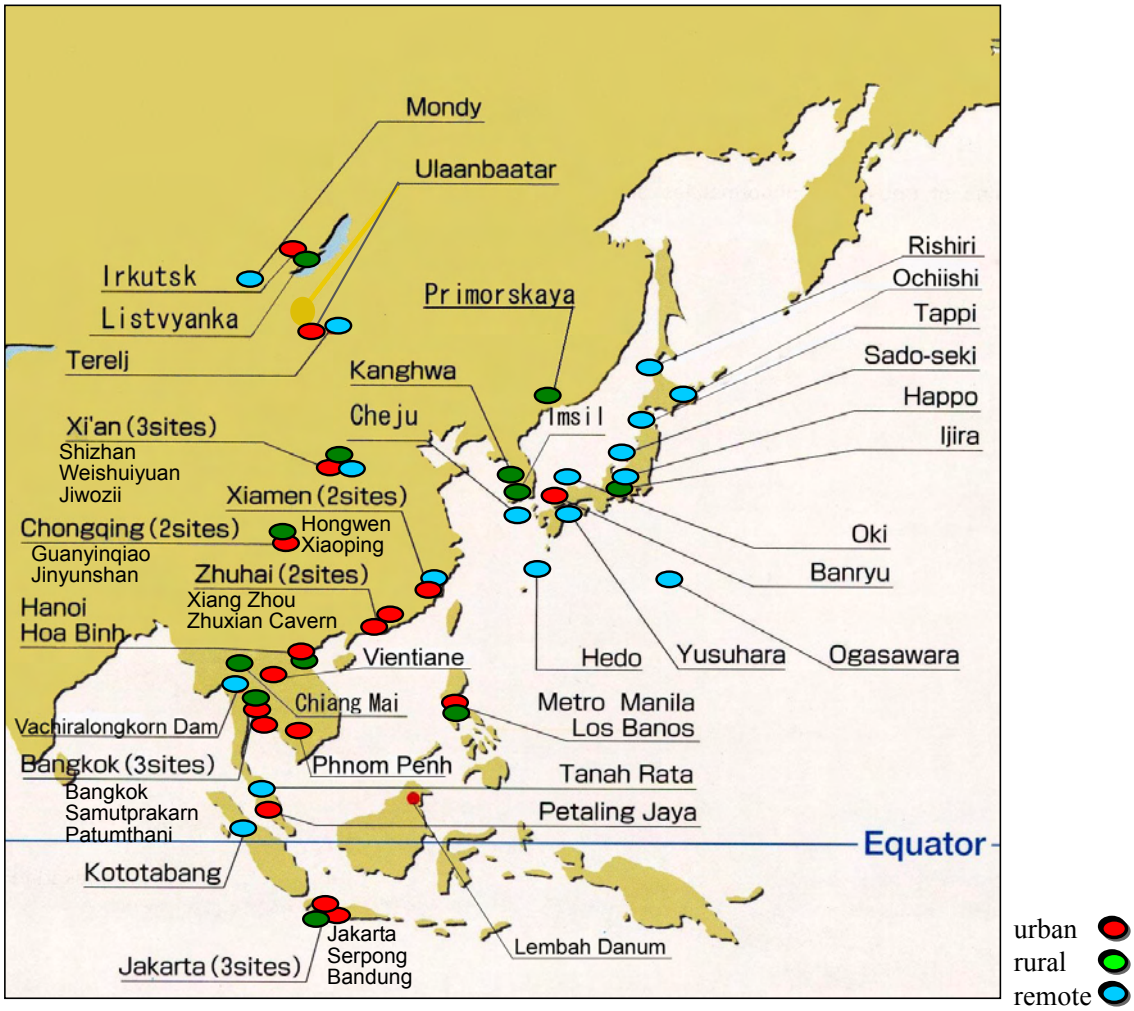

Figure 1.3.3 EANET monitoring sites throughout East Asia in 2004

Table 1.3.2 Outline of wet deposition monitoring sites

Country	Name of site	Site classification	Latitude	Longitude	Meters (m) above sea level	Data availability
Cambodia	Phnom Penh	Urban	11° 33' N	104° 50' E	10 m	04
China	Guanyinqiao	Urban	29° 34' N	106° 31' E	262 m	00, 01, 02, 03, 04
	Nanshan	Rural	29° 33' N	106° 38' E	570 m	00
	Jinyunshan	Rural	29° 49' N	106° 22' E	800 m	01, 02, 03, 04
	Shizhan	Urban	34° 14' N	108° 57' E	400 m	00, 01, 02, 03, 04
	Weishuiyuan	Rural	34° 22' N	108° 51' E	366 m	00, 01, 02, 03, 04
	Dabagou	Remote	33° 54' N	108° 51' E	1,200 m	00
	Jiwozi	Remote	33° 50' N	108° 48' E	1,800 m	01, 02, 03, 04
	Hongwen	Urban	24° 28' N	118° 08' E	50 m	00, 01, 02, 03, 04
	Xiaoping	Remote	24° 51' N	118° 02' E	686 m	00, 01, 02, 03, 04
	Xiang Zhou	Urban	22° 16' N	113° 34' E	40 m	00, 01, 02, 03, 04
	Zhuxian Cavern	Urban	22° 12' N	113° 31' E	45 m	00, 01, 02, 03, 04
Indonesia	Jakarta	Urban	6° 11' S	106° 50' E	7 m	00, 01, 02, 03, 04
	Serpong	Rural	6° 15' S	106° 34' E	46 m	00, 01, 02, 03, 04
	Kototabang	Remote	0° 12' S	100° 19' E	864 m	00, 01, 02, 03, 04
	Bandung	Urban	6° 54' S	107° 35' E	743 m	00, 01, 02, 03, 04
Japan	Rishiri	Remote	45° 07' N	141° 12' E	40 m	00, 01, 02, 03, 04
	Ochiishi	Remote	43° 09' N	145° 30' E	49 m	03, 04
	Tappi	Remote	41° 15' N	140° 21' E	105 m	00, 01, 02, 03, 04
	Ogasawara	Remote	27° 05' N	142° 13' E	230 m	00, 01, 02, 03, 04
	Sado-seki	Remote	38° 14' N	138° 24' E	136 m	00, 01, 02, 03, 04
	Happo	Remote	36° 42' N	137° 48' E	1,850 m	00, 01, 02, 03, 04
	Oki	Remote	36° 17' N	133° 11' E	90 m	00, 01, 02, 03, 04
	Yusuhara	Remote	33° 22' N	132° 56' E	790 m	00, 01, 02, 03, 04
	Hedo	Remote	26° 52' N	128° 15' E	60 m	00, 01, 02, 03, 04
	Ijira	Rural	35° 34' N	136° 41' E	140 m	00, 01, 02, 03, 04
	Banryu	Urban	34° 41' N	131° 48' E	53 m	00, 01, 02, 03, 04
Lao PDR	Vientiane	Urban	17 ° N	102° E		03, 04
Malaysia	Petaling Jaya	Urban	03° 06' N	101° 39' E	87 m	00, 01, 02, 03, 04
	Tanah Rata	Remote	04° 28' N	101° 23' E	1,470 m	00, 01, 02, 03, 04
	Danum Valley	Remote	04° 59' N	117° 51' E	427 m	00, 01, 02, 03, 04
Mongolia	Ulaanbaatar	Urban	47° 54' N	106°49' E	1,282 m	00, 01, 02, 03, 04
	Terelj	Remote	47° 59' N	107° 29' E	1,540 m	00, 01, 02, 03, 04
Philippines	Metro Manila	Urban	14° 38' N	121° 04' E	54 m	00, 01, 02, 03, 04
	Los Banos	Rural	14° 11' N	121° 15' E	35 m	00, 01, 02, 03, 04
Republic of Korea	Kanghwa	Rural	37° 42' N	126° 17' E	150 m	00, 01, 02, 03, 04
	Cheju	Remote	33° 18' N	126° 10' E	72 m	00, 01, 02, 03, 04
	Imsil	Rural	35° 36' N	127° 11' E		01, 02, 03, 04
Russia	Mondy	Remote	51° 40' N	101° 0' E	2,000 m	00, 01, 02, 03, 04
	Listvyanka	Rural	51° 51' N	104° 54' E	700 m	00, 01, 02, 03, 04
	Irkutsk	Urban	52° 14' N	104° 15' E	400 m	00, 01, 02, 03, 04
	Primorskaya	Rural	43° 42' N	132° 07' E	84 m	02, 03, 04
Thailand	Bangkok	Urban	13° 46' N	100° 32' E	2 m	00, 01, 02, 03, 04
	Samutprakarn	Urban	13° 44' N	100° 34' E	2 m	00, 04
	Patumthani	Rural	14° 02' N	100° 46' E	2 m	00, 01, 02, 03, 04
	Khanchanaburi	Remote	14° 46' N	98° 35' E	170 m	00, 01, 02, 03, 04
	Chiang Mai	Rural	18° 46' N	98° 56' E	350 m	01, 02, 03, 04
Vietnam	Hanoi	Urban	21° 01' N	105° 51' E	5 m	00, 01, 02, 03, 04
	Hoa Binh	Rural	20° 49' N	105° 20' E	23 m	00, 01, 02, 03, 04

Table 1.3.3 Outline of air concentration measurements at dry deposition monitoring sites

Country	Name of site	Site classification	Automatic instruments			Filter pack	Other methods
			SO_2, NO_x	O_3	PM		
China	Chongqing-Jinyunshan	Rural	✓	None	✓	None	None
	Xi'an-Weishuiyuan	Rural	✓	None	✓	None	None
	Xiamen-Hongwen	Urban	✓	None	✓	None	None
	Zhuhai-Xiang Zhou	Urban	✓	None	✓	None	None
Indonesia	Serpong	Rural	None	None	None	✓	None
Japan	Rishiri	Remote	✓	✓	✓	✓	None
	Tappi	Remote	✓	✓	✓	✓	None
	Ogasawara	Remote	✓	✓	✓	✓	None
	Sado-seki	Remote	✓	✓	✓	✓	None
	Happo	Remote	✓	✓	✓	✓	None
	Oki	Remote	✓	✓	✓	✓	None
	Yusuhara	Remote	✓	✓	✓	✓	None
	Hedo	Remote	✓	✓	✓	✓	None
	Ijira	Rural	✓	✓	✓	✓	None
	Banryu	Urban	✓	✓	✓	✓	None
Malaysia	Petaling Jaya	Urban	None	None	None	✓	LV, PS
	Tanah Rata	Remote	None	None	None	✓	LV, PS
Mongolia	Ulaanbaatar	Urban	None	None	None	✓	None
	Terelj	Remote	None	None	None	✓	None
Philippines	Metro Manila	Urban	None	None	None	✓	None
	Los Banos	Rural	None	None	None	✓	None
Republic of Korea	Kanghwa	Rural	✓	✓	✓	✓	None
	Cheju (Kosan)	Remote	✓	✓	✓	✓	None
	Imsil	Rural	✓	✓	✓	✓	None
Russia	Mondy	Remote	None	✓	None	✓	None
	Listvyanka	Rural	None	None	None	✓	None
	Irkutsk	Urban	None	None	None	✓	None
	Primorskaya	Rural	None	None	None	✓	None
Thailand	Bangkok	Urban	✓	None	✓	✓	AS
	Samutprakarn	Urban	✓	✓	None	None	AS
	Patumthani	Rural	None	None	None	✓	None
	Khanchanaburi	Remote	✓	✓	✓	✓	None
	Chiang Mai (Mae Hia)	Rural	✓	✓	✓	✓	None
Vietnam	Hanoi	Urban	None	None	None	✓	None
	Hoa Binh	Rural	None	None	None	✓	None

Note: LV = low volume air sampler; PS = passive sampler; AS = aerosol sampler

Table 1.3.4 Summary of EANET soil and vegetation monitoring sites

Name of area nearest the deposition monitoring site	Site classification	Name of individual monitoring site	Available data				
			2000	2001	2002	2003	2004
China							
Chongqing -Jinyunshan	Rural	Jinyunshan	S			S, F	
Xi'an-Jiwozi	Remote	Dabagou		S		S, F	
Xiamen-Xiaoping	Remote	Xiaoping	S, F			S, F	
Zhuhai-Zhuxiandong	Urban	Zhuxiandong	S, F	S		S, F	
Indonesia							
Serpong	Rural	Bogor Research Forest		S			
Japan							
Ijira	Rural	Ijira	S, F			F	F
		Yamato				F	F
Banryu	Urban	Banryu-2	F	S, F		F	F
		Iwami "Rinku" Factory Park		S, F		F	F
Malaysia							
—	Remote	Pasoh Reserve Forest	S				
Petaling Jaya	Remote	Sungai Tekala Reserve Forest					
Mongolia							
Ulaanbaatar	Urban	Bogdkhan mountain					
Philippines							
Los Banos	Rural	Mt. Makiling	F	S, F	S		
		UP Quezon, Land Grant	S	S, F			
Republic of Korea							
Imsil	Rural	Mt. Naejang		S, F			S, F
Russia							
Mondy	Remote	Ilchir Lake					
		Okinskoe Lake					
		Solar Observatory					F
Listvyanka	Rural	Bolshie Koty	S		F		
		Pereemnaya River Catchment					
Irkutsk	Urban	Irkutsk		S, F		F	
Primorskaya	Rural	Primorskaya					
Thailand							
Khanchanaburi	Remote	Vachiralongkorn Dam	S, F	S	S	S, F	
		Vachiralongkorn Puyea			S, F	S, F	
Vietnam							
Hoa Binh	Rural	Cave of Heaven					
		Thang Ranh					

Note: S = soil monitoring; F = forest monitoring

According to the *Manual for Monitoring Inland Aquatic Environment*, lakes chosen for monitoring should meet the following requirements: harmonic type of lake, depth of ten meters or less, water residence time is one year or less, area of one hectare or more, chemical properties of low alkalinity and electric conductivity, minimal anthropogenic impact (water pollution), and no coverage of water surface with aquatic organisms.

As described in Table 1.3.5, eight countries (China, Indonesia, Japan, Mongolia, Philippines, Russia, Thailand, and Vietnam) conduct inland aquatic environment monitoring. The total numbers of surface water objects with monitoring sites of continuous measurements in the regular phase of EANET are eight lakes/reservoirs and four streams.

Table 1.3.5 Outline of inland aquatic environment monitoring sites

Country	Name of lake	Site classification of the nearest acid deposition monitoring site	Year(s) of available data
China	Jinyunshan Lake (Chongqing)	Rural	01, 02, 03, 04
	Yueliang Lake (Chongqing)	Rural	00
	Taiyang Lake (Chongqing)	Rural	00
	Jiwozi River (Xi'an)	Remote	01, 02, 03, 04
	Xiaoping Dam (Xiamen)	Remote	01, 02, 03, 04
	Laizhu-keng (Xiamen)	Remote	00
	Chishui-keng (Xiamen)	Remote	00
	Zhuxiandong Stream (Zhuhai)	Urban	04
	Zhuxiandong Reservoir (Zhuhai)	Urban	00, 01, 02, 03
Indonesia	Patenggang Lake	Rural	00, 01, 02, 03, 04
Japan	Ijira Lake	Rural	00, 01, 02, 03, 04
	Banryu Lake	Urban	00, 01, 02, 03, 04
Mongolia	Terelj River	Rural	02, 03, 04
Philippines	Pandin Lake	Rural	04
	Mojicap Lake	Rural	00, 01, 02, 03
Russia	Pereemnaya River	Rural	04
	Ordinscoe Lake	Remote	00
	Krestovka River	Rural	00, 01, 02, 03
Thailand	Vachiralongkorn Dam	Remote	00, 01, 02, 03, 04
Vietnam	Hoa Binh Reservoir	Rural	00, 01, 02, 03, 04

1.3.3.2 Monitoring program from 2001 to 2004

The measurement program developed for monitoring sites under the general guidelines identifies the following monitoring parameters:

▶ Wet deposition
- pH, electric conductivity, concentrations of SO_4^{2-}, NO_3^-, Cl^-, NH_4^+, Na^+, K^+, Ca^{2+}, and Mg^{2+}

▶ Dry deposition
- Gases: concentration of SO_2, NO_2, NO, and O_3
- Aerosol: concentration of SO_4^{2-}, NO_3^-, Cl^-, NH_4^+, Na^+, K^+, Ca^{2+}, and Mg^{2+}
- Aerosol mass concentration (optional)

▶ Soil and vegetation
- Soil: pH (H_2O), pH (KCl), cation exchange capacity, concentration of exchangeable ions (Na^+, K^+, Ca^{2+}, and Mg^{2+}), concentration of exchangeable Al^{3+}, SO_4^{2-}, available PO_4^{3+} (optional)
- Vegetation: the degree of decline of trees, abnormality of leaves and branches, chemical content of fresh leaves (S, K, Ca, and Mg) (optional)

▶ Inland aquatic environments
- Inland water pH, electric conductivity, alkalinity, and concentration of SO_4^{2-}, NO_3^-, Cl^-, NH_4^+, Na^+, K^+, Ca^{2+}, and Mg^{2+} (optional)

QA/QC programs cover all aspects of the monitoring activities, from selection of sampling sites to data reporting, and should be integrated into all monitoring activities. Fundamental issues identified are the development of national QA/QC programs, definition of data quality objectives, appointment of QA/QC managers in the National Centers, and preparation of standard operation procedures (SOPs). QA/QC managers, being responsible for implementing country programs, have been appointed in each participating country to secure reliable and comparable monitoring data.

The NC is in charge of managing the overall QA/QC programs for EANET, and the Network QA/QC Manager appointed in the NC is responsible for providing appropriate guidance and advice to the participating countries. The NC also provides technical support for the National Centers and conducts comparative analysis of methods for both sampling and chemical analysis.

The NC has organized inter-laboratory comparison projects for wet deposition, inland aquatic environments, and soil monitoring, and it evaluates the analytical results of simulated rainwater and soil samples distributed for inter-laboratory comparison. This type of evaluation reveals each laboratory's analytical performance, and the results facilitate finding solutions to apparent and potential problems as well as improving laboratory work. This was shown to be effective when the annual attempt of the inter-laboratory comparison project for laboratory analysis of wet deposition considerably improved the quality of monitoring results.

1.3.3.3 Outline of sampling and measurement methods

a. Wet deposition

In order to produce comparable measurements, each participating country fundamentally employs the common methodologies specified in the *Technical Documents for Wet Deposition Monitoring in East Asia*.

Most of the participating countries use a wet-only sampler to collect samples during rain events only. Samples collected are shipped to laboratories for chemical analysis using a cooling box to keep the sample temperature low enough to preserve the sample's chemistry. In tropical sites, biocides such as thymol are added to the collection vessel in advance for that purpose when a refrigerator is not available during sampling, shipping, and storage periods in order to prevent microbial decomposition.

Whereas the analytical procedures are described in the technical documents mentioned above, ion chromatography is the main method used in EANET. Atomic absorption spectrometry for Na^+, K^+, Ca^{2+}, and Mg^{2+}, and spectrophotometry for NH_4^+ are also useful tools to determine their concentrations in samples. All data are checked in terms of ion balance (R_1) and conductivity balance (R_2). If any specific set of measurements is recognized to have a problem, such as "insufficient sample volume" or "low precision," this problem is recorded in the database by attaching respective flags to the data set. The specifics of data management are described in detail in the *Quality Assurance/Quality Control (QA/QC) Program for Wet Deposition Monitoring in East Asia*.

b. Dry deposition (air concentration)

Automatic instrument monitoring methods and the filter pack method are mainly used to implement the dry deposition (air concentration) monitoring of chemical species, in accordance with the *Strategy Paper for Future Direction of Dry Deposition Monitoring of EANET* (1999).

Sulfur dioxide, NO_2 (urban), NO, O_3, and PM of the first priority are monitored with instrumental measurements. The related QA/QC program for monitoring these is described in the *QA/QC Program for the Air Concentration Monitoring in East Asia* (2001).

The *Technical Document of Filter Pack Monitoring in East Asia* was endorsed at the Third Session of the Science Advisory Committee (SAC3) held in November 2003. The methods can determine

gaseous (SO_2, HNO_3, HCl, and NH_3) and particulate components (SO_4^{2-}, NO_3^-, Cl^-, Na^+, K^+, NH_4^+, Ca^{2+}, and Mg^{2+}). Monitoring is conducted by means of the four-stage filter pack method, which is described in the technical document.

c. Soil and vegetation

Basic surveys are principally carried out to meet EANET's initial objectives (establishment of baseline data and early detection of possible impact) in the participating countries. The interval of soil and vegetation monitoring was decided, as indicated in the *Technical Manual,* to be three to five years. Analytical methods recommended in the manual are presented in Chapter 3, Section 3.4.3, Table 3.4.3.

Basically, it is recommended that two forest areas whose soils have different sensitivities to acid deposition should be selected for monitoring in a given area. Several plots (at least two) of areas from five to ten meters in size are randomly chosen in each of the forest areas. Five quadratic subplots (one meter by one meter) are set up for soil sampling in the center and along the diagonal lines of each plot. Three coaxial round plots with areas of 1,000, 400, and 200 square meters, respectively, should be established to provide a general description of the trees in each plot. Observation of tree decline is carried out on twenty selected trees with an average height of around 20 meters.

d. Inland aquatic environment

The participating countries are expected to monitor the following suites: water temperature, pH, electric conductivity (EC), alkalinity, and concentrations of SO_4^{2-}, NO_3^-, Cl^-, NH_4^+, Na^+, K^+, Ca^{2+}, and Mg^{2+} of targeted lakes/rivers at least four times a year on a seasonal basis, and transparency, water color, DOC (if not possible, then COD), NO_2^-, and PO_4^{3-} more than once a year.

According to the *Technical Document for Monitoring Inland Aquatic Environment*, the lakes chosen for monitoring should be of a harmonic type. If a spring is selected as a monitoring site, it should preferably be located in a nature protection area with minimum human activities like deforestation or cultivation.

Surface water is sampled in the center of the lake. Values of pH and EC should be measured on site in addition to the precise measurements conducted in the laboratory. Water samples for later analysis are put in tightly stoppered polyethylene bottles and kept in a cool, dark place. The water samples for analysis of chemical components other than alkalinity are filtrated at the sampling site with a glass fiber filter. The samples are then shipped to the laboratory for chemical analysis immediately or after storage in a refrigerator using the methods specified in Table 1.3.6.

Table 1.3.6 Parameters and recommended analytical methods

Parameter	Analytical method
pH	pH meter (glass electrode)
Electric conductivity	Conductivity meter
Alkalinity	Titration by burette or digital burette with pH meter
NH_4^+, NO_3^-, NO_2^-, PO_4^{3-}	Ion chromatography or spectrometry
K^+, Mg^{2+}, Ca^{2+}, Na^+	Ion chromatography or atomic absorption spectrometry
SO_4^{2-}	Ion chromatography or turbidimetry
DOC	Combustion-infrared method or wet-oxidation method

1.3.4 Outline of the national monitoring plans

Each country participating in EANET is expected to submit a national monitoring plan to the NC in the proposed data reporting formats and is may be requested to revise its plan where appropriate, after feedback from the NC based on the experience obtained in previous years and scientific advice from SAC.

Each national monitoring plan should include the following information:
- Information on the National Center and the contact person
- National monitoring plan
  1. Responsible agency
  2. Number of monitoring sites
  3. Measurement parameters and their intervals
  4. Participating laboratories for each monitoring activity
- Information on respective monitoring sites
  1. Outline of each monitoring site, including name, address, and geographical description
  2. Sample collection
  3. Meteorological observation
  4. Situation around the site, including descriptions and sketch maps of the topography, land use, vegetation, source of air pollutants, etc.

a. National Centers

In EANET, each National Center is responsible for preparation and implementation of the participating country's national monitoring plan (Table 1.3.7).

Table 1.3.7 National Centers of participating countries

Country	Organization
Cambodia	Ministry of Environment
China	China National Environmental Monitoring Center (CNEMC)
Indonesia	Environmental Impact Control Facility (SARPEDAL)
Japan	Acid Deposition and Oxidant Research Center (ADORC)
Lao PDR	Science Technology and Environment Agency (STEA)
Malaysia	Malaysian Meteorological Service (MMS)
Mongolia	Central Laboratory of Environmental Monitoring (CLEM)
Myanmar	Department of Meteorology and Hydrology (DMH)
Philippines	Environmental Management Bureau (EMB), Department of Environment and Natural Resources (DENR)
Republic of Korea	National Institute of Environmental Research (NIER)
Russia	Institute of Global Climate and Ecology (IGCE), Russian Federal Service for Hydrometeorology and Environmental Monitoring (Roshydromet), and the Limnological Institute of Russian Academy of Sciences (RAS) (Siberian Branch)
Thailand	Pollution Control Department (PCD)
Vietnam	Environmental Research Center (ERC), Institute of Meteorology and Hydrology, Ministry of Natural Resources and Environment (MONRE)

b. Monitoring sites

Information on respective monitoring sites is reported in the national monitoring plans, with site name, address, site classification, and geographical descriptions included. The number of EANET acid deposition monitoring sites in 2004 is presented in Table 1.3.8.

Table 1.3.8 The number of monitoring sites in EANET in 2004

Country	Wet deposition	Dry deposition	Soil and vegetation	Inland aquatic environment
Cambodia	1	0	0	0
China	9	4	4	4
Indonesia	4	1	1	1
Japan	11	10	2	2
Lao PDR	1	0	0	0
Malaysia	3	2	2	0
Mongolia	2	2	1	1
Philippines	2	2	1	1
Republic of Korea	3	3	1	0
Russia	4	4	4	1
Thailand	5	5	1	1
Vietnam	2	2	1	1

1.4 Preparation of the *Periodic Report*

1.4.1 Background and preparation process

Monitoring data was accumulated through the efforts of the participating countries over the five years of regulatory-phase activities. The results and information obtained need to be evaluated scientifically to provide evident facts and possible conclusions on the state of acid deposition and its potential impact in East Asia. The necessity of initiating assessment studies as early as possible was recognized, based on the results of regular monitoring and the experience of other networks around the world.

At the Third Session of the Scientific Advisory Committee (SAC3), held in Pattaya, Thailand, in November 2003, it was decided to start preparation of the first periodic report on acid deposition in East Asia based on EANET's monitoring data accumulated during the regular phase. Approximately 30 participants and observers attended the First Scientific Workshop (SWS1) in Niigata, Japan, on 1 October 2004, to discuss methodologies for data evaluation, review the available monitoring data, and overview case studies. Based on the ideas expressed at the workshop, the NC developed a plan for the preparation of the first periodic report, meanwhile the "Procedures to Prepare the Periodic Report on the State of Acid Deposition in East Asia" (hereinafter referred to as the "Procedures") were developed and agreed on at SAC4.

The Drafting Committee (DC) for the periodic report was established and conducted its activities in accordance with the Procedures. The DC appointed Professor Muhamad Awang, Chair of the SAC Bureau, as Head of the DC. The First Meeting of the DC for the Periodic Report on the State of Acid Deposition in East Asia (PRSAD) was held on 14–15 April 2005 in Niigata, Japan. The lead authors and contributors decided on the draft content of the PRSAD and other issues in order to start the process of report preparation.

The Second Scientific Workshop (SWS2) was organized on 29–31 August 2005 in Niigata, Japan, in conjunction with SAC5. During SWS2 the DC discussed a preliminary draft of the PRSAD prepared by authors, and revised its content with an evaluation of the assumed number of pages of the main chapters. The National Assessments were presented to scientists for an overview and to gather comments.

The prepared materials of the first draft of the PRSAD were reviewed at the Second Meeting of the DC, held in Niigata, Japan, on April 19–20, 2006, where the lead authors and contributors responsible

for certain parts made presentations on their chapters. The Third Scientific Workshop (SWS3), attended by DC members, was held on 28–29 September 2006 in Patumthani, Thailand, to finalize the PRSAD, and the final discussion and review was done at SAC6 in October 2006.

1.4.2 Scope and procedures involved in the preparation of the report

The scope and procedures involved in creation of the PRSAD were discussed and developed at SAC4 as the "Procedures," which included the following important directives:

1. SAC will prepare the periodic report with assistance from the NC.
2. The first periodic report will be prepared as a scientific report on EANET to assess the state of acid deposition in East Asia.
3. The working draft should be circulated to the respective participating countries for comment.
4. The first periodic report will be completed at SAC6 in 2006.
5. EANET data in the regular phase (2001–2004) will mainly be used in the report.
6. Other national/international monitoring results can be used as references for additional assessment (for interpretation of EANET data). The first periodic report will consist of two parts: (1) regional assessment and (2) national assessments (presented on a voluntary basis).
7. National assessments may include data other than that reported to EANET, while regional assessment should use EANET data only.
8. There will be a drafting committee with one SAC member from each country participating, which will consist of sub-groups in accordance with the structure of the first periodic report. Each sub-group is headed by a lead author to reflect the subject of each chapter.
9. One or two resource persons from each country can be involved as contributing authors of the regional assessment (appointed by SAC members).
10. The drafting committee will start regional assessment soon. Prior to that the drafting committee may meet in person, if necessary.
11. A scientific workshop on the first periodic report should be held in conjunction with the SAC5 meeting in 2005. A special agenda item on editorial work will be included in the regular agenda.
12. The format for national assessments will be prepared by the drafting committee.

The directives listed above were followed in the preparation of this report during 2005 and 2006. The general opinion was to use this opportunity to identify the main features of acid deposition phenomena in East Asia, with the help of an examination of monitoring results, as well as to overview available information and data, along with their variations and changes, even though general trends or tendencies may not yet be clearly discerned. A deeper scientific analysis of materials received should provide conclusions and recommendations for improvement of monitoring activities and the further development of EANET.

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2. Quality Assurance and Quality Control and Data Quality

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CONTENTS

2.1 Introduction

Quality Assurance and Quality Control (QA/QC) plays a critical role in acid deposition monitoring as well as in other environmental measurements. For better explanations and predictions of natural phenomena, modern science offers three methodologies: theoretical modeling, laboratory experiments, and field measurements, all of which are complementary to each other. Laboratory experiments will offer some objective results for a working hypothesis, which will be discussed to examine the hypothesis. The experiment generally varies a single factor by repeating runs to evaluate the factor. Field measurement is also an experimental approach for explanations and predictions. In the field measurement, however, varying a single factor is extremely difficult and the measurement is unable to repeat because a number of factors are changing all the time in the field. For this reason, appropriate QA/QC procedures will facilitate us to draw sufficient scientific conclusions consistent with the data quality, which will ensure reliable modeling works and will eventually make a full use of the manpower, time, and financial resources.

The quality of the conclusions drawn from the measurements should be, of course, consistent with the data quality. “No data is better than data of unknown quality” is a frequently cited saying in the monitoring community. The two concepts, quality control and quality assurance, may be somewhat difficult to distinguish (Vet, 1991). Quality Control is defined as "the routine use of procedures designed to achieve and maintain a specified level of quality for a measurement system". Quality Assurance is defined as "a set of coordinated actions such as plans, specifications, and policies used to assure that a measurement program can be quantifiable and produce data of known quality".

The EANET program has four fields for monitoring: wet deposition, dry deposition, soil and vegetation, and inland aquatic environment. In this chapter, however, the focus will be placed on wet deposition because the wet deposition community worldwide has a long history of QA/QC activities and developed most of the common procedures.

The QA/QC program is composed of four procedures: i) siting, ii) sampling and sample handling, iii) chemical analysis, and iv) QA/QC for the measurements at each site. Data reporting is the final process of the QA/QC from each site to the national network centers.

The errors of the measurements are classified into two types: systematic and random errors. Unsuccessful adherence to the guidelines and operation manuals in the siting and sampling would introduce mostly systematic errors whereas chemical analysis would be associated both systematic and random errors because the analytical conditions would vary from time to time. Field errors are usually due to contamination which, in turn, induces positive systematic biases in the data. For example, occasional agricultural activities including biomass burning and fertilizer applications close to the sampler will contaminate samples with nitrate and ammonium ions. In order to cope with potential errors due to the nature of the analysis, annual interlaboratory comparison projects in addition to the routine calibration, and charge and conductivity balance examinations are practiced for respective purposes.

2.2 General procedures of QA/QC

2.2.1 QA/QC programs of EANET

2.2.1.1 Objectives

The objectives of the QA/QC program are to obtain reliable data that can be comparable among the countries of the East Asian region, as well as with other networks by ensuring data accuracy, precision, representativeness and completeness in acid deposition monitoring.

2.2.1.2 History of QA/QC program

Whereas the significance of QA/QC of the monitoring system was discussed in the second Expert Meeting to be one of the components of the Network, the QA/QC programs of EANET were developed and adopted at the First Interim Scientific Advisory Group (ISAG) Meeting in October 1998, mainly based on the Monitoring Guidelines and Technical Manuals for Acid Deposition Monitoring in East Asia, adopted at the Expert Meetings (1993-1997). It included some modifications taking into account the progress after the Technical Manuals had been adopted.

Considering the latest scientific and technical information and experiences accumulated during the preparatory-phase activities of the EANET, the Monitoring Guidelines and Technical Manuals for Wet Deposition Monitoring, Soil and Vegetation Monitoring, and Monitoring for Inland Aquatic Environment were revised at the Second ISAG Meeting in Jakarta in March 2000. Accordingly, the QA/QC programs were also revised at the same time to maintain consistency with these technical documents. As for dry deposition monitoring, QA/QC Program for the Air Concentration Monitoring in East Asia were developed in 2001 based on the Strategy Paper for Future Direction of Dry Deposition Monitoring of EANET.

The participating countries of EANET are expected to make efforts for implementing their QA/QC activities in accordance with these QA/QC programs, taking into account the situation in respective countries.

2.2.1.3 Fundamental matters

The QA/QC programs cover all QA/QC activities, including the activities of Network Center, the National Centers and the sampling/chemical analysis organizations. The National Centers and the sampling/chemical analysis organizations need to execute various QA/QC activities, including development of national QA/QC programs and SOPs. In the QA/QC programs, the following matters were suggested:

- Development of national QA/QC programs
- Clear assignment of responsibility: National QA/QC manager, supervisors in the sampling or analytical organizations, personnel in charge of data management and reporting
- Standard operating procedures (SOPs): Each sampling and chemical analysis organization (laboratory) should make efforts to prepare SOPs that meet the actual conditions of respective organizations, taking account of the Technical Manuals and the national QA/QC programs.
- Data quality objectives (DQOs): The required DQO values in EANET monitoring are defined for wet deposition, air concentration, and inland aquatic environment.

2.2.1.4 QA/QC of the monitoring practices of different environmental elements

The QA/QC programs have developed for the monitoring practices of the environmental elements: wet deposition, soil and vegetation, and inland-aquatic environment. For each element, siting, sample collection, chemical analysis, quality control of the data, data reporting are commonly discussed in terms of the QA/QC activities. The following two issues are equally important to all four subsections below:

- Data check procedures including routine data check, confirmation of measured data, and data screening;
- Statistical models on the multi-stage sampling and analysis for DQOs (refer to 3.4.3.1 for the details);

- Wet deposition
  - Operational check for sampling systems including rain gauges, precipitation collectors, and rainfall sensors;
  - Checks for ion balance (R_1) and conductivity balance (R_2);

- Evaluation of data completeness (%PCL, %TP, etc.);

- Air concentration monitoring for dry deposition
  - Calibration and maintenance of the measurement instruments for gas and particular matters (PM) monitoring;
  - Treatment of abnormal data;

- Soil and vegetation monitoring
  - Multi-stage sampling with several sampling levels, including area, soil type, plot, subplot, and horizon (layer) (refer to 3.4.3.1 "Soil monitoring sites and methods" for the details);
  - Repeated analysis for evaluation of reproducibility condition;

- Monitoring on inland aquatic environment
  - Duplicate sampling of lake/river water, and on-site measurements of pH and EC;
  - Calculation of ion balance (R_1) including alkalinity;
  - Collection of information on watershed parameters.

Audits or inspections by the National Centers and promotion of inter-laboratory comparison projects by NC were included as important common subjects for the monitoring of respective elements.

Based on the QA/QC programs, the inter-laboratory comparison projects started for wet deposition, soil, and inland aquatic environment from 1998, 1999, and 2000, respectively. The inter-laboratory comparison project on the filter-pack method operation was initiated in 2005, and the first report will be completed in 2006.

2.2.2 Siting

Siting criteria are given in the Guidelines and Technical Manual where the sites are categorized into four: urban, rural, remote stations and stations for ecological monitoring. The first three kinds of the stations have focus mainly on the atmospheric deposition measurements. The last kind, commonly stated ecological sites, is correspondent to one of these three mentioned above in terms of the location conditions, but its focus is on the data acquisition of the input to the ecological elements of interest.

The site is evaluated from a perspective of available potential sources of sample contamination which could violate its representativeness of the area of interest on the three different spatial scales: on-site, local, and regional. Detailed examinations of the site by inspection and the related documents will evaluate the type of the site. Any changes of the site conditions on three different scales (on-site, local and regional) and relocation of the sampler would require a reevaluation of the type of the site.

The first Periodic Report of the State of Acid Deposition in East Asia (this document) will provide the first opportunity to discuss the measurements and their data quality in terms of the site type for its review sometime after the start of the operation.

2.2.3 Sampling and sample handling

The sample is supposed to be collected on a wet-only daily basis. In order to eliminate, or at least minimize, possible conversion of the chemical species in the collected sample, the sample is refrigerated or applied with biocide chemicals such as thymol. The samples in the collector are shipped to analytical laboratory regularly and stored, mostly in a refrigerator, before chemical analysis. Currently refrigeration and biocide application techniques are used in 4 and 1 countries, respectively.

2.2.4 Chemical analysis

The sample is subjected to the chemical analysis of the major ions: H^+ (as pH), NH_4^+, Ca^{2+}, K^+, Mg^{2+}, Na^+, SO_4^{2-}, NO_3^-, and Cl^- as well as electric conductivity (EC). The operation manual provides some

acceptable analytical techniques to be applied in laboratories of the participating countries, but ion chromatography has considerably replaced the other techniques and hopefully the further replacement will be promoted in a couple of years.

2.2.5 QA/QC prior to the data submission to the national and network centers

The quality of the chemical analysis was evaluated in terms of ion balance and conductivity checks with the below defined quantitative measures R_1 and R_2:

$$R_1 = \frac{(C - A)}{(C + A)} \qquad R_2 = \frac{(\Lambda_{obs} - \Lambda_{calc})}{(\Lambda_{obs} + \Lambda_{calc})}$$

where the symbols are defined as below and the symbols of the ion denote their concentration on an equivalent basis.

$$C = [H^+] + [NH_4^+] + [Ca^{2+}] + [K^+] + [Mg^{2+}] + [Na^+]$$

$$A = [SO_4^{2-}] + [NO_3^-] + [Cl^-]$$

$$\Lambda_{calc} = \lambda_{H+}[H^+] + \lambda_{NH4+}[NH_4^+] + \lambda_{Ca2+}[Ca^{2+}] + \lambda_{K+}[K^+] + \lambda_{Mg2+}[Mg^{2+}] + \lambda_{Na+}[Na^+] + \lambda_{SO42-}[SO_4^{2-}] + \lambda_{NO3-}[NO_3^-] + \lambda_{Cl-}[Cl^-]$$

The acceptable ranges for R_1 and R_2 are defined as a function of the concentration sums of the analytical suits, details of which are available in the operation manual. When either R_1 or R_2 does not meet the criteria, the sample is supposed to be subjected to reanalysis as well as detailed examination of all analytical procedures involved.

For a considerable number of the samples collected in Russia, Mongolia, and parts of China, the analytical results do not meet the R_1 and R_2 standards, which strongly require either some ionic species including hydrogen carbonate (HCO_3^-) should be added to the analytical suites or the criteria should be modified as a function of pH. The acceptable ranges of R_1 and R_2 were simply adopted from US EPA guidelines. The acceptable ranges are encouraged to be revised in consideration of the ionic composition and concentration levels as well as the present state of arts of the analytical laboratories. More studies are needed to explore before revision of the criteria.

The acceptable ranges for R_1 and R_2 are dependent upon the concentration and conductivity levels respectively as is summarized in Technical Documents for the Wet Deposition Monitoring in East Asia (Tables 11-12, pp. 58-59). Consequently these acceptable ranges were taken from US EPA document (US EPA, 1994, Table 8-4, p. 5).

The data quality in terms of R_1 and R_2 are generally well within the acceptable ranges. When each measurement is evaluated for its validity, the chemistry of the sample should be explored from the viewpoint of the possible contribution of HCO_3^- and other ionic species. The performance of the round robin tests of the interlaboratory comparison projects is quite helpful for the exploration.

2.3 Interlaboratory comparison projects

2.3.1 Introduction

The inter-laboratory comparison project is a round-robin test of common lots of simulated rainwater, which involves all analytical laboratories for the EANET monitoring. The purposes of this project are to evaluate the analytical systems through the evaluation of analytical results, analytical instruments and their operating condition and other relevant and appropriate practices. Particular emphasis is placed on the issues: (i) to quantify the analytical precision and accuracy of the measurement of each

laboratory, and provide an opportunity for the laboratories to improve the quality of the chemical analysis on wet deposition, soil monitoring, and inland aquatic environment, and (ii) to improve reliability of analytical measurements through assessing the relevant techniques employed in the participating laboratories.

The first inter-laboratory comparison project on wet deposition was conducted in 1998 with the participation of the 24 laboratories of EANET, followed by start of the project on soil in 1999 and on inland aquatic monitoring in 2000. During the period up to 2005, the attempts were counted as seven of wet deposition, six times on soil and five ones on inland aquatic environment conducted every year among the EANET laboratories in the participating countries.

2.3.2 Wet deposition

2.3.2.1 The participating laboratories

The inter-laboratory comparison surveys were carried out 7 times from 1998 to 2004 with participating of 24 to 30 laboratories in the twelve countries: Cambodia, China, Indonesia, Japan, Lao-PDR, Malaysia, Mongolia, Philippines, Republic of Korea, Russia, Thailand, and Viet Nam. Table 2.3.1 shows the number of participating laboratories in each country.

Table 2.3.1 The number of participating laboratories and countries in the Inter-laboratory Comparison Project on wet deposition

Attempt	1st	2nd	3rd	4th	5th	6th	7th
Year	1998	1999	2000	2001	2002	2003	2004
Cambodia						1	1
China	5	4	4	4	4	4	4
Indonesia	2	2	3	2	2	2	2
Japan	8	8	8	8	8	8	8
Lao PDR						1	1
Malaysia	1	1	1	1	1	1	1
Mongolia	1	1	1	1	1	1	1
Philippines	1	1	1	1	1	1	1
Republic of Korea	1	1	1	1	1	1	1
Russia	1	1	1	1	2	2	2
Thailand	3	2	3	3	3	4	5
Viet Nam	1	1	1	1	1	1	1
Total No. of Laboratories	24	22	24	23	24	27	28
The number of Countries	10	10	10	10	10	12	12

2.3.2.2 Simulated rainwater samples and procedures

Two kinds of simulated rainwater of different concentration levels, the higher and lower concentration samples respectively, were prepared by the Network Center (NC) to include all ions of the analytical suits and distributed the samples to the participating laboratories at the end of each year.

The samples required a 100 times dilution to the lower concentrations to the analytical levels of the instrument utilized, and were determined for pH, EC and the concentrations of SO_4^{2-}, NO_3^-, Cl^-, Na^+, K^+, Ca^{2+}, Mg^{2+} and NH_4^+, and the results were submitted to NC to review the results by comparing

with the prepared concentrations and further by performing some statistical analysis. The annual "Reports of the Inter-Laboratory Comparison Project on Wet Deposition" included the lists of the participating laboratories together with their analytical results, laboratory codes, and statistical descriptions.

The values of concentrations in the simulated rainwater samples from 1st attempt (1998) to 7th attempt (2004) are presented in Table 2.3.2.

Table 2.3.2 The prepared values of each parameter of artificial rainwater of inter–laboratory comparison projects of EANET

Sample Code		pH (-)	EC ($mS\ m^{-1}$)	SO_4^{2-} ($\mu molL^{-1}$)	NO_3^- ($\mu molL^{-1}$)	Cl^- ($\mu molL^{-1}$)	Na^+ ($\mu molL^{-1}$)	K^+ ($\mu molL^{-1}$)	Ca^{2+} ($\mu molL^{-1}$)	Mg^{2+} ($\mu molL^{-1}$)	NH_4^+ ($\mu molL^{-1}$)
1998	No.1	4.05	7.94	83.5	93.3	129	95.8	11.1	41.1	13.1	84.8
	No.2	4.51	2.82	29.1	36.1	45.1	33.5	7.42	14.3	4.6	29.5
1999	No.1	4.14	6.38	67	75.0	104	77.0	8.9	33.0	11.0	68.0
	No.2	4.59	2.30	24.0	27.0	38.0	28.0	3.2	12.0	3.8	25.0
2000	No.1	4.10	6.23	59.7	63.3	101.3	51.3	9.9	29.4	11.7	60.5
	No.2	4.85	1.55	20.1	27.5	15.5	8.7	4.9	11.0	7.8	18.2
2001	No.1	4.10	7.45	85.0	93.3	108.4	68.4	15.8	41.1	18.7	87.8
	No.2	4.82	1.76	21.5	19.4	34.4	27.4	4.00	13.2	3.7	16.7
2002	No.021	4.30	3.75	40.3	51.0	33.7	13.7	6.92	19.1	7.02	42.4
	No.022	5.15	0.69	8.88	8.49	9.13	5.13	1.98	6.6	1.75	4.54
2003	No.031	4.52	3.44	44.7	30.9	66.0	46.1	6.9	20.5	7.0	48.3
	No.032	4.80	1.48	12.0	21.3	29.6	25.6	2.5	4.4	3.4	15.1
2004	No.041	4.60	3.93	58.5	41.4	76.6	66.6	7.0	38.9	9.7	39.3
	No.042	5.00	1.33	17.5	18.4	22.4	20.5	5.0	10.0	2.7	15.1

2.3.2.3 Results

The EANET QA/QC program has prescribed the Data Quality Objectives (DQOs) of as a value of ±15% for each analytical suit. The results of the present project were evaluated in terms of the excess of the DQOs value. The flag "E" was put to the data that exceed DQOs by a factor of 2 (±15%~±30%), and the flag "X" to the data exceeding DQOs by a factor of over 2 (<-30% or >30%). A set of the data for each sample was evaluated with the data checking procedures.

The inter-laboratory comparison surveys were carried out 7 times, and the overall percentages of flagged data, "E" and "X" respectively, are shown in Figure 2.3.1. The percentage of data within the data quality objectives (DQOs) increased from 75-78% to 84-93% until the 4th (2001) survey. The data quality seemed to be improved by accumulating experiences. But in the 5th project (2002), the number of successful results (within mentioned ranges) was decreased for both the higher concentration sample and the lower concentration sample because the ion concentrations were prepared as a half of their content in the samples of previous projects. The percentage of the flagged data, which may be related to the concentration levels of the simulated rainwater, has been gradually decreasing for next three years.

Figure 2.3.2 shows the percentages of flagged data ("E" and "X" together) for each parameter of the higher and lower concentration samples. More flags have been affected for cations than anions.

The relative standard deviations (R.S.D.) of project data sets were dramatically decreased from the first attempt to the second attempt (Figure 2.3.3) whereas the R.S.D. remained after almost at the same level during following attempts of the intercomparisons.

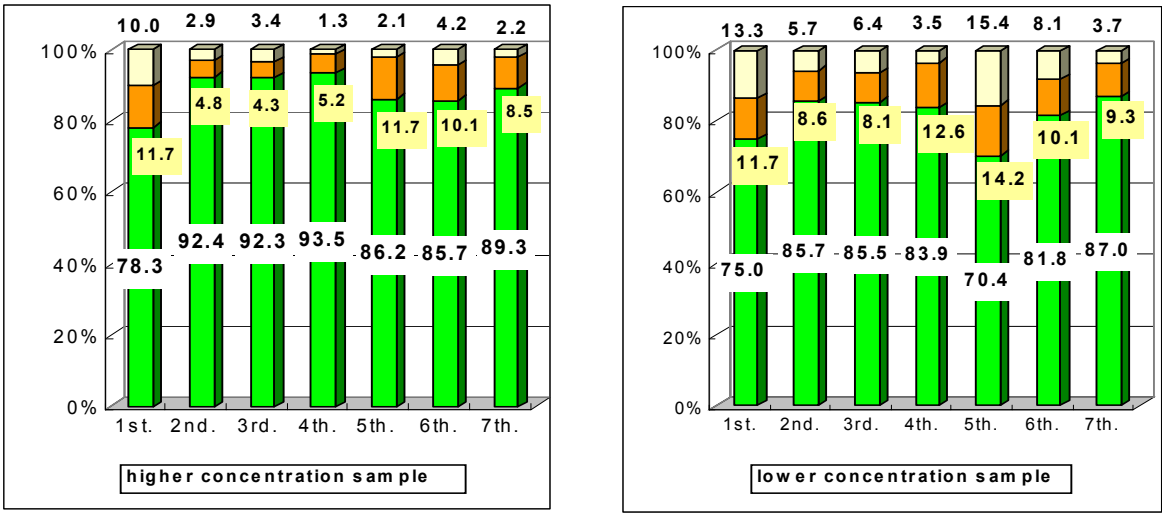

Figure 2.3.1 Overall comparisons of 1st to 7th inter-laboratory comparison projects

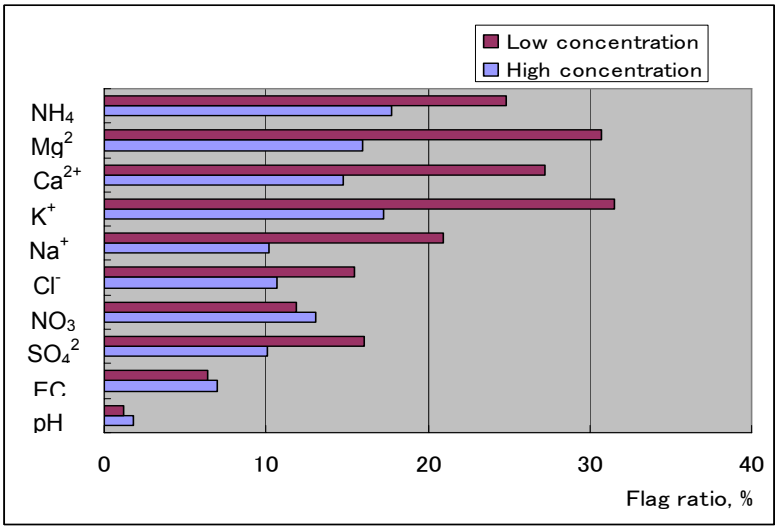

Figure 2.3.2 Percentage of flagged data (1998-2004)

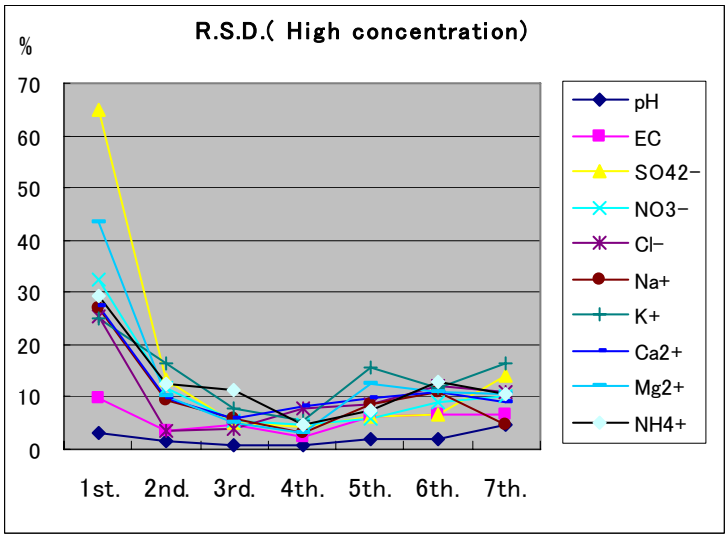

Figure 2.3.3 Relative standard deviation of each constituent data (1998-2004)

2.3.3 Soil

2.3.3.1 Outline

The project on soil sample analysis started in 1999 as one of the activities within the QA/QC programs. Fourteen laboratories participated from the following ten countries: China, Indonesia, Japan, Malaysia, Mongolia, Philippines, Republic of Korea, Russia, Thailand, and Viet Nam, participated in the projects. Air-dried soil samples, which were prepared by NC, were distributed to the laboratories every year except 2001. The laboratories carried out the whole procedures of the soil analysis including extraction, instrumental analysis or titration, and reporting. Performance at each step would be responsible for the interlaboratory variations. In order to eliminate the differences in the sample preparation, therefore, samples of soil extract were also distributed in 2001 and 2002 to evaluate the procedures of respective steps. Distributed samples of the respective years and mandatory parameters to be measured for soil samples were listed in Tables 2.3.3 and 2.3.4, respectively.

Table 2.3.3 Distributed samples and their characteristic

Year	Sample 1	Sample 2
1999 (1st)	No. 991: Acrisols (red soil)	No. 992: Gleysols (gley soil)
2000 (2nd)	No. 001: Cambisols (brown forest soil)	No. 002: Andosols (black soil: used for the 3rd and 4th Project)
2001 (3rd)	No. 011: Soil extract by CH_3COONH_4 solution (for exchangeable base cations)	No. 012: Soil extract by KCl solution (for exchangeable acidity, Al, and H)
2002 (4th)	No. 021: Andosols (black soil: soil sample)	No. 022: Soil extract by CH_3COONH_4 solution (for exchangeable base cations)
2003 (5th)	No. 031: Cambisols (brown forest soil)	No. 032: Arenosols (red soil)
2004 (6th)	No. 041: Andosols (black soil)	No. 042: Cambisols (brown forest soil)

Note: Soils were collected in Akita, Aichi, Niigata, and Tottori prefectures of Japan in 1999, 2000, 2003, and 2004, respectively.

Table 2.3.4 Mandatory parameters to be measured for the soil samples

Parameters	Unit
a) Moisture Content	wt %
b) pH (H_2O), pH (KCl)	
c) Ex- base cations, such as Ca, Mg, K, and Na	cmol(+) kg^{-1}
d) Ex- Acidity, Al, and H	cmol(+) kg^{-1}

Note: Ex-, exchangeable

2.3.3.2 Major outcomes

As for pH(H_2O) and pH(KCl), inter-laboratory precision was very high and stable through the projects. Coefficients of variation (CVs) among the laboratories were less than 5 %. It seems that pH values have enough precision to evaluate the results of the laboratories.

As for Ex-base cations, results of the first three projects from 1999 to 2001 suggested that instrumental analysis have relatively large effects on the total precision of soil analysis, and the following analytical conditions could have affected results:

- Addition of La or Sr solution for AAS analysis of Ex-Ca
- Preparation method of standard solution
- Instrument for Ex-K and Na

The participating laboratories shared the information on these possible factors to improve the precision. In addition to these technical issues, it was suggested that changes of analysts and/or analytical system in several laboratories might cause calculation/transcription errors in reporting process. Consequently, NC provided a digital format for calculation/reporting of the data in order to avoid such common

mistakes. Inter-laboratory precision of the representative parameters in each soil sample was shown in Figure 2.3.4. No obvious calculation error was found in the data in 2003 by using digital formats. The inter-laboratory precision in 2003 (No. 031 and 032) was still relatively large but clearly improved compared with the previous projects. However, the inter-laboratory precision increased again in the 2004 than in the previous projects.

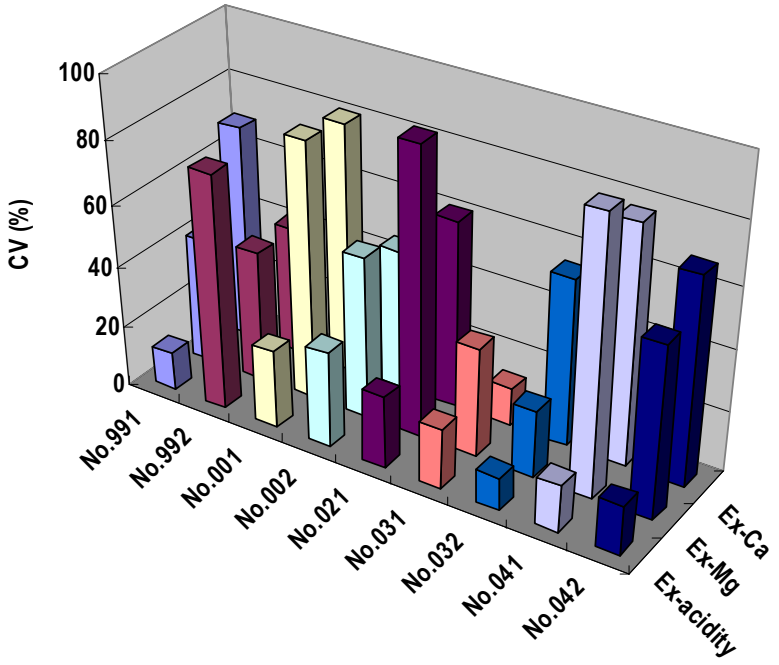

Figure 2.3.4 Inter-laboratories precision of the representative parameters

In 2004, effects of not only inter-laboratories precision but also repeatability precision and within-laboratory-reproducibility precision was also relatively larger in Ex-base cations, especially in Ex-Ca and Mg. Level of the concentrations might have influenced the precision. Further investigation should be concentrated on consideration of the concentration levels. Some outliers in 2004 have values of ten times larger than the averages and others demonstrated low within-laboratory reproducibility. It was suggested that quality control within the laboratories and standard operating procedures and reporting system should be elaborated in such laboratories.

The inter-laboratories precisions of Ex-acidity were relatively high and stable through the projects, probably due to application of a simple procedure (titration). Coefficients of variation (CVs) among the laboratories were about 15%.

2.3.3.3 Conclusions

Parameters of soil acidity, such as pH(H_2O), pH(KCl), and Ex-acidity are the most important and informative for evaluation of soil acidification. Due to evident progress in laboratory operation these parameters were measured with relatively high inter-laboratories precision. Coefficients of variation (CVs) of pH(H_2O), pH(KCl) among the laboratories were less than 5 %, and that of Ex-acidity was about 15%. However, Ex-base cations are also important for evaluation of soil nutrient status and impacts on vegetation. The inter-laboratories precision was still relatively highly fluctuated depending on concentrations of the samples. Further efforts to improve precision should be made for future evaluation of soil acidification on a regional scale.

2.3.4 Inland aquatic environment

2.3.4.1 Outline

This project started in 2000 in the EANET region as one of the activities within the QA/QC programs. Sixteen laboratories participated in the project from ten countries: China, Indonesia, Japan, Malaysia (from 2004), Mongolia, Philippines, Republic of Korea, Russia, Thailand, and Viet Nam. One artificial inland water sample, which contains all analyte ions, was prepared by NC and distributed among the laboratories annually; samples No. 001, 011, 021, 031, and 041 of 1st (2000), 2nd (2001), 3rd (2002), 4th (2003), and 5th (2004) attempts, respectively. Obtained data on pH, EC, Alkalinity and concentrations of SO_4^{2-}, NO_3^-, Cl^-, Na^+, K^+, Ca^{2+}, Mg^{2+} and NH_4^+ were compared with the prepared values and statistically used to analyze the results. Alkalinity was included in the list of parameters since 2002.

Concentration ranges of parameters for the distributed samples were listed in Table 2.3.5.

Table 2.3.5 Mandatory parameters and their concentration range of simulated inland water sample

Parameter	Range	Parameter	Range
pH	5.5 – 8.5	Na^+	2 – 20 mg L^{-1}
EC	1.5 – 15 mS m^{-1}	K^+	0.2 – 2.0 mg L^{-1}
Alkalinity	0.05 – 0.5 meq L^{-1}	Ca^{2+}	1 – 10 mg L^{-1}
SO_4^{2-}	2 – 20 mg L^{-1}	Mg^{2+}	0.1 – 1.0 mg L^{-1}
NO_3^-	1 – 10 mg L^{-1}	NH_4^+	0.05 – 0.5 mg L^{-1}
Cl^-	1 – 10 mg L^{-1}		

2.3.4.2 Major outcomes

The inter-laboratory comparison surveys on inland aquatic monitoring were carried out 5 times so far. The results with the overall percentages of flagged data (refer to 2.3.2.2) year by year are presented in Figure 2.3.5. The results were similar to each other through the projects. The rate of data corresponded to DQOs was slightly decreased from 88.6% in the 2nd attempt (2001) to 79.5% in the 5th attempt (2004). Data of analyzed constituents except NH_4^+ showed relatively high accuracy. The total number of the flags was seriously dependent on the accuracy of NH_4^+ determination. Actually, several specific laboratories provided data with flagged values every time in recent years. Efforts should be made to improve the accuracy of their analysis.

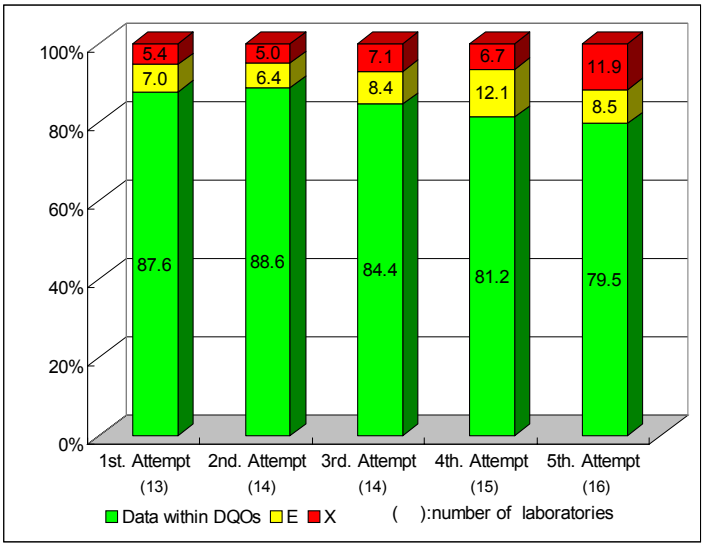

Figure 2.3.5 Rate of flagged data in the respective projects on inland aquatic environment

2.3.4.3 Conclusions

For such constituents of low concentrations, a contamination by poorly maintained instrument and measurement apparatus could be a crucial point. Moreover, it is also important to secure the reduction of background noise and to keep the linearity of calibration curve in analytical process. Appropriate concentrations of standard solutions should be prepared.

Inland water chemistry will be regarded as an output of biogeochemical process in their catchments, and provide us information on acidification of the terrestrial ecosystems. High quality chemical analysis of inland water would allow us to evaluate precise impacts of acid deposition on the ecosystems.

2.4 Evaluation of the measurements

2.4.1 Data flow for the reporting and qualification

The annual measurements in a participating country are subjected to the data qualification by its national committee of data evaluation. Some suspected datasets will be feedback to the analytical laboratories or appropriate organizations. The principal flow chart of data submission and verification is presented in Figure 2.4.1.

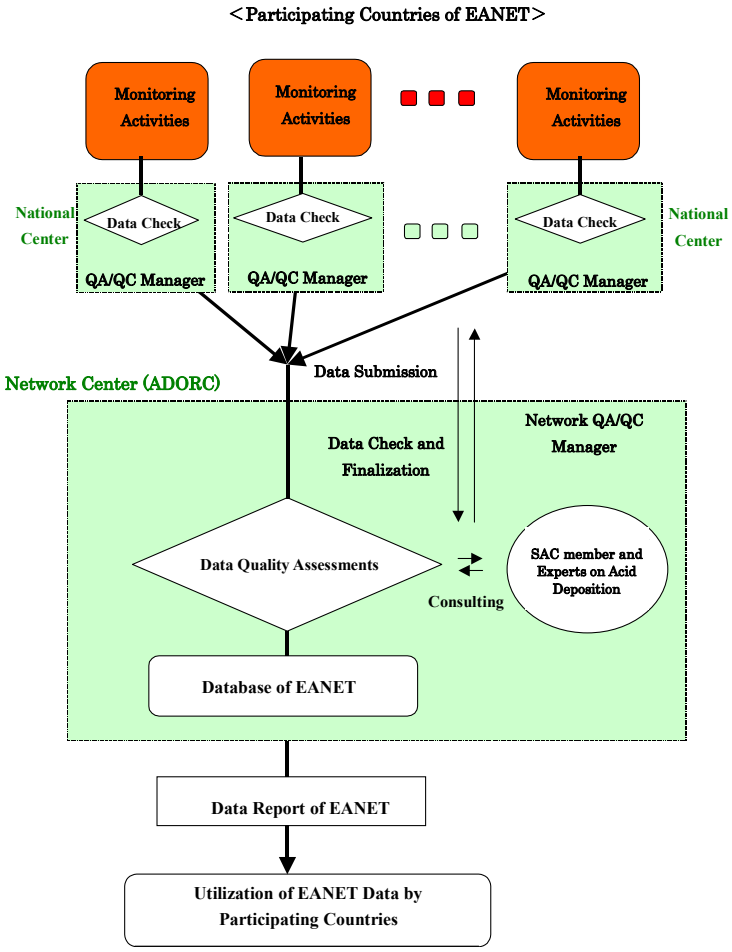

Figure 2.4.1 Flow Chart of EANET Monitoring Data

All datasets are eventually collected at the Network Center (NC) where the datasets are further examined and qualified through communications with national centers. The datasets qualified so far are submitted to the international data verification group for the final checking. The international experts of the monitoring activities qualify each of the datasets in a careful and detailed manner. After discussion between NC and national centers, the qualified datasets are submitted to the Scientific Advisory Committee to be scientifically and technically approved. The annual data report are actually completed after SAC consideration, which will be officially and finally approved by the Intergovernmental Meeting.

2.4.2 Judgment of valid data

All the data were checked in terms of ion balance (R_1) and the conductivity agreement (R_2) as presented in 2.2.5. If a sample or individual datum has problems including "insufficient sample volume" or "low precision", the flags corresponding to these problems were attached to the data. Details of data management are described in the "Quality Assurance/Quality Control (QA/QC) Program for Wet Deposition Monitoring in East Asia" adopted at the Second Interim Scientific Advisory group Meeting in March 2000.

2.4.3 Data completeness

Periodic reporting of mean concentrations and deposition should be based on the full operation measurements without any missing data, which would be actually inevitable in the long-term regional monitoring network activities. The quality of the annual and monthly means was , therefore, evaluated by setting two criteria of the data completeness. When the fraction of the missing data exceeds the first criterion but meets the second criterion, the annual or monthly mean was shadowed in the summary tables of the annual data reports. Of course, if the fraction even exceeds the second criterion, the mean was not approved as an official figure. In this way, the means are qualified in the tables for further analysis and interpretations.

2.4.4 Site representativeness

The characteristics of the individual site were reported by answers on a series of questions and photos from four or more directions. And the nature of the sites (e.g. urban, rural, remote, or ecological) were kept in mind for the analyses.

2.4.5 Overall data quality

Evaluation of the datasets from the four viewpoints mentioned above would have ensured that a large fraction of the measurements in the early stage are acceptable, and recent datasets are improved in the data quality.

2.5 Conclusion

Considerable developments have been made in the first five years of the regular operation. However, more efforts are encouraged to be made to settle the remaining problems in EANET region and also to solve some site-specific or area-specific problems including "poor" ion balance for samples with high pH and possible contribution of organic ions.

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Quality Assurance / Quality Control (QA/QC) Program for Wet Deposition Monitoring in East Asia.
Technical Manuals for Soil and Vegetation Monitoring in East Asia.
Technical Documents for Monitoring on Inland Aquatic Environment in East Asia including
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3. State of Acid Deposition in East Asia

Lead authors: *SeogYeon Cho, Muhamad Bin Awang*

CONTENTS

3.1 Introduction

Acid deposition is known as an environmental phenomenon that has expanded to vast areas of some regions in the world over the course of the industrialized era. Caused in most part by emissions of sulfur and nitrogen oxides being released into the atmosphere from the combustion of fossil fuels (including in transportation and other industrial processes), these pollutants are sometimes also released through natural processes that can contribute to acid deposition in certain regions under particular environmental conditions. These gases are transformed through chemical reactions in the troposphere into acidic compounds during their transport by atmospheric flows, and the compounds eventually fall back down onto ground as acidic precipitation and/or dry deposition. Starting in the atmosphere as anthropogenic byproducts, these compounds behave as natural ones do under the same influences of climate and geographical factors, such as the characteristics of ground surfaces, orography (average height of land), land use, and meteorological conditions, etc.

East Asia is a vast region that stretches from the northern mid-latitudes to the subtropics in the Southern Hemisphere. Considerable contrasts and differences exist between the countries in the region, including significant variability in topography, climate, population density, and industrial activities. Besides the anthropogenic influence on atmospheric chemistry and the excessive input of some compounds into ecosystems, the roles of natural driving forces in the atmosphere and other media are very important, and they should be taken into account as background processes in any scientific undertaking.

Once the most relevant knowledge available was examined on the variety of acids, bases, and their precursors emitted into the atmosphere from both anthropogenic and natural sources – including a number of precursors related to acid deposition such as sulfur dioxide (SO_2), nitrogen oxides (NO_x), ozone (O_3), and ammonia (NH_3) – countries participating in EANET began monitoring for these chemical species, even during the preparatory phase of the Network. Among the main goals of conducting this first overall assessment of the monitoring data collected between 2000 and 2004 was to produce an overview of the quality of data and to uncover any general characteristics related to acid deposition.

The input of acidic compounds on ecological objects and ecosystems through wet and dry deposition predominantly determines their impacts on ecosystems. Therefore, in order to determine these impacts it is critical to evaluate the integrity of ecosystems through long-term monitoring of precipitation, stream water, soil water chemistry, biomass accumulation, land-use changes in entire catchment areas, and modeling. A review of applicable theoretical frameworks and activities was first necessary to be able to extrapolate on the potential ecological impacts of acidic deposition already being experienced in the East Asian region. As well, scientific assessment of the baseline information being accumulated on soil, vegetation, and inland aquatic ecosystems will provide some useful conclusions and a basic evaluation of the state of the region's ecological health.

Many case studies have already been published on the different aspects of the impact of atmospheric acid deposition on the environment, including the following: some critical assessments of the loadings on sensitive forest species, streams, and other related aquatic ecosystems; evaluation of acidic depositions onto a forest canopy and the impact on the growth of trees; and the effects of soil acidification on forest species and ecosystems, etc. These contributions have significantly enriched the literature on the impacts of acidic deposition on ecological systems, and the knowledge obtained will be explored along with the data produced by ongoing, continuous monitoring.

3.2 Regional geography and climate

Lead author: *SeogYeon Cho*

Contributing authors: *Sergey Gromov, Shinji Nakayama, and Elena Gritsan*

CONTENTS

3.2.1 Introduction

Atmospheric pollutants that cause the acidification of precipitation come not only from anthropogenic sources but also from various natural processes and sources, such as volcanoes, hot springs, and lightning. The fallout of acidic compounds also occurs in certain regions due to particular environmental phenomena. Further to this, natural processes in the Earth's atmosphere affect the intensity of chemical transformation of precursor gases and their involvement in the transport and deposition of acidic compounds, adding to the distribution of deposition observed in the region. Therefore, the roles of natural driving forces in the atmosphere and other media are very important and should be taken into account as background processes that affect acidic deposition.

East Asia is characterized by considerable contrasts and differences between the areas of its extensive territories–which stretch from the boundaries of the northern circumpolar regions to the subtropics of the Southern Hemisphere–as well as by the significant variability in topographic relief, which ranges from high mountains to coastal plains and river deltas. These features may cause the appearance of acidification in specific ecosystems, a fact that should be kept in mind when investigating the experiences in other regions.

Regional geography and climate, obviously, have considerable influence on the spatial and temporal distribution of acid deposition over the EANET region. In contrast, the variability of climate regimes and meteorological conditions observed on seasonal and inter-annual bases affects acid deposition measurements by causing certain variations within data sets, as well as natural differences among measurement results collected at EANET monitoring sites. A brief description of the geography and climatology of East Asia is provided below, along with some information on particular features of natural conditions that should be taken into account during both evaluation of monitoring data on acid deposition and assessment of its impact in the EANET region.

3.2.2 General information on East Asia

Asia includes most parts of the Eurasian continent, traditionally defined as the landmass eastward from the Suez Canal, south of the Black Sea and the Caucasus Mountains, and to the east, from the Ural River and Ural Mountains. The whole area measures roughly 49.7 million square kilometers (including islands). Encompassing almost 30 percent of the world's land area, it is the most inhabited, being home to about 60 percent of the world's human population. The eastern part of the continent is the largest and most populated region, as are areas in its center (Figure 3.2.1). The areas with the largest emissions (caused by fuel combustion) mostly coincide with the territories that have higher population density, due to the necessity of supporting the lives of so many, as well as growing industrial activities, including energy, transport, and other services that consume fuel.

Several subregions of East Asia are traditionally recognized by geographers and demographers, although their boundaries are not clearly defined. The countries participating in EANET are located in East Asia, North Asia, and Southeast Asia, but countries like Russia have not yet provided a clear definition of what areas of their territories should be included in the EANET region (Figure 3.2.1).

Land surface altitudes range from the highest plateau of 4,000 meters–which climaxes in Tibet and is surrounded in the south by the Himalaya Mountains–to low plains of just a few meters above sea level. The mean altitude of the Asian continent is around 950 meters, the highest in the world. Mountain chains stretch across Asia, acting as natural boundaries and obstacles that separate areas with different geographical features, climates, potential land use, etc. The Tian Shan mountain range in Kyrgyzstan and China (at the northwestern edge) has steep, jagged peaks and clinging glaciers, and the Hindu Kush mountain range extends for around 800 kilometers through Central Asia.

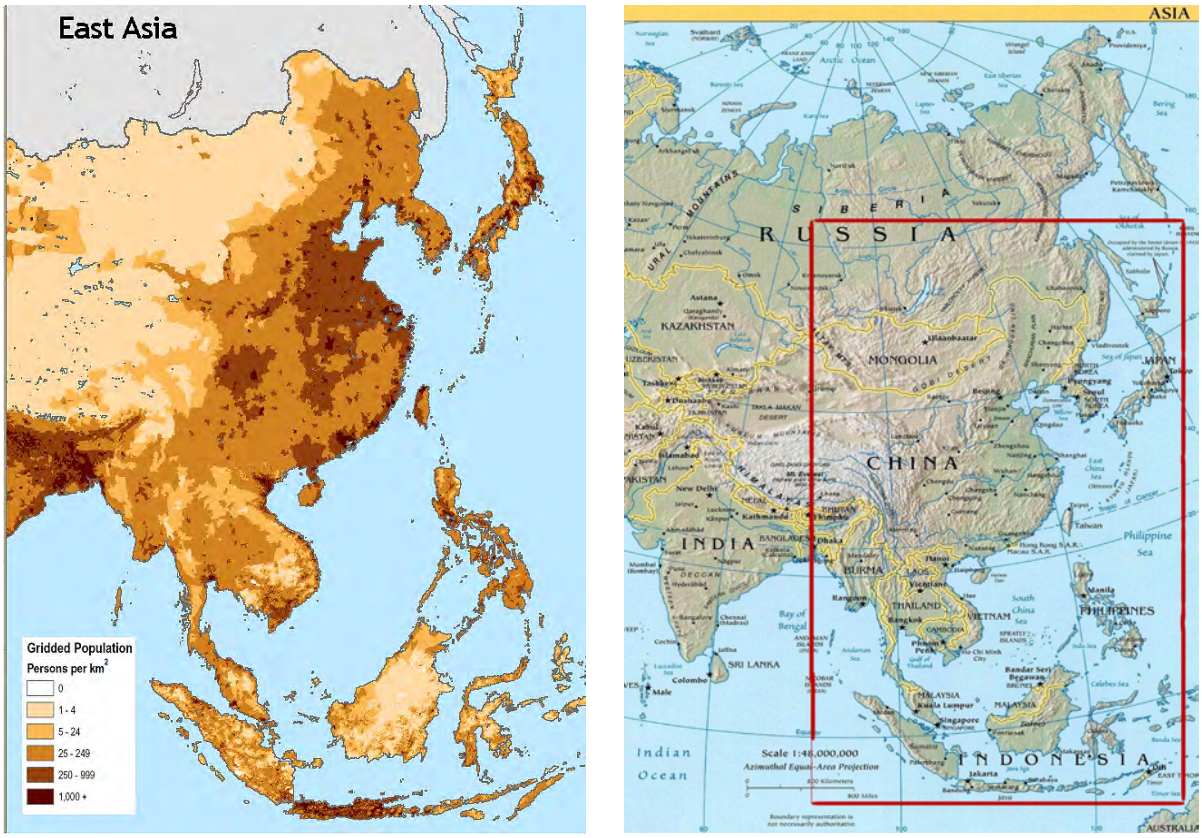

Figure 3.2.1 Population density in East Asia in 2000 (CIESIN, 2005) (*left*) and schematic of the EANET region overlaid on top of a map of the Asian continent (*right*)

These ridges and highlands are natural obstacles that cause changes to air mass flows and different climatic conditions between areas of the continent. These include the cold, arid regions of famous deserts, such as the Gobi, the Chang Tang, and the Taklimakan deserts in the highlands, and along the mountains to the north of the Himalaya. Lowlands cover most of the northern part (huge areas of Western Siberia) and the eastern sides of the continent, especially in China. The rugged, mountainous areas in Eastern Siberia and the Far East region are the most forested parts of the continent. The southeast territory includes plains surrounded by mountain ridges both on the continent and on the Malay Peninsula, as well as on a number of huge islands.

Besides the continental mainland, Asia includes many islands, some of which are the world's largest, such as Borneo and Sumatra, while others are the world's most populated, such as Java (Indonesia) and Honshu (Japan). Other islands are world-famous for being resorts, natural heritage sites, unique ecosystems, or for having other special features, including the following (among many others): Bali, Madera, and Sulawesi in Indonesia; Hokkaido, Shikoku, Kyushu, and Okinawa in Japan; Luzon, Cebu, and Mindanao in the Philippines; and Ko Pha Ngan and Ko Samui in Thailand.

Some areas along the West Pacific Ocean have volcanoes, which emit acid deposition precursors (gaseous compounds containing sulfur and nitrogen) into the atmosphere in amounts comparable to the anthropogenic emissions over highly industrialized areas. Islands of the Japan archipelago and Indonesia, for instance, are sometimes exposed to volcanic eruptions that release gases in harmful concentrations. These occasional, continuous, or pulsory events play a definite role in the spatial distribution of acid deposition over East Asia.

Some of the world's largest lakes and longest rivers are also found on the continent. Rivers in Asia generally originate in the high plateaus and break through the great mountain chains towards the peripheral lowlands. These include the Ob-Irtyshm, Yenisei-Argana, and Lena in Siberia, and the

Amur-Argan, Huang He, Yangtze, Xi, Mekong, Thanlwin, and Ayeyarwady in East and Southeast Asia. Lake Baikal in southern Siberia is famous for being one of the world's largest freshwater lakes, and is considered unique and important due to its high quality fresh water of considerable amount. As well, a number of other lakes on the continent and islands are very important economically, environmentally, and/or as wildlife habitat.

One of the most important natural assets in the EANET countries is the forests, which cover considerable land area. The percentage of forested areas in certain countries is higher, of course, than the average for the whole of Asia (Table 3.2.1), highlighting the critical importance of forest ecosystems and the fact that any potential damage to them should be carefully considered, together with the spatial density of population and industrial activities throughout the countries.

Table 3.2.1 Extent of forest and other woodland in 2005 (thousands of hectares) (FAO, 2005)

Country / Area	Land area					Inland water	Total area
	Forest		Other woodland	Other land			
	Area	% of land area		Total	With tree cover		
Cambodia	10,447	59.2	270	6,935	—	452	18,104
China	197,290	21.2	87,615	647,837	n.d.*	27,063	959,805
Indonesia	88,495	48.8	—	92,662	9,648	9,300	190,457
Japan	24,868	68.2	—	11,582	—	1,330	37,780
Malaysia	20,890	63.6	—	11,965	—	120	32,975
Mongolia	10,252	6.5	2,388	144,010	—	n.d.	156,650
Myanmar	32,222	49.0	10,834	22,699	—	1,903	67,658
Lao PDR	16,142	69.9	4,643	2,295	—	600	23,680
Philippines	7,162	24.0	3,611	19,044	—	183	30,000
Republic of Korea	6,265	63.5	—	3,608	—	53	9,926
Thailand	14,520	28.4	—	36,569	—	223	51,312
Russian Federation**	808,790	47.9	74,185	805,875	4,698	18,690	1,707,540
Vietnam	12,931	39.7	2,259	17,359	—	620	33,169
Total East Asia	244,862	21.3	90,003	812,891	n.d.	28,459	1,176,215
Total Asia	571,577	18.5	191,291	2,325,168	11,951	89,105	3,177,141
Total world	3,952,025	30.3	1,375,829	7,724,998	75,779	365,666	13,418,518

*No data
**Whole territory (including European part)

3.2.3 Climatology of East Asia

3.2.3.1 Specific climate phenomena affecting atmospheric deposition

a. Monsoon

One of the major peculiarities of atmospheric circulation over the East Asia region is the monsoon. Climatologically, *monsoon* is defined as a phenomenon whereby constantly occurring winds and air transport in the lower troposphere satisfy certain conditions, such as having a high frequency in the main season, and occupy a vast geographical space suitable to maintaining a generally circulating atmospheric wind system—and then reversing (or almost reversing) direction from winter to summer. The monsoon, having stable, seasonal winds with a changeable precipitation regime, has a major influence on the climates of the southern and southeastern coasts of Asia, as well as far into inland areas.

Two temporal parts of the East Asian monsoon can be distinguished: summer and winter. This is very different than the Indian subcontinent, which has no winter monsoon. There is considerable rainfall (occasionally heavy) and humid weather during the summer monsoon in East Asia, with slower

southwesterly winds most of the time, under the influence of a lower pressure depression in the lower troposphere layers over the inner regions of the Asian continent. This causes a convergence of flows in the lower atmospheric layers and air inflow from the ocean, effectively providing an increase in humidity. The summer monsoon starts to develop beginning in mid-May and continues until September or October in most territories. The amount of precipitation over the continent and islands above the latitude of 5°N is considerably higher during this period than in winter (Figure 3.2.2).

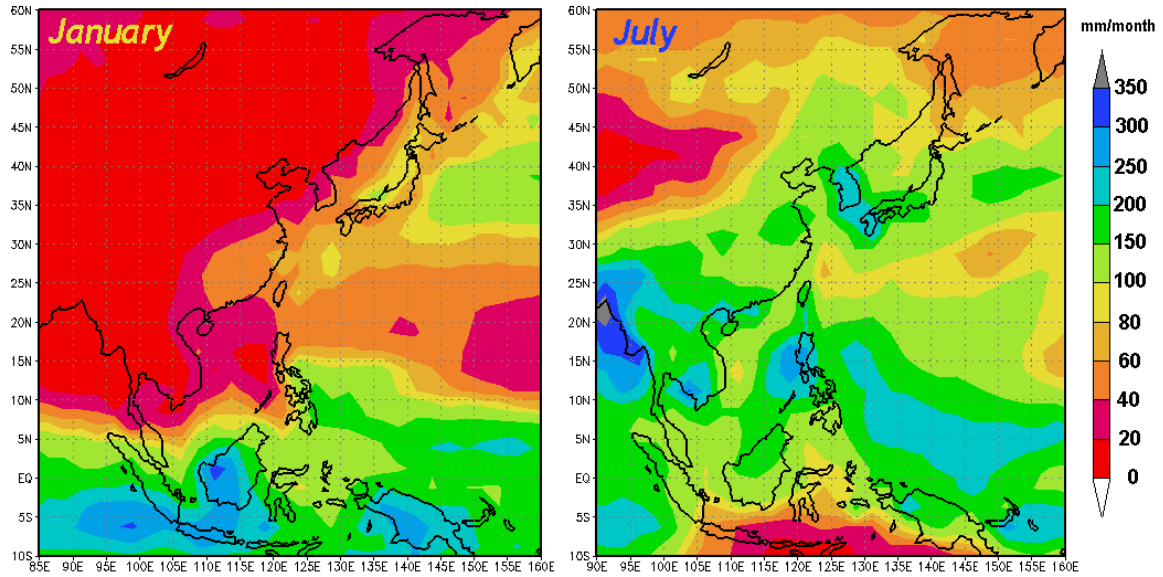

Figure 3.2.2 Seasonal changes in precipitation over the EANET region (1979–2005 average)

During the winter monsoon, the dominant northeasterly winds, which are highly stable for months, originate due to a vast anticyclonic circulation over the Siberian region. The winter monsoon brings dry weather by carrying air from the inner continent on winds from the north or northwest to the edges of East Asia. This large-scale circulation shifts the transformed continental air mass, characterized by cold temperatures and low humidity, to the east and south coasts of China and Indochina. The dominant wind switches in summer and blows from the seas, causing continuous hot and humid weather.

b. Typhoons

Tropical cyclones and typhoons are remarkable meteorological phenomena in much of the region, especially along the coast of the West Pacific Ocean. The strongest winds, tidal surges, and heaviest rainfall are experienced mostly in the coastal and island areas, although the influence of some cyclones extends into the interior of the Asian continent also. The islands in the Pacific and the Philippine archipelago are especially vulnerable to typhoons and cyclones. As the smallest islands here cannot deflect them and are not large enough to moderate general climatic circulation patterns, they are vulnerable to drought and other climatic events, which can destroy entire ecosystems. Up to 24 tropical cyclones are registered annually during the season from May to November.

3.2.3.2 Overview of the climate of East Asia

East Asia occupies a vast area, and the region experiences a considerable variety of climatic conditions. These varied climates include the bitter seasonal cold of the north latitudes; the hot, dry, continuous weather in the arid deserts of the middle and eastern parts of the continent; cooler mountainous areas; subtropical territories of warm, dry weather in Central Asia; wet, rainy seasons over the eastern coastal territories; and the hot, humid conditions of the tropical south.

Several different systems for classifying climate types were provided by climatologists over the last

century. The most famous one, prepared by Wladimir Köppen and improved further by other scientists, is based on the regimes of temperature and precipitation, and it is used below to provide an overview of climatic variations over East Asia (Figure 3.2.3).

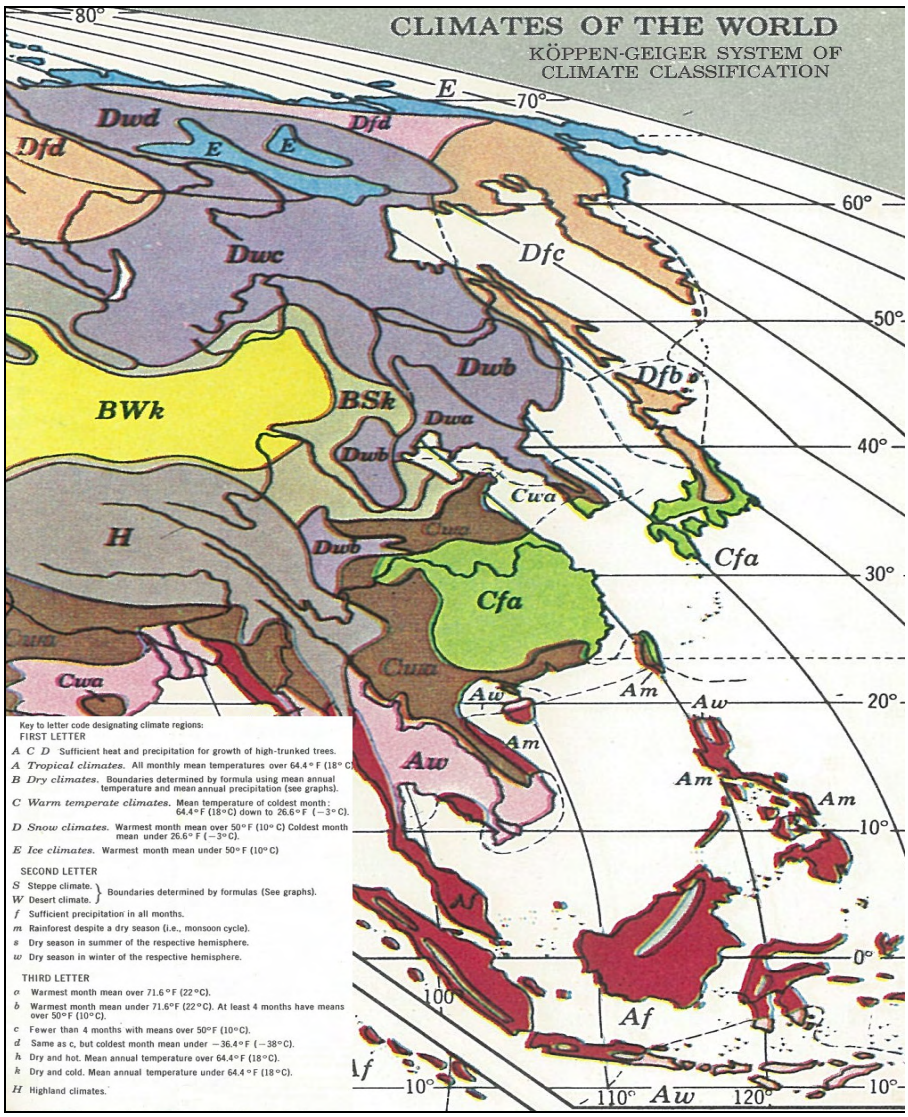

Figure 3.2.3 Distribution of climate features over the EANET region according to the Köppen-Geiger classification system (Strahler, 1969)

a. Northeast Asia

Northeast Asia is usually described as a subregion that consists of parts of Russia (Eastern Siberia and the Russian Far East) and Mongolia. This extensive region, located north of the 45ºN line of latitude, experiences snow cover for up to six months. This major territory is characterized by permanently frozen subsoil up to depths of several hundred meters. The annual average temperature over most of Siberia is around the freezing point or below. According to Köppen's climate classification system, this subregion is characterized as the *Dw* class (mid-latitude snow climate with dry, cold winter) and is found in the northern and western parts of the EANET region.

Most of Russia experiences only two main seasons (summer and winter) with very short intervals of moderation between them. This area has little exposure to ocean influence, and most parts of East Siberia receive low to moderate amounts of precipitation. The average annual number of days with snow cover, a critical factor for agriculture, varies from 120 to 250 days in Siberia, depending on both

latitude and altitude.

Mongolia's climate is determined by its highlands, extreme inner continental weather (cool and dry), and its long, cold winters and short summers (when most precipitation falls). A stable and extensive winter system of high atmospheric pressure usually appears annually, with its center located over the country. Average precipitation levels vary from a high in the north of 200–350 millimeters per year (mm/yr) to lower amounts in the south of 100–200 mm/yr. Extreme dry conditions exist over the arid southern areas of the Gobi Desert, where some regions receive no precipitation at all most years.

b. East Asia

According to Köppen's classification system, the *Cf* type of climate (mid-latitude and rainy, mild winters) and the *Cw* type (mid-latitude and wet with dry, mild winter) are predominant in the central part of East Asia. Monsoon winds are dominant in this region, determining alternating seasonal changes (moist in summer, dry in winter) due to the sharp turns executed by air-mass movements. The behavior of the monsoons is considered responsible for the dependable return of the rainy season and the large amount of rainfall they bring throughout this region.

Differences in latitude, distance from the sea, and altitude, however, give rise to sharp variations in precipitation and temperature. China, the largest country in Asia, for example, experiences a complexity of climatic patterns (although most of its territory lies in the temperate climate zone). Its northernmost point, at Heilong Jiang in Heilongjiang Province, is in the cold-temperate zone, while the climate of its southernmost point, Hainan Island, is tropical. The middle of China and the Republic of Korea both have temperate climates with four distinct seasons and considerable temperature differences in the winter, but less diversity in summer. Precipitation varies regionally even more than temperature. South China, for example, has abundant rainfall, most of it coming with the summer monsoon, while the rainfall regime in areas in the northern and western parts is more uncertain. Generally, Korea has sufficient rainfall for the most part (over 1,000 mm/yr), but total precipitation can vary from year to year. Typically, several typhoons a year can be expected to drop torrential rains on Korea, Japan, and the east coast of China in summer and early autumn.

c. Southeast Asia

The region of Southeast Asia has widely varying tropical monsoon climates, with predominating classes of *Aw* (tropical wet and dry climate) and *Am* (tropical monsoon climate), according to Köppen's system of climate classification. The southwest monsoon brings the rainy season, from May or July to September or October, and the northeast monsoon flow of drier and cooler air lasts from November to March. The monsoonal airflows are caused by seasonal alternations of atmospheric pressure systems over the central parts of the Asian continental landmass (high-pressure anticyclone in winter and low pressure in summer) interacting with general air circulation over oceans. During the summer monsoon, the heavy, moist air is driven landward from the southwest, mostly from the Indian Ocean. The airflow changes during winter, reversing direction, and this northeast monsoon carries dry air from the continent. The average annual temperature is generally higher over the plains than in the mountains and plateaus. Temperatures begin to rise in January, and a hot sun begins to parch the landscape. Average temperatures normally range from high annual values of around 40ºC to 18ºC in March. Minimum temperatures rarely fall below 10ºC in the northern parts and mountainous areas in January. The dry season is shortest in the southern parts, especially over the Malay Peninsula because of the proximity of all its parts to the sea.

d. Pacific Ocean Islands

There are many islands located between Eurasia and Australia along the boundaries of the Pacific Ocean and Indian Ocean, but their climates tend to vary considerably from place to place because of the differences in their latitudes, their topographical features, and other forces that influence climate. According to Köppen's system, *Af* (tropical rain forest) is predominant in Indonesia and the

Philippines, while *Cf* (mid-latitudes, rainy and mild winter) and *Df* (with snow in northern and mountain regions) are predominant in Japan.

The variations in rainfall are related to the behavior of the monsoons. In Indonesia, for example, winds are moderate, with monsoons usually blowing in from the south and east in June through September, and from the northwest in December through March. There is a dry season (June to September), influenced by Australia's continental air masses, and a rainy season (December to March). In July and August, high pressure over the Australian desert moves winds from that continent toward the northwest. During January and February, the monsoon blows with humid breezes from the Indian Ocean, producing significant amounts of rain throughout many parts of the archipelago. In the Philippines, the summer monsoon brings heavy rains to most of the archipelago from May to October, whereas the winter monsoon brings cooler and drier air from December to February. Japan is generally a rainy country with high humidity, although it has a variety of climates because of its wide range of latitude. The generally humid, temperate climate exhibits marked seasonal variation as well as regional variations that range from cool in Hokkaido to subtropical in Kyushu. Climate also varies with altitude and location on the Pacific Ocean and the Sea of Japan.

3.2.3.3 Meteorological conditions at EANET monitoring sites

The countries participating in EANET are requested to regularly collect meteorological data together with monitoring data and submit their results annually. The set of meteorological data includes measurements of temperature, humidity, wind speed, wind direction, amount of precipitation, duration of sunshine, and amount of solar radiation. EANET sites have been tentatively classified into the following four regions (as presented above):
- Northeast Asia (includes Russia and Mongolia)
- Central part of continental East Asia (includes China and the Republic of Korea)
- Southeast Asia (includes Cambodia, Lao PDR, Malaysia, Thailand, and Vietnam)
- Pacific Ocean Islands (includes Indonesia, Japan, and the Philippines)

An outline of averaged meteorological conditions at EANET sites is presented in Table 3.2.2.

Due to the considerable diversity of geography and climatic regimes throughout the EANET region, overviewed above, differences in specific meteorological conditions can be expected in each area. Figure 3.2.4 provides an overview of the multi-year probability of wind directions at EANET monitoring sites, while average monthly precipitation and temperature are presented further in Figures 3.2.5–3.2.7.

Table 3.2.2 Multi-year average monthly meteorological conditions at EANET monitoring sites

Country / Site		Temperature (C°) monthly mean			Humidity (%) monthly mean			Mean wind speed	Year precipi-tation	Sun-shine	Solar radiation	Years of data
		Year	Max	Min	Year	Max	Min	m·sec^{-1}	mm·	hours	MJ·m^{-2}	
Northeast Asia												
Mongolia	Ulaanbaatar	-0.1	21.9	-25.4	62	92	41	1.7	221	232	—	2001-2003
	Terelj	-3.8	16.4	-28.4	71	85	56	1.5	341	—	—	2001-2003
Russia	Mondy	-09	16.7	-22.3	66	79	48	1.8	360	207	251.3	2000,2002-2004
	Listvyanka	0.4	18.5	-20.4	75	87	53	3.4	428	—	408.2	2000,2002-2004
	Irkutsk	1.3	20.5	-23.4	71	88	48	2.1	445	177	320.3	2002-2004
	Primorskaya	2.6	19.4	-23.4	74	88	59	2.0	785	—	—	2002-2004
Central part of East Asia												
China	Chongquing	18.7	29.6	8.1	80	88	68	1.6	1,212	83	—	2002-2004
	Xi'an	15.0	28.9	0.2	65	82	49	6.9	961	150	—	2002-2004
	Xiamen	21.3	19.3	12.2	78	86	64	3.4	1,138	172	—	2002-2004
	Zhuhai	23.2	29.7	14.7	79	86	62	2.8	1,837	175	—	2002-2004
Republic	Kangwa	10.9	24.6	-6.2	66	89	52	1.7	1,285	221	—	2000-2004
of Korea	Cheju	15.5	27.3	4.3	73	92	62	7.4	1,225	164	447.7	2000-2004
	Imsil	11.4	24.9	-4.4	70	83	59	1.1	1,532	200	—	2001-2004
Pacific Ocean Islands												
Indonesia	Jakarta	29.8	31.0	28.5	69	76	64	1.0	1,595	—	—	2000
	Kototabang	21.5	22.3	20.7	87	92	80	2.1	2,340	120	—	2000
Japan	Rishiri	6.6	21.2	-8.0	76	89	66	4.1	821	—	244.3	2000-2004
	Tappi	10.0	23.5	-2.8	73	88	61	7.1	1,196	—	284.3	2000-2004
	Sado-seki	13.3	26.6	0.8	70	82	56	5.6	1,195	—	285.6	2000-2004
	Happo	3.5	16.7	-10.8	79	93	57	3.6	2,429	—	312.2	2000-2004
	Ijira	13.4	25.5	0.7	88	96	71	0.7	2,613	—	284.5	2000-2004
	Oki	14.6	26.5	3.3	74	84	64	3.5	1,075	—	310.4	2000-2004
	Banryu	15.2	26.4	4.2	75	85	63	3.1	1,524	—	319.7	2000-2004
	Yusuhara	12.2	23.3	-0.1	78	91	58	2.3	2,626	—	346.4	2000-2004
	Hedo	22.2	28.8	15.4	76	86	64	4.6	1,927	—	352.5	2000-2004
	Ogasawara	19.1	26.2	4.1	79	93	62	2.5	1,490	—	325.4	2000-2004
Philippines	Metro Manila	27.8	29.8	25.4	79	89	68	1.6	2,596	185	—	2002,2003
	Los Banos	27.6	29.5	25.5	83	90	76	2.3	1,986	181	566.9	2000-2003
Southeast Asia												
Malaysia	Petaling Jaya	27.9	29.2	26.6	78	82	74	0.4	3,376	—	—	2000
	Tarah Rata	17.8	18.5	17.1	91	93	88	1.7	3,128	—	—	2000
Thailand	Bangkok	28.1	31.1	24.6	86	96	66	0.9	1,535	—	374.3	2000-2004
	Samutprakarn	29.4	32.6	26.7	75	90	62	1.2	1,325	192	531.9	2000-2004
	Pathumthani	—	—	—	—	—	—	1.8	1,248	170	—	2000-2004
	Khanchanaburi	26.8	30.9	23.0	78	88	59	3.6	1,666	—	—	2000-2004
	Chiang Mai	25.6	30.3	19.9	74	91	48	7.2	1,111	—	474.2	2002-2004
Viet Nam	Hanoi	24.4	30.0	16.2	79	86	67	3.2	1,631	113	—	2000-2002,2004
	Hoa Binh	23.9	29.2	16.2	82	87	77	1.4	1,854	135	—	2000-2004

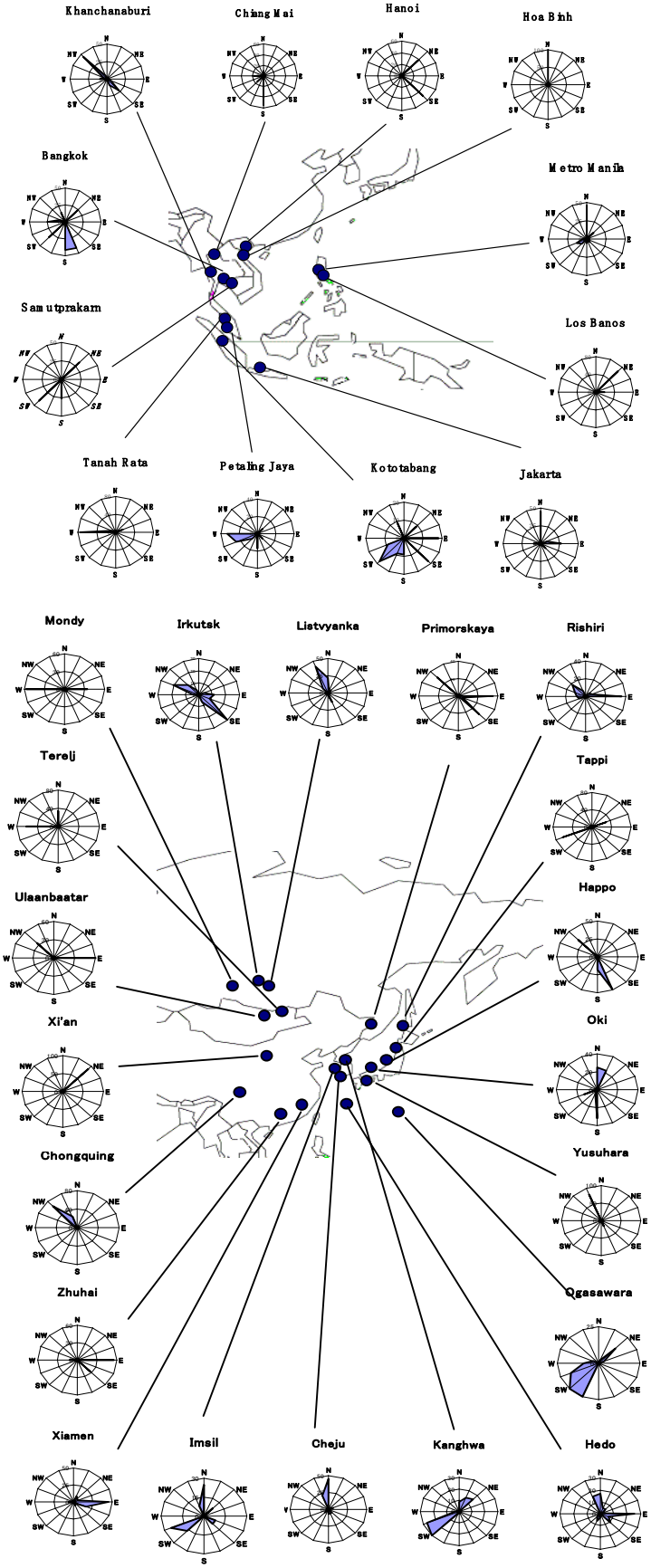

Figure 3.2.4 Annual probability of near surface wind directions at EANET sites

3.2.4 Variability of precipitation observed at EANET monitoring sites

3.2.4.1 Spatial variability over the EANET region

The regime of precipitation is one of the factors determining the amount of wet deposition, and additionally may influence the major ion concentrations in rainwater. The EANET monitoring network covers regions with low levels of precipitation, such as Russia, Mongolia, and northern central China, as well as tropical rainy regions, such as the Philippines and Malaysia. Monitoring sites in Ulaanbaatar and Terelj in Mongolia, as well as Mondy, Listvyanka, Irkutsk, and Primorskaya in Russia, mostly receive less than 500 mm/yr of precipitation (Table 3.2.2, Figure 3.2.5). On the other hand, the precipitation in Petaling Jaya and Tanah Rata in Malaysia, and Metro Manila in the Philippines exceeds 2,000 mm/yr (Figures 3.2.6–3.2.7).

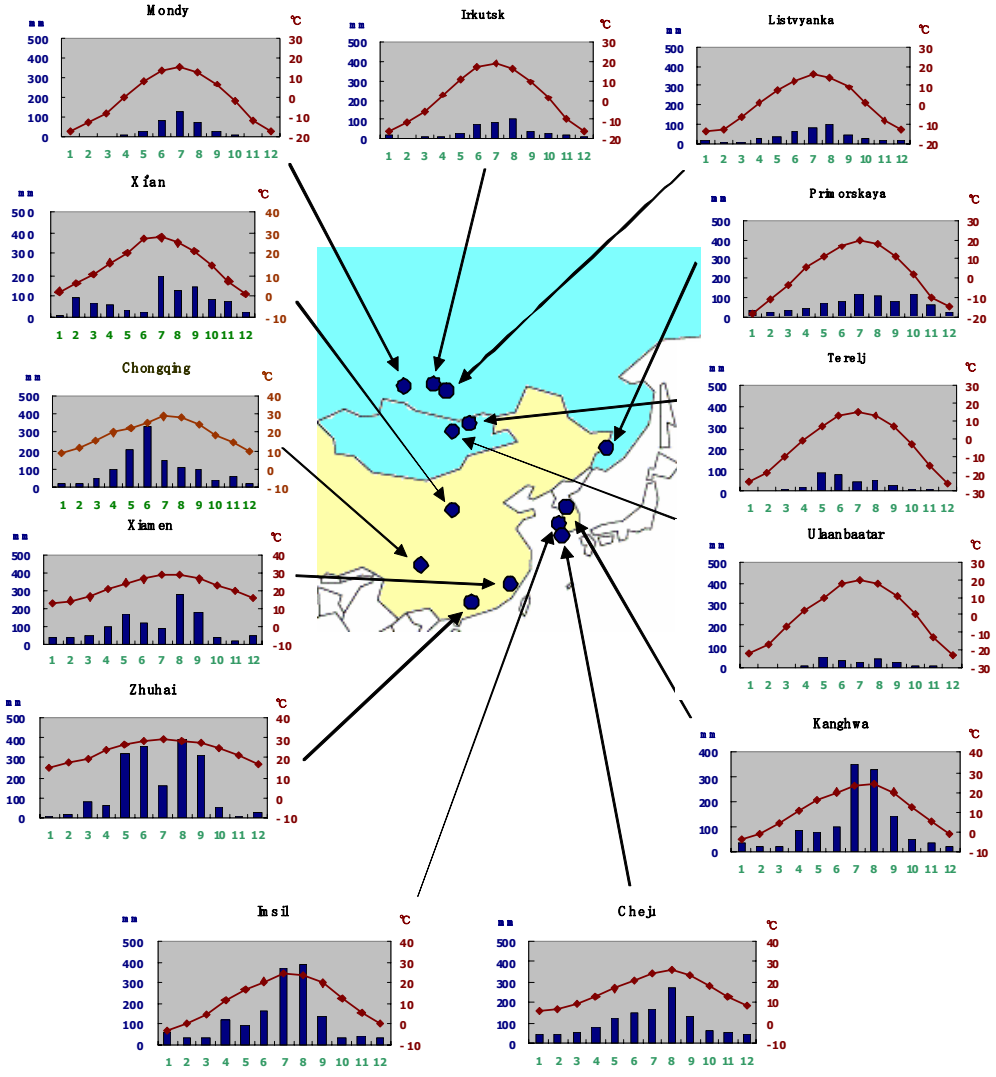

Figure 3.2.5 Monthly precipitation and temperature at EANET monitoring sites in Russia, Mongolia, China, and the Republic of Korea

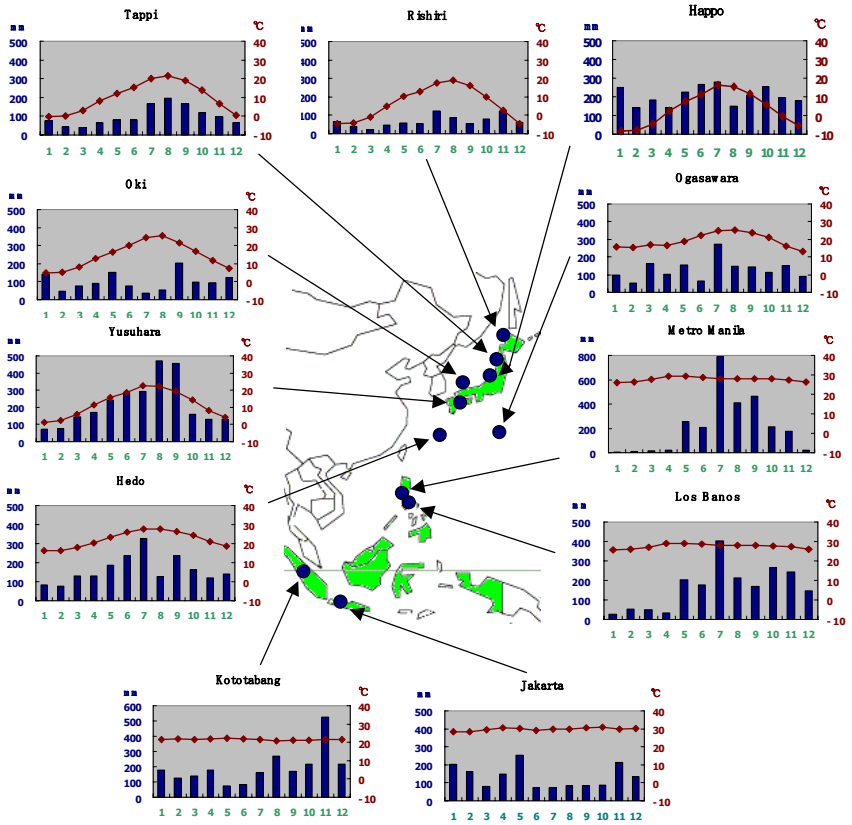

Figure 3.2.6 Average monthly precipitation and temperature at EANET monitoring sites in Japan, the Philippines, and Indonesia

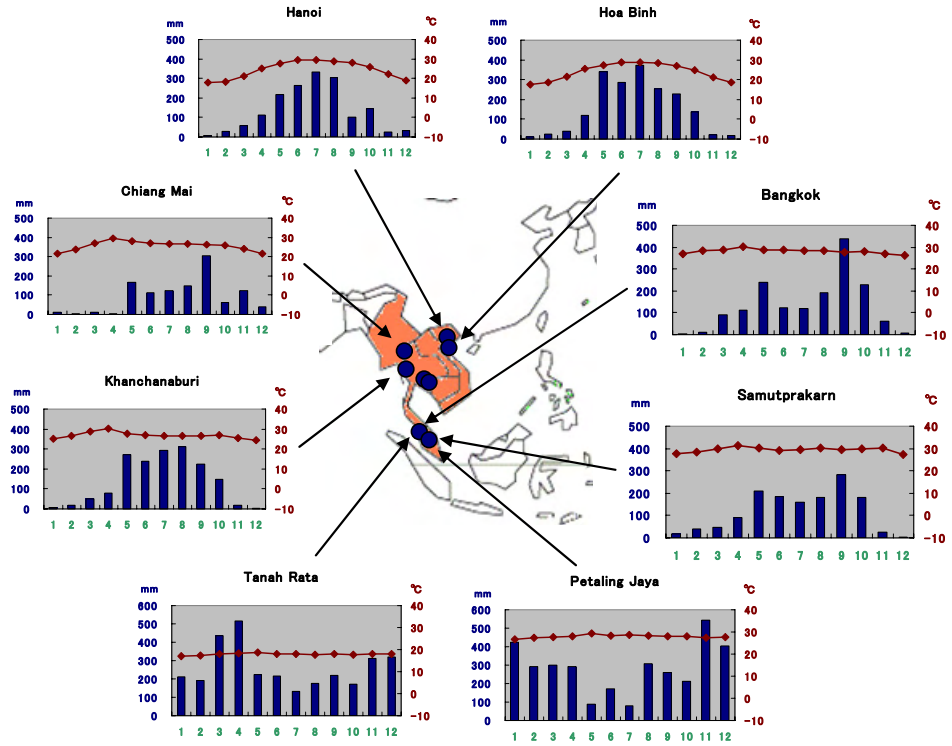

Figure 3.2.7 Average monthly precipitation and temperature at EANET monitoring sites in Thailand, Vietnam, and Malaysia

3.2.4.2 Temporal variability at EANET monitoring sites

In addition to spatial variation, the amount of precipitation changes considerably from year to year. Here, the annual change in precipitation (ΔP_a) is defined for successive years as follows:

$$\Delta P_a = \frac{P_i - P_{i-1}}{P_{i-1}} \qquad (3.2.1)$$

where P_i denotes the amount of precipitation in a given year and P_{i-1} denotes the amount of precipitation in the previous year. The defined inter-annual change in precipitation, averaged from 2000 to 2004, was found to be as large as 0.39. The year-to-year change of precipitation of more than 0.5 was recorded at 11 out of a total of 45 sites. These changes in annual precipitation should be carefully considered when analyzing the multi-year trend of wet deposition amounts as well as norm values.

The annual amount of precipitation significantly increased in the year 2003 at most sites in Korea, Mongolia, Russia, and one site in China (Figure 3.2.8). The decrease in precipitation in 2002 boosted the inter-annual change in precipitation in 2003.

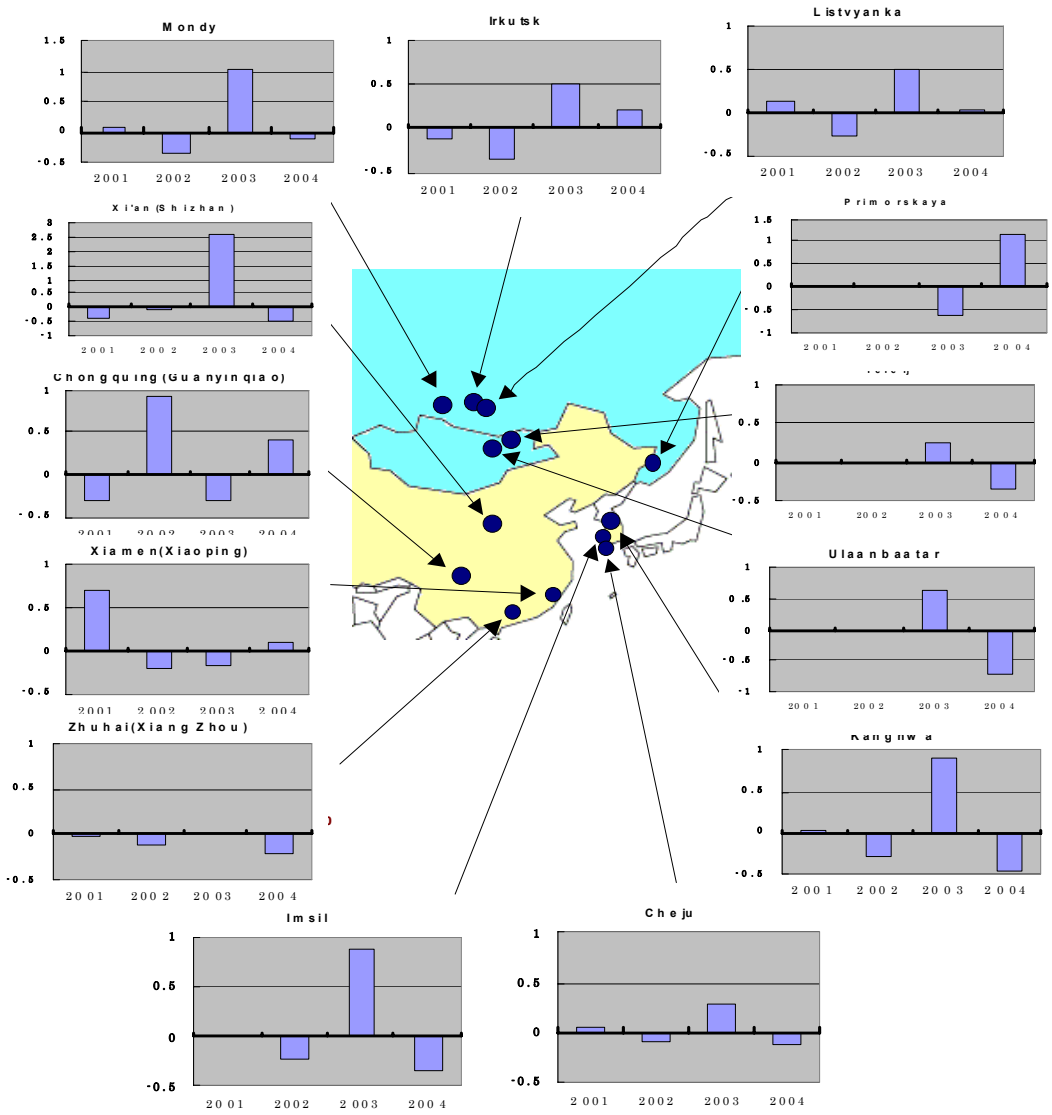

Figure 3.2.8 Inter-annual change in precipitation (ΔP_a) at EANET monitoring sites in China, Mongolia, the Republic of Korea, and Russia in 2000-2004.

The inter-annual change of precipitation was less than 0.5 at all sites in Japan, except Rishiri. And no significant increase in the annual amount of precipitation was observed at most sites in Japan in 2003 (Figure 3.2.9), despite the fact that they are in close proximity to the monitoring sites in Korea, Mongolia, and Russia where it was recorded evidently. Instead, the annual precipitation amounts increased for 2002 and 2004 at northern sites in Japan. The changes of annual precipitation were also less than 0.3 at all sites in the Philippines and Indonesia, except Kototabang. The reason for these smaller changes in annual precipitation at the sites in the archipelagoes than in the continental areas is because these sites are located in areas with higher precipitation and marine influence. The amount of precipitation in the arid regions tends to fluctuate more from one year to the next.

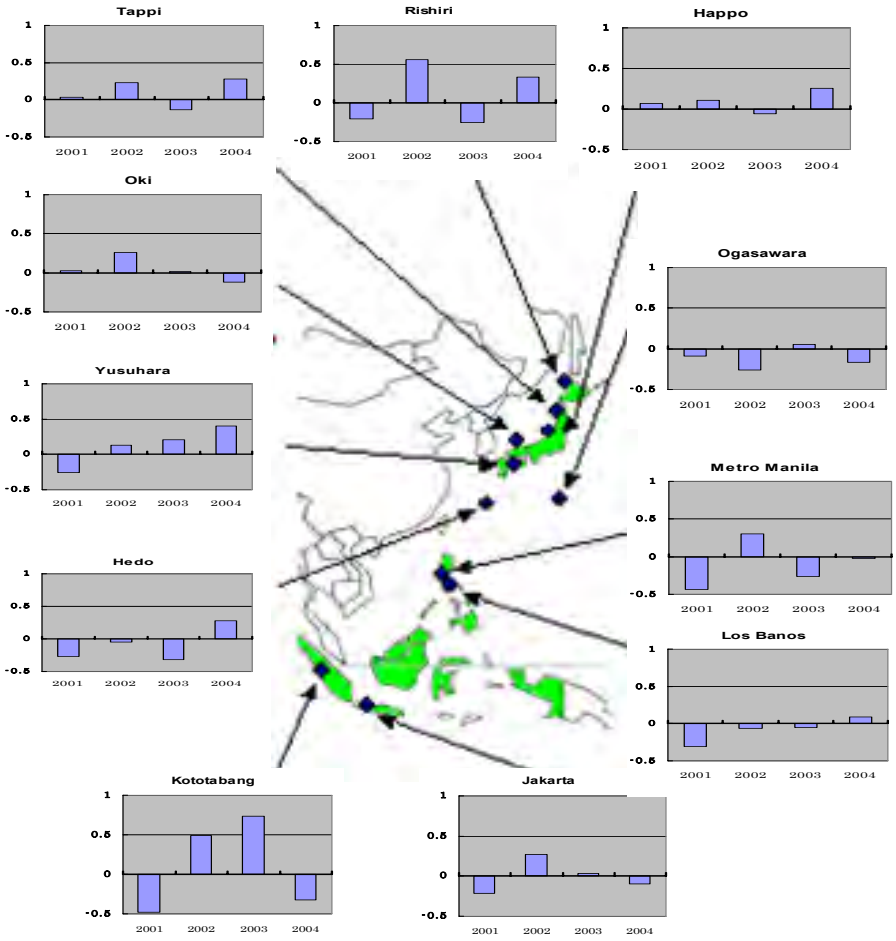

Figure 3.2.9 Annual change in precipitation (ΔP_a) at EANET monitoring sites in Japan, the Philippines, and Indonesia

The inter-annual changes in precipitation in Thailand, Vietnam, and Malaysia appeared to vary widely from one site to another (Figure 3.2.10), making it difficult to discern a trend in annual precipitation amounts in this tropical monsoon climate region. Inconsistencies in the year-to-year changes in precipitation over the same region may significantly hamper analysis of the temporal trend of wet deposition.

The significant variability of inter-annual change in precipitation amounts demonstrated above influences the total amount of wet deposition in the same area, making it difficult to detect temporal trends. The intensity of annual fluxes in most territories is determined by precipitation, so the possible impacts of climate change should be taken into account when assessing long-term monitoring data.

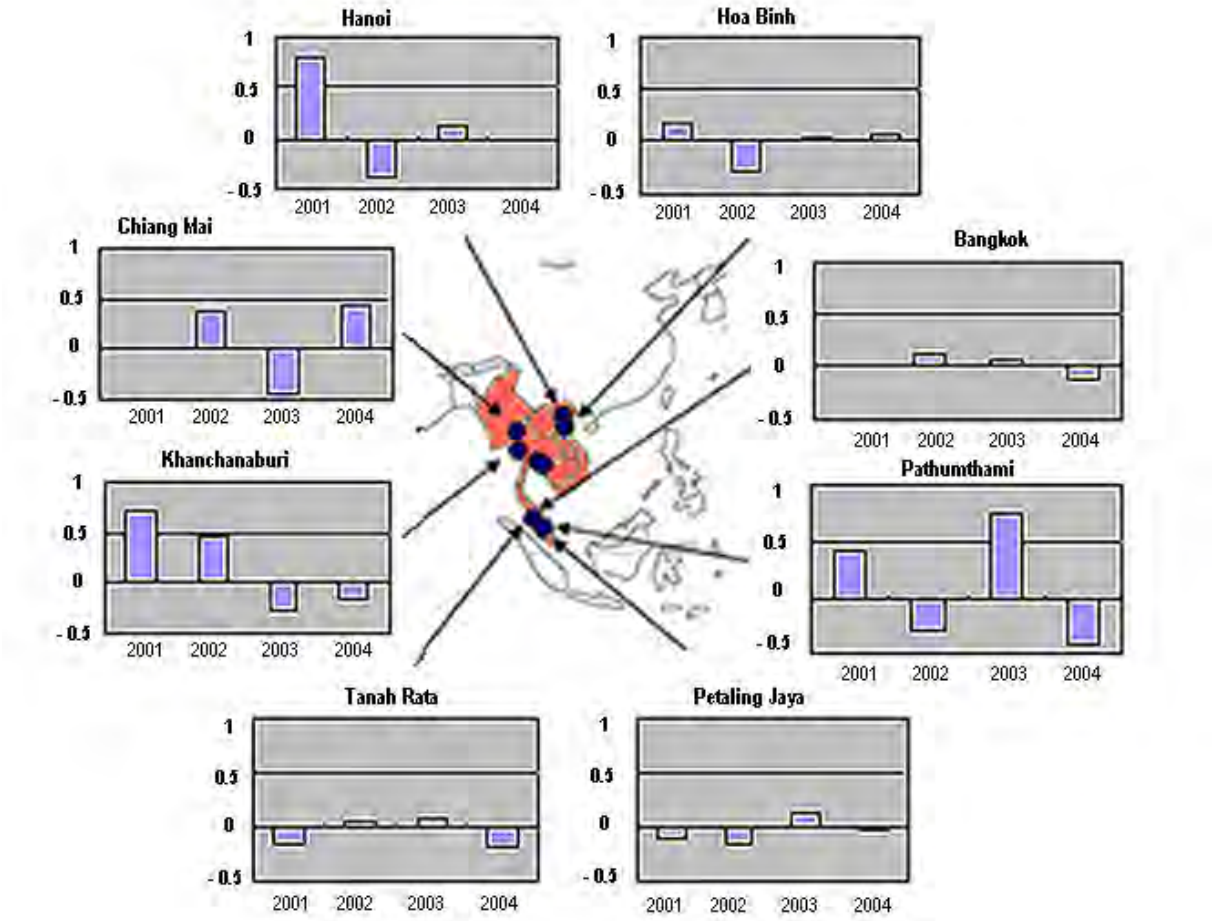

Figure 3.2.10 Changes in annual precipitation (ΔP_a) at EANET monitoring sites in Thailand, Vietnam, and Malaysia

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3.3 Atmospheric Deposition

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CONTENTS

3.3.1. Introduction

A variety of acids, bases and their precursors are emitted to the atmosphere both by anthropogenic and natural sources. The chemical species related to acid depositions are SO_2, NO_x, O_3 and NH_3 in the gas phase and sulfate, nitrate, NH_4^+ in the aerosol phase. The gaseous SO_2 and NO_x are precursors of sulfate and nitrate aerosols, respectively, and the gaseous O_3 plays an important role in photo-chemically producing H_2SO_4 and HNO_3 through the photo-chemical reactions below (Stockwell, 1986). In line with goals of the Network EANET has begun monitoring of these chemical species since the preparatory phase.

$$O_3 + h\nu(< 240\ \text{nm}) \rightarrow O_2 + O(^1D) \quad (3.3.1)$$

$$O(^1D) + H_2O \rightarrow 2\ OH \quad (3.3.2)$$

$$SO_2 + OH\ (+H_2O, O_2) \rightarrow H_2SO_4 + HO_2 \quad (3.3.3)$$

$$NO_2 + OH \rightarrow HNO_3 \quad (3.3.4)$$

The H_2SO_4 and HNO_3 undergoes complex gas and aerosol phase chemical processes to form various salts, The salts produced in these reactions may be in the solid and aqueous forms depending on thermodynamics (*a* and *g* denote below the aerosol and gas phases correspondently).

$$HNO_3(g) + NH_3(g) \rightarrow NH_4NO_3(a) \quad (3.3.5)$$

$$\text{Sulfate}(a) + 2NH_4^+(a) \rightarrow (NH_4)_2SO_4(a) \quad (3.3.6)$$

$$\text{Sulfate}(a) + Ca^{2+}(a) \rightarrow CaSO_4(a) \quad (3.3.7)$$

The gaseous acids and bases and salt aerosols are incorporated into the cloud or rain droplets to affect the chemical compositions. In addition, the SO_2 absorbed into cloud or rain droplets may react with dissolved oxidants to produce sulfates as listed below. The H_2O_2 in the droplets is appeared either by its absorption from gas phase or as a result of aqueous chemical reactions by recombination of HO_2 radicals (Chameides and Davis, 1982).

$$SO_2(aq)\ (+ H_2O) \rightarrow HSO_3^-(aq) + H^+(aq) \quad (3.3.8)$$

$$HSO_3^-(aq) + H_2O_2(aq) \rightarrow \text{multistep} \rightarrow SO_4^{2-}(aq) + H^+(aq) \quad (3.3.9)$$

The measured compounds of acid deposition monitoring should include major acids, bases, and salts in the gas, aerosol and water (of cloud droplet) phases as well as oxidants producing these acid deposition related species. Therefore, SO_2, NO_2, O_3, mass and chemical compositions of PM10 (suspended particulate matter of diameter less then 10 μm)are monitored at the EANET sites as a part of dry deposition monitoring as well as precipitation amount, pH, electric-conductivity, and ion concentrations contained in rain water as a part of wet deposition monitoring. The monitoring data collected from the year 2000 to the year 2004 are described in this section to mainly overview the quality of data and to show general characteristics related to acid deposition.

3.3.2 Gas and aerosol chemistry

EANET had 34 air-monitoring sites in operation (9 urban, 12 rural, and 13 remote) from 2000 to 2004 in the ten countries that participated during that period. (The chemical species monitored, along with the monitoring methods and site classifications employed, are listed in Table 3.3.1.) It should be noted that 8 of the 13 remote sites were located in Japan, highlighting the fact that there is still a need to establish additional remote monitoring sites in more parts of the whole region.

Table 3.3.1 Sampling methods and parameters of air concentration ('dry deposition') monitoring

Country	Site	Category	Automatic monitors			Filter pack
			SO_2, NO_x	O_3	PM	
China	Jinyunshan (Chongqing)	Rural	○*	None	○	None
	Weishuiyuan (Xi'an)	Rural	○	None	○	None
	Hongwen (Xiamen)	Urban	○	None	○	None
	Xiang Zhou (Zhuhai)	Urban	○	None	○	None
Indonesia	Serpong	Rural	None	None	None	○ (2001) **
Japan	Rishiri	Remote	○	○	○	○ (2002)
	Tappi	Remote	○	○	○	○ (2003)
	Sado-seki	Remote	○	○	○	○ (2003)
	Happo	Remote	○	○	○	○ (2003)
	Ijira	Rural	○	○	○	○ (2003)
	Oki	Remote	○	○	○	○ (2002)
	Banryu	Urban	○	○	○	○ (2003)
	Yusuhara	Remote	○	○	○	○ (2003)
	Hedo	Remote	○	○	○	○ (2003)
	Ogasawara	Remote	○	○	○	○ (2003)
Malaysia	Petaling Jaya	Urban	None	None	None	○
	Tanah Rata	Remote	None	None	None	○
Mongolia	Ulaanbaatar	Urban	None	None	None	○
	Terelj	Remote	None	None	None	○
Philippines	Metro Manila	Urban	None	None	None	○
	Los Baños	Rural	None	None	None	○
Korea	Kanghwa	Rural	○	○	○	○ (2001)
	Cheju (Kosan)	Remote	○	○	○	○ (2001)
	Imsil	Rural	○	○	○	○ (2001)
Russia	Mondy	Remote	None	○	None	○
	Listvyanka	Rural	None	None	None	○
	Irkutsk	Urban	None	None	None	○
	Primorskaya	Rural	None	None	None	○ (2001)
Thailand	Bangkok	Urban	○	None	○	○ (2003)
	Patumthani	Rural	None	None	None	○ (2003)
	Vachiralongkorn Dam	Remote	○	○	○	○
	Chiang Mai	Rural	○	○	○	○
Vietnam	Hanoi	Urban	None	None	None	○
	Hoa Binh	Rural	None	None	None	○

*A circle denotes an application of parameter or method for operating monitoring
**Parentheses denote the year (before 2005) that monitoring began.

More than one monitoring method was adopted, depending on the availability of equipment in each country participating in EANET. Gaseous species and PM (suspended particulate matter) were monitored using automatic instruments in China, Japan, and Korea, while these were monitored using the filter pack method in Malaysia, Mongolia, the Philippines, Russia, and Vietnam. Thailand used automatic monitoring instruments at three sites and the filter pack method at one site. The sites in China and in Thailand (Bangkok) did not monitor O_3. The site in Russia (Mondy) used automatic instruments to monitor O_3 levels, while the filter pack method was used for monitoring other species. Gaseous NH_3 (one of the major bases) along with calcium carbonate were monitored by filter pack at the sites in Malaysia, Mongolia, the Philippines, Russia, Vietnam, and Thailand.

Although SO_2 and NO_x are major precursors for sulfuric acid (H_2SO_4) and nitric acid (HNO_3) in rainwater, non-negligible amounts of sulfate and nitrate may also exist in the form of aerosols.

Because the dry deposition velocity of sulfate aerosol is much less than that of SO_2, sulfate aerosols may be transported for longer distances than SO_2. In addition, a substantial amount of nitrate and NH_3 may be partitioned into aerosols, depending on thermodynamic conditions. In recognition of the importance of the chemical species in the aerosol phase, all sites except those in China and Japan have monitored aerosol compositions using the filter pack method since EANET preparatory phase. Japan initiated aerosol composition monitoring in 2002.

3.3.2.1 SO_2 and sulfate aerosols

H_2SO_4 is known as a major acidifying chemical species in rainwater. The average concentrations of SO_2, an atmospheric precursor of H_2SO_4, and sulfate aerosol recorded from 2000 to 2004 are shown in Figures 3.3.1 and 3.3.2, respectively. The highest SO_2 concentrations, exceeding 4.5 ppb, were observed at the following five sites: Weishuiyuan, Jinyunshan, Hongwen, and Xiang Zhou in China, and at Bangkok, Thailand. All these sites are in urban areas, except for Weishuiyuan and Jinyunshan, which are both located near a big city. The sites with higher SO_2 concentrations, greater than 3.5 ppb but less than 4.5 ppb, were either located within an urban area or near a big city. Excluding the data from these urban sites or sites near an urban area from region-wide examination, the average SO_2 concentrations ranged from 0 (or less than detection limits of applied methods) to 2.5 ppb, which is a little higher or similar to the level of SO_2 concentrations measured in 2000 at EMEP monitoring sites in Europe (EMEP, 2004). SO_2 concentrations at all of the remote sites in the higher-latitude subregion (Terelj in Mongolia, Mondy in Russia, and Rishiri and Tappi in Japan) were recorded less than 0.5 ppb. The remote sites in the mid-latitude region (Cheju in Korea, and Sado-seki, Happo, Oki, and Yusuhara in Japan), however, recorded higher SO_2 concentrations, ranging from 0.5–1.5 ppb, probably due to the long-range transport effect.

As SO_2 is a primary air pollutant, it is found in the highest concentrations over source regions, usually in urban areas. On the other hand, sulfate aerosols are mostly secondary air pollutants that are photochemically produced in the atmosphere from the corresponding SO_2. Therefore, sulfate aerosols are more likely to be transported long distances, meaning that an area with high concentrations may be hundreds or even thousands of kilometers downwind from the source region.

The spatial distribution of non-sea salt (*nss*-) sulfate aerosol concentrations averaged over 2000–2004 is presented in Figure 3.3.2. It should be noted that there was no sulfate aerosol monitoring data for China during this period and that data on sulfate aerosol concentrations in Japan are only available from 2002 or 2003 (as noted in Table 3.3.1). Therefore, the spatial concentration distribution of sulfate aerosols presented in Figure 3.3.2 may not be directly comparable to that of the SO_2 concentrations in Figure 3.3.1. The sites with the highest and second highest sulfate aerosol concentrations did not coincide with the region with the highest SO_2 concentration, indicating a significant long-range transport effect. In order to improve the understanding of long-range transport mechanisms, all sites monitoring SO_2 should also conduct measurements of sulfate aerosols.

Figure 3.3.3 presents the temporal variations of monthly averaged SO_2 and *nss*-sulfate aerosol concentrations at selected remote sites from 2001 to 2004. Three monitoring sites (Rishiri, Oki, and Ogasawara) were considered here out of the eight remote sites in Japan. The other sites were Terelj in Mongolia and Mondy in Russia, representing the high-latitude region, Cheju in Korea, representing the mid-latitude region, and Tanah Rata in Indonesia and the Vachiralongkorn Dam in Thailand, representing the tropical region. The sites in Japan did not gather sulfate aerosol data in the first two or three years and the site in Korea did not gather SO_2 data and sulfate aerosol data in the first two years, simply because monitoring for these chemical species was not performed in the early stage.

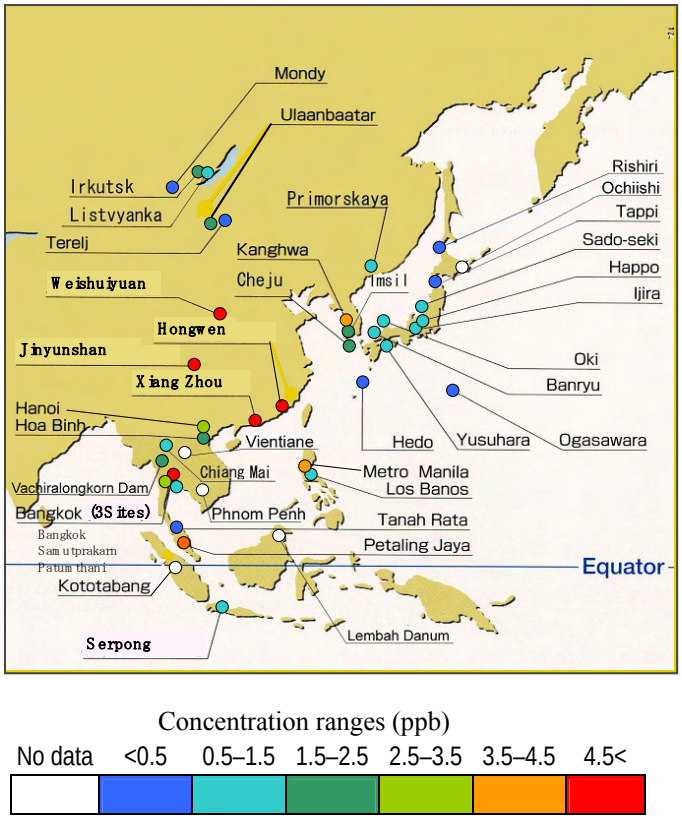


Figure 3.3.1 Levels of average SO_2 concentrations at EANET monitoring sites (2000–2004)

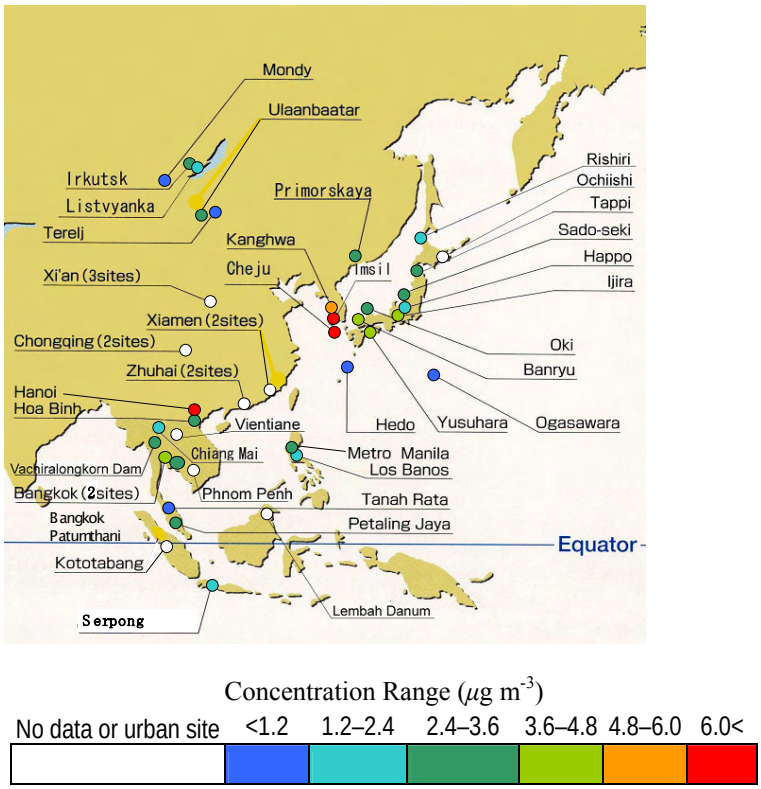


Figure 3.3.2 Levels of average *nss*-sulfate (non-sea salt) aerosol concentration (2000–2004)

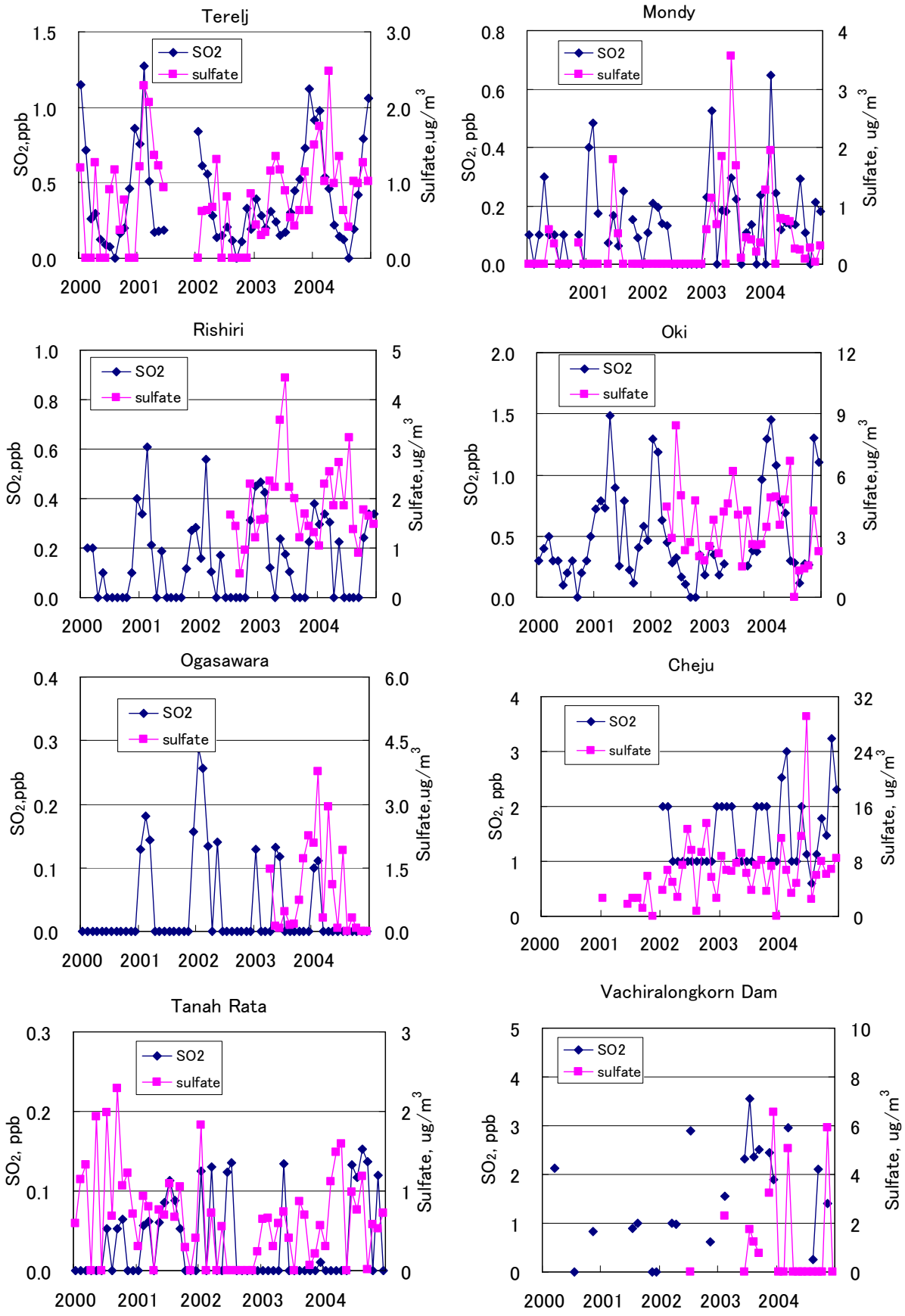


Figure 3.3.3 Seasonal variations of SO_2 and sulfate concentrations at remote EANET monitoring sites

As shown in Figure 3.3.3, the concentrations of gaseous SO_2 were lower than or equal to 2 ppb at all remote sites except Cheju (Korea) and the Vachiralongkorn Dam (Thailand). Despite these low concentration levels, the data on SO_2 from the sites in Northeast Asia (Terelj, Mondy, Rishiri, Oki, Ogasawara, and Cheju) demonstrated a distinct seasonal variation (high in winter, low in summer). This is associated with higher fuel usage in winter in the temperate zone. As noted in the *EMEP Assessment Report* (2004), this seasonal correlation with SO_2 concentrations may imply a need for further reduction of SO_2 emissions. Fuel usage does not have a seasonal variation in low latitudes area, but the amount of precipitation does. Note that SO_2 concentrations at Tanah Rata, however, were too low to be meaningful, and the completeness of monitoring data at the Vachiralongkorn Dam site was not good enough to derive a seasonal trend.

Sulfate aerosol concentrations were mostly lower than 2 $\mu g \cdot m^{-3}$ at the Terelj, Mondy, and Tanah Rata sites, but they were mostly higher than this value at Rishiri, Oki, and Cheju. The sulfate aerosol concentrations at the Cheju site appeared especially higher than in the other regions (except in 2001), indicating the effect of continental outflow on sulfate aerosol concentration. The seasonal variation of sulfate in the northeastern region was not as clear as for that of SO_2 (shown in Figure 3.3.3). The main reason for this ambiguity in the seasonal trends of sulfate aerosols is that the photochemical production rate of sulfate aerosols from SO_2 increases in summer, compensating for the decreased emission of SO_2.

The monthly variations of SO_2 and sulfate concentrations from 2000 to 2004 at EANET rural monitoring sites are presented in Figure 3.3.4. SO_2 concentrations at the rural sites were considerably higher than at the remote sites, while sulfate aerosol concentrations at the rural sites were only slightly higher than those at adjacent remote sites. In the countries of Northeast Asia, the seasonal variations of SO_2 concentrations at rural sites appeared more distinctively than those at remote sites (shown in Figure 3.3.3). In contrast to the seasonal variations of SO_2 concentrations at the sites in Northeast Asia (low in summer, high in winter), SO_2 concentrations were high in summer and low in winter at the sites in Los Baños and Hoa Binh in Southeast Asia. It should be noted that the seasonal variations of SO_2 concentrations at the other two sites in Southeast Asia (Serpong and Chiang Mai) were not very clear. Therefore, further study was recommended before drawing a conclusion on the seasonal variations of SO_2 concentrations in countries in Southeast Asia.

The seasonal variations at the monitoring sites in Northeast Asia of sulfate aerosol concentrations often behaved differently from those of SO_2 concentrations. For instance, the monitoring data from Kanghwa and Listvyanka in 2003 showed that SO_2 concentrations were low in summer, but the sulfate aerosol concentrations were high at the same time. As noted earlier, this difference in seasonal variations between SO_2 and sulfate concentrations in countries in Northeast Asia is due to the photochemical production rate of aerosols increased in summer, diminishing the benefits of decreased SO_2 concentrations. On the other hand, sulfate aerosol concentrations exhibited a seasonal variation similar to the SO_2 concentrations at the Los Baños and Hoa Binh sites in Southeast Asia, because SO_2 concentrations increased in summer, causing sulfate aerosol concentrations to increase without incurring any counter-effect caused by photochemical reactions.

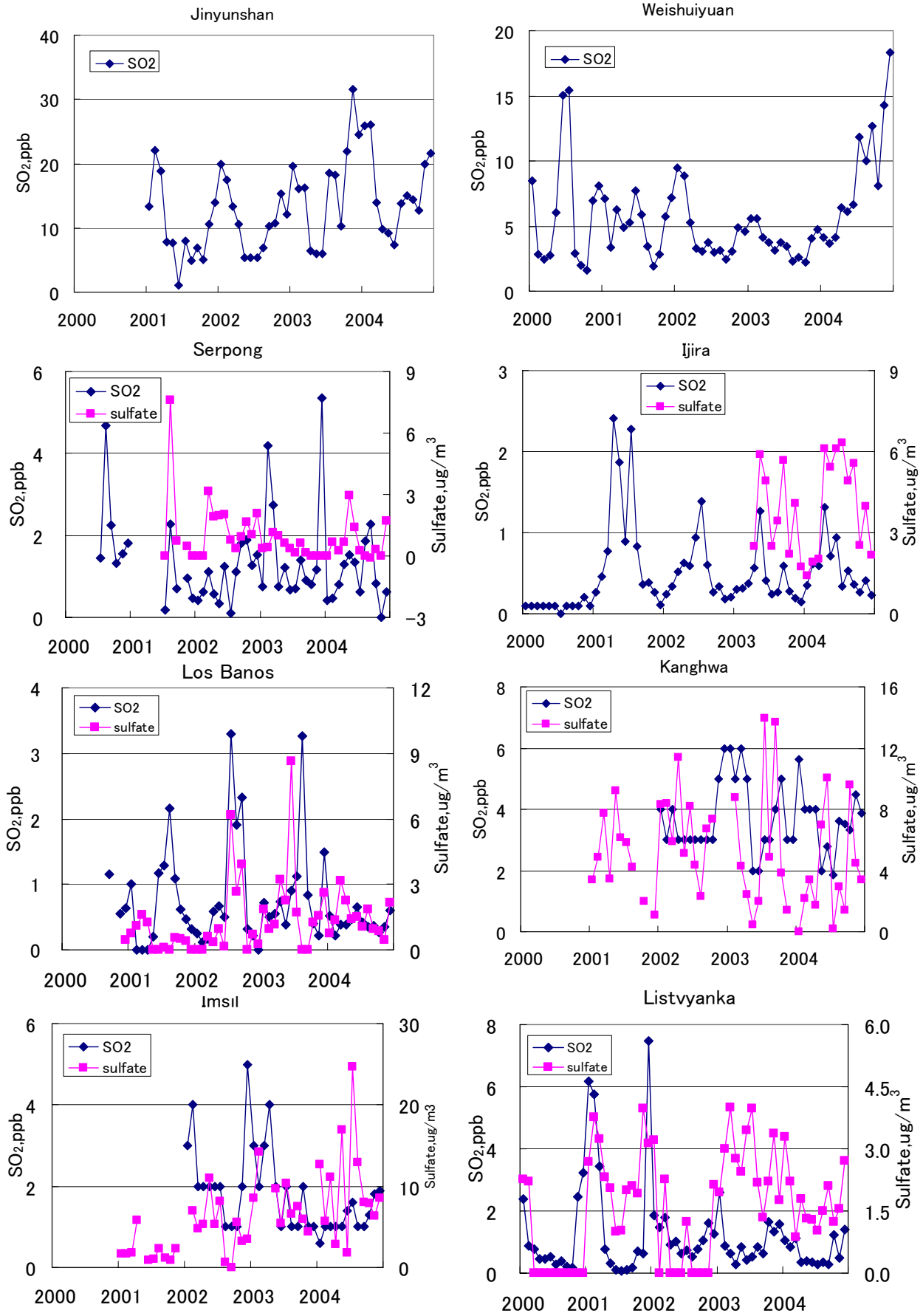


Figure 3.3.4 *(Continued on next page)*

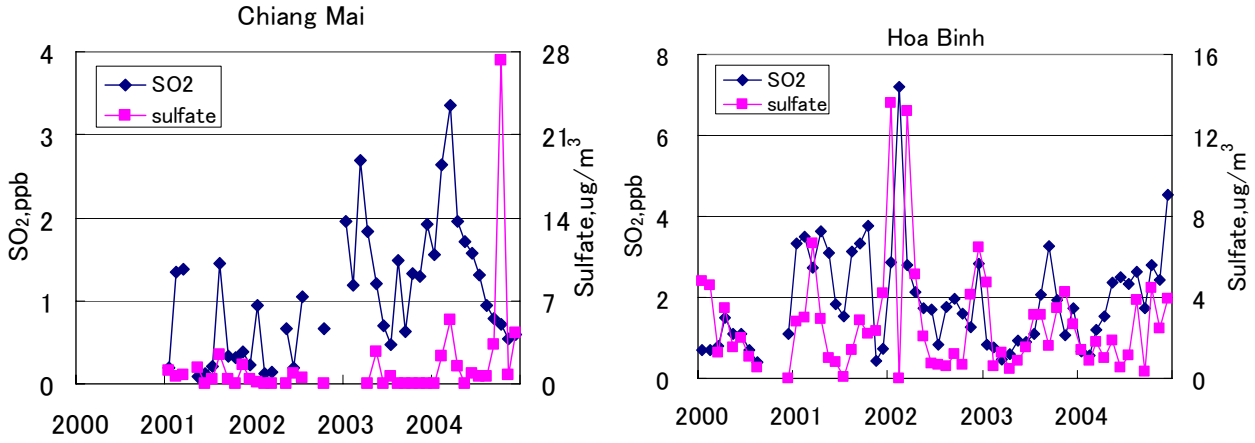
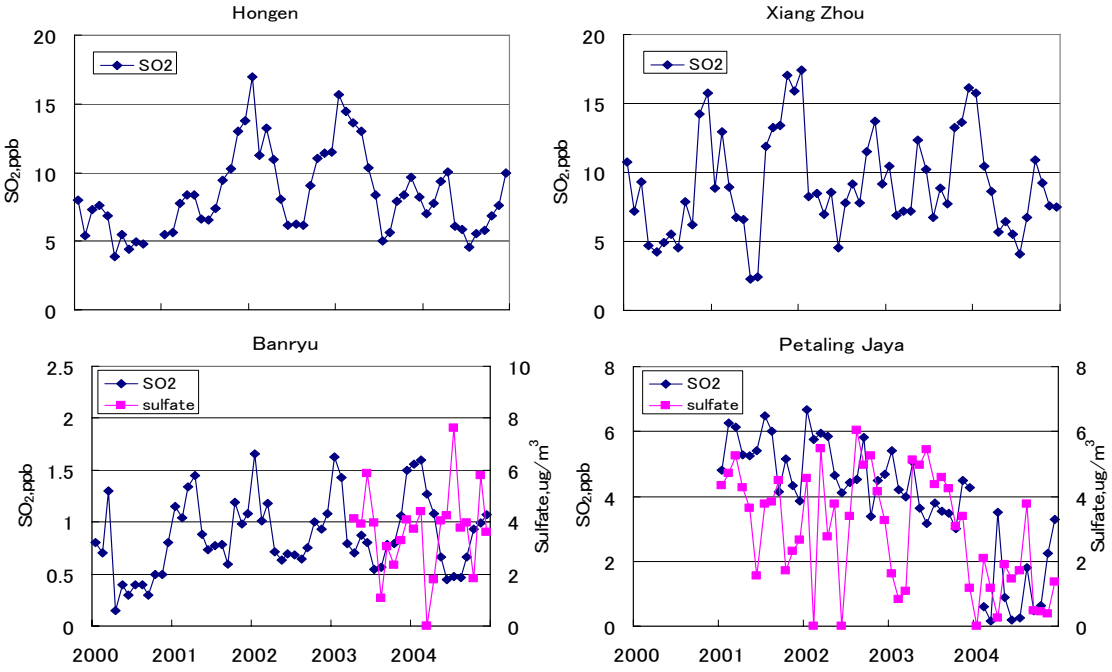


Figure 3.3.4 Seasonal variations of SO_2 and sulfate concentrations at EANET rural monitoring sites

Figure 3.3.5 shows monthly averaged SO_2 and sulfate aerosol concentrations at the urban monitoring sites located in major cities in East Asia. The each of these sites was associated with urban region with a population of over half a million. Note that in order to accurately assess SO_2 concentration levels, it is necessary to have a monitoring network consisting of multiple sites, so the results of EANET dry deposition monitoring, with only one site in each city seems to be not enough and its data should be interpreted very carefully. The concentration levels of both SO_2 and sulfate at the urban sites were comparable to or only a little higher than those at the rural sites, probably because a number of the rural sites were located near an urban area. In addition, most sulfate aerosols are secondary air pollutants that require a certain reaction time to be produced, and therefore sulfate aerosol concentrations are not necessarily high in big cities.



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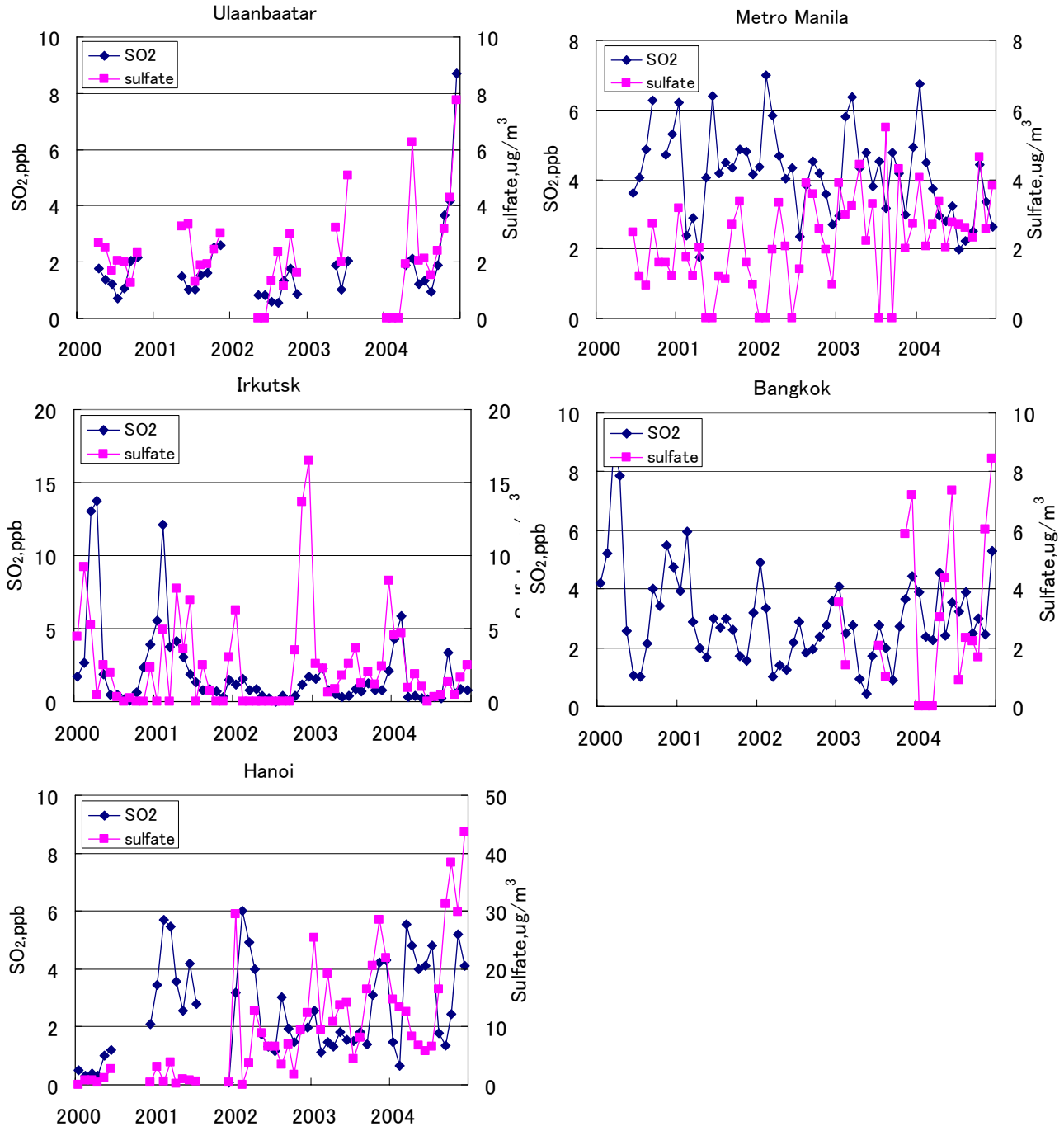


Figure 3.3.5 Seasonal variations of SO_2 and sulfate concentrations at EANET urban monitoring sites

Figure 3.3.6 shows the annual trend of gaseous SO_2 and sulfate aerosol at EANET remote sites. The average concentrations of both are presented in the unit of $\mu g \cdot m^{-3}$ of sulfur so that gaseous SO_2 and sulfate aerosol concentrations can be compared. Note that sulfate aerosols were not monitored in the first two or three years in Rishiri, Oki, Ogasawara, Cheju, and the Vachiralongkorn Dam, and that gaseous SO_2 was not measured in 2000–2001 in Cheju. (A missing bar denotes the periods with no monitoring data available.)

The five-year span of monitoring completed so far may not be sufficient to accurately deduce multi-year trends of airborne sulfur compounds. Also, the lack of measured sulfate aerosol concentrations for certain years further hampers a trend analysis, although it can be said that no distinct trend in total sulfur concentrations was observed at all sites except Cheju and Tanah Rata. Besides this, the ratios of aerosol sulfate to gaseous SO_2 vary over the years rather irregularly.

Data from Terelj and Mondy, located in the high-latitude region, showed a similar year-to-year trend, as follows: sulfur concentrations increased in 2001, decreased the next year, and then increased again in 2003. Four other remote sites (Cheju, Rishiri, Oki, and Ogasawara) were located in the mid-latitude region. Both SO_2 and sulfate concentrations increased steadily from 2002 to 2004 at the Cheju site, but this increasing trend did not appear at the other three sites.

From among the remote sites in the low-latitudes, sufficient monitoring data to provide annual sulfur concentrations were obtained only at the Tanah Rata site. Total sulfur decreased steadily from 2000 to 2003 at this site and then increased significantly in 2004. Note that because Tanah Rata is a single site, when calculating annual averages over the region was done it may not be valid to draw any conclusion yet for most of this area.

Sulfate aerosol concentrations were comparable to the SO_2 concentrations at the remote sites, although it should be remarked that the sulfur was emitted mostly as SO_2, because a significant amount of SO_2 released in the urban areas was converted to sulfate as the air masses reached the remote areas. The reactions (3.3.1), (3.3.2), and (3.3.3) are of the major pathway for sulfate production from SO_2, and the reaction rates increase with higher solar irradiation. Therefore, the ratios of sulfate aerosol to SO_2 concentrations at the low-latitude sites were higher than those at the high-latitude sites. For example, the sulfate aerosol concentrations were comparable to or smaller than the SO_2 concentrations at the high-latitude sites of Terelj and Mondy, whereas sulfate aerosol concentrations were much greater than SO_2 concentrations at the low-latitude sites, such as Tanah Rata. The sulfate aerosol monitoring data from the Vachiralongkorn Dam site were severely insufficient for accurately evaluating the importance of sulfate aerosol concentrations.

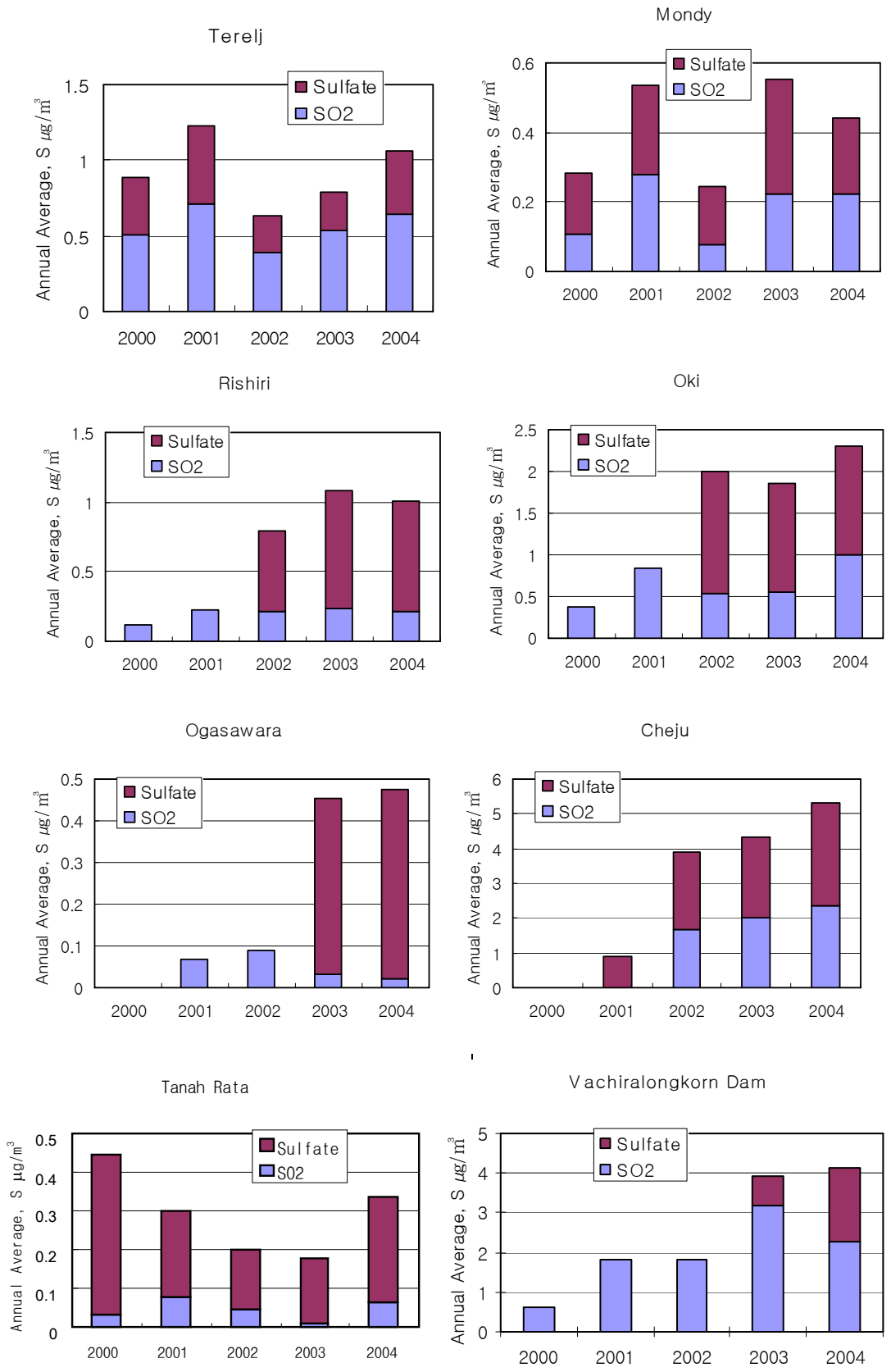


Figure 3.3.6 Average annual concentrations of atmospheric sulfur contained in SO_2 and sulfate at remote EANET monitoring sites

Figure 3.3.7 presents the annual sulfur concentrations contained in SO_2 and sulfate aerosols at the rural monitoring sites. The Jinyunshan and Weishuiyuan sites did not monitor sulfate aerosols, and the sites at Serpong and Ijira began monitoring in 2001 and 2003, respectively. Note that the Kanghwa and Imsil sites did not monitor gaseous SO_2 concentrations in 2000 and 2001. (In the figure, a missing bar denotes the periods with no sulfate aerosol or SO_2 monitoring data available.)

SO_2 and sulfate aerosol concentrations did not exhibit an ongoing annual trend. For example, SO_2 concentration increased in Jinyunshan from 2001 to 2003, but it decreased in the same period in Weishuiyuan, although they are both in the same country. Furthermore, the sulfate aerosol concentration decreased in Kanghwa but increased in Imsil from 2002 to 2004.

SO_2 concentrations were larger than the sulfate concentrations at most sites, while the reverse was found at the remote areas, with the exception of Ijira, Imsil, and Primorskaya. Moreover, the geographical latitude of a site did not affect sulfate concentrations relative to SO_2 concentrations, because the amounts of gaseous compounds emitted in plumes were much fresher at the rural sites than at the remote sites.

Figure 3.3.7 *(Continued on next page)*

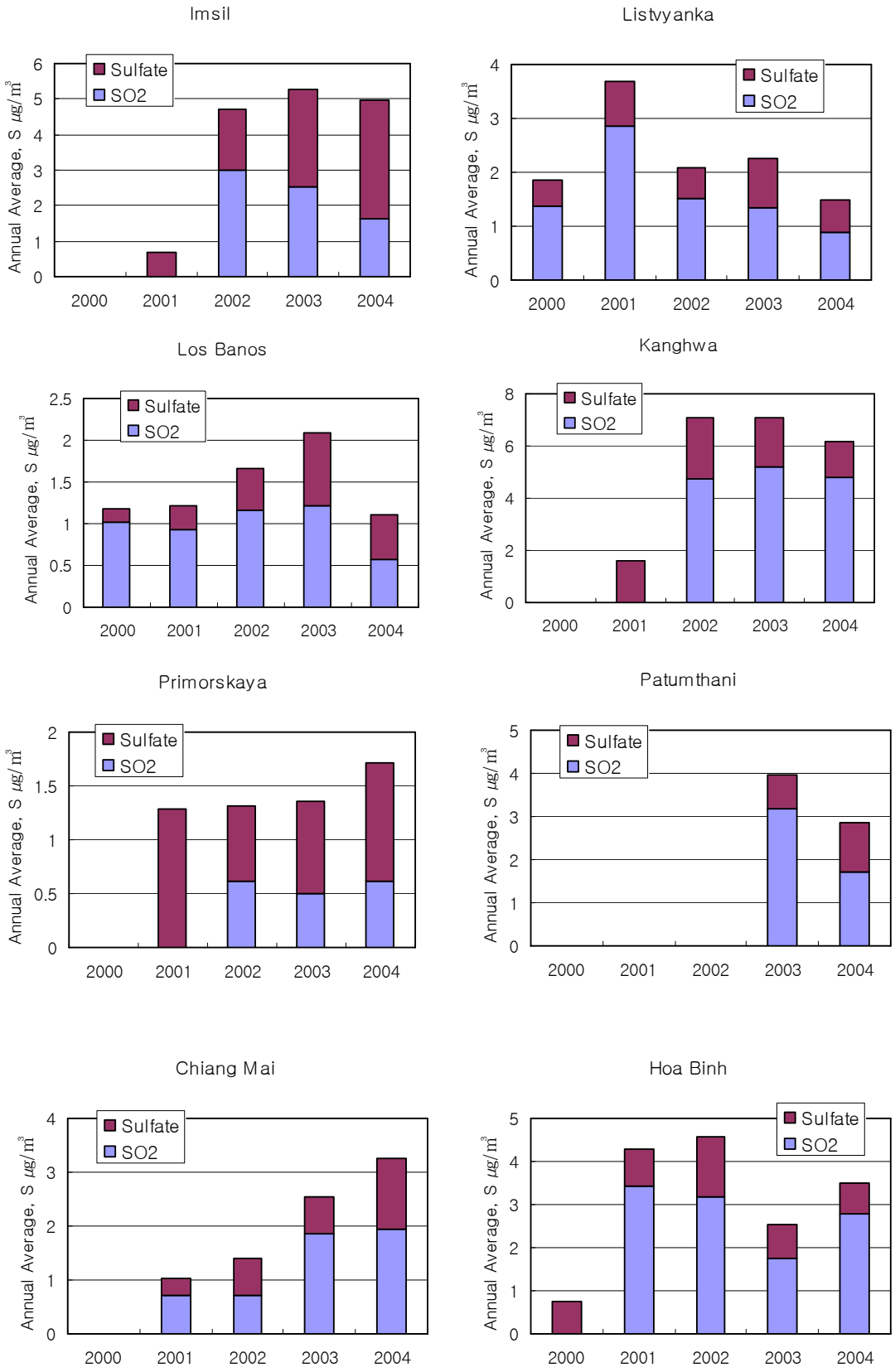


Figure 3.3.7 Average annual concentrations of sulfur contained in SO_2 and sulfate at rural sites

Annual SO_2 and sulfate aerosol concentrations at the urban sites are shown in Figure 3.3.8. A missing bar denotes the fact that data on sulfate aerosol concentrations were missing for some sites (such as Hongwen, Xiang Zhou, Banryu, and Bangkok) for the period when sulfate aerosol monitoring had not yet begun. Annual sulfate aerosol concentrations were significantly lower than the annual SO_2 concentrations at all urban sites except Banryu and Hanoi, similar to those at the rural sites. This implies that the plume was too fresh to have a sufficient resident time for the production of sulfate aerosols.

The World Health Organization (WHO) guideline recommends an acceptable limit of annual SO_2 concentration to be 18.8 ppb (50 $\mu g \cdot m^{-3}$), which is equivalent to 25 S $\mu g \cdot m^{-3}$ (WHO, 2006). Annual SO_2 concentrations at the EANET urban monitoring sites ranged from 0.7 to 15 S $\mu g \cdot m^{-3}$, which is below the WHO guideline. The Banryu site in Japan recorded the lowest annual SO_2 concentration level and the highest ratio of sulfate aerosols to SO_2 concentration among the urban sites. This is because the city of the Banryu site is rather small compared to the cities where the other urban monitoring sites are located.

SO_2 and sulfate aerosol concentrations at the urban monitoring sites were more directly linked to the emissions in the same areas than those at the remote and rural sites. Therefore, the annual variability of ambient SO_2 and sulfate aerosol concentrations is valuable information for understanding any annual emission trend. Sulfur concentrations generally increased over the monitoring period at the Hongwen and Hanoi sites, whereas sulfur concentrations generally decreased at the Petaling Jaya site. It is interesting to note that airborne sulfur concentrations decreased from 2000 to 2003 at Tanah Rata, the remote site adjacent to Petaling Jaya, as shown in Figure 3.3.6. The other sites did not show any discernible annual trends. The most important thing to note is that the number of urban sites in the EANET dry deposition-monitoring network was not sufficient enough to accurately represent SO_2 concentrations in the respective cities.

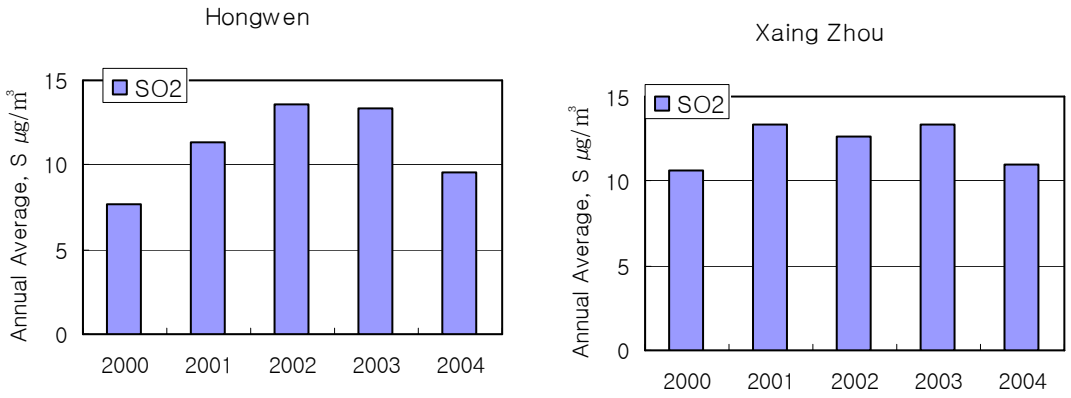


Figure 3.3.8 *(Continued on next page)*

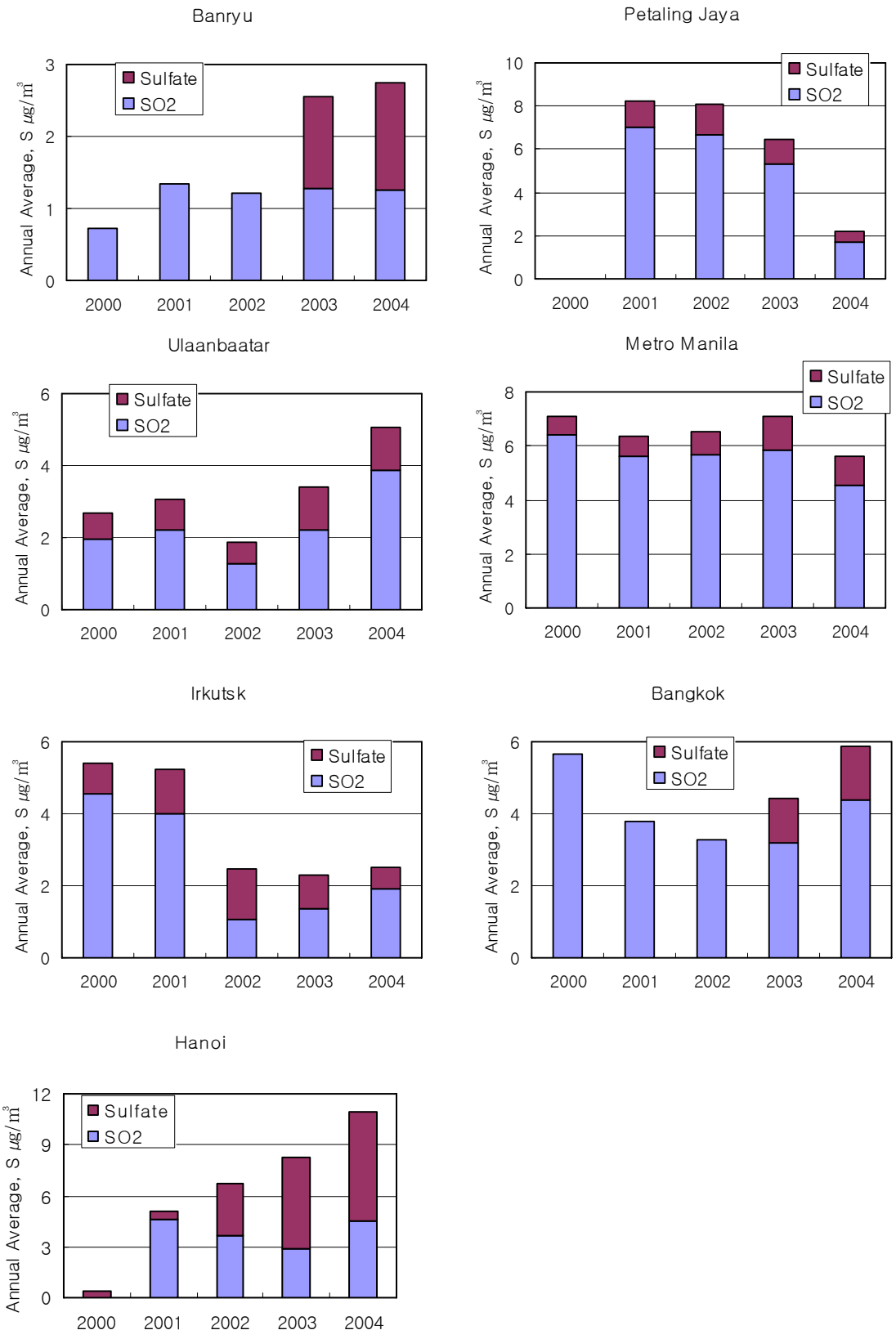


Figure 3.3.8 Annual average concentrations of total airborne sulfur contained in SO_2 and sulfate at EANET urban monitoring sites

3.3.2.2 HNO_3 and nitrate aerosols

Along with SO_2 and sulfuric acids, nitric acid in the gas and aerosol phase is a major acidic compound affecting the pH of rainwater. Nitric acid (HNO_3) is produced from nitrogen dioxide by reaction (3.3.4) (see section 3.3.1). Nitrogen oxide is usually emitted as a form of NO in the combustion process, and then NO is converted to NO_2 in the following reactions:

$$NO + O_3 \rightarrow NO_2 + O_2 \quad (3.3.10)$$
$$NO + RO_2 \rightarrow NO_2 + RO \quad (3.3.11)$$

On the other hand, NO_2 is susceptible to photo-dissociation and reversion back to NO, as follows:

$$NO_2 + \boldsymbol{hv}(+O_2) \rightarrow NO + O_3 \quad (3.3.12)$$

As reactions (3.3.10), (3.3.11), and (3.3.12) are very fast, both NO and NO_2 should be monitored simultaneously to properly analyze the concentration levels of nitrogen oxides. Unfortunately, only a few countries reported both NO and NO_2 concentrations, limiting the usefulness of the NO_2 monitoring data. In addition, the type of automatic instrument usually used at the EANET sites during this period employed a molybdenum converter, which often overestimates NO_2 concentrations in remote and rural areas. Due to this fact, only gaseous HNO_3 and nitrate aerosol concentrations were analyzed in detail for this report. The filter pack method was employed to measure HNO_3 and nitrate aerosol concentrations at the EANET sites except in China, which had not yet incorporated the filter pack method for dry deposition monitoring and did not monitor concentrations of these species.

The monthly variations of gaseous HNO_3 and nitrate aerosol concentrations measured at the remote sites are presented in Figure 3.3.9. It should be noted that most HNO_3 is removed by dry deposition before it reaches the remote areas due to little surface resistance, and it therefore appeared to be so low as to severely undermine monitoring accuracy and the identification of any annual variation. In fact, the dry deposition velocity of nitrate aerosols was too slow to maintain a concentration high enough to accurately measure at EANET remote sites. Nitrate aerosol levels were found to be high during the winter in the high- and mid-latitude regions. The reason for this seasonal variation of HNO_3 is yet not clear, and therefore further studies are required, plus the amount of monitoring data was still too little to validate this observation. Finally, for example, the HNO_3 and nitrate aerosol concentrations at the Cheju site were very high in the beginning of 2004 for no discernible specific reason (further data verification also required).

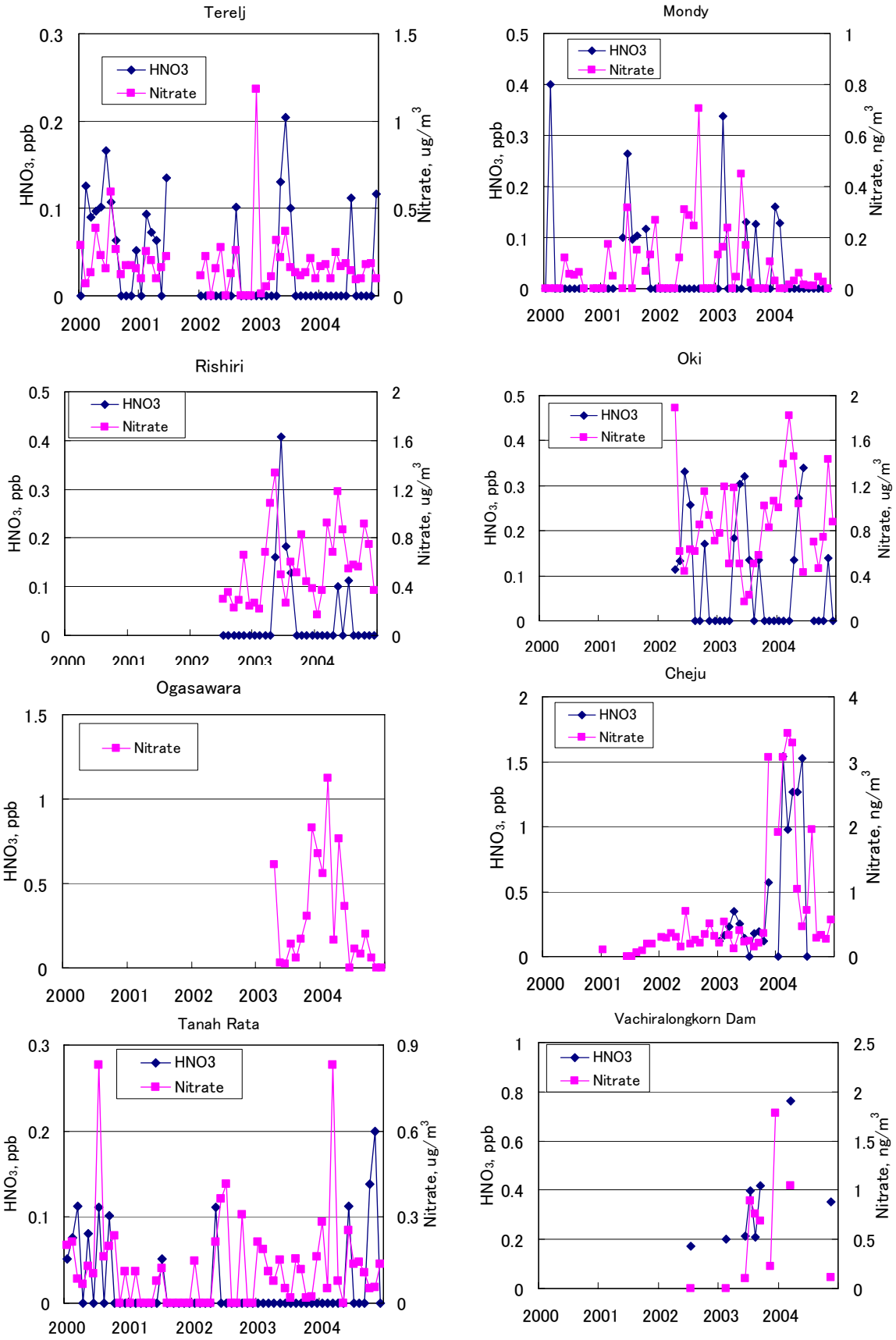


Figure 3.3.9 Seasonal variations of HNO_3 and nitrate at EANET remote monitoring sites

Figure 3.3.10 presents the monthly variations of HNO_3 and nitrate aerosol concentrations at the rural monitoring sites from 2000 to 2004. It was found that their concentrations at these sites were substantially higher than those at the remote sites. As previously noted, the levels of sulfate aerosol concentration did not differ much between rural and remote sites. The longer distance an air mass travels, the more secondary air pollutants (such as HNO_3, nitrate aerosols, and sulfate aerosols) are generated and the more they are removed from the air by wet and dry depositions, so the increased amount due to chemical generation helps to maintain the concentration levels of sulfate aerosol in remote areas. At the same time, the increased removal by wet and dry deposition has to contribute to lowering nitrate aerosol concentrations in these areas. This different response of sulfate from nitrate with long-range transport stems from differences in the rates of chemical production as well as dry and wet deposition.

The HNO_3 concentrations measured at the rural sites were, in most cases, closely related to nitrate aerosol concentrations. Note that the ratio of HNO_3 to nitrate aerosol concentration is thermodynamically determined by ammonia and sulfate concentrations in the aerosols as well as by humidity. It was found that the ratios of HNO_3 to nitrate aerosol concentration differed from one site to another, depending on local thermodynamic conditions.

Nitrogen dioxides are mainly emitted by vehicles rather than by heat production, and therefore they do not show a clear seasonal variation. For the remote sites, the wintertime nitrate aerosol concentrations were high in the high- and mid-latitude regions, as shown in Figure 3.3.9. On the contrary, the rural sites recorded higher HNO_3 and nitrate aerosol concentrations in summer than those in winter, as shown in Figure 3.3.10. It should be noted, however, that the monthly variations of HNO_3 and nitrate aerosol concentrations were large enough to considerably obscure a clear seasonal variation.

As shown in Figure 3.3.11, the monthly averaged HNO_3 and nitrate aerosol concentrations at the urban monitoring sites ranged from 0 to 3 ppb and from 0 to 9 $\mu g \cdot m^{-3}$, respectively. Relatively high nitrate aerosol concentrations were detected at the sites in Metro Manila, Irkutsk, and Bangkok. Although there were several cases when HNO_3 and nitrate aerosol concentrations were high in winter, the monthly variations were often irregular, which obscured any definite seasonal trend. More importantly, HNO_3 concentrations often do not correlate very well with nitrate aerosol concentrations in urban areas, unlike the case at the remote and rural sites. One reason for this poor correlation might stem from the fact that aerosols in urban areas are rich in the chemical components that affect the partitioning of HNO_3 between the gas and aerosol phases. Further study and the accumulation of monitoring data are required to identify the exact cause of this phenomenon.

Annual mean HNO_3 and nitrate aerosol concentrations are presented in Figure 3.3.12, with the molecular weight of HNO_3 set as equal to nitrate in order to make them directly comparable. The absence of bars implies missing data, except at the Mondy and Oki sites in 2002 (HNO_3 concentrations were below the detection limit). Because the level of concentrations was so low, the accuracy of annual mean value of concentrations was low as well, so the annual trend described below should be interpreted carefully.

The Global Ozone Monitoring Experiment (GOME) reported that NO_2 column concentrations in Northeast Asia increased noticeably from 1996 to 2002 (Richter, 2005), but EANET did not monitor both HNO_3 and nitrate aerosols in China to validate these findings. Instead, the sites in Mongolia and Russia as well as the sites in Korea and Japan were utilized to analyze the annual trend of nitrogen oxide compounds. In Terelj, the sum of HNO_3 and nitrate concentrations generally decreased, but the other high-latitude site, Mondy, did not show any clear annual trend. Three sites in Japan (Rishiri, Oki, and Ogasawara) did not monitor HNO_3 and nitrate levels for the first two or three years. As well, nitrate concentrations at Cheju site, monitored since 2001, were found to exhibit an increasing trend, but more monitoring data from the neighboring remote sites are still required to substantiate this trend.

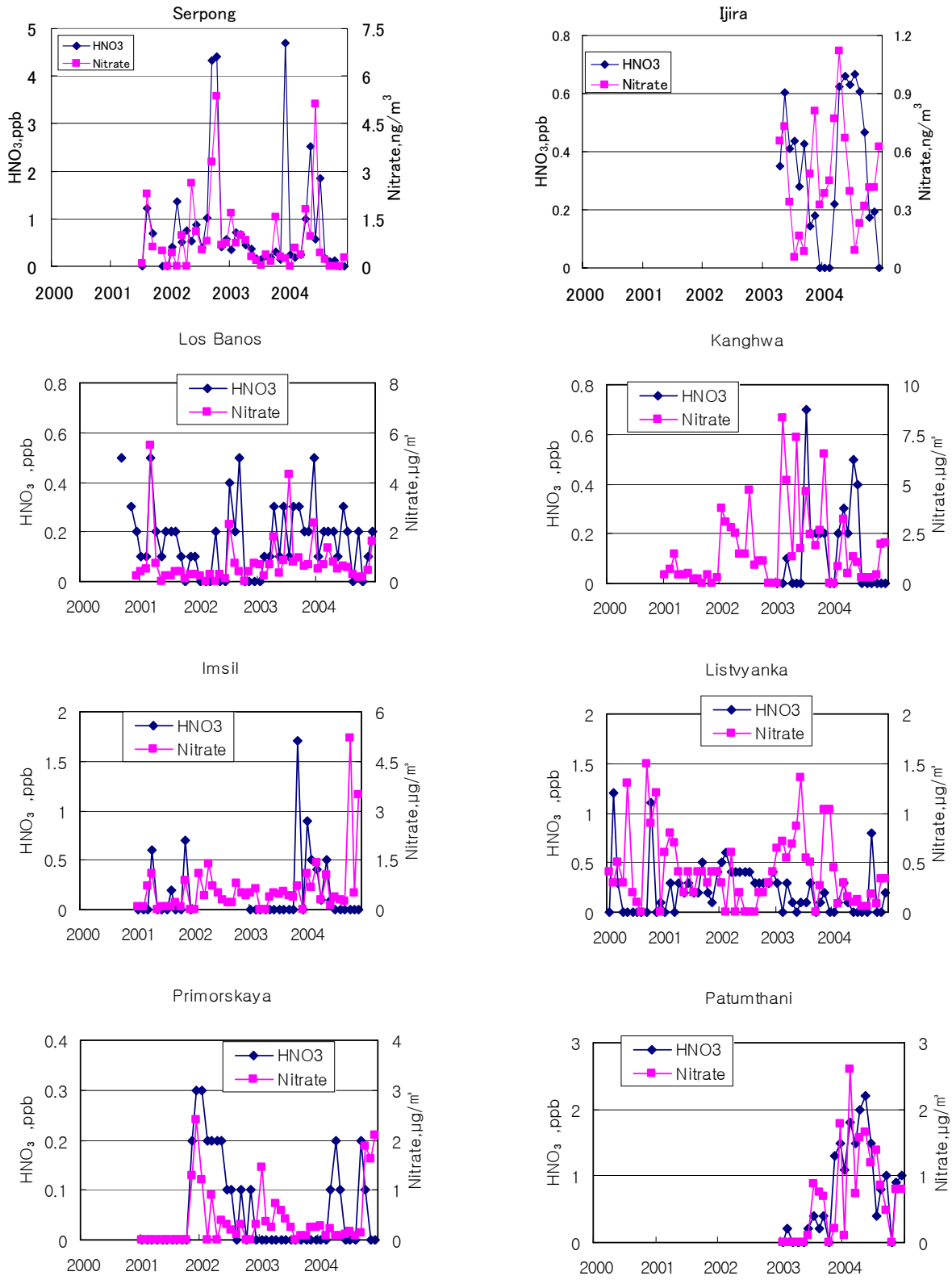


Figure 3.3.10 Seasonal variations of HNO_3 and nitrate at EANET rural monitoring sites

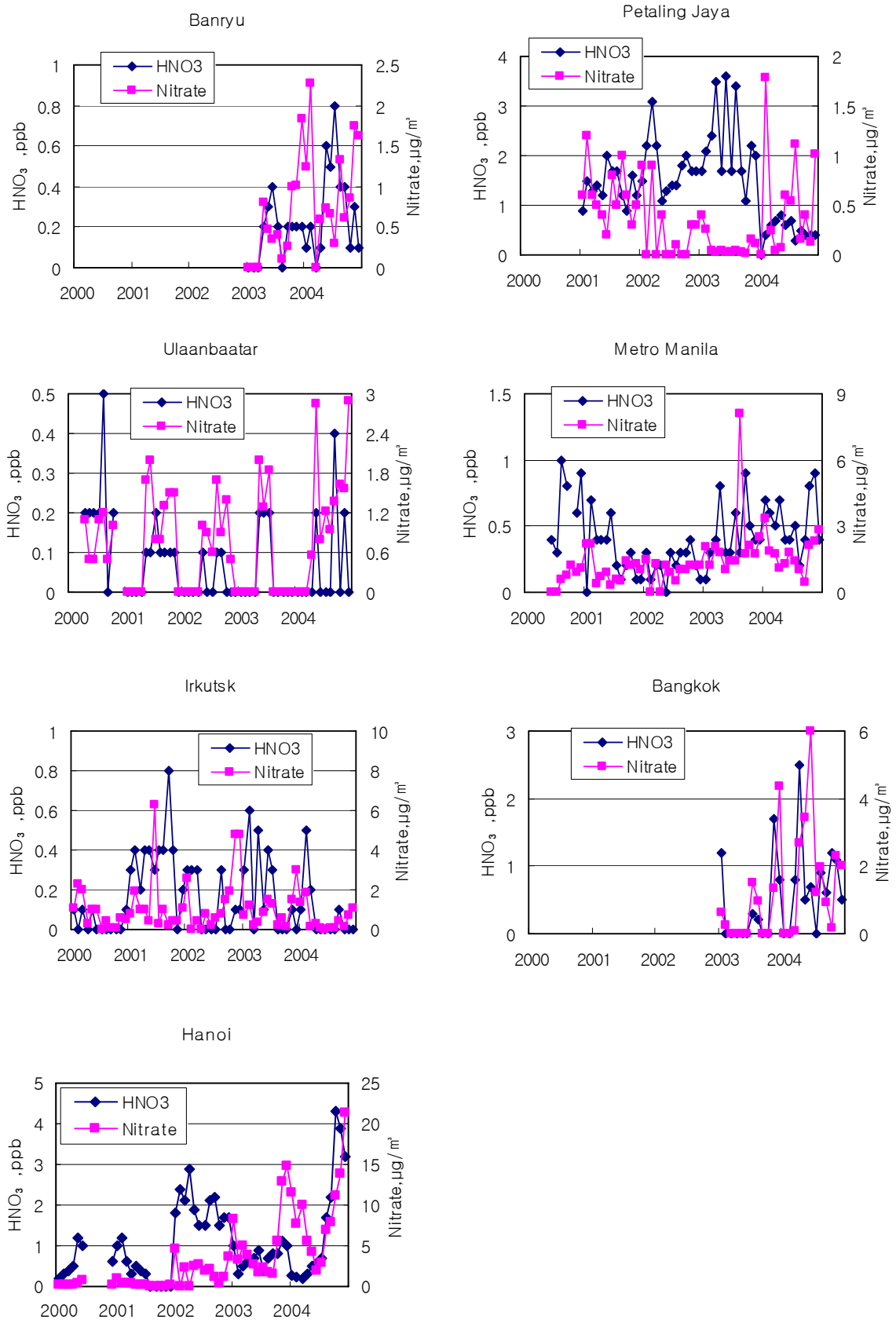


Figure 3.3.11 Seasonal variations of HNO_3 and nitrate at EANET urban monitoring sites

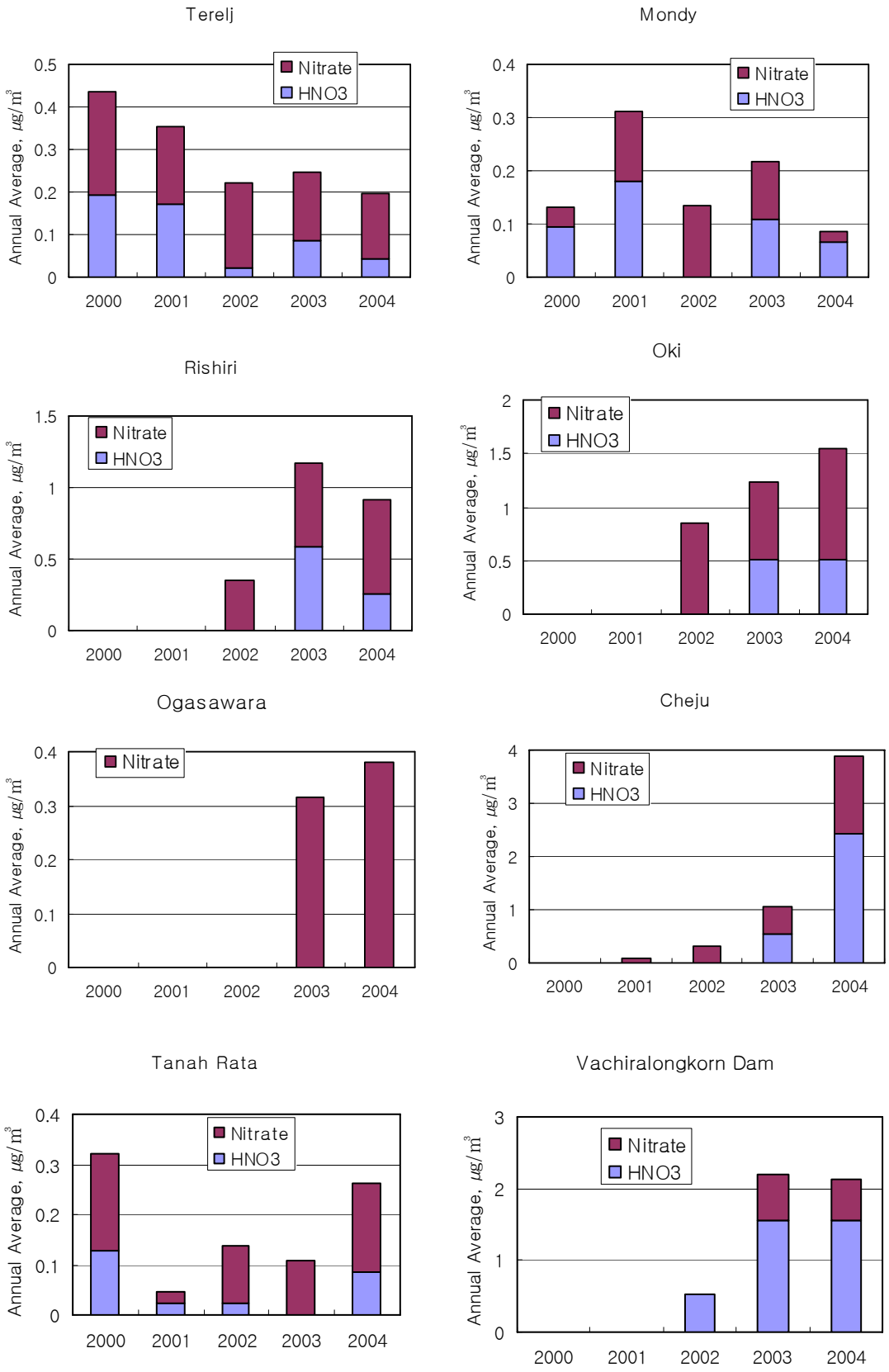


Figure 3.3.12 Annual averages of gaseous and particulate HNO_3 at EANET remote sites

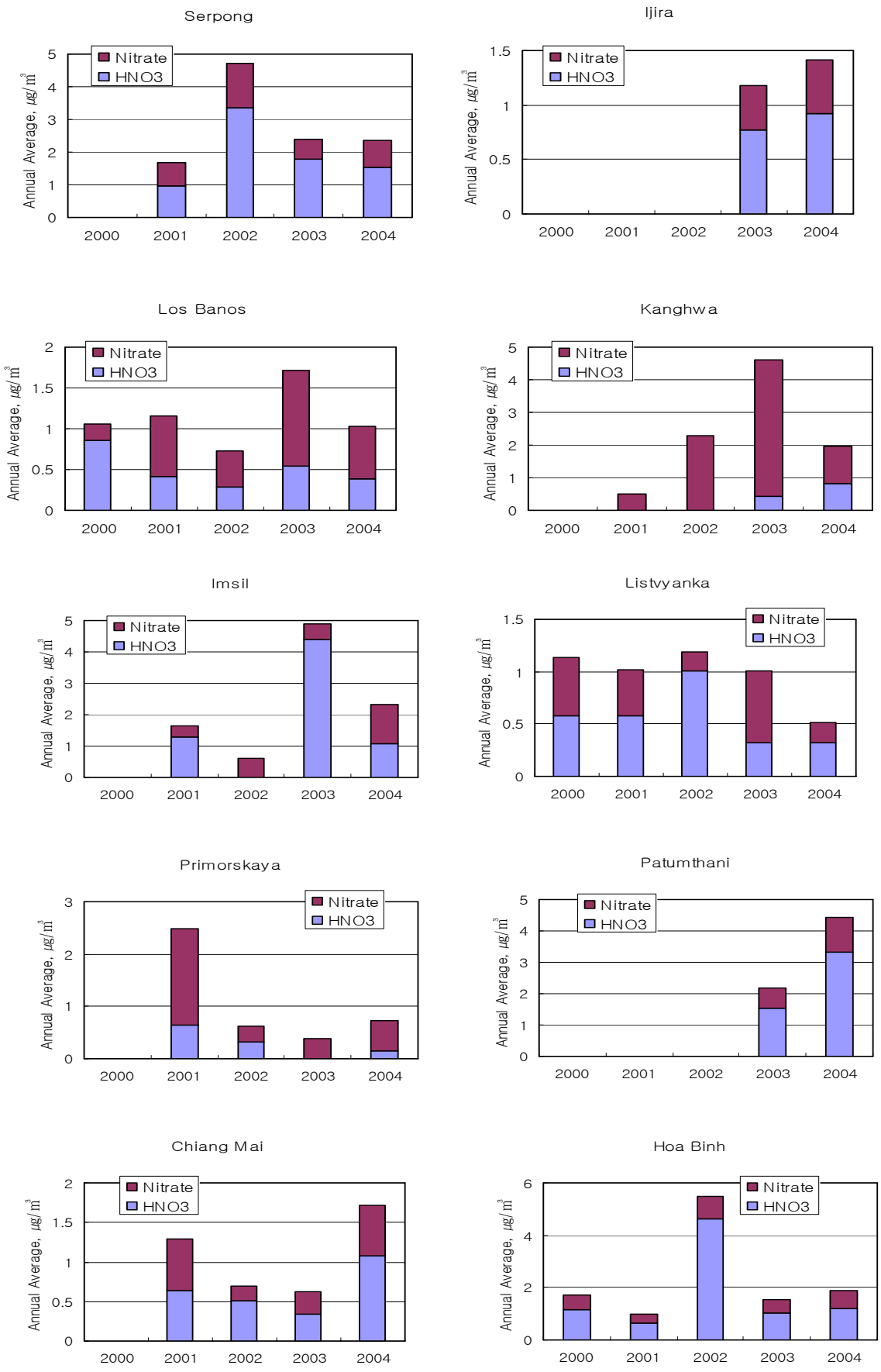


Figure 3.3.13 Annual averages of gaseous and particulate HNO_3 at EANET rural sites

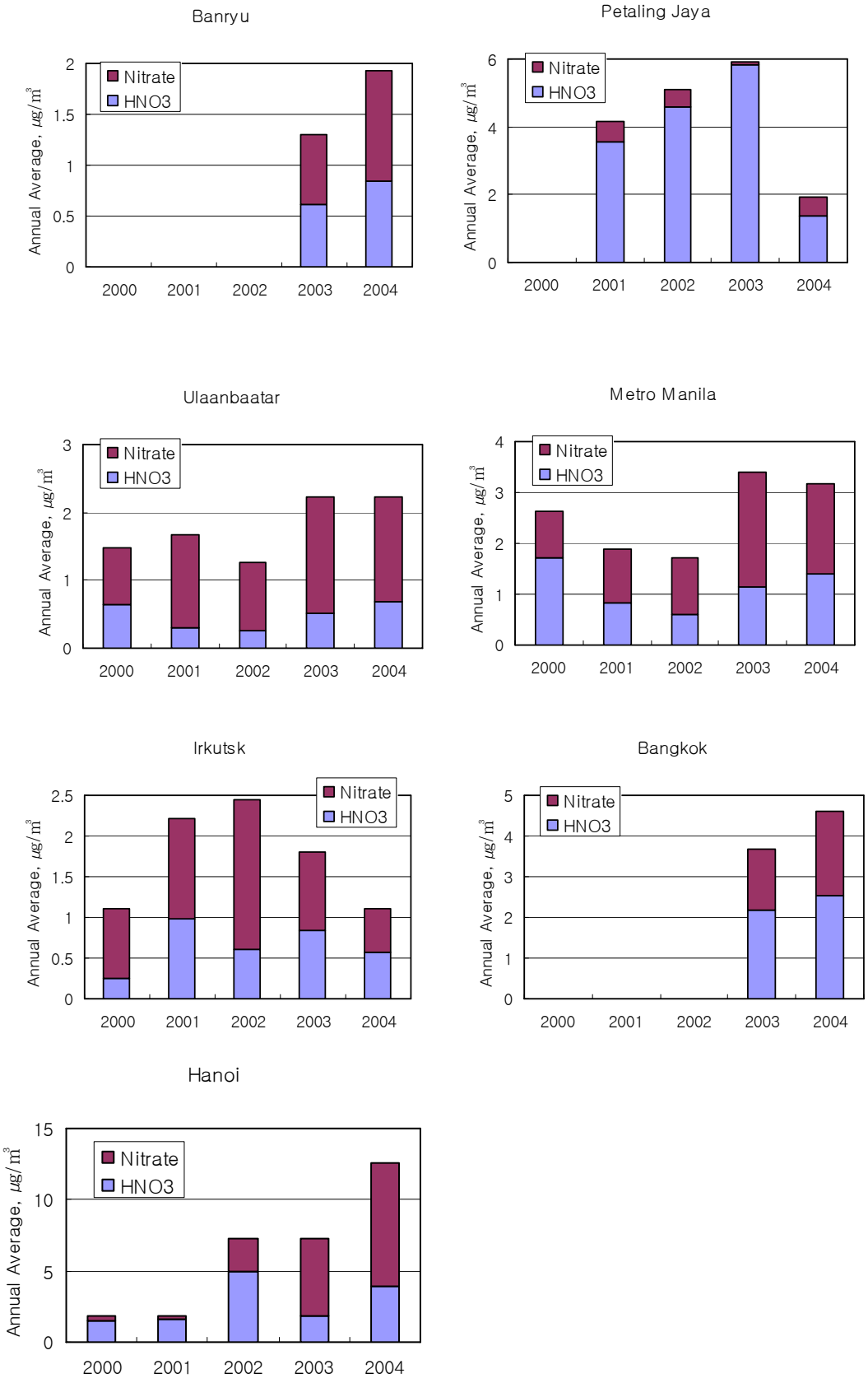


Figure 3.3.14 Annual averages of gaseous and particulate HNO_3 at EANET urban sites

Figure 3.3.13 shows the annual mean HNO_3 and nitrate aerosol concentrations at the rural monitoring sites. It was found that these concentrations were several times higher than those at the remote sites, because they are less affected by dry and wet depositions. Gaseous HNO_3 concentrations were generally higher than nitrate aerosol concentrations except at Los Baños, Kanghwa, and Primorskaya.

Nitrate aerosol concentrations at the Kanghwa site steadily increased from 2001 to 2003, but sharply decreased in 2004. In contrast, gaseous HNO_3 concentrations at Chiang Mai decreased from 2001 to 2003, and then sharply increased in 2004. Although these two sites showed an increasing or decreasing trend locally, there was no apparent regional trend for gaseous HNO_3 concentrations or nitrate aerosols.

Figure 3.3.14 displays the annual mean HNO_3 and nitrate aerosol concentrations at EANET urban monitoring sites. Note that the levels of these concentrations were similar to those at the rural sites, and nitrate aerosol concentrations were generally higher than gaseous HNO_3 concentrations except at Petaling Jaya. It was also found that nitrate aerosol concentrations were higher than gaseous HNO_3 concentrations at the remote sites and the reverse was true at the rural sites. Finally, no distinctive annual trend was observed at the urban sites, similar to the remote and rural sites. The dependency of the primary form of HNO_3 on site classification deserves further investigation.

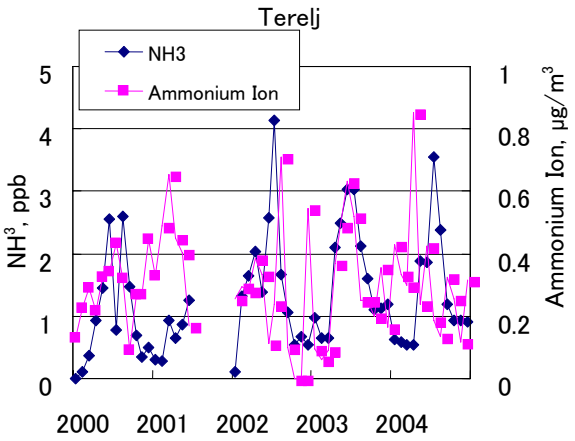
3.3.2.3 NH_3 and ammonium aerosols

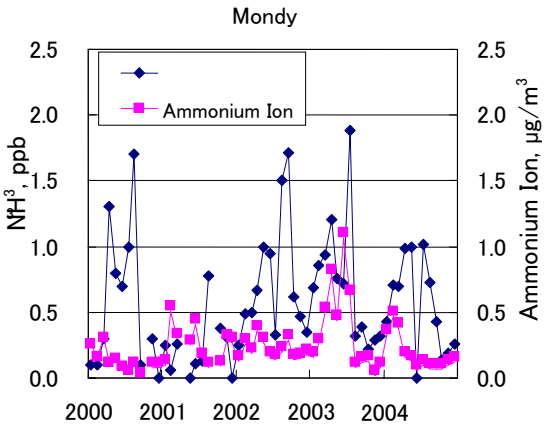
Although ammonia (NH_3) does not fall under the criteria as an air pollutant affecting human health, it does react with nitric and sulfuric acids in the atmosphere to form fine particulate matter. In respect to acid deposition, NH_3 is one of the bases that neutralize rainwater. In addition, it affects the partitioning of HNO_3 into gas and aerosol phases. A rich NH_3 content in the ambient air causes HNO_3 to be converted into nitrate aerosol, which has a dry deposition velocity slower than that of gaseous HNO_3. In addition, NH_3 deposited onto land surfaces may produce NO_3^- through oxidation, which results in soil acidification.

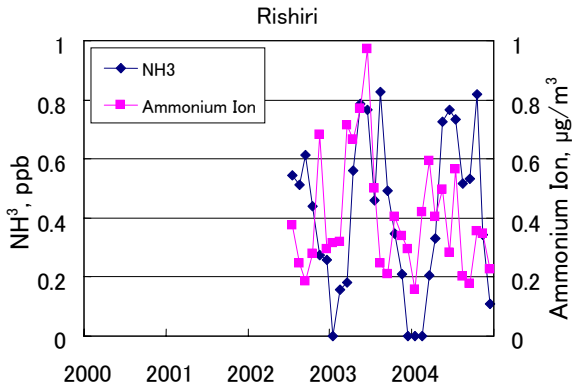
Fertilizers and livestock are major sources of NH_3 (Bouwman et al. 1997; Yamaji et al. 2004). A global emission inventory compiled by Bouwman et al. (1997) estimated that domestic animals and synthetic nitrogen fertilizers comprise 40 percent and 17 percent of total NH_3 emissions, respectively. NH_3 from livestock is produced as a by-product of the microbial decomposition of manure, and it changes seasonally depending on the geographic region, animal sector, and type of livestock management practices.

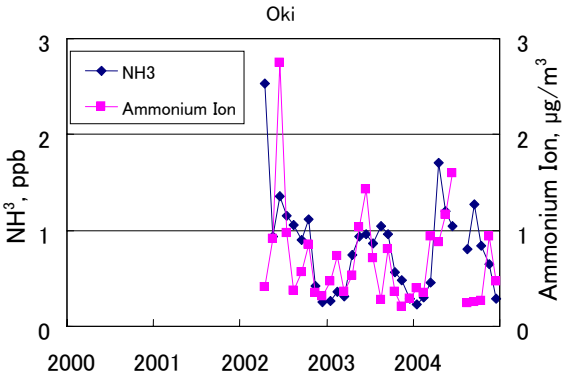
As the filter pack method was used to monitor NH_3 and NH_4^+ aerosol concentrations, similar to monitoring HNO_3 and nitrate aerosol, there was therefore no monitoring data from China and for the first two or three years of monitoring in Japan. Figure 3.3.15 presents the monthly variations of NH_3 and its corresponding aerosol species, NH_4^+, at EANET remote sites, where gaseous NH_3 and NH_4^+ aerosol concentrations were generally higher than HNO_3 and nitrate aerosol concentrations (Figure 3.3.12). NH_3 and NH_4^+ aerosol concentrations at the sites in Northeast Asia (Terelj, Mondy, and Cheju) exhibited a seasonal variation of high in summer and low in winter. This occurs because related agricultural activities and temperatures significantly affect NH_3, as described above.

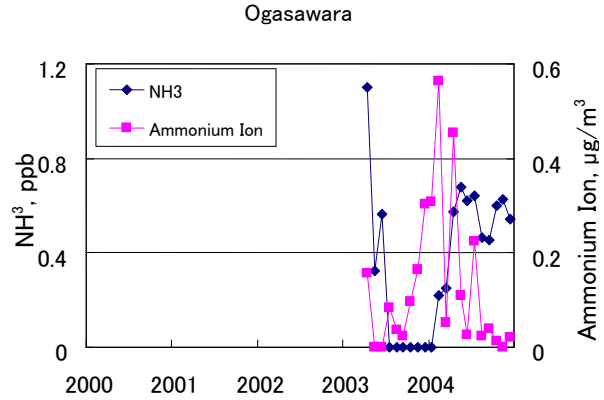
Gaseous NH_3 is a readily soluble chemical species with a relatively high dry deposition velocity, so it may not survive long-range transport. Therefore, NH_3 must be incorporated into aerosols to be able to travel a long distance. Note that the ratio of NH_3 to NH_4^+ aerosol concentrations is thermodynamically determined, similar to that of HNO_3 and nitrate aerosol. NH_3 concentration correlated with NH_4^+ aerosol concentration at the Terelj, Mondy, Rishiri, and Oki sites, but the correlation of NH_3 to NH_4^+ aerosol concentration significantly degraded at the Oki and Cheju sites, implying widely different thermodynamic conditions at these sites.

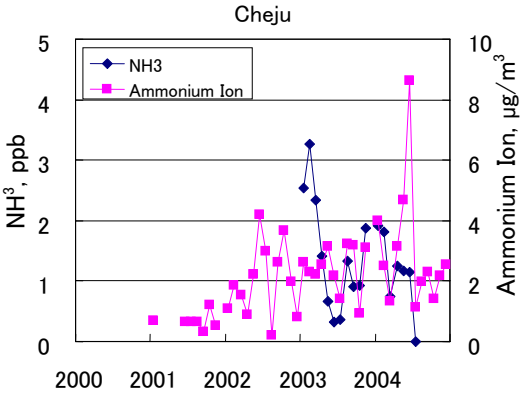

Terelj
NH3
Ammonium Ion
NH3, ppb
Ammonium Ion, μg/m3
0
1
2
3
4
5
0
0.2
0.4
0.6
0.8
1
2000
2001
2002
2003
2004

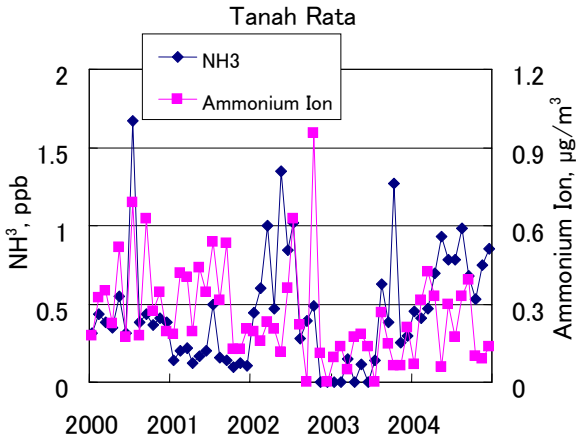

Mondy
Ammonium Ion
NH3, ppb
Ammonium Ion, μg/m3
0.0
0.5
1.0
1.5
2.0
2.5
2000
2001
2002
2003
2004


Rishiri
NH3
Ammonium Ion
NH3, ppb
Ammonium Ion, μg/m3
0
0.2
0.4
0.6
0.8
1
2000
2001
2002
2003
2004


Oki
NH3
Ammonium Ion
NH3, ppb
Ammonium Ion, μg/m3
0
1
2
3
2000
2001
2002
2003
2004


Ogasawara
NH3
Ammonium Ion
NH3, ppb
Ammonium Ion, μg/m3
0
0.4
0.8
1.2
0
0.2
0.4
0.6
2000
2001
2002
2003
2004


Cheju
NH3
Ammonium Ion
NH3, ppb
Ammonium Ion, μg/m3
0
1
2
3
4
5
0
2
4
6
8
10
2000
2001
2002
2003
2004


Tanah Rata
NH3
Ammonium Ion
NH3, ppb
Ammonium Ion, μg/m3
0
0.5
1
1.5
2
0
0.3
0.6
0.9
1.2
2000
2001
2002
2003
2004

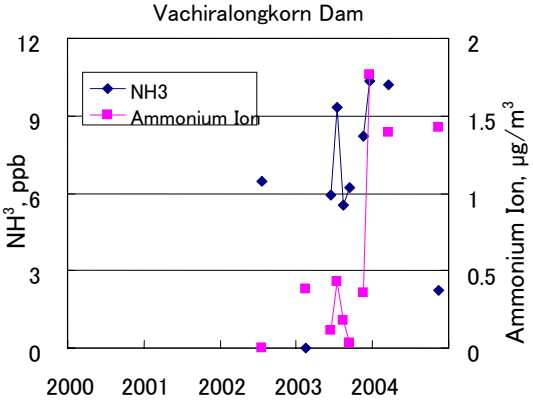

Vachiralongkorn Dam
NH3
Ammonium Ion
NH3, ppb
Ammonium Ion, μg/m3
0
3
6
9
12
0
0.5
1
1.5
2
2000
2001
2002
2003
2004

Figure 3.3.15 Seasonal variation of NH_3 and NH_4^+ aerosol concentrations at EANET remote sites

Figure 3.3.16 shows that the monthly averages of NH_3 and NH_4^+ aerosol concentrations at the rural sites were noticeably higher than those at the remote sites due to high NH_3 emissions in the rural areas. As NH_3 does not directly affect human health, therefore, most countries (including the countries participating in EANET) do not have an air quality standard for NH_3. It should be noted, however, that some jurisdictions in the United States and Canada have a state- or province-wide air quality standard for NH_3. For example, the province of Ontario in Canada (Ontario Ministry of Environment) has set the 24-hour NH_3 standard at 100 $\mu g \cdot m^{-3}$. Note that the annual mean NH_3 concentrations at EANET rural sites were found to be far below this.

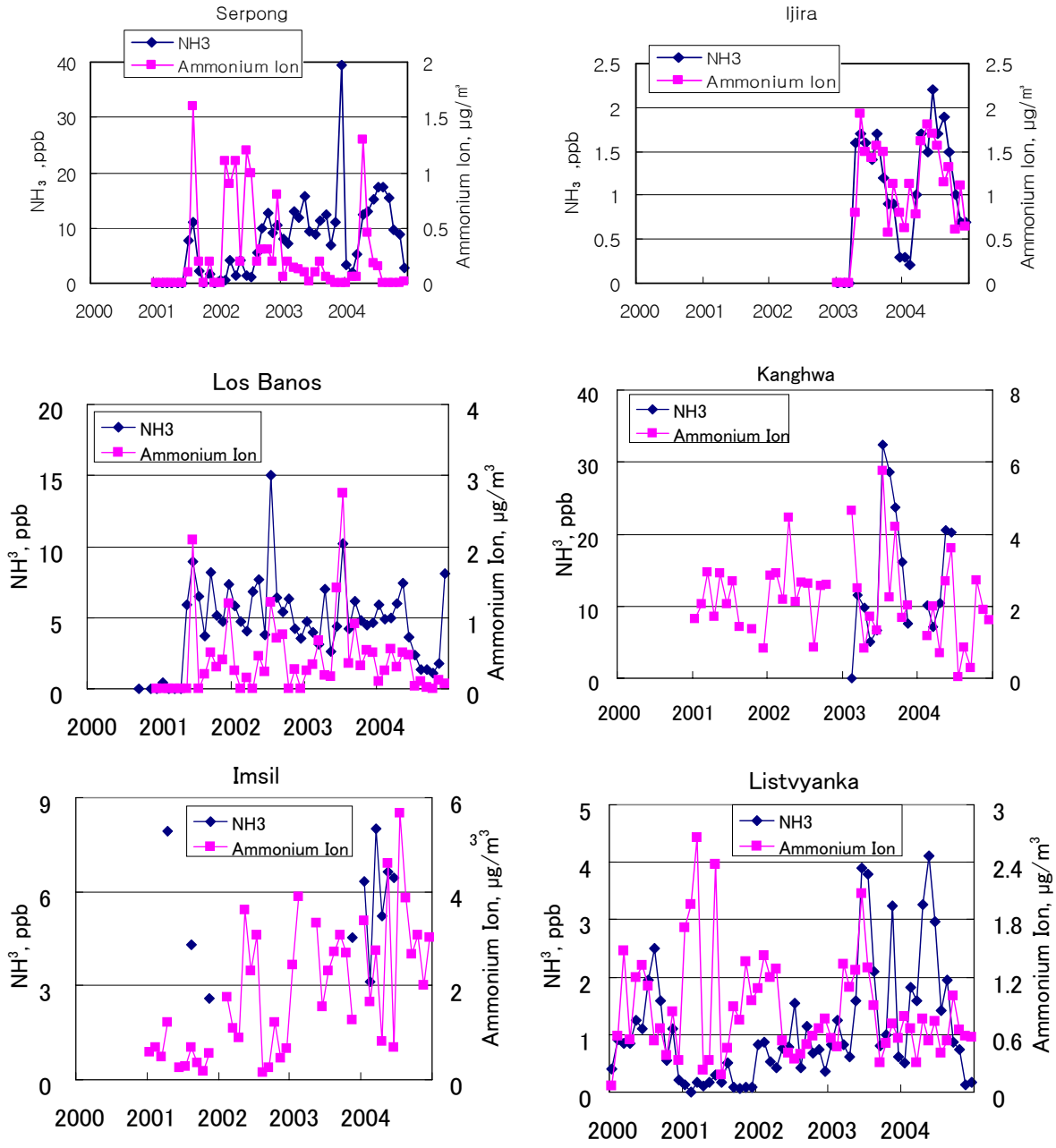


Figure 3.3.16 (*Continued on next page*)

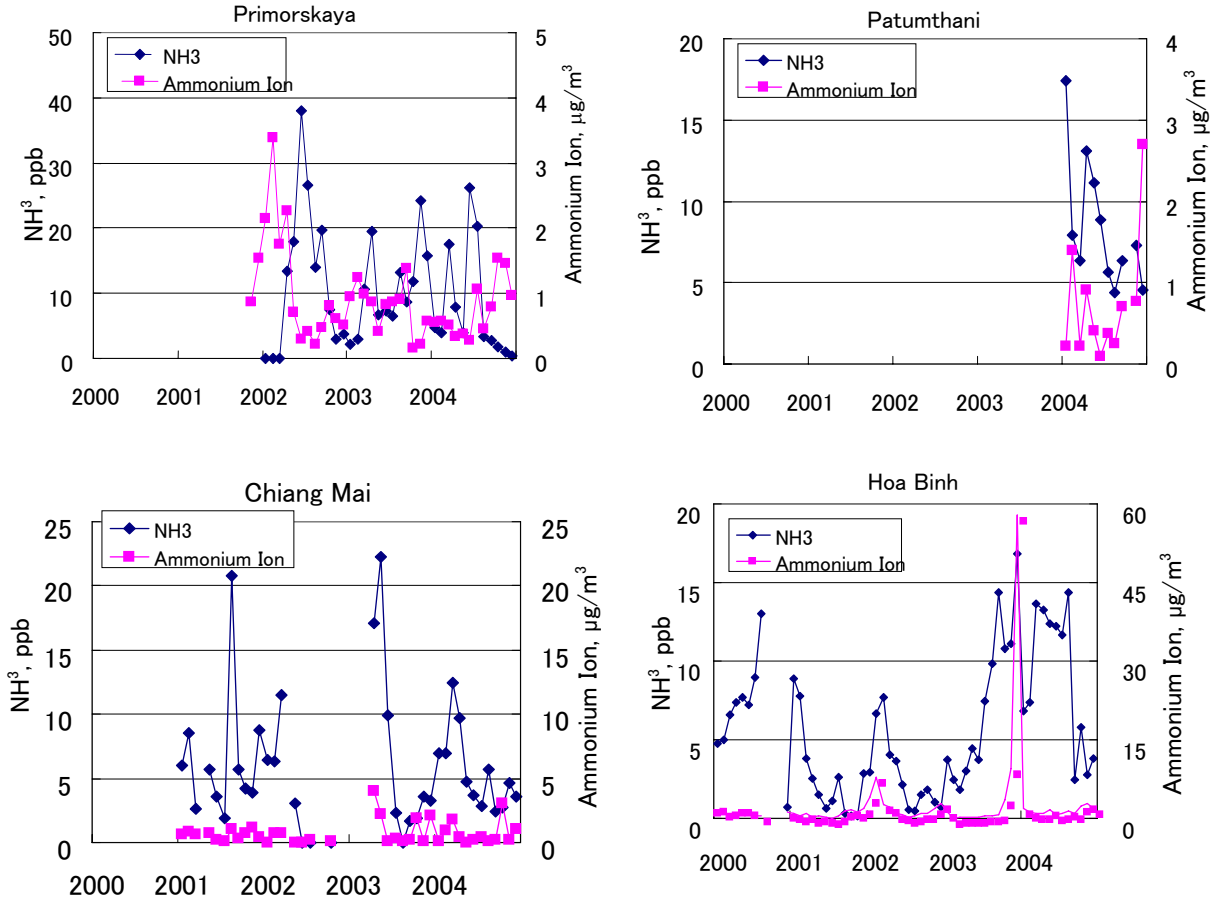


Figure 3.3.16 Seasonal variation of NH_3 and NH_4^+ aerosol concentrations at EANET rural sites

In addition, the monthly average of NH_3 concentrations at the rural monitoring sites varied significantly from one site to another, because some were directly affected by nearby agricultural sources. Because of this stronger influence by source, the rural sites in Northeast Asia exhibited a more distinctive seasonal variation than the remote sites. The NH_4^+ aerosol concentrations had a narrower spatial variation and a less distinctive seasonal variation. The monitoring data also showed that the ammonia was mainly partitioned into the gas phase, except at Ijira and Listvyanka, similar to the situation at the remote sites. The NH_3 and NH_4^+ aerosol concentrations at the rural sites represent the concentrations of the source region, but data on this is still limited as there were only three monitoring sites in the mid-latitudes of the EANET region despite highly intensive farming activities. Therefore, it would be desirable to add a few more sites in China and Japan to increase the spatial resolution.

Figure 3.3.17 presents the monthly averages of NH_3 and NH_4^+ aerosol concentrations at EANET urban sites. Because industrial emissions did not dominate the agricultural and biogenic emissions, NH_3 and NH_4^+ aerosol concentrations at the urban sites were comparable to those at the rural sites. In Northeast Asia, the Banryu and Ulaanbaatar sites exhibited a distinctive seasonal trend of NH_3 and NH_4^+ aerosol concentrations, which were high in summer and low in winter.

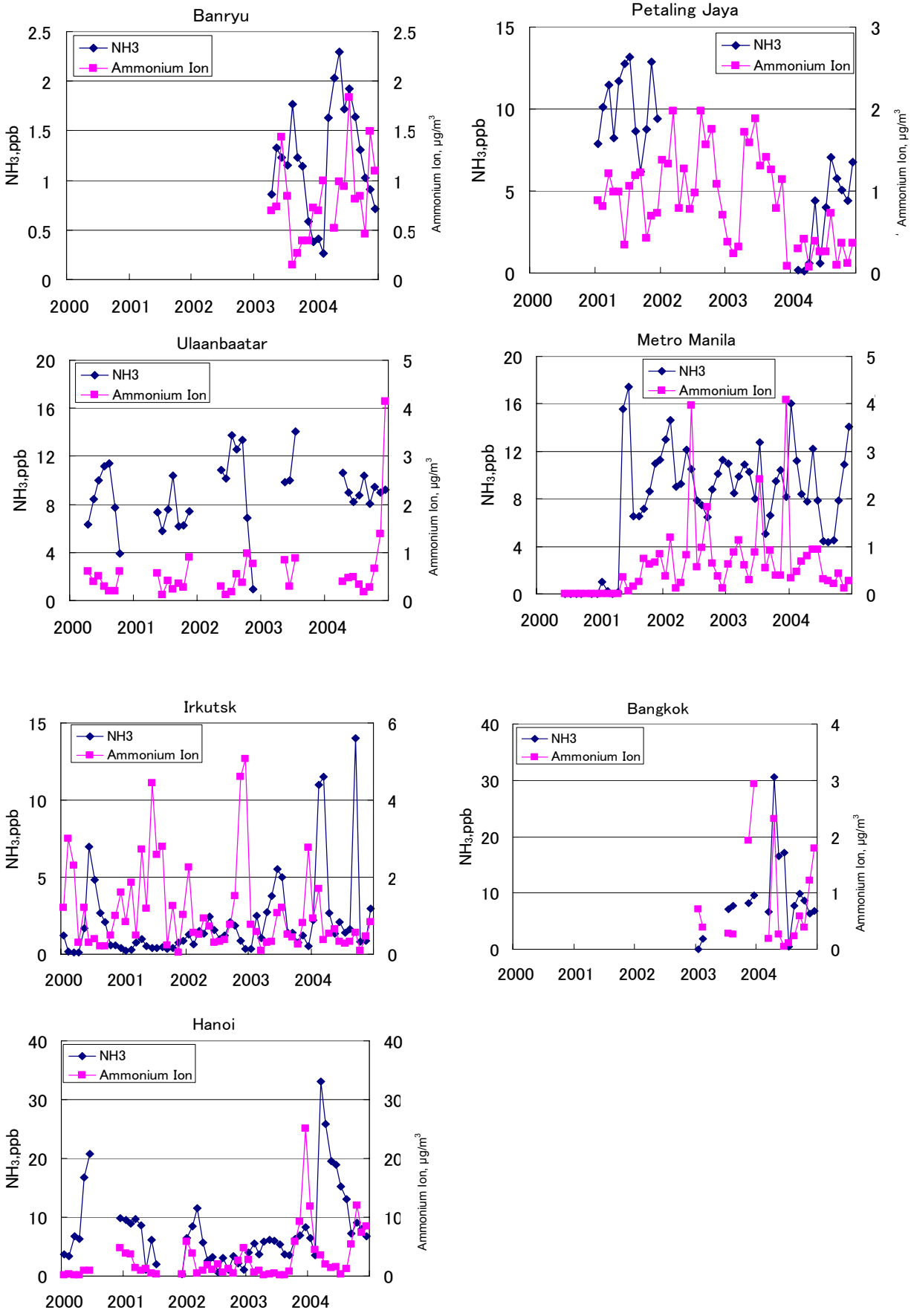


Figure 3.3.17 Seasonal variation of NH_3 and NH_4^+ at EANET urban sites

The annual mean NH_3 and NH_4^+ aerosol concentrations at the remote sites are presented in Figure 3.3.18. The gaseous NH_3 concentration was converted into a mass concentration by assuming its molecular weight was equal to that of NH_4^+. The NH_4^+ aerosol concentration was smaller or comparable to the NH_3 concentration except at Cheju, but the ratios of NH_4^+ aerosol concentration to NH_3 concentration were still significantly higher than at the rural and urban sites, as discussed below, because most of the NH_3 gas was removed by dry and wet deposition during transport.

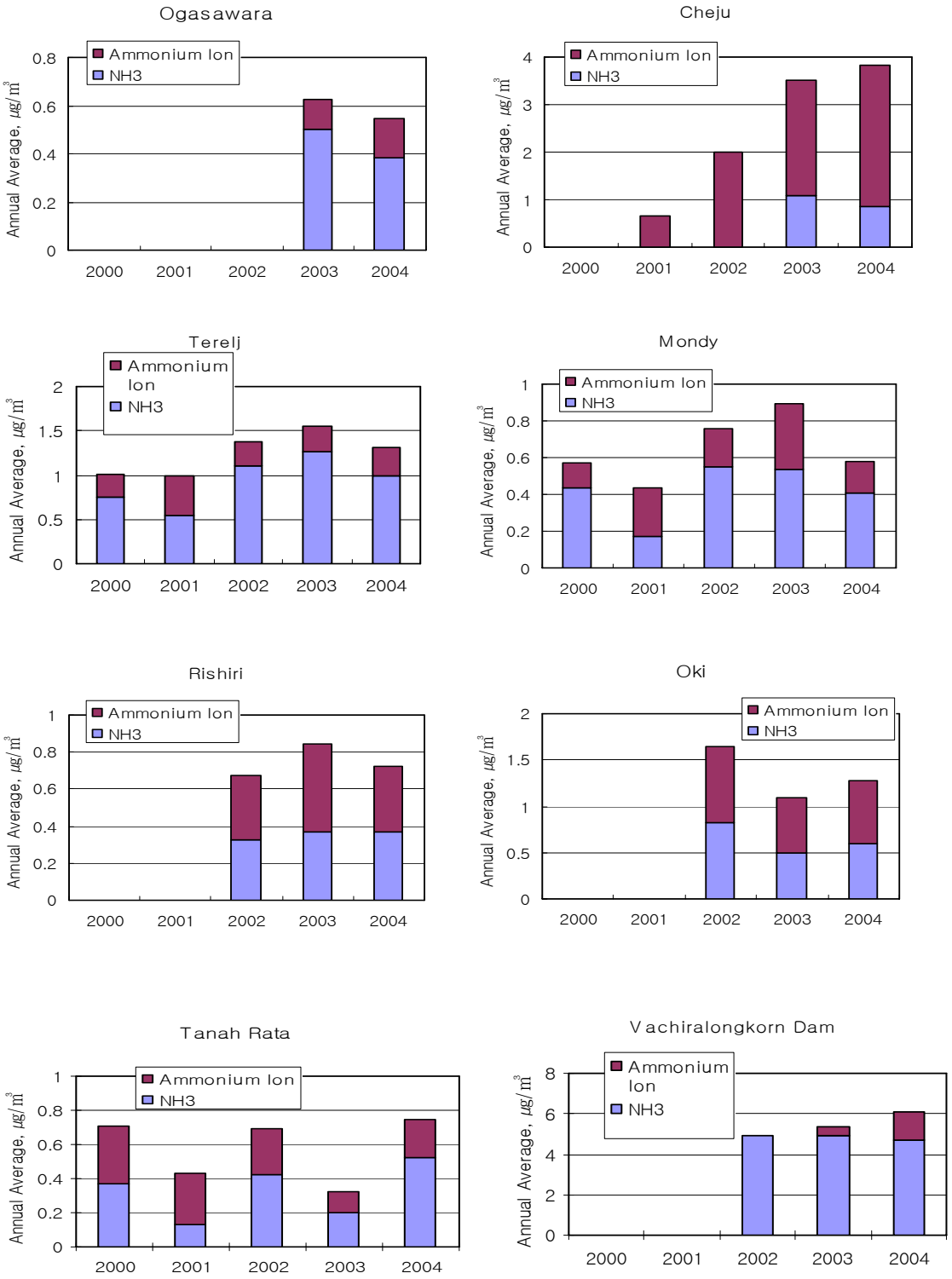


Figure 3.3.18 Annual average of gaseous $NH_3$and particulate ammonium at EANET remote monitoring sites

The amount of total ammonium concentrations in the air at the remote sites was considerably higher than of total sulfate or total HNO_3 concentration, as discussed previously, especially taking the low molecular weight of ammonium into account. The annual variability of total NH_3 concentrations was smaller than that of HNO_3, and an annual trend of total NH_3 concentrations was not visible.

The annual mean NH_3 and NH_4^+ aerosol concentrations over rural areas are presented in Figure 3.3.19. A number of monitoring data were missing, however, making it difficult to deduce an annual trend. Listvyanka and Hoa Binh were the only sites that collected five full years of monitoring data. The gaseous NH_3 concentrations far exceeded NH_4^+ aerosol concentrations except at Ijira and Listvyanka. Although biogenic activities are the main ones producing NH_3 in rural areas, the annual mean NH_3 and NH_4^+ aerosol concentrations in the high-latitude region did not differ considerably from those in the low-latitude region despite big temperature differences.

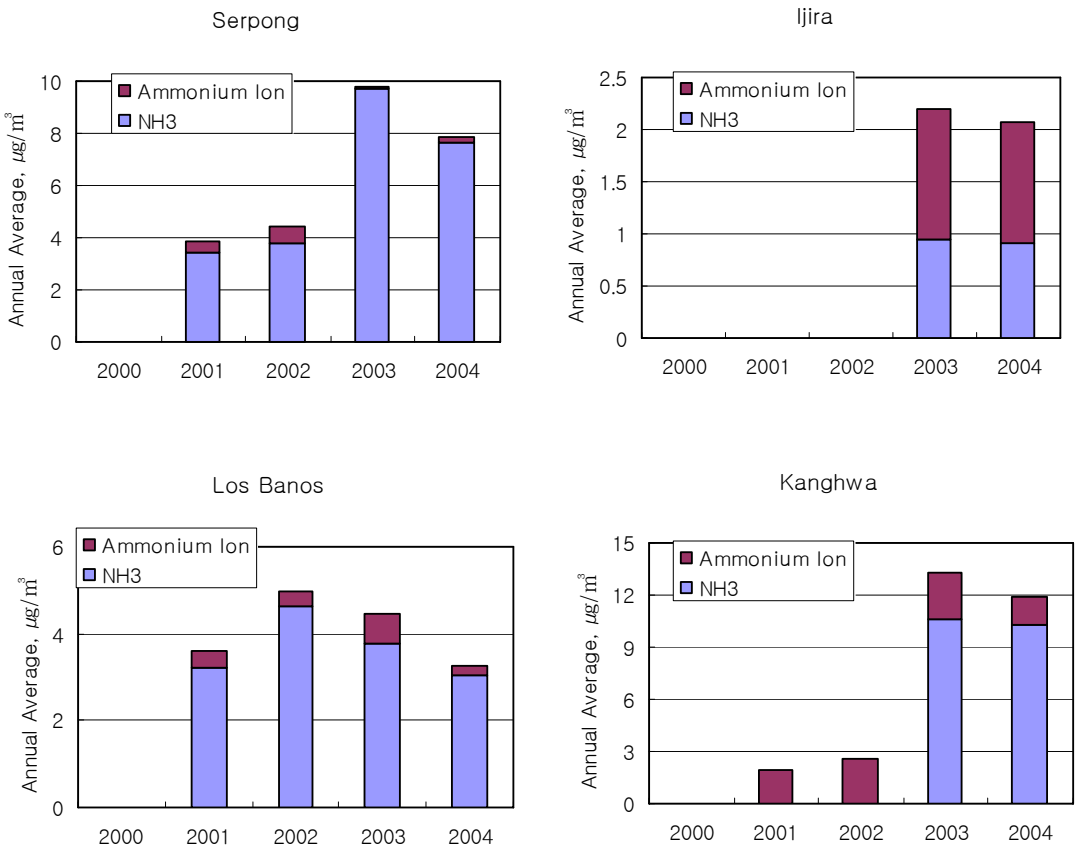


Figure 3.3.19 *(Continued on next page)*

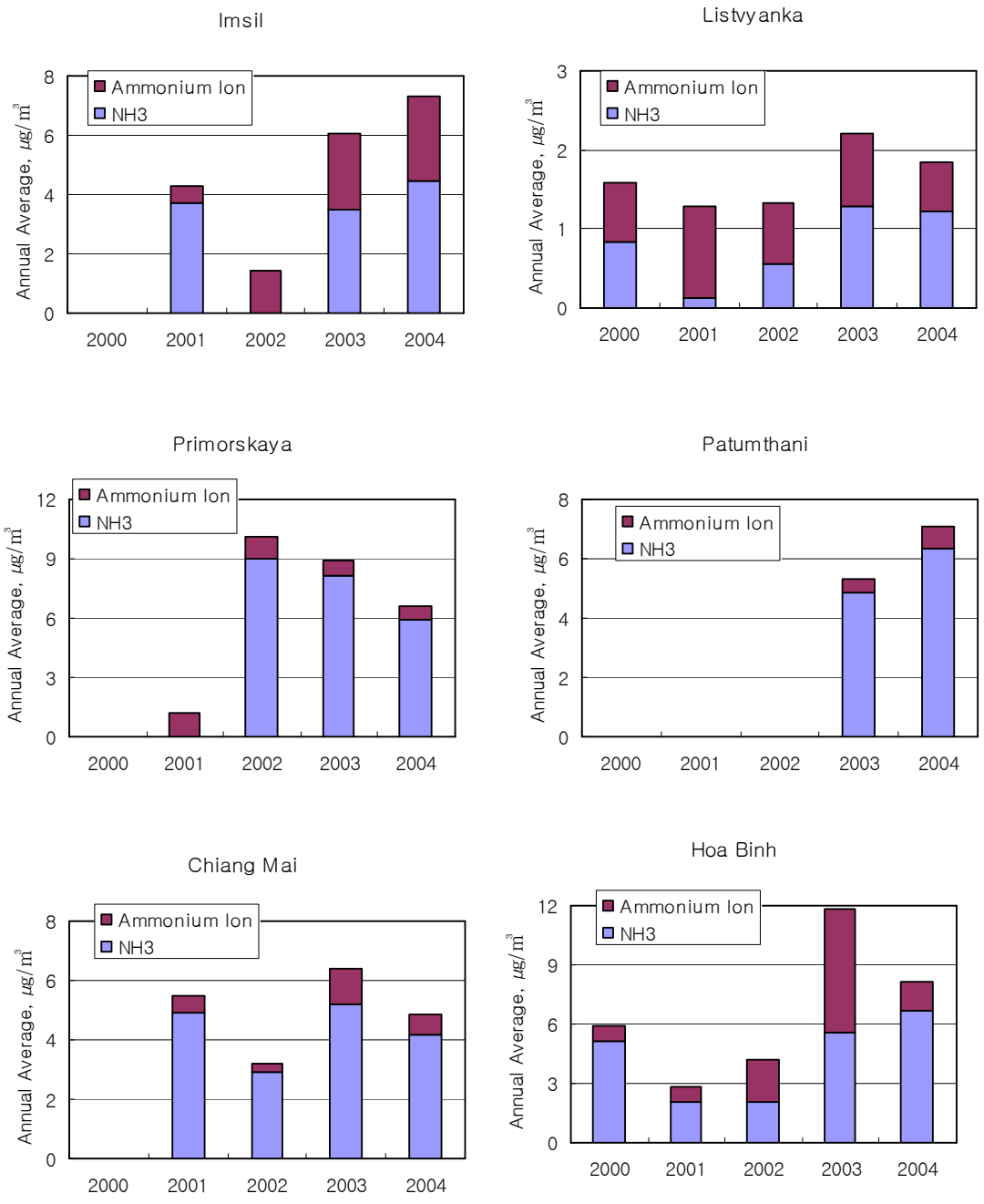


Figure 3.3.19 Annual average concentrations of gaseous NH_3 and particulate ammonium at EANET rural monitoring sites

Although NH_3 is mainly emitted by livestock and fertilizer usage, industrial processes and municipal waste treatment systems still produce a non-negligible amount of NH_3. Figure 3.3.20 shows that the annual mean NH_3 and NH_4^+ aerosol concentrations at the urban sites were comparable to or slightly lower than those at the rural sites. The ratios of NH_3 to NH_4^+ aerosol concentrations were high, and the NH_3 to NH_4^+ aerosol concentration levels did not show a clear dependency on differences in latitude.

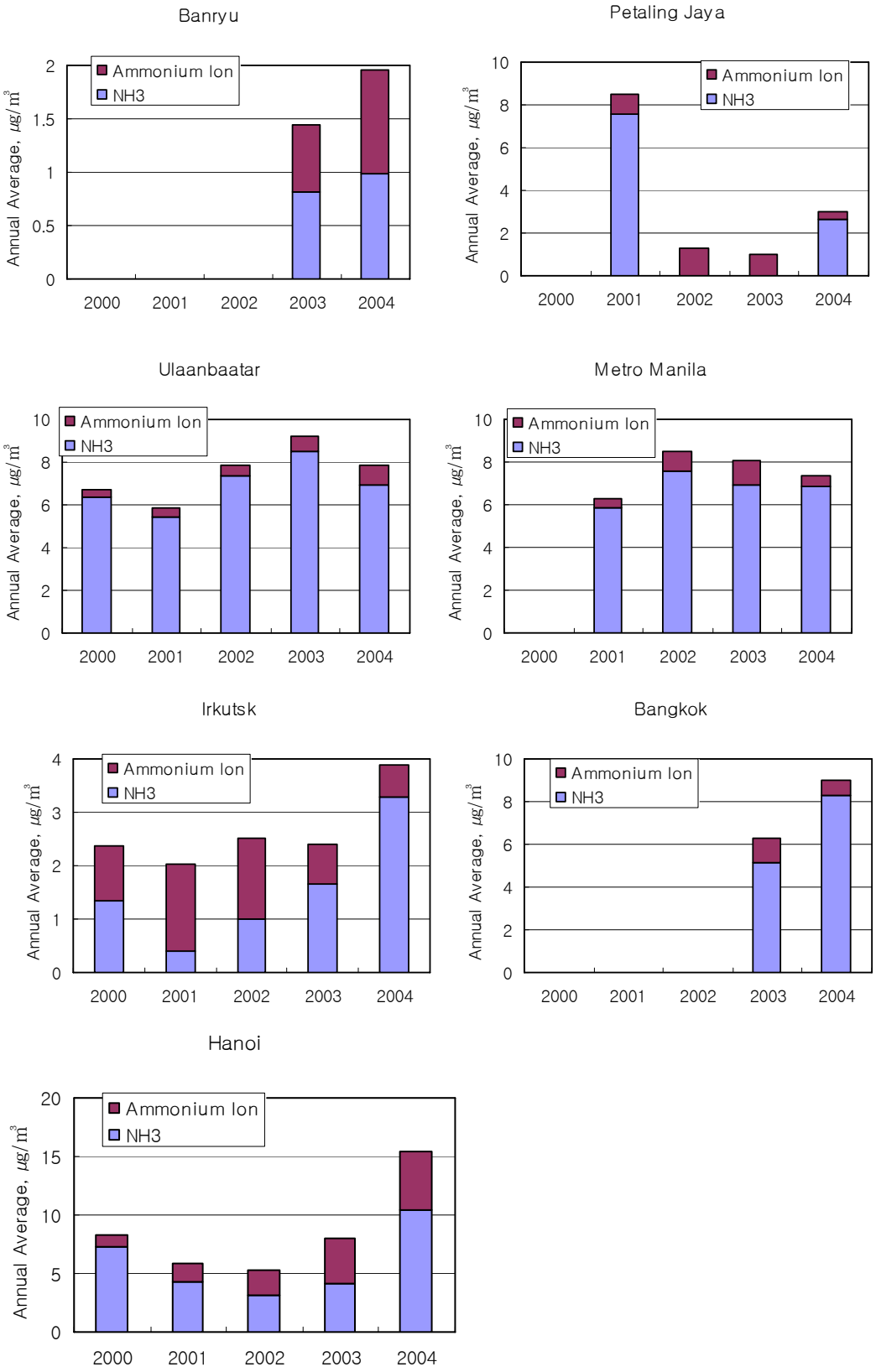


Figure 3.3.20 Annual average of gaseous NH_3 and particulate ammonium at EANET urban monitoring sites

3.3.2.4 Summary of air and aerosol chemistries

SO_2, NO_2, O_3, mass, and the chemical compositions of PM10 have been monitored as part of EANET dry deposition monitoring since 2000. This report mainly focuses on the chemical species directly related to acid deposition, such as SO_2 and sulfate aerosols, NH_3 and NH_4^+ aerosol, HNO_3, and nitrate aerosols. Because of the number of sites that did not measure aerosol species for the first two or three years of monitoring, the species related to acid deposition were averaged over only 2003 and 2004 (Figures 3.3.21–3.3.23). Here, a molar unit of sulfur or nitrate was used as appropriate to facilitate inter-comparison.

Figure 3.3.21 shows that gaseous NH_3 and ammonium aerosols appeared to be the most dominant species at all the remote monitoring sites, and that SO_2 and sulfate aerosol concentrations were comparable to each other. HNO_3 and nitrate aerosols were the smallest, implying the dominance of SO_2 and sulfate. The Cheju site recorded the highest concentrations for the species monitored, and the Oki site, located nearby, recorded the second highest concentrations. Therefore, further study is recommended to investigate a possible cause of these high concentrations in this region.

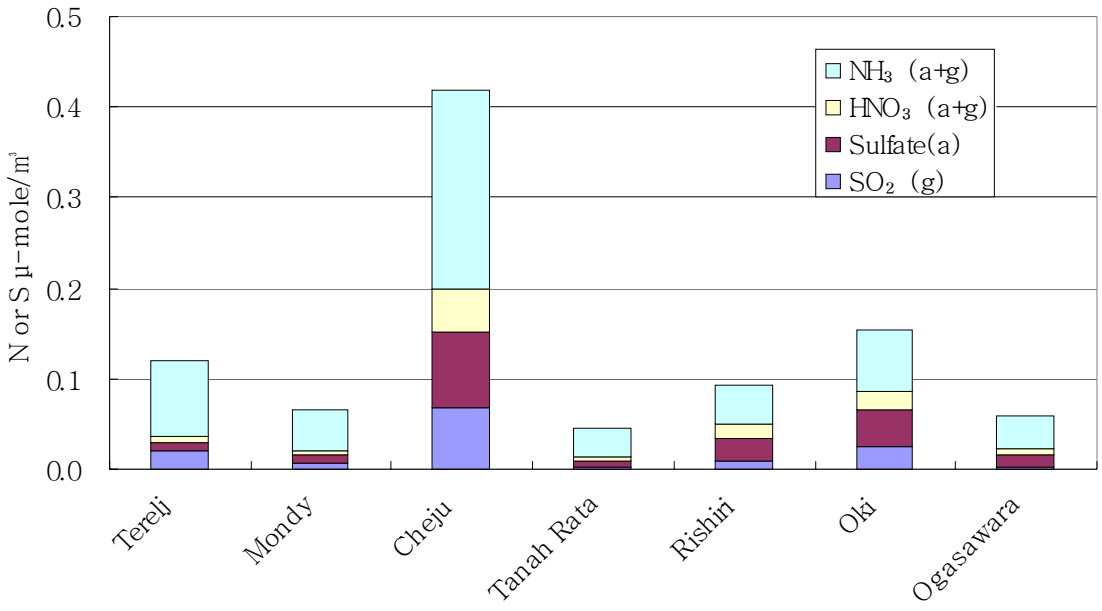


Figure 3.3.21 Average concentrations (μmole·m^{-3}) of major acid and base compounds of sulfur and nitrogen in the aerosol phase (*a*) and gas phase (*g*) at EANET remote monitoring sites in 2003 and 2004

As shown in Figure 3.3.22, NH_3 and NH_4^+ aerosol concentrations at the rural sites became more dominant over other species than those at the remote sites, because major sources of NH_3 are located in rural areas. Also, compared to the remote sites, HNO_3 and nitrate aerosol concentrations increased so much as to be comparable to sulfate aerosol concentrations. The Kanghwa site recorded the highest concentrations of NH_3 and NH_4^+ aerosols and SO_2, but because the Kanghwa site was located near Seoul, one of Asia's mega-cities, the high concentrations observed might not have been caused by the long-range transport of relevant chemical species. The sites at Hoa Binh and Serpong recorded the second and third highest NH_3 and NH_4^+ aerosol concentrations, indicating the importance of NH_3-related species in Southeast Asia.

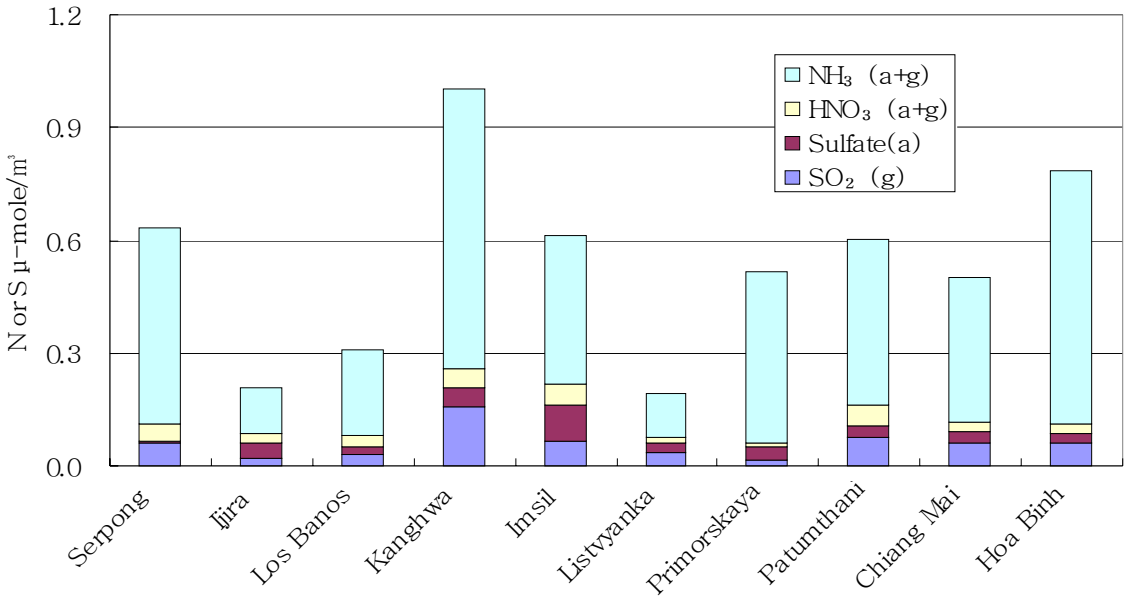


Figure 3.3.22 Average concentrations (μmole·m^{-3}) of major acid and base compounds of sulfur and nitrogen in the aerosol phase (*a*) and gas phase (*g*) at EANET rural monitoring sites in 2003 and 2004

Figure 3.3.23 shows the ambient concentrations of acid deposition-related species at EANET urban monitoring sites. Although NH_3 and ammonium aerosol concentrations were slightly lower that those at the rural sites, they were still higher than the other concentrations. The Hanoi site recorded the highest concentrations, and Ulaanbaatar, Metro Manila, and Bangkok recorded the next highest. As noted above, however, the number of EANET sites monitoring dry deposition is not yet sufficient to properly represent the air quality of urban areas.

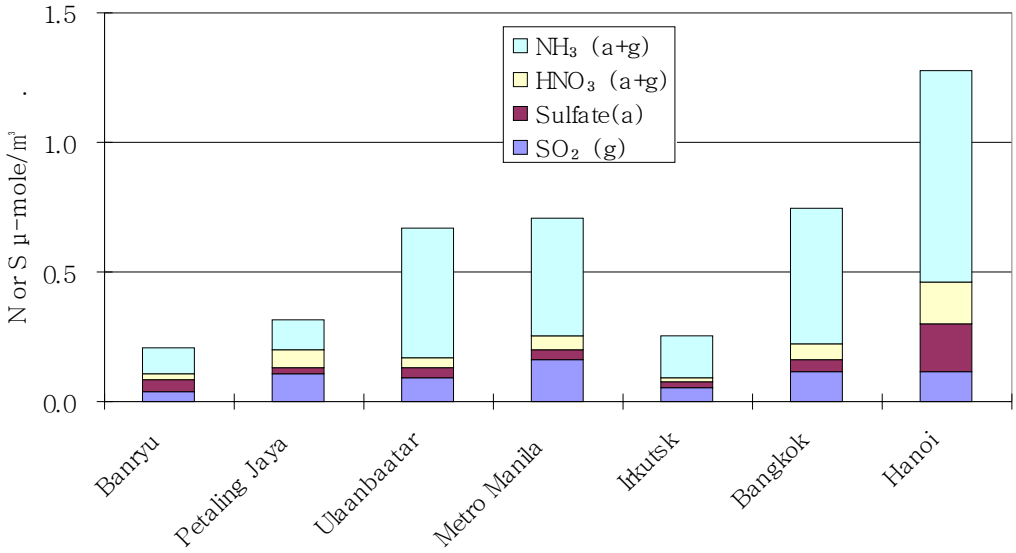


Figure 3.3.23 Average concentrations (μmole·m^{-3}) of major acid and base compounds of sulfur and nitrogen in the aerosol phase (*a*) and gas phase (*g*) at EANET urban monitoring sites in 2003 and 2004

3.3.3 Precipitation chemistry

Cloud droplets and precipitation particles absorb a number of chemical species (either in the gas or aerosol phase), which are released from both natural and anthropogenic sources. Sea salt, eroded earth crystalline materials, and biogenic activities are the major wide-spread natural sources, and fossil fuel combustion and agricultural activities are the major anthropogenic sources. The chemical species that dissolved in rainwater include both acids and bases, and it is these that determine the acidity of water. H_2SO_4 and HNO_3 are regarded as the major acids, whereas calcium carbonate and ammonia are regarded as the major bases.

Once the acids in rain droplets were identified as a potential cause of acidification of lakes and soils, it was widely recommended that regular monitoring of the pH and chemical composition of rainwater should commence in order to accurately estimate the amount of acid deposition. By January 2004, EANET had established a total of 45 wet deposition-monitoring sites consisting of 16 urban, 12 rural, and 17 remote sites (Figure 3.3.24). Although the number of remote sites itself seems to be sufficient, nine of them were located in Japan, highlighting the fact more remote sites are needed in other parts of the region.

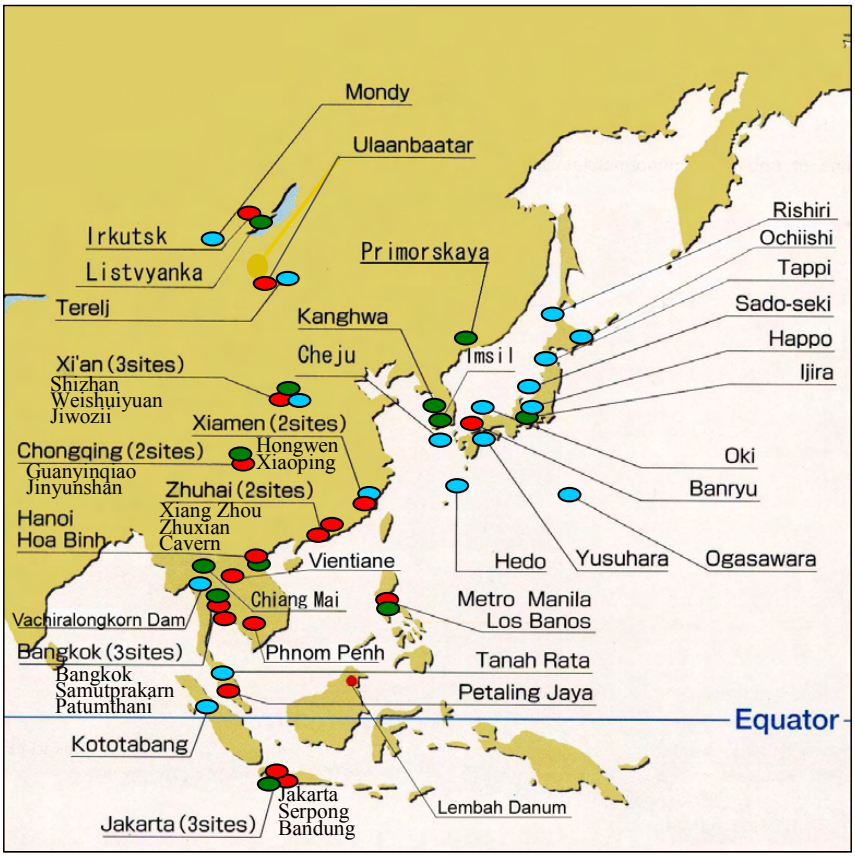


Figure 3.3.24 Locations of EANET wet deposition monitoring sites in 2004

The results of monitoring wet deposition at the EANET sites (2000–2004) were analyzed here to identify the chemical properties of rainwater samples. First, the chemical composition of rainwater samples was overviewed to investigate the characteristics of rainwater related to site location. Second, the acid and base concentrations observed were analyzed to identify their roles in determining the acidity of rainwater. Third, the effect of precipitation on ion concentrations was investigated by deriving the relation of the precipitation amount to major acid and base concentrations. Finally, the ratios of sulfate to nitrate concentration in rainwater were analyzed to reveal the characteristics of emission effects.

As this is EANET's first *Periodic Report*, daily or event-wise values were analyzed to find any anomalies or spurious monitoring data, and then to check the representation of monthly and yearly averaged values in addressing the properties of rainwater. Of course, monthly or yearly averaged values were also utilized to reveal any general trends whenever possible.

3.3.3.1 Overview of chemical compositions

Rainwater contains various dissolved anions and cations after incorporating gaseous and aerosol species from the ambient air. The anions and cations measured at EANET monitoring sites were SO_4^{2-}, NO_3^-, Cl^-, NH_4^+, Na^+, K^+, Ca^{2+}, Mg^{2+}, and H^+. Organic acids were usually not measured. Some laboratories measured hydrogen carbonate, although it could be calculated theoretically, as well as the non-sea salt (*nss*-) portion of SO_4^{2-} and Ca^{2+}. The volume-weighted, averaged compositions of directly measurable cations and anions were calculated and are shown in Figures 3.3.25, 3.3.26, and 3.3.27 to exhibit the characteristics of ionic species in precipitation at each monitoring site.

The major anions at the inland sites in China, Mongolia, and Russia were found to be SO_4^{2-} and NO_3^-, and the major cations were NH_4^+ and Ca^{2+} (Figure 3.3.25). Compared to the inland sites, the sea salt-driven ions, Cl^- and Na^+, appeared higher, and Ca^{2+}, as a soil-driven ion, appeared lower at the coastal monitoring sites in China (Hongwen, Xiaoping, Xiang Zhou, and Zhuxian Cavern). Also, the SO_4^{2-} presents higher molar percentile compositions than NO_3^- at all the sites, except Listvyanka in Russia, making it the most important anion species.

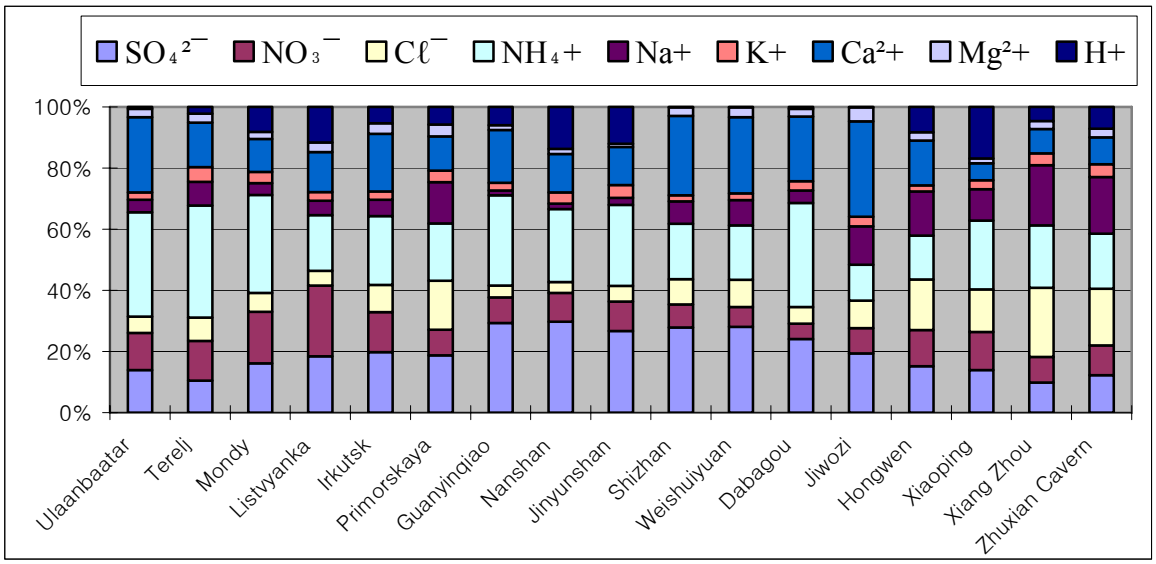


Figure 3.3.25 Anion and cation percentile concentrations of rainwater at the EANET monitoring sites in China, Mongolia, and Russia

Figure 3.3.26 shows that the chemical composition of rainwater at the monitoring sites in Japan and Korea, which are mostly located in coastal areas (except Happo, Ijira, and Imsil), were greatly affected by sea salt input. Therefore, the major anion and cation were Cl^- and Na^+, respectively, at all the coastal sites. It was discovered that the Cl^- concentration was equal to the Na^+ concentration, because they were incorporated into cloud or rain droplets in the form of salts. Besides Cl^-, SO_4^{2-} also appeared to be a major anion, followed by NO_3^-. Note that Ca^{2+} appeared to be negligible at all the Japanese sites except Happo, implying the insignificance of soil influences.

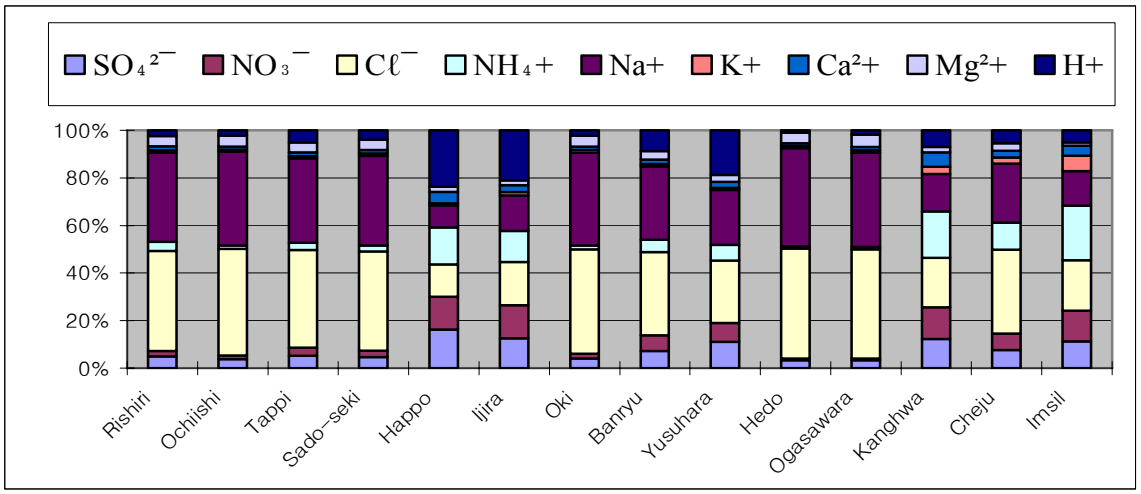


Figure 3.3.26 Anion and cation percentile concentrations of rainwater at the EANET monitoring sites in Japan and Korea

The chemical compositions of rainwater samples at the monitoring sites in Southeast Asia are presented in Figure 3.3.27. The major anions identified were SO_4^{2-}, NO_3^-, and Cl^-, while NH_4^+, Na^+, and Ca^{2+} were identified as the major cations. Precipitation in countries in Southeast Asia has Ca^{2+} contents less than in China and Mongolia, but more than in Japan. Non-negligible sea-salt contributions were recorded at all the sites. In addition, the molar percentile concentrations of NO_3^- exceeded those of SO_4^{2-} at several sites, which is different from the chemical composition of precipitation in Northeast Asia.

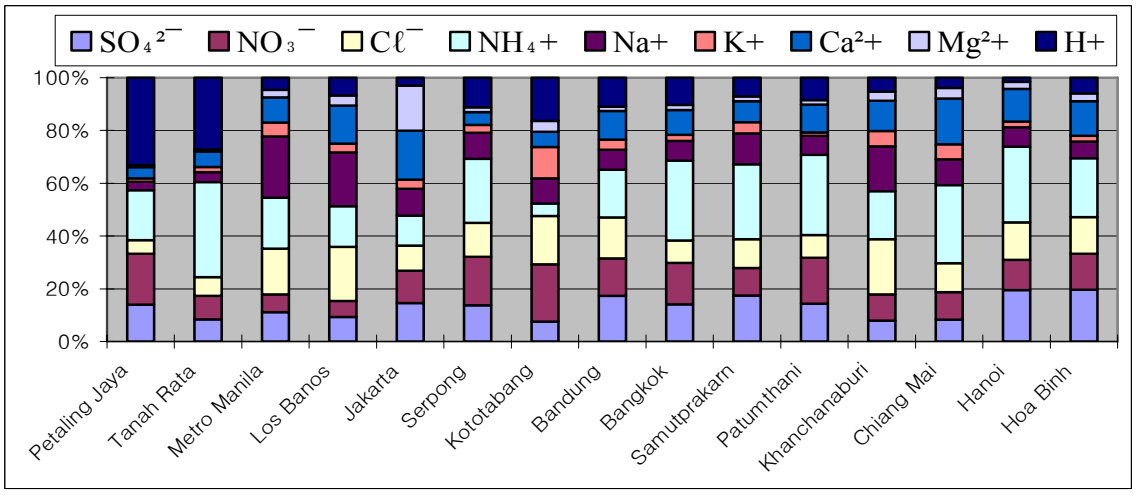


Figure 3.3.27 Anion and cation percentile concentrations of rainwater at the EANET monitoring sites in Southeast Asia

3.3.3.2 Major anions

Some quantitative parameters were proposed to analyze the wet deposition measurements in terms of acid-base chemistry. Acidity, or pH, is a fundamental measure of precipitation acidity, and it is determined by the nature and proportions of acids and bases in aqueous solutions. In this sense, pH is a secondary parameter, whereas acids and bases are primary ones. If any two of these three quantities are properly determined, then the other can be obtained theoretically. A complementary quantity of pH is also used below for a semi-quantitative discussion of the acid-base chemistry of wet deposition.

The acid-base balance is assumed to involve only four compounds: H_2SO_4, HNO_3, ammonia, and calcium carbonate. In this system, these acids are initially formed in a hygrometeor, and then incorporated into the bases proceeds. Particulate ammonium species are involved in the form of ammonium salts such as ammonium sulfate. Sulfate is produced from SO_2 both in the gas phase and in the liquid phase by photochemical reactions, whereas nitrate is produced from NO_x by photochemical reactions only in the gas phase.

The following sequence of chemical processes suffices for the quantification of acidity or pH.

$$H_2SO_4 \rightarrow 2H^+ + SO_4^{2-} \quad (3.3.13)$$

$$HNO_3 \rightarrow H^+ + NO_3^- \quad (3.3.14)$$

$$NH_3 + H_2O \rightarrow NH_4^+ + OH^- \quad (3.3.15)$$

$$CaCO_3 \rightarrow Ca^{2+} + CO_3^{2-} \quad (3.3.16)$$

$$CO_3^{2-} + H_2O \rightarrow HCO_3^- + OH^- \quad (3.3.17)$$

$$H^+ + OH^- \rightarrow H_2O \quad (3.3.18)$$

SO_4^{2-} and NO_3^- ions are released from the strong acids, H_2SO_4 and HNO_3, and they are not involved in the neutralization reaction once dissociated. Because the concentrations of SO_4^{2-} and NO_3^- remain unchanged throughout the neutralization, the SO_4^{2-} and NO_3^- concentrations are numerically identical to those of H_2SO_4 and HNO_3, respectively. The initial concentration of the H^+ ion is equal to the concentration sum of SO_4^{2-} and NO_3^-, which is termed *input acidity*, denoted as A_i in the following formula:

$$A_i = [nss\text{-}SO_4^{2-}] + [NO_3^-] \quad (3.3.19),$$

where concentrations are in the unit of eq mole L^{-1}. The parameter pA_i is defined in a similar manner to pH, as follows, and corresponds to the pH if no neutralization takes place after the initial formation of sulfuric and nitric acids.

$$pA_i = -log_{10}([nss\text{-}SO_4^{2-}] + [NO_3^-]) \quad (3.3.20)$$

Figure 3.3.28 shows a relation between pH and pA_i for the following four selected sites in China: Weishuiyuan (mid-north), Jinyunshan (central), Xiaoping (southeast), and Xiang Zhou (mid-south). Most of the points representing the measured pH values stayed well above the diagonal line of conditions, in which pH is equal to pA_i. This overshooting of pH values was caused by the existence of an appreciable amount of bases such as $CaCO_3$ and NH_3. (A detailed analysis of cations is presented in the next sub-section).

The highest overshoot of pH values was found at the Weishuiyuan site; all pH values except one exceeded 5.4 regardless of pA_i value. As presented in the next sub-section, Ca^{2+} derived from soil was a main cause for this high pH value. The effect of soils weakened along the direction of north to south. Therefore, the Jinyunshan site (central China) showed an overshoot of pH values of a lesser degree. Also, most pH values at the Xiaoping and Xiang Zhou sites (southern China) did not exceed the pA_i values by more than 2.0. In addition, there were some cases where pH values were lower than the pA_i values in Xiaoping, implying that anions other than *nss*-SO_4^{2-} and NO_3^- were present with concentrations higher than concentrations of cations other than the hydrogen ion.

Figure 3.3.28 also exhibited the seasonal characteristics of relations of pH to pA_i. First, the pA_i values were smaller in the spring and winter, implying larger input of acid than in the summer and fall. This is because of higher ambient SO_2 concentrations, as noted in section 3.3.2, as well as because of the lower amount of precipitation in the winter, as noted in section 3.2. In addition, the deviation of pH values from the diagonal line tends to be bigger in the spring, when favorable conditions for yellow sand events form.

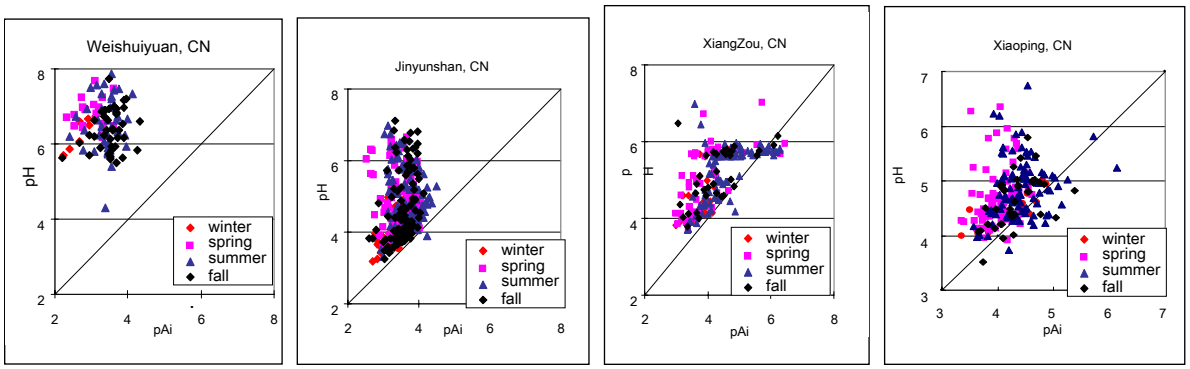


Figure 3.3.28 Measured pH versus pA_i at selected monitoring sites in China (2001–2004)

The data collected at the monitoring sites in Cheju and Imsil (Korea) and some remote sites in Japan exhibited lesser degrees of overshooting pH values with respect to pA_i values (Figure 3.3.29) than those recognized in northern China (Weishuiyuan), because the aerosols contained less Ca^{2+}, limiting its role in increasing pH values.

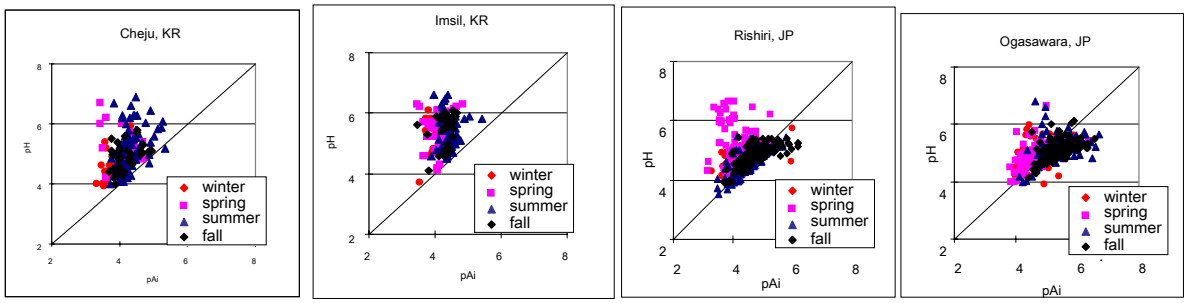


Figure 3.3.29 Measured pH versus pA_i values at selected monitoring sites in Korea and Japan (2001–2004)

The pA_i values ranged from 4.0 to 6.0, and the pH overshot pA_i values were considerable only when pA_i was low in Cheju (Korea), implying non-significant cation effects. The data from the Rishiri site (Japan) showed that most of the pA_i versus pH values lie on diagonal lines except ones in spring. Moreover, the overshooting of pH values in spring also appeared at other remote sites in Japan. As discussed in section 3.3.3.3, the high Ca^{2+} concentration in precipitation was responsible for this overshooting of pH. Because yellow sand events mainly occur in the spring and the yellow sands are rich in Ca^{2+}, they were probably associated with this phenomenon. The Ogasawara site exhibited stronger seasonal variations of pA_i values (low in winter and spring, high in summer and fall), compared to the sites in China, Korea, and the other sites in Japan. This strong seasonal variation is probably related to the long-range transport of sulfur and nitrogen compounds, and requires further study.

Figure 3.3.30 shows pH values with respect to pA_i for the sites located in high latitudes, namely, Mongolia and Russia. The pH values considerably overshot the pA_i values due to a strong effect of cations at all these sites. High pH values exceeding 7.0 were observed at the Ulaanbaatar and Terelj sites in Mongolia and the Irkutsk site in Russia. There were no distinctive seasonal variations of pA_i values despite well-defined seasonal changes of SO_2 (noted in section 3.3.2), but the stronger overshooting of pH values in spring and winter was characterized at sites in Russia rather than in summer and fall, similar to the data from the Rishiri site in Japan.

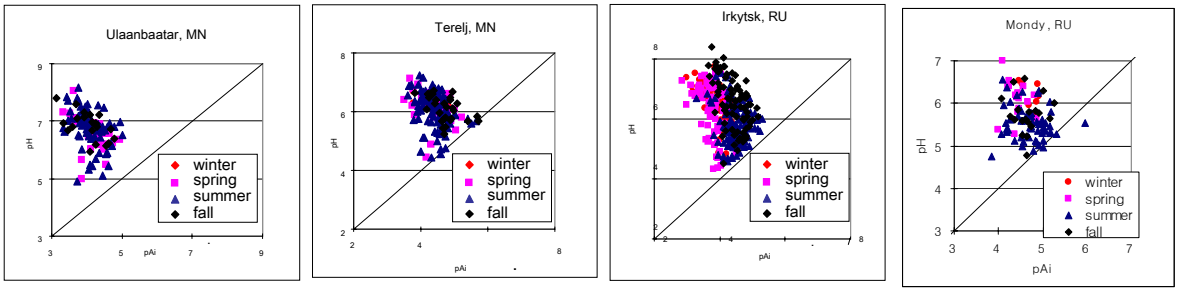


Figure 3.3.30 Measured pH versus pA_i at selected monitoring sites in Mongolia and Russia (2001–2004)

Figure 3.3.31 presents the pA_i-pH relations at the four sites in Thailand. Although the sites ranged from urban to remote, the magnitude of pA_i and pH as well as the pA_i-pH relations were very similar to each other, strongly exhibiting the regional-scale characteristics of acid deposition. All the measured data appeared to be situated above the diagonal lines, indicating that pH values were usually larger than the corresponding pA_i values. As discussed in the next section, both NH_4^+ and Ca^{2+} were responsible for these larger pH values. Despite the seasonal variation of precipitation amount, no distinctive seasonal changes were observed, in contrast to the countries in Northeast Asia.

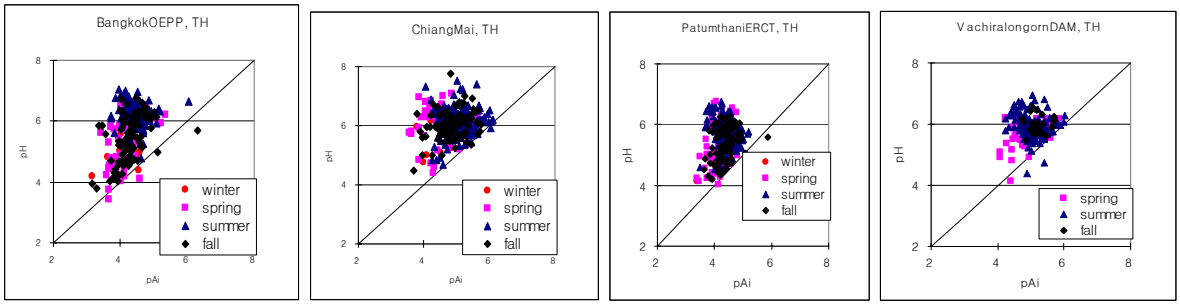


Figure 3.3.31 Measured pH versus pA_i at selected monitoring sites in Thailand (2001–2004)

As shown in Figure 3.3.3.32, the pA_i and pH relations at the sites in the Philippines and Vietnam behaved similarly to those shown previously in figures 3.3.29–32; the pH values often exceeded the pA_i values. Notably, there were several cases where pH values exceeded pA_i values by more than 3.0, indicating a significant cation presence. Despite pH generally exceeding pA_i, there were also some cases where pA_i values were lower than pH at the sites in the Philippines, indicating the presence of anions other than *nss*-SO_4^{2-} and NO_3^-. As noted earlier, this type of phenomenon was also observed at the Xiaoping site, where site conditions were very similar to those at the sites in the Philippines.

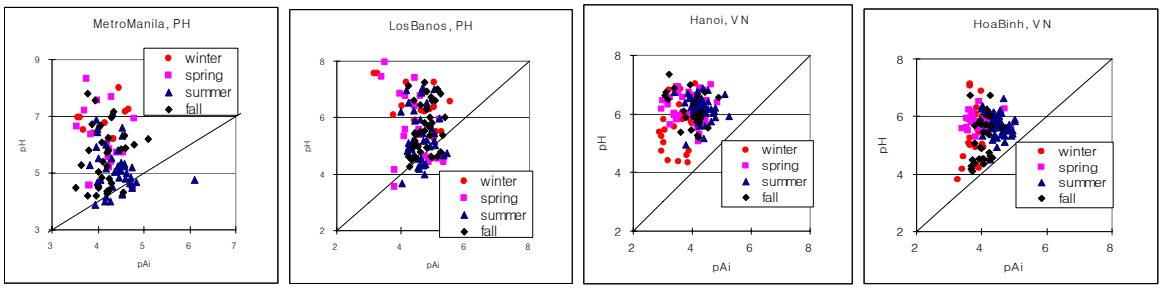


Figure 3.3.32 Measured pH versus pA_i at selected monitoring sites in the Philippines and Vietnam (2001–2004)

Figure 3.3.33 shows that the pA_i-pH relations at the sites in Indonesia behaved similar to the other sites in peninsular Indochina, as presented in figures 3.3.31–32; pAi values were larger than pH values. There was found, however, to be a substantial number of pA_i values that were lower than the corresponding pH values at the sites in Malaysia. Therefore, the dots of measured data were found not only to be above the diagonal but also below it in the pA_i-pH scatter diagram. Although the Xiaoping site in China and the Los Baños site in the Philippines also had events where pA_i values exceeded pH values, the number of occurrences and the degree of exceedance observed at the sites in Malaysia were more severe than at the sites mentioned above. Therefore, organic acids were measured at the sites in Malaysia to account for missing anions. A study is presently underway to include organic acids as inputs.

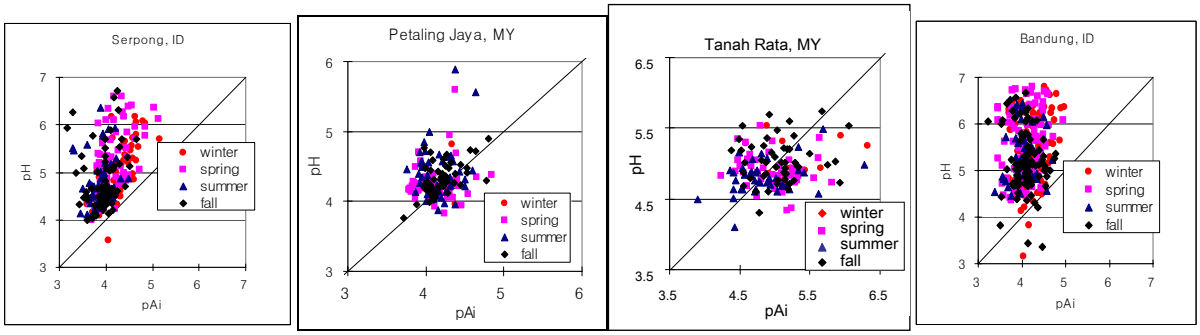


Figure 3.3.33 Measured pH versus pA_i at selected monitoring sites in Malaysia and Indonesia (2001–2004)

The pA_i-pH relations provide information on acid and base balance in precipitation. The pH values were always higher than pA_i values at the Weishuiyuan site in China, the Ulaanbaarar site in Mongolia, and the Hanoi site in Vietnam. On the contrary, the Xiaoping site in China, Ogasawara site in Japan, Los Baños site in Philippines, Petaling Jaya site, and Tanah Rata site in Malaysia had a non-negligible number of data points with pH values lower than pA_i values. In the other sites, the pH values were equal to or greater than the pA_i values.

In Northeast Asia, the pA_i values exhibited a rather distinctive seasonal trend, low in winter and high in summer, due to increased fuel usage in winter. Also, the values of (pA_i-pH) were the largest in the spring, probably due to the yellow sand effect.

3.3.3.3 Major cations

A main reason for the pH values being larger than pA_i values is the effect of cations, mainly non-sea salt Ca^{2+} and NH_4^+. (For the purpose of analysis here, Ca^{2+} for non-sea salt is denoted as *nss*-Ca^{2+}). Note that the *nss*-Ca^{2+} that appeared in rainwater from dust blown up from the soil and its effect on the aquatic environment is small. On the other hand, NH_4^+ is converted in rainwater from the NH_3 emitted by various agricultural and industrial sources. This ambient NH_3 exists in both the gaseous and aerosol phases of partitions that are determined by varying thermodynamic processes in the atmosphere. Furthermore, NH_4^+ in precipitation may play a role as a nutrient in aquatic environments or it may cause nitrification in soil environments.

The relative importance of Ca^{2+} and NH_4^+ can be identified by calculating the ratios of these two ions. Through analysis of EANET data, the ratios of *nss*-Ca^{2+} versus NH_4^+ were found to vary significantly, and are represented by the frequently used correspondent scatter diagram. The ratios D_{mc} of Ca^{2+} versus NH_4^+ (D_{mc} = $[NH_4^+]/[2 \cdot nss\ Ca^{2+}]$) were plotted against the corresponding pH values to fully visualize their variability in precipitation.

The values of D_{mc} at the Weishuiyuan site in mid-northern China were mostly less than 1.0, indicating that *nss*-Ca^{2+} is a major cation (Figure 3.3.34). On the contrary, D_{mc} values ranged from 0.01 to 1,000 in other regions of China, such as Jinyunshan (in the country's center), Xiaoping (southeastern), and Xiang Zhou (mid-southern). These sites had more cases of precipitation with a D_{mc} value greater than 1.0, implying that NH_4^+ is the major cation.

As NH_4^+ is a weak base, its apparent solubility is therefore dependent on pH, as follows:

$$S_{ap,NH_3} = \frac{NH_3(aq) + NH_4^+}{NH_3(g)} = \frac{NH_3(aq)}{NH_3(g)}\left(1 + \frac{K_{eq,NH_3}[H^+]}{K_w}\right) \qquad (3.3.21)$$

where S_{ap,NH_3} is the apparent solubility of NH_3, and K_{eq,NH_3} and K_w denote the equilibrium constant for NH_3 and water, respectively. The dependency of D_{mc} on pH was not apparent, however, for these sites in China due to the strong temporal variation of NH_3.

Figure 3.3.35 shows the D_{mc} values for selected sites in Korea and Japan. They exceeded 1.0 in Rishiri during all seasons, except during precipitation events with high pH values. At the other sites, most D_{mc} values exceeded 1.0 in summer and fall, while their distribution was more evenly in the range of 0.1–10.0 in spring and winter. The lower D_{mc} values in winter are considered to be associated with less agricultural and biogenic activities, but more studies on the emission characteristics of NH_3 should be done to further clarify the seasonal variations observed and the relative importance of NH_4^+ over *nss*-Ca^{2+} in precipitation.

Figure 3.3.35 shows that the minimums of D_{mc} decreased linearly based on log value as the pH increased in precipitation at the Rishiri and Oki sites. This behavior of D_{mc} also appeared at most of the other remote sites in Japan, because the apparent solubility of NH_3 decreases when pH increases, as noted in Equation (3.3.21). The dependency of NH_4^+ concentrations on changes in pH can be traced more clearly in Figure 3.3.36, where the set of measured NH_4^+ values form a band stretching from the top left to the bottom right in the NH_4^+-pH diagram. Some measurements with high pH in spring stay off the band, however, probably due to high ambient NH_3 concentrations in the spring. This dependency of NH_4^+ on pH was not observed at the sites in China and Korea, implying that the ambient NH_3 varied significantly.

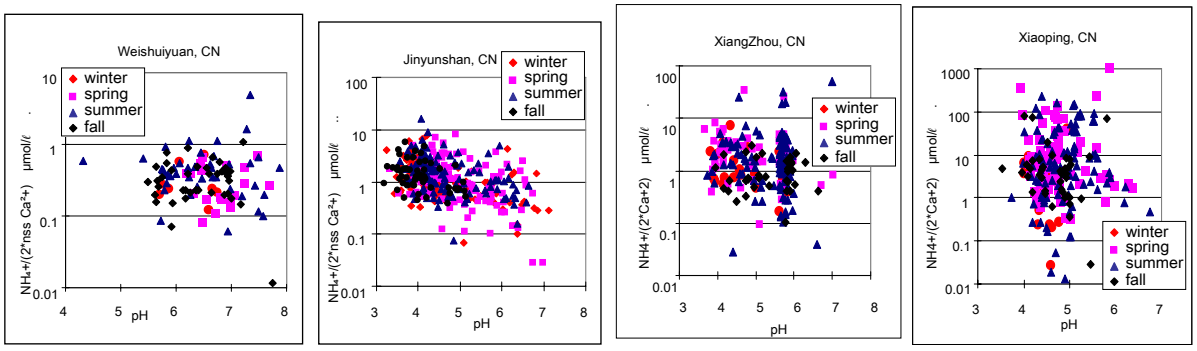


Figure 3.3.34 Measured D_{mc} ($[NH_4^+]/[2\cdot nss\text{-}Ca^{2+}]$) versus pH at selected EANET monitoring sites in China (2001–2004)

The dependency of D_{mc} on pH also appeared at the Ulaanbaatar and Terelj sites in Mongolia and Irkutsk in Russia (Figure 3.3.37), where the D_{mc} declined when pH increased due to the decrease in the apparent solubility of NH_3. The D_{mc} values appeared smaller in winter and spring except for at Ulaanbaatar, probably because the dust containing Ca^{2+} increases in the air during these seasons due to low humidity and precipitation. This increase of Ca^{2+} also promotes pA_i values to further deviate from pH in the winter and spring.

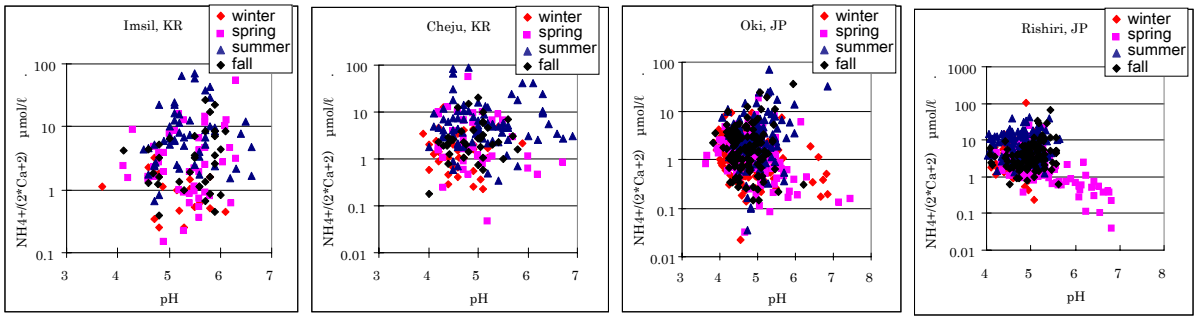


Figure 3.3.35 Measured D_{mc} versus pH at selected monitoring sites in Korea and Japan (2001–2004)

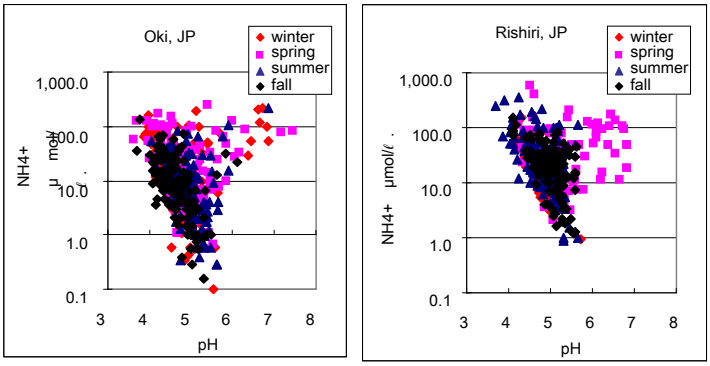


Figure 3.3.36 Measured NH_4^+ concentrations versus pH at selected monitoring sites in Japan (2001–2004)

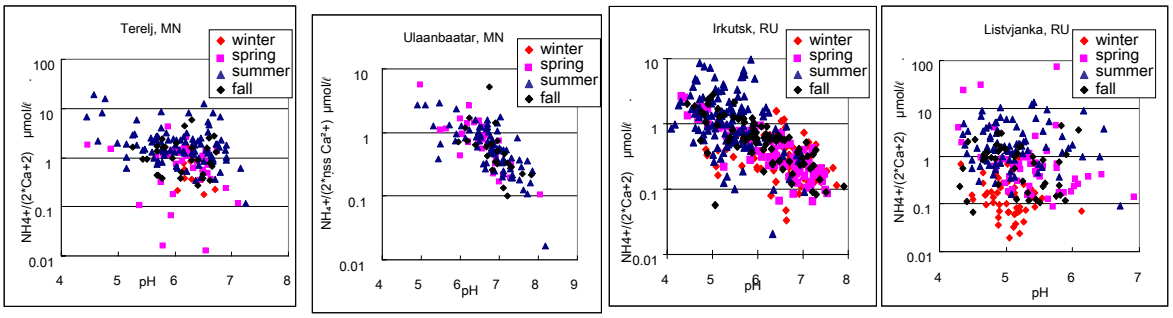


Figure 3.3.37 Measured D_{mc} versus pH at monitoring sites in Mongolia and Russia (2001–2004)

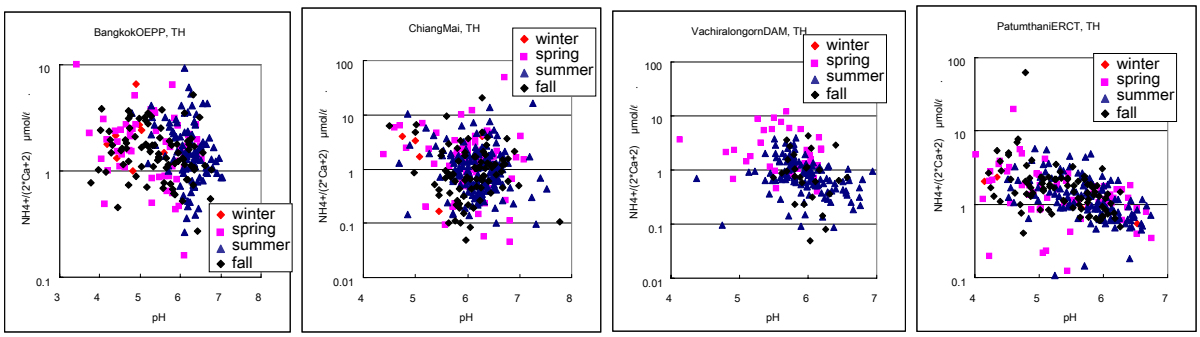


Figure 3.3.38 Measured D_{mc} versus pH at monitoring sites in Thailand (2001–2004)

Following the discussion above on the role of cations in precipitation chemistry at the monitoring sites, the D_{mc} values in Thailand, which ranged from 0.1 to 10.0, indicate that both NH_4^+ and *nss*-Ca^{2+} were important (Figure 3.3.38). Also, the minimal D_{mc} values tended to be higher with low pH due to the increase in apparent solubility of NH_3, as pointed out earlier.

D_{mc} values in the Philippines, Vietnam, and Indonesia were mostly in the range of 0.1 to 10.0 with not much bias, except for the Serpong site in Indonesia (Figure 3.3.39), indicating that both NH_4^+ and Ca^{2+} were equally important. The D_{mc} ratios recorded for wet deposition samples at the Serpong site were mostly higher than 1.0, indicating that NH_4^+ is a more important cation than *nss*-Ca^{2+}.

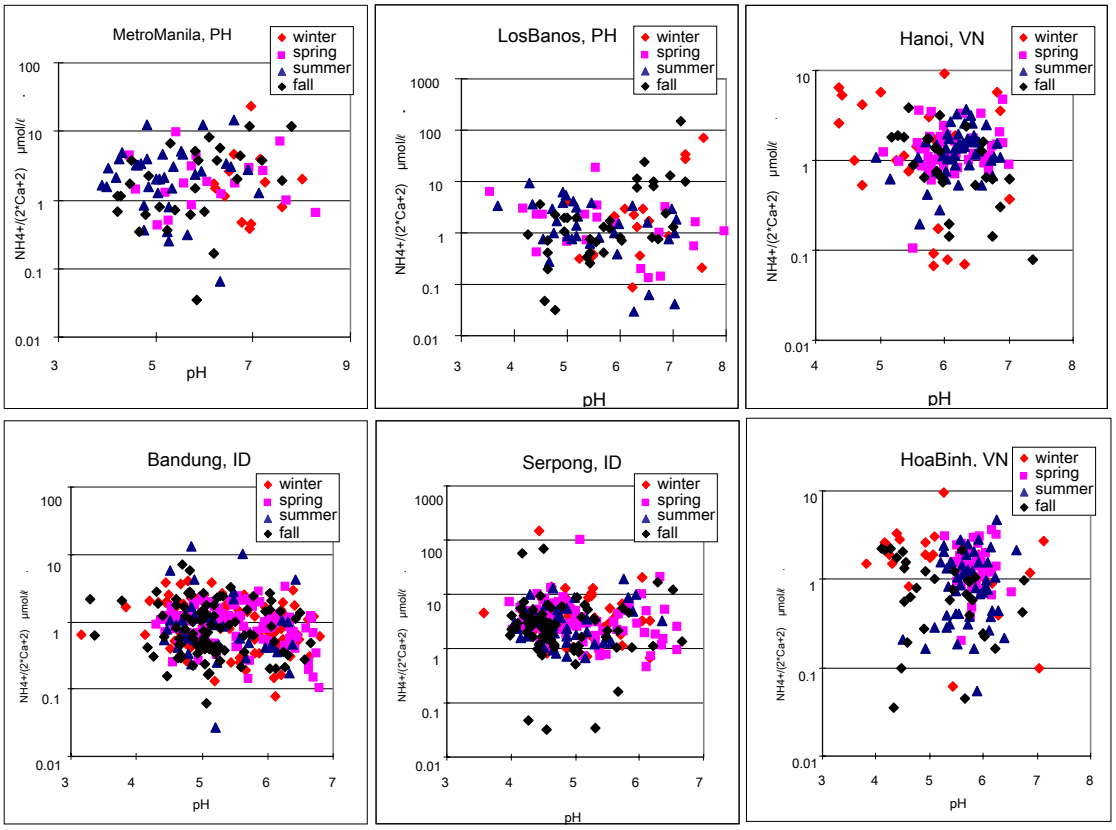


Figure 3.3.39 Measured D_{mc} versus pH at monitoring sites in the Philippines, Vietnam, and Indonesia (2001–2004)

3.3.3.4 Sulfate-to-nitrate ratio in rainwater

The correlation of ions in rainwater may reveal source characteristics as well as precipitation chemistry. The ratios of pairs of ion concentrations may be statistically meaningful, especially if they correlate reasonably well. The correlation of SO_4^{2-} and NO_3^- is often analyzed, because knowing the ratio of the two is useful in identifying major acidifying substances.

The SO_4^{2-} and NO_3^- concentrations correlated very well in rain samples at the six sites selected to represent various parts of East Asia, except for the ranges of very high concentrations (Figure 3.3.40). Very high concentrations of SO_4^{2-} and NO_3^- were often associated with cases of very small amounts of precipitation and may not be a meaningful for analysis of source characteristics. The wet deposition amount of SO_4^{2-} and NO_3^- was therefore chosen to minimize the influence of low precipitation cases. In addition, a monthly averaged deposition amount was used instead of a daily- or event-wise deposition amount to focus more on bulk properties.

The monthly averaged amounts of SO_4^{2-} and NO_3^- correlated very well, such that the R^2 values at the six selected sites were higher than 0.64 (Figure 3.3.41). The slope line in Figure 3.3.41 may be derived by linear regression analysis and could be interpreted as a molar ratio of SO_4^{2-} to NO_3 in precipitation. The results of this linear regression analysis performed for all the EANET sites are presented in Table 3.3.2. The R^2 values were larger than 0.5 for 36 out of all 44 EANET monitoring sites analyzed here, implying a statistically significant level of correlation. The sites with an R^2 less than 0.5 are shaded in Table 3.3.2 and excluded from the analysis of the molar ratios of SO_4^{2-} to NO_3 discussed below unless mentioned otherwise.

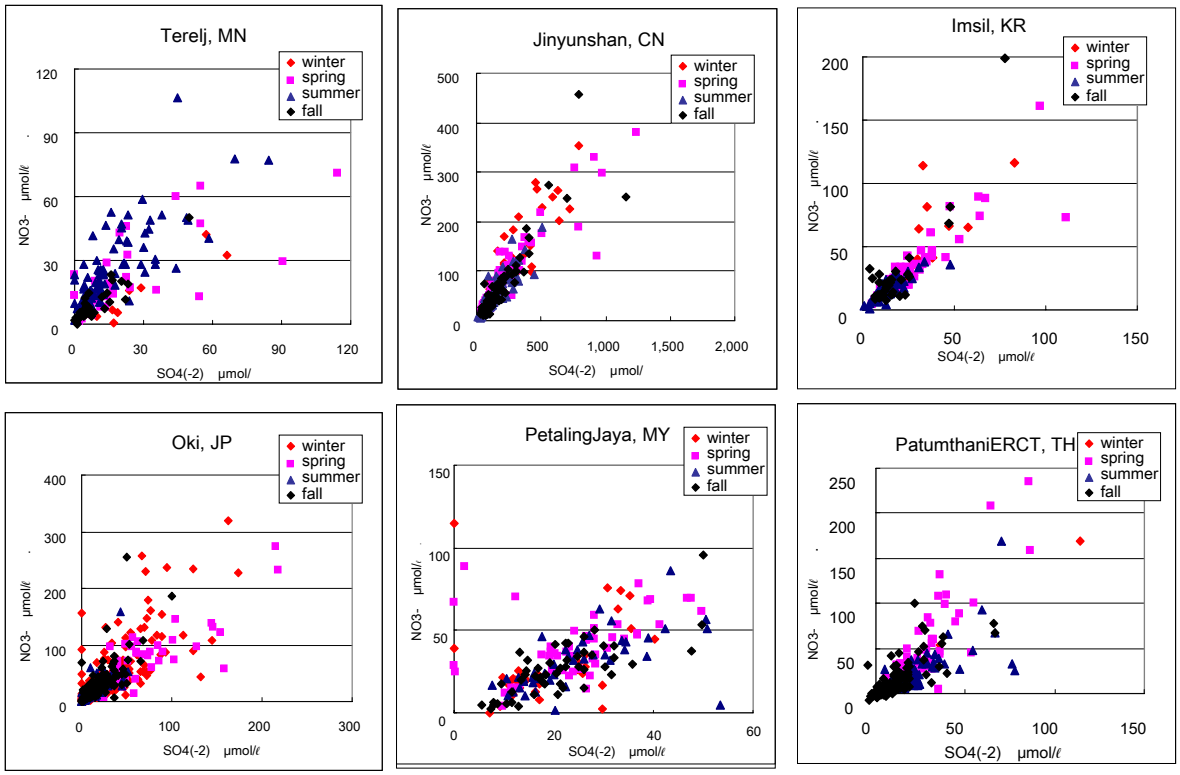


Figure 3.3.40 Measured concentrations (μmole L^{-1}) of SO_4^{2-} versus NO_3^- at selected sites in East Asia (2001–2004)

The molar ratios of SO_4^{2-} to NO_3 ranged from 3.62 to 0. The first and second largest ratios were recorded at the Guanyinqiao and Jinyunshan monitoring sites in central China. The next highest ratio of 1.72 was also recorded for precipitation at the Jiwozi site, located north of these two sites. It may be noted that for the Shizhan and Weishuiyuan sites in the same province as Jiwozi the values of molar ratios of SO_4^{2-} to NO_3 were above 2.0, although the R^2 values were calculated as only 0.43–0.49. Therefore, SO_4^{2-} may be regarded as a major acid ion in rainwater in northern and central China, surpassing NO_3^-, and its molar ratios were higher than those in other parts of the EANET region.

There were only seven sites from among all the others with the molar ratios of SO_4^{2-} to NO_3^- in wet deposition samples exceeding 1.0, but even for them these cases consisted of less than 30% of the total. Because five of these sites were in urban areas—Hongwen (China), Bandung (Indonesia), Ulaanbaatar (Mongolia), Metro Manila (Philippines), and Irkutsk (Russia)—the higher sulfate in precipitation could have appeared probably because of high SO_2 emissions from industrial fossil fuel combustion.

Only eight monitoring sites had molar ratios of SO_4^{2-} to NO_3^- values less than 0.7; at Jakarta (Indonesia), Banryu and Ogasawara (Japan), Terelj (Mongolia) the molar ratios were less than 0.7 but greater than 0.6. Molar ratios less than 0.6 were identified from the data from the monitoring sites in Xiaoping and Xiang Zhou (China), Petaling Jaya (Malaysia), and Khanchanaburi (Thailand). Note that these sites are scattered over East Asia with no specific commonly shared site characteristics.

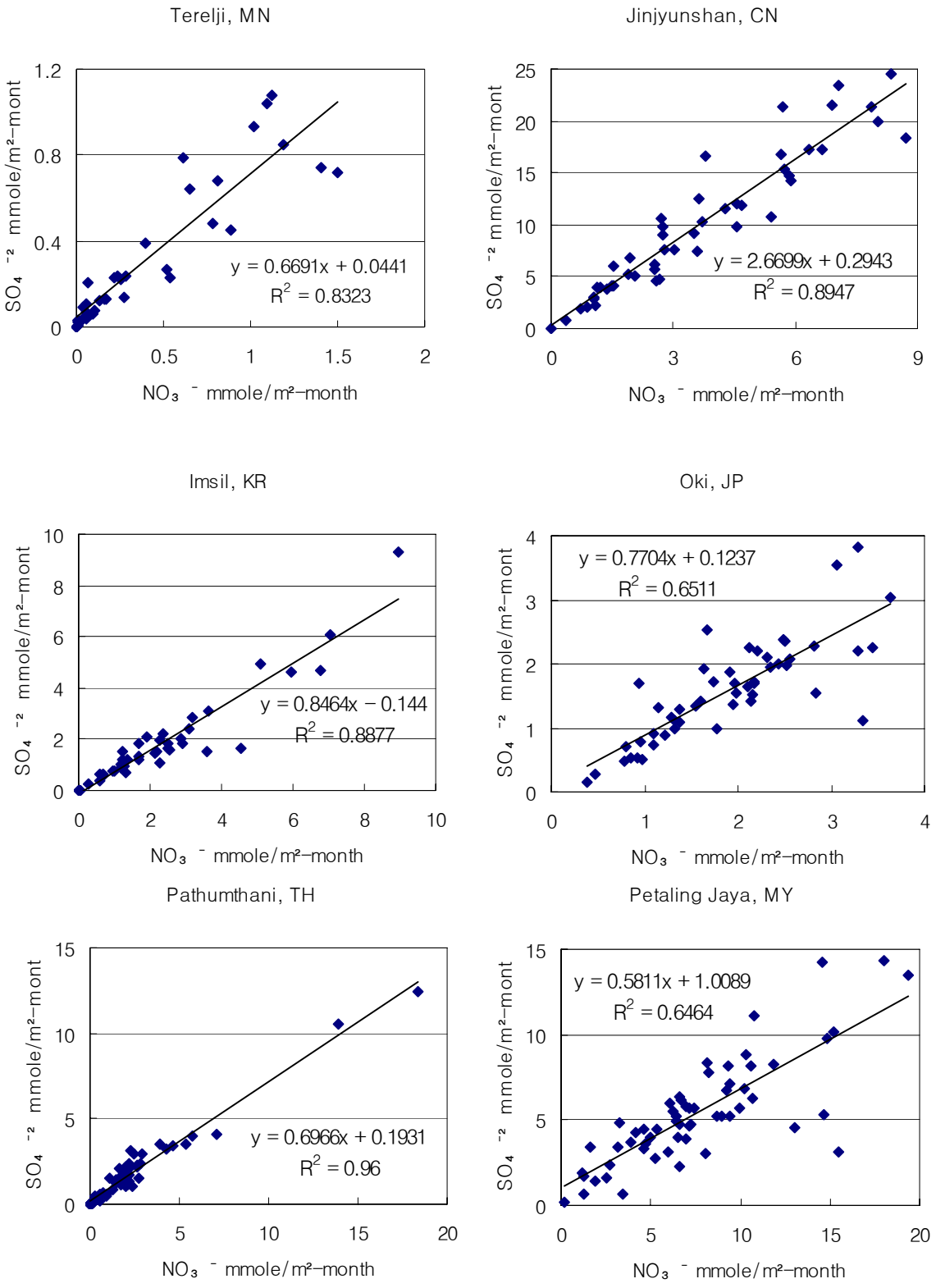


Figure 3.3.41 Monthly averaged wet deposition amounts of SO_4^{2-} and NO_3^- at selected monitoring sites in East Asia (2000–2004)

Table 3.3.2 Ratios of sulfate and nitrate estimated by linear regression analysis for 2000–2004

Country	Monitoring site	R^2	SO_4^{2-} / NO_3^- (*)	Monitoring site	R^2	SO_4^{2-} / NO_3^- (*)
China	Guanyinqiao	0.90	3.62	Hongwen	0.84	1.03
	Jinyunshan	0.89	2.67	Xiaoping	0.50	0.59
	Shizhan	0.49	2.12	Xian Zhou	0.54	0.59
	Weishuiyuan	0.43	2.21	Zhuxiangong	0.83	0.98
	Jiwozi	0.56	1.72			
Indonesia	Jakarta	0.74	0.68	Kototabang	0.25	0.06
	Serpong	0.93	0.70	Bandung	0.90	1.07
Japan	Rishiri	0.76	1.03	Oki	0.65	0.77
	Ochiishi	0.72	0.86	Banryu	0.67	0.62
	Tappi	0.98	1.00	Yusuhara	0.32	0.88
	Sado-seki	0.62	0.76	Hedo	0.35	1.03
	Happo	0.66	0.75	Ogasawara	0.50	0.67
	Ijira	0.84	0.78			
Korea	Cheju	0.86	0.85	Imsil	0.89	0.85
	Kanghwa	0.76	0.78			
Malaysia	Petaling Jaya	0.65	0.58	Tanah Rata	0.78	0.70
Mongolia	Terelj	0.83	0.67	Ulaanbaatar	0.93	1.14
Philippines	Los Baños	0.72	1.37	Metro Manila	0.73	1.17
Russia	Irkutsk	0.60	1.14	Listvyanka	0.46	0.43
	Mondy	0.63	0.86	Primorskaya	0.36	0.81
Thailand	Bangkok	0.91	0.74	Chiang Mai	0.29	0.52
	Khanchanaburi	0.70	0.58	Patumthani	0.96	0.70
	Samutprakarn	0.81	1.30			
Vietnam	Hanoi	0.47	0.73	Hoa Binh	0.43	0.71

(*) = Molar ratio

Note: Shaded cells indicate an R^2 less than 0.5.

3.3.3.5 Effect of precipitation on ion concentrations

Wet deposition flux of acidified substances is regulated by precipitation amounts and concentrations of compounds in precipitation during rain (or snow) events. However, as mentioned in scientific reviews, the values of chemical compound concentrations in fall-out rain waters are also dependent on both air pollutant properties washed out and precipitation rates. To observe a variability of wet deposition these facts should be taken into account. The relationships among multi-year annual values of those parameters for major ions in precipitation are demonstrated in Figures 3.3.42-3.3.46 based on the results of EANET monitoring for 2000-2004. The data of good completeness only (%PCL and %TP are more than 80%) were used for the calculations. Curved lines indicate the scale of wet deposition rates along corresponding values at the right side of graphs. Urban sites (upper diagram) were presented separately from rural and remote sites to recognize local effects of urban emission and air pollution apart from large-scale variations of regional atmospheric pollution.

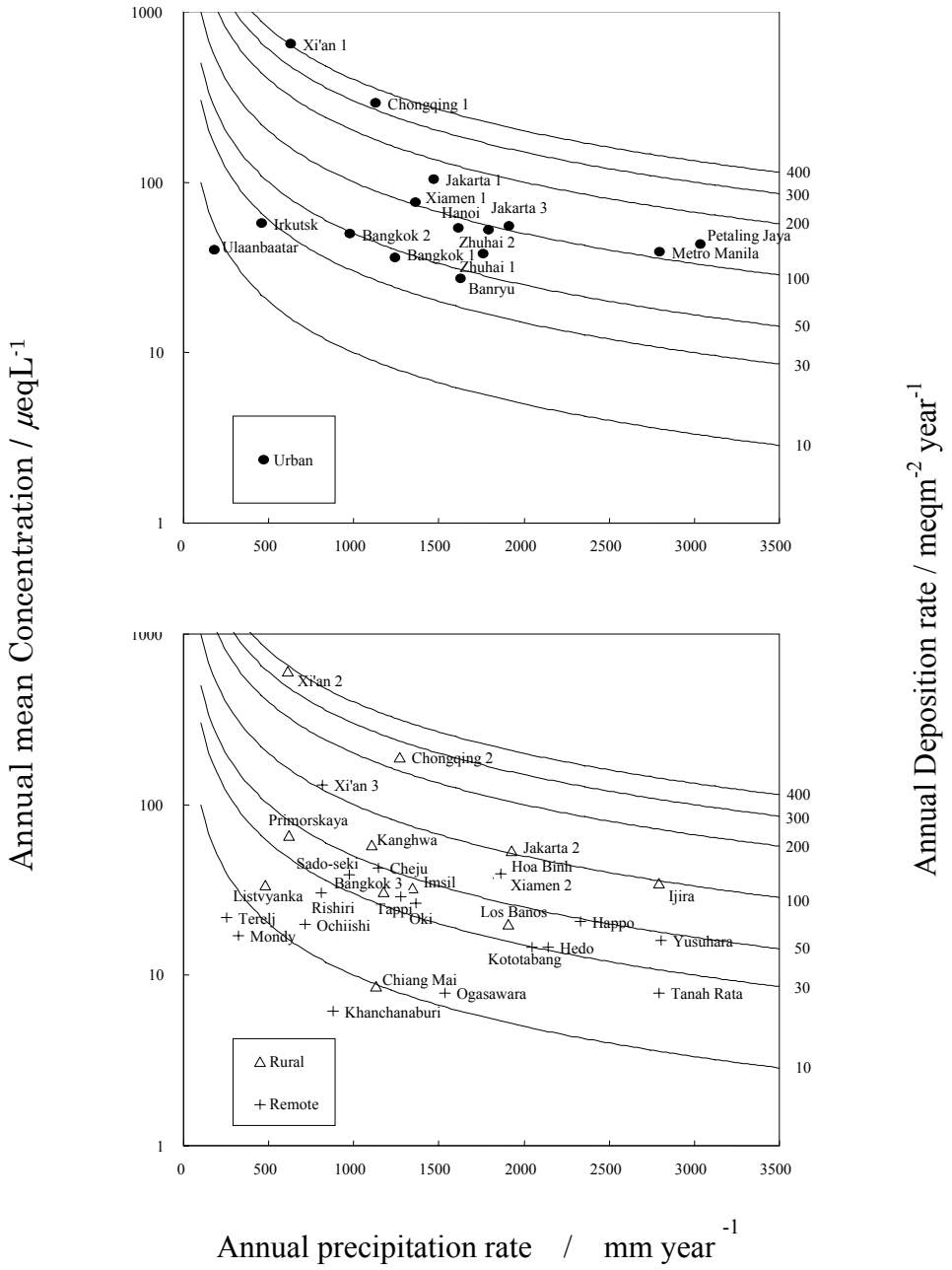


Figure 3.3.42 Relationship among annual precipitation rate, annual mean concentration, and annual wet deposition rate of nss-SO_4^{2-} in EANET (2000-2004). The descriptions of sites are:
Chongqing 1,2: Guanyinqiao, Jinyunshan; ***Xi'an 1,2,3***: Shizhan, Weishuiyuan, Jiwozi;
Xiamen 1,2: Hongwen, Xiaoping; ***Zhuhai 1, 2***: Xiang Zhou, Zhuxian Cavern,
Jakarta 1, 2, 3: Jakarta, Serpong, Bandung; ***Bangkok 1, 2, 3***: Bangkok, Samutprakarn, Patumthani.

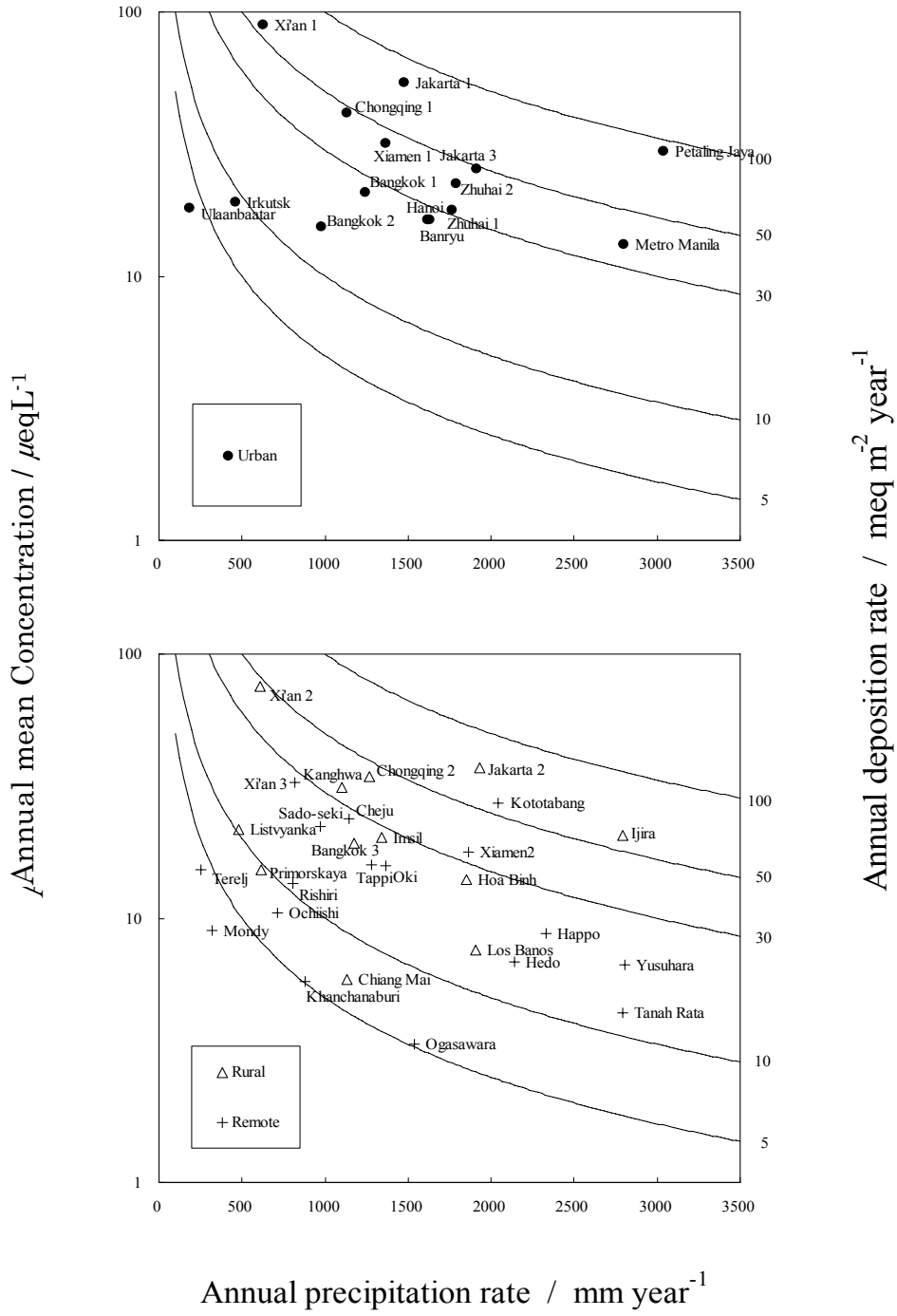


Figure 3.3.43 Relationship among annual precipitation rate, annual mean concentration, and annual wet deposition rate of NO_3^- in EANET (2000-2004) (See description of sites above).

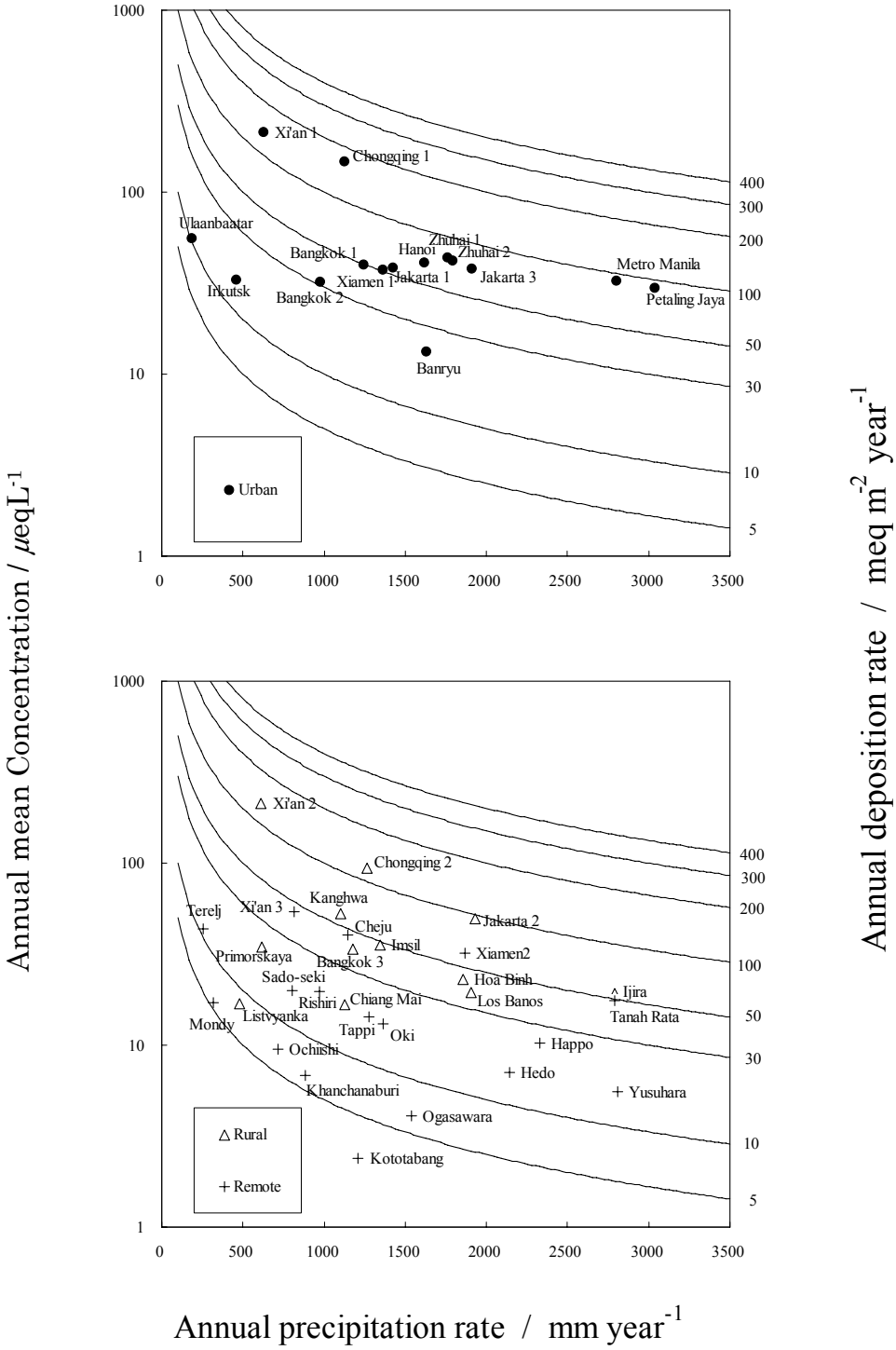


Figure 3.3.44 Relationship among annual precipitation rate, annual mean concentration, and annual wet deposition rate of NH_4^+ in EANET (2000-2004) (See description of sites above).

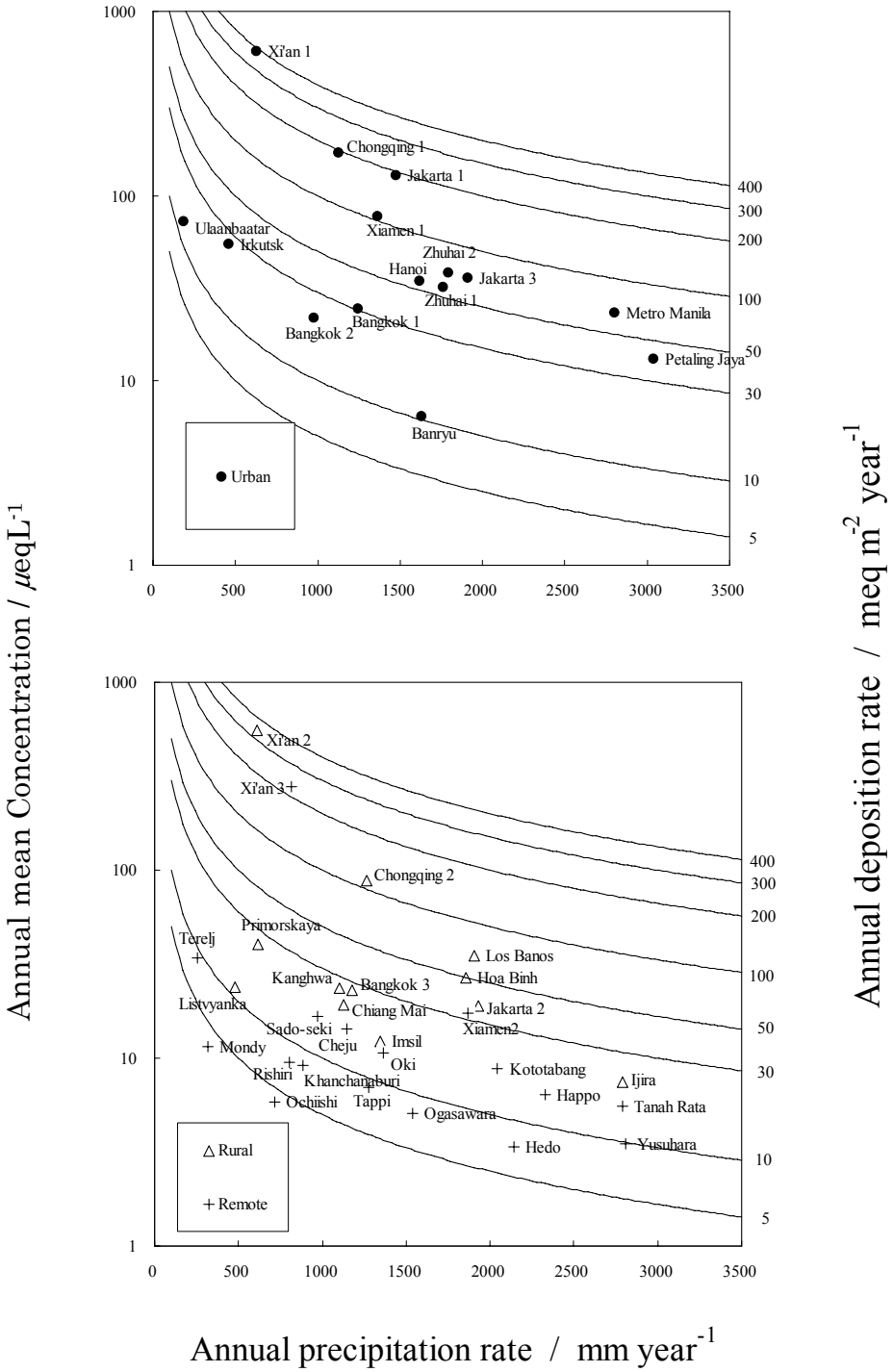


Figure 3.3.45 Relationship among annual precipitation rate, annual mean concentration, and annual wet deposition rate of *nss*-Ca^{2+} in EANET (2000-2004) (See description of sites above).

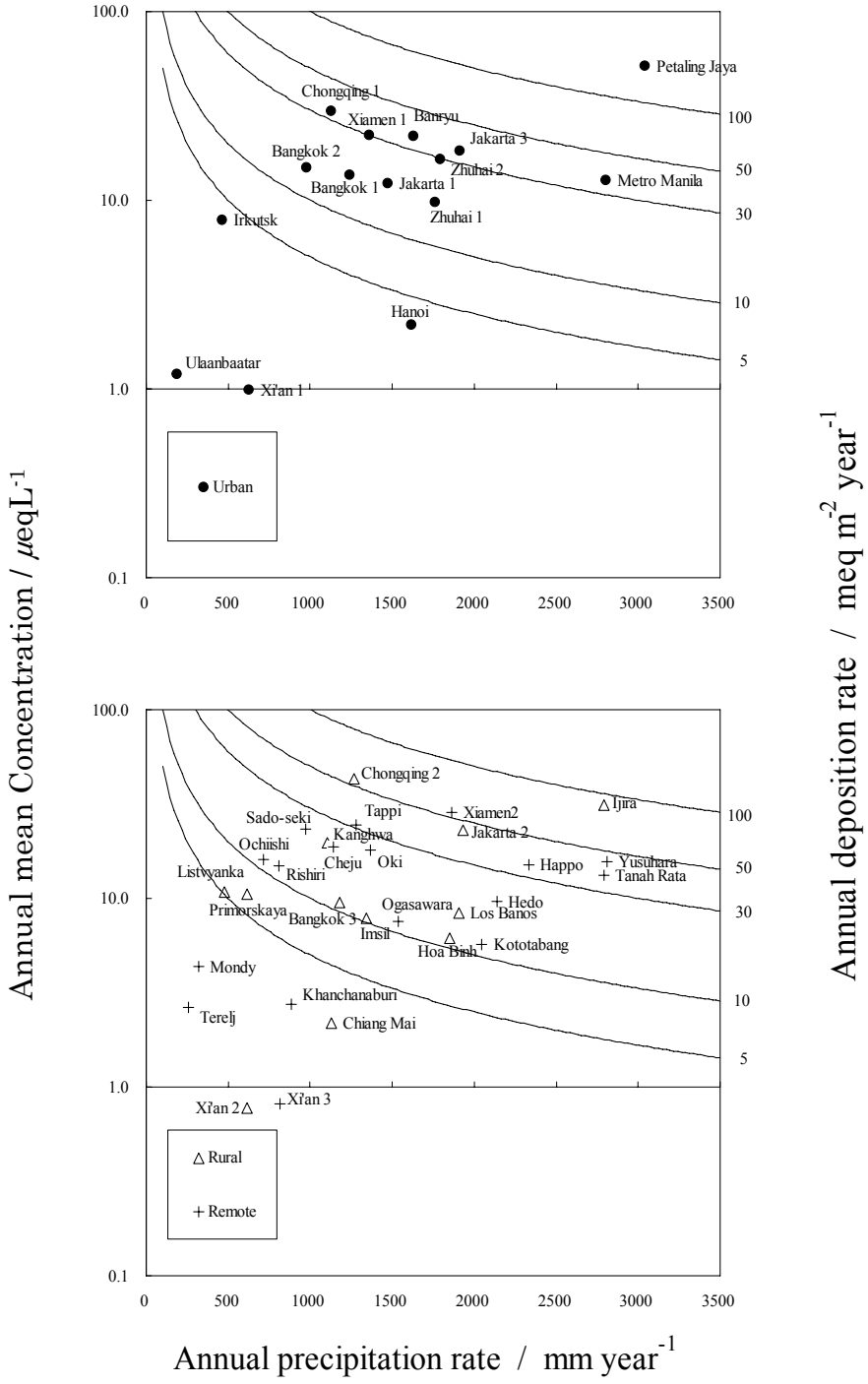


Figure 3.3.46 Relationship among annual precipitation rate, annual mean concentration, and annual wet deposition rate of H^+ in EANET (2000-2004) (See description of sites above).

The variety of wet deposition in East Asia is caused, from one hand, by different annual precipitation amounts in the range from 200 to 3000 mm·year^{-1}, being mostly high in two sites of Malaysia (Petaling Jaya and Tanah Rata), one in the Philippines (Metro Manila), and two in Japan (Ijira and Yusuhara) while lowest annual precipitation rates were observed in the sites of Russia and Mongolia. From other side, the range of concentrations was defined to be wider for the rural and remote sites, and there was no significant difference of maximum concentration values between measurements at sites of both urban and non-urban categories.

There was a considerable variation of nss-SO_4^{2-} concentrations found within ranges of 27 to 643 μeq·L^{-1} in urban sites and from 6.2 to 605 μeq·L^{-1} in rural and remote sites. Although there was no significant difference among maximum concentrations of all categories, the fluctuations of *nss*-sulfate concentrations were higher for the sites of rural and remote categories while the most data of urban sites were within the interval of values from 30 to 100 μeq·L^{-1}. High concentrations of compounds (*nss*-SO_4^{2-} more than 100 μeq·L^{-1}) were observed at five sites in China (Xi'an 1, 2, 3, Chongqing 1, and 2) with highest values of annual wet deposition fluxes mostly due to mentioned high concentrations (Figure 3.3.42). Sites in Indonesia (Jakarta 1, 2, and 3) and China (Xiamen 1) were also of considerable wet deposition because of relatively higher concentration and sufficient precipitation amounts. However, high wet deposition was caused mostly by high precipitation amounts in Ijira (Japan), Petaling Jaya (Malaysia), and Metro Manila (Philippines).

The smaller wet deposition fluxes were defined for sites with low concentrations (in particular, less than 10 μeq·L^{-1} of *nss*-SO_4^{2-}) monitored in two sites in Thailand (Chiang Mai and Khanchanaburi), one site in Japan (Ogasawara), and one site in Malaysia (Tanah Rata). However, the similar wet deposition values were calculated for the sites with average level of concentrations and small precipitation amounts (in Russia and Mongolia).

Nitrate concentrations were determined in the range from 13.2 to 89.1 μeq·L^{-1} in urban and of 3.3 to 75.5 μeq·L^{-1} in rural and remote sites with the similar peculiarities of distributions within mentioned limits like of nss-SO_4^{2-} (Figure 3.3.43). The annual deposition rates of urban sites spread widely within 5 to 100 meq·m^{-2}·year^{-1} reflecting the difference of precipitation rates. High deposition at the urban sites was observed in the metropolitan areas of Southeast Asia (Petaling Jaya, Malaysia and Jakarta, Indonesia). The lowest depositions were calculated for remote sites of Mongolia (Terelj), Russia (Mondy), Thailand (Khanchanaburi), and Japan (Ogasawara) being caused by low concentration and/or small precipitation.

Concentrations of NH_4^+ were within ranges of 13.2 to 213 μeq·L^{-1} in urban and from 2.4 to 214 μeq·L^{-1} in rural and remote sites where the wider variations occurred. The most data of urban sites were narrowed within 30 to 60 μeq·L^{-1}. However, deposition rates of ammonia were widely varied depending on precipitation rate with maximum value of 10 times higher than minimum. Annual deposition rates of almost all the rural and remote sites were 5–100 meq·m^{-2} year^{-1} (Figure 3.3.44).

Concentrations of nss-Ca^{2+} were changed over the EANET region within the similar ranges for both urban and rural/remote site categories being of 6.4 to 606 μeq·L^{-1} and from 3.4 to 553 μeq·L^{-1} respectively (Figure 3.3.45). The high deposition rates were observed in sites of China (Xi'an 2,3) due to extremely high concentration, while low deposition rates were monitored at the sites in Russia (Mondy) and Japan (Ochiishi).

There was no significant difference in the ranges of H^+ concentration and its deposition rates for sites of all categories, and also no relationship was recognized between concentration and precipitation rate to be as its distinctiveness among other substances (Figure 3.3.46). Maximum annual wet depositions were observed in Petaling Jaya (Malaysia) of urban and in Ijira (Japan) of rural/remote site category due to observed high concentrations and high precipitation rate. The lowest concentrations and annual deposition rates were monitored in Xi'an sites (China) where extremely high concentrations and deposition rates of other substances were observed.

3.3.3.6 Summary of precipitation chemistries

Figure 3.3.47 shows the relation between pH and pAi for 2000-2004. The pH values were in the range of 4.2-6.1 whereas the pA_i were concentrated within 2.7-5.1. Analyses of characteristic data points below describe some differences of acid-base chemistry throughout EANET region.

The points with pA_i<3.8 and pH>6.0 represent measurements in Xi'an (China). These great differences between pA_i and pH correspond to remarkably high degrees of neutralization of the input acidity. The lowest pH values were recorded in Chongquin (China) to be below 4.6 with pA_i less than 3.6. The original acidity of rain water in Chongquin was very high of similar levels as in Xi'an, but the additional bases were absorbed of rather low amounts to make result in pH below 4.5. As noted, the points even with the same pH values would have placed in Figure 3.3.47 as results from different acid-base interactions. The high pH (pH>6) were recorded at sites in Mongolia accompanied by low pA_i (pA_i<3.0). For the measurements in Japan the most data were characterized with pH 4.2 to 5.1 to be placed very close to the diagonal line meaning low degree of neutralization.

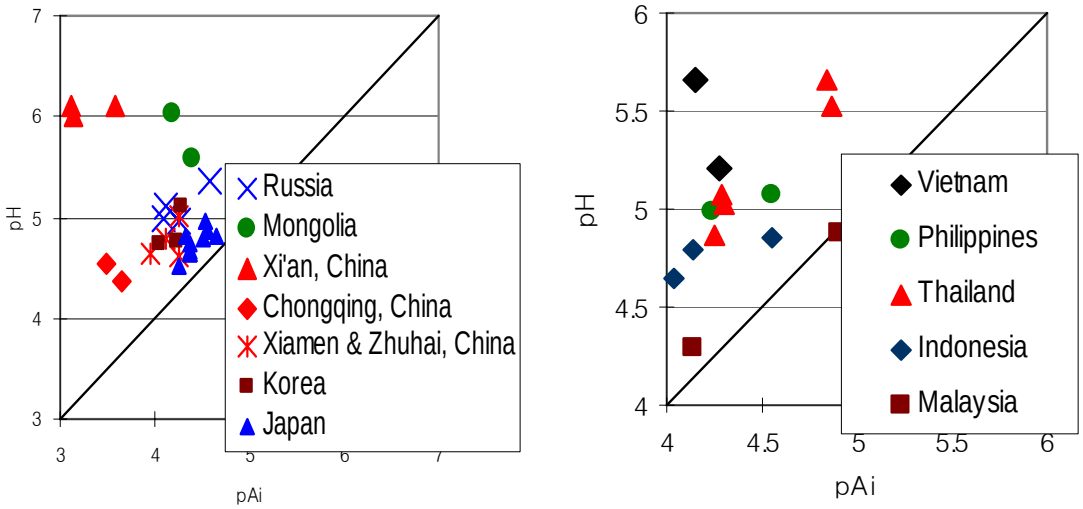


Figure 3.3.47 Volume weighted averages of pH vs pA_i in precipitation over East Asia for 2000-2004.

For the precipitation in Southeast Asia the values of pAi were ranged from 4 to 5, indicating a moderate level of inputting anion concentrations. The pH were larger than pAi by 0.5~1.5 in all the sites in Vietnam, Thailand and Philippines and in the two sites in Indonesia due to effects of both NH_4^+ and Ca^{+2}. The pAi were close to the pH in one sites in Indonesia and all the sites in Malaysia. A close examination of a distribution of the all ion concentrations revealed that a non-negligible amount of acid anions other than SO_4^{2-} and NO_3^- might existed to counter balance cations and to keep pH close to pAi at these sites.

Cations in rain waters made the pH of precipitation larger than the pAi at the most sites, and *nss*-Ca^{2+} and NH_4^+ were identified as the major cations in wet deposition at the EANET monitoring sites. The strength of cations along with the ratios of NH_4^+ and *nss*-Ca^{2+} for 2000-2004 is presented in Figure 3.3.48. The pB_i representing the strength of cations is defined similarly to pA_i (See formula (3.3.20)) as follows:

$$pBi = -log_{10}([nss\text{-}Ca^{2+}] + [NH_4^+]) \qquad (3.3.22),$$

where all the concentrations are volume weighted averages in [μeq mole·L^{-1}].

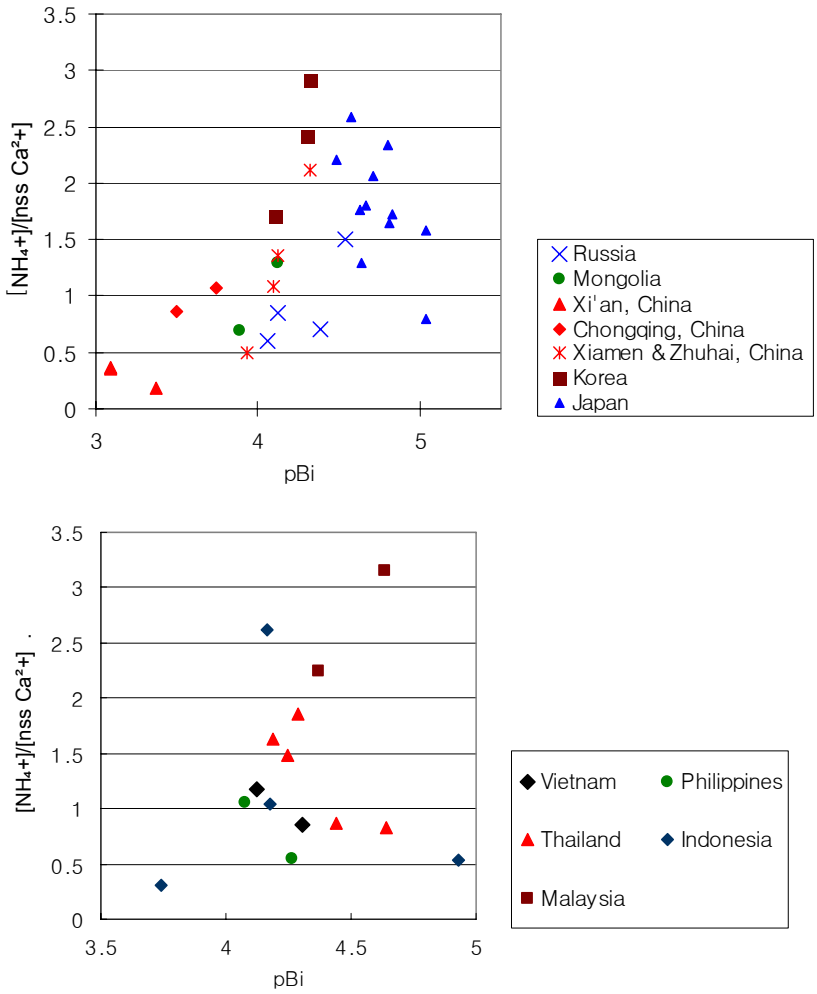


Figure 3.3.48 The ratios of major cations vs pBi in precipitation over East Asia for 2000-2004.

In general, as pBi increased, the $2D_{mc}$, (where $D_{mc} = [NH_4^+]/[2 \cdot nss\ Ca^{2+}]$) increased indicating more NH_3 absorption triggered either by low pH or by high gaseous NH_3 concentrations. The higher pBi together with high $2D_{mc}$ were recorded at the sites in Japan while for the sites in northern and central China low pBi and low $2D_{mc}$ were recognized.

The SO_4^{2-} and NO_3^- were identified as major acidifying species of wet deposition and the relative importance between them were analyzed by calculating molar S/N ratios in precipitation. There is more important input was identified of SO_4^{2-} than NO_3^- for the northern and central China where the molar S/N ratios exceeded 2 (Figure 3.3.49). On the other hand, S/N molar rations were recorded less than 1 for all other sites except some urban sites and two rural sites in Japan.

To overview the EANET measurements on the precipitation chemistry in a global context of on-going research the comparison were done with data produced by EMEP and NADP programs having experience in monitoring for longer period. The compatible datasets on chemical analysis of precipitation in Europe and the United States were used. Figure 3.3.50 is a scatter plot of NO3$^-$ and nss-SO4$_2^-$ concentrations measured at EANET sites with those obtained from EMEP (NILU web) for Europe and NADP (ISWS web) and the United States.

It is interesting to note that the concentration ranges of these species in EMEP and NADP were well comparable to those in EANET except the very high values in some sites in China. In more detail, however, NO_3^- concentrations are somewhat higher for the *nss*-SO_4^{2-} concentration.

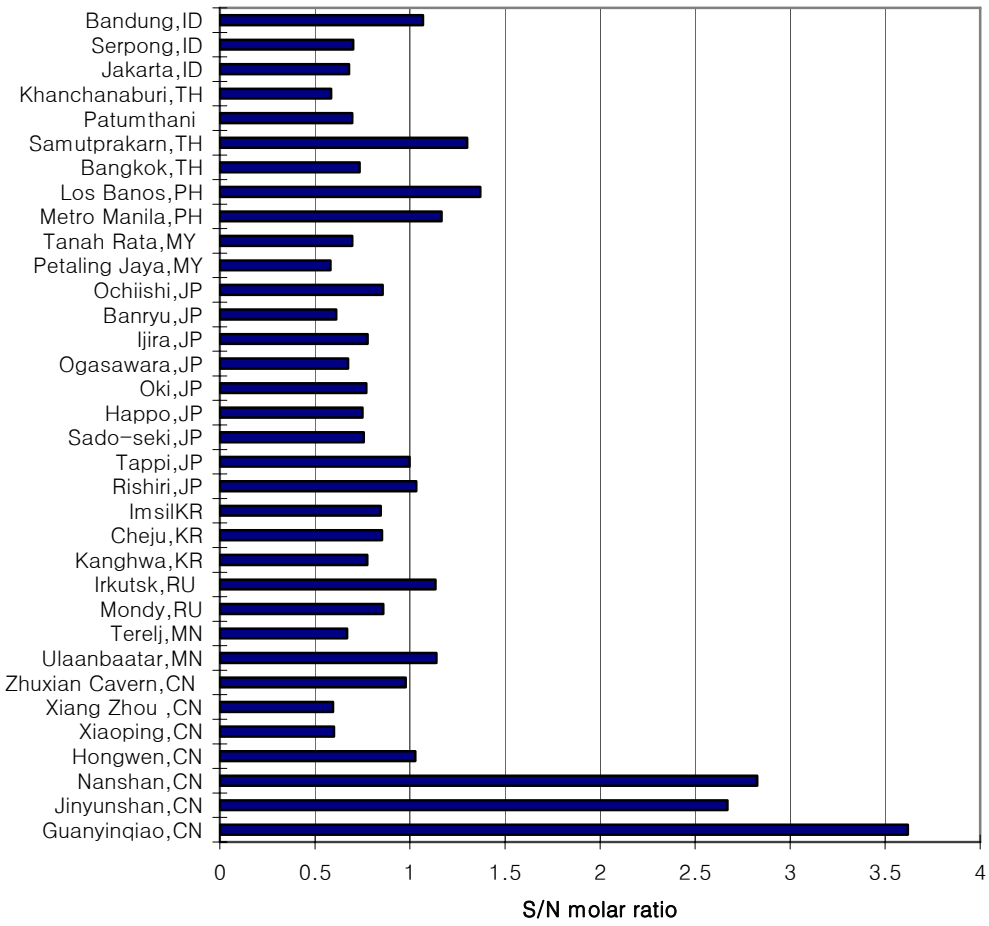


Figure 3.3.49 The molar S/N ratios in precipitation in East Asia

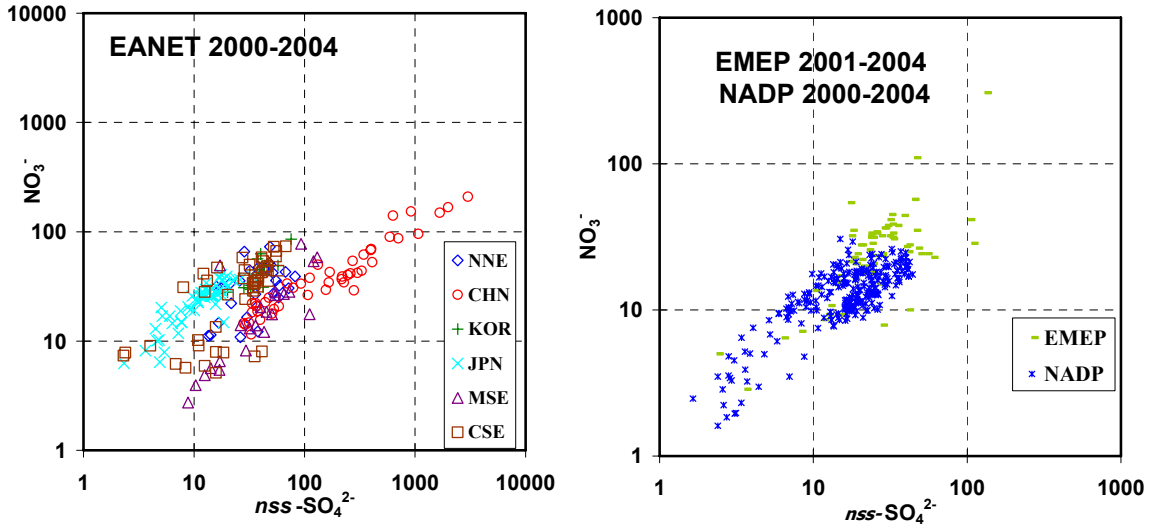


Figure 3.3.50 Nitrate concentration against *nss*-sulfate concentration (μeq·L^{-1}) in East Asia (*left*), and Europe and the United States (*right*).
Here are: *NNE*–Northern North East (Mongolia and Russia); *CHN*–China, *KOR*–Republic of Korea, *JPN*–Japan, *CSE*–Continental Southeast Asia (Malaysia, Thailand, Vietnam); *MSE*–Maritime Southeast Asia (the Philippines, Indonesia); *EMEP*–UN ECE European Monitoring and Evaluation Programme; *NADP*–U.S. National Atmospheric Deposition Program.

Lower concentrations of NO_3^- and *nss*-SO_4^{2-} measured at EANET site were also compared with those for global marine background data (Galloway, private communication). The concentrations of the global marine background are regarded to be less than 10 μeq L^{-1} at many places as in Samoa, Washington (US), Amsterdam, Barbados, Bermuda, and Mace Head (Figure 3.3.51). Tanah Rata (Malaysia), Ogasawara (Japan), Kototabang (Indonesia), Mae Hia and Khao Lam (Thailand) with the same levels of concentrations could be included in this list as measured at the global marine background. It would be noteworthy that *nss*-SO_4^{2-} concentration is seemed to be lower for the nitrate level than those in the global marine background. Some other stations in Mongolia, Russia, Japan, and Philippines recorded comparable concentrations to those at the EANET stations mentioned above (Figure 3.3.51).

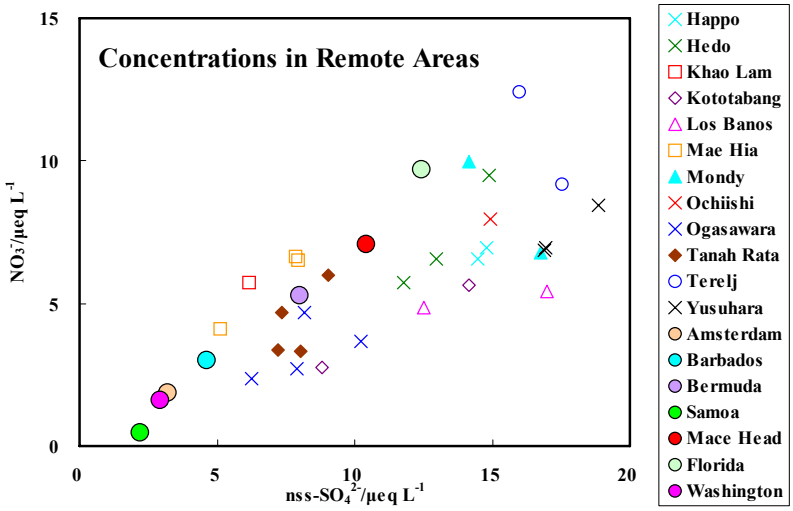


Figure 3.3.51 Nitrate concentrations against *nss*-sulfate concentration for EANET remote sites and global marine background (Galloway, private communication).

This comparison allows concluding the monitoring at these stations might be involved in the global assessment of precipitation chemistry although the precipitation concentration is generally determined by the air concentration of related gaseous and particulate species and by rainfall factors including precipitation amount, precipitation intensity, and dry period length prior to the precipitation event.

3.3.4 State of wet deposition and its temporal variation

The analyses presented in this report were based on data obtained from identified 34 EANET monitoring sites where measurements covered a full five-year period, from 2000 to 2004, with a level of data completeness acceptable for the more precise calculation of annual mean concentrations and rainfall amounts. Annual depositions recorded at the sites are summarized in Table 3.3.3 for the following major chemical species: *nss*-SO_4^{2-}, NO_3^-, NH_4^+, *nss*-Ca^{2+}, H^+, ΣN, and H^+_{eff}.

Table 3.3.3 Annual mean wet deposition of major ions ($meq \cdot m^{-2} \cdot y^{-1}$) and precipitation ($mm \cdot y^{-1}$) at EANET monitoring sites in 2000–2004

Site name and category		Precip.	*nss*-SO_4^{2-}	NO_3^-	NH_4^+	*nss*-Ca^{2+}	H^+	$NH_4^+ + NO_3^-$	$H^+ + 2NH_4^+$
China									
Guanyinqiao	urban	1130.3	326.9	46.8	165.0	192.8	33.3	211.8	363.4
Shizhan	urban	629.2	404.9	56.1	133.9	381.1	0.6	190.0	268.5
Weishuiyuan	rural	503.3	337.7	39.9	109.5	302.4	0.4	149.3	219.3
Hongwen	urban	1149.3	89.0	36.9	44.7	88.9	25.7	81.6	115.1
Xiaoping	remote	2389.0	88.9	43.1	76.2	35.0	53.8	119.3	206.2
Xiang Zhou	urban	1763.4	67.0	31.3	76.8	56.5	17.2	108.0	170.8
Zhuxian Cavern	urban	1792.5	93.7	40.3	74.7	69.1	29.5	115.0	178.9
Japan									
Rishiri	remote	799.2	25.6	11.5	18.1	8.2	12.0	29.6	48.2
Tappi	remote	1216.5	33.2	19.2	17.0	9.7	28.2	36.2	62.1
Sado-seki	remote	1227.3	34.0	19.1	18.2	10.4	27.7	37.3	64.1
Happo	remote	2538.0	48.6	21.9	24.1	14.1	35.9	46.0	84.2
Ijira	rural	2792.3	96.7	57.3	53.6	20.9	87.3	111.0	194.5
Oki	remote	1406.2	37.2	22.0	18.1	14.1	25.6	40.1	61.8
Banryu	urban	1629.2	44.1	26.5	21.5	10.4	35.4	48.0	78.4
Yusuhara	remote	2807.2	44.8	18.6	15.6	9.9	44.1	34.3	75.4
Hedo	remote	2047.1	36.8	16.2	21.3	8.9	21.9	37.5	64.4
Ogasawara	remote	1538.0	12.1	5.1	6.3	7.8	11.6	11.4	24.2
Malaysia									
Petaling Jaya	urban	3039.9	130.3	90.7	89.6	40.0	156.6	180.3	335.8
Tanah Rata	remote	2792.2	22.1	12.2	49.1	15.5	37.0	61.4	135.3
Mongolia									
Ulaanbaatar	urban	184.3	7.9	3.5	9.9	14.2	0.2	13.4	20.0
Terelj	remote	212.2	5.0	3.2	9.1	7.0	0.5	12.3	18.7
Philippines									
Metro Manila	urban	2798.6	117.8	41.4	118.0	111.5	28.2	159.4	264.3
Los Banos	rural	1972.1	39.8	15.0	38.3	67.9	16.4	53.3	93.0
Republic of Korea									
Kanghwa	rural	1106.4	63.8	37.2	54.9	32.0	19.7	92.1	129.6
Cheju (Kosan)	remote	1120.8	42.5	23.7	39.2	16.3	18.8	62.9	97.1
Russia									
Mondy	remote	319.2	5.5	2.9	5.5	3.7	1.4	8.4	12.4
Listvyanka	rural	477.3	16.1	10.3	8.1	11.4	5.2	18.4	21.3
Irkutsk	urban	463.0	26.4	8.8	15.2	25.3	3.6	24.0	34.1
Thailand									
Bangkok	urban	1243.7	44.8	25.8	49.7	30.4	16.9	75.5	116.2
Patumthani	rural	1177.3	36.4	22.7	39.7	26.9	11.2	62.4	90.5
Khanchanaburi	remote	1523.1	11.8	8.6	15.7	19.0	4.5	24.4	36.0
Viet Nam									
Hanoi	urban	1617.5	87.2	26.4	65.8	55.9	3.5	92.2	135.2
Hoa Binh	rural	1853.0	72.9	25.9	42.5	49.4	11.4	68.4	96.4

Total nitrogen (ΣN) is defined as the deposition sum of NH_4^+ and NO_3^- ions on an equivalent basis (which happens to be identical with the deposition on a molar basis) in order to retain consistency of

the discussion on deposition so far. The other parameter, H^+_{eff}, is calculated as the sum of H^+ deposition and two times the NH_4^+ deposition on an equivalent basis, in consideration of the microbiological conversion of ammonium to NO_3^- (van Breemen et al., 1982), as follows:

$$NH_4^+ + 2O_2 \rightarrow 2H^+ + NO_3^- + H_2O \qquad (3.3.23)$$

For the sake of convenience, the selected 34 stations in ten EANET countries were put into six groups (with the abbreviations in parentheses to be used for the figures): (a) Northern Northeast Asia (*NNE*) - Mongolia (2 sites) and Russia (3 sites); (b) China (*CHN*) (7 sites); (c) Korea (*KOR*) (2 sites); (d) Japan (*JPN*) (10 sites); (d) Maritime Southeast Asia (*MSA*) - Indonesia (1 site), Philippines (2 sites); (e) Continental Southeast Asia (*CSA*) - Malaysia (2 sites), Thailand (3 sites), and Vietnam (2 sites).

3.3.4.1 Spatial distribution of averaged annual deposition

An overview of the acidity of rainwater averaged from 2000 to 2004 shows that a pH under 5 was recorded over Japan, the Philippines, central and southern China, Malaysia, and Indonesia (Figure 3.3.52), but the average pH was below 4.5 at only four sites: Ijira (Japan), Jinyunshan (China), Petaling Jaya (Malaysia), and Metro Manila (Philippines). It should be noted, however, that the low values of H^+ do not necessarily imply high acidic concentration or considerable H^+ deposition. Cation concentration as well as precipitation amount should be considered together to properly interpret the data and implications of H^+ values.

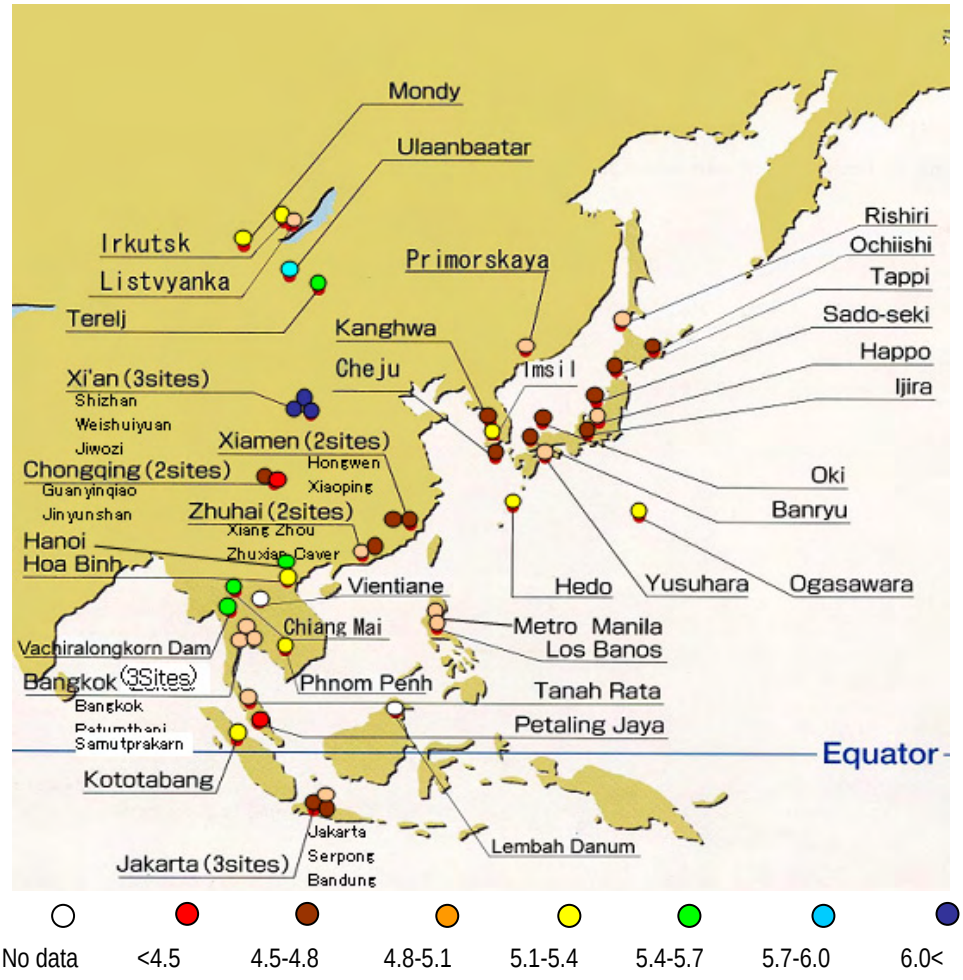


Figure 3.3.52 Distribution of annual pH values for 2000-2004

The annual mean deposition of *nss*-SO_4^{2-} and NO_3^- in the region is illustrated on the schematic map in Figure 3.3.53. The mean deposition of *nss*-SO_4^{2-} among the sites was 79.7 meq·m^{-2}·y^{-1}, with a range of 5.0 to 404.9 (Table 3.3.3). Their values were classified into four levels: (1) >300 meq·m^{-2}·y^{-1}, (2) 100–300 meq·m^{-2}·y^{-1}, (3) 10–100 meq·m^{-2}·y^{-1}, and (4) <10 meq·m^{-2}·y^{-1}. The highest amount of deposition occurred at sites in China, with an annual flux of more than 300 meq·m^{-2}·y^{-1}; a flux between 100 and 300 meq·m^{-2}·y^{-1} was measured at Jakarta and Petaling Jaya; and a flux less than 10 meq m^{-2}y^{-1} was associated with Northern Northeast sites at Ulaanbaatar, Terelj, and Mondy. The other sites recorded a deposition between 10 and 100 meq·m^{-2}·y^{-1}.

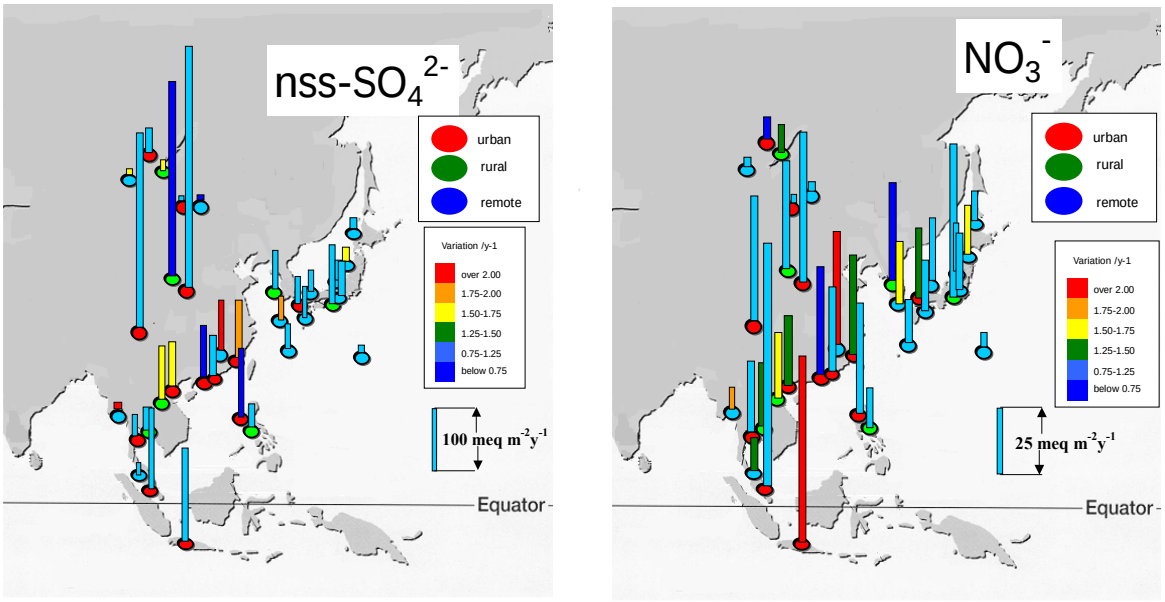


Figure 3.3.53 Distribution of annual wet deposition of *nss*-SO_4^{-2} and NO_3^- for 2000-2004

The deposition level of NO_3^- was classified into three levels: (1) > 50 meq·m^{-2}·y^{-1}, (2) 5–50 meq·m^{-2}·y^{-1}, and (3) <5 meq·m^{-2}·y^{-1}. The maximum deposition of NO_3^-, at 90.7 meq·m^{-2}·y^{-1}, occurred at Petaling Jaya, and depositions over 50 meq·m^{-2}·y^{-1} were seen at Jakarta, Ijira, Shizhan, and Guanyinqiao (Table 3.3.3). The lowest level values of less than 5 meq·m^{-2}·y^{-1} were recorded at Mondy, Terelj, and Ulaanbaatar, as well as Ogasawara.

The maximum values of *nss*-SO_4^{2-} deposition were approximately twice larger than those of NO_3^- deposition, and the ratios of NO_3^- with respect to *nss*-SO_4^{2-} had a strong spatial variation. In addition, the spatial variations of *nss*-SO_4^{2-} deposition were smoother than those of NO_3^-, probably because the chemical production rates of sulfate are generally slower than nitrates. Therefore, sulfate appears to be more susceptible to long-range transport than nitrates. The sites in mid-northern and central China and Indonesia recorded high wet depositions of sulfate and nitrates. The sites with higher wet depositions of sulfate and nitrates, however, were located in big cities or nearby, and therefore their representativeness is limited.

Calcium ion and NH_4^+ are major cations counter to *nss*-SO_4^{2-} and NO_3^- anions. The highest ammonium deposition of more than 100 meq·m^{-2}·y^{-1} occurred at three sites in mid-northern and central China, at Petaling Jaya, and Jakarta (Table 3.3.3). The lowest NH_4^+ levels of less than 10 meq·m^{-2}·y^{-1} were found over the Northern Northeast at a remote island, Ogasawara, in the Western Pacific (Figure 3.3.54). Except for the sites in China with very high Ca^{2+} depositions, the annual wet deposition fluxes of NH_4^+ were higher than of *nss*-Ca^{2+} (Figure 3.3.55) at the other sites.

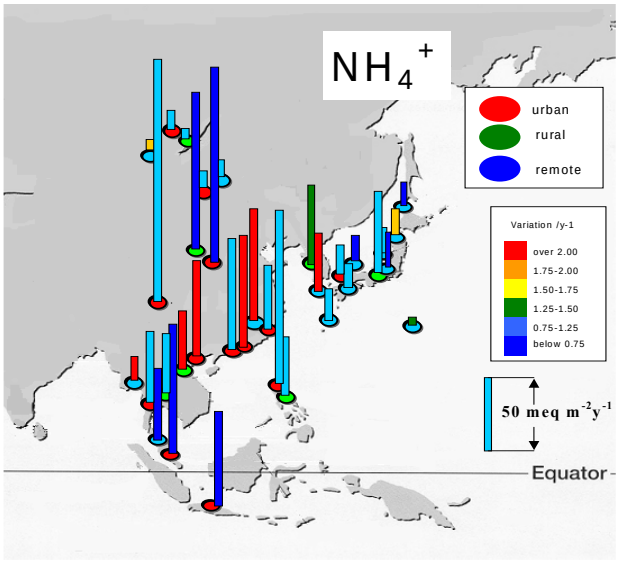


Figure 3.3.54 Distribution of annual wet deposition of ammonium for 2000-2004

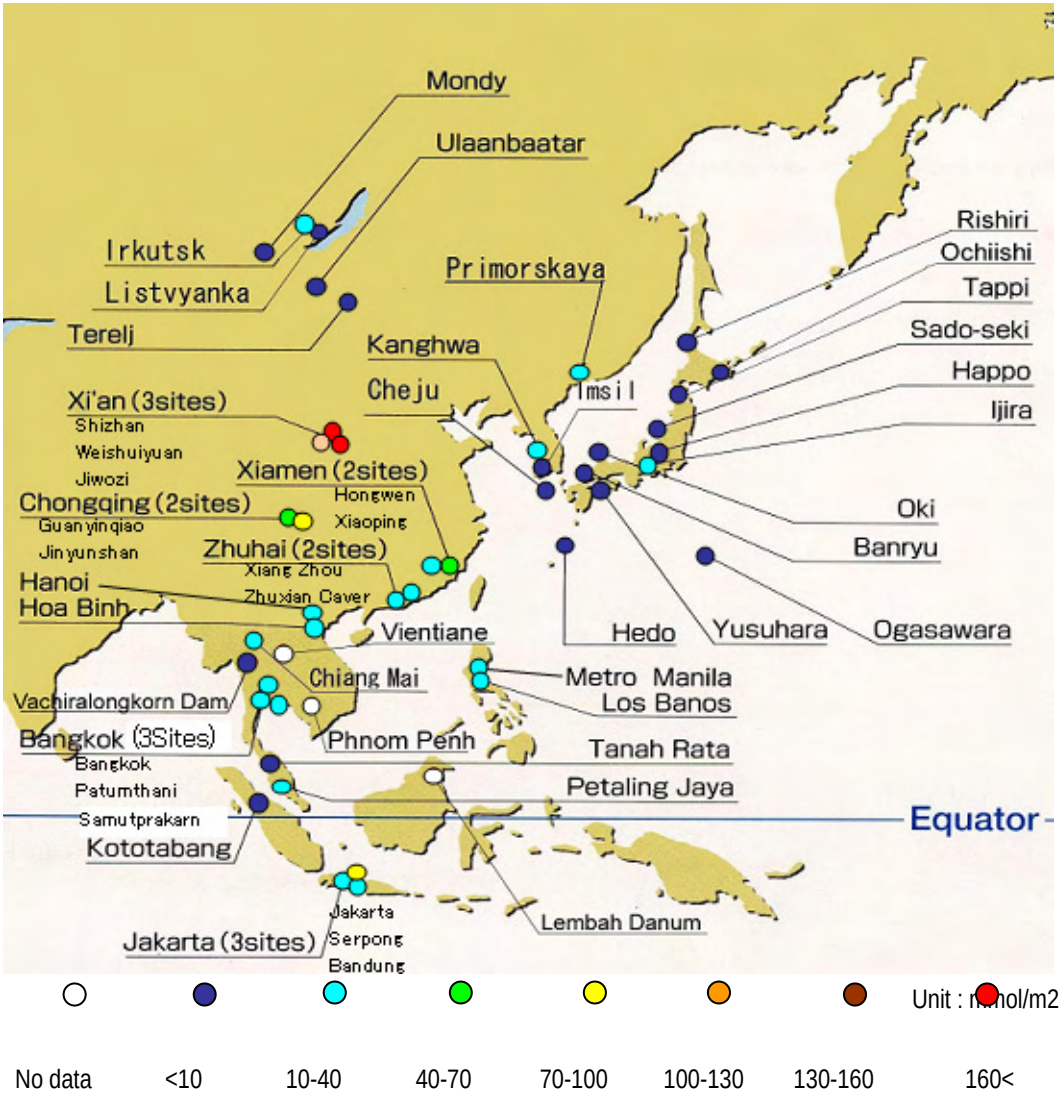


Figure 3.3.55 Distribution of annual wet deposition of *nss*-Ca^{+2} in 2000-2004

The highest level of *nss*-Ca^{2+} deposition was far larger than the medium and lowest levels. Deposition of more than 300 meq·m^{-2}·y^{-1} was observed in mid-northern China, and between 100 and 300 meq·m^{-2}·y^{-1} was recorded at two sites (Table 3.3.3). The lowest level was less than 10 meq·m^{-2}·y^{-1} over Northern Northeast Asia and at Ogasawara.

The highest deposition of H^+ was observed at Petaling Jaya, with a value of 156.6 meq·m^{-2}·y^{-1}, and the second highest was 87.3 meq·m^{-2}·y^{-1} at Ijira. The spatial distribution of H^+ has different patterns compared to the ions discussed above. Deposition of 5 meq·m^{-2}·y^{-1} or less occurred at nine sites: Shizhan and Weishuiyuan in China, Ulaanbaatar and Terelj in Mongolia, all of the Russian sites, Khanchanaburi in Thailand, and Hanoi in Vietnam. As discussed in the previous section, the hydrogen ion concentration, and consequently the pH value, was the result of the acid-base interaction in rainwater with possible neutralization, and therefore the level of H^+ deposition was not necessarily related with the deposition fluxes of ions derived from acids or bases.

The five highest and the bottom five lowest values of ΣN and H^+_{eff} deposition parameters were distinguished at the same sites in the case of ammonium. The highest depositions were observed at Guanyinqiao, Shizhan, Weishuiyuan, Petaling Jaya, and Metro Manila; the lowest were at the four sites of the Northern Northeast and Ogasawara (Table 3.3.3).

3.3.4.2 Relationships of ions and comparisons of depositions

Since wet deposition is dependent on both ion concentration and rainfall amount, high wet deposition values may occur if ion concentration is high and/or rainfall amount is large. Annual deposition was investigated against the rainfall amount for the three major ions (*nss*-SO_4^{2-}, NO_3^-, and NH_4^+) and demonstrated by respective plots where the concentration level is implicitly evaluated as the slope of the line connecting the data point and the zero point of the coordinates. The largest deposition of *nss*-SO_4^{2-} occurred at three sites (Shizhan, Weishuiyuan, and Guanyinqiao in China), where rainfall is relatively low (629.2, 503.3, and 1,130.3 mm·y^{-1}, respectively) (Figure 3.3.56). This implies that *nss*-SO_4^{2-} concentrations in precipitation were remarkably high in these areas.

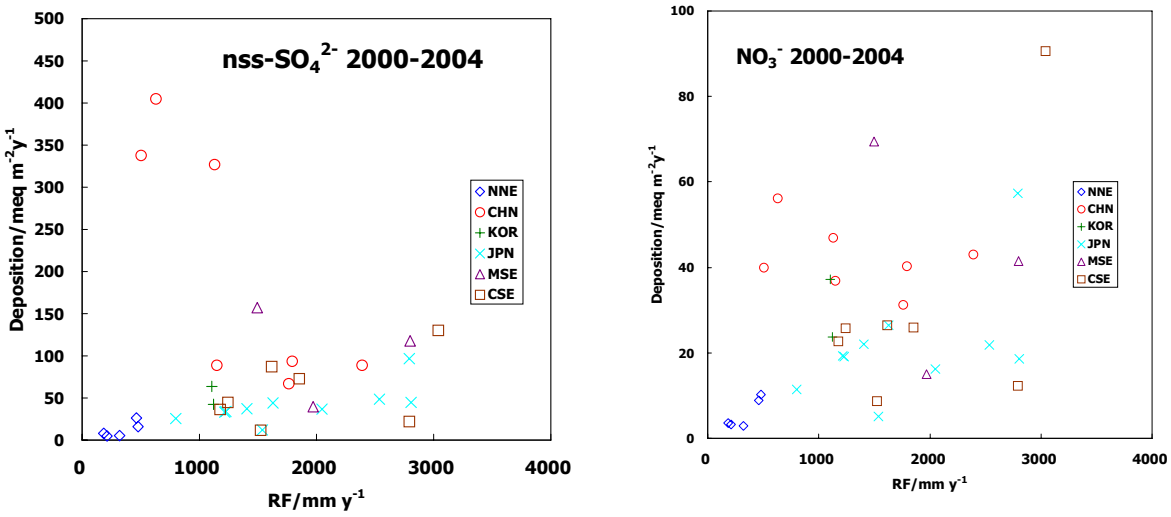


Figure 3.3.56 Annual wet deposition of *nss*-SO_4^{2-} (*left*) and NO_3^- (*right*) against annual precipitation amounts in 2000-2004 (See abbreviation above.)

High levels of NO_3^- deposition could be attributable to both high concentrations and large amounts of rainfall, as illustrated in Figure 3.3.56. The largest deposition value was 90.7 meq·m^{-2}·y^{-1} at Petaling Jaya, due to a large rainfall amount of 3,039.9 mm·y^{-1} and also a relatively high concentration, 29.8 μeq·L^{-1}. It is interesting to note that, in some cases, higher deposition was associated with high concentrations and small rainfall amounts. For example, nitrate depositions were a relatively high of

56.1 and 39.9 meq·m^{-2}·y^{-1} at two Chinese sites, Shizhan and Weishuiyuan, with lower rainfall amounts of 629.2 and 503.3 mm·y^{-1}, and high concentrations of 89.1 and 79.2 μeq·L^{-1}, respectively.

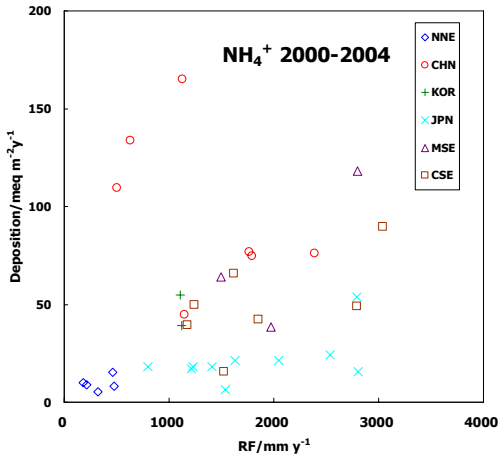


Figure 3.3.57 Annual wet deposition of NH_4^+ against precipitation amounts in 2000-2004

The largest deposition of NH_4^+ was evaluated as being related with high concentrations at the following sites in China: Shizhan (133.9 meq·m^{-2}·y^{-1}, 629.2 mm·y^{-1}, 212.8 μeq·L^{-1}), Weishuiyuan (109.5 meq·m^{-2}·y^{-1}, 503.3 mm·y^{-1}, 217.5 μeq·L^{-1}), and Guanyinqiao (165.0 meq·m^{-2}·y^{-1}, 1,130.3 mm·y^{-1}, 146.0 μeq·L^{-1}), while it was caused by large rainfall amounts at the Metro Manila monitoring site (118.0 meq·m^{-2}·y^{-1}, 2,798.6 mm·y^{-1}, 42.2 μeq·L^{-1}). It is noteworthy that NH_4^+ deposition was very low in Ulaanbaatar (9.9 meq·m^{-2}·y^{-1}), with a concentration of 53.7 μeq·L^{-1}, along with a small rainfall amount of 184.3 mm·y^{-1}.

Comparison with Deposition of Different Ions

In order to show clear relationships between the deposition of NO_3^- and that of *nss*-SO_4^{2-}, the equivalent ratio of deposition, $NO_3^-/[$*nss*-$SO_4^{2-} + NO_3^-]$, was plotted against *nss*-SO_4^{2-} deposition (Figure 3.3.58). The ratio was in the range of 0.10–0.42, illustrating that sulfuric acid contributed to acid deposition more than nitric acid. The figure also depicted that three sites in China (Guanyihqiao, Shizhan, and Weishuiyuan) received the highest contribution of sulfuric acid in both absolute and relative senses.

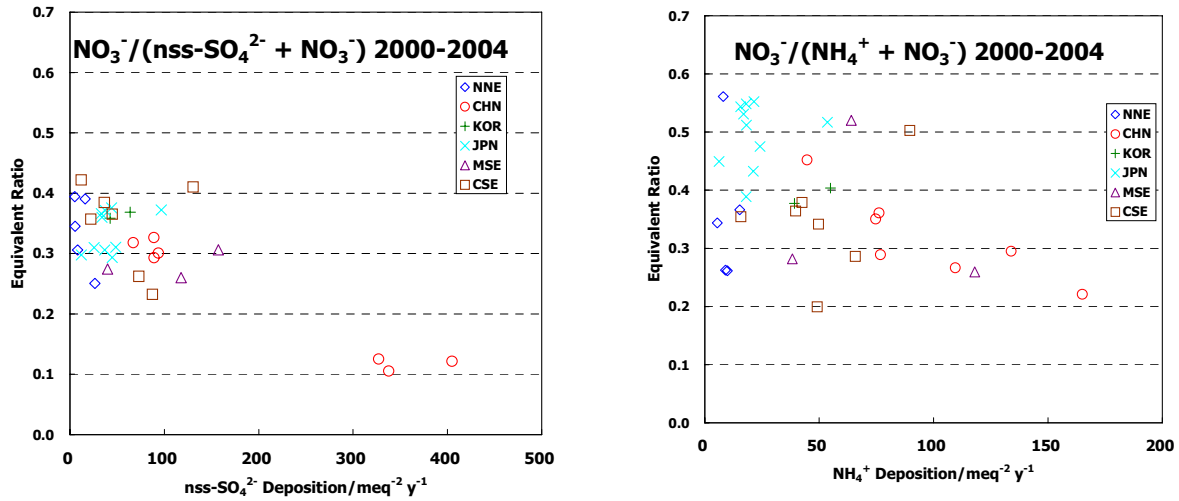


Figure 3.3.58 Relationships of annual depositions at the EANET sites: *nss*-SO_4^{2-} with ratio of $NO_3^-/[$*nss*-$SO_4^{2-} + NO_3^-]$ (*left*) and NH_4^+ with $NO_3^-/[NH_4^+ + NO_3^-]$ (*right*), in 2000-2004

This type of assessment was extended to another ion pair, NH_4^+ and NO_3^-, because both nitrogen species are related to nitrogen saturation (Figure 3.3.58). The deposition ratio $NO_3^-/[NH_4^+ + NO_3^-]$ was generally higher than $NO_3^-/[nss\text{-}SO_4^{2-} + NO_3^-]$, and its values were more than 0.50 for some sites, including most sites in Japan. This suggests that NH_4^+ was generally a more significant nitrogen species of the nitrogen saturation phenomena in the EANET region.

Comparison of Ionic Deposition in EANET with European and U.S. Deposition

The deposition of three major species, *nss*-SO_4^{2-}, NO_3^-, and NH_4^+, was also compared with those in Europe and the United States using EMEP and NADP datasets. Deposition fluxes of NO_3^- against those of *nss*-SO_4^{2-} at the EANET sites are presented in Figure 3.3.59 on a logarithmic scale together with the information from EMEP and NADP. It is apparent that soils and other surfaces in the EANET region received more *nss*-SO_4^{2-} than NO_3^- compared with these two other regions (Europe and the United States); the ranges of the ion deposition fluxes over EANET were larger than those in EMEP, and the range of NADP data seemed to lie in between.

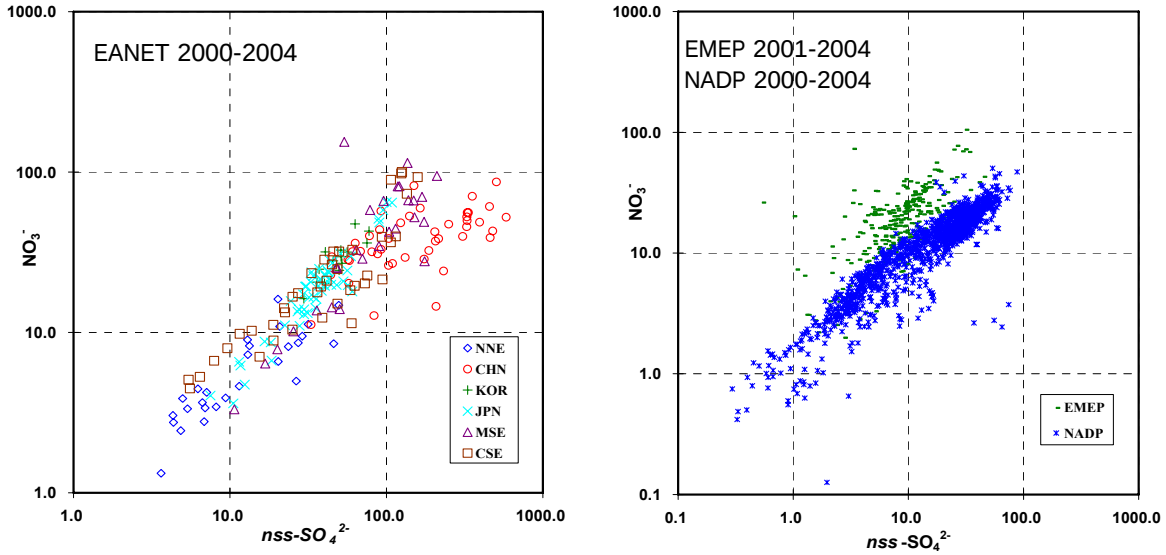


Figure 3.3.59 Annual deposition (of NO_3^- against that of *nss*-SO_4^{2-} at the EANET sites (*left*) and those of EMEP and NADP (*right*).

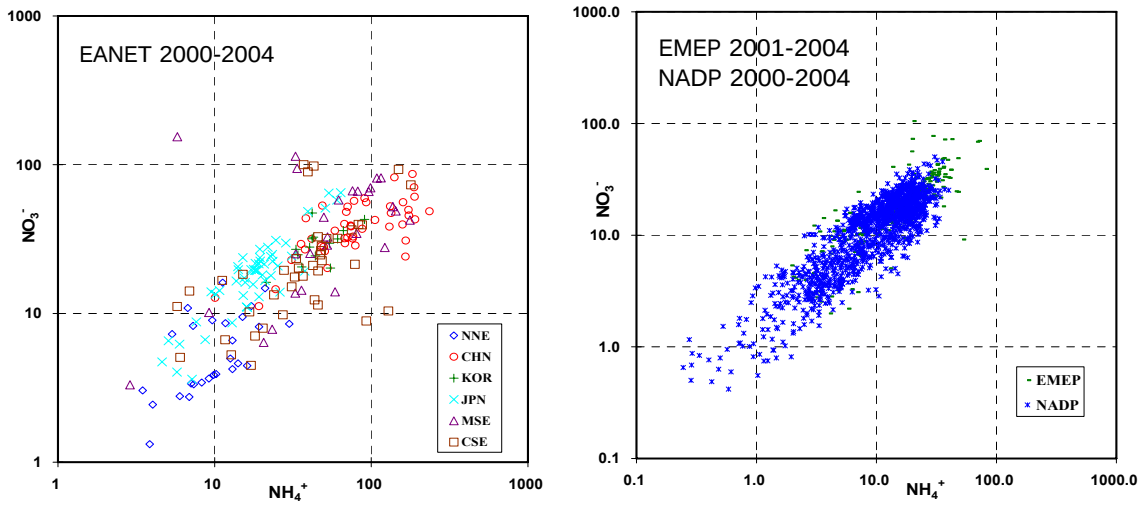


Figure 3.3.60 Deposition of NH_4^+ against that of NO_3^- at the EANET sites (*left*) and those of EMEP and NADP (*right*).

It is interesting to note from a comparison of the relationship of the deposition of NO_3^- and NH_4^+ between the monitoring networks that ammonium deposition was generally higher in the EANET region than in EMEP and NADP, but nitrates showed an opposite pattern (Figure 3.3.60).

3.3.4.3 Temporal variation of depositions

Although only a five-year record of wet deposition has been accumulated at the EANET monitoring sites, an investigation on temporal variation can be initiated during the current regional assessment of acid deposition. Note that it is very difficult to determine what length of record is required to establish a trend until it is known what the trend is (Likens 1983), but it should be based on long-term monitoring or at least measurements taken over ten years, although no clear criteria were established for trend analysis. EANET started its regular phase of operation relatively recently, and the datasets cover only five years or less, which may discourage the performance of a prevailing time-trend analysis. It is not sensible at all, however, to simply wait for enough data to accumulate. The state of acid deposition should be monitored year-by-year through analyses of the datasets produced so far in order to detect symptoms of any changes, if they occur at all. Following these reasons a linear regression analysis was applied to the annual wet deposition data for the five years of EANET monitoring, and the discussion was extended to integrated deposition over multiple years.

Linear regression of annual deposition

Of the 31 EANET monitoring sites shown in Table 3.3.3, 20 sites were further selected in terms of data completeness in order to study temporal variations.

Temporal variations in the ionic deposition measurements and deposition flux evaluation, which were normalized to the quantity for the initial year, 2000, were explored using regression analysis. The annual dataset was the first subjected to a quality evaluation to screen the data. As deposition is dependent on concentrations and rainfall amount, the temporal variation of rainfall amounts was explored first. The slopes and determination coefficients (r^2) for annual precipitation were calculated for the number of EANET sites, and this analysis was extended to the deposition of *nss*-SO_4^{2-}, NO_3^-, NH_4^+, *nss*-Ca^{2+}, and H^+, as well as the deposition parameters of ΣN (= $NH_4^+ + NO_3^-$) and H^+_{eff} (= $H^+ + 2NH_4^+$), as summarized in Table 3.3.4.

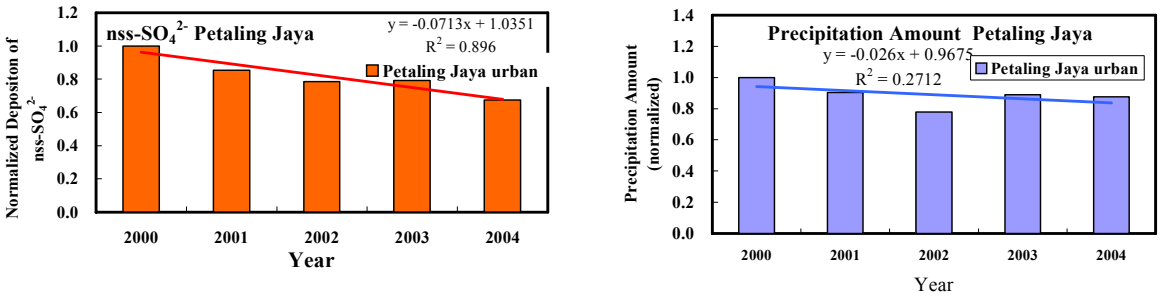
Cases of r^2 of over 0.83 were found at certain sites separately for the species listed below, and the signs of the slopes were statistically significant ($p<0.05$). These cases are illustrated in Figure 3.3.61. Positive slopes were found at Hanoi and Hoa Binh for NH_4^+, ΣN, and H^+_{eff}, while negative slopes were found for *nss*-SO_4^{2-} at Petaling Jaya, *nss*-Ca^{2+} at Ijira, and ΣN at Tanah Rata. The slopes for NH_4^+ deposition at these sites were 0.93 (r^2=0.953) and 0.40 at Hoa Binh and Hanoi, respectively. Therefore, a rapid increase of NH_4^+ deposition seemed to cause positive slopes for ΣN and H^+_{eff}. In spite of the limitations of the current dataset, it should be noted that the Hoa Binh site showed a significantly positive slope, suggesting a rapid increase of NH_4^+ deposition, which should be monitored by making sure that quality control and quality assurance measures are set so as to detect any possible signals of changes in temporal course.

Table 3.3.4 Parameters of slope and determination coefficient for lines of linear regression analysis of annual deposition time series

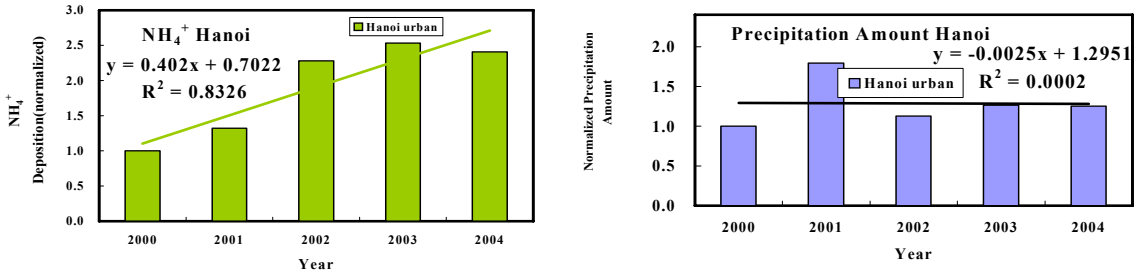
Country	Name of sites		Precipitation		*nss*-SO_4^{2-}		NO_3^-		NH_4^+	
			Slope	r^2	*Slope*	r^2	*Slope*	r^2	*Slope*	r^2
China	Guanyinqiao	urban	0.0783	0.22	0.0519	0.10	0.0647	0.26	0.0018	0.00
	Shizhan	urban	0.1776	0.17	-0.0524	0.05	0.0157	0.00	-0.0871	0.20
	Xiaoping	remote	-0.1232	0.07	0.1063	0.03	-0.0480	0.01	0.0445	0.00
	Xiang Zhou	urban	-0.0810	0.89	-0.0825	0.37	0.0118	0.04	0.1474	0.04
	Zhuxian Cavern	urban	-0.1023	0.36	-0.1474	0.79	-0.1549	0.72	-0.0604	0.39
Japan	Happo	remote	0.0876	0.78	-0.0200	0.03	0.0261	0.03	-0.0474	0.14
	Ijira	rural	0.0823	0.63	-0.0037	0.01	-0.0177	0.06	-0.0179	0.04
	Banryu	urban	0.0197	0.06	-0.0086	0.01	0.0343	0.11	-0.0011	0.00
	Yusuhara	remote	0.1106	0.46	-0.0367	0.16	0.0282	0.13	0.1048	0.55
	Ogasawara	remote	-0.1026	0.88	-0.1358	0.44	-0.0318	0.03	-0.0300	0.02
Malaysia	Petaling Jaya	urban	-0.0260	0.27	-0.0713	0.90	0.0214	0.09	-0.2425	0.69
	Tanah Rata	remote	-0.0333	0.33	-0.0362	0.22	0.0648	0.12	-0.2580	0.82
Philippines	Los Banos	rural	-0.0486	0.24	-0.1018	0.34	-0.1306	0.22	-0.0666	0.08
Russia	Mondy	remote	0.0654	0.17	0.0230	0.01	-0.0593	0.65	0.0013	0.00
	Listvyanka	rural	0.0601	0.29	0.1667	0.74	0.1714	0.41	0.0660	0.10
	Irkutsk	urban	0.0048	0.00	-0.0286	0.10	-0.0353	0.13	0.0192	0.03
Thailand	Bangkok	urban	0.0294	0.30	-0.0263	0.17	0.0000	0.00	0.0135	0.02
	Patumthani	rural	0.0367	0.03	-0.0300	0.07	0.0744	0.18	-0.0178	0.02
Viet Nam	Hanoi	urban	-0.0025	0.00	0.1615	0.77	0.3315	0.71	0.4020	0.83
	Hoa Binh	rural	-0.0347	0.20	0.1857	0.74	0.2142	0.58	0.9265	0.95

(**Table 3.3.4** *Continued*)

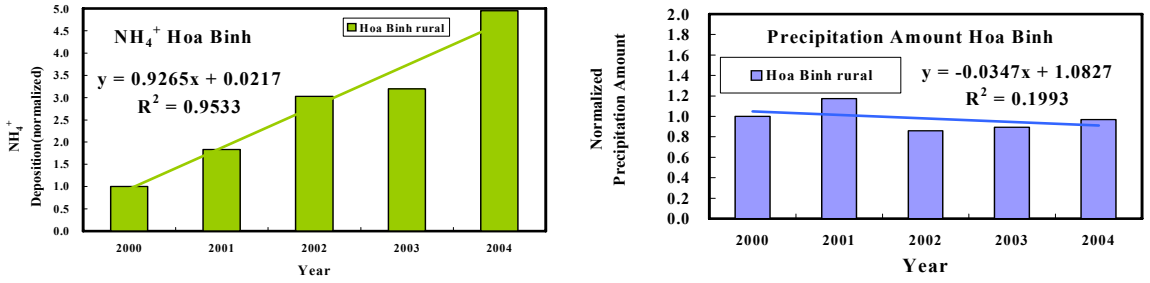
Country	Name of sites		*nss*-Ca^{2+}		H^+		$NH_4^+ + NO_3^-$		$H^+ + 2NH_4^+$	
			Slope	r^2	*Slope*	r^2	*Slope*	r^2	*Slope*	r^2
China	Guanyinqiao	urban	0.194	0.342	-0.019	0.012	0.015	0.029	-0.0008	0.000
	Shizhan	urban	0.003	0.000	-0.052	0.030	-0.070	0.152	-0.087	0.204
	Xiaoping	remote	3.105	0.170	0.399	0.293	0.005	0.000	0.128	0.033
	Xiang Zhou	urban	-0.037	0.049	0.047	0.050	0.089	0.041	0.1328	0.042
	Zhuxian Cavern	urban	-0.069	0.744	-0.127	0.415	-0.098	0.616	-0.0725	0.440
Japan	Happo	remote	-0.073	0.177	0.006	0.004	-0.015	0.014	-0.0264	0.057
	Ijira	rural	-0.138	0.857	0.031	0.065	-0.018	0.051	0.0011	0.000
	Banryu	urban	-0.110	0.334	-0.003	0.001	0.018	0.041	-0.0018	0.001
	Yusuhara	remote	-0.101	0.350	-0.009	0.006	0.060	0.351	0.0301	0.087
	Ogasawara	remote	-0.196	0.573	-0.075	0.354	-0.031	0.036	-0.055	0.142
Malaysia	Petaling Jaya	urban	-0.053	0.305	-0.025	0.288	-0.141	0.775	-0.1686	0.688
	Tanah Rata	remote	-0.013	0.007	-0.059	0.345	-0.234	0.852	-0.2254	0.818
Philippines	Los Banos	rural	-0.688	0.146	0.538	0.161	-0.084	0.165	0.0052	0.002
Russia	Mondy	remote	-0.022	0.055	0.045	0.072	-0.027	0.023	0.0098	0.002
	Listvyanka	rural	0.149	0.459	0.148	0.707	0.122	0.292	0.0829	0.269
	Irkutsk	urban	-0.074	0.389	0.112	0.146	-0.002	0.001	0.0292	0.079
Thailand	Bangkok	urban	0.021	0.019	0.144	0.046	0.009	0.006	0.029	0.055
	Patumthani	rural	-0.079	0.236	0.526	0.373	0.012	0.007	0.0196	0.014
Viet Nam	Hanoi	urban	0.120	0.574	-0.060	0.316	0.376	0.876	0.3738	0.832
	Hoa Binh	rural	0.089	0.262	-0.227	0.723	0.537	0.890	0.5492	0.935



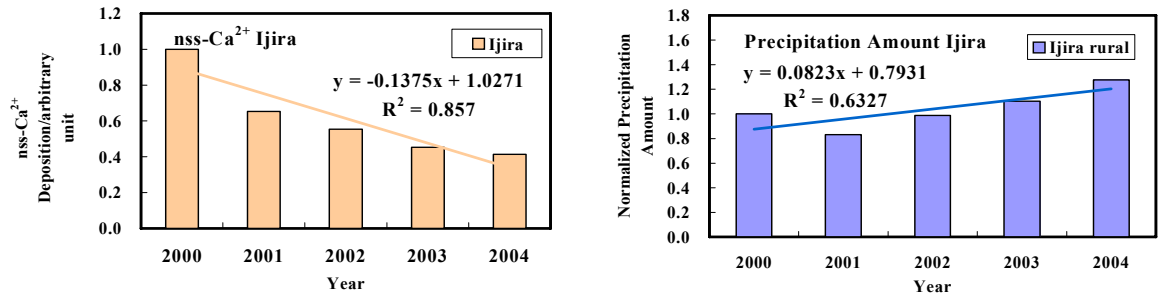
(a) nss-SO_4^{2-} deposition (left) and Annual Precipitation Amount (right) at Petaling Jaya, Malaysia.



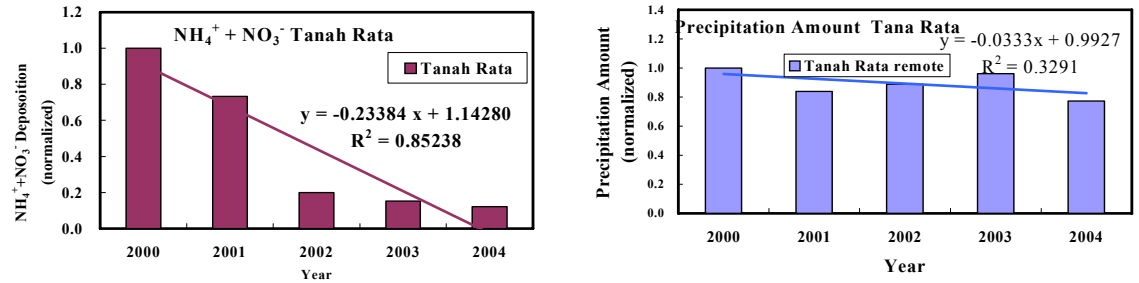
(b) NH_4^+ deposition (left) and Annual Precipitation Amount (right) at Hanoi, Vietnam



(c) NH_4^+ deposition (left) and Annual Precipitation Amount (right) at Hoa Binh, Vietnam

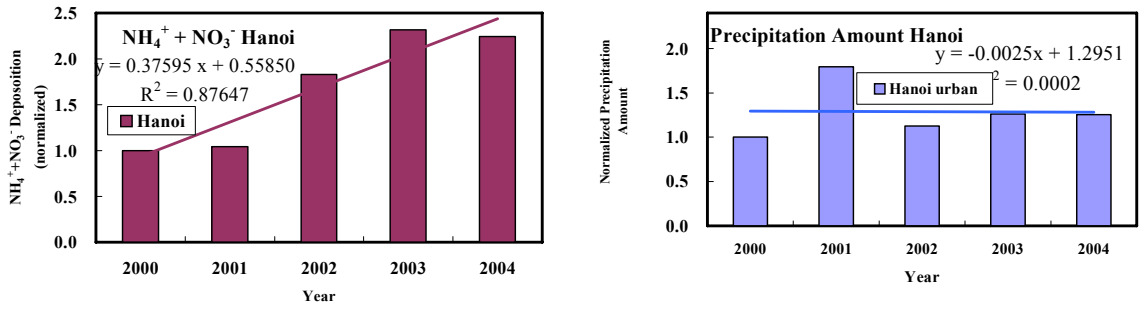


(d) nss-Ca^{2+} deposition (left) and Annual Precipitation Amount (right) at Ijira, Japan

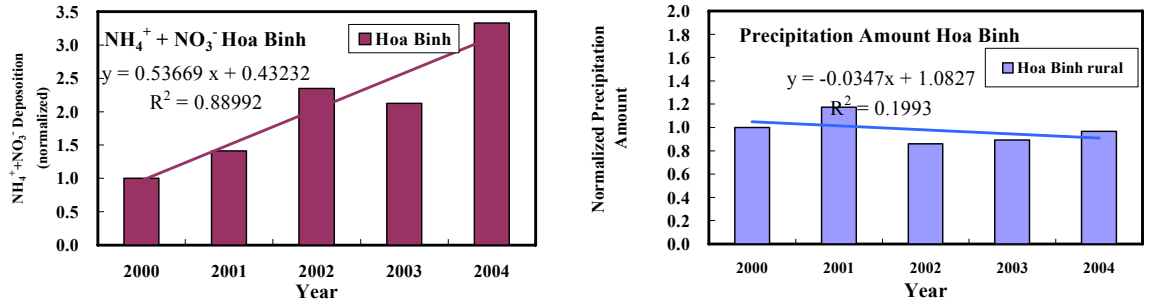


(e) $NH_4^+ + NO_3^-$ deposition sum (left) and Annual Precipitation Amount (right) at Tanah Rata, Malaysia

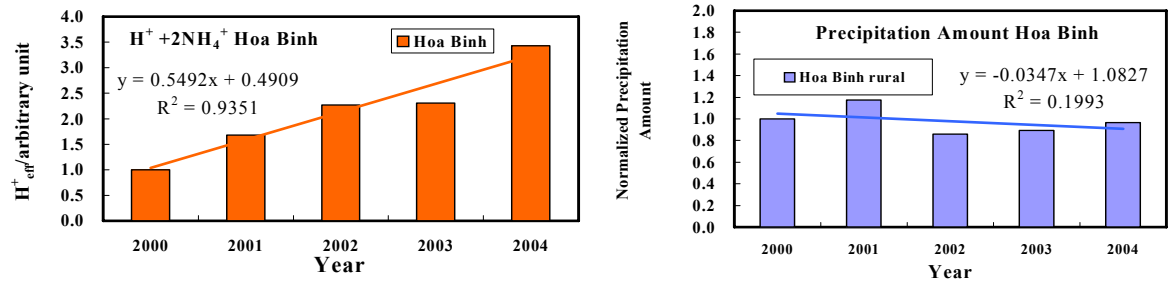
Figure 3.3.61 (*Continued on the next page*)



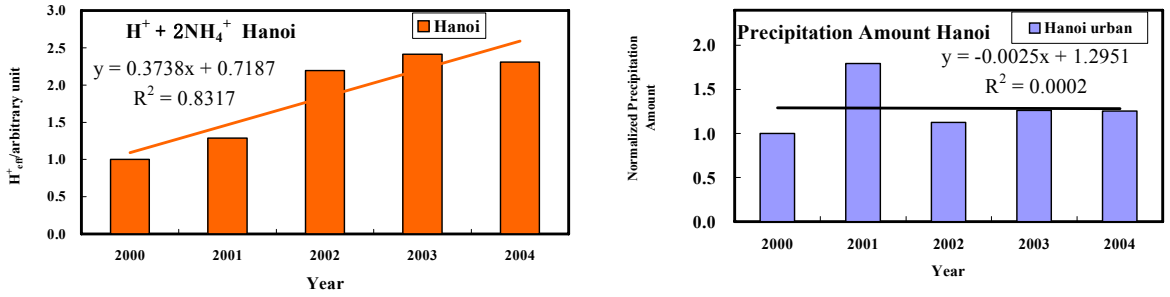
(f) $NH_4^+ + NO_3^-$ deposition sum (left) and Annual Precipitation Amount (right) at Hanoi, Vietnam



(g) $NH_4^+ + NO_3^-$ deposition sum (left) and Annual Precipitation Amount (right) at Hoa Binh, Vietnam



(i) $H^+ + 2NH_4^+$ deposition sum (left) and Annual Precipitation Amount (right) at Hoa Binh, Vietnam



(h) $H^+ + 2NH_4^+$ deposition sum (left) and Annual Precipitation Amount (right) at Hanoi, Vietnam

Figure 3.3.61 A linear regression of annual deposition (*left column*) of compounds and annual precipitation (*right*) at the EANET sites for the period of 2000-2004

Annually integrated deposition

In the discussion of the potential impacts of acid deposition on ecosystems, the annually integrated deposition will be involved in the prevailing biogeochemical cycles in ecosystems. Integrated deposition will therefore be a phenomenological parameter of atmospheric loads. Differing from the temporal variation of the annual deposition, integrated deposition, of course, never decreases at all.

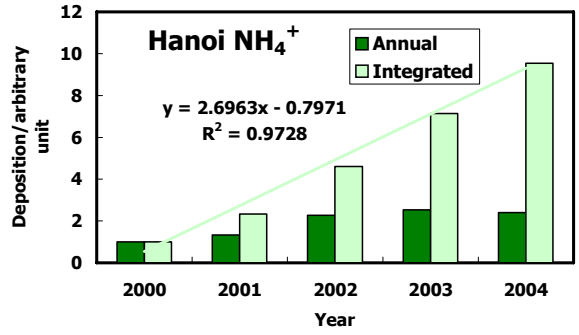
The integrated deposition was calculated for each successive year, and temporal variation was assessed in terms of the slope of linear-regression lines (Table 3.3.5). Figure 3.3.62 shows the temporal variation of the integrated deposition of NH_4^+ at Hanoi and Hoa Binh, where the slope of the annual deposition was significantly positive ($p<0.05$).

Table 3.3.5 Parameters of slope and determination coefficients of linear regression for the integrated deposition

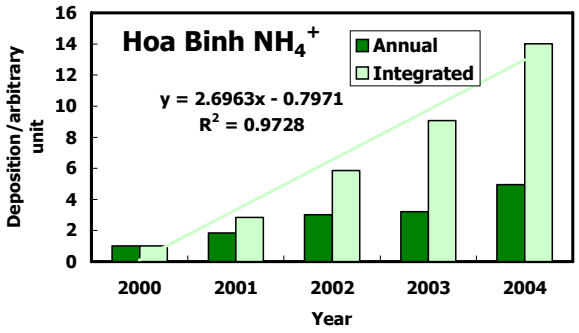
Country	Name of sites		Precipitation		*nss*-SO_4^{2-}		NO_3^-		NH_4^+	
			Slope	r^2	*Slope*	r^2	*Slope*	r^2	*Slope*	r^2
China	Guanyinqiao	urban	1.07	0.99	0.97	0.99	1.02	0.99	0.92	1.00
	Shizhan	urban	1.22	0.94	1.10	0.98	1.24	0.99	0.48	0.98
	Xiaoping	remote	1.58	0.96	2.15	0.98	2.00	0.97	2.70	0.97
	Xiang Zhou	urban	0.84	1.00	0.82	0.99	1.00	1.00	2.18	0.96
	Zhuxian Cavern	urban	1.00	0.98	0.46	0.99	0.57	0.96	0.77	1.00
Japan	Happo	remote	1.19	1.00	0.80	0.99	0.84	0.99	0.69	0.99
	Ijira	rural	1.05	0.99	0.97	1.00	0.87	1.00	0.82	1.00
	Banryu	urban	1.04	1.00	1.00	1.00	1.27	1.00	1.23	1.00
	Yusuhara	remote	0.99	0.98	0.75	1.00	0.95	1.00	1.15	0.99
	Ogasawara	remote	0.71	0.99	0.95	0.97	1.10	0.99	1.42	0.99
Malaysia	Petaling Jaya	urban	0.86	1.00	0.78	1.00	0.99	1.00	0.45	0.85
	Tanah Rata	remote	0.88	1.00	0.87	1.00	1.28	0.99	0.20	0.68
Philippines	Los Banos	rural	0.67	1.00	0.85	0.98	1.00	0.96	1.10	0.98
Russia	Mondy	remote	1.05	0.99	1.32	1.00	0.93	1.00	1.76	0.99
	Listvyanka	rural	1.08	1.00	1.25	0.99	1.35	0.98	1.19	0.99
	Irkutsk	urban	0.81	0.99	0.77	1.00	0.72	1.00	0.88	0.99
Thailand	Bangkok	urban	1.12	1.00	0.92	1.00	1.10	0.99	1.09	1.00
	Patumthani	rural	1.30	0.99	0.99	1.00	1.34	1.00	1.10	1.00
Viet Nam	Hanoi	urban	1.33	0.99	1.25	0.99	1.41	0.95	2.19	0.99
	Hoa Binh	rural	0.95	1.00	1.27	0.98	1.52	0.99	3.22	0.97

(**Table 3.3.5** *Continued*)

Country	Name of sites		*nss*-Ca^{2+}		H^+		$NH_4^+ + NO_3^-$		$H^+ + 2NH_4^+$	
			Slope	r^2	*Slope*	r^2	*Slope*	r^2	*Slope*	r^2
China	Guanyinqiao	urban	1.45	0.98	0.59	0.98	0.94	1.00	0.88	1.00
	Shizhan	urban	1.68	0.98	0.46	0.88	0.61	0.98	0.48	0.98
	Xiaoping	remote	24.00	0.99	3.38	1.00	2.40	0.97	2.86	0.99
	Xiang Zhou	urban	0.64	0.98	1.20	0.99	1.67	0.98	2.04	0.97
	Zhuxian Cavern	urban	0.75	1.00	0.61	0.96	0.69	0.99	0.74	0.99
Japan	Happo	remote	0.78	0.98	0.83	1.00	0.76	0.99	0.75	0.99
	Ijira	rural	0.52	0.99	1.12	1.00	0.85	1.00	0.94	1.00
	Banryu	urban	0.84	0.97	0.97	1.00	1.25	1.00	1.10	1.00
	Yusuhara	remote	0.62	0.98	0.78	0.99	1.03	0.99	0.90	0.99
	Ogasawara	remote	0.92	0.95	1.00	0.99	1.26	0.99	1.18	0.99
Malaysia	Petaling Jaya	urban	0.85	1.00	1.03	1.00	0.66	0.98	0.65	0.96
	Tanah Rata	remote	1.19	0.99	0.67	1.00	0.28	0.84	0.27	0.86
Philippines	Los Banos	rural	2.02	0.71	2.09	0.85	1.07	0.98	1.21	1.00
Russia	Mondy	remote	1.03	1.00	0.79	0.98	1.37	0.99	1.57	0.99
	Listvyanka	rural	1.03	0.97	1.43	1.00	1.28	0.99	1.24	0.99
	Irkutsk	urban	0.79	0.99	0.79	0.94	0.81	1.00	0.87	0.99
Thailand	Bangkok	urban	1.26	1.00	1.52	0.94	1.09	1.00	1.14	1.00
	Patumthani	rural	1.10	0.99	2.36	0.95	1.18	1.00	1.19	1.00
Viet Nam	Hanoi	urban	1.09	0.99	0.74	1.00	1.90	0.98	2.10	0.99
	Hoa Binh	rural	0.99	0.98	0.69	0.92	2.29	0.98	2.40	0.98



(a) Annual and Integrated Deposition of NH_4^+ at Hanoi, Vietnam.



(b) Annual and Integrated Deposition of NH_4^+ at Hoa Binh, Vietnam.

Figure 3.3.62 Annual and integrated deposition of NH_4^+ in Hanoi (*upper*) and Hoa Binh (*bottom*).

One intrinsic limitation of this analysis is that the slope of the integrated deposition is dependent upon the annual deposition of the initial year. The slope could be somewhat intensified if the deposition of the year happens to be significantly lower than the annual deposition for most of the year. In spite of this potential shortcoming, the physical meaning of the integrated deposition is a significant quantity in the discussion of impact studies, and the concept of integration will be complementary to the temporal variation of annual deposition.

A preliminary discussion was extended to the temporal variation of deposition. At present, any evaluation is definitely limited by the monitoring duration. It is worthwhile, however, to make attempts to detect any symptoms of potential temporal trends, if they occur at all, because the verified datasets are available for some period. More detailed analysis, including the involvement of forthcoming datasets, will shed light on the question of temporal variations or trends of acid deposition in East Asia.

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3.4 Ecological impacts

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CONTENTS

3.4.1 Introduction

Poor understanding, due to lack of precise information, of the relationships between structures and functions that maintain an ecosystem—especially the detailed budget of inputs and outputs of energy and matter—often makes it difficult to assess the impact of anthropogenic activities on the biosphere (Likens and Bormann, 1995). Consequently, those involved in industrial activities, traditional land-use, and related natural resources management practices, in the course of maximizing their own benefits, fail to understand the secondary short- or long-term effects on ecological systems as a whole. In addition, confusion and inaccurate understanding about the importance of services provided to humanity by natural forested ecological systems have led to irreparable damage of pristine ecosystems.

The word *ecosystem* was coined in 1935 by Sir Arthur Tansley, one of the British founders of the field of ecology. It refers to the whole community of organisms and their environment taken as a single functioning unit, while "communities" are interacting components belonging to the living world (Jarvis, 2000). Likens and Bormann (1995) outlined the entire ecological system as a reflection of a single interacting unit encompassing biological structures and diversity, hydrology, geology, heterogeneity, climate, and related seasonal changes that control the flux of both water and chemicals through ecosystems. In regulating the flow of matter within and between ecosystems, commonly known as the biogeochemical cycle, both biotic (living) and abiotic (non-living) components are essential. The pathway of chemicals tends to circulate from non-living components to living organisms and back to the living environment. A healthy system can support life indefinitely.

A conceptual model of deciduous forest ecosystems developed by Likens and Bormann (1995) facilitates the quantitative evaluation of the input-output flux and cycling of water, chemicals, and other materials across an ecosystem's boundaries (Figure 3.4.1). It encompasses the following four basic compartments: atmosphere, living and dead organic matter, available nutrients, and primary as well as secondary minerals. Theoretically, the inputs and outputs are moved to the ecosystems by meteorological, geological, and biological vectors—often defined as vehicles for transporting nutrients, matter, or energy—that ensure the completion of the biogeochemical cycle.

The inputs from the atmospheric components are characterized by the availability and changes of the atmospheric chemical species compositions and their transformation in the form of aerosols or gases governed by climatic or meteorological conditions. In addition, the macro- and micro-climatic conditions are very much influenced by the changeability of the weather—including variations of daily, monthly, and annual temperatures, precipitation distribution, as well as long- and short-range regional air mass transport—that predominantly determines wet and dry acidic deposition and their impacts on ecosystems. Studies to evaluate the integrity of ecosystems require long-term monitoring of precipitation, stream water, soil water chemistry, biomass accumulation, manipulation of entire catchment areas, and modeling (Likens and Bormann, 1995).

This chapter describes some applicable theoretical frameworks and efforts made over the last five years through research conducted for the Acid Deposition Monitoring Network in East Asia (EANET) to provide information for extrapolating the potential ecological impacts of acidic deposition experienced in the East Asian region (Awang, 2005).

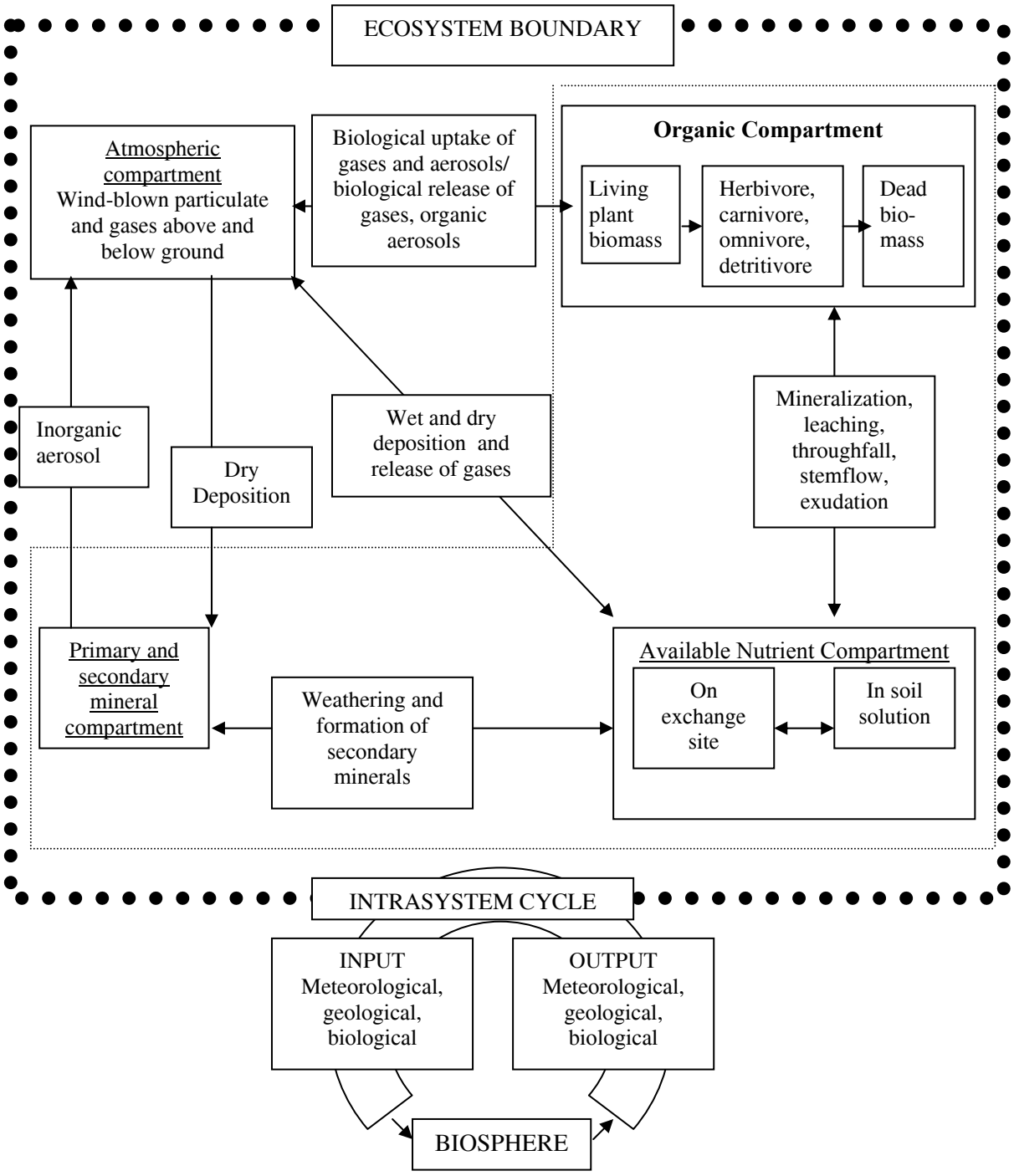

Figure 3.4.1 Schematic depicting nutrient relationships in a terrestrial ecosystem
Source: Modified from Likens and Bormann (1995).

3.4.2 Acidic deposition and its impact on ecological systems—A theoretical framework

3.4.2.1 Definitions and concepts

A revised definition of *ecology* provided by Likens (1992) describes it as the scientific study of the processes influencing the distribution and abundance of organisms, the interactions among organisms, and the interactions between organisms and the transformation and flux of energy and matter. Specifically, an ecological system has a richly detailed budget of inputs and outputs of energy and matter (Likens and Bormann, 1995). From this point, the hydrological cycle—being a major subsystem of the biosphere that drives biogeochemical cycles as part and parcel of ecological systems—represents the processes that determine the input-output of nutrients within those systems. This definition has the advantage of being very complete, as it bridges the gap between large-scale geochemical processes and those dealing with organisms, not only from the perspectives of physiology and taxonomy but also from that of genetic diversity (Bourdeau, 1992).

In connection to this, Likens (1992) also defines *global change* as covering more than just climate change or stratospheric ozone depletion. It also involves continued widespread land-use changes, including the introduction of natural substances into the biosphere in amounts greatly exceeding those involved in natural cycles (or of xenobiotic substances completely unknown to nature), the invasion of exotic species, and the further loss of biotic diversity. Thus, global change covers a multitude of modifications or alterations in the *biosphere* (or a "thin green smear" on the Earth's surface, as firstly Eduard Seus, an Austrian geologist defined it floutingly in the nineteenth-century), which must be studied and understood fully (Bourdeau, 1992). Ecological systems can be viewed at different organizational and spatial scales that are changing through time (Jarvis, 2000). The biosphere represents all the ecosystems of the planet viewed as a whole. It includes all the plants, animals, and microbes; all the tangible consequences of life on Earth, including the products of decomposition; and all the air, water, and soil where life exists. Similarly, Jarvis (2000) describes the atmosphere as an immediate layer above the surface of the land or water that lies in a
zone where aerial organisms exist, as well as where chemical species are released, transformed, transported, dispersed, and deposited on terrestrial and aquatic ecosystems, accordingly.

Cherrett (1989) ranks fifty of the most important concepts of ecology, based on a survey conducted among the members of the British Ecological Society in 1986. Clearly considered among the top most important concepts in comprehending ecological principles was understanding of the ecosystem concept, succession, energy flow and productivity, conservation of resources, competition, niches, material cycling, communities, life-history strategies, ecosystem fragility, food webs, ecological adaptations, environmental heterogeneity, species diversity, density-dependent regulation, limiting factors, and carrying capacity. These ecological systems and processes provide a life support system that can be identified by considering our environment as a whole, and they allow partitioning of the landscape into functional units in some systematic manner (Odum, 2000). The intricacy of the life support system is based on ecological system operations mirrored by a vast, diffuse network of processes operating on different time scales without set-point control. This becomes even further complicated for systems to manage natural ecosystems that are dependent on a multitude of biophysical, ecological, socio-political, and economic factors that vary geographically.

As pointed out by Landsberg and Gower (1997), there is likely to be considerable variation in ecosystems within any particular *biome* (the term refers to vegetation units of similar physiognomy or appearance) brought about by differences in topography, soils, and local differences in precipitation amounts and patterns. Consequently, any "lumped" or large-scale grouping will encompass a number of smaller ecosystems that are coherent and readily identifiable both in terms of their structure and function. The application of ecological principles, including ecophysiological analyses, to management problems in any forest or aquatic ecosystems affected by changes in atmospheric chemistry (air pollution and acid deposition) will depend on more detailed knowledge about the geographical location/area of concern, as well as of the levels of ecological system organization, particularly at their end-points (Jarvis, 2000). In addition, it has been recognized that there is immense

value in sound understanding of the effects of management actions in minimizing environmental stresses due to acidic deposition on ecological systems, such as forest and environment interactions at the physical level, as well as on ecophysiological processes (such as interactions with water and nutrient release and uptake) (Landsberg and Gower, 1997).

3.4.2.2 Dry and wet depositions

The deposition of gases and particles directly onto terrestrial surfaces of any ecological system being usually referred to as *dry deposition* represents a major flux of substances that provides their dominant input for many areas. There are several gases among the atmospheric compounds that contribute to acidifying inputs, such as sulfur dioxide (SO_2), nitrogen dioxide (NO_2), nitric acid (HNO_3), hydrogen chloride (HCl), and ammonia (NH_3). The inclusion of NH_3 is due to its nature of biological transformation both in soils (through the process of nitrification) and after plant uptake from an ammonium ion (NH_4^+) to nitrate (NO_3^-) resulting in the release of acidity into the soil that contributes to soil acidification. This dry deposition is commonly controlled by a number of surface process that commonly expressed by the parameter of deposition velocity $V_d(z)$ and determined from the deposition flux (F)for ambient concentrations, as follows:

$$V_d(z) = -F/C(z) \qquad (3.4.1)$$

where concentration (C) and V_d are both referenced to a height (z) above the ground. The deposition velocity is highly variable in terms of space and time as a consequence of variability in the rate of turbulent transport to absorbing surfaces, and in the chemical affinity of the surfaces for reaction with the pollutants. The atmospheric diffusion processes in the surface layers are regulated by the interaction of wind with aerodynamically rough surfaces and the rate of turbulent transfer, thereby increasing with vegetation height and wind speed (DoE, 1997). Consequently, the reactivity of the pollutant gases with terrestrial surfaces is also very much influenced by the wide range of types of surface, as each has a different affinity for the pollutant gases.

In the case of wet deposition, this encompasses the acidification of rain, mist, fog, or snow, and is recognized as the major transport route over most upland areas. Therefore, as suggested by the DoE (1997), it is essential to produce accurate estimates in order to determine more precise total acidifying inputs to ecosystems. There are problems, however, associated with the accurate measurement of wet depositions (in addition to those mentioned in Chapter 2), such as the efficient collection of precipitation; the exclusion of dry deposition input; the avoidance of contamination from wind-blown dust, bird droppings, and other debris; and the prevention of chemical changes in the sample between the time of collection and analysis.

It is also stressed that the input of wet deposition to soil, either directly or after passing overlying vegetation surfaces (throughfall), represents a pathway by which plant processes both above and below ground are potentially impacted. Exposure to belowground plant parts is typically modified initially from occurred precipitation by interaction with aboveground plant parts as throughfall and stemflow. Throughfall and stemflow in turn represent the combination of materials deposited on plant surfaces by both wet and dry deposition processes to be capable of either being washed off by physical processes, or removed from the surface matrix or leaf interior by ion exchange processes and/or diffusion. Before contact with biologically responsive belowground plant structures, the chemistry of throughfall and stemflow is further modified by interaction between organic and mineral soil horizons. The degree and rate of these interactions is largely dependent on the amount, rate, and duration of the falling precipitation, as well as the rooting depth and structure of the plant root's system (Likens and Bormann, 1995). Furthermore, the rates of natural processes of soil acidification and nutrient uptake, and the size of the available soil exchangeable pools of base cations, are also primary factors defining the belowground exposure on the environment.

3.4.2.3 Mechanisms of vegetation response to dry and wet depositions

Stress to a plant from exposure to air pollutants or acidic deposition occurs when the plant is unable to metabolize or detoxify the pollutant, as well as when the rate of uptake exceeds the level at which the plant can tolerate. Under conditions of acute stress, cellular and tissue death leads to a reduction in total photosynthetic area, while chronic stress results in injury or altered function in plants following long-term or repeated exposure to low concentrations of a pollutant or pollutants. These altered biochemical states within tissue typically lead to the inability of the plant to respond properly to existing environmental conditions or further stress.

Biochemical and ultrastructural studies have clearly demonstrated that plant membranes are the primary sites of action of gaseous air pollutants and their derivatives. Besides alterations in membrane permeability, injury is also expressed as those in metabolism, including enzyme and metabolite pools. The cellular effects can accumulate as necrosis of foliar tissue, altered carbohydrate allocation, reduced growth and yield, and these ultimately lead to impacts on plant communities and ecosystems.

Physiologically, these pollutants have been shown to slow plant growth through the following: reducing the amount of carbon fixed through photosynthesis; causing fixed carbon to be shifted from growth, storage, or reproduction to increased respiration or repair; reducing nutrient uptake efficiency; making the plant a more suitable host for insects or pathogens; and/or reducing its reproductive efficiency, success, or its competitive advantage with other plants (Awang, 1979). Figure 3.4.2 summarizes schematically the principal pathways and mechanisms of plant response to acidic deposition and gaseous pollutants in natural ecosystems.

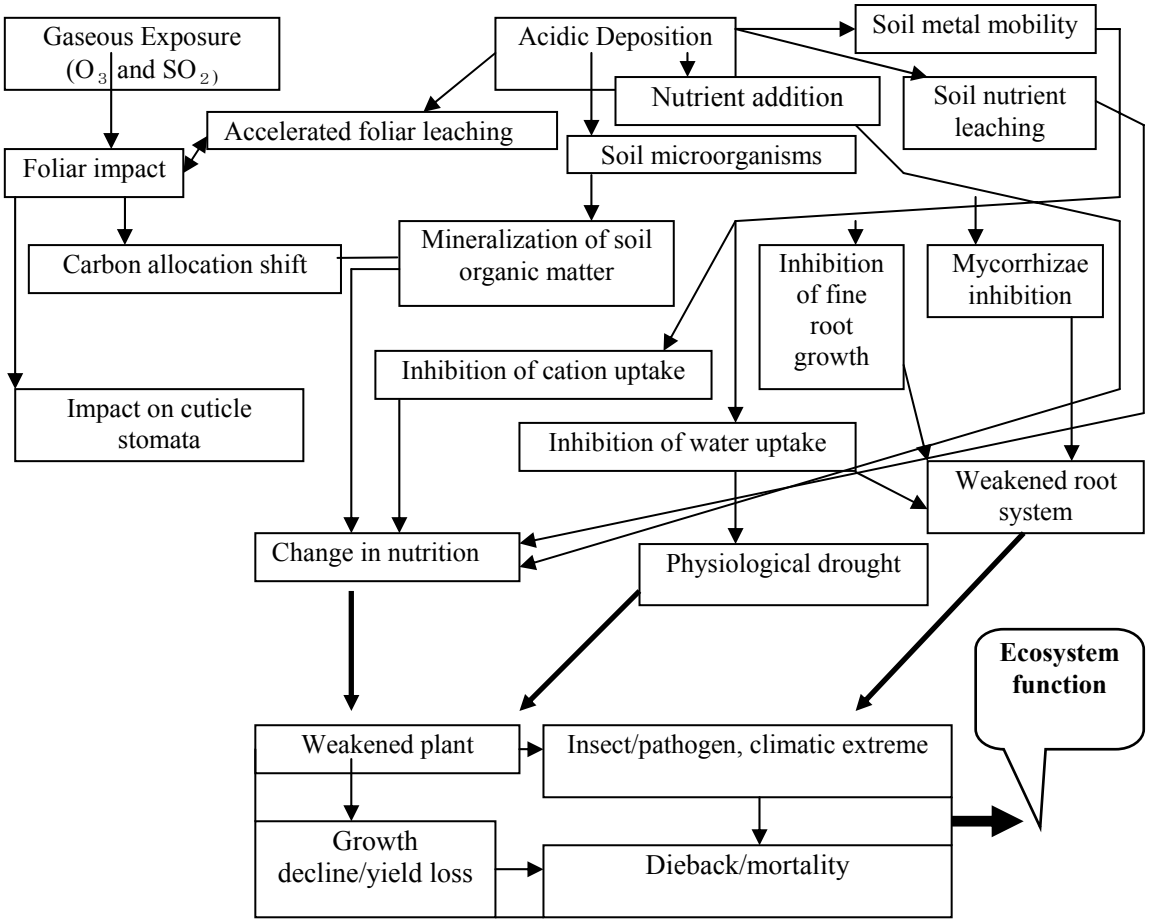

Figure 3.4.2 Schematic illustrating the complexity of impacts of gaseous pollutants and acidic deposition on forest ecological systems, as adapted from Awang (2005)

3.4.2.4 Direct-effect mechanisms

Direct-effect mechanisms can be subdivided into two broad categories: surface phenomena or physiological phenomena. The former explains the result of the interaction of the pollutants with the exterior surface of the plant. Basically, solutions, particles, and gases can all be classified as surface-active ingredients. Physiological phenomena, on the other hand, concern the results of the uptake of pollutants by diffusion through stomatal pores or through the cuticular membrane to the intercellular spaces within the leaf where the sequence of physicochemical events begins, leading to alteration of intracellular biochemical pathways. The exchange at the atmosphere-leaf interphase is somewhat unique, since the deposition surface is physiologically responsive, and it is highly variable in its capacity to function as a sink for pollutants. These processes are regulated by the plant's physiological state, the mix of species in the plant canopy, the canopy architecture and atmospheric turbulence, the chemical characteristics of the pollutant, and environmental conditions.

The cuticle, the outermost layer of the leaf, is the first line of defense for a plant. It has an important function as a structural element of the plant leaf, holding the cellular tissues compact and firm, and also as the point or layer of interphase between the body of the plant and its environment. Other functions include water conservation in the plant, prevention of loss of plant components by leaching, and protection from injuries caused by physical abrasion, frost, and radiation. The nature of the cuticle greatly influences the deposition and subsequent behavior of wet and dry deposition of air pollutants. It has been recognized—based on studies of the process of foliar leaching of nutrients by rain, mist, and dew—that atmospheric deposition in the form of acidic precipitation could potentially play an important role in the nutrient status of plants. It is important to note that increased rates of cation nutrient loss as a result of exposure to acidic precipitation were also observed.

A strong correlation has been consistently found between increased leaching of cation nutrients from foliage (calcium ion [Ca^{2+}], magnesium ion [Mg^{2+}], and potassium ion [K^{+}], in particular) as the hydrogen ion concentration of the leaching solution increased. It appears that cations on exchange sites of the cuticle are replaced by hydrogen from rain, mist, fog, or dew. Cations may also move directly from the translocation stream within the leaf into the leaching solution by diffusion and mass flow through areas devoid of cuticle. Leaching losses of cations from foliage have been shown to increase as a function of time. The studies have also suggested that accelerated loss of foliar Mg^{2+}, and possibly Ca^{2+}, may be related to symptoms of needle chlorosis characteristics of the forest decline currently being observed in several parts of Europe, North America, Japan, and China. This needle chlorosis appears to be a sequence of events that begins with ozone (O_3) stress, making the foliar tissue more susceptible to leaching by directly attacking the cell membrane and by reducing photosynthate allocation to the roots, thereby reducing the capacity of roots to take up nutrients from the soil.

It has also been suggested that the mechanism involves increased leaching of Mg^{2+} and Ca^{2+} from the ozone-injured foliage by acid rain or fog, leading to a reduced nutrient content of the foliage. This condition, coupled with the root system's reduced capability to replenish leaching losses, is hypothesized to lead to the expression of nutrient deficiency symptoms and the associated reduction in growth and vigor. The response of plants to acidic deposition appears to be very much related to leaf wettability and influenced by the following processes: buffering, possibly from dissolution of dry basic particulates on the leaf surface and/or leachates from leaves; evaporative concentration of acids; and neutralization, possibly through cellular disruption. It appears that leaves with high surface tension had greater buffering ability. Several studies demonstrated the contrasting morphology of the epicuticular wax on cotyledons and leaves as the major factor determining the extent of acid rain damage.

3.4.2.5 Physiological phenomena

As plants can be regarded as a complex system of sources and sinks that has evolved under selective pressure for the efficient management of resources, this may also be visualized as a dynamic balance between the allocation of carbon, water, and mineral nutrients between growing shoots and roots (Bazzaz, 1997). Exposure to dry and wet acidic depositions will disrupt that dynamic balance, resulting in alteration of growth, stress tolerance, and reproductive efficiency. A primary physiological effect of dry deposition (such as O_3, SO_2, and NO_2) is its disruption of carbon allocation pathways, including both the reduction of photosynthesis, increased dark respiration, and reduced transport of photosynthate to root systems. In the case of O_3 toxicity, it is well known for its ability to attack chemical double bonds, altering molecular structure and the biochemical states of tissues and organelles, leading to the inability of the plant to respond properly to the existing conditions and further stress.

Reports of the National Acid Precipitation Assessment Program (NAPAP, 1990) conclusively demonstrated that the effects of acid precipitation on plant growth responses were more variable than photosynthetic responses. For instance, simulated acid precipitation did not appear to suppress rates of photosynthesis in certain species studied. Similarly, the growth of most hardwood species was either not affected or was stimulated at pH levels of 3.0 and 3.5 when compared to a pH of 4.2, but certain species exhibited negative growth responses. Generally, growth reductions in field-grown crops have not been found at pH levels above 3.0. Furthermore, a wide range of field studies involving the irrigation of seedling and sapling trees with simulated acid rain in both Scandinavia and the United States typically produced growth stimulation, which was attributed to the fertilizer effect of sulfur (S) and nitrogen (N) in the irrigant. It has therefore been suggested that studies on the effects of acid deposition on terrestrial systems must be evaluated both in terms of direct effects on growth and indirect effects associated with changes in soil nutrient availability.

With reference to water interactions, it has been shown that reduced water supply capacity can be a direct effect of the release of ionized aluminum (Al^{3+}) and other metals toxic to the fine roots of plants through the addition of strong acid anions to the soil by precipitation. Simulated acid rainfall at near ambient pH (4.1) has been found to reduce mycorrhizal vigor in loblolly pine, a potential factor in the uptake of both water and nutrients. It appears that several researchers have reported differential sensitivities and inconsistency responses of field crops and forest species to simulated acid rain, particularly in relation to water status among the species. Preferential stimulation of shoot growth and altered shoot physiology associated with increased nitrogen deposition has been a principal tenet of the so-called nitrogen hypothesis of forest decline. In this connection, increased sensitivity to drought by red spruce seedlings treated with simulated acid rain at near ambient conditions (pH 4.1 and 3.6) was mainly attributed to stimulation of transpirational loss from increased needle biomass, and was not from altered physiological resistance to drought. It is reported that the presence of nitrogen oxides (NO_x) in the atmospheric environment at an ambient level can be utilized directly by foliage of high-elevation red spruce through induction of nitrate reductase activity. This induction provides a mechanism for foliar fertilization and a basis for altering root-to-shoot ratios, resistance to water stress, and possibly sensitivity to winter injury (NAPAP, 1990).

Another important factor receiving a direct impact from wet and dry deposition is seedling establishment. Generally, this is more sensitive to soil acidity than seedling growth under normal conditions, and the response varies from one species to another. The pH value of throughfall is normally in the range between 2.3 and 4.0, and thus could potentially impact the litter layer where seedling establishment takes place. This would lead to leaching of metabolically active substances from seeds with possible adverse physiological effects.

3.4.2.6 Indirect or soil-mediated effect mechanisms

Concern about forest declines due to acidic deposition is very much related to soil acidification and nutrient deficiency. Besides long-term depletion of cation nutrients from soil (such as loss of sodium ion [Na^+], Mg^{2+}, and Ca^{2+} through leaching), a mobilization of trace metals (such as ferric ions [Fe^{3+}] and Al^{3+}) up to levels toxic to root growth is also of great importance. Mechanisms by which cation deficiencies affect plant growth have been shown to be associated with the slow growth of apical meristem and increased dark respiration due to a loss of membrane integrity resulting from reduced availability of Ca^{2+}. It has been suggested that the mechanisms by which Al^{3+} affects plant physiology and growth can be grouped into two categories: (1) direct toxicity effects that inhibit root growth, shoot growth, or both; and (2) indirect effects via the antagonism of Al^{3+} towards the uptake and/or transport of cations. Researchers found that the ratio between Al^{3+} and various cations (particularly Ca^{2+} and Mg^{2+}) in soil or plant tissues are demonstrated to be better indices of plant response than concentration of Al^{3+} alone, in particular with respect to the indirect effects of Al^{3+} on cation uptake coupled with interactive cation effects upon the activities of one another in solution.

Uptake of Al^{3+} by roots is thought to be primarily a non-metabolic process involving the binding of Al^{3+} to organic complexes. Aluminum has also been shown to precipitate as inorganic phosphate salts within roots. The metabolically accumulated aluminum may enter the cell by Ca^{2+} or Mg^{2+} membrane transport systems. Uptake within root tissues is relatively rapid, occurring within a few hours. It has been proposed that some plants accumulate Al^{3+} in the shoots, with older leaves accumulating the highest concentrations, and speculated that the apoplastic location of Al^{3+} in older leaves may explain the absence of phytotoxicity even with very high concentrations of Al^{3+} in those tissues. Among the important measurable effects of Al^{3+} are a reduction of root elongation, premature cell maturation and senescence, alteration of secondary root formation and branching, and fine root dieback—all leading to reduced root surface area. Aluminum toxicity may result in reduced stomatal aperture and increased diffusion resistance, increased membrane permeability, foliar chlorosis and necrosis, reduced leaf number and size, and late bud break or early bud set. Physiologically, this toxicity is thought to be highly cytotoxic, associated with the inhibition of hexokinase and ATPase activities, and dependent upon specific ion effects, ionic ratios, pH, and Al-organic matter complexes found in the soil. Consequently, differences in aluminum tolerance exist among plant species. In natural forest ecosystems, there is evidence, using a mass balance approach, that natural cation leaching rates can be substantially increased by acid deposition. In addition, vegetation also plays an important role in soil acidification. Along with biomass accumulation, the storage of cations results in a proportional input of hydrogen ions (H^+) to soil, leading to increases in acidification due to changes in cation exchange equilibrium.

3.4.2.7 Impact on ecosystem integrity in East Asian countries

Preliminary assessment using available short- and long-term data from countries participating in EANET (at least from Japan, China, Thailand, and South Korea) on the relationship between emissions of SO_2 and NO_2 and depositions of SO_4^{2-} and NO_3^-, and changes in pH values and other chemical species that represent wet and dry depositions, clearly demonstrated a significant ecological impact (Awang, 2005). The estimated sulfur and nitrate loadings from the atmosphere could be about four or five times higher than the values recommended for protection of sensitive forest species, streams, and other related aquatic ecosystems. It is also interesting to note that, in certain areas, reduction in base cations inputs from the atmospheric environment could lead to higher sensitivity of forest species and aquatic life to atmospheric inputs of acidic depositions, but further clarification will be needed to explain these situations.

Changes in the species compositions of these ecosystems have been observed, with the disappearance of some highly sensitive species and replacement by more acidic-tolerant species. Such scenarios are yet to be determined scientifically, as it is predominantly observed in regions where wet and dry depositions are significantly changing, at least over the last two decades. There was a lot of published

work in Japan, South Korea, and China in the 1990s related to these subjects. Among those noted are the integrated analysis of energy growth and acid deposition (Carmichael and Arndt, 1996); evaluation of acidic depositions onto a forest canopy (Kobayashi et al., 1996); growth responses of deciduous broad-leaved trees (Kitao et al., 1996); effects of soil acidification on the growth of *Cryptomeria japonica* (Izuta and Totsuka, 1996); acidic outer bark of a conifer (Satake et al., 1996); phenological disorder of cold death of apical shoot of red pine (Shan et al., 1996); estimation of dry deposition onto a Japanese cedar stand (Hosono and Nouchi, 1996); rainfall, throughfall, and stemflow sampling for monitoring the effects of acid rain on a forest ecosystem (Tamaki et al. 1996); tolerance of some epiphytic bryophytes to simulated acid (Taoda, 1996); impact on a soil microbial community (Yokoyama et al., 1996); impact on the growth and germination of wood destroying fungus (Hattori and Satake 1996); the acid neutralizing ability of coniferous seedlings (Matsui 1996); application and evaluation of the critical load model for Japanese ecosystems (Shindo and Hakamata, 1996); deficiency of calcium in a forested ecosystem (Nakano et al. 1996); chemical speciation of aluminum in soil extract (Tsunoda et al., 1996); physiological studies of acid-tolerance in fish (Yada et al., 1996); and phototrophs in highly acidic waters (Whitton and Satake, 1996). These contributions have significantly enriched the literature on the impacts of acidic deposition on ecological systems in the past few decades, particularly in the northeast Asian regions.

Using international or at least European Union standards, the vitality of forest stands was observed in parts of China, Japan, Russia, and South Korea at certain periods of the year, based on defoliation and leaf discoloration. This also needs further elucidation. The reduction in biomass production, annual wood increment, the response of saplings and matured trees, and changes in tree or canopy architecture and ecosystem health also need to be further investigated. It is suggested that the compounding effects of dry and wet deposition, as well as the overall impact of air pollution on trees, should not be seen as indicative of the unknown effects on other parts of forest ecosystems. The effects on herbs and grasses in the undergrowth, as well as on the biodiversity of plants and animals, are likely to be more pronounced. Future tasks to be considered for the EANET program include determining the overall impacts of acidic deposition on ecosystems, the responses to either increased or reduced nitrogen and sulfur inputs due to changes in dry and wet depositions, and the integrity of the ecosystems and ecological impacts as a whole.

3.4.3 Soil features

3.4.3.1 Soil monitoring sites and methods

The initial objectives of soil monitoring for EANET are the establishment of baseline data and the early detection of possible impacts of acid deposition.

As soils are characterized by several types of variation, the quality of monitoring data depends mainly on determining such variability. Baseline data, for instance, should be described not only in mean values but also in variances. Thus, the impacts of acid deposition can be detected through statistical analyses to evaluate the variability of soil properties using a hierarchical system of sampling units and adopting the nested experimental design of statistics to analyze the data model (Snedecor and Cochran, 1989).

The average value of soil chemical properties should be known in a large population of soil. First, a random sample of m soil cores is collected from a monitoring site. For each core sample, n independent chemical analyses are made. These procedures are operated for l horizons. The horizon is not sampled at random from a population but rather fixed to be the uppermost or underlying one. It is then tested whether data from the uppermost and underlying soil horizon are statistically significant different or not.

The mixed model of analysis of variance (ANOVA) (Snedecor and Cochran, 1989) is assumed for the monitoring value. The soil chemical content, for instance, found for the k^{th} determination from the j^{th} subplot of i^{th} horizon is described as:

$$X_{ijk} = \mu + \theta_i + c_{ij} + \varepsilon_{ijk} \quad (i = 1, \ldots, l; j = 1, \ldots, m; k = 1, \ldots, n) \tag{3.4.2}$$

where $\Sigma\theta_i = 0$, $c_{ij} = N(0,\sigma^2_c)$, and $\varepsilon_{ijk} = N(0, \sigma^2)$. The θ_i are constant (*fixed value*) and associated with the horizons, but the c_{ij} and the ε_{ijk} are dependent and *random* variables drawn from normal distribution with means of 0 and variances σ^2_c and σ^2, corresponding to subplots and determination, respectively. This is the so-called *mixed* model, one that occurs frequently in environmental studies.

The mean chemical content of a population of soil, μ, can be estimated in each of the horizons, and then the contents from the horizons are compared to each other. The sources of variation for an ANOVA table are horizons, subplots in the same horizon, and determination in the same subplot, in this case. Unbiased estimates of the two components of variance are obtained under an AVOVA. The null hypothesis to be tested is $\sigma^2_c = 0$. If the F value is far beyond its 5% or 1% point, then the content evidently varies from subplot to subplot in the sampled population.

In the real case of soil sampling for EANET, the mixed model is written in a simplified form with all suffixes omitted, as follows:

$$X = \mu + \theta + c + a + s + p + i + \varepsilon \tag{3.4.3}$$

where μ is a mean value; θ is the fixed effect of horizon on a soil profile, while there are random effects of country (c), area (a), soil type (s), plot (p), and subplot (i), as well as (ε), which is an error under the repeatability condition.

Besides this, within-laboratory and between-laboratory variances can be obtained from the *QA/QC Program for Soil and Vegetation Monitoring in East Asia* (ISAGM/EANET, 2000). Using this information, total QA/QC practices are realized throughout the whole process of soil monitoring, including evaluation of reliability at each stage of the hierarchy and preciseness of chemical/physical analysis.

The model, including terms corresponding to between-laboratory and within-laboratory variances, is described as follows:

$$X = \mu + \theta + c + a + s + p + i + b + w + \varepsilon \quad (3.4.4),$$

where b and w are random effects of between-laboratory and within-laboratory, respectively (terms from μ to i and ε are described above).

Expected mean values and components of variance can be calculated from data or the ANOVA of the statistical model. The terms b and w, and also sometimes ε, are estimated from an inter-laboratory experiment. The image of the hierarchical system of soil sampling from the country level to a subplot level is shown in Figure 3.4.3. This model is allocated to the soil sampling scheme in each country.

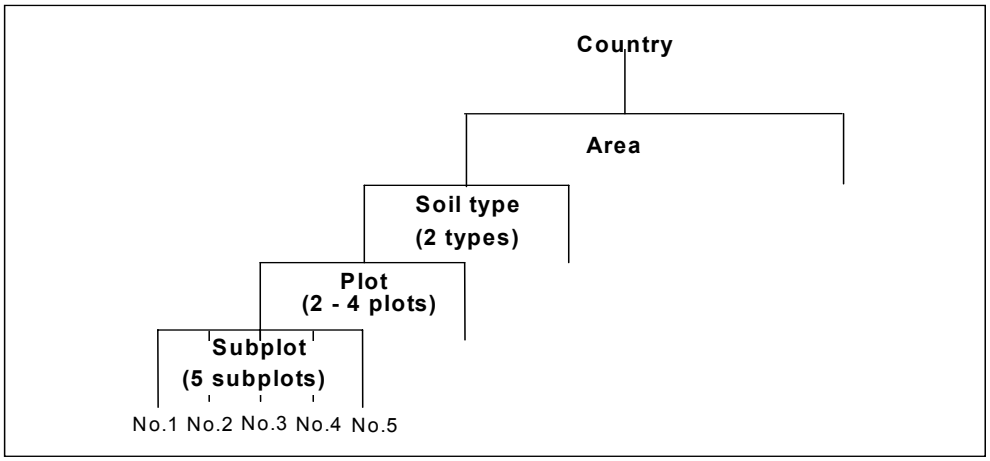

Figure 3.4.3 Schematic of multi-stage sampling for soil monitoring

Monitoring sites of each country are shown in Table 3.4.1 and Figure 3.4.4.

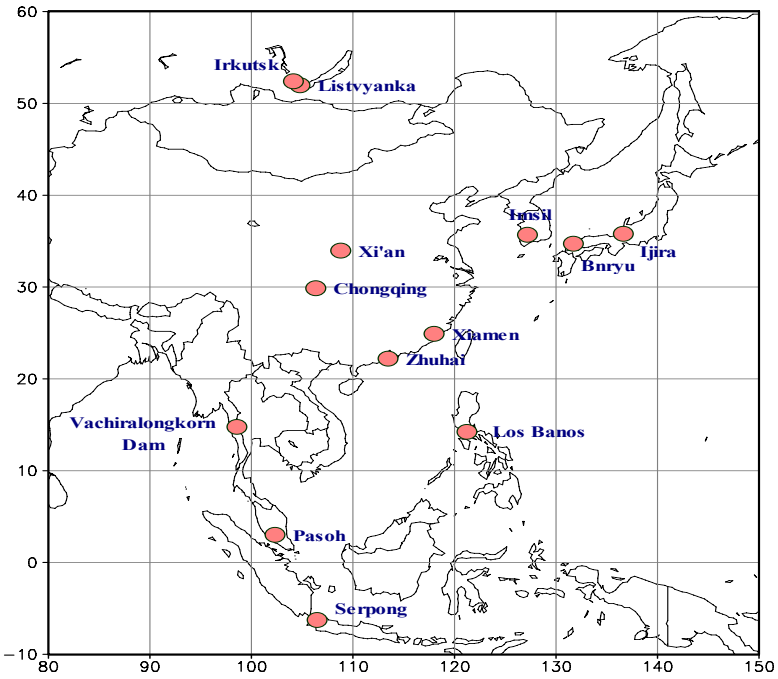

Figure 3.4.4 Location of EANET soil monitoring survey areas in East Asia (2000–2004)

Table 3.4.1 EANET soil monitoring survey sites (2000–2004)

Country/area	Site	Soil type	Number of plots (with five subplots)	Year
China				
Chongqing	1. Jinyunshann	Acidic-Udic Argosols	2	2000, 2003
Jiwozi, Xi'an	2. Dabagou	Brown soil	2	2003
	Jiwozi[*1]		2	2001
Xiaoping, Xiamen	3. Xiaoping	Red soil	2	2003
	Xianjiaoji[*1]		2	2000
	Huacuo[*1]		2	2000
	Zhuangyuanshan[*1]		2	2000
Zhuxiandong, Zhuhai	4. Zhuxiandong	Ochinic Udic Ferrosols		2003
	Four forest plots with different tree species[*1]		*One sample pit in the respective forests*	2000, 2001
Indonesia				
Serpong	5. Bogor Research Forest	Not reported	1	2001
Japan				
Ijira	6. Lake Ijira	Dystric Cambisol	4	2000
Banryu	7. Banryu-2	Cambisols	2	2001
	8. Iwami "Rinku" Factory Park	Acrisols	2	2001
Malaysia				
Pasoh	9. Pasoh-1 and -2	Dystric Nitosol	2 (two subplots in the respective plots)	2000
	10. Pasoh-3	Rhodic Ferralsol	1 (two subplots in the plot)	2000
Philippines				
Los Banos	11. Mt. Makiling	Eutric Cambisol	2	2002, 2005[*2]
	12. UP Quezon - Laguna Land Grant	Dystric Nitosol	2	2001, 2005[*2]
Republic of Korea				
Imsil	13. Mt. Naejang	Not reported	2	2001, 2004
Russia				
Listvyanka	14. Bolshie Koty Varnachka	Mollic Leptosol	1	2000
	15. Bolshie Koty Temnaya	Umbric Leptosol	1	2000
Irkutsk	16. Irkutsk (near the Limnological Institute)	Eutric regosol	1	2001
	17. Irkutsk	Calcaric Luvisol	1	2001
Thailand				
Vachiralong- korn Dam	18. Vachiralongkorn (Khao Lam) Dam	Ferric Acrisols	2	2000, 2001, 2002, 2003
	19. Vachiralongkorn (Puyea)	Luvisols	1	2002, 2003

Notes: [*1]Italic letters show preliminary surveyed sites in China.
[*2]The surveys were carried out in February 2005 due to postponement of surveys in autumn 2004.

Nineteen soil monitoring sites have been established in eight participating countries so far. Soil types, number of plots, and surveyed years are described in the table above. Two data sets were obtained in China, the Philippines, Republic of Korea, and Thailand during this term. At one site in Thailand, soil monitoring is also conducted voluntarily twice a year.

The parameters for monitoring soil are shown in Table 3.4.2. Eleven chemical parameters and two physical parameters are analyzed. Analytical equipment and methods used for soil monitoring are summarized in Table 3.4.3.

Table 3.4.2 Monitoring parameters for soil

Parameters	Unit	Criterion	Frequency of analysis
Chemical properties of soil			
a) Moisture content	wt%	M	
b) pH(H_2O) and pH(KCl)		M	
c) Exchangeable base cations (Ca, Mg, K, and Na)	cmol(+)·kg^{-1}	M	
d) Exchangeable acidity	cmol(+)·kg^{-1}	M	
e) Exchangeable Al, H	cmol(+)·kg^{-1}	O	
f) Effective cation exchange capacity (ECEC)	cmol(+)·kg^{-1}	M	Every
g) Carbonate content (for calcareous soil)	%$CaCO_3$	M*	3–5 years
h) Total carbon content	g·kg^{-1}	O	
i) Total nitrogen content	g·kg^{-1}	O	
j) Available phosphate	P mg·kg^{-1}	V	
k) Sulfate	S mg·kg^{-1}	V	
Physical properties of soil			
a) Fine earth bulk density	Mg·m^{-3}	O	
b) Penetration resistance (in the fieldwork)	kg·cm^{-2}	O	

Notes: M = mandatory items; O = optional items; V = voluntary items. *. Carbonate content is a mandatory item only for calcareous soil.

Table 3.4.3 Analytical equipment and methods for soil monitoring

Parameters	Equipment/methods
Chemical properties of soil	
a) Moisture content	Drying oven, balance
b) pH(H_2O) and pH(KCl)	Glass electrode
c) Exchangeable base cations (Ca, Mg, K, and Na)	AAS, ICP-AES, or ICP-MS (CH_3COONH_4-extraction)
d) Exchangeable acidity	Titration (KCl-extraction)
e) Exchangeable Al, H	Ibid.
f) Effective cation exchange capacity (ECEC)	Calculation (as sum of exchangeable cations)
g) Carbonate content (for calcareous soil)	Volumetric calcimeter
h) Total carbon content	Titration (Walkley-Black method) or CN-analyzer
i) Total nitrogen content	Titration (Kjeldahl method) or CN-analyzer
j) Available phosphate	Spectrophotometry (Bray-1 test)
k) Sulfate	Turbidimetry, IC, ICP-AES or ICP-MS
Physical properties of soil	
a) Fine earth bulk density	Metal sampling cylinder, drying oven, balance
b) Penetration resistance (in the fieldwork)	Pocket penetrometer

3.4.3.2 State of soil conditions: baseline soil data

Tables 3.4.4 and 3.4.5 present the mean values of chemical properties of the uppermost and underlying soil layers, respectively. Note that these data, being the first reported from each country, are the most fundamental baseline information used to analyze and evaluate the present conditions of soil properties in most areas.

The mean values of each property from the uppermost layers is equal to or larger than those of the underlying layers.

Table 3.4.4 Mean values of chemical properties of uppermost soil layers at respective monitoring sites in (cmol(+)·kg^{-1}) [*Note:* ECEC = effective cation exchange capacity; BS = base saturation]

Country	Site	Soil type	PH		Exchangeable base cations			
			H_2O	KCl	Ca	Mg	K	Na
China	1. Jinyunshann	Acidic-Udic Argosols	3.9	3.3	0.7	0.2	0.1	0.03
	2. Dabagou	Brown soil	6.4	5.3	6.4	0.7	0.5	0.1
	3. Xiaoping	Red soil	4.4	3.8	0.1	0.1	0.2	0.05
	4. Zhuxiandong	Ochinic Udic Ferrosols	4.0	3.7	3.8	1.3	1.5	0.7
Indonesia	5. Bogor Research Forest	Not reported	4.3	3.9	0.9	0.3	0.1	0.0
Japan	6. Lake Ijira	Dystric Cambisol	4.2	3.3	0.3	0.8	0.1	0.2
	7. Banryu-2	Cambisols	4.7	3.8	0.4	0.3	0.2	0.1
	8. Iwami “Rinku” Park	Acrisols	4.3	3.4	0.4	0.5	0.3	0.1
Malaysia	9. Pasoh-1	Dystric Nitosol	4.0	3.7	—	—	—	—
	10. Pasoh-2	Rhodic Ferralsol	4.3	3.8	—	—	—	—
Philippines	11. Mt. Makiling	Eutric Cambisol	5.8	4.8	17.8	14.0	4.2	3.3
	12. UP Quezon-Laguna Land Grant	Dystric Nitosol	4.1	3.8	0.3	0.4	0.3	0.4
R. of Korea	13. Mt. Naejang	Not reported	4.9	4.0	0.6	0.2	0.1	0.1
Russia	14. Bolshie Koty Varnachka	Mollic Leptosol	6.7	5.9	28.2	3.8	0.4	0.1
	15. Bolshie Koty Temnaya	Umbric Leptosol	4.8	3.9	23.1	6.7	1.6	0.1
	16. Irkutsk (near LIN)	Eutric regosol	6.7	5.4	19.6	4.2	0.4	0.2
	17. Irkutsk	Calcaric Luvisol	6.4	5.5	24.4	6.3	0.2	0.2
Thailand	18. Vachiralongkorn (Khao Lam) Dam	Ferric Acrisols	6.4	5.6	12.9	17.0	0.3	0.2
	19. Vachiralongkorn(Puyea)	Luvisols	4.6	4.2	3.2	1.7	0.1	0.05
Mean			5.0	4.3	8.4	3.4	0.6	0.3

Table 3.4.4 (*Continued*)

Country	Site	Soil type	Ex-acidity	Ex-acid cation		ECEC	BS
				Al	H		%
China	1. Jinyunshann	Acidic-Udic Argosols	6.4	6.4	0.7	9.0	11.2
	2. Dabagou	Brown soil	0.0	0.03	0.01	7.8	99.4
	3. Xiaoping	Red soil	5.6	5.0	0.7	6.0	6.6
	4. Zhuxiandong	Ochinic Udic Ferrosols	3.3	3.0	0.4	10.6	68.6
Indonesia	5. Bogor Research Forest	Not reported	—	3.3	0.2	4.8	26.8
Japan	6. Lake Ijira	Dystric Cambisol	7.4	7.9	0.9	8.8	16.4
	7. Banryu-2	Cambisols	3.5	3.2	0.4	4.6	22.1
	8. Iwami “Rinku” Park	Acrisols	8.3	7.3	1.0	9.6	13.6
Malaysia	9. Pasoh-1	Dystric Nitosol	3.6	—	—	—	—
	10. Pasoh-2	Rhodic Ferralsol	3.8	—	—	—	—
Philippines	11. Mt. Makiling	Eutric Cambisol	0.4	0.1	0.3	39.7	98.9
	12. UP Quezon - Laguna Land Grant	Dystric Nitosol	5.6	4.6	1.0	7.1	20.6
R. of Korea	13. Mt. Naejang	Not reported	4.5	3.3	0.4	4.9	18.9
Russia	14. Bolshie Koty Varnachka	Mollic Leptosol	0.1	0.0	0.1	32.5	99.7
	15. Bolshie Koty Temnaya	Umbric Leptosol	1.1	0.6	0.6	32.6	96.5
	16. Irkutsk (near LIN)	Eutric regosol	0.1	0.1	0.05	24.5	99.3
	17. Irkutsk	Calcaric Luvisol	0.1	0.1	0.02	31.1	99.9
Thailand	18. Vachiralongkorn (Khao Lam) Dam	Ferric Acrisols	7.9	0.04	10.4	38.2	79.6
	19. Vachiralongkorn(Puyea)	Luvisols	19.4	1.8	17.6	24.3	43.5
Mean			4.5	2.7	2.0	17.4	54.2

Table 3.4.5 Mean values of chemical properties of subsequent soil layers at respective monitoring sites in (cmol(+)·kg^{-1})

Country	Site	Soil type	PH		Exchangeable base cations			
			H_2O	KCl	Ca	Mg	K	Na
China	1. Jinyunshann	Acidic-Udic Argosols	4.2	3.6	0.9	0.2	0.1	0.03
	2. Dabagou	Brown soil	6.4	5.2	6.1	0.6	0.5	0.1
	3. Xiaoping	Red soil	4.5	3.9	0.0	0.1	0.2	0.0
	4. Zhuxiandong	Ochinic Udic Ferrosols	4.1	3.8	3.1	1.1	1.4	0.7
Indonesia	5. Bogor Research Forest	Not reported	4.3	3.9	0.9	0.3	0.1	0.0
Japan	6. Lake Ijira	Dystric Cambisol	4.4	3.7	0.1	0.2	0.1	0.1
	7. Banryu-2	Cambisols	4.8	3.8	0.2	0.2	0.2	0.1
	8. Iwami “Rinku” Park	Acrisols	4.5	3.6	0.1	0.3	0.2	0.1
Malaysia	9. Pasoh-1	Dystric Nitosol	4.3	3.8	—	—	—	—
	10. Pasoh-2	Rhodic Ferralsol	4.3	3.8	—	—	—	—
Philippines	11. Mt. Makiling	Eutric Cambisol	5.6	4.4	13.8	13.4	3.8	2.9
	12. UP Quezon - Laguna Land Grant	Dystric Nitosol	4.1	3.8	0.3	0.4	0.2	0.3
R. of Korea	13. Mt. Naejang	Not reported	4.9	4.0	0.2	0.1	0.1	0.1
Russia	14. Bolshie Koty Varnachka	Mollic Leptosol	6.7	5.9	28.2	3.8	0.4	0.1
	15. Bolshie Koty Temnaya	Umbric Leptosol	4.8	3.9	23.1	6.7	1.6	0.1
	16. Irkutsk (near LIN)	Eutric regosol	6.7	5.4	19.6	4.2	0.4	0.2
	17. Irkutsk	Calcaric Luvisol	6.4	5.5	24.4	6.3	0.2	0.2
Thailand	18. Vachiralongkorn (Khao Lam) Dam	Ferric Acrisols	6.1	5.4	8.8	10.6	0.3	0.2
	19. Vachiralongkorn(Puyea)	Luvisols	4.6	4.2	3.2	1.7	0.1	0.05
Mean			5.0	4.3	7.8	2.9	0.6	0.3

Table 3.4.5 (*Continued*)

Country	Site	Soil type	Ex-acidity	Ex-acid cation		ECEC	BS
				Al	H		%
China	1. Jinyunshann	Acidic-Udic Argosols	4.9	4.3	0.6	6.6	18.6
	2. Dabagou	Brown soil	0.04	0.02	0.01	7.4	99.5
	3. Xiaoping	Red soil	4.8	4.3	0.5	5.1	5.8
	4. Zhuxiandong	Ochinic Udic Ferrosols	3.3	2.9	0.3	9.5	65.4
Indonesia	5. Bogor Research Forest	Not reported	—	3.3	0.2	4.8	26.8
Japan	6. Lake Ijira	Dystric Cambisol	5.3	5.4	0.5	5.8	8.6
	7. Banryu-2	Cambisols	3.4	3.0	0.4	4.2	17.3
	8. Iwami “Rinku” Park	Acrisols	7.1	6.4	0.7	7.7	8.2
Malaysia	9. Pasoh-1	Dystric Nitosol	3.4	—	—	—	—
	10. Pasoh-2	Rhodic Ferralsol	3.8	—	—	—	—
Philippines	11. Mt. Makiling	Eutric Cambisol	1.1	0.7	0.4	35.0	96.3
	12. UP Quezon - Laguna Land Grant	Dystric Nitosol	5.5	4.5	1.0	6.6	17.7
R. of Korea	13. Mt. Naejang	Not reported	3.7	3.1	0.2	3.9	13.5
Russia	14. Bolshie Koty Varnachka	Mollic Leptosol	0.1	0.03	0.1	32.5	99.7
	15. Bolshie Koty Temnaya	Umbric Leptosol	1.1	0.6	0.6	32.6	96.5
	16. Irkutsk (near LIN)	Eutric regosol	0.1	0.1	0.05	24.5	99.3
	17. Irkutsk	Calcaric Luvisol	0.1	0.1	0.02	31.1	99.9
Thailand	18. Vachiralongkorn (Khao Lam) Dam	Ferric Acrisols	7.8	0.05	10.3	27.8	79.3
	19. Vachiralongkorn(Puyea)	Luvisols	19.4	1.8	17.6	24.3	43.5
Mean			4.2	2.4	2.0	15.8	52.7

The pH(H_2O) data range from 4.1 to 6.7 with a mean value of 5.0. A high correlation is recognized between pH(KCl) and pH(H_2O), as usual. Values higher than 6.0 in pH(H_2O) were found in sites at the Vachiralongkorn Dam (Thailand), Dabagou (China), and Russia (three sites), besides at Bolshie Koty Temnaya. The lowest values of pH(H_2O) were found at Zhuxiandong (China: Ochinic Udic Ferrosols) and UP Queson (Philippines: Dystric Nitosol). If significant change over time is revealed in soil pH data, it will sometimes be an important indicator of the impact of acid deposition.

On exchangeable calcium (Ca) contents, there are two groups, i.e., higher than 5 cmol(+)·kg^{-1} and lower than 3 cmol(+)·kg^{-1}. High contents of exchangeable Ca and/or magnesium (Mg) tend to be related to high soil pH. Low values of exchangeable aluminum (Al) (lower than 1.0) are related to low soil pH. Because ex-acidity is equal to ex-Al plus ex-hydrogen (H) and the former is usually larger than the latter, ex-acidity is mainly controlled by ex-Al in this area. Note that very high values of base saturation (BS) (larger than 90%) very often mean low values of ex-acidity (lower than 2.0 cmol(+)·kg^{-1}).

3.4.3.3 Preliminary analysis of soil variability

The baseline data used to evaluate present conditions of soil properties include information on soil variability itself. Table A-3.4.1 (Annex) provides mean values and variation data of pH (in parentheses) for the uppermost soil layer at each stage of the monitoring system hierarchy. Table A-3.4.2 (Annex) presents data on ex-Ca/Al in the same manner. Tables A-3.4.3 and A-3.4.4 in the Annex present the same data for underlying soil layers. How large or small are not only the mean values as the baseline data but also the variability of the data? Answering these questions is the major target of monitoring.

To be precise, the variation data of these tables were not derived from the model described in 3.4.3.1. Confidence limits were calculated here from the standard deviation for the next lower stage of hierarchy, so these are preliminary results of evaluation of baseline data analysis. Correct confidence limits for the components of variance should be calculated employing a slightly more complicated method using some data from ANOVA and the *F*-distribution table of statistics.

Some information concerning the quality of monitoring can nevertheless be obtained from the table. If the variation data from a country, for instance, is abnormally larger or smaller than other countries, then the sources of variance should be investigated and it should be clarified whether there are any methodological mistakes or not. This is included in a data validation step of the QA/QC program.

The sample data from planned experiments are usually of equal size, but monitoring sample sizes can be little controlled in field studies like these. Sample sizes are set throughout the monitoring procedures according to the standard manual, including statistical models, as described above. The actual structure of this monitoring is complicated and (so-called) unbalanced, i.e., the number of monitoring areas in each country is not necessarily the same, e.g., four areas in one country and two areas in other countries, etc. There are also sometimes missing data in some properties, some subplots, soil types, etc.

ANOVA tables, however, can be shown in Table A-3.4.5 (Annex) on pH, ex-Ca, and ex-Al. In all cases, the mean square ratio of site (soil type)/plot, and, in the case of ex-Ca and ex-Al, those of country/area are large and statistically significant. These facts mean that in a sampled population the pH, ex-Ca, and ex-Al contents evidently vary from site (soil type) to site (soil type), and the ex-Ca and ex-Al contents also evidently vary from country to country, but they don't vary from area to area and plot to plot. These facts of cumulative contribution of the sampling stages to the variance are shown visually in Figure 3.4.5.

The most serious problem faced is that chemical analysis is not repeated in almost all countries, so it is not verified that each procedure of chemical analysis gives the same result and exact data every time.

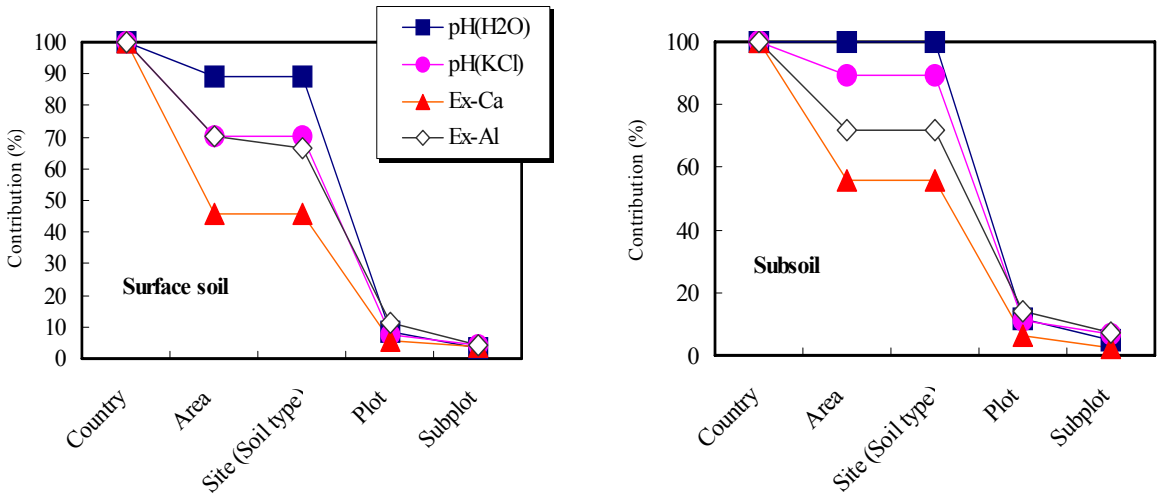

Figure 3.4.5 Cumulative contribution of the sampling levels to the variance of pH(H_2O), pH(KCl), and exchangeable Ca and Al

All monitoring processes should be properly conducted according to the official document, the *Technical Manual for Soil and Vegetation Monitoring in East Asia* (ISAGM/EANET 2000), and an adaptable system of computer software should be developed to analyze complicated monitoring data as soon as possible.

3.4.3.4 Preliminary analysis of short-term changes of soil properties

Temporal changes of soil properties are mainly monitored to evaluate the impacts of acid deposition, although the soil monitoring program is just beginning at almost all monitoring sites. Some countries have obtained data twice so far. The annual changes of surface soil pH in China, the Philippines, Republic of Korea, and Thailand are presented in Figure 3.4.6. No statistically significant differences have been found between the years.

There are both wet and dry seasons in tropical countries in East Asia. Figure 3.4.7 shows the seasonal differences of pH(H_2O), pH(KCl), and ex-Ca between April (the beginning of wet season) and December (the beginning of dry season) in the uppermost (left) and underlying (right) layers at the Vachiralongkorn Dam area, Thailand, in 2003. Some significant differences were recognized between the seasons. At Vachiralongkorn Dam-1, pH(H_2O) increased from April to December. At Vachiralongkorn Puye, pH(H_2O) increased and ex-Ca decreased from April to December. No substantial evidence or theories have been developed yet about these increases or decreases. These kinds of changes in soil properties should be carefully monitored, and data and information in this area of concern should be accumulated.

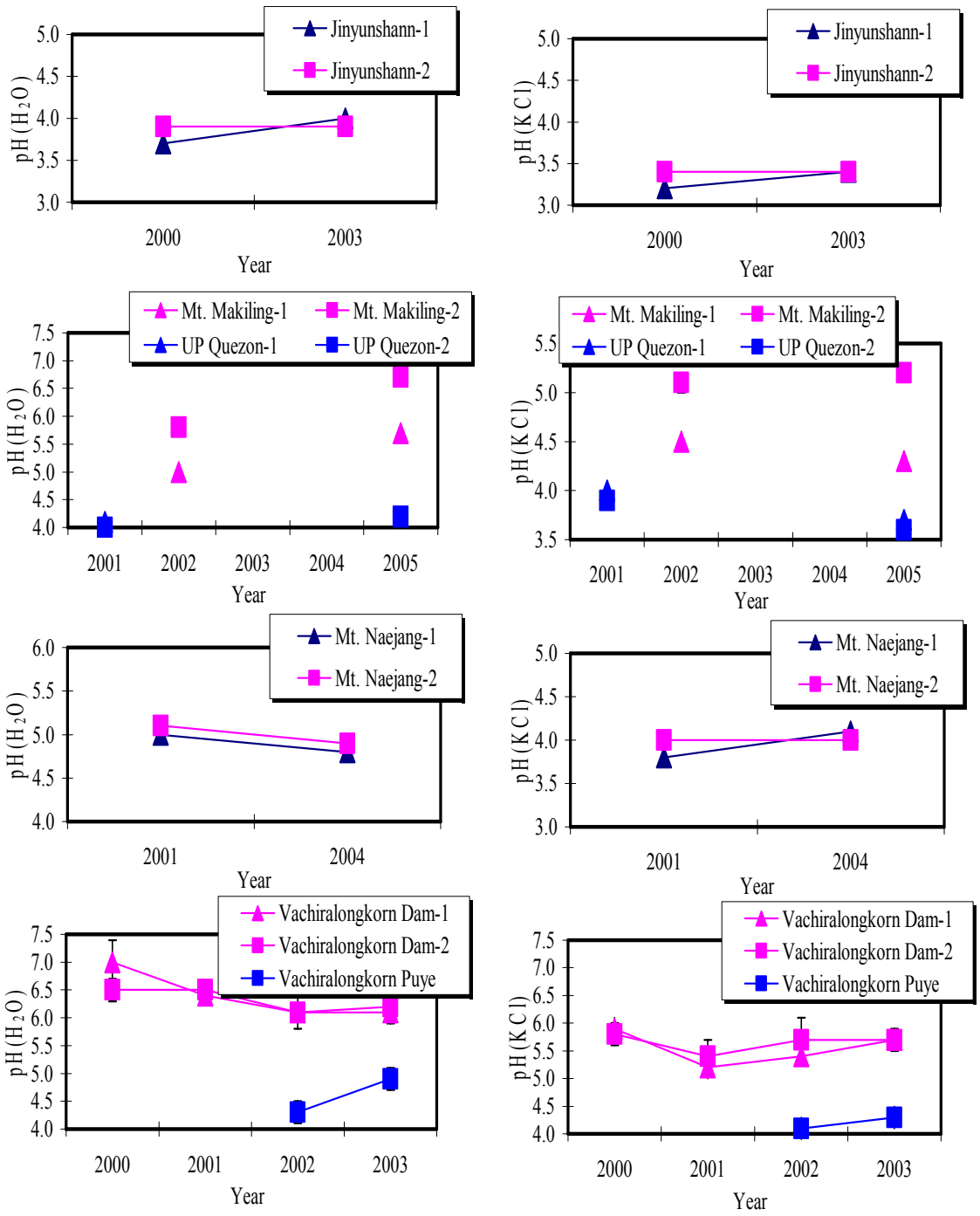

Figure 3.4.6 Changes in annual mean pH values of underlying soil at sites in China, the Philippines, Republic of Korea, and Thailand

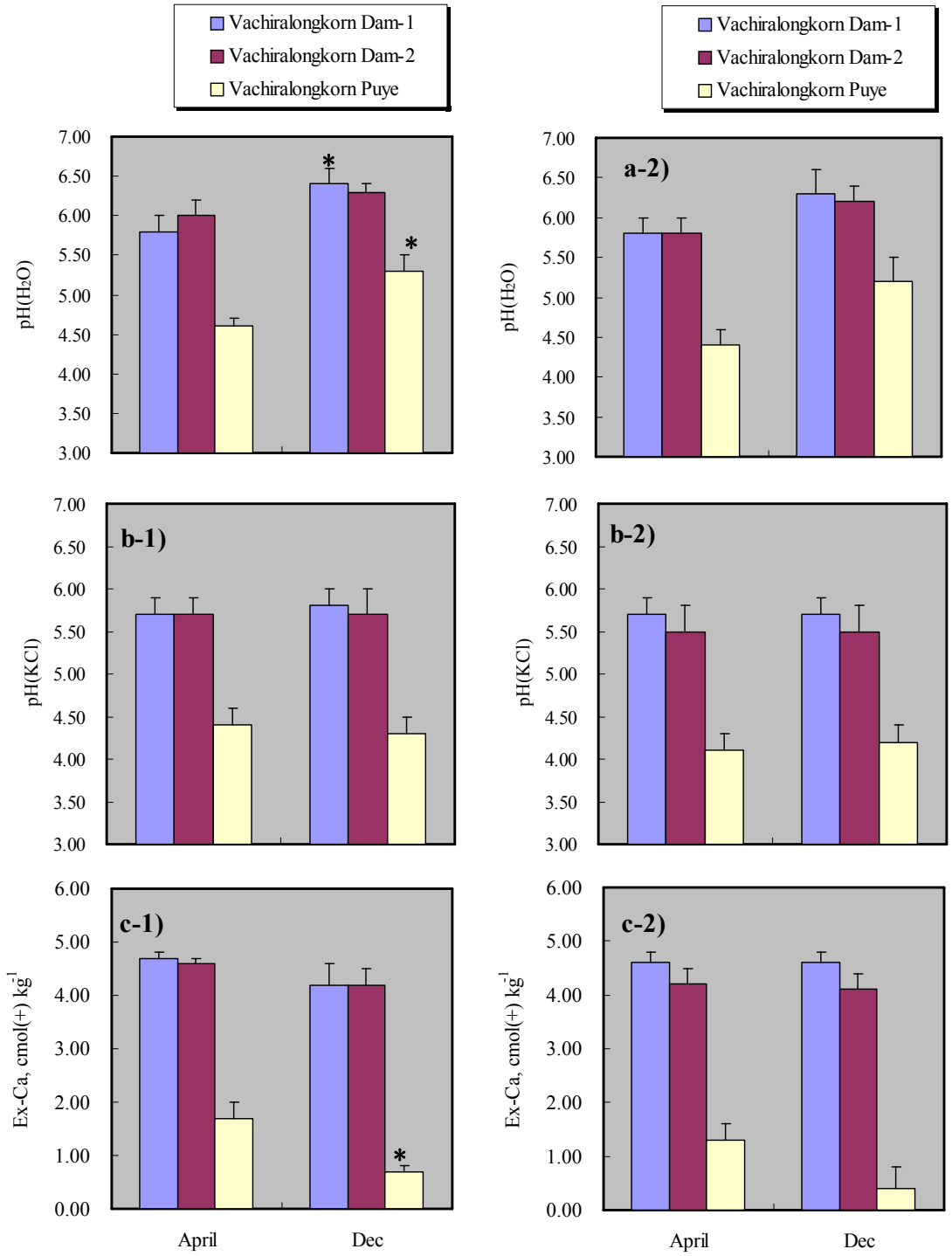

Figure 3.4.7 Seasonal differences of (a) pH(H_2O), (b) pH(KCl), and (c) exchangeable Ca between April (the beginning of wet season) and December (the beginning of dry season) in the uppermost soil layer (1) and the underlying soil layer (2) around Vachiralongkorn Dam in 2003
Notes: Error bars show standard error. Asterisks (*) represent any significant differences at the 0.05 level.

3.4.3.5 Case studies

Combined with the results of previous and ongoing studies, the following two case studies are useful for all participating countries to use to promote soil comprehensive ecological monitoring and monitoring itself. The first, conducted in Malyasia's Pasoh Forest Reserve is well known as a well-managed study area of long-term, comprehensive ecological research, including soil monitoring. The second, conducted in Japan's Ijira Lake catchment, resulted in recognition of the first significant impact of acid deposition on the pedosphere, and further investigation is underway.

a. Pasoh Forest Reserve in Malaysia

Characteristics of the study site

The Pasoh Forest Reserve (lat. 2º59′ N, long. 102º18′ E) is located in Negeri Sembilan, 140 kilometers southeast of Kuala Lumpur, Malaysia. It is covered with a primary lowland mixed dipterocarp forest comprised of various species of *Shorea spp.* and *Dipterocarpus spp.* with a leaf area index (LAI) of approximately 6.52. The continuous canopy height is about 35 meters (m), with emergent trees not exceeding 45 m. Regenerating logged-over forest and primary hill dipterocarp forest cover the surrounding area, with a gently undulating topographical feature at an altitude ranging from 75 to 150 m above sea level. The soil series is characterized by the presence of a band of laterite and a compact structure derived from shales within the area. Yoda (1978) describes the A horizon as thin (<2 centimeters [cm]), with deeper soils that are bright yellowish- and reddish-brown, light to heavy clay, and abundant lateritic boulders below the 30-cm depth and increasing with depth. Climatic conditions in the Pasoh forest are considered to be drier than any other tropical rainforests. The area is very much influenced by annual precipitation (approximately 1,600 millimeters [mm] and a temperature of 26 degrees Celsius), whereby during the dry season the precipitation is less than 100 mm per month. Fluctuations in air temperature and any deviation from the mean are appeared to be very small.

Energy exchange and surface conductance

The characteristics of energy exchange and surface conductance were studied in the Pasoh Forest Reserve from 1995 to 1999 via micro-meteorological monitoring from a 52-m-high canopy tower and walkway (Tani et al. 2003). The five-year observations, which included a low rainfall period due to the 1997/98 El-Niño, suggest that the latent heat flux estimated by the Bowen ratio method occupied a dominant portion of energy exchange, even during the driest conditions in early 1998. Forest albedo and the relationship of net radiation and solar radiation appeared to be similar to those previously obtained from other tropical rainforests. In addition, although evapotranspiration from the dry canopy tended to be smaller in the dry period than the wet period at the end of 1998, the surface conductance, estimated using the Penman Monteith Equation, was consistently controlled by the same function of solar radiation and specific humidity deficit. The study suggests that evaporation was not affected even under severe soil water stress during the driest conditions.

Soil physico-chemical properties of the Pasoh Forest Reserve (1973–2004)

Awang et al. (2002) provided an overview of the soil physico-chemical properties in the Pasoh forest over the last 30 years and their potential impact on the growth and performance of tropical rainforest, based on studies by Allbrook (1973), Yoda (1978), and Abdullah et al. (2004). It was clearly demonstrated that soil acidity did not change significantly over the last three decades. High soil acidity was maintained, with a soil pH(H_2O) between 3.57 and 4.79 and pH(KCl) between 3.5 to 4.0, and the bulk density and electrical conductivity ranged from 0.94 to 1.83 g·cm^{-3}, and 0.01–0.26 mS·cm^{-1}, respectively. While exchangeable acidity ranged between 2.35 and 5.00 cmol(+)·kg^{-1}, Al (2.29–4.89) and H (0.05–0.52) cmol(+)·kg^{-1} with exchangeable base cations were relatively poor (Yoda 1978), except for sodium, with total stock exchangeable of Mg^{2+}, K^+, Na^+, and Ca^{2+} ranging between 68 to 156, 335–487, 150–256, and 98–345 kg·ha^{-1}, and exchangeable Mg^{2+}, K^+, Na^+, and Ca^{2+} were

0.17–1.57, 0.01–3.82, 0.03–14.17, and 1.16–14.96 cmol(+)·kg^{-1}, respectively. Abdullah et al. (2004) reported that available sulfate (SO_4^{2-}) and phosphate (PO_4^{2-}) ranged from 8.21 to 11.95 mg·kg^{-1} and 0.1–4.64 mg·kg^{-1}, respectively. Essentially, no appreciable leaching of exchangeable base cations was observed during the study period. It was concluded that there were no obvious effects of acidic deposition on the forest species, particularly with respect to foliar discoloration and defoliation. This suggested that no significant impact of acidic deposition had occurred, at least over the last thirty years, in the Pasoh forest ecosystems.

In another related study on soil and belowground characteristics of the Pasoh forest, Yamashita et al. (2003) utilized the Malaysian classification system and analyzed the physico-chemical properties of various soil horizons in a range of forest environments, including gap and closed forests, with special reference to soil nitrogen (N) dynamics as a soil biological process. The findings show that total carbon (C) and N contents ranged from 0.13 to 3.37% and 0.02–0.26%, respectively. Available phosphorus (P) was in the range of 0.3–4.2 mg·kg^{-1}. The sum of the exchangeable cations (K+Na+Mg+Ca) varied between 0.11 and 1.54 cmol(+)·kg^{-1} and CEC from 2.31 to 11.56 cmol(+)·kg^{-1}. Exchangeable Al was 1.3–5.02 cmol(+)·kg^{-1}, with base saturation results between 0.4 and 29.8%, decreasing abruptly from the upper to deeper horizons.

The pH(H_2O) ranges between 3.9 and 4.8, increasing with depth, reflecting the increase in iron (Fe) and Al oxide contents and decrease in organic matter content (Yamashita and Takeda 2003). The pool sizes of NH_4^+-N and NO_3^- in 0–10-cm deep soil ranged from 1.0 to 4.7 μgN·g^{-1} and 8.3–17.0 μgN·g^{-1}, respectively, with the highest rate of N mineralization of the topsoil at 0.98 μgN·g^{-1} ·day^{-1}. Although earlier studies reported that the pool size of NH_4^+-N exceeded that of NO_3^--N, Yamashita et al. (2003) found the NO_3^--N pool appeared to exceed that of NH_4^+-N at all sites. Arguably, negatively charged NO_3^--N tended to leach from the soil profile due to lack of anion exchange capacity (AEC) on soil particles, while upward transport or accumulation of NO_3^--N was supposed to occur when the soil became drier, also highlighting the importance of electrostatic adsorption in controlling the losses of excess NO_3^--N to aquatic ecosystems in the tropics (Matson et al. 1999).

The Pasoh forest soil also accumulated a greater amount of aluminum (Al^{3+}), as shown in most cation exchange capacity (CEC) being occupied by Al, and consequently lower in P availability. The study also found that the pool of inorganic N at 0–10-cm in soil ranged from 14.8 to 23.9 μgN·g^{-1}, with net N mineralization rate in the primary forest estimated to be 100 kgN·ha^{-1}·yr^{-1}, and nitrification appeared to be most pronounced in the uppermost layer, while fine root biomass (<2 mm in diameter) constitutes a major part of the total within the top 20 cm that effectively absorbs nutrients released from decomposing organic matter with an annual litterfall of 8.6 Mg·ha^{-1}·yr^{-1} (Yamashita and Takeda 1998). A comprehensive study by Yamashita and Takeda (2003) on soil nutrient flux in relation to trenching effects under two different dipterocarp forest sites (Pasoh Forest Reserve and the Forest Research Institute Malaysia, Kepong) showed a similar finding as the physico-chemical soil characteristics in the Pasoh forest. Special attention was given to the standing stock of soil nutrients, nutrient flux, soil leachate, trenching effects, and site effects.

A recent report by Awang and Abdullah (2005) on the results of a laboratory analysis of soil samples collected from the Pasoh forest from each layer of the subplots, using standard methods recommended by the *Technical Manual for Soil and Vegetation Monitoring in East Asia* (EANET 2000), found that the bulk density of the Pasoh forest soil was highly variable. Throughout the 1-m profile, the bulk density of Plot 1 (subplot 1 and subplot 41) exhibited a similar pattern, as the soil texture represents their similar horizons. The highest bulk density was 1.81 g·cm^{-3} detected in plot 2 of subplot 1. Note that the bulk density was not significantly different among the subplots. It generally increased with depth as the soil structure changed from granular structural units often found in the surface horizon to the blocky and prismatic types found in the lower horizon. The bulk density of the 0–10-cm soil layer ranged between 0.94 and 1.29 g·cm^{-3}, indicating that the layer was well-structured, medium-textured soils containing high organic matter. This finding was in agreement with previous work by Boniao et al. (1998), where organic matter was found to be high in the topsoil and lower in the subsoil.

Electrical conductivity ranged from 0.01 to 0.26 $mS \cdot cm^{-1}$, with the highest reading recorded in the topsoil of the 0–10-cm layer for every subplot, and did not differ significantly among the subplots. It did, however, vary significantly with depth. The pH(H_2O) and pH(KCl) ranged between 3.57 and 4.79 and 3.5–4.0, respectively. Again, pH(H_2O) was not significantly different between the subplots, but it varied with depth. The pH(KCl) was significantly different among the subplots, however, as well as significantly varied with depth. The mean lowest pH(H_2O) and pH(KCl) values were 4.30±0.37 at plot 2 (subplot 1) and 3.8±0.08 at plot 1 (subplot 1), respectively. Such a situation was commonly found in areas of moderate to low acid deposition, and it appeared to be similar to earlier findings by Allbrook (1973), Yoda (1978), and Yamashita et al. (2003). Similarly, exchangeable acidity of the Pasoh forest soil ranged from 2.35 to 5.00 $cmol(+) \cdot kg^{-1}$, and was found to be significantly different among the subplots and varied with depth.

The study also found that exchangeable Mg^{2+}, K^+, Na^+, and Ca^{2+} ranged from (no data) to 1.56, 0.001–3.82, 0.03–14.17, and 1.16–14.96 $cmol(+) \cdot kg^{-1}$, respectively. Exchangeable Mg^{2+} and K^+ were not significantly different between the subplots and also did not vary with depth, but the exchangeable rates of Mg^{2+}, K^+, Na^{2+}, and Ca^{2+} were relatively higher compared to the previous findings by Allbrook (1973). This may be attributed to a high weathering rate (Hovmand and Billie-Hanse, 1999) that causes high mineralization processes by microbial decomposers, as suggested by Markewitz et al., (1998), to form mobile Mg^{2+}, K^+, Na^+, and Ca^{2+} (Brahy and Delvaux, 2001). In addition, base cations in soil solutions can be derived from a variety of sources and processes, including cation exchange, decomposition of organic matter, atmospheric inputs, and mineral weathering (April, Newton, 1992).

The ECEC of the Pasoh forest soil ranged from 5.40 to 31.22 $cmol(+) \cdot kg^{-1}$. Based on soil profile analysis, it was observed that the ECEC values of plot 2 (subplot 41) and plot 3 (subplot 1) were fairly uniform. The ECEC was significantly different between the subplots, but it was not significantly varied with depth. The highest mean value of ECEC was 24.56±2.70 $cmol(+) \cdot kg^{-1}$ (subplot 1). As suggested by Boniao et al. (1998), the ECEC of the topsoil was almost entirely attributable to organic matter similar to an earlier report by Baert and Van Rasnt (1998) that ECEC is also pH dependent.

The base saturation of the Pasoh forest soil ranged between 42.06 and 92.95% with a fairly uniform distribution throughout the 1-m profile of all subplots. The degree of dissociation or acid base status was consistent with an increase in depth and was significantly different between the subplots. Significant differences between the subplots may be attributed to different levels of organic acid production due to the decomposition of the forest floor, as suggested by Yamashita and Takeda (2003). The highest mean value of base saturation was 86.57±10.04% detected in plot 1 (subplot 41). Throughout the 1-m profile the mean value of base saturation was 82.42±5.17% at the 10–20-cm layer.

Available SO_4^{2-} and PO_4^{2-} ranged from 8.21 to 11.95 $mg \cdot kg^{-1}$ and 0.11–4.46 $mg \cdot kg^{-1}$, respectively. The available SO_4^{2-} was significantly different between the subplots. Throughout the 1-m soil profile, the highest mean value of available SO_4^{2-} was 10.84±0.68 $mg \cdot kg^{-1}$. The presence of a large amount of SO_4^{2-} might explain the high availability of soluble Al in the soil samples. In the case of available PO_4^{2-}, the highest mean value was 1.00±1.40 $mg \cdot kg^{-1}$ found in topsoil, and was not significantly different among the subplots, but it varied significantly with depth. Based on the 1-m soil profile, the highest value of available PO_4^{2-} was 2.65±1.85 $mg \cdot kg^{-1}$, presumably due to the organic matter retaining the available PO_4^{2-}, as suggested by other researchers.

In conclusion, this study clearly demonstrated that the findings were closely similar to those reported earlier by Allbrook (1973), Yoda (1978), and Yamashita et al. (2003). It suggested no clear indication that the Pasoh forest had experienced significant changes in soil properties, at least over the last 30 years. Essentially, there was no significant detectable impact of acidic deposition on the Pasoh Forest Reserve ecosystems. More information is needed, however, especially from detailed studies of highly sensitive forest species in response to changes of acidity through either dry or wet depositions. As suggested earlier, although there were no clear symptoms of foliar defoliation or discoloration observed on the forest species during the study period, special reference should be made on

physiological responses to gaseous pollutants and particulates, especially during a "haze episode," since the acidity of the soil has maintained a "naturally" high level over the years.

b. The catchment area of Lake Ijira in Japan

Figure 3.4.8 shows the trend of water quality in the Ijira River, which flows into Lake Ijira. The white dots in subfigures (*c*) and (*d*) indicate the water quality of the river, and the gray dots represent rainwater. Dotted lines are drawn at the concentration of sulfuric ion that balances the input of sulfuric ion by rainwater with the output by average outflow from 1988 to 2003.

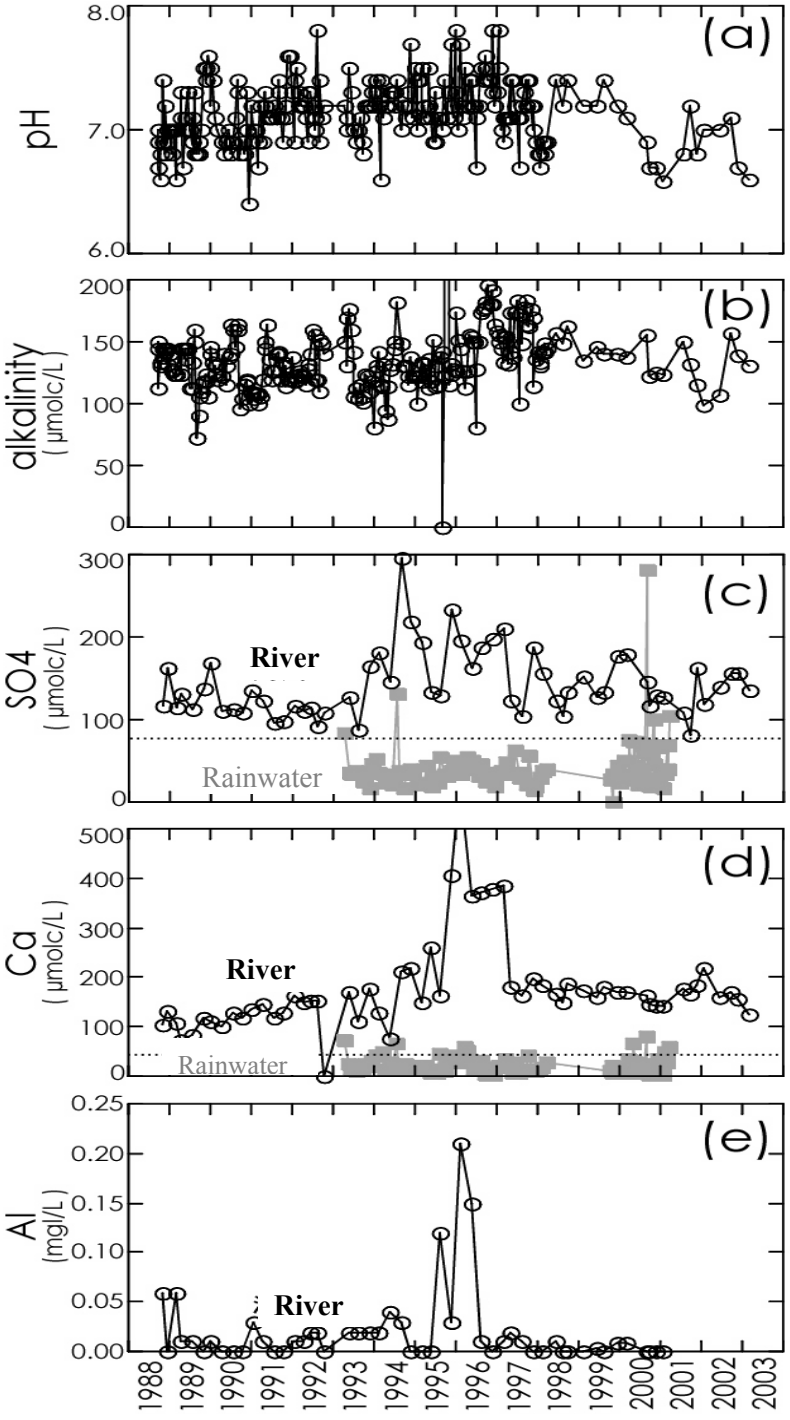

Figure 3.4.8. Change of water quality in the Ijira River flowing into Lake Ijira (1998–2003)

The concentration was calculated using the ratio of the outflow to inflow concentrations of chloride ions, which are practically not consumed in the ecosystem. Ion concentrations in the river above the line mean that the output (outflow) exceeds the input (deposition), while concentrations below the line indicate that output is below input.

The output of SO_4^{2-} has been slightly exceeding input since 1988, when monitoring began. This indicates that the catchment of Lake Ijira was always at the state of saturation in terms of SO_4^{2-}, and for four years, from 1994 to 1997, a sudden outflow of these ions took place.

Along with this, concentrations of calcium and aluminum rose, and the basin became acidified. Moreover, since 1997, when the outflow of SO_4^{2-} started to decline, the pH and alkalinity of the river started to decline. This kind of acidification of the river can be attributed to the supply of protons generated by the release of SO_4^{2-} in the soil upstream.

Although there is no immediate evidence showing that acid deposition caused the change in water quality, it could certainly explain this phenomenon. Specifically, without both conditions of a continuous supply of SO_4^{2-} and saturation with SO_4^{2-} in the catchment, the sudden outflow of SO_4^{2-} observed from 1994 could not have happened. The most reasonable assumption is that such continuous supplies of SO_4^{2-} came from acid rain, given that no natural source (e.g., volcanoes) or agricultural source (e.g., fertilizer) was present. Further investigation based on this hypothesis should continue.

In this connection, depositions of SO_4^{2-} and H^+ onto this catchment were more than in any other monitoring area, and the precipitation pH was the lowest among them. The pH level of the surface water at the center of the lake has been trending downward since 1996. The concentration of nitrates was increasing year-by-year in lake water as well as in the river flowing into the lake.

3.4.3.6 Possible impacts on soil and future directions of soil monitoring

The major effect of acid deposition in the soil is the change in soil chemical properties, especially soil pH. In soils with extreme to very strong acidity, one or more nutritional problems may exist that would limit plant growth. The problems vary from toxic quantities of exchangeable Al, manganese (Mn), and H to associated low levels of bases, nitrogen (N), phosphorus (P), sulfur (S), and some other micronutrients (Samonte and Ocampo, 1989). Acidification of soil by acid deposition also causes adsorption of bases like calcium and magnesium. As a result, nutritive salts become scarce and the activity of soil biota declines (Arther and Wagner, 1983; Dighton and Skeffington, 1987). These acidity related problems tend to worsen further under a hot and humid climate when soils under continuous cropping systems are not limed. Soil degradation can occur whether or not cropped soils are fertilized.

Other consequences that may be caused by low soil pH are: (***a***) Al toxicity, probably the most important growth-limiting factor for plants in many strongly acidic soils (pH less than 5.0, or even pH 5.5 in kaolinitic soils); H ion toxicity, which may directly affect plant growth (only at a pH less than 4.2); (***b***) organisms responsible for decaying organic matter and mineralizing N, P, and S may be low in number and activity; (***c***) symbiotic N fixation by legumes is greatly reduced (the symbiotic relationship requires a more narrow pH range for optimum growth than plants not requiring N fixation); the symbiotic bacteria for soybeans function best in a 6.0–6.2 pH range; alfalfa bacteria function best in a 6.8–7.0 pH range; (***d***) highly acidic clay soils are less well aggregated (this causes low permeability and aeration, an indirect effect because limed soils produce more crop residue, which provides better soil structure); and (***e***) the availability of nutrients such as P and molybdenum (Mo) is reduced, while the tendency for potassium (K) to leach is increased.

a. Other effects on soils and their consequences

The essential role of soil in the water and element cycle of forest ecosystems is that it acts as storage for water and compensates for irregular deposition. The element transformations take place in the soil,

and, similar to water, the soil serves in the spatial and temporal decoupling in the organic cycle of nutrients (Ulrich, 1994). The chemical, biological, and physical conditions in soils strongly influence each other. A decrease in pH (chemistry) impairs the conditions for earthworms (biology), leading to reduced bioturbation, which results in a decrease of the gas volume due to less macropores (physics).

Air pollution has been shown to have an indirect impact via acidifying and eutrophying effects on the forest ecosystem (e.g., depletion of base cations from the soil, changed soil solution chemistry, imbalance in available nutrients caused by N deposition). Since there are differences in sensitivity between areas with different soil types, between ecosystem types, between climatic zones, etc., critical loads have been defined for acidification by S and N deposition, as well as for eutrophication by N deposition. Eutrophication is the process by which waters (lakes, rivers, etc.) become excessively enriched with nutritive salts such as N and P. It is not the deposition load in itself that determines the risk of effect but the load exceeding the critical value (UN-ECE, 1996).

Awang (2005) noted, based on the data from the countries participating in EANET (Japan, China, Thailand, and South Korea), that the estimated S and NO_3 loadings from the atmosphere could be about four or five times higher than the values recommended for protection of sensitive forest species, streams, and other related aquatic ecosystems. These high emissions and the changes in pH values indicate significant ecological impact. Awang also added that reduction in base cations inputs from the atmospheric environment could lead to higher sensitivity of forest species and aquatic life to atmospheric inputs of acidic depositions. In the study conducted in the Pasoh Forest Reserve in Malaysia, however, he concluded that there were no significant impacts of acidic deposition at this study site, but more information is needed on the response of highly sensitive forest species to changes in acidity.

b. Effects on nutrient balance

It is widely known that N is an important nutrient and is the most limiting factor in the growth of forests. Sustained increase in the growth of forests occurs only if increased N deposition is balanced by the supply of other nutrients such as Ca, Mg, K, P, and other micronutrients. Wet deposition containing NH_4^+ induces leaching of K^+ and other cations (Van der Eerden et al., 1995). Bauer et al. (1997) observed significant changes in nutrient contents and dry weights of spruce needles along a European transect. For Norway spruce, measurement of nutrient content and dry weight indicate that acquired N was immediately used for growth, indicating a high demand for nutrients at sites with high loads of airborne N. In a recent study covering ten years in Sweden, it could be confirmed that ongoing eutrophication led to nutrient imbalances in Norway spruce as well as in Scots pine stands (Thelin et al. 1998); notably, the K/N ratio decreased considerably between 1985 and 1994. If soil weathering and deposition of base cations cannot balance the nutritional demands, then symptoms of nutrient deficiency and therefore forest decline may be expected.

Increase in the deposition amount of N compounds has the effect of improving the nutritional condition of soil, but excessive deposition of N not only acidifies soil, it also saturates soil water with N. It is supposed that such a condition causes depression of vitality in plants, and by inducing stress, makes them vulnerable to disease (Schulze, 1989).

EANET soil monitoring has basically just begun, so little evidence of acid deposition causing changes in soils has yet been observed. Not all the processes reviewed above are being monitored yet, but monitoring of some of the possible impacts on soil described above should be considered. If some signs of the impact of acid deposition are recognized, then additional parameters relating to the evidence should be carefully investigated and integrated into future monitoring. It should be noted that the impacts of acid deposition on soil could be evaluated precisely as parts of the total process of the biogeochemical cycle and from long-term, comprehensive points of view, including atmospheric, ecological, and aquatic processes.

3.4.4 Vegetation features

3.4.4.1 General description of forest plots in participating countries

The East Asian region encompasses an extensive area that stretches from the northern latitudes to the southern islands of Indonesia, and it consists of various climatic zones ranging from tropical to sub-arctic. Consequently, it includes various biome types of vegetation, depending on the varied climates (Whittaker 1975); i.e. tropical rainforest (zones 1–3), tropical seasonal forest (zones 3 and 4), temperate evergreen forest and temperate deciduous forest (zones 5 and 6), and taiga (boreal) forests of sub-arctic and sub-alpine needle-leaved trees (zones 6 and 7). Thus, while this categorization is rough and simplified, there are at least five formation types of forest that can be monitored in the East Asian region. Figure 3.4.9 shows the location of existing EANET forest monitoring sites, surveyed from 2000 to 2004, according to zone.

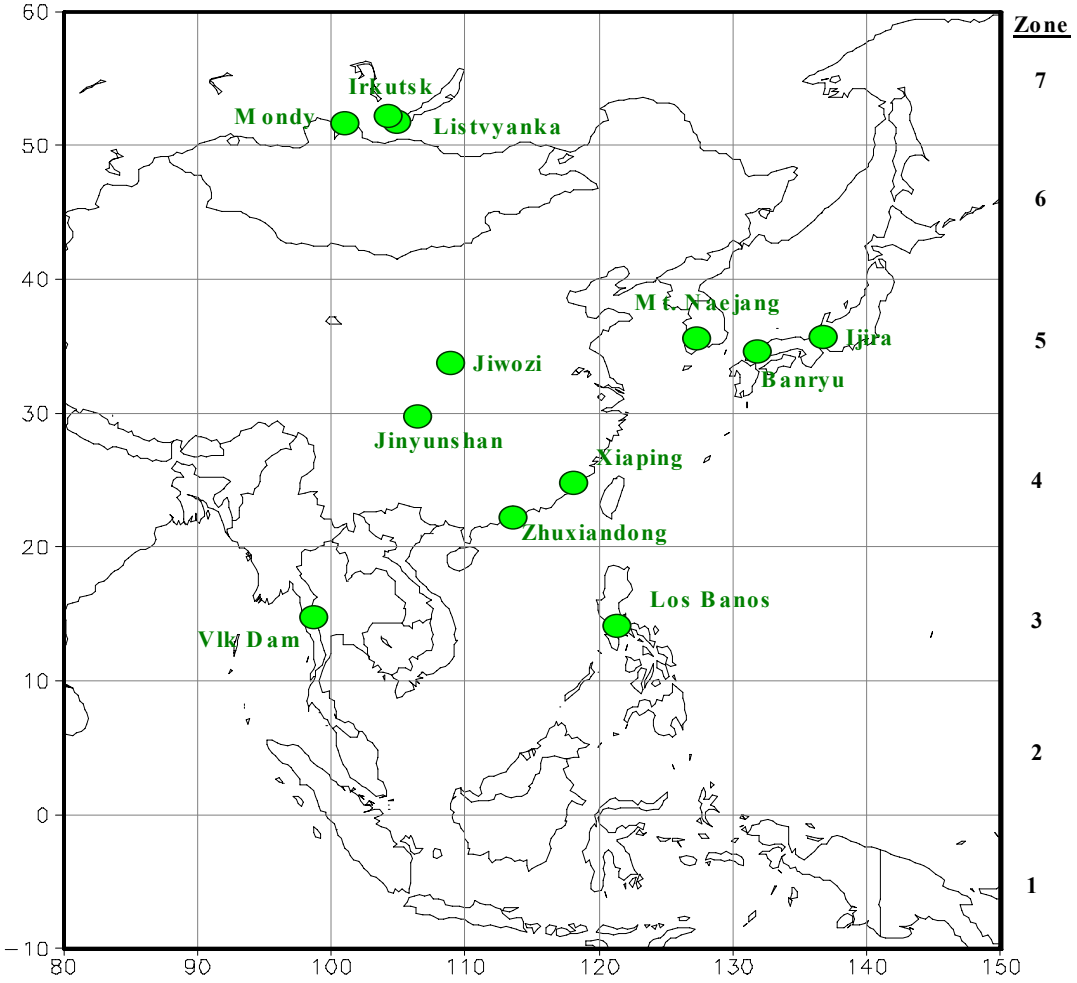

Figure 3.4.9 Map of the East Asian region showing the location of EANET forest monitoring sites
Note: Vlk Dam = Vachiralongkorn Dam, Thailand.

Presently, there are monitoring sites in four out of seven zones in the region. There are plans to establish survey sites in zones 1 and 2 in Indonesia and Malaysia, although forest surveys have not yet been carried out. It should be noted, however, that in Malaysia considerable basic information on tropical rainforests has been accumulated through many international joint studies in the Pasoh Forest Reserve, and studies have been done on exposure testing and trend analysis of acid deposition. Also,

an area in Hoa Binh, Viet Nam, was surveyed, but only once in 1999 during EANET preparatory phase. Moreover, one area in Mongolia has not yet been surveyed for zone 6. The map does not include these sites. Therefore, there is no data available yet on typical tropical rainforest in zones 1 and 2. Data on temperate grassland and taiga in zone 6 are also not available. Hence, the results of the representative monitoring forests are limited to the following six countries: China, Japan, the Philippines, Republic of Korea, Russia, and Thailand (Table 3.4.6). One to four areas were selected in the respective countries, and then one to five forest plots were established in each area. A total of 25 forest plots were surveyed from 2000 to 2004 in the countries participating in EANET.

Monitoring plots were mostly established in man-made or secondary forests, while information on four plots was not reported. Tree species in these plots were highly varied. Coniferous tree species, such as pine (*Pinus sp*.), cypress (*Fokienia hodginsii* and *Chamaecyparis obtusa*), larch (*Larix sibirica*), and Japanese cedar (*Cryptomeria japonica*), are found in China, Japan, Korea, and Russia, from the temperate to sub-arctic zones. Most of these coniferous trees were planted mostly for timber, while two natural coniferous forest plots were monitored in Russia. Broad-leaf evergreen trees, such as chinquapins (*Castanopsis sp.*), are found in China and Japan in the temperate zone. Monitored species in tropical countries, such as the Philippines and Thailand, were quite different from those in the temperate and sub-arctic zones. Typical tropical species, such as those from the Dipterocarpaceae family (*Diperocarpus turbinatus*) and Leguminisae (*Xylia xylocarpa*), were monitored in Thailand. Burmese rosewood (*Pterocarpus indicus*) and a specific species, *Diplodiscus paniculatus,* which were monitored in the Philippines, are listed in the International Union for the Conservation of Nature and Natural Resources (IUCN) Red List of Threatened Species (World Conservation Monitoring Center 1998), meaning that such species should be monitored for conservation.

Forest surveys were carried out once or twice from 2000 to 2004 in these plots, since the monitoring interval is set at three to five years. Surveys of tree decline were done annually from 2003 in Japan. In the Philippines, surveys were carried out in February 2005 due to the postponement of surveys scheduled for autumn 2004. These data were also included in the *Data Report 2004* and are reported here. Thailand began conducting surveys every three years starting in 2003.

3.4.4.2 Forest monitoring

General forest indices, such as diameter at breast height (DBH), height, basal area, and number of species in the understory, are summarized for the respective forest plots in Table 3.4.7. The values were calculated based on the largest survey plot (0.1 ha, DBH >18 cm). The mean values of the latest surveys in the respective plots are also shown in Figure 3.4.10 for visual comparison. These indices show clear differences among plots and climatic zones.

Forest growth indices were highly varied; the mean value of DBH was from 19 centimeters (cm) at XPZ-02 (China) to 56 cm at the Vachiralongkorn Dam (Thailand); the mean value of height was from 10 meters (m) at Zhuxiandong No.1 (China) to 36 m at the Vachiralongkorn Dam; basal area was from 0.3 m^2 ha^{-1} at Mondy to 61.5 m^2 ha^{-1} at Mt. Naejang; and the number of species in the understory was from three at XPZ-01 and XPZ-02 to 46 at Mondy.

Large trees with a DBH larger than 100 cm were recorded, especially in tropical forests such as at Mt. Makiling (Philippines) and the Vachiralongkorn Dam. Actually, mean DBH was relatively larger in two plots in Thailand and at Mt. Makiling than other plots, as shown in Figure 3.4.10. Trees taller than 35 m were also recorded in these tropical forests, including Vachiralongkorn Puye (Thailand), but these indices in UP Quezon-Land Grant (Philippines) were relative small. This secondary forest might still be immature because the forests were completely clear-cut once in the 1970s.

The basal area was also relatively larger at Mt. Makiling and two plots in Thailand than other plots (Table 3.4.7, see at the end of 3.4.4), but the largest value was recorded at Mt. Naejang, and Iwami-rinku FP (Japan) was the third largest. This reflects the number of large trees (DBH >18 cm) in

the plots. The number of trees with a DBH larger than 18 cm could be 1,067 stands ha^{-1} at Mt. Naejang (96 stands were recorded in the 0.09-ha plot) and 570 stands ha^{-1} at Iwami-rinku FP, while the total mean value was 234 stands ha^{-1}. The number of species in the understory was highly varied and did not show any clear trend.

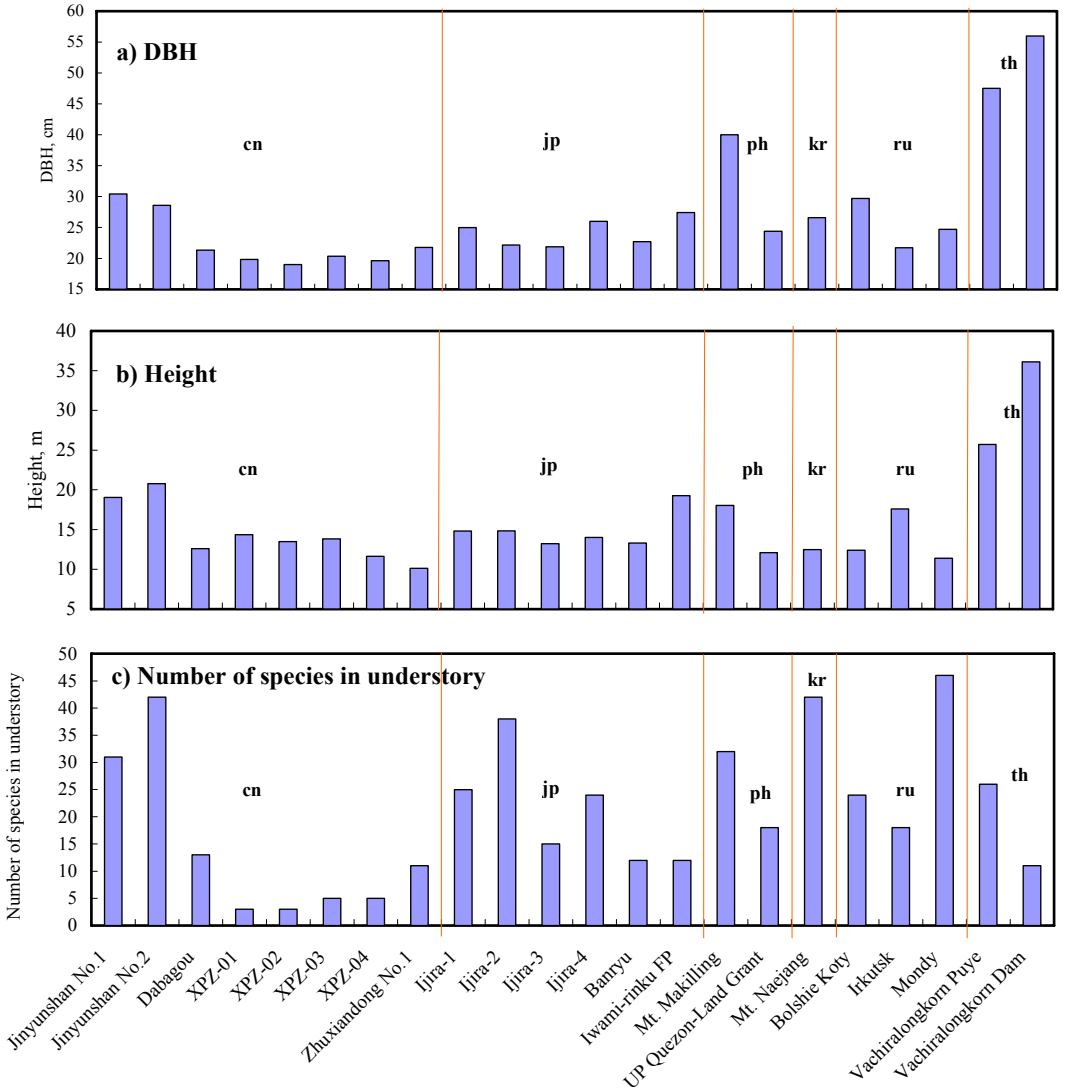

Figure 3.4.10. General description of the respective forest plots
Notes: Indices were calculated based on the largest survey plot (0.1 ha; trees, DBH >18 cm). Data of the latest surveys were used. Zhuxiandong No.2 and No.3 do not have trees with a DBH >18cm.

During the period from 2000 to 2004, the surveys were done twice at Mt. Makiling, UP Quezon Land-Grant, Mt. Naejang, and Vachiralongkorn Puye, while the actual survey was carried out in February 2005 in plots in the Philippines, as mentioned above. It seems that trees grew for three to five years in the former three plots, although mean DBH and height at Vachiralongkorn Puye decreased after one year (Table 3.4.7), because some big trees were killed due to lightning strikes. Relatively small trees might also be counted for calculation of these indices at Vachiralongkorn Puye, because the number of trees (DBH >18 cm) increased from 100 to 120. Thus, the growth rate of individual trees should be calculated when the forest increment is evaluated. The serial numbers of individual trees in these plots were sometimes a little confusing, however, and comparison of accurate increment could, unfortunately, not be shown here. The serial numbers of individual trees should be checked carefully for accurate evaluation of tree growth. The number of species in the understory shows the emergence

of new species in two plots in the Philippines and at Mt. Naejang, while the species composition did not change at Vachiralongkorn Puye. No specific change in species composition in understory vegetation was found in this period.

The number of trees at Mt. Makiling and UP Quezon Land-Grant decreased in the second survey years because of dead trees. In fact, the number of trees recorded, including trees smaller than 18 cm in DBH, also decreased; 129 trees were recorded in the plot at Mt. Makiling in 2000, and nine of those were dead in February 2005 due to strong typhoon winds in December 2004; 92 trees were recorded in the plot at the UP Quezon Land-Grant, and 13 of them were dead. The East Asian region is subject to large meteorological events such as typhoons, especially in the Philippines, Japan, coastal areas of China, and Korea. The effects of such events should be carefully recorded for precise evaluation of anthropogenic effects such as acid deposition.

Several types of forests were included as monitoring plots, as mentioned above. Trees in man-made forests were planted and may have been affected by some management activities. Secondary forests here naturally regenerated after forestry activities. Plots in man-made forests and natural/secondary forests are compared in Figure 3.4.11. Note that the mean DBH was significantly larger in natural/secondary forests than in man-made forests. Other indices were also relatively larger in natural/secondary forests than in man-made forests, but differences were not significant at the 5% level. Variations of the indices on tree size in the man-made forest plots were relatively small, probably due to forest management activities, even if species were different. The indices in natural/secondary forests might be more diverse.

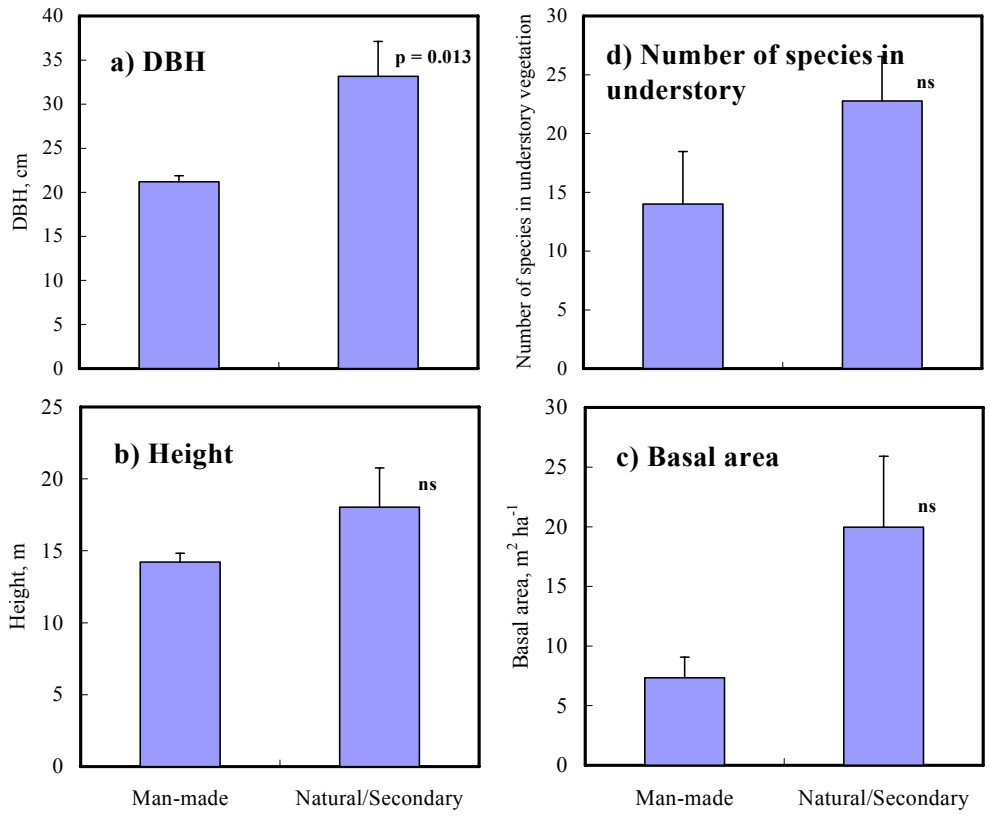

Figure 3.4.11 Comparison of general forest indices between man-made forests and natural/secondary forests

Notes: Bar plots show the mean value among forest plots and the standard error. The numbers of plots were eight and nine for man-made forests and natural/secondary forests, respectively. The letters "ns" mean no significant difference, while the *p* value indicates significant difference by analysis of variance.

3.4.4.3 Present state of tree decline

Surveys of tree decline were carried out in 22 plots from 2001 to 2005. Twenty trees were basically selected for observation, but smaller numbers of trees were also monitored in several plots depending on the respective situations. Decline levels for several observation items, such as defoliation, discoloration, and dieback of stem, were categorized into five classes, from Level 0 (healthy) to Level 4 (dead). The present state of tree decline in the monitoring plots is summarized in Table 3.4.8. Results from 2000 were omitted here, because the surveys used a slightly different method than the one prescribed in the *Technical Manual for Soil and Vegetation Monitoring in East Asia* (hereafter, *Technical Manual*).

Several symptoms of decline were observed in sixteen plots of four countries, but decline levels were mostly in the Level 1 or Level 2 classes. According to reports by National Centers, the estimated causes of the decline symptoms were mostly natural environmental factors (strong winds and topographical or soil conditions) and effects of biotic factors (disease, including fungal infection, insect attack, and suppression of other trees). The number of monitored trees decreased year by year, especially in Japan, due to the effects of a severe pine-wilting disease and management responses. Decline symptoms were reported for some trees at XPZ-01, -02, -03, and -04, and Mt. Makiling, but no cause was stated. The effects of the typhoon should be considered, however, in the case of Mt. Makiling, as mentioned above. No clear phenomenon of acid deposition impacts has been reported yet, but all trees showed some decline symptoms in Irkutsk (Russia), and it was surmised in the national report that the effects of local air pollution had an influence on the tree decline. (Detailed information on the phenomena is described in Part II, National Assessment, in this periodic report.)

3.4.4.4 Discussions

As mentioned above, the East Asian region includes various climatic zones and various formation types, from tropical rainforest to taiga, which could be the forests to be targeted for monitoring under the EANET monitoring program. The present monitoring plots already include most formation types of forests, but surveys in some additional plots should be promoted, especially in tropical rainforests.

General forest indices, such as DBH, height, basal area, and number of understory species, showed clear differences among plots and climatic zones, and these indices were highly varied among plots. Forest data in the East Asian region should be evaluated while taking the diversity of forest types into account. As a technical issue to be improved upon, it was suggested that the serial numbers of individual trees should be checked carefully for accurate evaluation of tree growth. No specific change in the species composition of understory vegetation was found in this period.

No clear phenomenon of acid deposition impacts has been reported yet. It could be suggested that East Asian countries are strongly affected by seasonal meteorological events, including typhoons, as shown at the plots in the Philippines. Recently, severe effects of typhoons were also reported in Japanese national monitoring. Sometimes, such natural events confused the surveyors, highlighting the importance of distinguishing such natural meteorological events for precise evaluation of anthropogenic impacts such as acid deposition. Frequent observation of tree decline may be helpful for this purpose, while observations were carried out on a three- to five-year interval in accordance with the current *Technical Manual*.

3.4.4.5 Possible impacts on forests

Forest ecosystems are exposed to various destabilizing and stabilizing effects. *Destabilizing effects* include climatic extremes, excess input of nitrogen and acids, high ozone concentration, and pests. *Stabilizing effects* include cool-wet weather during the vegetation period, moderate nitrogen input, decrease of acid input, and liming. Stabilizing effects are able to compensate for destabilizing effects, destabilizing effects are able to overlay stabilizing effects, and destabilizing effects are able to reinforce themselves (Augustin and Andreae, 1998). Ohkita et al. (1996) and Murano (1993) also cited

various factors of concern that can cause forest decline, such as natural death and damage caused by blight, insects, animals, weather, and air pollution (including acid rain).

The forest decline process originates from multiple stresses acting sequentially, concurrently, synergistically, or cumulatively on a forest stand, and results in progressive loss of tree vigor. Mortality is common, although affected trees may recover subsequent to the removal of the stresses.

One common feature of stress impact, however, is the uneconomic use of nutrients, energy, and water, leading to alterations of storage patterns in trees, soils, and at the ecosystem level. In trees, stress-activated repair and adaptation mechanisms lead to altered allocation of nutrients and energy. Branching anomalies and loss of needle and leaf biomass are the consequences of changed resource partitioning at the tree level. Impacts on the element budgets are detectable in nutrient ratios in the assimilation organs of plants; in soils, a net loss of elements is often detectable; and at the ecosystem level, deviations from a steady state can be seen in time-series of matter balances.

The majority of atmospheric matter input reaches the forest soil via precipitation or litter fall, or is washed off by rain. Some gaseous pollutants (ozone, sulfur dioxide, ammonia) can be taken up directly by the leaves. The most important input pathways of nitrogen are wet deposition, dry deposition of ammonia and nitric acid (up to 90% of total gas deposition, depending on the site), and particulate deposition of nitrate and ammonium. Rihm (1994) noted that emissions of nitrogen components from the soil could contribute significantly to the nitrogen budget (20% at mountainous sites in Switzerland). According to a study in Germany in a forested site at Solling, at an altitude of 500 meters above sea level (Gravenhorst et al., 1992), the total sulfate deposition in 1990 was stated to consist of 30% wet deposition, 15% cloudwater deposition, and 55% dry deposition (equally distributed between gaseous and particulate deposition).

a. Effects on plants

In general, forest decline is associated with visual symptoms of thinning crowns, changes in crown structure, foliage discoloration, and excessive mortality (Oren 1989). Premature needle/leaf shedding and chlorosis are the most commonly used qualitative indicators of tree damage and its severity (UN-ECE 1998).

During the 1970s, forest condition deteriorated remarkably in different parts of Europe (Muller-Edzards et al., 1997). Trees lost their foliage or showed discoloration of needles and leaves, and the vitality of forest trees decreased. Forest stands collapsed, especially on low mountain ranges. Trees of different age classes showed the same signs of reduced vitality, irrespective of species and geographical distribution.

The results of several studies at German and Austrian spruce tree sites proved that the symptom of "montane yellowing" is a consequence of secondary reactions rather than an initial state of decline (Wild et al., 1993; Tausz et al., 1996).

Wet and dry deposition also results in the supposed melting of the wax layer on the surface of leaves, and then desorption of various ions takes place (Ohkita et al., 1996; Murano, 1993). The leaf surface is covered by a thin, waxy cuticle, which has many essential protective and regulatory effects. Its integrity is vital to maintenance of a healthy tree. The cuticle has chemical (Percy et al. 1994) and physical (Huttunen 1994) characteristics, which can be deleteriously altered by dry and wet acid deposition. Deterioration of epicuticular wax and unhealthy stomata may cause severe water stress on trees, accelerating water loss from the leaf surface (Sase et al. 1998; Takamatsu et al. 2001).

Air pollution composed of gaseous pollutants like ozone (O_3), sulfur dioxide (SO_2) nitrogen dioxide (NO_2), nitric acid vapor (HNO_3), and fluorides have been shown to damage vegetation, including forest trees, directly on leaf surfaces and via stomata and cuticular uptake. High concentration levels of reactive trace gases like SO_2, O_3, or NO_2 can directly damage leaves of trees if critical levels are

exceeded (UN-ECE, 1996). Results showed that 30–50% of the variation in defoliation could be explained by the variation in stand age, soil type, precipitation, N and S deposition, and foliar chemistry (De Vries et al., 2002). The effect of total dose of ozone (total = product of concentration and exposure duration) on the amount of leaf damage rises progressively with rising ozone concentration. Single events with peak concentrations are therefore particularly damaging, but even where the ozone exposure is long lasting, the damage may increase more with increasing concentration than with duration. At low ozone concentrations, the contrary trend may appear (UN-ECE, 1988).

b. Interaction effects

Wet deposition increases foliar leaching, resulting in the reduction of foliar nutrient concentration and growth, unless compensated through increased uptake or internal redistribution (Hogan 1992). Chronic exposure of conifers to ambient, sub-acute SO_2 concentrations leads to accumulation of sulfate in the cell vacuole. The deposited sulfate has to be neutralized with base cations (Ca^{2+}, K^+, Mg^{2+}) to maintain pH in the vacuole. These sulfate-base cation-compounds in the vacuole are non-toxic and mostly immobilized. The additional supply of cations has to be covered by the xylem-phloem cycle of roots and crown. Therefore, at the cellular level, SO_2 uptake results in inactivation of cations and symptoms of mineral deficiency could be obvious in the long term. This effect is most evident at forest sites with a poor supply of magnesium and potassium.

Chronic exposure to SO_2 enhances the sub-acute impact of airborne pollutants. By means of short-term exposure studies, Houston and Stairs (1972) found already in 1970 that the exposure of *Pinus strobes* to a combination of SO_2 and O_3 results in a synergistic reaction concerning the damage of needles. The combinations of SO_2, O_3, and simulated acid rain led to alterations of growth in green and white ash (Chappelka et al. 1988); i.e., alterations in assimilate partitioning, leading to shifts in leaf weight ratio (LWR) were observed. Accelerated senescence is characteristic for ozone as well as for SO_2 treatment. The combination of both pollutants results in an enhancement of the individual effects. Synergistic effects have been found in nearly all studies concerning SO_2 and NO_2 (Wellburn, 1990).

An increased level of nitrogen (N) assimilation, not balanced by essential amounts of minerals, frequently leads to a decreased resistance to pests (insects, fungi). Several field studies indicate a connection of fungal infection to N content and increased N/K ratio of leaves or needles, respectively (compilation by Fangmeier et al. 1994). Forest stands with low potassium supply concurrent with high N inputs are particularly at risk of fungal infection. Frequently, the weakening of trees induced by air pollutants is the precursor to a pest attack, exemplified by the infection of *Pinus sylvestris* with *Sphaeropsis sapinea* near sources of NH_3 in the Netherlands (De Temmermann et al. 1987; Bobbink et al. 1996).

Studies reveal that loss of potassium and magnesium increases insect damage to foliage, a finding that is noteworthy, given that trees affected by pollutants are predisposed to secondary attack by insects and diseases (Smith 1991). For example, Horak and Tesche (1993) found a high infection rate with *Armillaria ostoyae* at the roots of Norway spruce after SO_2 fumigation, while Capecki et al. (1989) reported enhanced susceptibility of natural forests to insect attacks as a reaction to high SO_2 doses. Maynard et al. (1994) noted that trembling aspen, adversely affected by sulfur deposition, had increased incidences of *Armillaria* root rot and *Hypoxylon* canker.

Table 3.4.6 General information of the monitoring forests

Country	Area	Name of forest plot	Forest type	Major species	Survey year
China	Jinyunshan, Chongquing	Jinyunshan No.1	NI	*Castanopsis carlesii var. spinulosa, etc.*	2003
		Jinyunshan No.2	NI	*Michilus pingii*	2003
	Jiwozi, Xian	Dabagou	NI	*Pinus armandi*	2003
	Xiaoping, Xiamen[*1]	XPZ-01	Man-made forest	*Michelia macclurei*	2003
		XPZ-02	Man-made forest	*Michelia macclurei*	2003
		XPZ-03	Man-made forest	*Fokienia hodginsii*	2003
		XPZ-04	Man-made forest	*Fokienia hodginsii*	2003
	Zhuxiandong, Zhuhai	Zhuxiandong No.1	NI	*Pinus elliottii, Acacia confusa*	2003
		Zhuxiandong No 2	NI	*Acacia confusa*	2003
		Zhuxiandong No 3	NI	The plot is basically fernland.	2003
Japan	Lake Ijira, Gifu Prefecuture	Ijira-1	Man-made forest	*Chamaecyparis obtusa, Cryptomeria japonica*	2000
		Ijira-2	Man-made forest	*Chamaecyparis obtusa*	2000
		Ijira-3 (Lake Ijira)	Man-made forest	*Chamaecyparis obtusa*	2000, (2003), (2004)[*2]
		Ijira-4	Secondary forest	*Pinus densiflora,* broadleaf tree species	2000
		Yamato	Man-made forest	*Chamaecyparis obtusa*	(2004)[*2]
	Lake Banryu, Shimane Pref.	Banryu	Secondary forest	*Ilex integra, Machilus thunbergii, etc*	2001
		Iwami-rinku FP	Secondary forest	*Castanopsis cuspidata*	2001
Philippines	Los Banos	Mt. Makiling	Secondary forest	*Diplodiscus paniculatus, Celtis luzonica, etc.*	2000, (2005)[*3]
		UP Quezon-Land Grant	Secondary forest	*Pterocarpus indicus, etc.*	2001, (2005)[*3]
Republic of Korea	Imsil	Mt. Naejang	NI	*Pinus densiflora*	2001, 2004
Russia	Listvyanka	Bolshie Koty	Natural forest	*Larix sibirica, Pinus sylvestris*	2002
	Irkutsk	Irkutsk	Man-made forest	*Pinus sylvestris, Betula pendula*	2003
	Mondy	Mondy	Natural forest	*Larix sibirica*	2004
Thailand	Vachiralonglorn Dam	Vachiralongkorn Puye	Secondary forest	*Dipterocarpus turbinatus, etc.*	2002, 2003
		Vachiralongkorn Dam	Secondary forest	*Xylia xylocarpa, etc.*	2003

Note: NI, no information; *1. The first survey in 2000 was carried out in different plots; *2. The survey of tree decline only was carried out in 2003 and 2004 in two Japanese forests; *3. The surveys were carried out in February 2005 due to postponement of surveys in autumn 2004.

Table 3.4.7 Summary of "general description of forest"

Country	Name of forest plot	Survey year	Number of trees stands/ha	DBH (cm)		Height (m)		Basal area m^2/ha	Number of species in understory
				Max.	Mean	Max.	Mean		
China	Jinyunshan No.1	2003	270	75.7	30.4	26.6	19.0	21.6	31
	Jinyunshan No.2	2003	280	45.5	28.6	26.1	20.8	18.1	42
	Dabagou	2003	160	30.0	21.3	19.3	12.6	5.5	13
	XPZ-01	2003	180	25.0	19.8	15.3	14.4	5.1	3
	XPZ-02	2003	30	19.8	19.0	14.5	13.5	0.5	3
	XPZ-03	2003	140	23.4	20.4	15.5	13.8	4.3	5
	XPZ-04	2003	180	22.9	19.6	12.9	11.6	5.2	5
	Zhuxiandong No.1	2003	40	28.2	21.8	11.0	10.1	1.3	11
	Zhuxiandong No 2	2003	No trees, DBH > 18cm		-	-	-	-	10
	Zhuxiandong No 3	2003	No trees, DBH > 18cm		-	-	-	-	11
Japan	Ijira-1	2001	300	45.7	25.0	21.1	14.8	15.5	25
	Ijira-2	2001	270	28.3	22.2	17.9	14.8	10.0	38
	Ijira-3	2001	150	38.5	21.9	17.2	13.2	5.7	15
	Ijira-4	2001	150	33.2	26.0	17.4	14.0	7.7	24
	Banryu	2001	110	33.9	22.7	17.2	13.3	4.3	12
	Iwami-rinku FP	2001	570	60.6	27.4	24.0	19.3	35.6	12
Philippines	Mt. Makiling	2000	340	110.0	39.4	26.6	14.0	51.9	23
		2005	330	110.0	40.0	39.3	18.0	52.3	32
	UP Quezon-Land Grant	2001	50	28.0	21.8	12.5	11.2	1.6	14
		2005	40	28.4	24.4	13.5	12.1	1.5	18
Republic of Korea	Mt. Naejang	2001	1022	38.0	25.8	16.0	12.5	55.3	30
		2004	1067	39.0	26.6	16.0	12.5	61.5	42
Russia	Bolshie Koty	2002	310	52.2	29.7	20.0	12.4	22.6	24
	Irkutsk	2003	340	28.3	21.7	20.0	17.6	12.3	18
	Mondy	2004	20	29.0	24.7	12.3	11.4	0.3	46
Thailand	Vachiralongkorn Puye	2002	100	83.0	49.3	37.0	26.4	23.1	26
		2003	120	83.0	47.5	37.0	25.7	25.8	26
	Vachiralongkorn Dam	2003	90	142.0	56.0	50.0	36.1	29.5	11
Total mean			234		27.1		16.0	15.7	20

Note: Calculation was based on the largest survey plot (0.1 ha; DBH>18cm).

Table 3.4.8 Present state of tree decline in the monitoring sites

Country	Area	Name of forest plot	Monitored trees		Trees, in which symptoms were recorded				
			Species	Number	2001	2002	2003	2004	(2005)[*2]
China	Jinyunshan, Chongquing	Jinyunshan No.1	*Symplocos setchuenensis, etc.*	10			2		
		Jinyunshan No.2	*Symplocos setchuenensis, etc.*	10			3		
	Jiwozi, Xian	Dabagou	*Pinus armandi*	20			20		
	Xiaoping, Xiamen	XPZ-01	*Michelia macclurei*	20			1		
		XPZ-02	*Michelia macclurei*	16			4		
		XPZ-03	*Fokienia hodginsii, etc.*	15			1		
		XPZ-04	*Fokienia hodginsii*	17			3		
	Zhuxiandong, Zhuhai	Zhuxiandong No.1	*Pinus elliottii, Acacia confusa*	5			2		
		Zhuxiandong No 2	*Acacia confusa*	5			0		
		Zhuxiandong No 3	*Sapium discolor*	5			0		
Japan	Lake Ijira, Gifu Pref.	Lake Ijira	*Chamaecyparis obtusa*	20			5	6	
		Yamato	*Chamaecyparis obtusa*	20				3	
	Lake Banryu, Shimane Pref.	Banryu	*Machilus thunbergii, etc.*	11 - 14[*1]	1		1	0	
		Iwami-rinku FP	*Castanopsis cuspidata, etc.*	17	0		0	1	
Philippines	Los Banos	Mt. Makiling	*Diplodiscus paniculatus, etc.*	20					3
		UP Quezon-Land Grant	*Macaranga bicolor, etc*	20	0				0
Republic of Korea	Imsil	Mt. Naejang	*Pinus densiflora*	20	0			0	
Russia	Bolshie Koty	Bolshie Koty	*Pinus sylvestris*	18		18			
	Irkutsk	Irkutsk	*Pinus sylvestris, Betula pendula*	20			20		
	Mondy	Mondy	*Larix sibirica*	20				6	
Thailand	Vachiralonglorn Dam	Vachiralongkorn Puye	*Dipterocarpus turbinatus*	20			0		
		Vachiralongkorn Dam	*Xylia xylocarpa*	20			0		

Note: *1. Some monitored trees were changed due to the management of pine wilting disease; *2. The surveys were done in February 2005 due to postponement of surveys in autumn 2004; *3. Decline level was classified into five classes, from Level 0 (healthy) to Level 4 (dead), for several observation items, such as defoliation, discoloration, dieback of the stem, etc.

3.4.5 Inland aquatic environment

3.4.5.1 Introduction

Acid deposition was first identified as a major environmental problem in Europe and eastern North America in the 1960s and 1970s. This phenomenon was indicated by a decrease in the pH levels of lake water in the 1970s compared to levels in the 1930s. Resulting damage included declines in fish populations. The cause of this pH decline is believed to be the deposition of acidic substances into lakes in amounts that exceeded the neutralizing or buffering capacity of the lakes. In general, inland bodies of water with low alkalinity and low electrical conductivities are prone to sensitivity to acidification caused by acid deposition.

It is well known that acid deposition is a human-induced environmental problem caused by the emission of sulfur and nitrogen compounds into the atmosphere from sources in economic sectors such as energy production, transport, industry, and agriculture. The experiences in Europe and North America with the impact of acid deposition on streams and lakes raised concerns in countries in East Asia that rapid industrial and population growth in this region would also impact the environment, resulting in similar damage to lakes and streams.

There was also concern that other human activities, such as an increasing use of fertilizers and insecticides in agriculture, would also eventually acidify the soil. It was concluded that it is important to continuously monitor the environment in order to assess the impacts of acid deposition. Government agencies responsible for water quality in East Asian countries participating in EANET have been conducting surveys on the influence of acid deposition on selected lakes, rivers, dams, and reservoirs wherever possible since 2000. These monitoring programs and activities have been carried out independently for each site. The results of ongoing monitoring are presented in this periodic report, together with preliminary observations of the influence of acid deposition on inland aquatic environments in East Asia.

3.4.5.2 Monitoring inland aquatic environments

Monitoring was conducted from 2000 to 2005 to identify impacts of acid deposition on the water quality of lakes, rivers, dams, and reservoirs in the following countries participating in EANET: Indonesia, the Philippines, Thailand, Vietnam, China, Japan, and Russia. Monitoring was also started in Mongolia from 2002. In Malaysia, monitoring was started in 2005, but there is not enough data for any assessment. Cambodia and Laos, recent EANET members, have also made some efforts, and they will begin monitoring in the near future. No monitoring data has been received from Korea up to 2006.

Ensuring high quality of monitoring data is very important in order to properly assess the level of acid deposition impact on inland aquatic environments. Before starting monitoring, each country must conduct a survey to select the most appropriate sampling location(s). This preliminary screening of lakes, rivers, dams, and reservoirs was done to meet the criteria of monitoring developed by EANET, with objective to identify surface water bodies to monitor that are highly sensitive to acid deposition.

a. Characteristics of lakes/rivers selected for monitoring

According to *Technical Manual for Monitoring on Inland Aquatic Environment in East Asia*, the lakes to be selected for monitoring should be harmonic-type lakes, preferably with depths of approximately ten meters or less, a water residence time of one year or less, and an area of one hectare (ha) or more, with low alkalinity and electrical conductivity, as well as minimal anthropogenic water pollution and no surface coverage by aquatic organisms. For monitoring of springs in countries with four seasons, it is desirable to locate sites in protected areas (i.e., a nature reserve) with a minimum of human activities such as deforestation. Also, the upstream area should be under cultivation or being planned for it. Details on the aquatic environment sites monitored in 2000-2005 are summarized in Table 3.4.9.

Table 3.4.9 Monitoring sites for inland aquatic environments in EANET countries (2000–2005)

Country/ location	Name of lake/river	Nearest acid deposition monitoring site	Sampling frequency (times per year)	Properties
China				
Chongqing	1. Jinyunshan Lake	Rural	4	
Xiamen	2. Jiwozi River	Remote	3	
Xi'an	3. Xiaoping Dam	Remote	4	
Zhuhai	4. Zhuxiandong Reservoir	Urban	4	
Indonesia				
Bandung	Patenggang Lake	Rural	3	
Japan				
Gifu Prefecture	1. Ijira Lake	Rural/ ecological	4	Area: 0.1 square kilometers (km^2) Depth: 5.4 meters (m) Water volume: 0.00054 cubic kilometers (km^3) Utilization: irrigation and fishing
Shimane Prefecture	2. Banryu Lake	Urban/ ecological	4	
Mongolia				
Terelj	Terelj River	Rural	5	—
Philippines				
San Pablo City, Laguna	Mojicap Lake	Rural	5	Area: 0.02 km^2 Depth: 25 m
Russia				
Listvyanka	Krestovka River (2000–2003)	Rural	12	Length: ~15 km
	Pereemnaya River (from 2004)	Rural	4	Length: 42 km Drainage area: ~360 km
Primorskaya	Komarovka River (from 2005)	Rural	4	Length: 66 km
Thailand				
Kanchanbur Province	Vachiralongorn Dam	Remote	4	Area: 3,720 km^2 Depth: 149 m Water volume: 6.7276 km^3 Residence time: 165 days Utilization: irrigation and electric power
Vietnam				
Hoa Bin Province	Hoa Binh Reservoir	Rural	4	Area: 208 km^2 Depth: 60 m Volume: 9.45 km^3 Residence time: 365 days Utilization: electric power

Two sites in Russia—Ilchir Lake (1999–2000) and Lake Ordynskoe (2000)—were considered during EANET's preparatory phase as potential permanent sites for monitoring, but it was found that both were not sensitive enough to acid deposition, so monitoring was terminated. Also, the Pereemnaya River was selected (since 2004) instead of the Krestovka River for monitoring in East Siberia, because it proved to be more sensitive to acidification.

b. Present state of water quality (pH, EC, alkalinity, and ion concentration)

The monitoring of inland aquatic environments at sites such as lake, rivers, dams, and reservoirs has been conducted through water sampling between 3 to 12 times annually in most EANET countries since 2000. The data produced from the results of monitoring from 2000 to 2004 were analyzed and then summarized in graph form to identify the trends and changes in surface water properties. The

EANET countries that actively conducted monitoring from 2000 to 2004 can be divided into three groups according to climate: (1) tropical (includes Indonesia, the Philippines, and Thailand), (2) subtropical (Vietnam, China, and Japan), and (3) temperate (Mongolia and Russia).

The annual average results of monitoring pH, electrical conductivity, alkalinity, and ion concentrations from 2000 to 2004 at each monitoring site in countries participating in EANET are presented in Figures 3.4.12 to 3.4.16.

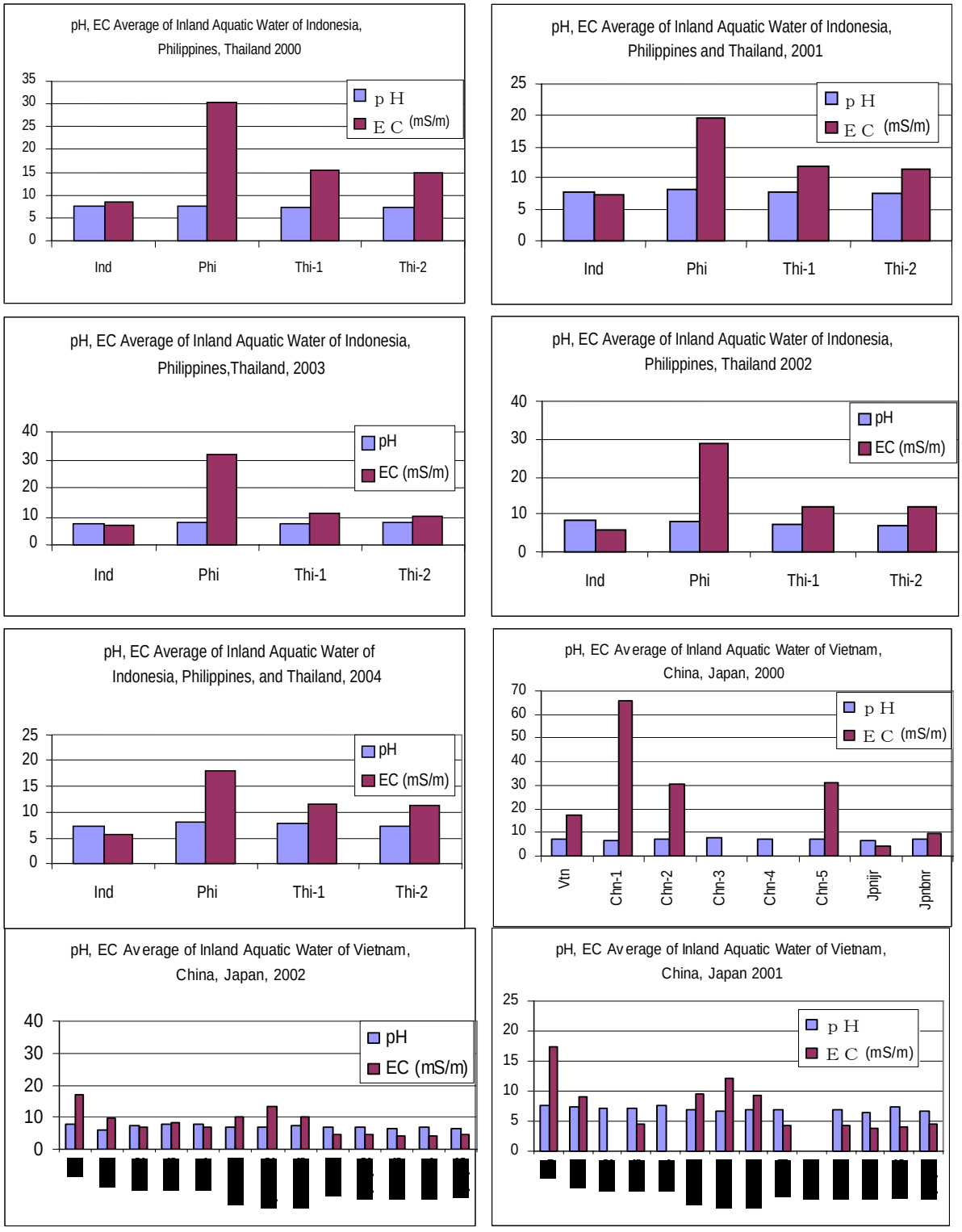

Figure 3.4.12 (part 1) Annual average pH and EC levels at EANET monitoring sites (2000–2004)

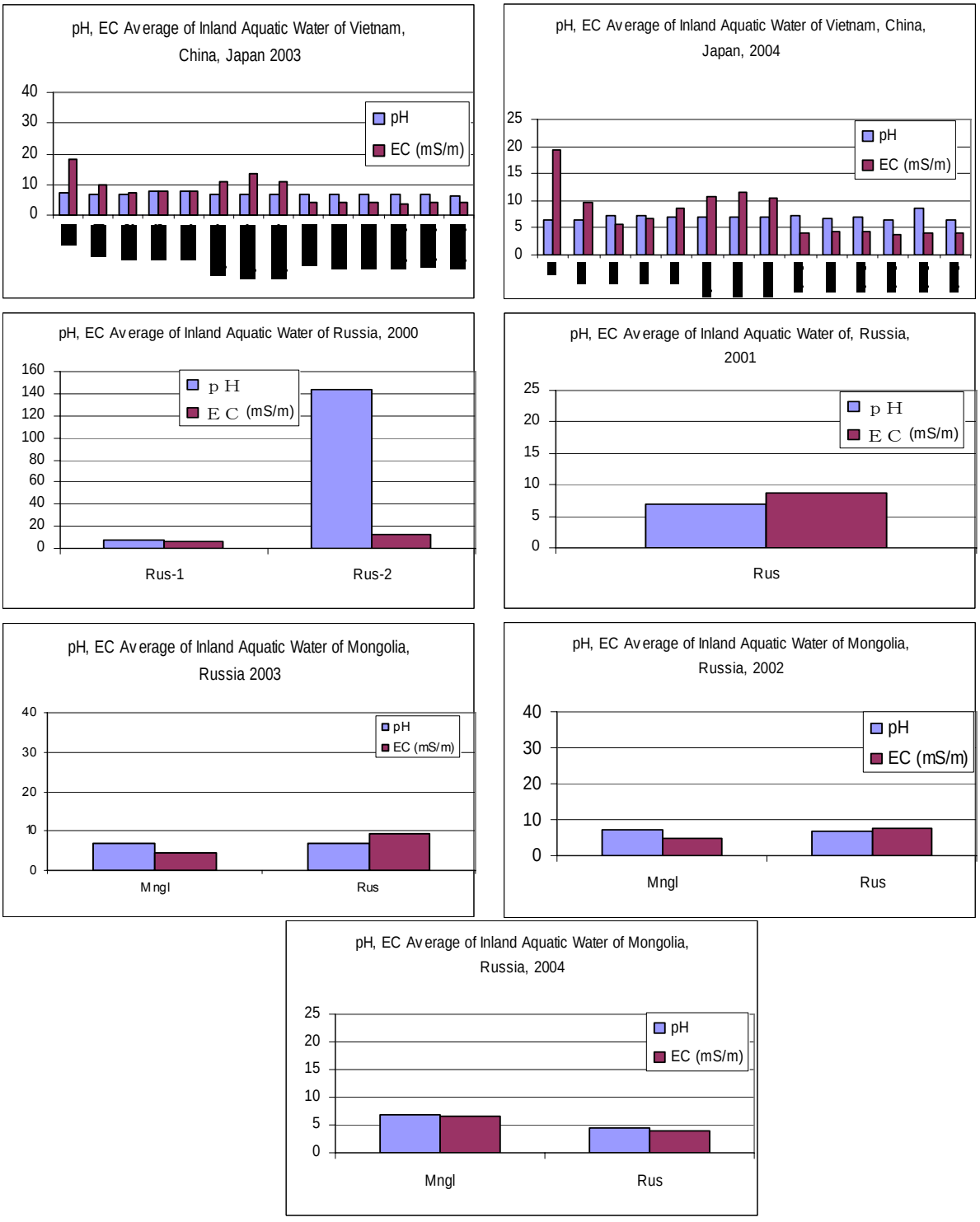

Figure 3.4.12 (part 2) Annual average pH and EC levels at EANET monitoring sites (2000–2004)

There was no clear trend of change in pH values in the aquatic environments monitored in Indonesia, the Philippines, Thailand, Vietnam, China, Japan, Mongolia, or Russia (Figure 3.4.12). The lowest value of annual average pH of inland aquatic environments at all monitoring sites was pH 6.12 (Jinyunshan Lake in China). Overall, it was found that about 46.2% of all lakes, rivers, dams, and reservoirs that were monitored had a pH over 6, while about 47.3% had a pH value over 7 and 6.6% had a pH over 8.

Electrical conductivity (EC) was lower than 5 $mS \cdot m^{-1}$ in surface waters monitored in Japan and Mongolia that were selected for being sensitive to acidification. As well, EC values over 5 $mS \cdot m^{-1}$ were recorded in Indonesia, the Philippines, Thailand, and parts of Japan. A data range of 5–8 $mS \cdot m^{-1}$ was reported for Patenggang Lake, Indonesia, while values of 11–32 $mS \cdot m^{-1}$ were recorded at the following sites: Mojicap Lake in the Philippines, Khaolang Dam in Thailand, Hoa Bin Reservoir in Vietnam, and the selected lake and river in China. There was no obvious trend at any of the monitoring sites in Indonesia, the Philippines, Thailand, Japan, or Mongolia, but, in contrast, a trend of EC was evident at sites in China and Russia.

Also, according to monitoring data, the alkalinity of lakes, rivers, dams, and reservoirs in Indonesia, Thailand, Vietnam, China, Japan, Mongolia, and Russia was lower than 2 meq L^{-1} (Figures 3.4.13 and 3.4.14).

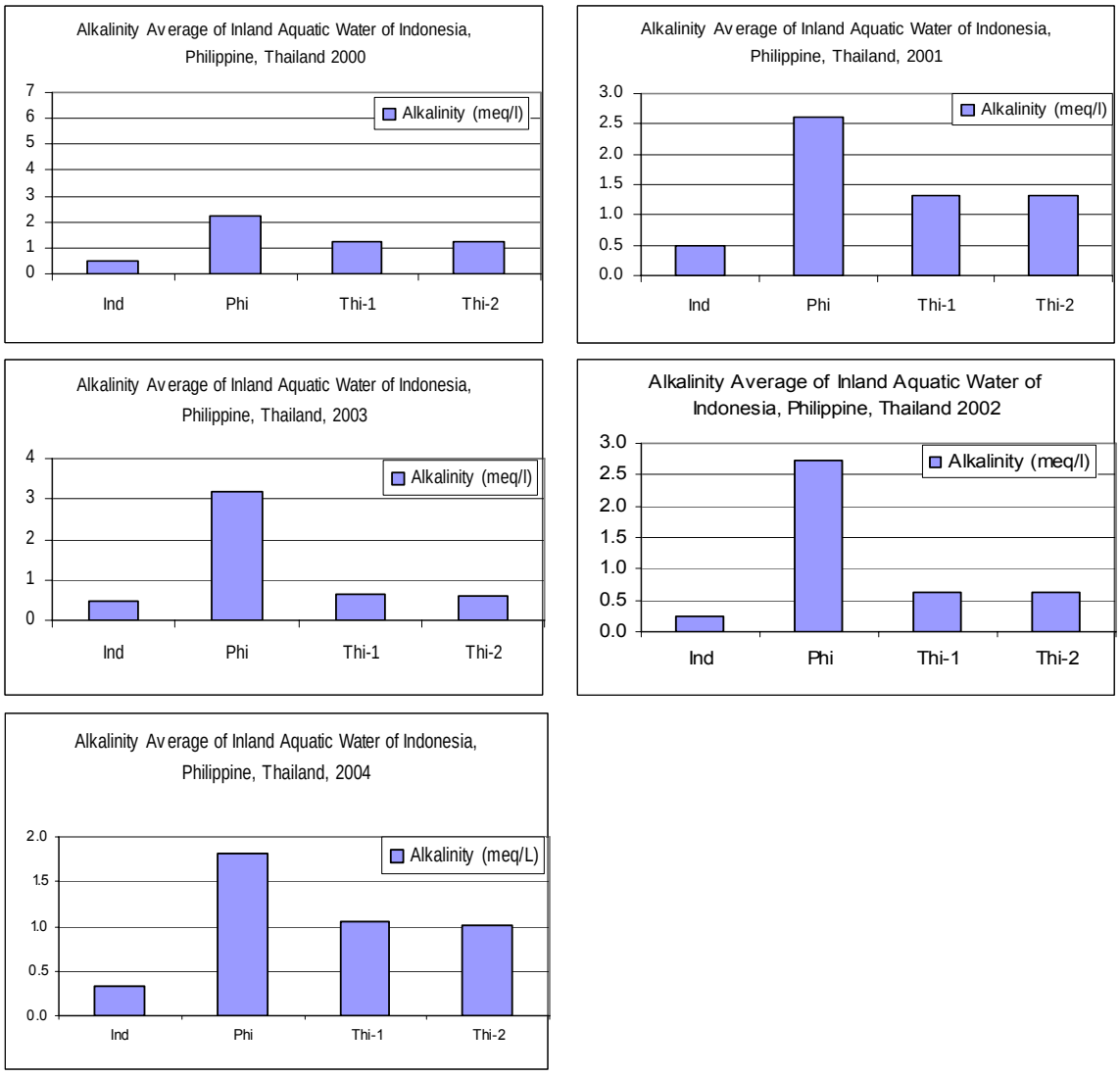

Figure 3.4.13 Average annual alkalinity at inland aquatic environment monitoring sites in Indonesia, the Philippines, and Thailand (2000–2004)

Based on monitoring data for 2000–2004 at sites in EANET countries, no obvious trend was detected in the alkalinity of inland aquatic environments. The lowest alkalinity value of 1 meq·L^{-1} was detected in lakes and rivers in Indonesia, China, Mongolia, Japan, Russia, and in some locations in Thailand. Alkalinity values over 1 meq·L^{-1} were detected in the Philippines, Vietnam, and parts of Thailand.

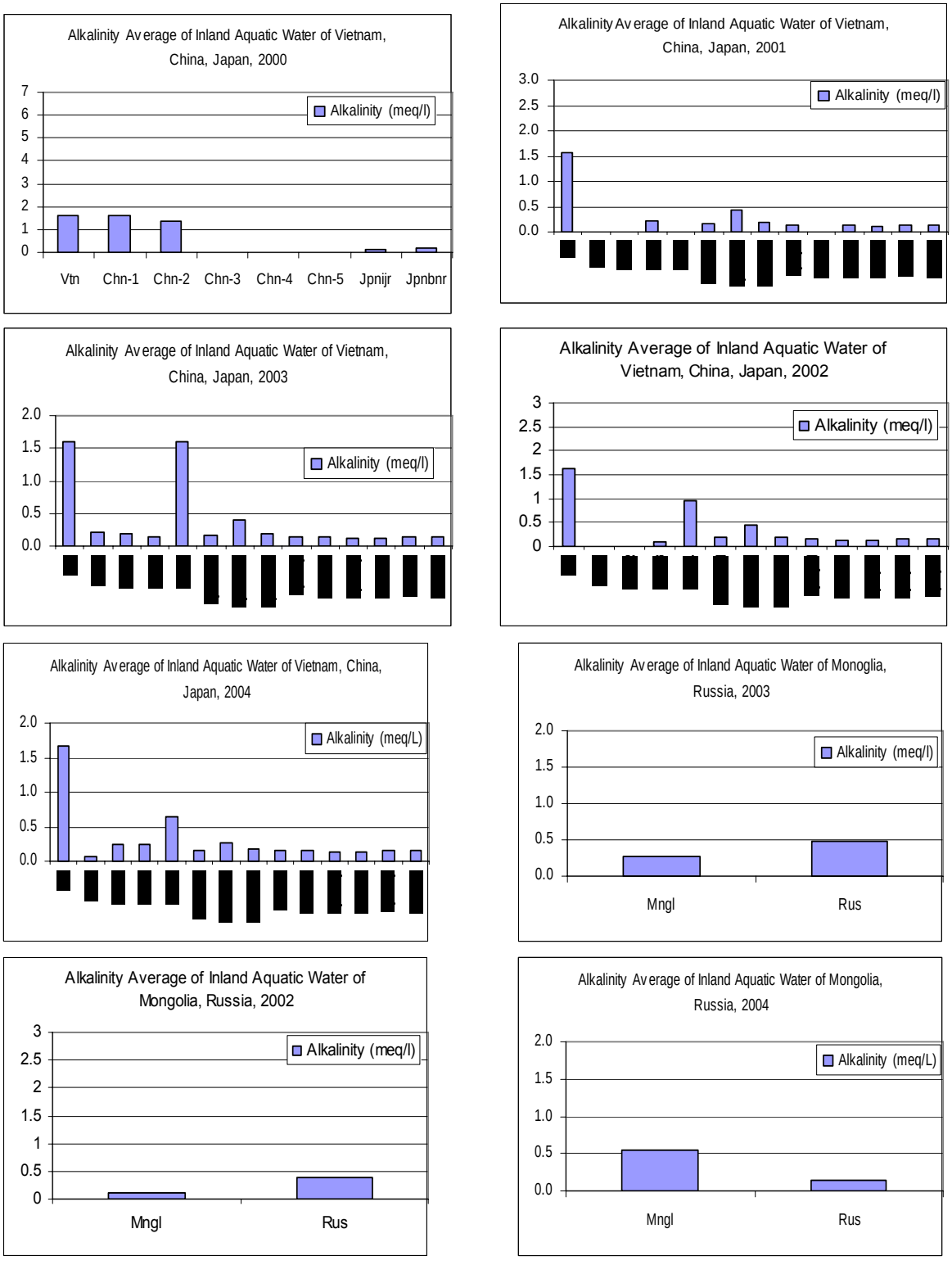

Figure 3.4.14 Annual average alkalinity at inland aquatic monitoring sites in Vietnam, China, Japan, Mongolia, and Russia (2000–2004)

There was no clear trend in the concentrations of major anions (SO_4^{2-}, NO_3^-, Cl^-) in inland aquatic environments recorded at the monitoring sites of EANET countries for the period 2000–2004 (Figures 3.4.15 to 3.4.17).

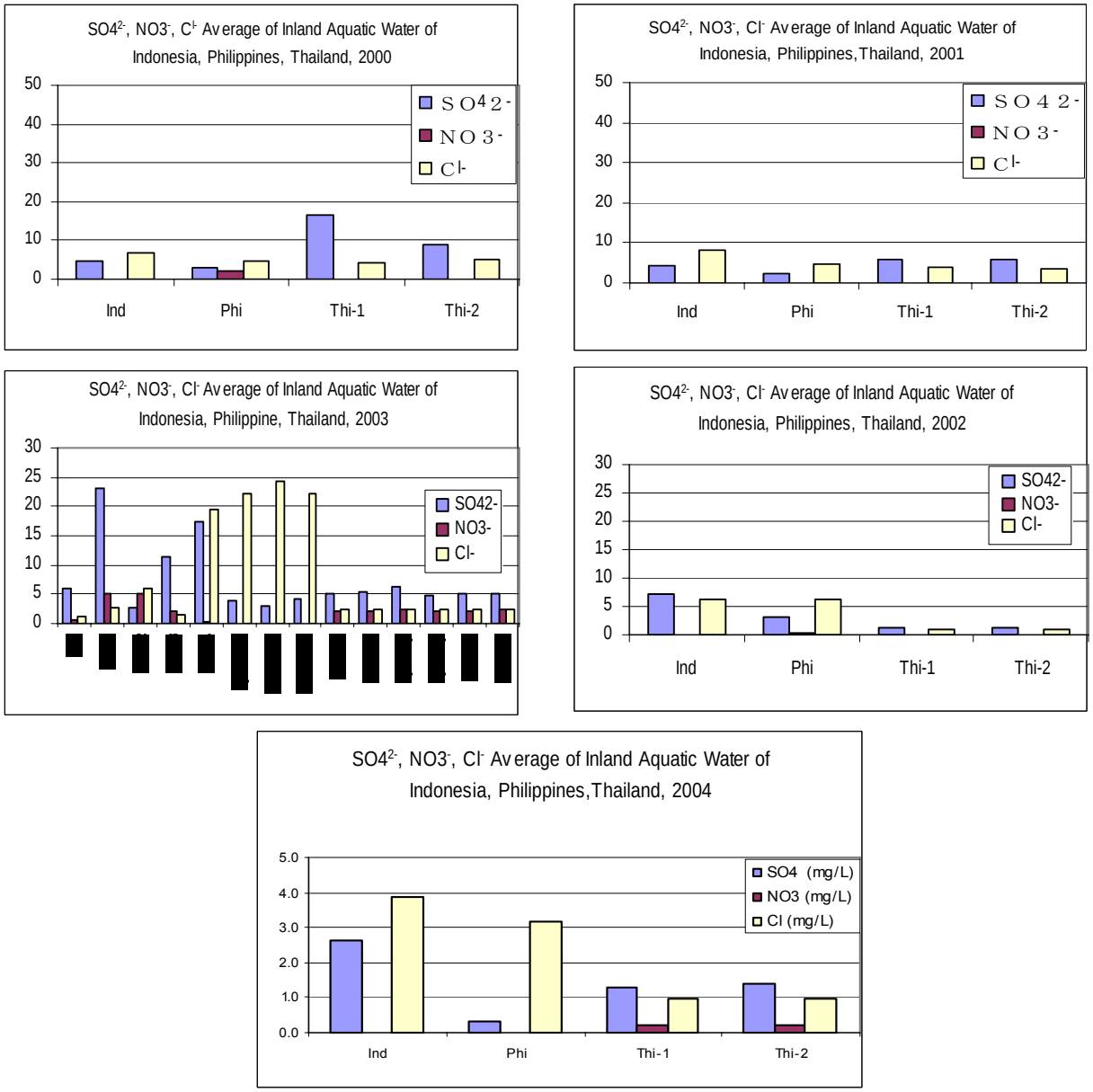

Figure 3.4.15 Annual average values for major anions at inland aquatic environment monitoring sites in Indonesia, the Philippines, and Thailand (2000–2004)

The lowest content of anions with values of sulfate (SO_4^{2-}) below 2 mg·L^{-1} was detected in water bodies in China and parts of Thailand; and lower concentrations of nitrate (NO_3^-) were detected at sites in Indonesia, the Philippines, Thailand, Vietnam, Japan (Banryu Lake), Mongolia, and Russia. Values over 2 mg·L^{-1} were recorded in China and Japan (Ijira Lake). Lower concentrations of chloride ions (Cl^-) with values below 1 mg·L^{-1} were detected in Thailand and parts of China, Mongolia and Russia. Other values obtained ranged from 3 mg·L^{-1} to 42 mg·L^{-1}.

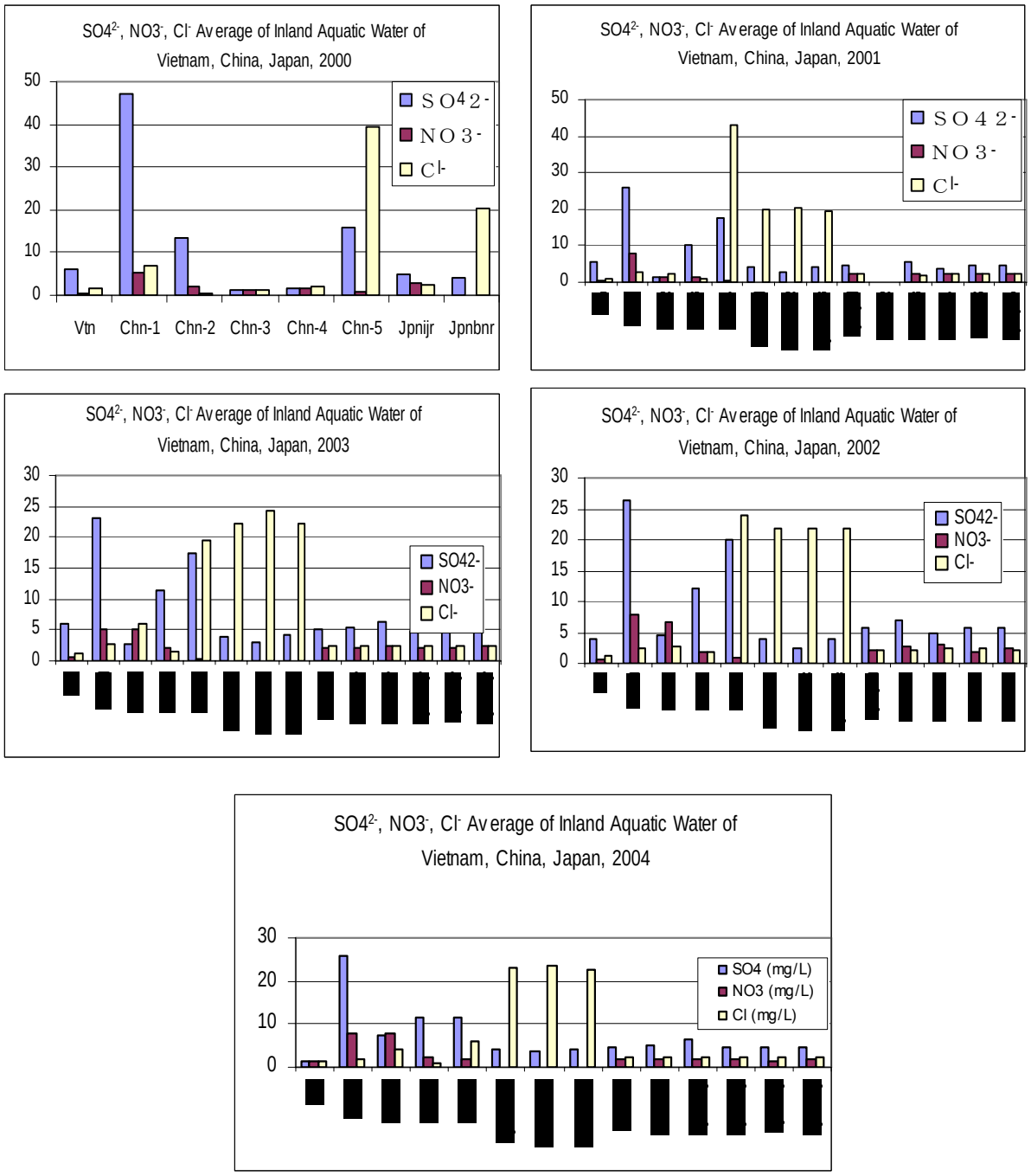

Figure 3.4.16 Annual average values for major anions at inland aquatic monitoring sites in Vietnam, China, and Japan (2000–2004)

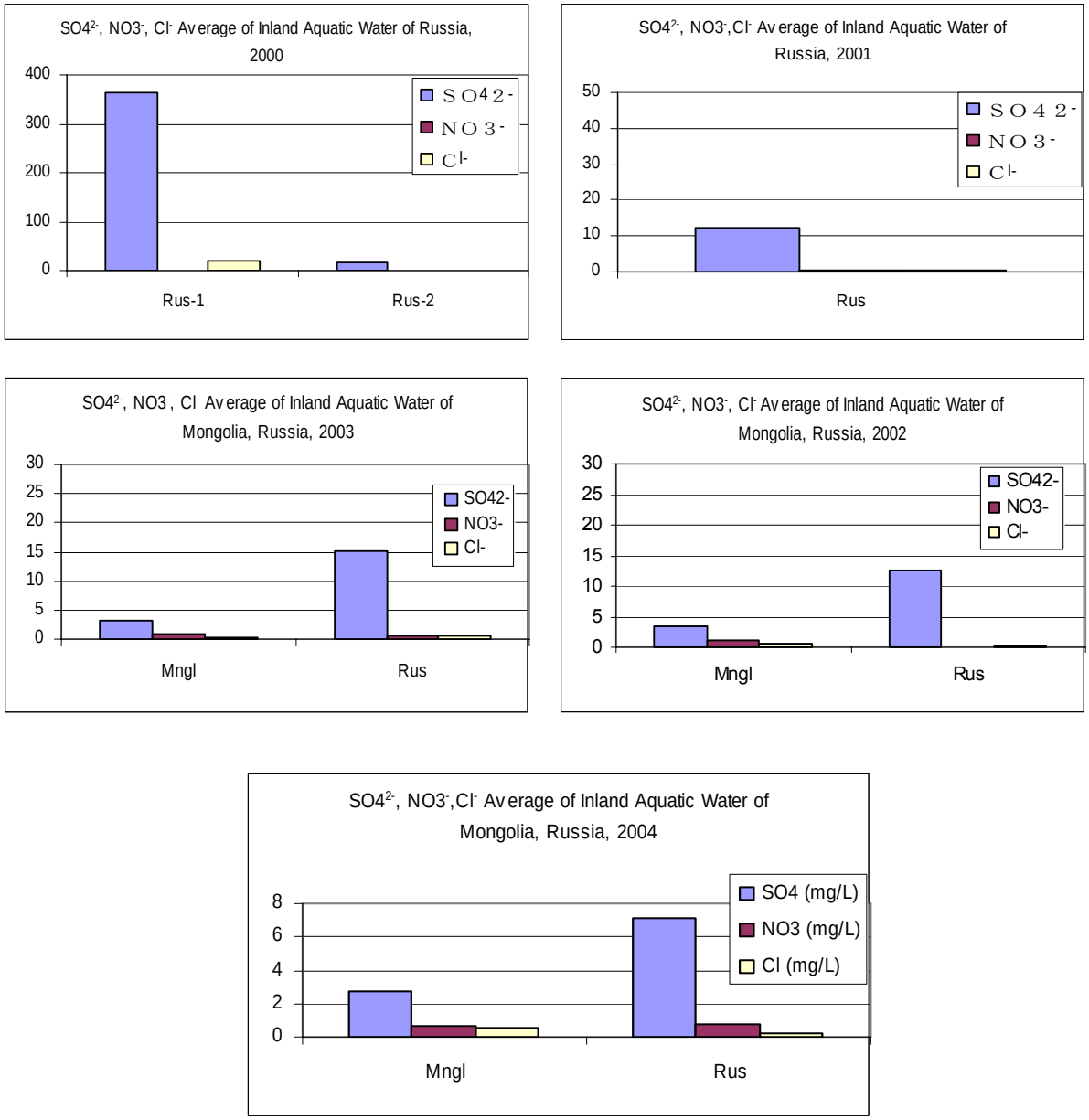

Figure 3.4.17 Annual average values of major anions at inland aquatic monitoring sites in Mongolia and Russia (2000–2004)

Major cations (Na^+, K^+, Ca^{2+}, and Mg^{2+}) were monitored in the inland aquatic environments of EANET countries from 2000 to 2004, but no obvious trend was identified in data from monitoring sites in Indonesia, the Philippines, Japan (Ijira Lake), and Mongolia (Figures 3.4.18 to 3.4.20).

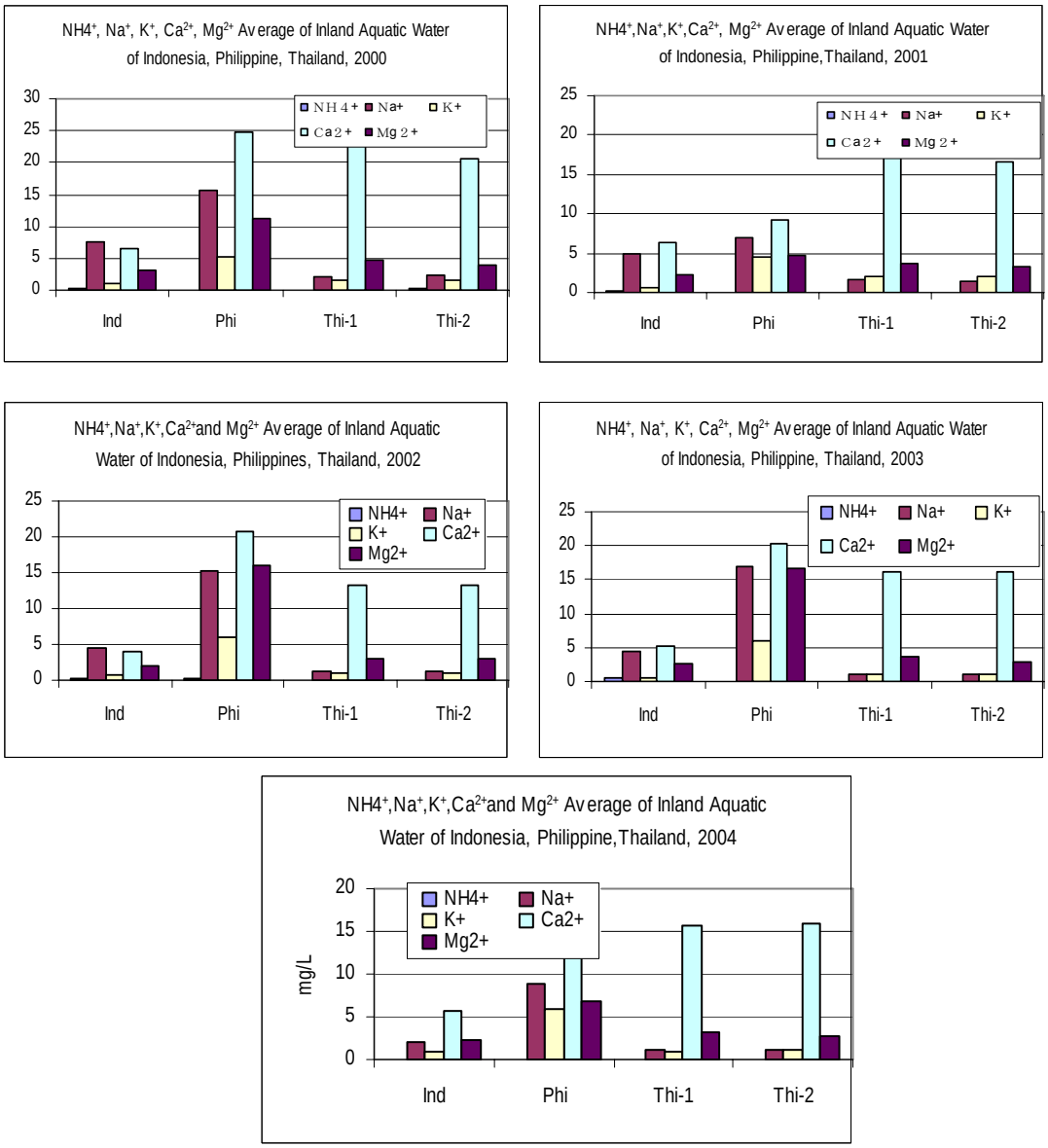

Figure 3.4.18 Annual average values of major cations at inland aquatic monitoring sites in Indonesia, the Philippines, and Thailand (2000–2004)

The lowest cation concentrations of ammonium (NH_4^+) below 2 mg·L^{-1} were detected in water bodies in Mongolia, Japan (Ijira Lake), and parts of Russia, Thailand, and Indonesia. A variety of Na^+, K^+, Ca^{2+}, and Mg^{2+} concentrations from 0.9 mg·L^{-1} to over 70 mg·L^{-1} were also recorded. Lower concentrations of Na^+ with values below 2 mg·L^{-1} were detected in Indonesia, Thailand, Vietnam, and in some Japanese lakes (Ijira Lake and Banryu Lake), while other concentrations over 2 mg·L^{-1} were detected at sites in the Philippines, Mongolia, and Russia. Concentrations of K^+ below 2 mg·L^{-1} were recorded in Japan's Ijira Lake and rivers in Mongolia and Russia. Values over 2 mg·L^{-1} were detected in water bodies in Indonesia, the Philippines, Thailand, Vietnam, and China. The monitoring of Mg^{2+} did not produce complete data sets for all monitoring sites in EANET countries; only limited data were provided for water bodies in Indonesia, the Philippines, Thailand, Japan, and Russia.

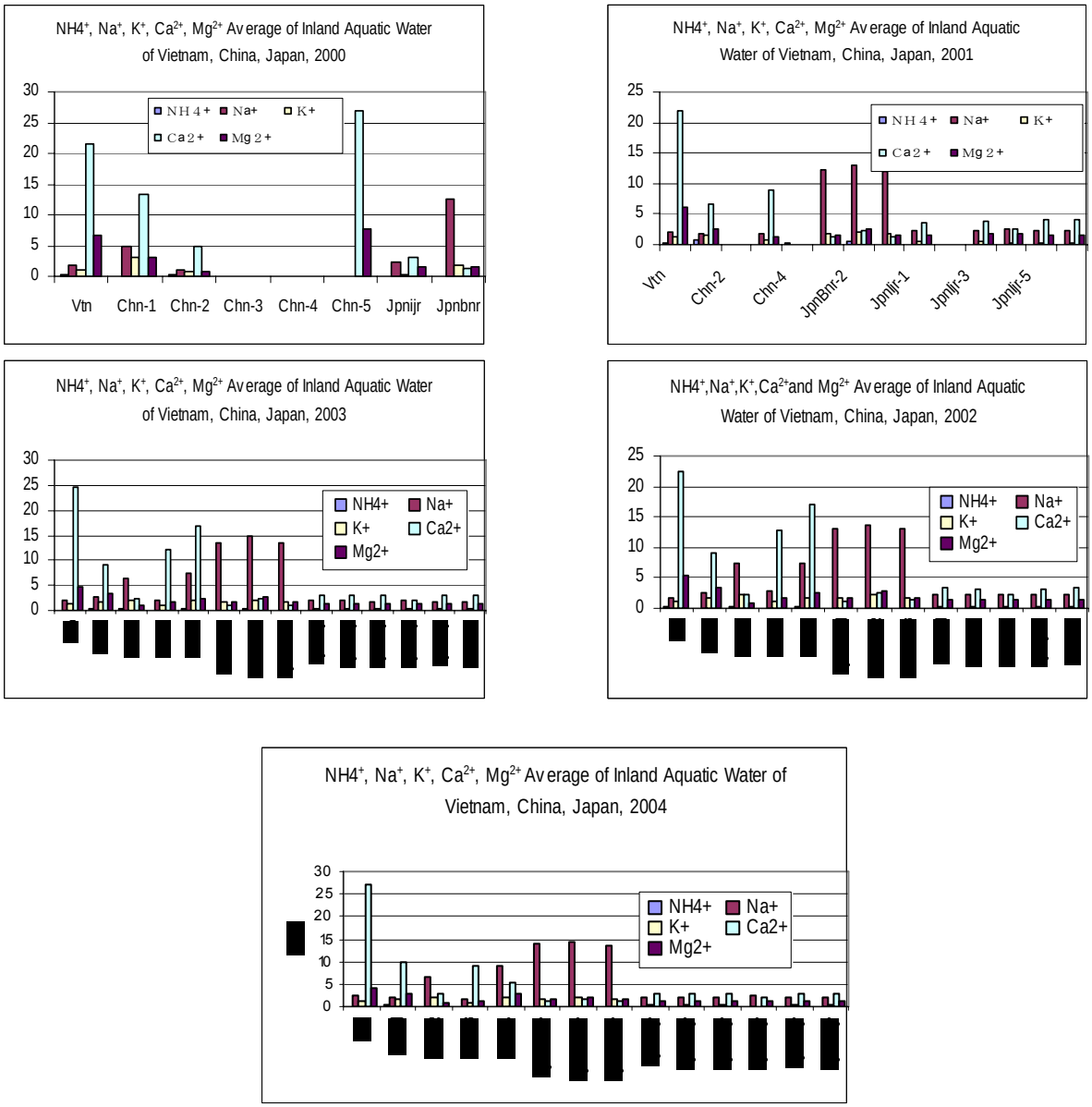

Figure 3.4.19 Annual average values of major cations at inland aquatic monitoring sites in Vietnam, China, and Japan (2000–2004)

It may be concluded that some water bodies in EANET countries have experienced acid deposition. It is very difficult, however, to conclude whether the impact of acid deposition has occurred or not (in particular, in Southeast Asian countries like Indonesia, Thailand, the Philippines, and Vietnam) by evaluating monitoring data from inland aquatic environments only. It is better to conduct an integrated evaluation of all data on atmospheric deposition, soil, forest, and inland aquatic environment to determine any impacts of acid deposition.

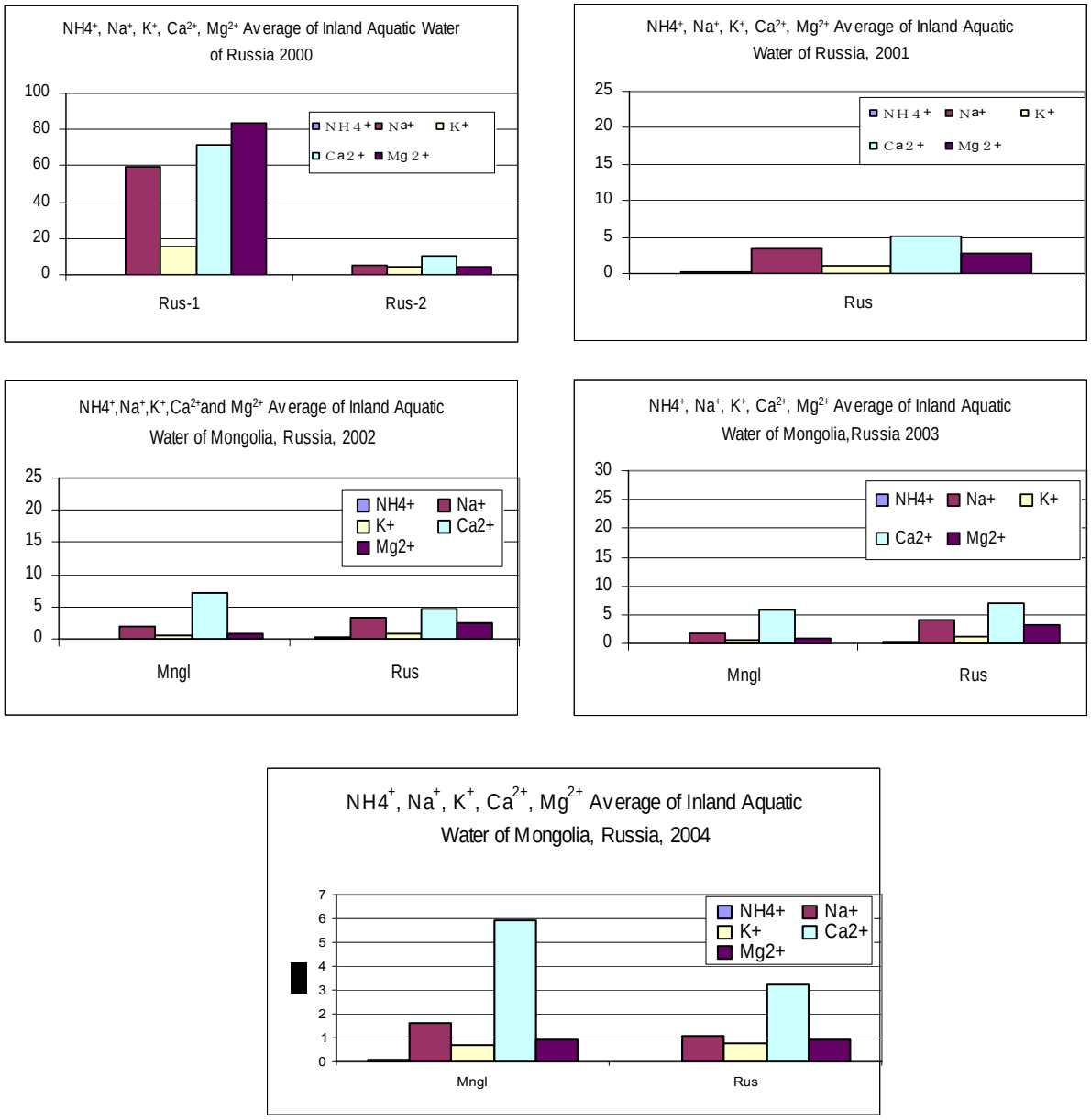

Figure 3.4.20 Annual average values of major cations at inland aquatic monitoring sites in Mongolia and Russia (2000–2004)

3.4.5.3 Possible impacts on inland aquatic environments

Inland waters such as river and lakes possess an inherent acid neutralizing capacity (ANC), or buffering capacity, wherein the pH value will not change easily, even if a small amount of acids is added. Bicarbonate ions (HCO_3^-) and carbonate ions (CO_3^{2-}) are the main factors contributing to alkalinity in most lakes with a pH of 6 to 9. These ions are usually leached from soil and rocks in the water catchment (the land area from which any rainfall drains into a lake).

The equilibrium system in freshwater [$CO_2 – HCO_3^- – CO_3^{2-}$] is the major buffering mechanism that keeps pH values stable and counters additional acid deposition when gaseous carbon dioxide dissolves into water and dissociates into HCO_3^- and CO_3^{2-}. Thus, freshwater is generally able to store a large amount of carbonate and bicarbonate ions (Fukuhara 2003). If more acid is added to the water, bicarbonate ions in turn form carbonic acid to maintain the equilibrium, and carbonic acid dissociates,

producing carbon dioxide and water. Thus, hydrogen ion (H^+) concentrations in the water remain relatively stable until the bicarbonate and carbonate ions are exhausted. Therefore, lakes with low alkalinity can be considered to be sensitive to acid deposition.

a. Effects on aquatic organisms

It is well known that acid rain can cause the acidification of lakes and rivers and directly impact terrestrial ecosystems. In Northern Europe and America, the effects of acid rain appeared in the 1970s, and damage such as the devastation of fauna and flora in inland waters was often reported from many places. Furthermore, a new kind of phenomenon appeared called "fish kill," which occurs when there is a sudden flow acidifying substances into inland waters due to snowmelt ("snowmelt acid shock"), or loading of acidifying substances occurs due to heavy rain, which increases the acidity of water and kills a large quantity of adult fish (Ikuta 2001).

Fish in lakes and rivers are likely to die off when they are suddenly exposed to acidity levels below pH=5. Even under a moderately acidic environment that does not cause death, fish are responsive and susceptible to the condition; it is known that such stress negatively affects their physiological and reproductive functions. Research and comparative surveys have been conducted on the effects of acidification on not only fish but on many other biological groups under various conditions of water acidity, such as phytoplankton, algae, water weeds (aquatic plants), moss, non-vertebrates, and other forms of life in the food chain.

b. Contribution of air pollutants to ocean waters

Air pollution may pose a significant threat to coastal and marine ecosystems, because pollutants are circulated in a cycle between ocean, atmosphere, and terrestrial systems. Under the framework of the *International Convention for the Prevention of Pollution from Ships* (MARPOL), sources of marine pollution are identified as follows: land-based sources and activities; shipping and other sea-based activities such as fishing and aquaculture; dumping; seabed activities, both near and offshore; and atmospheric sources.

In the Baltic Sea area, for example, over 20% of the total nitrogen input to the sea comes from airborne sources. Loading of inorganic nutrients such as nitrate is one of the possible causes of the eutrophication of the sea. Furthermore, it is thought that one-third of the total amount of lead and one-fifth of all mercury and cadmium entering the sea comes from the atmosphere. A report by the *United Nations Economic and Social Commission for Asia and the Pacific* (UN/ESCAP) states that 33% of total marine pollution in the Asia-Pacific region comes from the atmosphere.

c. Eutrophication

In the process of eutrophication, the excess inputs of nitrogen and phosphorus nourish phytoplankton, causing an acceleration of growth called an algal bloom. The phytoplankton then consumes more dissolved oxygen in the water, causing oxygen depletion, which may kill fish and shellfish.

Eutrophication is naturally-occurring process, that usually advances slowly over a long period of time. Population growth and greater industrial production that accompany economic development increase the amount of wastewater from households, industry and agriculture, with the result that eutrophication occurs more quickly. Eutrophication referred to here is thus an anthropogenic process accelerated by human activity.

One of the main substances leading to eutrophication is ammonia (NH_3). Modernization of agriculture often leads to an increase in the use of chemical fertilizers containing ammonium, and the number of livestock being raised often increases with economic growth. The emissions of ammonia into the atmosphere from agriculture and livestock, therefore, tend to increase. Along with the inflow of

agricultural wastewater, the loading of ammonia from the atmosphere can also be an important factor that accelerates eutrophication. It has also been indicated that the wet deposition of NH_4^+ onto the ground leads to the acidification of soil due to the action of nitrifying bacteria (Klimont et al., 2001).

Nutrient imbalances can occur due to the selective uptake of NH_4^+, leading to potassium and magnesium deficiencies (Rosen et al. 1992; Hildebrand 1994). Increased nitrogen content leads to substantial changes in natural vegetation (Falkengren-Grerup, 1986; Brodin and Kuylenstierna, 1992). Finally, excess nitrogen is leached as NO_3^- to ground and surface water, causing serious problems for water supplies and giving rise to the eutrophication of the seas.

3.4.6 Future directions and possible impacts on ecosystems

3.4.6.1 Comprehensive analysis and lessons learned

Comprehensive analysis of the state of the environment and changes caused by the impact of atmospheric pollution includes investigation of the relationships among wet and dry deposition, changes of soil and vegetation properties, and possible transformation of inland aquatic ecosystems.

The different gases released or emitted into the atmosphere by industry, factories, households, office buildings, and vehicles through the use or burning of different kinds of fuels are carried down to the ground directly (dry deposition) or deposited in the form of precipitation (wet deposition). The compounds contained in wet deposition can both directly and indirectly affect vegetation. They can have a direct effect on plants through settling or falling rain, snow, or fog, where immediate contact with the leaves, branches, or trunks of plants occurs. Indirectly, wet deposition can be absorbed by the soil and could affect vegetation through an acidifying effect on the soil and the reaction of different ions in the soil. Base cations may also be lost through leaching in the soil, in which case the pH level will become more acidic, and aluminum concentrations of soil solutions will increase, thereby affecting their oppressing availability to plants.

Since the effects of acid deposition on forest vegetation may result in defoliation or thinning of leaves, gaps in the forest canopy will be created, or existing gaps will become wider. At numerous forest sites, increased nitrogen tends to promote an increased rate of succession of the vegetation. Crown thinning causes higher solar radiation to reach the ground. Furthermore, by combining with increased nitrogen supply, this leads to the growth of nitrophillic grasses and shrubs. The latter compete with trees for water and nutrients, which leads to severe water and nutrient deficiencies in forest stands. The N-induced changes could cause considerable water stress during dry weather, especially on hot, dry summer days.

Continuous rainfall can wash away the nutrients in the soil through leaching or erosion, and surface water bodies (like lakes, rivers, streams, etc.) could act as the final catchment pool or depository for these leachates. Through the process of eutrophication, surface water bodies become excessively enriched with nutritive salts such as nitrogen and phosphorus, which nourish phytoplankton and cause excessive growth, resulting in algal blooms. The quickly growing phytoplankton consume more dissolved oxygen in the water and may cause severe oxygen depletion, which kills fish and shellfish. Inland water is known to have a naturally high acid neutralizing capacity (ANC), or buffering capacity, but with a continuous addition of acid rain substances the time would come when the pH of the inland water becomes acidic, thereby affecting not only the aquatic life but also their sources of food.

Some data submitted by the countries participating in EANET revealed high values of sulfur and nitrate loadings from the atmosphere and low pH values. The effects on vegetation and aquatic life are still inconclusive, however, and more study is needed, especially regarding sensitive species. Since tree species have been growing for so long in these areas, they might have developed some mechanisms to tolerate the more acidic nature of the soil (i.e., stress-activated repair and adaptation mechanisms).

Based also on previous studies conducted in different areas, the ecological impact of acid deposition, especially on forest tree species and aquatic organisms, could not be determined or was not observed in a short period of time or even over 10 years. It would be wise, however, to be aware of the situation and prepare for any eventualities that may occur, as well as to find possible solutions for the probable effects that acid deposition may cause to exposed ecological systems.

3.4.6.2 The Way forward

The lack of long-term studies on relevant changes of soil and water chemistry is one of the major challenges faced by researchers in understanding acid deposition and its potential impacts on soil and vegetation with respect to soil nutrient status, nutrient depletion, and aluminum toxicity, as well as on aquatic ecosystems (streams and lakes). This section provides critical observations and recommendations for future studies.

i. Since nutrient availability and toxic metals are not linearly related to inputs of soil acidity, it is difficult to establish a representative scale of chronic change in soil and plant nutrient status, when conducting and interpreting controlled experiments on acid deposition with respect to spatial and temporal changes.

ii. The elemental budget approach (Likens and Bormann, 1995) needs further elucidation to determine the extent to which soil acidification rates are accelerated or reduced by atmospheric deposition. The elaboration should involve (1) comparison of H^+ input via atmospheric deposition with internal H^+ generated by natural acid production (carbonic, organic, and sometimes nitric), (2) aspects of growth and nutrient uptake by vegetation, and (3) decomposition of organic matter or litter decomposition processes and humus formation. Special attention must be given to knowledge on soil solution chemistry, particularly on soil acidity and the roles of the following factors: concentration of Al^{3+}, Ca^{2+}, Mg^{2+}, and K^+; concentration of heavy metals and toxic contaminants; organic matter; and microbial conditions such as fungal, bacterial, and heterotrophic communities.

iii. In assessing the hydrological implications of changes in atmospheric chemistry input, of primary importance is knowledge on canopy filtration of aerosol and related pollutants, carbon balance and calculations of water loss rates from different canopy formations, forest stand water balance, the hydrological implications of stem structure, and energy balance and exchange processes.

iv. Levels of knowledge need to be improved on ecological compatibility between tree species and related organisms; appropriate management schemes to achieve sustainability from the viewpoints of biogeochemistry, economics, and biological conservation; and the interactions between the soil and tree species in a forest stand, as well as between different tree species in a mixed stand.

v. With reference to forest health in relation to soil acidification, at least three principle ways have been identified by which acidic soil can reduce tree vitality (Stjernquist et al., 2002): (1) an increase of Al^{3+} caused by decreasing pH below 4.5 leads to negative effects on nutrient uptake and growth; (2) soil acidification causes leaching of base cations from the root zone, reducing the available nutrient pool; and (3) soil acidification has direct negative effects on growth and nutrient uptake. Studying these phenomena will be beneficial for future deliberation.

vi. The experience of Nordic countries has demonstrated that many secondary effects of the acidification on forest soils are apparent outside of the forest ecosystem (Kalen et al. 2002). Among others, forest soils leach acid water to adjacent watercourses, and the run-off water eventually ends up in lakes, resulting in an increase in lake acidity. It was estimated in 1985 that 21,500 of 85,000 lakes in Sweden were practically dead and aquatic organisms could no longer survive in them. Acidity in forest soils will proceed downwards through the soil profile as long as the acidification continues, and acidified water will eventually reach the groundwater. Acidified drinking water may also lead to negative health effects (Bjertness and Alexander 1997) due to higher concentrations of acid metal ions

such as Al^{3+}, Fe^{3+}, Cd^{2+}, and Mn^{2+} as pH values become lower (Johansson et al. 1999). The economics of measures and amelioration processes need to be translated since proper management becomes necessary as an ecological implication of acidic deposition.

vii. It is essential that the concept of *critical load* be introduced to the scientific community and become widely understood. (*Critical load* in this case is defined as the maximum amount of sulfur and nitrogen deposition that an ecosystem will tolerate before causing long-term damage to ecosystem structure and function.) Compared to the concept of *critical limit*, the concept of *critical load* allows more flexibility in managing the impacts of acid deposition on ecological systems (Sverdrup and Warfvinge, 1995). Meanwhile, it has been recognized that it is difficult to define exact thresholds above which chemicals have long-term, harmful effects on the structure and functions of ecosystems (Barkman, 1997).

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4. Achievements and Experiences for the First Five Years of EANET

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CONTENTS

4.1 Introduction

The thirteen countries presently participating in the Acid Deposition Monitoring Network in East Asia (EANET) cover a vast area. Their wide geographical coverage means that the network is highly diverse in terms of climate, economy, technology, and culture. To achieve the common goal of establishing an acid deposition monitoring system network with a reliable quality of data collection and assessment, considerable efforts have been made and shared by each participating country since EANET inception. Other EANET activities aimed at raising political and public awareness of the causes and impacts of acid deposition are considered ambitious but important components of the network.

The participants of EANET began their work with a thorough understanding that there were challenges to address among the participating countries in respect to their varying levels of economic, political, and technological advancement and experience. At the First Intergovernmental Meeting (IG1) on the Acid Deposition Monitoring Network in East Asia, in March 1998 in Yokohama, Japan, discussions were held on the fundamental characteristics of the Network, such as the objectives of activities, a schedule for establishment, and institutional and financial matters. After observing the progress of scientific discussions and developments on how to effectively organize a common network among the countries, an agreement to begin the preparatory phase was reached by ten countries in the East Asian region. Under interim guidance from 1998 to 2000, EANET was able to overcome certain barriers and set up a baseline of activities. These included establishing a monitoring system step-by-step; compilation of standard methods for collecting and analyzing samples; issuing technical manuals; verification of data; implementing a program of quality assurance and quality control (QA/QC), which included inter-laboratory comparison projects, database procurement and disclosure, and programs for strengthening technical capacity; as well as promoting EANET activities and joint research projects to suit the unique needs of selected participating countries.

At the Second IG Meeting in 2000, the decision was made to go to the regular operational phase of the network, based on the following achievements produced by EANET activities that had been started on an interim basis in April 1998: (1) development of principal documents on Network design and operation, (2) development and issue into practice of relevant guidelines and technical manuals, and (3) development of the national monitoring systems for the common Network. The decision to start the regular phase of EANET activities from January 2001 was based on the following two documents: the *Joint Announcement of the Implementation of EANET*, and the *Tentative Design of the Acid Deposition Monitoring Network in East Asia* (EANET/IG 2/5/3). To ensure that the operations and development of the Network progressed in a well-coordinated and efficient manner, the United Nations Environment Programme/Regional Resource Centre for Asia and the Pacific (UNEP/RRC.AP) in Thailand was designated as the Secretariat for EANET and the Acid Deposition and Oxidant Research Center (ADORC) in Japan as EANET Network Center.

Significant institutional progress was made during the first five years of EANET regular phase of activities (2001–2005). Among the major accomplishments was the establishment of the "Rules of Procedure for EANET" (EANET/IG 3/12 Annex II) in 2001; an agreement titled the "Financial Contribution to the Secretariat Budget Using the Latest UN Assessment Scale-based Burden Sharing" (Decision 1/IG.5, EANET/IG 5/10) in 2003; and "The Niigata Decision" in 2005, which was aimed at starting discussions on an appropriate instrument and its legal status to provide a sound basis for financial contributions to EANET (Decision 1/IG.7, EANET/IG 7/15 Annex 2). Much effort was also made to improve the transparency and efficiency of the Network through the leading role of the Working Groups organized by the IG. Also of note is a principal document, titled *Procedures on Data and Information Disclosure*, which was issued to provide benefits for the participating countries as well as scientists outside of EANET for access to monitoring information.

This present chapter deals mostly with the progress and achievements in technical aspects and the mining of scientific information, whereas for institutional arrangements, readers are referred to other documents. Also summarized are the most significant outcomes and learning experiences that resulted

from EANET activities in the regular phase, in order to aid further progress of the Network and to disseminate knowledge of good practices to interested parties. As well, the achievements reached before EANET regular phase of activities began in 2001, which are closely related to topics discussed below, are also described.

4.2 Creation of a monitoring system

To create a common understanding of the state of acid deposition problems in East Asia and to provide useful inputs for decision-making at local, national, and regional levels, EANET launched the priority task of creating a monitoring network with the involvement of the participating countries—a monitoring system that can provide assessable and verifiable data on acid deposition for policy makers. The task is a large and complex undertaking, and it required substantial support from technical personnel as well as financial resources provided by each of the participating countries. Utilizing existing monitoring sites that already comply with the technical guidelines has helped to accelerate the monitoring work among the participating countries. The NC has played a critical role in preparing technical documents endorsed by the Scientific Advisory Committee (SAC), i.e., technical guidelines and manuals on selection of monitoring sites, types of chemicals to be monitored for wet and dry deposition, and the types of chemical contents in soil and inland aquatic environments to be monitored for the long-term study of ecosystem impacts. During the preparatory phase and continuing into the regular operational phase of the Network, however, EANET has had to deal with several constraints in terms of setting aside the required technical personnel and securing adequate financial resources to carry out the necessary work among the participating countries.

4.2.1 Monitoring sites

Starting with the selection of monitoring sites, those proposed for wet and dry collection monitoring, as well as ones for monitoring inland aquatic environments and soil and vegetation, had to conform to EANET criteria and guidelines. For example, it is required that sites for monitoring wet and dry deposition be in the same area and be specified as being urban, rural, industrial, or remote. Meeting these requirements is the responsibility of participating countries so as to safeguard each of their best interests. They also had to plan for the availability of facilities and funds to carry out monitoring fieldwork throughout the year.

Meeting the criteria for soil and inland aquatic monitoring sites is even more challenging to comply with. For soil monitoring, a site must have two types of soil within ten kilometers of the forest to be monitored. For an inland aquatic monitoring site, it should be at the same location as the soil-monitoring site, and the alkalinity of the inland aquatic environment should be less than 0.05 $meq \cdot L^{-1}$. Despite certain constraints, however, EANET member countries were collectively able to overcome the challenges and successfully established 48 wet monitoring sites (17 remote, 12 rural, and 19 urban) and 34 dry monitoring sites (10 remote, 11 rural, and 13 urban) in 12 participating countries (one country joined EANET after 2004). In addition, for the purpose of conducting an ecological impact study, 12 inland aquatic monitoring sites (nine lakes/reservoirs and three streams) in eight participating countries and ten soil and vegetation monitoring sites in five participating countries were established. This is a significant number of monitoring sites established as part of East Asia network.

Establishing monitoring sites is only one part of the monitoring network. Participants are also required to follow standardized methods of collecting, storing, transporting, and analyzing samples. The NC provided technical manuals and examples of standard operating procedures (SOP) for all participating countries so they could follow identical guidelines and ensure the QA/QC of the monitoring data. The first package of technical documents was distributed to all participating countries at the startup of the monitoring network, containing the specification of chemical content and the standard method of collecting, storing, and analyzing the samples collected from dry and wet deposition, inland aquatic environments, and soil and vegetation monitoring sites.

4.2.2 Establishment of task forces

Due to the complexity of determining the sampling data of dry deposition (air concentration) and to assess the impact of acid deposition on inland aquatic environments, soil, and vegetation, SAC appointed two task forces, consisting of both SAC members and non-SAC experts specialized in these areas. The two task forces are responsible for ensuring the QA/QC programs are followed for sample collection and chemical analysis, and to develop strategy papers for EANET future direction for both dry deposition monitoring and soil and vegetation monitoring. The duties of the two task forces are explained below.

4.2.2.1 Task Force on Dry Deposition Monitoring

The initial task of developing the *First Strategy Paper for the Future Direction of Dry Deposition Monitoring of EANET* was completed in 1999. The document identified the priority chemical species and the necessity of preparing a QA/QC technical manual, as well as discussed EANET future direction in dry deposition monitoring. The *Second Strategy Paper for the Future Direction of Dry Deposition Monitoring of EANET* was issued in 2005, which further elaborated on the future activities of combining research activities with routine monitoring and intensive research on the methodology for dry deposition monitoring. As the filter pack sampling technology is somewhat susceptible to sampling problems when humidity is high, further research on air sampling technologies by the NC and participating countries is expected.

To elaborate on the importance of obtaining accurate and precise data on dry acid deposition, the Task Force on Dry Deposition Monitoring issued a second document in 2002 focusing on QA/QC activities for monitoring air concentration in East Asia. The QA/QC manual provides guidelines on the levels of specifications for automatic instruments, data quality objectives, site selection, site performance auditing, measurement and analysis, routine and periodic checks and maintenance of automatic instruments for gas concentration monitoring, and data checking and data quality control, etc. Specific QA/QC activities, such as inter-laboratory comparison of filter pack samples and inter-calibration of ozone (O_3), were proposed during SAC discussions on the future direction of dry deposition monitoring. By early 2005, the inter-laboratory comparison of filter packs was first attempted, and the filter pack synthesized chemical samples were distributed to all participating countries to carry out assessments of laboratory performance—an important step toward achieving proper QA/QC in the area of dry deposition monitoring in the East Asia region.

4.2.2.2 Task Force on Soil and Vegetation Monitoring

Assessing the ecological impacts of acid deposition is an ambitious task, which requires a long-term spatial and temporal database of changes in soil and vegetation both chemically and physically. The Task Force on Soil and Vegetation Monitoring was first appointed by SAC in 1999, and then reappointed later for the regular phase in 2001 to prepare the *Strategy Paper for the Future Direction of Soil and Vegetation Monitoring of EANET*. Based on that document, various activities have been carried out to promote soil and vegetation monitoring. Especially of note is the fact that improving the methodologies for forest monitoring has been discussed in cooperation with the International Co-operative Programme on Assessment and Monitoring of Air Pollution Effects on Forests (ICP-Forests) under the Convention on Long-Range Transboundary Air Pollution (CLRTAP). Although the number of participating countries conducting soil and vegetation monitoring is small compared to those involved in wet and dry deposition monitoring, due to an un-readiness to join the program at this time, the experiences learned during EANET first five years will greatly enhance discussion among soil and forest scientists of the effects of acid deposition.

4.2.3 Establishment of a database and dissemination of information

With the enormous amount of data resulting from the monitoring conducted by the participating countries since the year 2000, EANET had to create a system to store and retrieve this information for Network members, as well as to decide how to share it with other interested researchers and organizations outside EANET. The NC compiled all sets of verified monitoring results to create a common database for data processing and application. The data obtained through EANET activities from the start of its regular phase are quite valuable in promoting understanding of the acid deposition phenomena in the East Asian region. Two relevant documents, *Procedures on Data and Information Disclosure for the Acid Deposition Monitoring Network in East Asia (EANET)* and *Detailed Mechanism of Article 4 of the Procedures on Data and Information Disclosure for EANET*, were endorsed, respectively, at the Third Session of the Intergovernmental Meeting and the Fifth Session of the Intergovernmental Meeting.

Data are now available as follows:
- EANET monitoring data are published in the annual *Data Report on the Acid Deposition in the East Asian Region*, which began publication in 2000.
- The data and information obtained during EANET regular phase are available upon request by CD or through EANET website for download upon registration.
- Disclosure of data to the public outside of EANET is available upon request at no charge.

Furthermore, the data submitted to the NC and relevant scientific and technical information have also been disseminated among the participating countries through the EANET website or by other means, as well as to other countries, relevant organizations, and individuals, in accordance with the adopted procedures. Periodic updating of the EANET website has been undertaken to include all-important records of EANET activities, as deemed appropriate.

4.3 Strengthening technical capacity in participating countries

4.3.1 NC technical missions to participating countries

In acknowledgement of the varying levels of technical capability among participating countries, the NC dispatched technical missions to assist laboratory personnel in improving their skills, to discuss technical problems, and to exchange and disseminate the latest technical information and experiences with the national focal points (NFPs) and other relevant staff at local and national levels. NC missions were sent to all participating countries each year with the aim of visiting network monitoring sites and laboratories, to have technical discussions with local experts on acid deposition issues, and to exchange information and experiences on the preparatory and regular-phase activities (Table 4.1).

The missions often included not only NC staff but also experts from national institutes, universities, and local governments from Japan. These missions were considered very useful for the Network in assessing the current and potential capacities of the participating countries, as well as for them to have detailed technical discussions among various experts from relevant agencies and academies.

EANET cooperated with the Japan International Cooperation Agency (JICA) to conduct a development study titled *The Acid Deposition Control Strategy in the Kingdom of Thailand*. Along with contributions to certain topics, the NC dispatched experts to Thailand in January/February 2003 as members of the advisory committee for the study.

Table 4.1 NC technical missions to countries participating in EANET (2001–2005)

Country	Purposes of each technical mission	Number of missions
Cambodia	To exchange information and views on institutional and technical arrangements for EANET activities in Cambodia, and to visit a laboratory and a candidate monitoring site, etc.	4
China	To exchange information and views on the progress of EANET, including monitoring activity in China, and to exchange other information and views on China's new monitoring plan, including new monitoring sites and monitoring methodology, etc.	5
Indonesia	To discuss and exchange information on technical issues, especially QA/QC activities and data reporting, including checking the analytical instruments and visiting the candidate site for inland aquatic environment monitoring, etc.	5
Lao PDR	To exchange information and views on technical cooperation by the NC, to visit a laboratory and a candidate monitoring site for EANET activities, and to exchange information and views on technical support to Lao PDR, etc.	4
Malaysia	To strengthen the skills of laboratory personnel, exchange and disseminate the latest technical information and experiences with the NFP, and to discuss and exchange information on wet and dry deposition monitoring by the Malaysian Meteorological Service (MMS), etc.	4
Mongolia	To discuss the methodologies of wet and dry deposition monitoring, especially the condition of the filter pack sampling system, and to exchange information and views in detail on the progress of EANET soil and vegetation monitoring, etc.	4
Myanmar	(Began participating in EANET in November 2005)	
Philippines	To discuss and exchange information on technical issues, especially QA/QC activities and data reporting, and to visit the candidate monitoring site for wet/dry deposition and inland aquatic environment, and to discuss the arrangement of suitable site performance, etc.	5
Republic of Korea	To hold the Workshop on Joint Research Project for the Measurement of Aerosol, and to exchange information and views in detail on the progress of EANET monitoring of wet and dry acid deposition and soil and vegetation in the Republic of Korea, etc.	5
Russia	To finalize a memorandum of agreement (MOA) with the Cooperative Research Project, visit atmospheric monitoring stations in East Siberia and a site for inland aquatic environment monitoring, and to attend the Vereshchagin Baikal Conference at the Limnological Institute, etc.	5
Thailand	To discuss the Joint Research on Dry Deposition Flux and its MOA, attend the Thailand national training, and to visit monitoring sites and laboratories and discuss technical issues, etc.	5
Viet Nam	To exchange information and views on the progress of activities on acid deposition monitoring in Viet Nam, and to visit relevant agencies for the exchange of information and discussion of cooperation in acid deposition monitoring activities in Viet Nam, etc.	5

4.3.2 Senior Technical Managers' Meeting

Participating countries have occasionally needed assistance with troubleshooting and resolving problems, such as being unsure of the procedures proposed by the Network, resolving certain differences in techniques used, as well as difficulties faced in finding a responsible person to make appropriate decisions or to advise laboratory personnel, among other things. Senior Technical Managers (STM) were appointed by the NFPs to take on such responsibilities. In order to strengthen their capacity to do the work, the NC organized a series of STM meetings, starting from the beginning of EANET regular phase of activities in 2001. There were six meetings held at ADORC (Niigata, Japan) and in one participating country up to 2005, which were attended by the respective STMs of all participating countries as well as experts from relevant organizations. They discussed important technical issues such as national monitoring plans, yearly monitoring data, and the results of the inter-

laboratory comparison projects. Also discussed and observed were other EANET activities, including the process of preparing this first *Periodic Report*, as well as guidelines and research studies (Table 4.2). The last STM meeting, in 2005, was attended by some SAC members in order to maintain connections and provide advice to country representatives.

Table 4.2 List of Senior Technical Managers' meetings (STM) (2001–2005)

No.	Meeting objectives	Date/location
1	To exchange information and experiences on the technical issues of participating countries during the preparatory phase and to clarify some important technical issues, such as site selection criteria, etc.	20–22 February 2001, Niigata
2	To report on the progress of scientific and technical matters related to EANET since the First STM Meeting and to consider the national monitoring plans of participating countries, etc.	19–21 September 2001, Niigata
3	To report on the progress on scientific and technical matters related to EANET since the Second STM Meeting and to consider the monitoring data and results of inter-laboratory comparison projects in 2001, etc.	2–4 October 2002, Niigata
4	To consider the monitoring data and results of inter-laboratory comparison projects in 2002 and to discuss other technical issues to be considered further at the Third Session of the Scientific Advisory Committee (SAC3), etc.	1–3 October 2003, Niigata
5	To consider improvement of monitoring methodologies and to discuss other technical issues to be considered further at the Fourth Session of the Scientific Advisory Committee (SAC4), etc.	28–30 September 2004, Niigata
6	To provide an overview of the EANET activities of participating countries, presented by the NC and the participating countries, and to consider the research activities on acid deposition, etc.	27–29 July 2005, Hanoi

4.3.3 Training workshops on monitoring acid deposition in East Asia

Improving the capabilities of personnel to be involved in EANET activities in participating countries was started during the preparatory phase with the goal of preparing qualified people to carry out Network operations and development. Considering the importance of such endeavors at the beginning of such a long-term project, the kick-off training workshops were described in this chapter because they are closely related to EANET regular-phase activities during 2001–2005.

The First Special Training Workshop was organized in Niigata, Japan, in 1998, immediately after the participating countries agreed to start the preparatory phase of EANET. The results of the work of the Interim Scientific Advisory Group and the Special Working Group were used to assist participating countries with the start-up of monitoring activities in a smooth and effective manner, including dissemination of technical matters on monitoring and reporting procedures, QA/QC programs, and recommendations on the implementation of measurements under the sometimes unique situations in the respective countries. The improvement of technical capacities was recognized as being necessary, together with priority placed on training in ecological monitoring. Further elaboration of the guidelines, technical manuals, and training materials was requested in order to overcome difficulties with their application and to monitor performance.

Due to existing problems with monitoring and applying methodologies suitable for vegetation in the diverse soils and climatological conditions in participating countries, the Second EANET Training Workshop on Ecological Impact Monitoring was organized in Beijing, China, in 1999. The workshop met the objectives of disseminating technical information on soil and vegetation surveys involved in EANET monitoring, elaboration of the methodologies for conducting soil and vegetation surveys together with QA/QC activities suitable for East Asia, as well as ways for reviewing the monitoring guidelines, technical manual, and the QA/QC program for soil and vegetation monitoring. Analytical methods based on the latest scientific information and the experiences gained by the participating countries were discussed during the workshop sessions.

The workshop yielded the establishment of the Network on Soil and Vegetation Specialists among the participating countries of EANET in order to facilitate the exchange of information and experiences, as well as to implement the inter-laboratory comparison program of chemical analysis on soil monitoring. It was also requested that the Task Force on Soil and Vegetation Monitoring for EANET be established in order to create a step-by-step strategy towards the ultimate objectives of soil and vegetation monitoring, together with developing methodologies suitable for East Asia and strengthening collaboration with other international organizations dealing with acid deposition problems. The involvement of technical officers from the participating countries and supporting organizations in these important capacity-building events is presented in Table 4.3.

The Workshop on Elaboration and Development of Forest Monitoring in East Asia was organized jointly by the NC and the CLRTAP International Co-operative Programme on Assessment and Monitoring of Air Pollution Effects on Forests (ICP-Forests) in Malaysia (16–19 December 2002) to discuss numerous technical issues involved with preparation and starting of forest monitoring in East Asia. Participants from ten EANET countries, representatives of ICP-Forests and the Integrated Monitoring Program on Acidification of Chinese Terrestrial Systems (IMPACTS, China), as well as other experts from East Asia and Europe, provided evaluation of existed methodologies and the need for these activities. The preparation of a sub-manual for EANET forest monitoring was pushed ahead using outlines and results summarized by the NC on these topics in line with the *Strategy Paper*.

Table 4.3 Number of workshop participants (1998–2002)

Country	Workshops		
	1st Training (1998)	2nd Training (1999)	On Elaboration of Forest Monitoring (2002)
Cambodia			1
China	2	7	1
Indonesia	2	1	1
Japan	5	3	1
Lao PDR			1
Malaysia	1	2	6
Mongolia	1	1	1
Philippines	1	1	1
Republic of Korea	1	1	
Russia		1	
Thailand	1	2	1
Viet Nam	1	1	1
International experts		1	9
JICA experts		4	
Observers	10*	10**	
Total	25	35	24

* From Japan; ** From China

4.3.4 Assistance and technical support for individual participating countries

The NC has implemented technical cooperation programs for participating countries, with the Ministry of the Environment (MOE), Japan, providing technical and financial support. Various technical recommendations and dissemination of the latest technical information on acid deposition monitoring were also provided to national centers and relevant offices of the EANET network. The NC donated to many of the participating countries the materials necessary for conducting measurements, such as spare parts and consumable supplies for monitoring equipment as well as standard reference materials for analysis of samples.

With special attention to the capacity of newly participating countries to start EANET activities, monitoring equipment, such as pH meters, electric conductivity meters, sets of consumable supplies and standard reference materials for wet deposition monitoring, were provided to Cambodia and Lao

PDR in February 2004. Furthermore, a sales contract was executed between the EANET Secretariat (UNEP/RRC.AP) and a distribution company for the procurement and installation of ion chromatographs in Cambodia and Lao PDR using funds available due to cost savings of the Secretariat, under a decision made at the Sixth Session of the Intergovernmental Meeting (IG6) in 2004.

4.3.5 Dispatch of JICA experts on acid deposition to EANET countries

Since 1999, JICA has dispatched Japanese experts on acid deposition to EANET countries for short term missions to promote QA/QC activities, in cooperation with the Ministry of the Environment, Japan, and the NC. These included conducting capacity-building activities in the developing countries involved in the Network. From 1999 to 2005, a total of 42 JICA experts visited China, Indonesia, the Philippines, Thailand, and Viet Nam (Table 4.4). The results from 1998–2000 are also included here because the project, titled *Dispatch of Short Term Experts on Acid Deposition*, was started from the Japanese fiscal year (JFY) 1998.

Table 4.4 Number of Japanese experts from JICA dispatched to the participating countries since 1998

Country	1998	1999	2000	2001	2002	2003	2004	2005	Total
Cambodia									
China	1	2	6	3	4	4	4		24
Indonesia	2	1		1	2				6
Lao PDR									
Malaysia									
Mongolia									
Myanmar									
Philippines			1	1		1			3
Thailand	1					2	2	2	7
Viet Nam		1	1						2
Total	4	4	8	5	6	7	6	2	42

Notes: Japan, the Republic of Korea, and Russia have not been involved in this supporting activity because JICA rules do not allow it. Included in the table is the number of experts that participated in Technical Cooperation Projects and the Third Country Training Course on Acid Deposition in Thailand.

4.3.6 Communication and coordination with other programs and donor agencies

The NC and the EANET Secretariat tried to maintain close cooperation and coordination with other initiatives by maintaining ongoing contact with relevant international and bilateral organizations such as UNEP, Co-operative Programme for Monitoring and Evaluation of the Long-range Transmissions of Air Pollutants in Europe (EMEP), World Meteorological Organization (WMO), etc. Their representatives had participated in important EANET meetings and workshops, and provided updated information on all kinds of their activities relevant to EANET and possible cooperation among programs. The technical documents (manuals, guidelines, reports) and assessment materials are put in an exchange with other international networks.

A joint seminar held by EANET and EMEP was organized with the cooperation of the Russian NFP in November 2005 to identify and discuss the integrated modeling and monitoring approaches for the assessment of long-range transboundary pollution transport in East Asia. Various activities of EANET, participating countries, and EMEP in the fields of atmospheric monitoring, emission inventories, and modeling of regional and hemispheric long-range transport were introduced and discussed. A number of conclusions and recommendations for future collaboration were agreed by the participants to encourage closer cooperation between EANET and EMEP at the regional and hemispheric scale.

4.4 Implementation and coordination of QA/QC activities

To ensure the quality of the monitoring data, the NC carried out inter-laboratory comparison projects on wet deposition (with synthesized rainwater samples for round-robin analyses), soil, and artificial surface water by sending the samples to participating EANET laboratories. To expand QA/QC activities to dry deposition monitoring, the inter-laboratory comparison of a four-stage filter pack method was conducted at the end of 2005 after the set of relevant research was completed. By the end of the first five-year period of EANET activities, the inter-laboratory comparisons were implemented for all measurement media except vegetation monitoring. The analytical results were processed and published in annual issues of the *Report of the Inter-laboratory Comparison Project* on the listed monitoring items, and improvement of the analytical technical capabilities of the laboratory staff of participating countries was seen. More detailed analysis is presented in Chapter 2, and a number of attempts for the period of 1999–2004 are detailed for each project category, as follows.

- Seven attempts were processed on the analysis of wet deposition samples. Synthesized rainwater samples were dispatched to 27 laboratories of 12 participating countries during the latest one. Reports of the inter-laboratory comparisons on wet deposition during 1999–2005 are available for general references.
- The fifth attempt was performed on inland aquatic environment monitoring. The synthesized surface water samples were sent and analyzed by 15 laboratories of eight participating countries. Reports of correspondent inter-laboratory comparisons during 2000–2005 are also available for general references.
- The sixth attempt was started on soil analyses in 2004. The soil samples prepared by the NC were dispatched for analysis to 14 laboratories of ten participating countries. Reports of inter-laboratory comparisons on soil during 2000–2005 are available for general references.

Improvements were made in the QA/QC of the participating laboratories through the inter-laboratory comparisons. At the least, the analytical precision and accuracy of equipment used and methods of laboratory analysis employed can be identified for each participating laboratory. The precision can be specified both within-laboratory and among the inter-laboratory project as a whole. Hence, the monitoring data on acid deposition for long-term assessment can be compared and assessed with correspondent recognition of their quality.

In response to a SAC recommendation, the *Questionnaire on Participation in International Inter-laboratory Comparison Projects* has been distributed by the NC as a biannual survey of national centers in participating countries since 2002. Respondents indicated their interest in greater involvement of EANET laboratories in a worldwide inter-comparison on analysis of acid deposition samples. Several laboratories of EANET countries started contributing to EMEP and ICP-Water campaigns, resulting in some successes and benefits for those who participated. The NC is also continuing to provide advice to promote further EANET participation for increasing both the coverage of national centers and the scope of analysis using the possibility of international cooperation.

4.5 Training and education

4.5.1 Development of training programs and materials

In order to identify the needs of the participating countries and to strengthen the capacity-building activities of EANET in the regular phase, the NC carried out a special questionnaire survey in 2001. The results obtained by this survey were used by the NC to develop a document titled *Training Programs for EANET in its Regular Phase*. It was endorsed at the Third Session of the Intergovernmental Meeting (IG3) in November 2001, and was applied to coordinate implementation of EANET capacity-building activities during the regular phase of activities.

In accordance with the document mentioned above, the NC developed annual programs of individual training at ADORC that are implemented twice a year. The experience of trainees in conducting

monitoring and sample analysis was taken into account, as well as the national results of inter-laboratory comparison projects and the specific circumstances of respective participating countries. This training program includes selected candidate countries for training, scheduling, and contents of the training course prepared under consultation with participating countries to meet their needs and requests. Basically, the programs include the main topics of monitoring (wet deposition, dry deposition monitoring, soil and vegetation monitoring, and inland aquatic environment monitoring) as well as data management.

To support the training courses, the NC developed a number of textbooks on basic knowledge on monitoring approaches, such as *Fundamental Methodology for Wet Deposition Monitoring* (2005), *Fundamental Limnology for Inland Aquatic Environment Monitoring on Acidification* (2003), and *Quality Assurance and Quality Control in Soil Monitoring* (2001), and practical tutoring on procedures for data management of wet deposition monitoring. These issues were prepared by leading experts of EANET countries to be used for EANET training activities, in line with the document titled *Training Programs for EANET in the Regular Phase*.

4.5.2 National training activities on EANET-related issues

It is very important to know the present status of the participating countries in terms of their capability to deal with acid deposition problems and to identify their actual training needs. Through the experiences accumulated during the preparatory and the regular phases, the NC has been making efforts to identify the specific training needs of participating countries, improve training activities, and elaborate on the relevant capacity-building activities in close communication, cooperation, and coordination with relevant organizations. A special questionnaire survey on national training activities is conducted annually by the NC, and as a result it is recognized that there are still various training needs of the participating countries to be addressed.

After EANET first five years, the technical capabilities and skills of monitoring execution have been improved through the national training programs. The participating countries are expected to continue to implement them in various fields, such as maintenance of sampling equipment, transportation and analysis of samples, and data management, for example. Table 4.5 summarizes the national training conducted in participating EANET countries.

Table 4.5 National training activities in participating EANET countries (2001–2005)

Country	Themes of national training and capacity-building activities	Number of activities
Cambodia*	Training on Atmospheric Pollution and its Influence, etc.	8
China	Annual Workshop on EANET in China, Training Course on Acid Deposition, etc.	10
Indonesia	Training on analysis method	1
Japan	Training on Instrumental Analysis, Training on Water Analysis, Training on Operation of Automatic Ambient Air Monitoring Instruments, etc.	37
Lao PDR*	Air Quality Monitoring in Vientiane in 2006–2010	1
Malaysia	Meteorological Aspects on Pollution Course, Workshop on Regional GHG Measurement and Modeling, etc.	18
Mongolia	Annual seminar on environmental monitoring, air pollution, and acid deposition.	11
Philippines	Introduction of Passive Sampling Method/Preparation of Sampler, Seminar/Workshop on Acid Deposition Monitoring, etc.	12
R.of Korea	Training on Air Quality Measurement, Acid Rain Measurement	4
Russia	Individual training, training course on water analysis, on inter-laboratory comparison project on "reference material," etc.	21
Thailand	Seminar on Acid Deposition Problem in Thailand, National Training on Acid Deposition Monitoring in Thailand, etc.	9
Viet Nam	Advanced Training Workshop on Regional greenhouse gas measurement and modeling, Technical Workshop on QA/QC activities for wet and dry deposition	7

*The surveys covered the years after the start of participation in EANET.

According to the summaries of the annual *Questionnaire Survey for National Training* (2001–2005) reported by the NC, most participating countries carried out annual activities in national training and capacity building, such as national workshops, technical meetings, and individual training, etc. They implemented various kinds of training/capacity-building activities in line with their specific needs and under the existing institutional framework. The major topics of national training during the regular phase in 2001–2005 were improvement of wet deposition (including sampling and analysis) and dry deposition monitoring (including air quality monitoring and analysis). Correspondent training on soil, vegetation, and inland aquatic environment monitoring (including sampling and analysis of inland water) were implemented, as well as tutoring on data management and emissions inventory.

The NC conducted continuous cooperation with the participating countries and provided necessary technical support for implementation of their national training programs on acid deposition monitoring by sending experts to Thailand (March 2002), China (five times between 2002 and 2004), and Indonesia (February 2003). An NC expert also participated and contributed to a special annual national workshop in China on acid deposition monitoring in March 2003.

4.5.3 Coordination with other training programs and support for their implementation

4.5.3.1 JICA Training Course on Acid Deposition Monitoring in Japan

The JICA Training Course on Acid Deposition Monitoring has been carried out in Kobe, Japan, since 1997. Developed together with the progress on monitoring activities, the contents of courses mostly correspond to the practices and needs of the EANET network. Using this opportunity, the NC has maintained close communication and coordination with the organizers of the JICA course on their curriculum by sending experts to attend the steering committee meeting and to lecture on EANET monitoring and data management, as well as by holding ad hoc technical coordination meetings and introductory short-term practice for trainees in ADORC and operating monitoring sites.

During the training period of about 2.5 months, knowledge was provided on many relevant issues, with a focus on the transport and transformation of air pollutants and the mechanism of acid deposition; the damage to ecosystems caused by acid deposition; technologies for monitoring acid deposition, including ecosystem monitoring; and measures to reduce the emission of substances, etc. Table 4.6 provides information on the number of specialists from EANET countries that increased their capacity by attending the *JICA Training Course on Acid Deposition Monitoring* in 1997 to 2005.

Table 4.6 Participation of technical officers in EANET countries in the JICA Training Course on Acid Deposition Monitoring (1997–2005)

Country	1997	1998	1999	2000	2001	2002	2003	2004	2005	Total
Cambodia	1		1	1	1	1	1	1	1	8
China	1	1	1	1	1		1	1	1	8
Indonesia	2		1	1	1	1	1	1	1	9
Lao PDR		1			1	1	1	1	1	6
Malaysia	1	1	2	1	2	2	1	1	1	12
Mongolia	1	1	1	1	1	1	1	1	1	9
Myanmar								1	1	2
Philippines	1	1	1	1	1	1	1	1	1	9
Republic of Korea	1	1								2
Thailand	1	1		1	1	1	2	1	1	9
Viet Nam		1	1	1	1	1	1	1	1	8
Total each year	9	8	8	8	10	9	10	10	10	83*

Notes: Japan, the Republic of Korea, and Russia have not been involved in this activity during the regular phase of EANET (from 2000) because of JICA rules. Also, since this course supported the Network with relevant technical officers and managers in the participating countries before the establishment and operation of EANET, the training courses held from 1997 to 2000 are included.

*The total of 83 participants includes one participant from another region (India) in 1998.

4.5.3.2 JICA Third Country Training and other JICA training courses

The Third Country Training was identified in the *Training Programs for EANET* document as one of the activities of the Network supported by JICA. As one relevant initiative in collaboration with EANET, JICA organized a workshop on overall acid deposition problems in East Asia (not just monitoring) in Bangkok in October 1999. The Development Study on Acid Deposition Inventories and Modeling for Thailand was organized as the result of discussions, and it was conducted for several years under collaboration with the NC. Based on the results of this study and capabilities identified, the initiative to conduct the Third Country Training was accepted by JICA with the aim of utilizing and sharing the major outcomes of the experiences in Thailand.

In the first phase, Thailand organized the Third Country Training on Acid Deposition Monitoring and Assessment for the junior staff of interested participating countries in 2004 for the following two years. Experts from ADORC and the host country gave lectures on scientific subjects related to acid deposition and laboratory training. The second-phase of the Third Country Training, titled Emission Inventory and Modeling for Acid Deposition Assessment, was decided to be in Thailand in 2005 for the next two years. The training course included methods to carry out emissions inventory of stationary and mobile sources, as well as sessions on the hand application of the RAINS-Asia model. One of the benefits gained from completing this training course is that it will allow more efforts in looking further into extensive laboratory exercises, including training for maintenance of equipment and focusing more on specific issues of concern, etc. The number of specialists from EANET countries involved in the *Third Country Training courses* and JICA training-related acid deposition monitoring is presented in Table 4.7.

The participating countries and the NC cooperated on utilizing other opportunities through various JICA training programs. The expert from the Philippines received experience on air quality monitoring, including acid deposition monitoring, at the NC in February 2003, as part of his JICA counterpart trainings, and another trainee from Thailand received training focused on emissions inventory and numerical modeling at the NC in March 2003.

Table 4.7 The number of technical officers in EANET countries that participated in the Third Country Training Program (Thailand) and other JICA training courses

Country	Third Country Training				JICA counterpart training			
	2003	2004	2005*	Total	1999	2000	2003	Total
Cambodia	2	3	2	7				
China	2	2	2	6				
Indonesia		1	3	4	1			1
Lao PDR	2	2	2	6				
Malaysia		2	1	3				
Mongolia	2	2	3	7				
Myanmar		2	2	4				
Philippines		1	1	2		1	1	2
Thailand	6	4	6	16			1	1
Viet Nam	4	3	2	9				
Total	18	22	24	64	1	1	2	4

Note: The table includes the number of relevant participants from JFY 1999, when the JICA counterpart training for acid deposition first began.

* The training was conducted at the beginning of 2006 but financed under the 2005 budget.

4.5.4 Individual training by the EANET Network Center

To improve the professional skills of the specialists and meet the needs of the participating countries, individual training has been carried out at the NC every year, upon consultation with participating countries and in consideration of their specific purposes, such as installation of new equipment, personnel changes, and so on. It was organized in line with the document titled *Training Programs for EANET in the Regular Phase*. The NC decided on the content of training and some specialization after

consultation with the NFPs and supervisors of the trainees. The number of trainees that completed the individual training course at ADORC since 2000 is presented in Table 4.8.

Table 4.8 Country of origin and number of technical officers trained at the NC (2000–2005)

Country	2000	2001	2002	2003	2004	2005	Total
Cambodia				1	1	1	3
China			2	1	1	1	5
Indonesia		3	1			1	5
Lao PDR				1	1	1	3
Malaysia		1			1		2
Mongolia			1				1
Philippines		1	1		1		3
Russia	1						1
Thailand	2		1	1		1*	5
Viet Nam		1		1		1	3
Total	3	6	6	5	5	6	31

*Travel costs and other individual expenses during the training were borne by each country.

4.6 Joint research activities on acid deposition

Because of the geographical diversity found within the region of East Asia, the extensive scientific research conducted on acid deposition in certain areas of interest can be beneficial for countries under different climate conditions. The Joint Research Projects on acid deposition have been raised since the first SAC meeting, and the NC was requested to explore the possibility of carrying out joint research projects with selected participating countries of EANET. The existing Japanese fellowship schemes, such as the fellowship grants under the Ministry of Education, Culture, Sports, Science and Technology, and the Eco-Frontier Fellowship Program under the Global Environment Research Program, are used to financially support the research programs. The overall scientific and technical levels of the Network have improved through such joint activities. It is especially favored to undertake research on the ecological impacts on soil and vegetation. The current joint research activities and the outcomes of the research conducted during the first five years of EANET are listed below.

4.6.1 Joint research project with Russia

The NC implemented the first phase of a joint research project, titled *Standardization and Advancement of Assessment Methods of Acid Deposition in the Frigid Zone*, with the Limnological Institute, Russian Academy of Science–Siberian Branch. The objective of the joint research was to obtain basic information for improving monitoring methodologies applicable to the frigid zone by implementing test monitoring, in accordance with EANET technical manuals on acid deposition monitoring, and investigate the following items: (1) applicability of QA/QC programs, (2) workability and applicability of a wet-only sampler, (3) applicability of filter pack methods in dry deposition monitoring, (4) evaluation of snow-melt water on the inland aquatic environment, and (5) evaluation of the methodology of species composition monitoring of diatoms.

The second phase of the joint research project, titled Evaluation of the Atmospheric Environment in East Siberia and the Primorsky Region, was implemented in order to obtain basic information on the atmospheric environment in East Siberia and the Primorsky region and on transboundary air pollution over the North East Asian/Pacific part in the Northern Hemisphere. In this project, annual acid deposition as well as heavy metals (mercury and lead) and lead isotope ratios are measured.

4.6.2 Joint research projects with Thailand

In order to calculate the amount of acid deposition using the monitored air concentration data, an evaluation of deposition velocity parameter values is required. These values are varied depending on

the type of land cover (i.e., agriculture, forest, or bare land) and the regional climate (i.e., seasonal or weather changes in tropical, subtropical, or temperate zones). Information on the dry deposition velocity and a model to predict this value for many gases is available mostly for the areas located in the temperate regions. To receive suitable data for the EANET region, the Joint Research Project on Dry Deposition Fluxes and Velocities of SO_2 and O_3 for Tropical Forest was initiated in Thailand in 2000. It was also pointed out as one of the activities in line with the *Strategy Paper for Future Direction of Dry Deposition Monitoring of EANET*. The dry deposition flux and velocity of O_3 were evaluated and obtained after the five years of the project's implementation; however, those for sulfur dioxide (SO_2) require further study.

Another joint research project that the NC started in 2005 in Thailand was on catchment analysis, with the cooperation of Thailand's Royal Forest Department (RFD) and the Environmental Research and Training Center (ERTC), by using the Global Environment Research Fund of the Ministry of the Environment, Japan. Monitoring of input (atmospheric deposition) and output (stream water) fluxes in/from a small catchment area have been carried out continuously, together with analysis on other biogeochemical aspects, and with this information the nutrient dynamics and acid deposition impacts in the area will be estimated. The project will be informative for evaluation of the adverse effects on ecosystems, in line with the *Strategy Paper for the Future Direction of Soil and Vegetation Monitoring of EANET*.

4.6.3 Joint research project with Mongolia

In order to study the direct effects of acid deposition on plants, it is necessary to accumulate information on plant sensitivity to acid deposition in respective climatic zones. The Mongolian ecosystems are quite different from others within the East Asia region due to specific regional variations in climate and topography. In addition, in the (sub-) arid zone, the sensitivity and/or physiological response of plants to acid deposition have not been studied to a great extent. A decline of larch trees (*Larix sp.*) has been reported on Bogdkhan Mountain around Ulaanbaatar, Mongolia, and it might be due to air pollution from the thermal power plants around this area. The results of study will be useful for identifying emission effect indications in other areas of climate similar to Mongolia.

The *Joint Research Project on Plant Sensitivity to Acid Deposition in Mongolia* was carried out over several years. The basic information on air concentration and the physiological responses of investigated plants to acid deposition were obtained and will be used for further studies.

4.6.4 Fellowship research

A researcher from the Republic of Korea carried out a joint study with the NC on the inland aquatic environment from October 2001 to March 2002. His research was supported by the Eco-Frontier Fellowship Program of Japan, and experience obtained by him through this study is expected to be benefit for the ecosystem assessment in the participating country.

The Russian researcher was supported by the *Japan Society for the Promotion of Science* (JSPS) Fellowship Program for Research in Japan (short term) under the application of the NC as the host organization. In line with the main goal of promoting research on monitoring methodology for detection of acid deposition impacts on forests, he came to the NC in April 2004 for two months to study methodologies of monitoring lichens in East Asia.

The research fellowship was established at the NC during 2005–2006, under the agreement reached at the Sixth Session of the Intergovernmental Meeting (IG6) in November 2004, with a budget to invite two researchers a year from participating countries. A special guideline for a short-term research fellowship at the NC was developed and adopted to carry out the application procedure in 2005. The NC received nine applications from five participating countries, and decided to invite two researchers (from China and Philippines) after consideration of the contents of proposed research plans, with a view on future development of EANET and increased promotion of monitoring research activities.

4.7 Programs for promotion of EANET activities

One of the important programs to promote EANET activities is to raise public awareness in the participating countries. It is an initiative to increase understanding among the public of the causes and impacts of acid deposition. In particular, it aims to provide some understanding and evidence that these impacts can come across the East Asian regions. This initiative provides the general public with information on what they can do to avoid these impacts. To raise public awareness about the issue, open workshops on acid deposition were organized by participating countries during EANET first five years. Teaching materials have been developed to strengthen the capacity of educators to teach about the issues of acid deposition.

4.7.1 Development of the *Report for Policy Makers*

Special reporting was started with the first *Report for Policy Makers* (RPM) to make them aware of the acid deposition problem and relevant efforts in East Asia. The EANET Secretariat prepared an RPM, titled *EANET Goals, Achievements and Way Forward*, in cooperation with the NC and experts from participating countries. This report was launched during the High Level Segment at the Seventh Session of the Intergovernmental Meeting (IG7) in November 2005 in Niigata, Japan. Development of the RPM was requested by the IG6 after consideration and recognition that policy makers have an important role in rendering their leadership support for coordination among the concerned agencies, creation of more awareness, and promotion of national and regional initiatives to take appropriate measures on acid deposition. The major topics of acid deposition and its effects, development of EANET monitoring, and its achievements were refined for decision-makers, as well as introduction of the integrated approach and policy measures against atmospheric pollution and acidified deposition. For common agreement on this message, the special Review Workshop on RPM was held in Thailand in October 2005 to review its contents.

4.7.2 Joint projects on public awareness

The NC has been undertaking joint projects with selected participating countries to develop their own national brochures and/or videotapes on acid deposition since 1999, when brochures were first prepared in China and Thailand. The NC has promoted the development of these materials by selected participating countries every year with the cooperation of some organizations. In addition to the preparation of brochures in the respective national languages, a special workshop was also promoted for its dissemination in the countries. The number of joint projects on the development of national public awareness materials is presented in Table 4.9.

Table 4.9 List of promotion projects on public awareness of acid deposition problems in the participating countries (1999–2005)

Year	Country	Awareness material	In-country workshop
1999	China and Thailand	Brochures	
2000	China	Videotape and VCD	
2000	Malaysia and Philippines	Brochures	
2001	Indonesia and Viet Nam	Brochures	Philippines
2002	Mongolia	Brochures	Indonesia and Viet Nam
2003	Russia	Brochures	Mongolia
2004	Cambodia	Brochures	Russia
2005	Lao PDR	Brochures	Cambodia
Total	Brochures in ten countries and a videotape and VCD in one country		Six countries

Note: Activities from JFY 1999 are included, since the mentioned joint projects with the participating countries were started in that year.

4.7.3 EANET workshops on public awareness of acid deposition problems

The NC organized a workshop series, titled *Workshop on Public Awareness for Acid Deposition Problems*, starting with the first one in 2001 in Niigata, Japan, with the goals of exchanging experience and coordinating among participating countries on these activities, as well as to identify appropriate ways to promote environmental issues at the national level. The second workshop in 2002 in Beijing, China, was attended by approximately fifty participants and observers from participating EANET countries, as well as the following meetings listed in Table 4.10. The local government of the host country actively participated and supported these public awareness events by offering workshops for other target groups such as the general public and school children.

Table 4.10 International Workshop on Public Awareness for Acid Deposition Problems

	Purposes of each Workshop on Public Awareness	Date/venue
1	To exchange information and share relevant experience, mainly through the implementation of projects in Japan and joint projects with countries, etc.	23 February 2001, Niigata
2	To further encourage and promote public awareness activities in each participating country, etc.	21–22 February 2002, Beijing
3	To further encourage and promote public awareness activities in each participating country, and to exchange information and share experiences.	20–21 February 2003, Niigata
4	To exchange information and share experiences on public awareness activities and environmental education among the participating countries, and to enhance public awareness activities among the general public and school children, etc.	19–20 December 2003, Niigata
5	To exchange information and share experiences on public awareness activities and environmental education among EANET countries, and to enhance public awareness among the general public and school children	28–29 January 2005, Niigata

4.7.4 Development of an e-learning program

The promotion programs are meant to achieve their objective of creating awareness of acid deposition among the general public through education extended to secondary schools and institutions of higher learning in countries participating in EANET. An e-learning program on acid deposition problems has been developed by the NC for environmental education in collaboration with the Institute for Global Environmental Strategies (IGES) since 2002. An English version, titled Acid Deposition and the Environment, was finalized and is available on EANET website (http://www.eanet.cc). The NC also distributed CDs of the program to participating countries in 2006 in consideration of limited Internet access in those countries.

4.8 Major achievements of EANET

4.8.1 Major achievements during the preparatory phase (1998–2000)

Since EANET regular-phase activities have been implemented based on the experience gained during the preparatory phase, it is necessary to briefly describe the major achievements accomplished during this earlier period, as follows:

Guidelines and technical documents. A set of required methodologies and operational procedures was prepared, based on the results of the Expert Meetings in 1993–1995, to be applied for implementation of Network monitoring from the start of EANET preparatory phase. Further development and improvement of the guidelines and technical documents was done after submissions were received from the participating countries and a review was completed of the experience gained during the preparatory phase. Finally, the Interim Scientific Advisory Committee (ISAG) prepared and endorsed the revised guidelines and technical documents at its second meeting in March 2000 for use from that point onwards.

Quality assurance and quality control programs. These special programs, which accompanied the technical documents, were developed and adopted in 1998 by the First ISAG for the purpose of obtaining reliable data on acid deposition monitoring that could be comparable among the countries in the East Asian region, as well as with other regions, by ensuring data accuracy, precision, etc. The countries participating in EANET are expected to conduct their activities in accordance with the QA/QC programs, while still taking into account the particular situation in each country. To support the QA/QC activities, the first version of the *Training Programs for the Network* was also adopted at the First ISAG meeting. It included various kinds of capacity-building activities of EANET during the preparatory phase.

Report on the Acid Deposition Monitoring of EANET during the Preparatory Phase. The first evaluation report on EANET acid deposition monitoring activities during the preparatory phase, along with some preliminary results, was prepared by the end of that phase and published in August 2000. Besides describing the progress made in creating and developing the Network, the *Report on the Acid Deposition Monitoring of EANET during the Preparatory Phase* also emphasized ways and means to further improve EANET monitoring in the East Asian region.

4.8.2 Major achievements in 2001–2005

Network development: The acid deposition monitoring network was established as an operating international system which had an increased number of sites during 2001–2005. There are now 48 sites for atmospheric (wet and dry deposition) monitoring of different categories (17 remote, 12 rural, and 19 urban sites) in 12 participating countries (one country joined EANET in November 2005). For the purpose of conducting ecological impact studies, data and information were obtained at 12 inland aquatic monitoring sites (nine lakes or reservoirs and three streams) in eight participating countries and at ten sites for soil and vegetation monitoring established in five participating countries.

***Integrity of data acquisition and methodologies*:** Methodological unification and technical conformity were ensured within the network in terms of site selection, sampling techniques and collection, chemical analyses, etc., based on EANET technical manuals and guidelines, as well as coordinated promotion of technical capabilities.

***Data publication*:** Summaries of annual monitoring results are made in a regularly published *Data Report on the Acid Deposition in the East Asian Region*. All averaged data and information received with the help of monitoring by 12 participating countries for the first five years of EANET are disclosed and available outside the region.

***Implementation of quality assurance and quality control*:** A high-level control of data quality and assurance is performed regularly through implementation of the Inter-laboratory Comparison Project schemes. Six attempts were completed on analysis of wet deposition by the NC and 27 laboratories of 12 participating countries, while five attempts were made on soil analyses by 14 laboratories of ten participating countries, and four attempts were made on inland aquatic environments by 15 laboratories of eight participating countries. All results are summarized and reported by EANET in a special publication.

***Database establishment and data disclosure*:** EANET monitoring data is available to be studied and assessed in the annual *Data Report on the Acid Deposition in the East Asian Region*, which started as a regular publication in 2000. The verified measurement data from 2001 and thereafter are prepared for distribution on CD upon request. The NC and the participating countries make further efforts to organize data dissemination through the EANET website for download upon registration.

***Improving the technical capacity of participating countries*:** Capacity building-activities within EANET during its regular phase of activities were implemented in accordance with the document titled *Training Programs for EANET in the Regular Phase*. The NC sent special technical missions to

participating countries of EANET to assist them in monitoring performance, laboratory operations, data management, and other procedures to obtain data of appropriate quality. Cooperation between the NC, experts, and participating countries on efforts to increase the skills of personnel were made through conducting national workshops, individual training at the NC, annual meetings of Senior Technical Managers, as well as scientific workshops on ecological impacts and other relevant topics related to acid deposition in East Asia. The *Third Country Training Program* is promoted with support from EANET and JICA in each participating country with active contributions from EANET experts.

***Public awareness*:** The growth of creating awareness on acid deposition among the general public continues with the efforts of EANET bodies at the national and network levels, as well as educating awareness extended to secondary school and teachers of higher learning in countries participating in EANET. The special reporting was started with the first *Report for Policy Makers* to educate them on the acid deposition problem and relevant efforts in East Asia.

***Research activities on acid deposition*:** Extensive joint scientific research projects on acid deposition and its effects are conducted by the NC and some participating EANET countries in certain areas of mutual interest for countries with diverse natural environments and climatology.

4.9 Publications of the last five years

Starting in the preparatory phase, EANET bodies have issued numerous publications related to a variety of Network activities. All are available to both researchers and the public in and outside of EANET participating countries, following the decision laid out in a document titled *Procedures on Data and Information Disclosure for the Acid Deposition Monitoring Network in East Asia (EANET)*, which was endorsed at the IG3 (see 4.2.3).

Most of the publications were prepared by the NC and issued as technical documents and information for the specialists and researchers that deal with monitoring, data quality, and management—all aimed at increasing the capacity of personnel in EANET countries. The special proceedings of annual EANET meetings are printed by the Secretariat (UNEP/RRC.AP), as are brief information and awareness reports aimed at decision-makers and the general public.

Being limited printings, they are categorized as follows: technical manuals and guidelines; data publications; reports on OA/QC projects; proceedings of EANET meetings, including workshops and scientific seminars; training materials; public awareness brochures, etc. Most are available on EANET website at www.eanet.cc/product.html. The NC also provides the following publications on request:

Technical documents:

Guidelines for Acid Deposition Monitoring in East Asia (adopted March 2000)
Technical Documents for Wet Deposition Monitoring in East Asia (adopted March 2000)
Technical Documents for Soil and Vegetation Monitoring in East Asia (adopted March 2000)
Technical Documents for Monitoring on Inland Aquatic Environment in East Asia (March 2000)
Data Reporting Procedures and Formats for Acid Deposition Monitoring in East Asia (adopted March 2000)
Quality Assurance/Quality Control Program for the Air Concentration Monitoring in East Asia (2001)
Technical Document for Filter Pack Method in East Asia (November 2003)

Data publications:

Report on the Acid Deposition Monitoring of EANET during the Preparatory Phase 1998–2000 (August 2000)
Data Report on the Acid Deposition in the East Asian Region (annually from 2001 to 2005; published after SAC endorsement the following year)

Reports on QA/QC activities:

Report on the Inter-laboratory Comparison Projects on Wet Deposition (annually from 1998 to 2005; published after consideration by SAC the following year)

Report on the Inter-laboratory Comparison Projects on Soil (annually from 1999 to 2005; published after consideration by SAC the following year)

Report on the Inter-laboratory Comparison Projects on Inland Aquatic Environment (annually from 2000 to 2005; published after consideration by SAC the following year)

Prospective plans:

Strategy Paper for Future Direction of Soil and Vegetation Monitoring (November 2002)

Strategy Paper for Future Direction of Dry Deposition Monitoring (2nd edition/September 2005)

Public awareness materials:

Report for Policy Makers on Acid Deposition Monitoring Network in East Asia (EANET) "Goals, Achievements and Way Forward" (November 2005)

EANET - Acid Deposition Monitoring Network in East Asia (brochure, March 2004; re-edited July 2006)

Tropospheric Ozone: A Growing Threat (brochure, ADORC, May 2006)

Proceeding of the Workshop on Public Awareness for Acid Deposition Problems (series of annual meetings from 2001 to 2005)

EANET Newsletter (first issue in 2003)

Training and education materials:

Acid Deposition and the Environment (e-learning course, March 2006, http: //www.eanet.cc/product/e_learning/index.htm)

Quality Assurance and Quality Control in Soil Monitoring System (textbook, March 2001)

Data Reporting, Data Quality Assessment, and Data Treatment of Wet Deposition Monitoring of EANET (textbook, March 2002)

Fundamental Limnology for Inland Aquatic Environment Monitoring on Acidification (textbook, second edition, March 2004)

Besides the publications listed above, many scientific papers and contributions were prepared by the scientists in the participating countries who are closely involved in EANET research and other relevant activities, as well as NC researchers. Most were devoted to the assessment of monitoring data and the results of joint studies conducted by the NC and organizations in participating countries, as well as on the outcome of collaborative projects using EANET monitoring data. A number of these can be found in the proceedings of world-famous gatherings such as the Acid Rain conferences (Japan in 2000, Czech Republic in 2005), the IGAC/WMO symposia, series of ASAAQ (Atmospheric Sciences and Applications to Air Quality) conferences, etc.

4.10 Conclusion

After the first five years of enormous inputs and efforts by the countries participating in EANET, as well as national and international experts, the Network is seen as moving progressively forward with unity and strength to accomplish its goals. While some major achievements have been made already, there is still more to do to improve performance and attain an even higher quality of monitoring data. EANET is looking forward to further advancement and sophisticated steps in assessing and utilizing its growing database, in developing the transboundary models, and in raising the level of common understanding and awareness of the impacts of acid deposition on our ecosystem within the East Asia region.

5. Other Regional Studies for East Asia

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CONTENTS

5.1 Introduction

Due to rapid economic development and population growth, Asia has attracted much concern over air pollution in recent decades. In addition to the efforts of EANET, there have been other important organizational initiatives and scientific studies on monitoring, emission inventory, and modeling that target acid deposition and other regional air pollution in Northeast and Southeast Asia (defined as *East Asia* in EANET). In this chapter, the initiatives and research outputs of the last decade related to these topics are reviewed in order to provide perspectives of regional activities and scientific knowledge that have been conducted and obtained outside of EANET. The scope of the review is confined here to cover initiatives and studies at the regional scale; those dealing only with specific countries or cities are not covered. Observational studies are reviewed only for those based on continuous measurement of at least a year or longer, and short-term, campaign-based studies are not included, considering the nature of EANET. Also, for the same reason, modeling studies of regional pollution distributions are reviewed, as are discussions on source-receptor relationships, while those involving process analysis are not included. After introducing atmospheric studies, a review of ecological modeling and assessment studies in the region is also given in the last section. It should be emphasized that the data and discussion referred to in this chapter are not necessarily endorsed by EANET. The purpose of this review is rather to summarize a number of regional studies that have advanced understanding of acid deposition and air quality in this region in order to assist with the further development of EANET.

5.2 Regional organizational initiatives other than EANET

Other than EANET, several region-wide governmental and non-governmental programs related to acid deposition and air pollutants have been carried out and are ongoing that cover the whole of Asia or Northeast/Southeast Asia. In this section, such organizational initiatives are reviewed to give a perspective of activities related to EANET.

5.2.1 RAINS-ASIA

The Regional Air Pollution Information and Simulation for Asia (RAINS-ASIA) (IIASA 2005, available online) is an international project aiming to construct a policy tool for the mitigation of acid deposition in Asia. In order to develop and introduce an assessment tool to understand acid deposition in Asia, as well as to help with developing strategies to mitigate or avert acid deposition problems, the RAINS-ASIA Phase I project, funded by the World Bank and the Asian Development Bank, was conducted under the international collaboration of scientists from Asia, Europe, and North America (Foell et al., 1995; Downing et al., 1997). RAINS-ASIA is an integrated assessment model developed by the International Institute for Applied System Analysis (IIASA) (RAINS-Asia, 2005). It has the same framework as RAINS-EUROPE, which was developed to provide scientific support for international negotiations in Europe under the UN ECE Convention on Long-Range Transboundary Air Pollution in Europe (CLRTAP).

Phase I of the RAINS-ASIA program, which began in July 1992 and completed in June 1995, covers the countries of East, South, and Southeast Asia, with particular emphasis on Japan, India, China, Indonesia, Thailand, and South Korea. The model was applied for the period of 1990–2020. The RAINS-ASIA modeling tool consists of the following four basic modules: (1) the Regional Energy Scenario Generation module (RESGEN), (2) Energy and Emissions module (ENEM), (3) Atmospheric module (ATMOS), and (4) the Impacts module (IMPACT).

The RESGEN module estimates current and future energy supply and sectorial energy consumption, corresponding to a wide variety of socioeconomic and technological assumptions. The information on energy demand, types of fuels used, and location of major sources of emissions developed by the RESGEN module is used in the ENEM module, which estimates the resulting amounts and patterns of SO_2 emissions and the costs of various control options.

The ATMOS module provides estimates of ambient air levels of acid precursors (SO_2) and acid deposition by sulfate (SO_4^{2-}) loading throughout the 94 regions as a function of changing emission scenarios. The IMPACT module then assesses the sensitivity of various ecosystems to acidic deposition and compares this information to the deposition data generated by the ATMOS module.

The IMPACT module assesses the sensitivity of ecosystems to acidic deposition and identifies the areas facing danger of ecosystem degradation, based on the estimated sensitivity and deposition data provided by the ATMOS module. In the Phase I study, a *Critical Load* of acidity was used as an index of ecosystem sensitivity based on the steady-state mass balance model. Key parameters and base data of the mass balance model, which were used to estimate critical loads and ecosystem sensitivities, include the neutralizing capacity by chemical weathering of soil minerals, groundwater flux, and critical BC/Al (e.g., base cations/aluminum) ratios.

The World Bank decided to fund RAINS-ASIA Phase II to disseminate and improve the model. Japanese scientists and scientists from the Phase I team conducted the Phase II work in cooperation with their counterparts in other Asian countries. The RAINS-ASIA Phase II project was implemented during 1998–99, and the final report was prepared by the Overseas Environmental Cooperation Center (OECC, 2000). An emission inventory of sulfur oxides from area sources (1° x 1°) and point sources in Asia was one of the most important outputs from the project. The current version of emission inventories for SO_2 with base years of 1990 and 1995, and also its projections from 2000 to 2030, are available on CD-ROM (IIASA, 2001).

As the reliability of the ecosystem impact assessment depends on the accuracy of the base data, the first objective of the IMPACT module in Phase II was to update the base data by replacing the data from Phase I with the latest ones and verifying them with Asia-based data maps, whenever available. Some new base data that could not be applied in Phase I were incorporated in Phase II. These data made it possible to improve the calculation methods for deriving key parameters and to overcome some of the problems remaining from the previous phase. The second objective was to verify and improve these calculation methods and to update the critical load map. An example of the output from the model is the map of exceeding critical load in 2020 in the reference case (Figure 5.2.1).

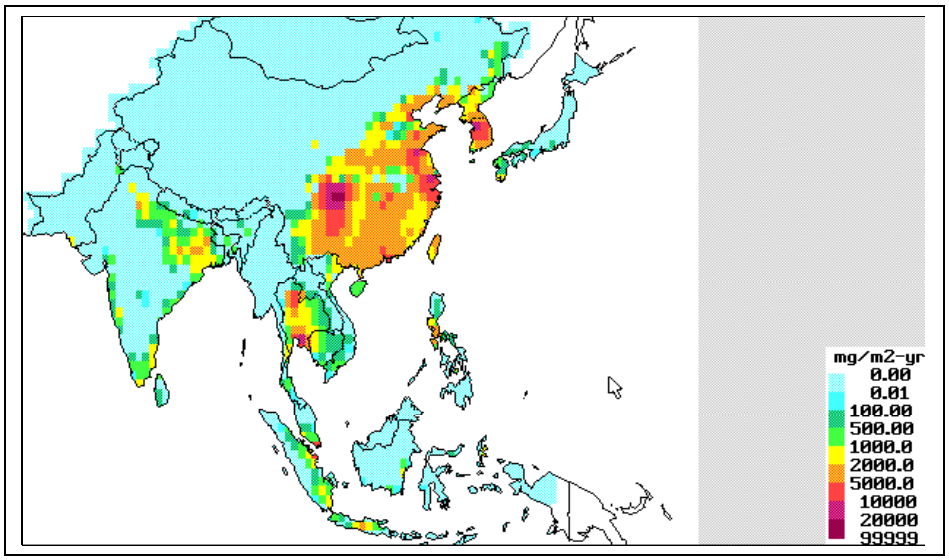

Figure 5.2.1 A map demonstrating the exceedance of critical loads in 2020 of the reference scenario case (OECC, 2000)

The RAINS-ASIA modeling project has a drawback in that its target chemical pollutant is limited only to sulfur, and the effect of sulfur deposition on soil is assessed using the "critical load" approach, which was not necessarily validated under Asian conditions (see the discussion in 5.6.2). Nevertheless, RAINS-ASIA had a very important impact on Asian scientists and policymakers by introducing a concept of a science-based policy tool to address atmospheric environmental issues for the first time.

5.2.2. LTP project

Long-range Transboundary Transport of Air Pollutants in Northeast Asia (LTP) is an international project established in 1995 upon the initiative of the Korean government, with China, Japan and the Republic of Korea now as member countries (LTP, 2004: <www.temm.org/docs/banner/ltp.html>). The objective of LTP is to promote collaborative studies on monitoring, emission inventory, and modeling, targeting Northeast Asia, in order to improve understanding of long-range transboundary air pollution in region. Regular monitoring began in 1998 at eight sites in these three countries. The monitoring program consists of both long-term and intensive monitoring by aircraft as well as at ground stations. (The LTP monitoring sites are listed in Table 5.2.1 together with an outline of measurement programs.)

Table 5.2.1 Monitoring sites of LTP and duration of observation (LTP, 2004)

Party	Long term continuous monitoring		Short term intensive monitoring				
			surface		upper layer		
	Site	Duration	Pollutant	Duration	Path	Duration	Pollutant
CHI.	Dalian Xiamen				none		
JAP.	Oki Rishiri			'00.11.10-20	none		
KOR.	Ganghwa Taean Gosan Geoje	'00. 8 1 '03.6	SO_2 O_3 NOx $PM_{2.5}$ PM_{10}	'01.4.10-20 '01.8.5-15 '01.11.10-20 '02.3.5-15 '02.12.10-20 '03.5.25-6.6 '03.11.10-20	Latitude: 34.30' - 37° Longitude: 124.10' - 127°	'00.11 '01. 4 '01.11 '02. 3 '02.12 '03. 3 '03.11 '04. 3 '04.10	SO_2 NO_x O_3

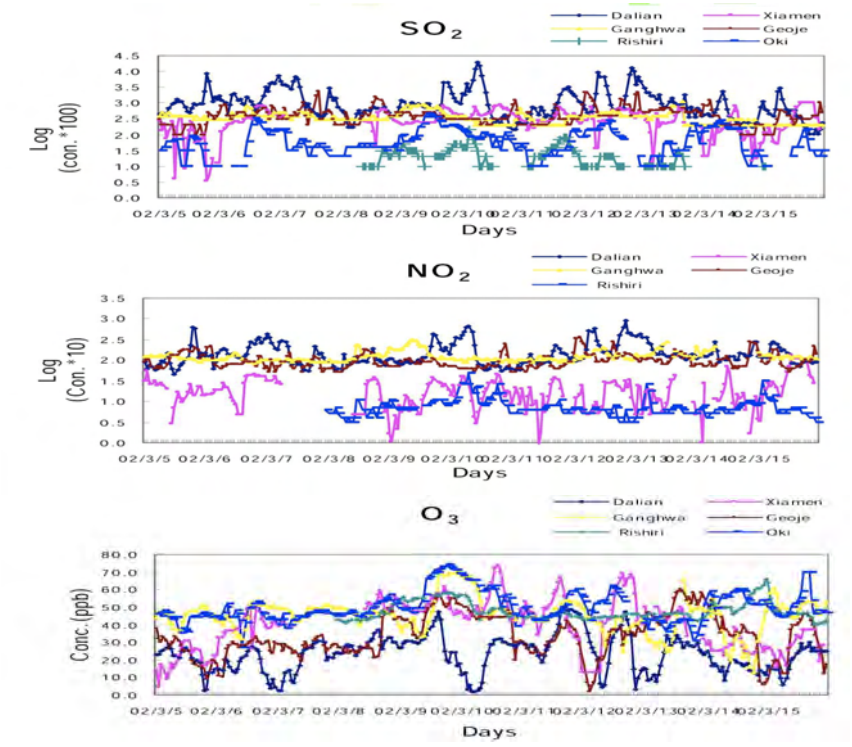

Figure 5.2.2 Daily variation of concentrations of SO_2, NO_2, and O_3 during March 5–15, 2002 (LTP, 2004)

Figure 5.2.2 shows the daily concentrations of SO_2, NO_2, and O_3 during the period March 5–15, 2002, observed at the LTP stations. Among the observation sites, Dalian in China had the highest concentrations of SO_2 (average 15.9 ppb, maximum 192.2 ppb) and NO_2 (average 4.4 ppb, maximum 89.1 ppb). In contrast, the average concentration of O_3 higher in Japan, and lowest in China. Oki site (Japan) recorded data of tropospheric ozone with the highest average of 50.1 ppb, and also with the maximum value of 74.0 ppb.

The LTP leads a joint effort to generate a source emission inventory by the national research center of each participating country to ensure credibility. The bottom-up approach was chosen to incorporate not only activity data but also to take control technology into account. A source emission inventory was compiled for SO_2, NO_x, CO, PM, while that for VOCs is underway. Acknowledging that various

air quality models may produce results significantly different from one model to another, the LTP provides test platforms on which the three participating countries, China, Japan, and Korea, compare their model results, as shown in Table 5.2.2.

The models were performed for the selected periods in 1998 of March 26–26, July 6–11, September 21–26, and December 14–19. The comparison between the observed and the simulated concentrations for SO_2, NO_2, and O_3 is observed in Table 5.2.3 for the averages of four seasons at each site. Table 5.2.3 demonstrates both some agreement and disagreement with observations and with other models, reflecting the present status of regional modeling efforts.

Table 5.2.2 Model application in LTP (LTP, 2004)

Party / Concerns	China	Japan	Korea
Model	CRAES-Sulfur CAMx CHAQM	EA GERF ADORC, RAQM	CADM-II SADM Yu-SADM
Model cases	Apr. 3~9, 1990 Oct. 16~20, 1995 May 20~25, 1998 Mar. 28~31, 1998 July 6~10, 1998 Sep. 21~26, 1998 Dec. 14~18, 1998 Mar. 1~31, 2002 July 1~31, 2002	Apr., 1999 July, 1999 Mar. 28~31, 1998 July 6~10, 1998 Sep. 21~26, 1998 Dec. 14~18, 1998 Mar. 1~31, 2002 July 1~31, 2002	Nov. 25~28, 1989 Jan. 1~31, 1993 Apr. 28~May 1, 1996 June 23~24, 1996 Mar. 28~31, 1998 July 6~10, 1998 Sep. 21~26, 1998 Dec. 14~18, 1998 Mar. 1~31, 2002 July 1~31, 2002
Model domain	70×66×60km (E120°, N36°) 60×60×64km (E120°, N32°)	20°~50°N, 115°~145°E 0°~55°N, 75°~146°E	20°~50°N, 115°~145°E 5°~47°N, 94°~158°E
Emission data	SO_2, NO_x, VOCs by RADM2	IGAC/GEIA RAINS-Asia CRIEPI LTP	CGRER SO_2, NO_x by Akimoto LTP
Output	Sulfate Nitrate SO_2 NO_2 O_3	Sulfate Nitrate SO_2 NO_2 O_3	Sulfate Nitrate SO_2 NO_2 O_3

Table 5.2.3 Comparison of concentrations by observations and simulations (LTP, 2004)

(Unit : ppb)

Site	SO_2				NO_2				O_3			
	Korea	China	Japan	OBS*	Korea	China	Japan	OBS*	Korea	China	Japan	OBS*
Gosan	1.47	1.24	3.03	1.75	1.34	1.16	2.22	4.75	39.22	-	41.47	34.33
Rishiri	0.37	0.05	1.95	0.15	0.27	0.12	0.80	0.69	39.59	-	42.49	39.95
Oki	3.75	0.47	7.42	0.13	4.52	0.86	6.78	1.43	34.78	-	56.63	43.00
Dalian	16.04	6.21	26.06	10.68	3.03	3.57	9.15	16.66	41.63	-	59.10	-
Xiamen	2.85	0.85	5.18	-	2.93	1.21	8.00	-	33.35	-	46.91	-

* Observation

5.2.3 MICS-Asia

The Model Intercomparison Study in Asia (MICS-Asia), information on which is available online, is an international intercomparison study of existing models to be applied to East Asia region with the purpose of creating a common understanding of model performance and uncertainties in Asia on long-range transport and deposition. Phase I was carried out, focusing on sulfur during the period from 1998 to 2000, as part of joint collaborative studies between the Central Research Institute of Electric Power Industry (CRIEPI, Japan) and IIASA. Eight models were used in the Phase I study, and the findings were published by the group of leaders (Carmichael et al., 2001, 2002). It was recognized that a wider perspective could yield important insights by including nitrogen compounds, ozone, and aerosols for effective control of various environmental problems.

Phase II activities began in 2003 as a collaborative study between the Acid Deposition and Oxidant Research Center (ADORC), which is the Network Center for EANET, and IIASA, with the participation of scientists from China, Korea, Japan, and other countries from Europe and North America. Under this project, EANET monitoring data and relevant information were provided for the evaluation of model results, which made it possible to conduct detailed analyses for model validation (http://www.adorc.gr.jp/adorc/mics.html).

As an example, Figure 5.2.3 shows the modeled and observed SO_2 concentrations (monthly averaged) at EANET sites in March 2001. Each model (with codes from M-1 to M-8) result is represented by a particular symbol with its ensemble means. In this comparison, it can be seen that all models were good at simulating SO_2 spatial variability, showing higher levels over China and moderate levels over Japan associated with input emission inventories, but relatively large differences of concentrations among models appeared at some stations, such as Weishuiyuan in China.

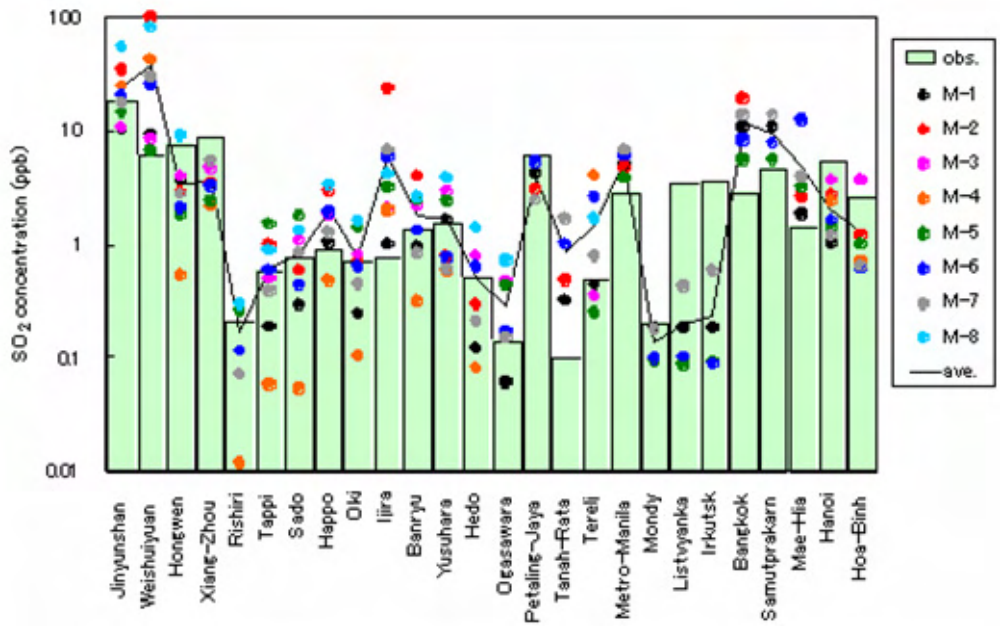

Figure 5.2.3 Averaged SO_2concentrations (modeled and observed) at EANET sites in March 2001

5.2.4 ABC

Atmospheric Brown Cloud-Asia (ABC) is a new international project under the United Nations Environment Programme (UNEP), which was started in 2002 (http://www.abc-asia.ucsd.edu/). It has been supported by the National Oceanic & Atmospheric Administration (NOAA) in the United States and by governmental research funds in some countries, including Japan and Korea. In recent years, it has been well recognized that not only long-lived greenhouse gases but also some air pollutants, such as aerosols and tropospheric ozone, have a strong impact on regional climate change. Aerosols, in particular, suppress global warming by reflecting solar radiation (direct effect) and also affect radiation and precipitation by modifying cloud formation (indirect effect). Such climate impacts of aerosols are very much dependent on the chemical properties and size distribution of aerosols, so aerosol chemistry and physics are very important in studying global warming and climate change. Tropospheric ozone is recognized as the third most important greenhouse gas next to methane (IPCC, 2001), and it is also a concern because of its direct, adverse effect on agricultural crops and forests. Thus, the UNEP project is aimed at studying the following: atmospheric sciences and the climate effects of aerosols and gaseous air pollutants; their impacts on agriculture, human health, and water cycles; and their policy relevance. It should be noted that the regional scope of ABC covers the South, Southeast, and Northeast regions of Asia.

The conceptual scheme of the UNEP/ABC project is presented in Figure 5.2.4 (ABC, 2003). So far, the main focus of the project has been on physics/chemistry and the climate effect of aerosols, which also includes the chemistry-climate interaction of ozone. A science team has been assembled consisting of scientists from the United States, Europe, and several Asian countries, including China, Japan, India, and South Korea.

ABC is now trying to specify several monitoring stations in Asia (ABC, 2003). Over the region of East Asia, it was decided that Gosan, in Cheju, Korea, was to be a so-called super site, and Cape Hedo in Okinawa, Japan, was assigned as one of the main sites. Note that both the Gosan and Cape Hedo sites are also EANET sites. Other stations, Phimai in Thailand and several sites in China (Boshan, Lin'an, Hefei, and Wuzhishan) are operated or proposed as main ABC sites in the East Asia region.

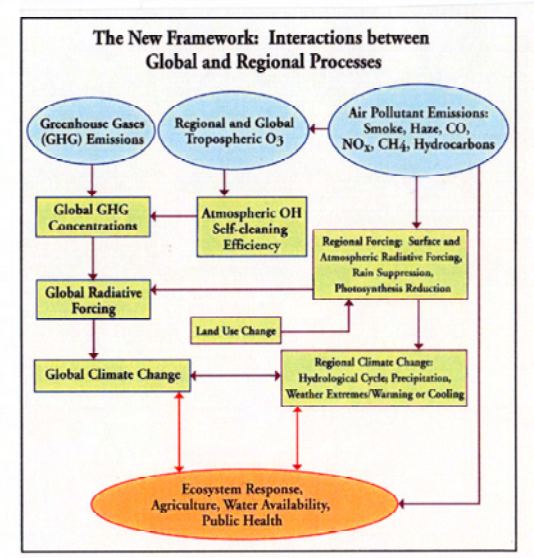

Figure 5.2.4 Conceptual scheme of UNEP/ABC project (ABC, 2003)

5.2.5 WMO/GAW program

The World Meteorological Organization (WMO) operates the Global Atmosphere Watch (GAW) programme (http://www.wmo.ch/web/arep/gaw/gaw_home.html) with the following mission, which takes into account the Integrated Global Atmospheric Chemistry Observations (IGACO, 2004) strategy: (1) reduce environmental risks to society and meet the requirements of environmental conventions; (2) strengthen capabilities to predict climate, weather, and air quality; and (3) contribute to scientific assessments in support of environmental policy. The GAW monitoring system focuses on six classes of variables (ozone, ultraviolet radiation, greenhouse gases, aerosols, selected reactive gases, and precipitation chemistry). The precipitation chemistry activities of GAW focus on quality assurance and the coordination of major regional networks, e.g., EANET, EMEP, etc. Surface ozone has been monitored at several GAW stations in Asia. Table 5.2.4 cites the stations reporting data on surface O_3 to the data center as of 2006. In addition to these stations, surface ozone measurement has been carried out at GAW stations such as Mt. Waliguan, Shangdianzi, and Lin'an in China, and Anmyon-do and Cheju in Korea.

Table 5.2.4 WMO GAW surface O_3 stations in Asia

Station Name	Country/Territory	Latitude	Longitude	Altitude
Hok Tsui	Hong Kong, China	42° 37' N	76° 59' E	60 m
Issyk-Kul	Kyrgyzstan	24° 18' N	153° 58' E	1640 m
Minamitorishima	Japan	39° 02' N	141° 49' E	8 m
Ryori	Japan	36° 03' N	140° 08' E	260 m
Tsukuba	Japan	24° 28' N	123° 01' E	25 m
Yonagunijima	Japan	42° 37' N	76° 59' E	30 m

5.2.6. IGACO/IGOS

More general discussion has occurred on research and long-term monitoring from a global perspective for understanding various processes of the Earth system under an initiative called the Integrating Global Observing Strategy (IGOS). The Integrated Global Atmospheric Chemistry Observations (IGACO) is a component of the IGOS partnership and focuses on the integration of satellite and ground-based observations (IGACO/IGOS, 2004). Although rainwater monitoring is not given much attention in the report, it provides insight for future development of an international monitoring network for atmospheric composition change (http://www.eohandbook.com/igosp/). The IGACO

strategy is now being implemented under the leadership of the WMO as part of the WMO-GAW program for 2008–2015. One focus will be on integrated observations of the long-range transport of air pollution, deposition, and air quality on a hemispheric scale.

5.2.7. Task Force on Hemispheric Transport of Air Pollution

While local and regional emissions sources are the main cause of air pollution problems worldwide, there is increasing evidence that many air pollutants are transported on a hemispheric or global scale. To develop a fuller understanding of this growing body of scientific evidence, the Task Force on Hemispheric Transport of Air Pollution (TF-HTAP) was established in 2005 by the European Council and the Executive Body of the UNECE CLRTAP. The Task Force will report its findings to the Convention's Steering Body in collaboration with its Cooperative Programme on the Monitoring and Evaluation of Long-range Transmission of Air Pollutants in Europe (EMEP). The potentials for intercontinental transport are recognized as including ozone and its precursors, fine particles, acidifying substances, mercury, and persistent organic pollutants. The Task Force has organized workshops and annual meetings three times a year since 2006, and is currently preparing the 2007 *Interim Assessment Report*. Although none of the Asian countries has joined the CLRTAP, governments and scientists of Asian countries are invited to participate in its workshops and Task Force meetings, and to be authors of its interim report parts. Particularly, one of the workshops focusing on emissions inventories and future projections was held in Beijing in October 2006.

5.3 Output from observational research

This section introduces several key outputs of observational study on spatial distribution, temporal variation, and the long-range transport of acidic/alkaline gases, ozone, and aerosols in the Northeast/Southeast Asian region that have been published in international refereed journals. This short review focuses only on the results of continuous observations; campaign-based studies are not covered.

5.3.1 Measurements of SO_2, NH_3, and O_3 by passive samplers

Measurements of gaseous SO_2, NH_3, and O_3 using passive sampler technology were obtained as a pilot measurement program of the WMO/GAW Urban Research Meteorology and Environment (GURME) project during 1991–2001 (Carmichael et al., 2003). Monthly measurements were obtained at 50 stations in Asia, Africa, South America, and Europe. The locations of the measurement sites of this study are presented in Figure 5.3.1. WMO/GAW will continue to promote the development and use of precision passive sampling of gaseous pollutants as a low cost, high-density measurement approach suitable for addressing some pollution issues that range from urban to regional.

The observed concentrations of SO_2, NH_3, and O_3 obtained at the regional sites are shown in Figure 5.3.2 (*a-c*, respectively). The observed SO_2 concentrations ranged from a high value of 13 ppb at Lin'an, China, to less than 0.03 ppb at Mt. Kenya. The high concentrations of SO_2 have been ascribed to major contributions from anthropogenic sources except at Mt. St.Thomas, where SO_2 levels were impacted by emissions from an eruption of the Mayon volcano that occurred during the measurement period. Median concentrations of ammonia, shown in Figure 5.3.2(*b*), varied from 20 ppb at Dhangadi, India, to <1 ppb at Mt. Kenya. The high NH_3 concentrations in the Indian sub-continent, Southeast and South Asia, and Africa reflect high NH_3 emissions from agricultural activities, livestock, and the use of biofuels as domestic fuel. The median ozone concentrations varied from a maximum of 45 ppb at Waliguan Mountain, China, to 8 ppb in Petit Saut, French Guiana. Four stations had the highest O_3 levels (Oki in Japan and the Waliguan Mountains, Shang Dian Zi, and Lin'an in China), and all of them are located in the mid-latitudes of the Northern Hemisphere. In general, Northern Hemisphere mid-latitude values exceeded the levels of the Southern Hemisphere mid-latitude, and the lowest values were typically found in the tropical region.

Figure 5.3.1 Location of the measurement sites used in the study (squares and triangles represent regional and urban sites, respectively) (Carmichael et al., 2003)

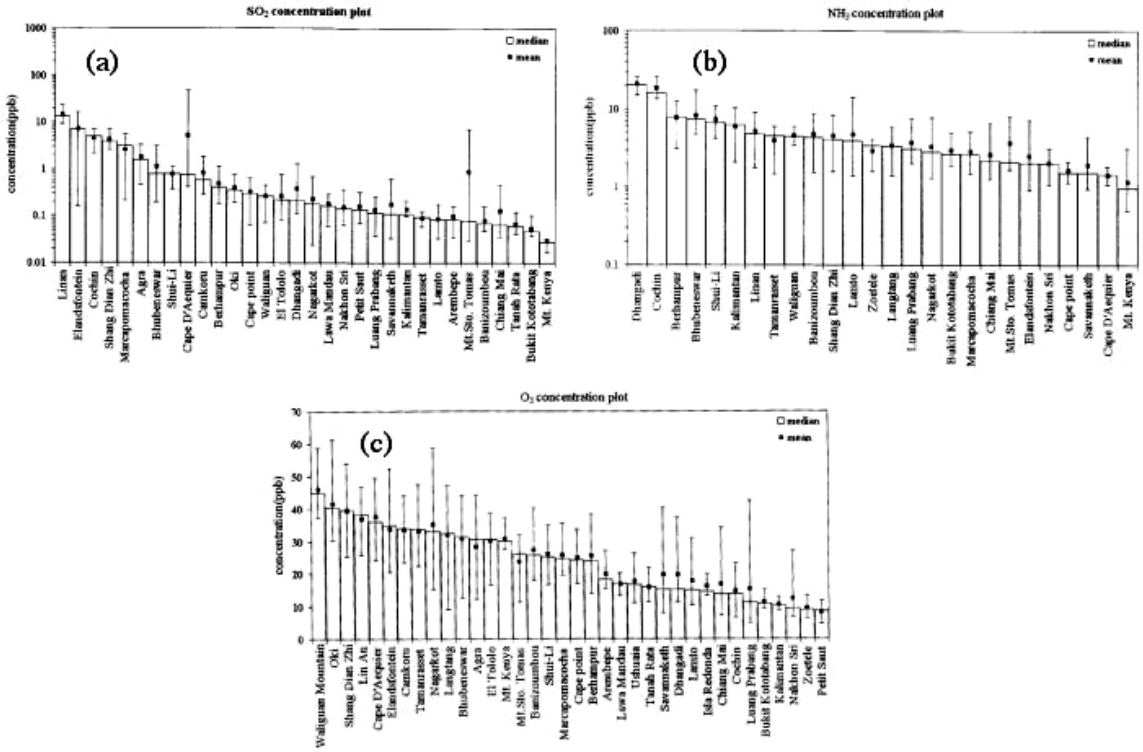

Figure 5.3.2 Measured SO_2 (*a*), NH_3 (*b*) and O_3 (*c*) concentrations within GURME project. The bars indicate maximum, minimum, and mean values, and the solid box designates the media values (Carmichael et al., 2003)

5.3.2 Long-range transport of ozone in Northeast Asia

Although the long-range transport of acid rain is mentioned on many occasions, direct observational evidence has been very scarce, at least in East Asia, and most discussions have relied on modeling studies (introduced later). This is due to the complex processes involved in the uptake of pollutants into clouds, the complicated meteorological process involved in rainfall from cloud formation, as well as the sporadic nature of rain episodes. Instead, less complicated mechanisms are involved, at least in the transport process of ozone and aerosols, and a clearer long-range transport picture has been established by several research outputs. The long-range transport of ozone and aerosols in East Asia has been quantified by both observational output and modeling studies. Here key results are described that are useful for gaining insight into the transboundary transport of air pollutants in this region.

Pochanart et al. (2002) reported surface ozone data at four remote islands in Japan, i.e., Rishiri, Oki, Okinawa, and Ogasawara. It should be noted that all these sites are EANET stations, although the analyzed data were obtained from research conducted before the regular phase of EANET operations. Figure 5.3.3 shows the seasonal variations of O_3 levels based on multi-year averaged observational data at these four islands. The O_3 concentrations at all four island stations show a clear trend of a spring maximum and summer minimum, which is known to be due to the combined effect of long-range transport, monsoon modulation, and stratospheric ozone contribution. It can be seen that monthly O_3 levels in spring are as high as 40–50 ppb, even at these remote sites free from local emissions of precursors.

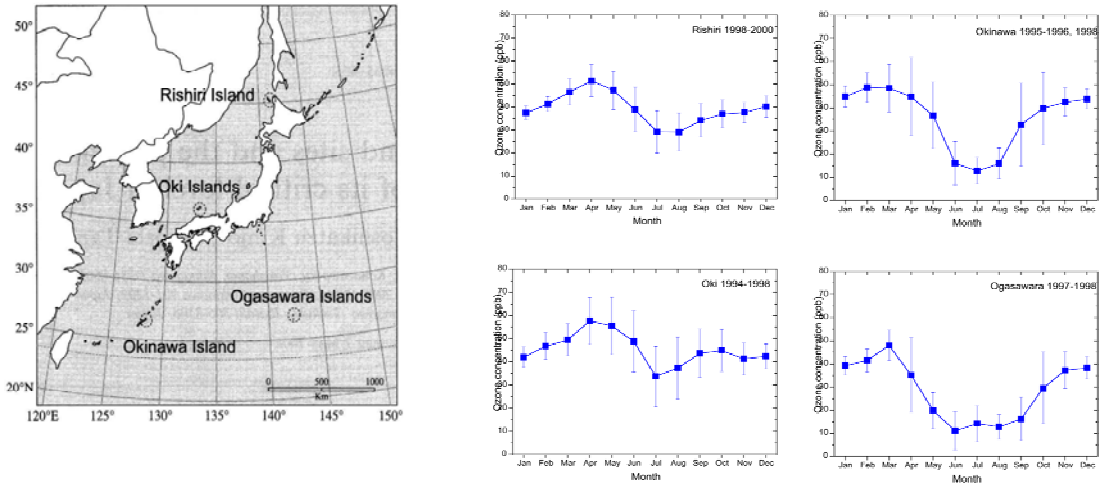

Figure 5.3.3 Seasonal variation of O_3 at remote island sites in Japan (see map on the left): Rishiri (upper left), Oki (lower left), Okinawa (upper right) and Ogasawara (lower right) (Pochanart et al., 2002)

The results of O_3 concentrations analysis using the trajectory categorization are demonstrated in Figure 5.3.4. Three types of air masses—"clean continental" (green), "regionally polluted continental" (red), and "marine" (blue) air masses—were categorized in this study. Figure 5.3.4 demonstrates that O_3 levels at these remote sites are well characterized by the origin of air masses categorized by these trajectories. Thus, it can be seen that the regionally polluted continental air mass contained a monthly average of 54–61 ppb in spring, whereas the clean continental air mass contained 45–50 and 40–45 ppb at Rishiri and Oki, respectively. The clean marine air mass observed at Okinawa and Ogasawara contained 13–14 ppb, whereas higher O_3 concentrations of 24–27 ppb were observed at Oki and Rishiri due to additional pollution, mainly from Japan. Thus, it has been established that O_3 levels in the regionally polluted continental air mass in springtime reaches a monthly average of nearly 60 ppb in the Northeast Asian Pacific Rim region.

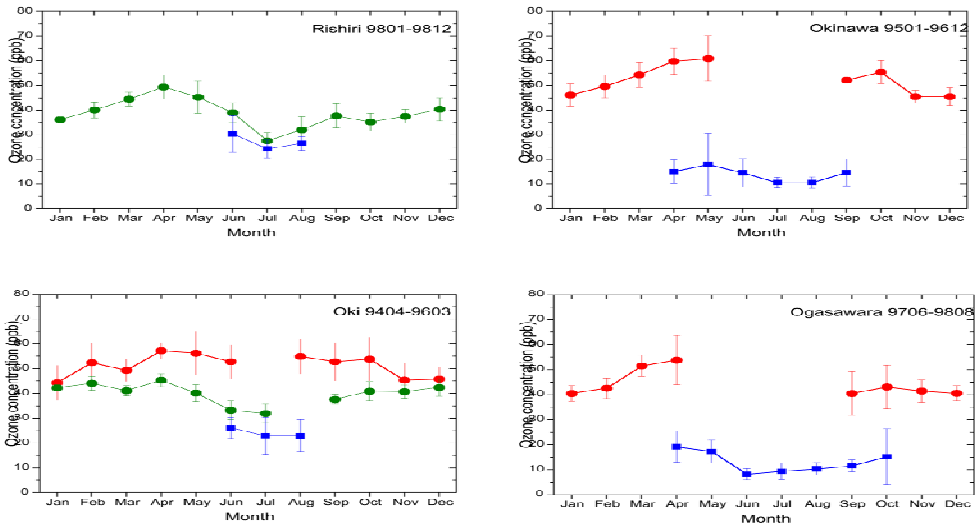

Figure 5.3.4 Trajectory-categorized seasonal variation of O_3 at remote sites in Japan (Pochanart et al., 2002)

Pochanart et al. (2004) further analyzed the data from Happo, Mondy, and Oki (all EANET sites, although the data used were obtained before EANET began regular operations) and succeeded to extract the quantitative contribution of transboundary long-range transport of O_3 to these remote sites. Figure 5.3.5(*a*) depicts the seasonal variation of surface O_3 in the background of a clean continental air mass at these three sites, and the upper curves of Figure 5.3.5(*b*) are those in the regionally polluted continental air masses at Happo and Oki. The contribution of long-range transport to these sites was obtained by subtracting the background O_3 levels in the clean continental air masses from the regionally polluted continental air masses, presented by the lower curves in Figure 5.3.5(*b*). Thus, it has been concluded that the monthly averaged build-up of O_3 due to long-range transport of regionally polluted continental air masses is typically around 10–15 ppb in spring and 20 ppb in summer.

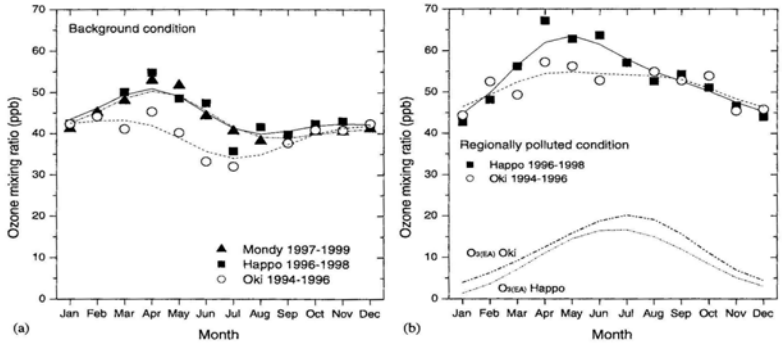

Figure 5.3.5 Seasonal variation of O_3 : (a) in the background clean continental air masses at Happo, Mondy and Oki; (b) in the regionally polluted continental air masses at Happo and Oki (upper curves) and contribution of O_3 build-up due to East Asian continent (O_3(EA)) at these sites (lower curves) (Pochanart et al., 2004).

5.3.3 Impact of biomass burning on O_3 in continental Southeast Asia

The climatological regime in Southeast Asia is quite different from Northeast Asia. It has been reported that the seasonal variation of O_3 concentration in continental Southeast Asia is characterized by very high levels in the dry season and very low levels in the wet season, as presented in Figure 5.3.6 (Pochanart et al., 2001). The high O_3 in the dry season has been known to be due to emissions from biomass burning affecting continental air masses, and the low O_3 in the wet season is due to the influence of a pristine marine air mass (Pochanart et al., 2003).

A case study on biomass burning in Southeast Asia and the enhancement of tropospheric ozone over Hong Kong was also reported (Chang et al., 2000). Tracing air trajectories backward showed that these ozone-rich air masses had passed through the Indo-Burma region of Southeast Asia, where large-scale fires were recorded at the time.

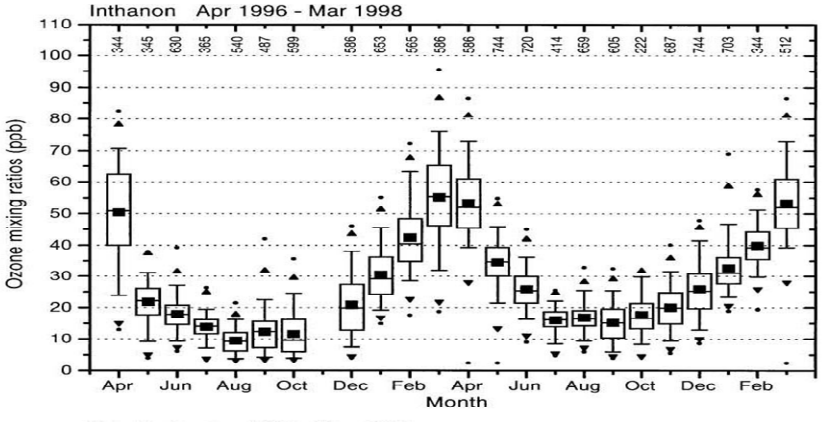

Figure 5.3.6 Seasonal variation of O_3 at Inthanon, a remote mountain site in Thailand (Pochanart et al., 2001)

5.3.4 Long-range transport of aerosols in East Asia

Although a tremendous number of observational studies have reported on the spatial/temporal variability and long-range transport of anthropogenic aerosols and natural dust (yellow sand) in East Asia, they are mostly based on rather event-based studies. The most recent, comprehensive, campaign-based observations of aerosols were made in ACE-Asia (IGAC)/TRACE-P (NASA) in the spring of 2002, which integrated ship, aircraft, and ground-based measurements. The scientific outputs were published in a special issue of the *Journal of Geophysical Research* (Vol. 108, No. D23, 2003).

In contrast to those event-based studies, others based on long-term observations are very scarce. Prospero et al. (2003) reported a study on long-term monitoring of aerosols at Midway Island in the North Pacific Ocean (Figure 5.3.7) over the period 1981–2000. Figure 5.3.8 shows the annual cycle of monthly mean total and "anthropogenic" nss-SO_4^{2-} and NO_3^- and mineral dust. As can be seen in the figure, concentrations of "anthropogenic" aerosols reach maximum in spring with a peak in April, interpreted to be due to the highest impact of long-range transport form Asia in this season. Here, "anthropogenic" nss-SO_4^{2-} and NO_3^- are estimated by subtracting the estimated concentration of natural contribution from the total based on methanesulfonate (MSA) and summertime concentration, respectively. Figure 5.3.9 depicts long-term trends of estimated "anthropogenic" sulfate and nitrate in spring during the whole period. Although year-to-year variability is evidently large, a clear increase of both "anthropogenic" sulfate and nitrate by a factor of around two can be seen from 1981 to the mid-1990s.

Figure 5.3.7 Location of the Midway aerosol-monitoring site in the North Pacific

No increasing trend can be discerned after the mid-1990s. It is consistent with the emission trend of SO_2 and NO_x in Asia, which have been decreasing, or at least their increasing trend slowed considerably during the last half of the 1990s due to the Asian economic crisis.

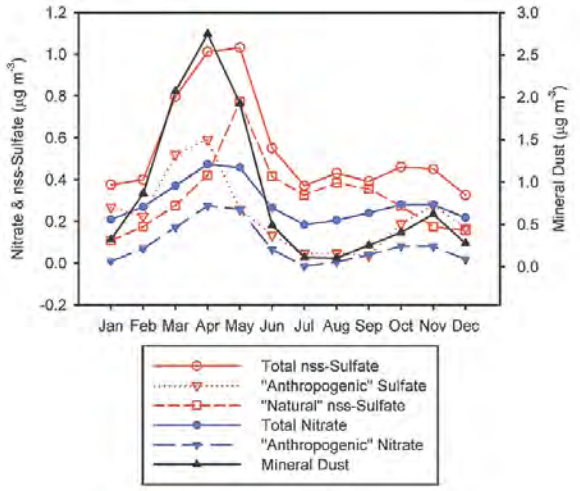

Figure 5.3.8 Seasonal cycle of monthly mean concentrations of total and "anthropogenic" nss-sulfate and nitrate in Midway Island

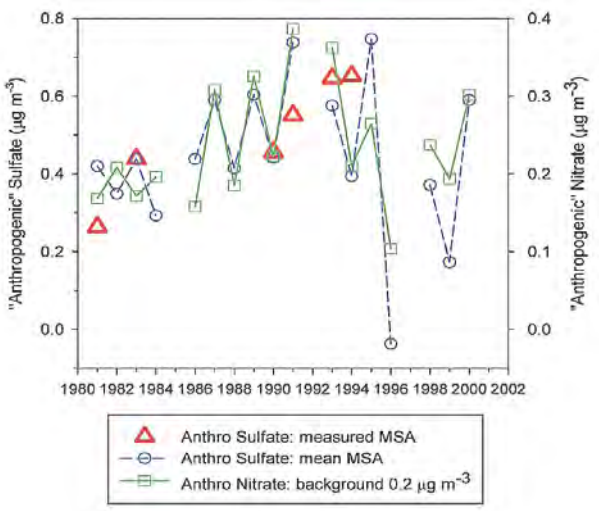

Figure 5.3.9 Long-term trend of estimated spring concentrations of "anthropogenic" sulfate and nitrate at Midway Island

Trajectory-assisted categorization has been reported early for trace elements in aerosols (Mukai and Suzuki, 1996) based on the samples obtained at Oki Island (Figure 5.3.3) over a three-year period (1988–1991). Figure 5.3.10 shows a map of the observed area and sector classification for air trajectory analysis, and also shows a picture selected from the paper with the calculated representative concentrations of certain heavy metals (Pb, As, V) and *nss*-sulfate for each sector. Notice that the concentrations of Pb and As were higher for the air mass from central China and the northern Asian continent sector, respectively. Concentrations of vanadium and *nss*-sulfate were higher in the air coming from western Japan, which included the contribution of the Sakurajima volcano emissions.

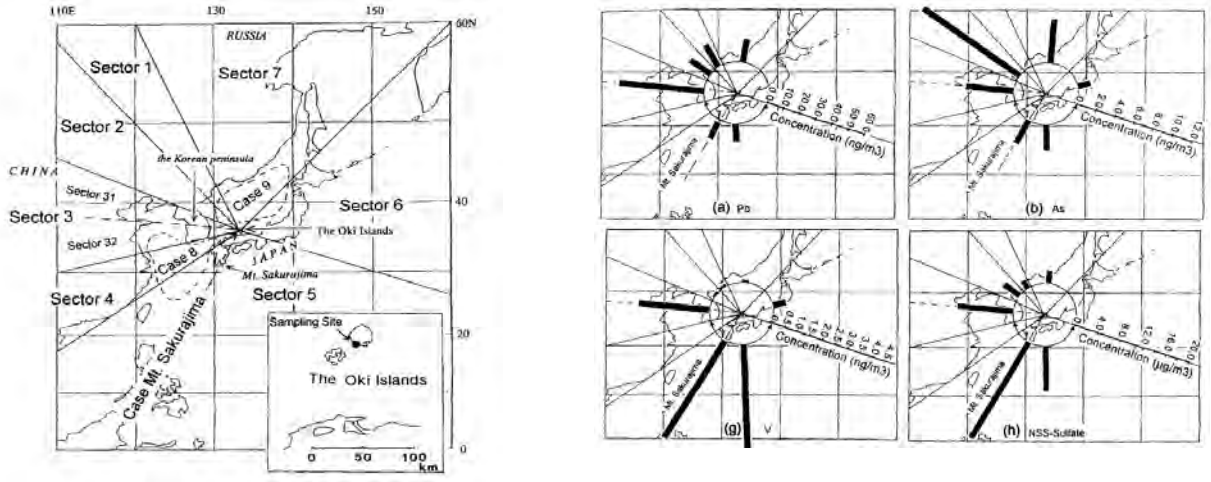

Figure 5.3.10 Map of sector classification for backward air mass trajectory to Oki site (*left*) and calculated representative concentrations of Pb (*a*), As (*b*), V (*g*) and nss-sulfate (*h*) for each trajectory sector (Mukai and Suzuki, 1996)

Nine years of observational data of PM_{10} from 72 Taiwan EPA monitoring stations during 1994 to 2002 were analyzed climatologically (Wang, 2005). Long-term trend analysis for each season was made with the data from a selection of 30 northern and 17 southern stations (results presented in Figure 3.5.11). The PM_{10} concentrations in the south of island were higher than in the north in spring, fall, and winter, while this tendency reversed in summer. A downward trend can be discerned over the nine years during all seasons in both north and south. The reason for this has not yet been elucidated, although the combination of the impact of regional and local air pollution has been suggested.

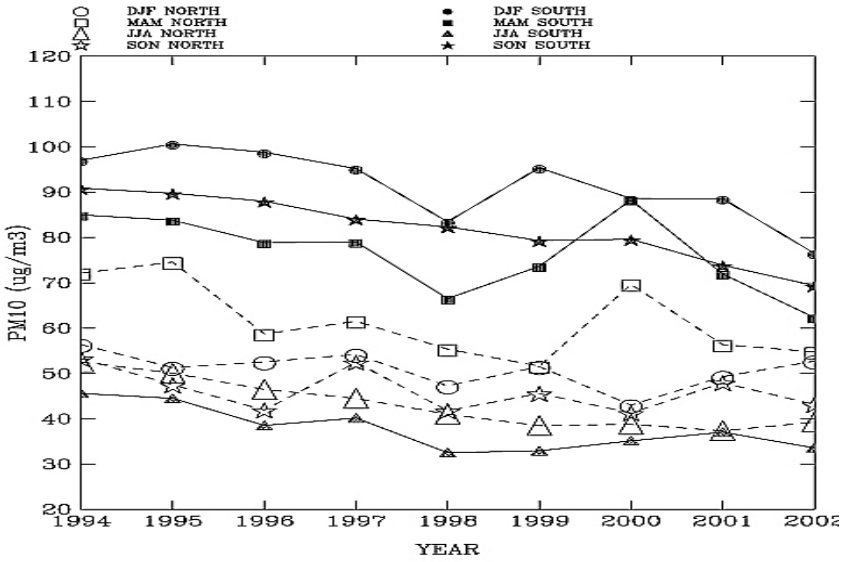

Figure 5.3.11 Trends of seasonal average concentrations of PM_{10} for the period of 1994-2002 in Taiwan China (open and solid symbols are for the north and south stations, respectively) (Wang, 2005)

5.4 Emission inventory

The importance of emission inventories has been recognized both in scientific studies and policy making. Although emission inventories have not yet been fully developed under the initiative of EANET, several studies have been reported in the scientific community in the last decade. Inventories of the base-year 1995 or later covering East, Southeast, and/or South Asia are summarized below.

5.4.1 Review of emission inventories in Asia

The origins of the region-wide emission inventory in Asia (including the EANET region) can be traced back to the early work of Kato and Akimoto (1992), with their 1º x 1º grid maps targeting SO_2 and NO_x for the period 1975–1987 (Akimoto and Narita, 1994). Their work was expanded on by Streets et al. (2000, 2001) to provide more recent data for these species in 1985–1997 in this region. A review of Asian emission inventories was given in a later publication (Akimoto and Ohara, 2004), and a summary of it is presented in Table 5.4.1.

Table 5.4.1 Summary of research on regional emission inventory in Asia (based on Akimoto and Ohara, 2004)

Research group	Base year	Domain	Species	Grid size, degree	References
ACESS	2000	All Asia	SO_2, NO_x, CO, NMVOC, BC(*), OC(**), NH_3, CH_4	1	ACESS (2002)
REAS	1995, 2000	All Asia	SO_2, NO_x, CO, NMVOC, BC, NH_3, N_2O, CH_4	0.5	Ohara et al. (2001), Yan et al. (2002)
RAINS-ASIA	1995	All Asia	SO_2	1	IIASA (2001)
Streets et al.	1985-1997	All Asia	SO_2, NO_x	-	Streets et al. (2001, 2002)
Klimont et al.	1995	East Asia	SO_2, NO_x, NMVOC, NH_3	1	Klimont et al. (2001)
Murano et al.	1994-1996	East Asia	SO_2, NO_x, NMVOC, NH_3	0.5	Murano et al. (2002)

(*) - Black carbon; (**) - Organic carbon

5.4.1.1 ACESS

The most recent inventory, developed by D. Streets with colleagues (Streets et al., 2003), has been publicized on the Internet as ACESS (2002). The inventory includes SO_2, NO_x, CO, non-methane volatile compounds (NMVOC), black carbon (BC), organic carbon (OC), NH_3, and CH_4. Twenty-two countries and regions in East, Southeast, and South Asia are included, and 1º x 1º degree grid maps for the base year 2000 were provided. NMVOC from biomass burning and other biogenic sources were also included in the ACESS inventories, together with Mg and Ca from soil weathering, as well as CH_4 from wetlands and SO_2 from volcanoes.

5.4.1.2 REAS

Another region-wide inventory has recently been publicized on the web as REAS (2005) under the initiative of the Frontier Research Center for Global Change (FRCGC)/Japan Agency for Marine-Earth Science and Technology (JAMSTEC). The inventory includes country-based data for SO_2, NO_x, CO, NMVOC, and BC from combustion sources, as well as NO_x, NH_3, N_2O, and CH_4 from agricultural sources, with 0.5º x 0.5º resolution grid maps.

5.4.1.3 EDGAR

A joint project of the National Institute of Public Health and Environment (RIVM) and TNO in the Netherlands released the EDGAR database (available online), a global emission inventory on a 1º x 1º grid net for 1990/1995, and 1970–1995 trends for the direct-effect greenhouse gases (CO_2, CH_4, and N_2O) and the ozone and aerosol precursors (CO, NO_x, NMVOC, and SO_2, as well as HFCs, PFCs, and SF_6). More recently, other European institutes, JRC-IES (Ispra, Italy) and MPIC-AC (Mainz, Germany), joined this project and the consortium released the most current version, EDGAR 3.2 (EDGAR, 2005).

5.4.1.4 Other Studies

Klimont et al. (2001) and Murano et al. (2002) published their inventories of SO_2, NO_x, NMVOC, and NH_3 for East Asia with resolutions of 1º x 1º and 0.5º x 0.5º, respectively.

5.4.2 Comparison of inventory data

5.4.2.1 SO_2

A summary of SO_2 emissions in Asia from different inventories is presented in Table 5.4.2. The estimates by ACESS and REAS 1.1 in 2000 are lower and higher than in 1995, respectively. The EDGAR 3.2 data are 36% and 72% higher than those of REAS 1.1 and ACESS, respectively, for the year 2000.

Table 5.4.2 Summary of SO_2 emissions (Tg SO_2/year) (updated from Akimoto and Ohara, 2004)

Inventory Area (Base Year)	**ACESS (2000)**	**REAS 1.1 (2000)**	**RAINS (1995)**	**Streets et al. (1995)**	**Klimont et al. (1995)**	**Murano et al. (1995,96)**	**EDGAR 3.2 ()**
East Asia *total*	22.6	30.1	26.5	28.6	24.6	26.3	43.0
Southeast Asia *total*	3.1	3.6	3.3	3.1	-	-	4.6
Indian Sub-continent *total*	7.1	7.5	6.2	6.7	-	-	9.0
Ships	1.1	1.5	0.8	-	-	-	1.7
Asia - total	**33.9**	**42.8**	**36.8**	**38.5**	**-**	**-**	**58.4**

5.4.2.2 NO_x

Estimates of NO_x emissions are overviewed in Table 5.4.3. Regional inventory estimates are within 25% for most of the major emitting countries and for the Asian total. The EDGAR 3.2 data are higher than the regional inventory by about 50% for the year 2000.

Table 5.4.3 Summary for NO_x emissions (Tg NO_2/year) (updated from Akimoto and Ohara (2004))

Inventory Area (Base Year)	**ACESS (2000)**	**REAS 1.1 (2000)**	**Streets et al. (1995)**	**Klimont et al. (1995)**	**Murano et al. (1995, 1996)**	**EDGAR 3.2 ()**
East Asia *total*	14.9	15.6	17.2	13.9	14.4	19.7
Southeast Asia *total*	3.1	3.8	3.2	-	-	6.4
Indian Subcontinent *total*	4.8	5.7	5.2	-	-	8.0
Ships		2.0				2.2
Aviation		0.2				0.4
Asia Total	**22.7**	**25.1**	**25.6**	**-**	**-**	**36.6**

5.4.3 Past and future emission trends in Asia

The trends in past emissions of two acidifying species, SO_2 and NO_x, in Asia (including South Asia) have been reported by Streets et al. (2000, 2001) for 1985–1997, as shown in Figure 5.4.1. Emissions of SO_2 in Asia grew from 26.6 Tg in 1985 to 33.7 Tg in 1990 and 39.2 Tg in 1997. Although SO_2 emissions used to grow as fast as fossil fuel consumption, recent limitations on the sulfur content in coal and oil slowed down the growth of emissions, providing much lower values compared to the interpolation from RAIN-Asia (Foell et al., 1995). The annual average emission growth between 1990 and 1997 was 2.2%, considerably lower than the economic growth rate. On the other hand, emissions of NO_x continue to grow rapidly, from 14.1 Tg in 1985 to 18.7 Tg in 1990 and 28.5 Tg in 1997. The annual growth rate was 6.2% between 1990 and 1997 with no sign of abating.

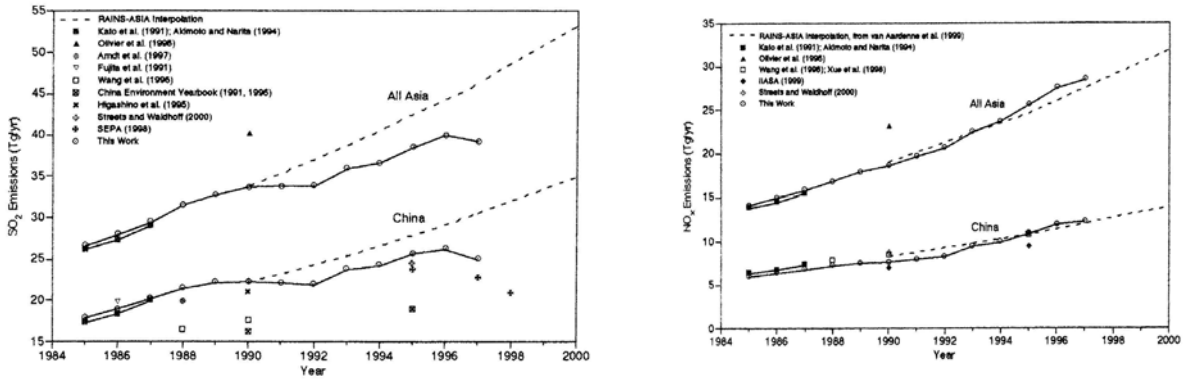

Figure 5.4.1 Trends in SO_2 (left) and NO_x (right) emissions in Asia in 1987-1997 (Streets et al., 2001)

As for future emissions, anthropogenic NO_x emissions in Asia (including South Asia) in the period 1990–2020 have been estimated by van Aardenne et al. (1999), and projections up to 2030 of SO_2, NO_x, NH_3, and VOC emissions in Northeast Asia have been provided by Klimont et al. (2001). IIASA also prepared scenarios of world anthropogenic emissions of air pollutants up to 2030 (Cofala et al., 2006). According to Aardenne et al. (1999) emissions of NO_x increase to 350% from 19 Tg to 86 Tg (in NO_2) in 2020. In contrast, the estimate by Klimont et al. (2001) is more modest, citing an increase of 200%, from 10.8 Tg to 21.1 Tg in Northeast Asia.

5.5 Chemical transport modeling studies

5.5.1 Regional distribution of acid rain in Northeast Asia

One of the purposes of EANET monitoring is to obtain a regional perspective of acid rain distribution in East Asia. Although the number of EANET monitoring sites may not yet be sufficient to obtain region-wide spatial distribution of acidity and chemical composition of rainwater in high enough resolution, some characteristics have emerged from EANET observational data. For example, pH in rainwater is relatively high (6.0–7.2) in northern China, but it decreases in South Korea (5.0–5.6) and Japan (average 4.7) in this order, in spite of the fact that the emission intensity of SO_2 is higher in China. Also, the southern part of China suffers much lower pH in rain compared to the northern part. Figure 5.5.1 shows the annual average pH value of precipitation over Northeast Asia in 1998, composed from data from SEPA (1999) and EANET (2000).

Such basic characteristics of the spatial distribution of pH in Northeast Asia have been successfully reproduced by a model simulation that takes soil dust (yellow sand, or Kosa) explicitly into account (Wang et al., 2002). The model has been validated by comparison with EANET observations in its preparatory phase (EANET, 2000) for each acidic (SO_4^{2-}, NO_3^-) and alkaline chemical species (Ca^{2+}, NH_4^+). Figure 5.5.1 depicts the simulated annual pH value in rainwater from the model simulation for 1999. Basic characteristics of the observed distribution of annual average rainwater pH are quantitatively well reproduced. Thus, the simulation results exhibited strong neutralization of precipitation by soil aerosols over Northeast Asia. The annual mean pH values in northern China and Korea show a remarkable increase of acidity (pH 0.8–2.5), while the increases in mean pH over southern China and Japan are less than 0.1.

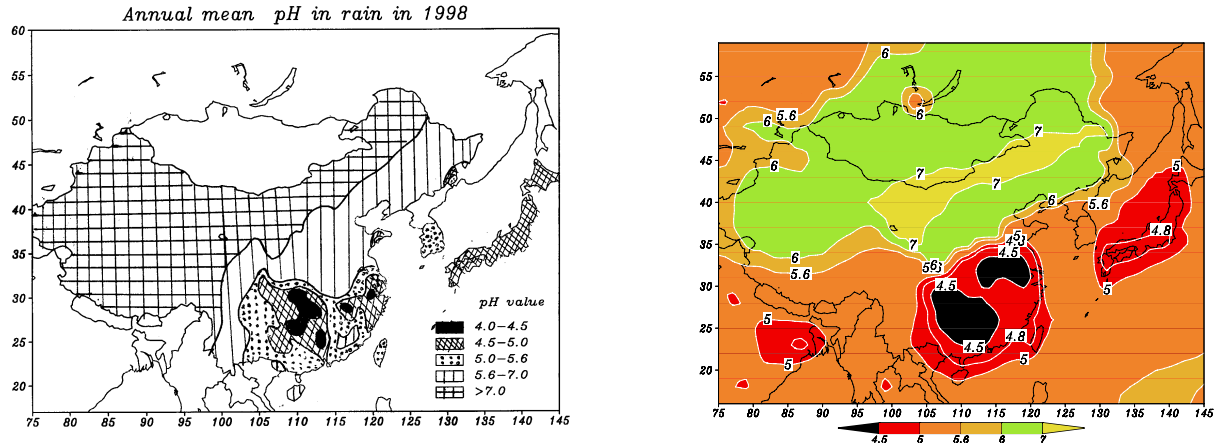

Figure 5.5.1 Observed annual average pH value of precipitation over Northeast Asia in 1998 (left) and simulated annual pH value in rainwater by the model for 1999 (right) (Wang et al., 2002)

5.5.2 Regional distribution of sulfur in Southeast Asia

A regional modeling study of anthropogenic sulfur in Southeast Asia has been reported by Engardt and Leong (2001). The calculated results of annual-mean anthropogenic sulfur concentration in precipitation and deposition (sum of dry and wet deposition) are shown in Figure 5.5.2. As seen in these figures, anthropogenic sulfur concentrations and depositions are particularly high near the large cities of the region, around a metal smelter in the southern Philippines, and in a region extending from northern Vietnam into southeastern China. These areas coincide with the high-emission regions of Southeast Asia, and it was concluded that areas particularly at risk include the large cities, northern Vietnam, most of central Thailand, most of peninsular Malaysia, eastern Sumatra, and parts of Java, with total-sulfur deposition in excess of 0.5 g S m^{-2} yr^{-1}.

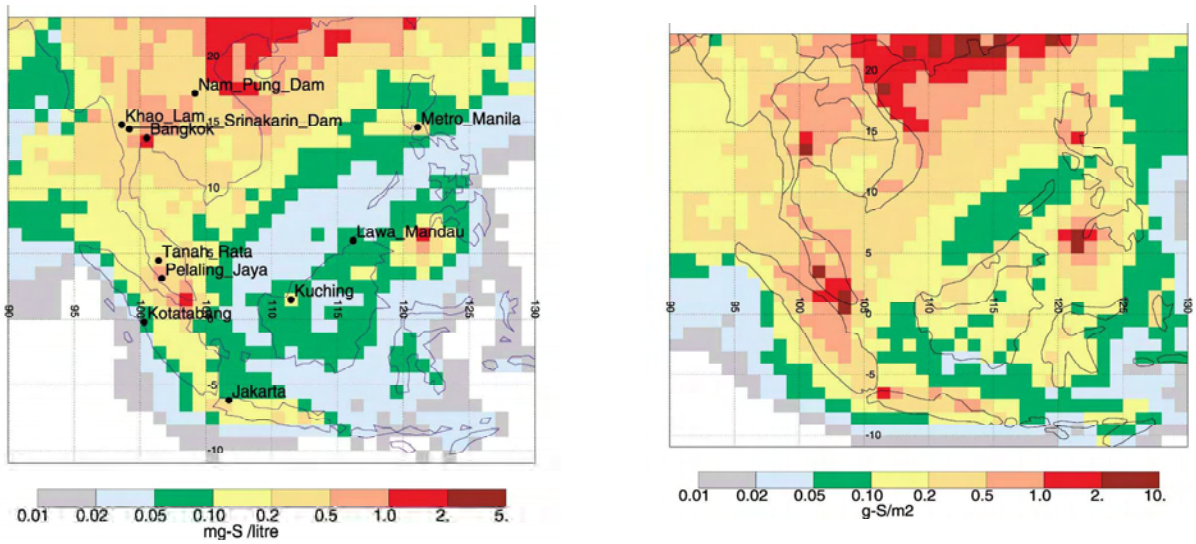

Figure 5.5.2 Calculated annual-mean anthropogenic sulfate concentration in precipitation (left) and sulfur deposition (right, in g S m^{-2} yr^{-1}) in Southeast Asia, The location and name of the monitoring stations are presented on left graph (Engardt and Leong, 2001)

5.5.3 Source-receptor matrix for sulfur

It is of great concern to accurately estimate the source-receptor relationship of acid precursors in Asia by model simulation, but because of the uncertainties involved in model parameters and the complexity of meteorological conditions in Asia due to Asian monsoon, there has not yet been full consensus on the quantitative source-receptor relationship in this whole region. This is particularly the case for mid-latitude Northeast Asia, where meteorological dynamics play an important role in transport mechanisms and a large heterogeneity of emission intensity from country to country exists. In comparison to Northeast Asia, the situation seems to be relatively simpler in the Southeast Asia region, as shown in a recent report (outlined below). Here, the source-receptor relationship in Southeast Asia is introduced first, which is followed by a review of studies for Northeast Asia.

Recently, Engardt et al. (2005) published a country-to-country study of the transport of anthropogenic sulfur in Southeast Asia. Compared to the conditions in the mid-latitudes (Europe, North America, and Northeast Asia), less long-range transport has been found to occur in this part of the world. In all countries in the region (except those with a very small area, i.e., Singapore and Brunei), the major part of domestic emissions (60%–70%) fall on the emitting country itself. The fraction of each countries' own emissions contributing to the total national deposition varied from 10% for Laos, with its small emissions and neighboring large emitters, to 80%–90% in countries not surrounded by significant emitters, i.e., Thailand, Indonesia, Singapore, and Brunei.

There have been substantial studies on source-receptor relationships for Northeast Asia, although a full matrix covering all countries in this region has rarely been reported. Also, there is large uncertainty in the estimated export and import values produced by different models. As an example, Table 5.5.1 presents the source-receptor relationship of sulfur deposition in Japan from different sources obtained from different models (Inoue et al., 2005). As seen in the table, the contribution of sulfur deposition in Japan from China ranges from 3% to 49%. Arndt et al. (1998) pointed out that the difference was mainly caused by the difference in the assumed wet removal rate of SO_2 and sulfate; much larger wet removal rates were assumed by Huang et al. (1995) than others. Low removal rates provided results in greater transport away from source locations and thus higher transboundary pollution.

The difference among models is also thought to be originated from different assumptions of other parameters, such as dry deposition velocities of SO_2 and sulfate aerosol, gas-to-particle conversion

rates, vertical convection efficiency, etc. Although verification of simulation results by observational data is generally presented to some extent in each model, it is desired that future model results could be anchored by more detailed observational data.

Table 5.5.1 Source-receptor relationship of sulfur deposition on Japan from different sources (%) (Inoue et al., 2005)

Authors	Year	Model Type	Japan	Volcano	China	Korea	others
Huang et al. (1995)	1989	Eulerian		94	3	2	1
Carmichael and Arndt (1995)	1990	Trajectory	38	45	10	7	0
Ikeda and Higashino (1997)	1988	Eulerian	37	28	25	10	0
Ichikawa et al. (1998)	1988/89	Hybrid	40	18	25	16	1
Ichikawa et al. (2001)	1995	Trajectory	26-29	24-32	29-32	12-13	1-2
Inoue et al. (2005)	1995	Eulerian	21	13	49	12	5

Another important factor to be considered in estimating source-receptor relationships in Asia is a strong dependence on season due to the Asian monsoon. Arndt and Carmichael (1998) studied the seasonal source-receptor relationships for countries in South, Southeast, and Northeast Asia. Figure 5.5.3 depicts the calculated seasonal sources and their magnitude of anthropogenic sulfur deposition for Bangladesh, Nepal, Vietnam, Malaysia, China, and Japan. Small sulfur-emitting countries in the region were found to receive more sulfur deposition than they emit, with the majority of their deposition coming from neighboring or even distant countries.

Compared to sulfur deposition, the regional exchange of nitrogen species has received much less attention. Holloway et al. (2002) present the source-receptor relationships of total HNO_3 deposition due to fossil fuel burning in Northeast Asia and India, as shown in Table 5.5.2.

Table 5.5.2 Annual source-receptor relationship for total HNO_3 deposition due to fossil fuel burning (in % of total HNO_3 deposition in "receptor" countries). "Source" countries listed in left column, "receptor" countries - in the top row. (Holloway et al, 2002)

Emitters	Emissions (10^9 g N·yr^{-1})	Receptors					
		Taiwan China	Japan	N. Korea	S. Korea	China	India
Taiwan China	116	80	2			2	
Japan	556	1	65	1	4		
N. Korea	120		3	34	7	1	
S. Korea	256		12	20	63		
China	2132	18	18	46	26	90	
India	1020	1				6	95
Total deposition (10^9 g N·yr^{-1})		31	276	66	69	1173	372

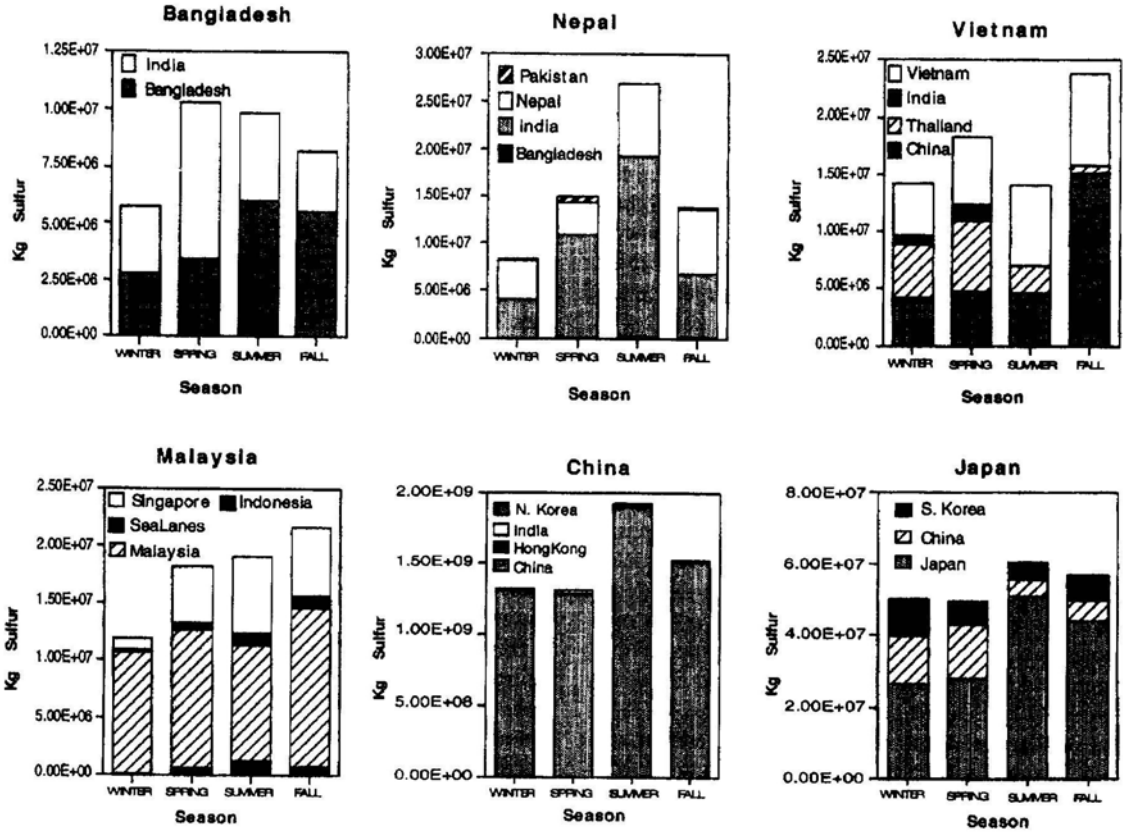

Figure 5.5.3 Model calculated seasonal sources and their magnitudes of anthropogenic sulfur deposition for Bangladesh, Nepal, Vietnam, Malaysia, China and Japan. (Arndt et al., 1998)

5.5.4 Long-range transport of ozone in East Asia

Simulated regional distributions of surface ozone in Asia have recently been presented by using regional-scale chemical transport models (Zhu et al., 2004; Yamaji et al., 2006). Zhu et al. (2004) calculated the region-wide spatial and temporal distribution of surface ozone in monthly average for months of high ozone concentrations (April–July) using January and October for reference. A high ozone belt was identified to extend from Central to East Asia in May–June (Figure 5.5.4), and particularly high ozone was seen in the North China Plain (from north of the Yangtze River to the Beijing/Tianjin area) in East Asia with the monthly average higher than 70 ppb.

Yamaji et al. (2006) presented a similar distribution of boundary layer ozone in East Asia bimonthly. The Community Multi-scale Air Quality model (CMAQ) was validated by using the data from EANET and WMO/GAW on surface ozone in 2002 from Japanese monitoring stations. Long-range transport of ozone in Northeast Asia was evaluated as a zonal mean concentration for a diagnostic transect between Japan and the Asian continent. As seen in Figure 5.5.5, the contribution is as much as around 20 ppb in summer and 10–15 ppb in spring, which agrees well with the estimates obtained from observational data (Figure 5.3.4*b*). The latitudinal gradient in the surface O_3 spring maximum over the East Asia Pacific Rim region has been discussed by Tanimoto et al. (2005).

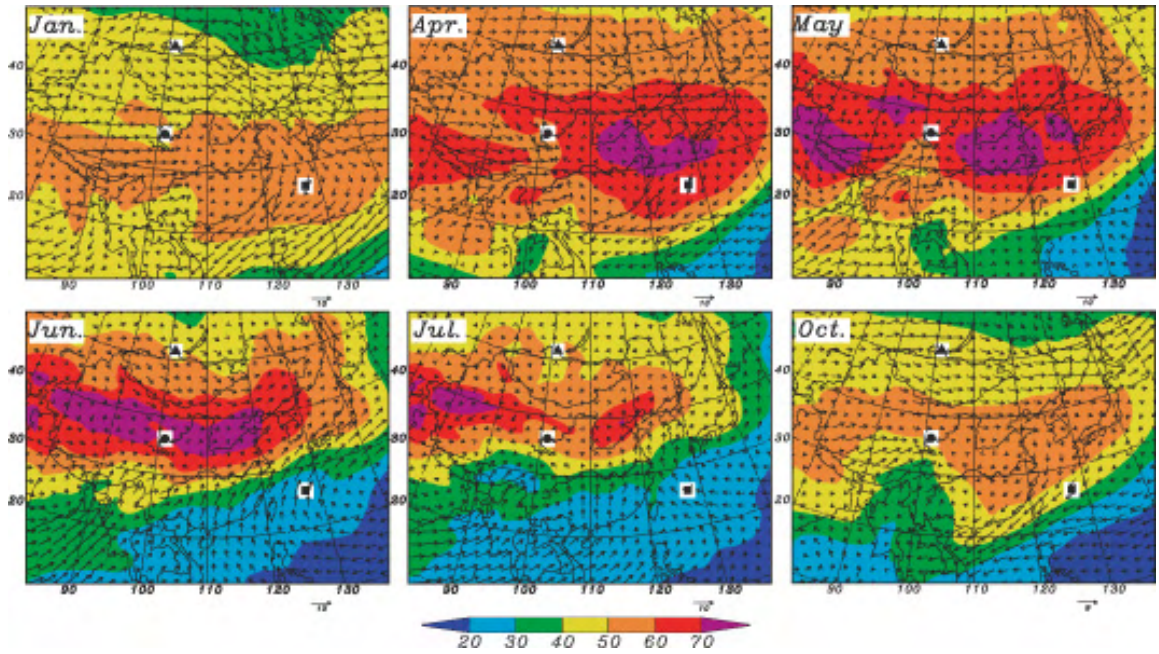

Figure 5.5.4 Distributions of monthly averaged concentration of surface ozone calculated by a regional model (Zhu et al., 2004)

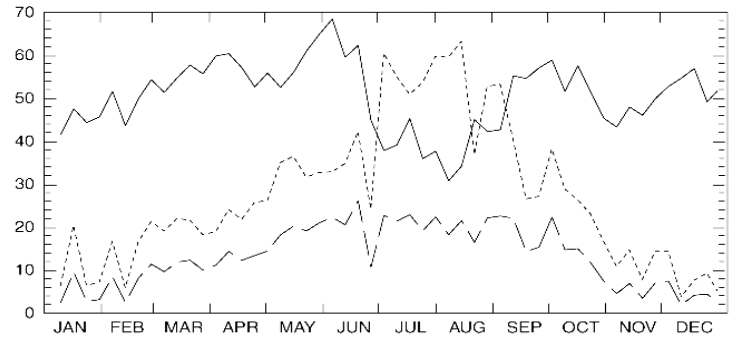

Figure 5.5.5 Zonal average contribution of boundary layer ozone due to Asian emissions in ppb (dash line) and in % (dotted line) against total (solid line). (Yamaji et al., 2006)

5.6 Ecological modeling and assessment studies in EANET region

5.6.1 Evaluation of acid deposition impact on ecosystems in Europe

The sensitivity of ecosystems to acid deposition has been included in a *Sulfur protocol* of the UN ECE CLRTAP. As a basis of the *Sulfur protocol* in Europe, the concept of critical load has been applied as an indicator of the sensitivity of ecosystems to acidification. Critical load (CL) is defined as "the highest deposition of a compound that will not cause chemical changes leading to harmful effects on ecosystem structure and function" (Nilsson and Grennfelt, 1988). The CL concept has been used together with integrated models, such as the Regional Acidification Information and Simulation model (RAINS), to assess a variety of emission reduction strategies in relation to abatement costs and environmental protection. The RAINS model consists of the following: (a) an energy/emission module that computes national emissions as a function of energy combustion (SO_2, NO_x) and agricultural practices (NH_3); (b) an atmospheric module that computes acidic depositions in 150 x 150 km^2 grid cells using the EMEP transport model; and (c) an effects module that computes acidic depositions to critical loads produced.

The method for computing CL is based on the Steady State Mass Balance Method (SSMB) (Sverdrup et al., 1990). The SSMB assumes a steady state of chemical compounds in soils and surface waters. The ratio of base cations to aluminum and aluminum concentration are used as indicators for the steady state of geochemical processes, but the method for estimating CL has many controversial factors from the scientific viewpoint. It should be stressed that the CL approach is employed as a useful tool to derive suitable abatement scenarios.

5.6.2 Application of ecosystem models to Asian countries

The project (RAINS-ASIA Phase I) for the estimation of critical load in Asian countries started in 1992 with the financial support of the World Bank and Asian Development Bank. (An overview of the RAINS-ASIA model was described in 5.2.1.) The project was mostly based on the RAINS-EUROPE model, including an energy/emission module, atmospheric deposition module, and effects module (IMPACT), where the critical load concept was introduced in relation to the deposition of sulfur compounds. (An example of the output from the model, the map with exceedance of critical load for sulfur in 2020 in the reference scenario case, was shown in Figure 5.2.1.)

Recently, Yamashita et al. (2006) reported a study for evaluating cost-effective reduction strategies for nitrogen oxides in the Asian regions. The source-receptor relationships of the Lagrangian "puff" model of long-range transportation (ATMOS-N) were used to calculate the wet/dry deposition of nitrogen (N) in Asia. Excess nitrogen deposition above the critical load was then calculated, as shown in Figure 5.6.1. Critical loads of N deposition in Asia were calculated from the relationships between the critical load of sulfur (S) and in/out balance of N using the data of S critical load from RAINS-ASIA. The cost functions of N reduction of Asian countries were derived using regression analysis on the data of cost functions of European countries used in RAINS-EUROPE. In order to assess environmental impact, the gaps between N deposition and critical load of N were calculated. From the model calculation, the emission of NO_x was reduced in some cases in this model, and the changes of gaps between N deposition and critical load were observed as changes of the reduction cost. It is shown that a uniform reduction of NO_x emissions by countries in Asia is not a cost-effective strategy.

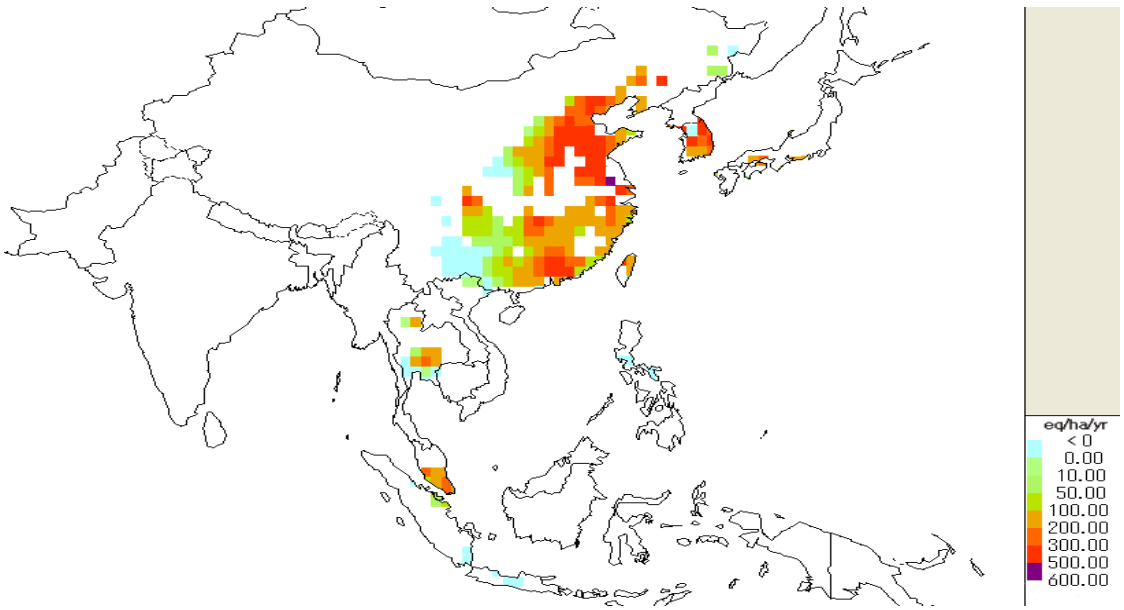

Figure 5.6.1 The cells of N_{dep}-$CL_{min}(N)$ with no reduction of NO_x emission

The application of the RAINS-ASIA model, derived from the RAINS-Europe model, to estimate the critical load in Asian countries has been controversial, however, because the regional characteristics of climatic conditions and ecosystems are different than those in Europe. It may be desirable to develop models with a site-specific approach applicable to the East Asia region.

Shindo et al. (2003) created a numerical model to evaluate the anthropogenic nitrogen load on the environment and the nitrogen concentration in river water in East Asia. They estimated the nitrogen load of each country in East Asia from statistics provided by the Food and Agriculture Organization of the United Nations (FAO, 2002) on fertilizer consumption, food balance sheet data, and grid data of NO_x emissions due to fossil fuel consumption as reported by the emission inventory of ACESS (2002). The concentration in river water and the riverine export of nitrogen were calculated by assuming a first-order reaction model in which denitrification and organic matter accumulation was a function of temperature and resident time. The results show that more than 90% of the nitrogen load originated from food production and supply. The contribution of NO_x emissions was important only in Japan and South Korea.

The estimated loads of nitrogen on the catchments of major rivers were 10–30 times larger than the measurements on riverine export of nitrate reported before in the literature. A recent report by Shindo et al. (2006) shows the relationship between nitrogen load and nitrogen concentration in groundwater, and they estimated in eastern Asian countries for the years 1961–2020 (Figure 5.6.2) that groundwater and river water will be highly polluted by the nitrogen load in an extremely wide area by 2020. Shindo et al. (2005) roughly indicated the correlation between nitrate concentrations in stream water in the catchment and estimated nitrogen deposition in Japan. An excess nitrogen load on terrestrial ecosystems will be harmful to forest tree growth.

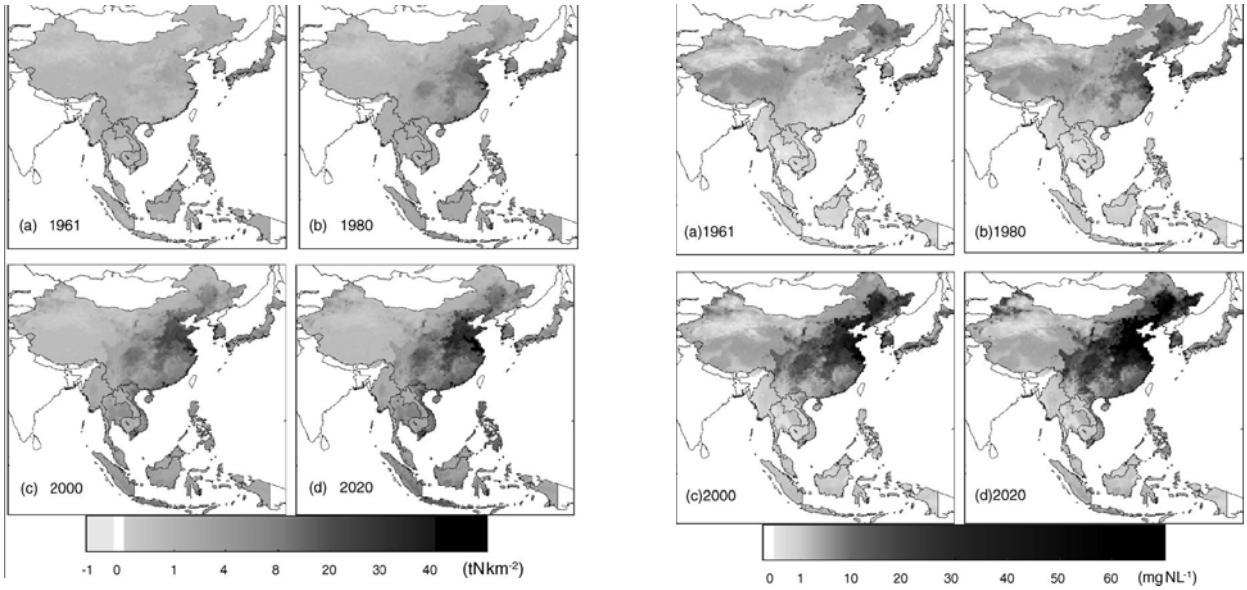

Figure 5.6.2 Estimated and predicted spatial distribution of total nitrogen load (t km^{-2}, *left*) and nitrogen concentration in groundwater (*right*) for the year 1961-2020 (Shindo et al., 2006)

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6. Recommendations for Future Activities

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CONTENTS

6.1 Introduction

EANET has made considerable progress and reached important achievements in monitoring, data acquisition and management, research, and other technical issues. This inaugural edition of the *Periodic Report* presents the first results of a scientific evaluation of the information obtained on the regular phase to date and provides some conclusions, despite limited datasets and a shortage of measurements as well as weaknesses topics were identified and explained in previous chapters.

Further development of EANET will include a focus on certain priorities that correspond to the main goals and objectives of the network. The measurements collected for five years are still not sufficient to draw precise and definite conclusions on temporal and spatial variations of atmospheric deposition. Presented assessments of data up to date have identified weaknesses and some measures that should be taken to detect their potential impact on the environment. Discussions until now have been based on limited datasets and knowledge, but there is general agreement that improvements in monitoring and data quality are among the most important directions for EANET to focus on. Progress in these areas should provide a more solid basis for advanced assessment of acid deposition and related environmental problems. In this regard, the number of coordinated research projects and studies support both the elaboration of technical issues and the use of other approaches to investigate the state of the atmospheric environment in EANET region.

Many discussions were held among the scientists, experts, and representatives from the participating countries at the meetings of EANET bodies on approaches for further development of the network as well as new directions and topics. The discussions highlighted the necessity of more comprehensive and wider application of data obtained using the experience of other international programs. They also emphasized the need to provide fact-finding basis for ensuring healthy conditions for humans and a sustainable environment in East Asia. Certain planning and coordinating efforts were made within EANET during the last few years, the most notable being the preparation of a *Strategy on EANET development (2006-2010)* covered almost all network activities to be coordinated among the participating countries, the EANET secretariat, and the Network Center.

The views of scientists and experts on the research and studies that need to be undertaken were prepared as recommendations for future projects. The recommendations took into account not only the necessity to eliminate weaknesses in current monitoring and data evaluation, but also the challenges of prospective directions in environmental assessments and new issues of the network.

6.2 Quality assurance/quality control activities

As mentioned in Chapter 2, quality assurance and quality control (QA/QC) play a critical role in acid deposition monitoring as well as other environmental measurements. QA/QC activities are also seen as a critical part of EANET monitoring to ensure that meaningful data are obtained. Through QA/QC activities, it is especially important that measured data satisfy specified levels of reliability and are accompanied by required information on the measurements themselves.

Several documents on QA/QC programs have been developed by EANET to guide receiving reliable data that can be comparable among the participation countries as well as with other monitoring networks outside the East Asian region. The QA/QC programs cover activities for the components of the measurement/analysis system in a general way, i.e., the field (sampling sites), laboratory, data management, and data reporting processes. According to EANET documents, QA/QC activities should be documented by each relevant entity.

Proper execution of QA/QC programs is regarded as an essential process for obtaining unbiased, precise, and representative data in EANET. The Inter-laboratory Comparison Project is one of the activities under the QA/QC programs, and it has been conducted annually since the preparatory phase with all laboratories participated in EANET for the most of environmental measurements where

samples are taken. Through this project, each laboratory can take advantage of the opportunity to assess their performance in established analytical procedures and identify problems in order to improvement data quality. As also mentioned in Chapter 2, the ratio of flagged data has decreased from the start of projects in spite of an increase in the number of laboratories participating. These results prove that most laboratories satisfied the requirements for certain levels of data quality.

Investigation of the datasets obtained so far determined that most measurements with unacceptable values of criteria on analysis (R_1 or R_2) are associated with ions derived from weak acids that are not included in the ongoing analytical suite, including carbonic and organic acids. In these cases, the samples with unacceptable R_1 and R_2 values are subjected to re-analysis regardless of the potential reasons. These situations require further experimental and theoretical research, with the aim of updating relevant parts of the QA/QC procedures.

Meanwhile, none of the laboratories met whole sets of requirements in other activities provided QA/QC programs (preparing standard operating procedures (SOPs), conducting audits of sites and laboratories, developing their own QA/QC programs, etc). To refine EANET activities in participating countries, it is quite important to establish special QA/QC programs for promoting these activities at the national level, including proper documentation on the QA/QC procedures and regulation of each relevant entity. Promotion of QA/QC activities is highlighted as one of the major parts of the *Strategy on EANET development (2006–2010)*, including the preparation of SOPs and the recommendation for auditing to be realized within the action plan. The following recommendations use to be further steps for improving QA/QC activities with the aims to establish harmonization with international QA/QC activities, and to apply stringent procedures of data management, in order to ensure that accuracy and precision are maintained:

- Compare data from EANET with other sources such as Co-operative Programme for Monitoring and Evaluation of the Long-range Transmissions of Air Pollutants in Europe (EMEP) and networks coordinated by the World Meteorological Organization (WMO).
- Establish traceability of data acquiring using international standards.
- Analyze and standardize uncertainty of measurements.
- Introduce a management system with set standardized procedure on sampling, laboratory analysis and data proceeding.

6.3 Monitoring of wet and dry acid deposition

As of 2004, there were 46 wet deposition monitoring sites and 35 air concentration monitoring sites operating in the EANET network. There are still no monitoring sites, however, in 20 blocks in the region on a 10-degree by 10-degree resolution. In order to clarify the state of the atmospheric environment in the whole region of East Asia, additional monitoring sites should be established, while taking into account geographic, climatic, and ecological situations, as well as an occurrence of *Dust and Sandstorms (DSS)* phenomena and effects of volcano emissions. Furthermore, the location of historical monuments or nature valuables, such as world heritage objects and places, as well as an implication of measurements to trace inter-continental transport of air pollutants are important factors to consider when selecting monitoring areas.

Although almost all precipitation chemistry parameters are determined for every sample of wet deposition monitoring around network, the set of air concentration compounds differs depending on the monitoring site and applied equipment. Use of the filter pack method is recommended by EANET as the most suitable method for monitoring gas and aerosol concentration, but it cannot determine levels of nitrogen oxides (NO_x) and ozone (O_3). Increased emission of NO_x and volatile organic compounds (VOCs) causes a higher concentration of ozone in East Asia, and long-range transportation of ozone is an issue of great concern in the regional environment related to health and forest damage. Therefore, ozone concentration should be monitored in the whole area covered by EANET. It is convenient to use passive samplers at first for the screening of averaged concentration, and then automatic air monitors should be installed in the areas where high concentrations are observed.

In order to obtain high-quality analytical data, the Inter-laboratory Comparison Projects should be continued for wet deposition monitoring and for gas concentration monitoring using the filter-pack method. The data completeness should also be assessed and it could be kept on high level by maintenance of equipments with appropriate frequency and reduction of human errors. Overall quality of monitoring data should be improved and kept at the high level by continuous implementation of those activities.

The dry deposition fluxes have been identified as being necessary for evaluation at the regional level in addition to wet deposition, in order to provide more comprehensive data on atmospheric impacts on the environment. The indirect measurement (inferential) method has been suggested as the most applicable methodology during the consideration on future strategy for estimating the dry deposition flux in EANET countries. The Task Force for Dry Deposition Monitoring (TFDD) indicated that related procedures should include the following main components:
1. Ascertainment of land surface properties at the monitoring site and the surrounding area, as well as of the properties of the depositing substances being targeted, especially if they are in aerosol form
2. Monitoring of the air concentrations of deposition substances and meteorological parameters
3. Estimation of deposition velocity values by the application of a numerical model
4. Calculation of the dry deposition flux with the use of continuous sets of air concentration and deposition velocity for the monitoring sites

Since there are various seasonal and land-use categories to be identified among monitoring sites and natural surfaces in the EANET region, existing approaches to apply indirect measurements cannot be adopted for implementation in EANET without modification. The relevant guidelines for these dry deposition flux observations and estimations will be developed for operational application by the participating countries. This new data should also be available for the regular assessment of acid deposition. Conducting non-routine, direct measurements of dry deposition flux, however, can also be recommended at selected sites or as experiments. Their implementation could provide an ad hoc database of direct flux observation in a parallel manner to compare with estimating dry deposition fluxes and to improve the inferential method, particularly the numerical model of dry deposition velocity by continuous examination.

6.4 Monitoring of ecological effects

Basic surveys of soil, vegetation, and inland aquatic environments are carried out to accumulate baseline data and to detect possible impacts of acid deposition on terrestrial ecosystems, according to the *Technical Manuals* (ISAG, 2000) and the *Strategy Paper for Future Direction of Soil and Vegetation Monitoring of EANET* (TFSV, 2002). The surveys are promoted independently for each ecosystem component. During the period from 2000 to 2004, the characteristics and present states of soil, vegetation, and lakes or rivers in the respective plots/sites were clarified as the baseline data, which must be informative for detection of unusual phenomena possibly related to acid deposition. Long-term data with the multi-stage sampling systems should be accumulated for soil, and frequent observations should be promoted for forest and surface water, in order to distinguish anthropogenic impacts from natural factors. Surveys of each component of ecosystems cannot be enough, however, to clarify the impacts of either natural phenomena or acid deposition effects. More systematic and comprehensive approaches should be promoted to assess impacts on terrestrial ecosystems.

As for acidification of soil and surface water by acid deposition and resulting impacts, contribution of ecosystem components, including atmosphere, vegetation, soil, and surface water, should be assessed while taking biogeochemical elemental/ion flows and budgets into account. For this purpose, continuous observations of input (atmospheric deposition) and output (stream water) should be carried out in forested catchments based on the water budget in the ecosystem. Case studies on catchment-scale monitoring should be promoted in the EANET participating countries, as recommended in the *Strategy Paper* (TFSV, 2002). Catchment-scale monitoring may contribute to quantitative assessment of acid deposition impacts on ecosystems. Relevant technical documents, such

as guidelines or manuals, should be prepared for this integrated monitoring. In addition, in order to assess the regional degradation of ecosystems there is a basic need to describe the present status of soil acidification in the whole region of East Asia, and thus advanced monitoring procedures should be developed to detect the sensitivity and capacity of soil to acid deposition.

As for direct effects of dry deposition on plants, it has been suggested that high concentrations of tropospheric ozone may be harmful to the growth of trees and crops in Europe, and specific visible injuries of plant leaves caused by ozone have been identified as indicators for observation. High concentrations of ozone have also already been reported in EANET participating countries. Accumulation of ozone data in forest areas by passive sampling and application of surveys of visible injury should be considered for future assessment of ozone impacts. Consequently, the critical level of ozone concentration will be an issue to be discussed in future.

6.5 Emission inventories

EANET started as a cooperative network for acid deposition monitoring. Nevertheless, the degradation of air quality in East Asia, which may be caused by rapid economic development in this region, requires the establishment of a scientific basis for air quality management, and monitoring should be one component of this effort. Another basic component is the preparation of emission inventories.

Whether it is local or global air pollution, it is first of all essential to know the sources and quantities of released pollutants which are provided by emission inventories. The use of emission inventories helps to elucidate cause-effect relationships relating to the spatial distribution of pollutants. These inventories, along with socioeconomic projections, make it possible to estimate future emissions. Studies regarding reduction measures by emission sources would contribute to the planning of cost-effective measures and technical cooperation to support those measures, as well as the setting of reduction targets.

With these merits in mind, in the future EANET will promote activities to develop emission inventories, including continuous QA/QC activities for emission data, similar to the approach that was taken for monitoring. Securing transparency in the estimation methods of emissions will help to create a common understanding on issues surrounding emissions.

6.6 Modeling projects

Together with monitoring, numerical models are indispensable to provide better understand acid deposition and its effects on ecosystems. Numerical models can reveal the dynamics of the transport and diffusion, effect of chemical reactions, and wet- and dry-deposition processes of air pollutants as well as the dynamics of acidification of soil and inland aquatic environments. In order to understand acid deposition, sophisticated air quality modeling, which includes detailed sub-models or modules of physical and chemical processes, is ongoing and should be encouraged. The number of modeling projects relevant to the effects on soil and inland aquatic environments is limited, however, and there are few being conducted for East Asia in particular. The time variation in acidification of soil and inland aquatic environments is much slower compared with the time period of EANET monitoring. Thus, modeling in parallel with the monitoring of soil and inland aquatic environments is indispensable.

Numerical models should also be developed as a supplemental tool for EANET monitoring. There are presently 45 sites for measuring wet deposition and air concentrations, 12 for monitoring inland aquatic environments, and ten for soil and vegetation monitoring in the vast East Asian region. To what extent can the regional environment be assessed using this limited monitoring network? For the best results on the regional scale, monitoring data must be objectively interpolated and/or extrapolated for the whole of East Asia. At present, the most reliable technique available for interpolation and

extrapolation of observations in space and time is the four-dimensional variational analysis method (4DVar). Such an algorithm should be developed for air quality data analysis. Elaboration of the modules reproducing physical and chemical processes is also indispensable. An example of such modules that has been already used in the EANET network is the dry deposition module. Without this module, dry deposition monitoring in the present version of EANET procedures can loose its important identity.

In addition, an integrated numerical model for assessment and policy analysis should be developed to analyze long-term strategies to address acid deposition problems at national and regional levels. Such a model will help decision-makers make projections, analyze future trends in emissions, estimate long-range transboundary transport of air pollutants and the regional consequences for acid deposition levels, evaluate the vulnerability of natural and artificial systems, and estimate the cost-effectiveness of alternative mitigation actions that might be taken. A typical example of such models is the Regional Acidification Information and Simulation (RAINS) model developed by the International Institute for Applied System Analysis (IIASA). The results of its application contributed to the emission control of air pollutants at the regional scale, keeping in mind cost performance, and derived international consensus on important protocols under the CLRTAP, like the 1994 Oslo Protocol.

For the reasons outlined above, EANET will promote and encourage modeling activities.

6.7 Expanding EANET scope to include impacts on human health

EANET is the only system for regional environmental monitoring in operation in East Asia. For the past five years EANET has restricted its activities to concentrating mainly on monitoring acid deposition and its adverse effects on ecosystems, and has implemented this successfully. The countries participating in EANET are at varying levels of industrial and economic development, however, and so they experience different extent of air pollution as well as variable rates of change in condition. Thus, a priority should be also given to investigations of the impacts on human health including measures for mitigation or prevention to be a prerequisite for environmental management. This is a key issue to address in activities involving all other regional initiatives.

EANET has subsequently been promoting the monitoring of not only acidic species but also ozone and other precursors, as these chemical compounds allow evaluation using more objective data. Their air concentrations have also been monitored in order to estimate dry deposition fluxes. For the purpose of studying health effects, however, other chemical species such as persistent organic pollutants (POPs) and priority heavy metals should be included on the list of measured chemical compounds; and their air concentrations, together with their content in precipitation and other media, should be monitored to provide important information on factors with potential harmful effect on health.

6.8 Cooperation with other regional activities on inter-regional and global pollution issues

As a regional network covering the vast territory of East Asia, EANET is encouraged to have closer cooperation with other initiatives on inter-regional and global atmospheric pollution. For the “regional community” of EANET countries, this issue is of great concern and integral to the conservation of the global environment and achieving sustainable development. The coordination of main EANET activities are to be done with other regional networks over the world for investigations on the global and inter-regional dispersal of air pollutants that have harmful effects on human health and environment, and that have potential climate change effects. By engaging in cooperative activities, EANET will in turn acquire good practices for solving regional and transboundary problems, relating to modeling and emission inventories, evaluation of long-term impacts, and mitigation measures, among other benefits.

Other potential advantages for EANET include developing a monitoring infrastructure based on unified principles and standardized equipment over the whole region; coordination on ongoing training, capacity building, and QA/QC activities; collecting extensive data on atmospheric pollution and deposition; and the involvement of many East Asian scientists in wider cooperative activities, etc.

Approaches to pursue greater cooperation in the near future could be summarized as follows:

- Organizing pilot studies in the EANET region for cooperative monitoring among interested countries, the Network Center, and researchers from other regional activities
- Supporting the activities of the CLRTAP Task Force on Hemispheric Transport of Air Pollutants (TF HTAP) as a participating model in the model-intercomparison study, as a data resource, and as contributors in preparation of its *Assessment Report* for 2007–2009
- Promoting collaboration with the WMO on a wide range of activities within its programs of the Global Atmosphere Watch (GAW) on atmospheric chemistry and pollution in the troposphere of tropical areas, GAW Urban Research Meteorology and Environment (GURME) on megacities in EANET countries, and the World Climate Research Programme (WCRP) on the relationship between air pollution issues and climate change, including investigation of the El Niño Southern Oscillation (ENSO) as well as providing EANET contributions to the WMO/GAW global precipitation chemistry assessment proposed to be initiated in 2007.

References

ISAG, 2000. Guidelines for Acid Deposition Monitoring in East Asia. 2nd Interim Scientific Advisory Group Meeting, 25 p.

TFSV, 2002. Strategy Paper for Future Direction of Soil and Vegetation Monitoring of EANET, Task Force on Soil and Vegetation Monitoring on EANET (TF SV), 20 p.

Appendix

Overview of national/regional criteria, standards or guidelines relevant to acid deposition

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Compilation: *Sergey Gromov, Shinji Nakayama, Kyoko Hasegawa*

CONTENTS

National Air Quality Standard of Participating countries of EANET

The criteria for the evaluation on state of environmental media and their pollution are still the topics for scientific studies. There are sets of indicators proposed by the researchers and ad hoc teams within different programs including regional Conventions (CLRTAP, CIEA), UNEP, UNDP and others. However, these findings play role of references for reviews or comparison including tracing of environmental changes.

The special standards are established at the national levels with the main goal to provide certain values of pollution (or impact) levels which are not to be exceeded due to anthropogenic activities (through emission of pollutant into ambient air or their release into waters as well as dumping on soil, etc. As a common approach there are primary standards to be designed to protect human health, including sensitive populations such as children, the elderly, and individuals suffering mostly from respiratory disease. In some countries the secondary standards are also provided to protect public welfare (e.g. building facades, visibility, crops, and domestic animals).

The compilation of the national standards or guidelines relevant to acid deposition and air quality was proposed to be included in this report to recognize the situation with environmental legislation in this field over the EANET region. The national criteria were presented by the NFPs of the participating countries and SAC members based on existed documents adopted or approved by respective governments. They are mostly concerned the atmospheric pollution over the local inhabited areas which are the first order of regulations from the viewpoint of human health and preventing damage of living conditions.

However, some other criteria were expected to be informed as recommendation for ensuring environmental sustainability and ecosystem health. The scientific reviews demonstrated the approaches done in some countries and the correspondent overview would be provided later.

The national standards and guidelines presented below country by country with some unification in terminology and used units. Their comparison is likely to be not suitable due to different levels of their legislation and application among the participating countries.

References

Government Regulation No 41/1999, 1999. National Ambient Air Quality Standard Regarding Air Pollution Control. PP No. 41/1999, Indonesia.

PCD, 2004. "Thailand State of Pollution Report 2004", PCD 06-018, Pollution Control Department, Thailand. ISBN 974-9879-03-1

Republic Act No. 8749, 1999. Republic Act No 8749 “Philippine Clean Air Act of 1999”, Congress of the Philippines, Republic of the Philippines.

Report, 2004. Malaysia Environmental Quality Report 2004, Department of Environment, MONRE, 59 p.

China

Table A.1 Air Quality Standard of China

Substance	Average time	Limit of concentration			Unit *
		1st grad	2nd grad	3rd grad	
Sulfur dioxide (SO_2)	Annually	0.02	0.06	0.10	$mg \cdot m^{-3}$
	Daily	0.05	0.15	0.25	
	1 hour	0.15	0.50	0.70	
Total suspended particles (TSP)	Annually	0.08	0.20	0.30	
	Daily	0.12	0.30	0.50	
Particulate matter (PM10)	Annually	0.04	0.10	0.15	
	Daily	0.05	0.15	0.25	
Nitrogen dioxide (NO_2)	Annually	0.04	0.08		
	Daily	0.08	0.12		
	1 hour	0.12	0.24		
Carbon monoxide (CO)	Daily	4	4	6	
	1 hour	10	10	20	
Photochemical oxidants (O_3)	1 hour	0.16	0.20		
Lead (Pb) in TSP	3-months	1.5			$\mu g \cdot m^{-3}$
	Annually	1.0			
B[a]P in PM10	Daily	0.01			

***** - given at standard conditions of (0 ^{o}C, 101.3 kPa)

Indonesia

Table A.2 Ambient Air Quality Standard of Indonesia

No	Parameter	Measurement Time	Quality Standard Values ($\mu g \cdot m^{-3}$)*	Methods for Analysis	Analytical Instrument
1	Sulfur dioxide (SO_2)	1 hour	900	Pararosaniline	Spectrophotometer
		24 hours	365		
		1 year	60		
2	Carbon monoxide (CO)	1 hour	30,000	NDIR	NDIR Analyzer
		24 hours	10,000		
3	Nitrogen dioxide (NO_2)	1 hour	400	Salzmann	Spectrophotometer
		24 hours	150		
		1 year	100		
4	Oxidizer (O_3)	1 hour	235	Chemiluminescent	Spectrophotometer
		1 year	50		
5	Hydrocarbons (HC)	3 hours	160	Flame Ionization	Gas Chromatography
6	Particulate matter (PM10)	24 hours	150	Gravimetric	Hi-Vol
7	Particulate matter (PM2.5)	24 hours	65	Gravimetric	Hi-Vol
		1 year	15		
8	Total suspended particles (TSP)	24 hours	230	Gravimetric	Hi-Vol
		1 year	90		
9	Lead (Pb) in aerosol	24 hours	2	Gravimetric Extraction	AAS
		1 year	1		
10	Sulfate Index	30 days	1 g SO_3 m^{-3}	Colorimetric	Lead Peroxide Candle
11	Dust fall	30 days	10 (residential) 20 (industrial) $tons \cdot km^{-2} \cdot month^{-1}$	Gravimetric	Canisters

* - excluding the use of special units (of 10 and 11)

Source: Government Regulation No 41/1999.

Japan

Table A.3 Air Quality Standard of Japan

Substance	Environmental conditions	Measuring method
Sulfur dioxide (SO_2)	The daily average for hourly values shall not exceed 0.04 ppm, and hourly values shall not exceed 0.1 ppm (Notification on May 16, 1973)	Conductometric method or ultraviolet fluorescence method
Carbon monoxide (CO)	The daily average for hourly values shall not exceed 10 ppm, and average of hourly values for any consecutive eight hour period shall not exceed 20ppm (Notification on May 8, 1973)	Nondispersive infrared analyzer method
Suspended particulate matter (TSP)	The daily average for hourly values shall not exceed 0.10 $mg \cdot m^{-3}$, and hourly values shall not exceed 0.20 $mg \cdot m^{-3}$ (Notification on May 8, 1973)	Weight concentration measuring methods based on filtration collection, or -rayblight scattering method; or piezoelectric microbalance method; or attenuation method that yields values having a linear relation with the values of the above methods.
Nitrogen dioxide (NO_2)	The daily average for hourly values shall be within the 0.04-0.06 ppm zone or below that zone (Notification on July 11, 1978)	Colorimetry employing Saltzman reagent (with Saltzman's coefficient being 0.84) or chemiluminescent method using ozone.
Photochemical oxidants (O_3)	Hourly values shall not exceed 0.06 ppm (Notification on May 8, 1973)	Absorption spectrophotometry using a neutral potassium iodide solution; coulometry; ultraviolet absorption spectrometry; or chemiluminescent method using ethylene.
Benzene	Annual average shall not exceed 0.003 $mg \cdot m^{-3}$ (Notification on February 4,1997)	Preference method: gas chromatograph-mass spectrometer (sample gas should be collected with a canister or tube) or equivalent method.
Trichloro-ethylene	Annual average shall not exceed 0.2 $mg \cdot m^{-3}$ (Notification on February 4,1997)	
Tetrachloro-ethylene	Annual average shall not exceed 0.2 $mg \cdot m^{-3}$ (Notification on February 4,1997)	
Dichloromethane	Annual average shall not exceed 0.15 $mg \cdot m^{-3}$ (Notification on April 20,2001)	
Dioxins (PCDDs, PCDFs and coplanar PCBs)	Annual average shall not exceed 0.6 pg-TEQ $\cdot m^{-3}$ (Notification on December 27,1999)	Using high resolution gas chromatograph - high resolution mass spectrometry (HRGC-HRMS). (Samples should be collected by an air sampler equipped with an inlet filter followed by a cartridge filled with polyurethane foam.

Note:
1. Suspended particulate matter is defined as airborne particles with a diameter smaller than or equal to 10 μm.
2. Photochemical oxidants are oxidizing substances such as ozone and peroxiacetyl nitrate produced by photochemical reactions (only those capable of isolating iodine from neutral potassium iodide, excluding nitrogen dioxide.)

Malaysia

Table A.4 Ambient Air Quality Guidelines of Malaysia

Pollutant	Averaging time	Malaysia Guideline	
		ppm	**$\mu g \cdot m^{-3}$**
Ozone (O_3)	1 hour	0.10	200
	8 hours	0.06	120
Carbon monoxide (CO)	1 hour	30	35
	8 hours	9	10
Nitrogen dioxide ($NO_{2)}$	1 hour	0.17	320
	24 hours	0.04	-
Sulfur dioxide (SO_2)	1 hour	0.13	350
	24 hours	0.04	105
Particulate matter (PM_{10})	24 hours		150
	1 year		50
Total Suspended Particulate (TSP)	24 hours		260
	1 year		90
Lead (Pb)	3 month		1.5

Source: Report, 2004, p.10.

Mongolia

Table A.5 Air Quality Standard of Mongolia (MNS-4585-98)

Substance	Average time	Unit	MAC		Method
			A	B	
Sulfur dioxide (SO_2)	20minutes 24 hours	$\mu g \cdot m^{-3}$	500 30	500 70*	Wet chemical *UV fluorescence
Carbon monoxide (CO)	20 minutes 24 hours	$\mu g \cdot m^{-3}$	8 3		NDIR
Nitrogen dioxide (NO_2)	20 minutes 24 hours	$\mu g \cdot m^{-3}$	85 40	150* 60*	Wet chemical *Chemiluminescence
Ozone (O_3)	1 hour	$\mu g \cdot m^{-3}$	120		UV photometric
Particulates (TSP)	20 minutes 24 hours	$\mu g \cdot m^{-3}$	500 150	500 200*	Gravimetric *HVS
Lead (Pb)	24 hours	$\mu g \cdot m^{-3}$	1		AAS
Benzo(a)pyrene B[a]P	24 hours	$\mu g \cdot m^{-3}$	0.001		HPLC&GC

Note: MAC- Maximum Allowable Concentration
A, B – version of MAC which depends on the analytical methods

Philippines

Table A.6 National Ambient Air Quality Guideline for Criteria Pollutants of the Philippines

Pollutants	Short Term [a]			Long Term [b]		
	µg/NCM	ppm	Averaging Time	µg/NCM	ppm	Averaging Time
Suspended Particulate Matter [c]: TSP	230 [d]		24 hour	90	--	1 year [c]
PM-10	150 [f]		24 hour	60	--	1 year [e]
Sulfur Dioxide (SO_2) [c]	180	0.07	24 hour	80	0.03	1 year
Nitrogen Dioxide (NO_2)	150	0.08	24 hour	--	--	--
Photochemical Oxidants as Ozone (O_3)	140	0.07	1 hour	--	--	--
	60	0.03	8 hour	--	--	--
Carbon Monoxide (CO)	35mg/NCM	30	1 hour	--	--	--
	10mg/NCM	9	8 hour	--	--	--
Lead (Pb) [g]	1.5		3 months[g]	1.0		1 year

Note:

NCM – cubic meter under the normal conditions (25 ^{o}C, 101.3 kPa)

a Maximum limits represented by ninety-eight percentile (98%) values not to be exceeded more than once a year.

b Arithmetic mean.

c SO_2 and Suspended Particulate Matter are sampled once every six days when using the manual methods. A minimum of twelve sampling days per quarter or forty-eight sampling days each year is required for these methods. Daily sampling may be done in the future once continuous analyzers are procured and become available.

d Limits for Total Suspended Particulate Matter with mass median diameter less than 25-50 µm.

e Annual Geometric Mean.

f Provisional limits for Suspended Particulate Matter with mass median diameter less than 10 microns and below until sufficient monitoring data are gathered to base a proper guideline.

g Evaluation of this guideline is carried out for 24-hour averaging time and averaged over three moving calendar months. The monitored average value for any three months shall not exceed the guideline value.

Source: Republic Act No. 8749, 1999

Republic of Korea

Table A.7 National Ambient Air Quality Standard of Republic of Korea

Air Pollutants	Standards	Averaging times
Sulfur dioxide (SO_2)	0.02 ppm	Annual
	0.05 ppm	24 hr
	0.15 ppm	1
Carbon monoxide (CO)	9 ppm	8 hr
	25 ppm	1 hr
Nitrogen dioxide (NO_2)	0.05 ppm	Annual
	0.08 ppm	24 hr
	0.15 ppm	1
Particulate matter (PM10)	70 $\mu g \cdot m^{-3}$	Annual
	150 $\mu g \cdot m^{-3}$	24 hr
Ozone (O_3)	0.06 ppm	8 hr
	0.1 ppm	1 hr
Lead (Pb)	0.5 $\mu g \cdot m^{-3}$	Annual

Russia

Table A.8 Maximum permissible concentrations (MPC), which are set in Russian Federation for those elements connected with acid deposition issues ($mg \cdot m^{-3}$) (Modified from MEP, 1994)

Pollutant	Episodic MPC	Daily MPC
Nitrogen dioxide (NO_2)	0.2*	0.04
Nitrogen oxide (NOx)	0.4	0.06
Sulphur dioxide (SO_2)	0.5	0.05
Carbon monoxide (CO)	5	3
Black carbon (BC)	0.15	0.05
Total suspended particles (TSP)	0.5	0.15
Lead (Pb)	0.001	0.0003
Ozone (O_3)	0.16	0.03

*New MPC for nitrogen dioxide was set to be equal to 0,2 $mg \cdot m^{-3}$ by the Ministry of Health and Social Development in February 2006. The previous value of MPC level for NO_2 was 0.085 $mg \cdot m^{-3}$.

Thailand

Table A.9 Air Quality Standard of Thailand

Substance	Average time	Standard
Carbon monoxide (CO)	1 hour	30 ppm (34.2 $mg \cdot m^{-3}$)
	8 hour	9 ppm (10.26 $mg \cdot m^{-3}$)
Nitrogen dioxide (NO_2)	1 hour	0.17 ppm (0.32 $mg \cdot m^{-3}$)
Ozone (O_3)	1 hour	0.10 ppm (0.20 $mg \cdot m^{-3}$)
Sulfur dioxide (SO_2)	1 year	0.04 ppm (0.10 $mg \cdot m^{-3}$)
	24 hour	0.12 ppm (0.30 $mg \cdot m^{-3}$)
	1 hour	0.3ppm (0.78 $mg \cdot m^{-3}$)
Lead (Pb)	1 month	1.5 $\mu g \cdot m^{-3}$
Particulate matter (PM10)	24 hour	0.12 $mg \cdot m^{-3}$
	1 year	0.05 $mg \cdot m^{-3}$
Total Suspended Particulate (TSP)	24 hour	0.33 $mg \cdot m^{-3}$
	1 year	0.10 $mg \cdot m^{-3}$

Source: PCD, 2004

Viet Nam

Table A.10 Air quality standards of Vietnam, $mg \cdot m^{-3}$ (TCVN 5937-1995)

Parameter	1 hour average	8 hr-average	24 hr- average
Carbon monoxide (CO)	40	10	5
Nitrogen dioxide (NO_2)	0.4	-	0.1
Sulfur dioxide (SO_2)	0.5	-	0.3
Lead (particulate)	-	-	0.005
Ozone (O_3)	0.2	-	0.06
Suspended particulate matter (SPM)	0.3	-	0.2

Annex

Tables of Chapter 3, Part 3.4

Table A-3.4.1 Mean values and variations of soil pH at each sampling level in the multi-stage sampling system (for uppermost soil layer)

pH(H_2O)

Mean		Country			Area			Sites			Plot	
4.9	(0.56)	China	4.7	(1.88)	Jinyunshann, Chongqing	3.9		1. Jinyunshann	3.9	(0.64)	1	3.8 (0.04)
											2	3.9 (0.15)
					Jiwozi, Xi'an	6.4		2. Dabagou	6.4	(0.00)	1	6.4 (0.22)
											2	6.4 (0.13)
					Xiaoping, Xiamen	4.4		3. Xiaoping	4.4	(1.27)	1	4.3 (0.15)
											2	4.5 (0.14)
					Zhuxiandong, Zhuhai	4.0		4. Zhuxiandong	4.0	(0.43)	1	4.1 (0.21)
											2	4.1 (0.08)
											3	3.8 (0.17)
		Indonesia	4.3		Serpong	4.3		5. Bogor Research Forest	4.3		1	4.3 (0.12)
		Japan	4.4	(1.91)	Ijira	4.2		6. Lake Ijira	4.2	(0.55)	1	3.9 (0.13)
											2	4.1 (0.14)
											3	4.1 (0.15)
											4	4.7 (0.21)
					Banryu	4.5	(3.18)	7. Banryu-2	4.8	(0.64)	1	4.8 (0.32)
											2	4.7 (0.35)
								8. Iwami "rinku" FP	4.3	(0.64)	3	4.3 (0.11)
											4	4.2 (0.15)
		Malaysia	4.2		Pasoh	4.2	(1.91)	9. Pasoh-1&2	4.0	(2.54)	1	4.2 (4.33)
											2	3.8 (2.76)
								10. Pasoh-3	4.3		1	4.3 (5.20)
		Phippines	5.0		Los Banos	5.0	(10.48)	11. Mt. Makiling,	5.8	(5.08)	1	5.4 (0.33)
											2	6.2 (0.18)
								12. UP Quezon	4.2	(0.64)	1	4.2 (0.06)
											2	4.1 (0.06)
		Republic o	5.0		Imsil	5.0		13. Mt. Naejang	5.0	(0.64)	1	4.9 (0.07)
											2	5.0 (0.05)
		Russia	6.2	(5.08)	Listvyanka	5.8	(12.07)	14. Bolshie Koty Varnachka	6.7		6	6.7 (0.12)
								15. Bolshie Koty Temnaya	4.8		7	4.8 (0.23)
					Irkutsk	6.6	(1.91)	16. Irkutsk (near Institute)	6.7		8	6.7 (0.35)
								17. Irkutsk	6.4		9	6.4 (0.36)
		Thailand	5.5		Vachiralongkorn Dam	5.5	(11.12)	18. Vachiralongkorn Dam	6.4	(0.64)	1	6.4 (0.11)
											2	6.3 (0.52)
								19. Vachiralongkorn (Puyea)	4.6		1	4.6 (0.33)

pH(KCl)

Mean		Country			Area			Sites			Plot	
4.2	(0.49)	China	4.0	(1.37)	Jinyunshann, Chongqing	3.4		1. Jinyunshann	3.4	(0.64)	1	3.3 (0.04)
											2	3.4 (0.17)
					Jiwozi, Xi'an	5.3		2. Dabagou	5.3	(0.00)	1	5.3 (0.22)
											2	5.3 (0.15)
					Xiaoping, Xiamen	3.8		3. Xiaoping	3.8	(0.00)	1	3.8 (0.07)
											2	3.8 (0.06)
					Zhuxiandong, Zhuhai	3.7		4. Zhuxiandong	3.7	(0.25)	1	3.8 (0.12)
											2	3.7 (0.06)
											3	3.6 (0.04)
		Indonesia	3.9		Serpong	3.9		5. Bogor Research Forest	3.9		1	3.9 (0.06)
		Japan	3.5	(1.91)	Ijira	3.3		6. Lake Ijira	3.3	(0.34)	1	3.1 (0.16)
											2	3.2 (0.07)
											3	3.3 (0.10)
											4	3.6 (0.03)
					Banryu	3.6	(2.54)	7. Banryu-2	3.8	(1.27)	1	3.9 (0.16)
											2	3.7 (0.25)
								8. Iwami "rinku" FP	3.4	(1.27)	3	3.5 (0.19)
											4	3.3 (0.19)
		Malaysia	3.7		Pasoh	3.7	(0.95)	9. Pasoh-1&2	3.7	(0.64)	1	3.7 (0.21)
											2	3.6 (1.25)
								10. Pasoh-3	3.8		1	3.8 (0.32)
		Phippines	4.3		Los Banos	4.3	(6.35)	11. Mt. Makiling,	4.8	(5.08)	1	4.4 (0.33)
											2	5.2 (0.20)
								12. UP Quezon	3.8	(0.00)	1	3.8 (0.04)
											2	3.8 (0.03)
		Republic o	4.0		Imsil	4.0		13. Mt. Naejang	4.0	(0.64)	1	3.9 (0.08)

Table A-3.4.2 Mean values and variations of exchangeable Ca and Al at each sampling level in the multi-stage sampling system (for uppermost soil layer)

Ex-Ca cmol(+) kg^{-1}

Mean		Country			Area			Sites			Plot		
6.5	(7.06)	China	2.7	(4.73)	Jinyunshann, Chongqing	0.7		1. Jinyunshann	0.7	(0.64)	1	0.6	(0.13)
											2	0.7	(0.11)
					Jiwozi, Xi'an	6.5		2. Dabagou	6.5	(4.45)	1	6.8	(0.39)
											2	6.1	(0.58)
					Xiaoping, Xiamen	0.1		3. Xiaoping	0.1	(0.64)	1	0.0	(0.04)
											2	0.1	(0.04)
					Zhuxiandong, Zhuhai	3.8		4. Zhuxiandong	3.8	(0.66)	1	3.6	(1.64)
											2	3.7	(1.03)
											3	4.1	(1.13)
		Indonesia	0.9		Serpong	0.9		5. Bogor Research Forest	0.9		1	0.9	(0.71)
		Japan	0.4	(0.64)	Ijira	0.3		6. Lake Ijira	0.3	(0.15)	1	0.4	(0.13)
											2	0.3	(0.13)
											3	0.2	(0.05)
											4	0.4	(0.20)
					Banryu	0.4	(0.32)	7. Banryu-2	0.5	(1.91)	1	0.3	(0.31)
											2	0.6	(0.51)
								8. Iwami "rinku" FP	0.4	(1.27)	3	0.5	(0.42)
											4	0.3	(0.23)
		Malaysia	-		Pasoh	-		9. Pasoh-1&2	-		1	-	
											2	-	
								10. Pasoh-3	-		1	-	
		Phippines	9.1		Los Banos	9.1	(110.86)	11. Mt. Makiling,	17.8	(55.91)	1	13.4	(3.24)
											2	22.2	(1.74)
								12. UP Quezon	0.4	(0.64)	1	0.3	(0.05)
											2	0.4	(0.11)
		Republic o	0.6		Imsil	0.6		13. Mt. Naejang	0.6	(0.64)	1	0.5	(0.37)
											2	0.6	(0.33)
		Russia	23.8	(23.19)	Listvyanka	25.7	(32.40)	14. Bolshie Koty Varnachka	28.2		6	28.2	(8.23)
								15. Bolshie Koty Temnaya	23.1		7	23.1	(7.59)
					Irkutsk	22.0	(30.49)	16. Irkutsk (near Institute)	19.6		8	19.6	(8.00)
								17. Irkutsk	24.4		9	24.4	(3.45)
		Thailand	8.1		Vachiralongkorn Dam	8.1	(61.62)	18. Vachiralongkorn Dam	12.9	(21.60)	1	14.6	(2.57)
											2	11.2	(3.89)
								19. Vachiralongkorn (Puyea)	3.2		1	3.2	(1.06)

Ex-Al cmol(+) kg^{-1}

Mean		Country			Area			Sites			Plot		
2.9	(1.73)	China	3.6	(4.40)	Jinyunshann, Chongqing	6.4		1. Jinyunshann	6.4	(10.16)	1	7.2	(0.74)
											2	5.6	(1.29)
					Jiwozi, Xi'an	0.0		2. Dabagou	0.0	(0.00)	1	0.0	(0.01)
											2	0.0	(0.04)
					Xiaoping, Xiamen	5.0		3. Xiaoping	5.0	(5.72)	1	5.4	(1.16)
											2	4.5	(1.26)
					Zhuxiandong, Zhuhai	3.0		4. Zhuxiandong	3.0	(1.63)	1	2.9	(0.56)
											2	2.4	(0.40)
											3	3.7	(0.99)
		Indonesia	3.3		Serpong	3.3		5. Bogor Research Forest	3.3		1	3.3	(0.57)
		Japan	6.6	(16.99)	Ijira	7.9		6. Lake Ijira	7.9	(2.10)	1	8.9	(1.64)
											2		(0.00)
											3	8.4	(1.39)
											4	6.4	(0.42)
					Banryu	5.2	(26.36)	7. Banryu-2	3.2	(1.91)	1	3.3	(0.47)
											2	3.0	(0.63)
								8. Iwami "rinku" FP	7.3	(12.71)	3	6.3	(0.82)
											4	8.3	(1.48)
		Malaysia	-		Pasoh	-	-	9. Pasoh-1&2	-		1	-	
											2	-	
								10. Pasoh-3	-		1	-	
		Phippines	2.4		Los Banos	2.4	(28.91)	11. Mt. Makiling,	0.1	(1.27)	1	0.2	(0.59)
											2	0.0	(0.00)
								12. UP Quezon	4.7	(8.26)	1	4.0	(0.33)
											2	5.3	(0.35)
		Republic o	3.4		Imsil	3.4		13. Mt. Naejang	3.4	(1.91)	1	3.5	(0.42)

Table A-3.4.3 Mean values and variations of soil pH at each sampling level in the multi-stage sampling system (for underlying soil layer)

pH(H_2O)

Mean		Country		Area		Sites		Plot		
4.9	(0.47)	China	4.8 (1.74)	Jinyunshann, Chongqing	4.2	1. Jinyunshann	4.2 (0.64)	1	4.1	(0.08)
								2	4.2	(0.27)
				Jiwozi, Xi'an	6.4	2. Dabagou	6.4 (0.00)	1	6.4	(0.14)
								2	6.4	(0.15)
				Xiaoping, Xiamen	4.5	3. Xiaoping	4.5 (1.27)	1	4.4	(0.07)
								2	4.6	(0.23)
				Zhuxiandong, Zhuhai	4.1	4. Zhuxiandong	4.1 (0.57)	1	4.2	(0.21)
								2	4.2	(0.10)
								3	3.8	(0.19)
		Indonesia	4.3	Serpong	4.3	5. Bogor Research Forest	4.3	1	4.3	(0.16)
		Japan	4.6 (1.59)	Ijira	4.4	6. Lake Ijira	4.4 (0.30)	1	4.3	(0.25)
								2	4.4	(0.16)
								3	4.3	(0.14)
								4	4.7	(0.09)
				Banryu	4.7 (2.22)	7. Banryu-2	4.9 (0.64)	1	4.9	(0.14)
								2	4.8	(0.29)
						8. Iwami "rinku" FP	4.5 (0.00)	3	4.5	(0.08)
								4	4.5	(0.10)
		Malaysia	4.4	Pasoh	4.4 (0.64)	9. Pasoh-1&2	4.3 (1.27)	1	4.4	(0.71)
								2	4.2	(0.39)
						10. Pasoh-3	4.4	1	4.4	(2.51)
		Phippines	4.9	Los Banos	4.9 (9.21)	11. Mt. Makiling,	5.6 (7.62)	1	5.0	(0.31)
								2	6.2	(0.18)
						12. UP Quezon	4.2 (0.64)	1	4.2	(0.08)
								2	4.1	(0.05)
		Republic of Korea	4.9	Imsil	4.9	13. Mt. Naejang	4.9 (0.00)	1	4.9	(0.18)
								2	4.9	(0.09)
		Russia	6.0 (3.81)	Listvyanka	5.7 (13.98)	14. Bolshie Koty Varnachka	6.8	6	6.8	(0.20)
						15. Bolshie Koty Temnaya	4.6	7	4.6	(0.25)
				Irkutsk	6.3 (1.27)	16. Irkutsk (near Institute)	6.4	8	6.4	(0.31)
						17. Irkutsk	6.2	9	6.2	(0.66)
		Thailand	5.3	Vachiralongkorn Dam	5.3 (10.16)	18. Vachiralongkorn Dam	6.1 (1.27)	1	6.2	(0.35)
								2	6.0	(0.67)
						19. Vachiralongkorn (Puyea)	4.5	1	4.5	(0.32)

pH(KCl)

Mean		Country		Area		Sites		Plot		
4.1	(0.31)	China	4.1 (1.17)	Jinyunshann, Chongqing	3.6	1. Jinyunshann	3.6 (0.00)	1	3.6	(0.04)
								2	3.6	(0.18)
				Jiwozi, Xi'an	5.2	2. Dabagou	5.2 (2.54)	1	5.4	(0.18)
								2	5.0	(0.10)
				Xiaoping, Xiamen	3.9	3. Xiaoping	3.9 (0.00)	1	3.9	(0.02)
								2	3.9	(0.06)
				Zhuxiandong, Zhuhai	3.8	4. Zhuxiandong	3.8 (0.14)	1	3.8	(0.06)
								2	3.8	(0.09)
								3	3.7	(0.05)
		Indonesia	3.9	Serpong	3.9	5. Bogor Research Forest	3.9	1	3.9	(0.06)
		Japan	3.7 (0.00)	Ijira	3.7	6. Lake Ijira	3.7 (0.08)	1	3.7	(0.32)
								2	3.6	(0.10)
								3	3.7	(0.10)
								4	3.7	(0.03)
				Banryu	3.7 (1.59)	7. Banryu-2	3.8 (1.27)	1	3.9	(0.04)
								2	3.7	(0.19)
						8. Iwami "rinku" FP	3.6 (0.64)	3	3.6	(0.03)
								4	3.5	(0.09)
		Malaysia	3.9	Pasoh	3.9 (0.64)	9. Pasoh-1&2	3.8 (0.00)	1	3.8	(0.53)
								2	3.8	(0.24)
						10. Pasoh-3	3.9	1	3.9	(0.16)
		Phippines	4.1	Los Banos	4.1 (4.45)	11. Mt. Makiling,	4.5 (5.72)	1	4.0	(0.33)
								2	4.9	(0.30)
						12. UP Quezon	3.8 (0.64)	1	3.8	(0.08)
								2	3.7	(0.05)
		Republic of Korea	4.1	Imsil	4.1	13. Mt. Naejang	4.1 (0.64)	1	4.0	(0.05)

Table A-3.4.4 Mean values and variations of exchangeable Ca and Al at each sampling level in the multi-stage sampling system (for underlying soil layer)

Ex-Ca cmol(+) kg^{-1}

Mean		Country			Area			Sites			Plot		
4.7	(4.68)	China	2.5	(4.36)	Jinyunshann, Chongqing	0.9		1. Jinyunshann	0.9	(3.81)	1	0.6	(0.10)
											2	1.2	(1.19)
					Jiwozi, Xi'an	6.2		2. Dabagou	6.2	(9.53)	1	6.90	(0.36)
											2	5.40	(0.41)
					Xiaoping, Xiamen	0.0		3. Xiaoping	0.0	(0.00)	1	0.00	(0.01)
											2	0.00	(0.01)
					Zhuxiandong, Zhuhai	3.1		4. Zhuxiandong	3.1	(1.31)	1	2.90	(0.82)
											2	3.70	(1.07)
											3	2.70	(0.39)
		Indonesia	0.9		Serpong	0.9		5. Bogor Research Forest	0.9		1	0.90	(0.66)
		Japan	0.1	(0.48)	Ijira	0.1		6. Lake Ijira	0.1	(0.00)	1	0.1	(0.06)
											2	0.1	(0.07)
											3	0.1	(0.02)
											4	0.1	(0.06)
					Banryu	0.2	(0.95)	7. Banryu-2	0.3	(1.91)	1	0.1	(0.06)
											2	0.4	(0.37)
								8. Iwami "rinku" FP	0.1	(0.00)	3	0.1	(0.15)
											4	0.1	(0.07)
		Malaysia	-		Pasoh	-		9. Pasoh-1&2	-		1		
											2		
								10. Pasoh-3	-		1		
		Phippines	7.0		Los Banos	7.0	(85.77)	11. Mt. Makiling,	13.8	(52.73)	1	9.60	(3.43)
											2	17.90	(1.07)
								12. UP Quezon	0.3	(0.64)	1	0.20	(0.09)
											2	0.30	(0.06)
		Republic o	0.3		Imsil	0.3		13. Mt. Naejang	0.3	(0.64)	1	0.3	(0.20)
											2	0.2	(0.11)
		Russia	15.6	(0.64)	Listvyanka	15.7	(62.89)	14. Bolshie Koty Varnachka	20.6		6	20.6	(4.40)
								15. Bolshie Koty Temnaya	10.7		7	10.7	(2.46)
					Irkutsk	15.6	(43.84)	16. Irkutsk (near Institute)	12.1		8	12.1	(1.57)
								17. Irkutsk	19.0		9	19.0	(4.13)
		Thailand	6.8		Vachiralongkorn Dam	6.8	(26.36)	18. Vachiralongkorn Dam	8.9	(15.88)	1	10.1	(1.33)
											2	7.6	(3.41)
								19. Vachiralongkorn (Puyea)	4.7		1	4.7	(3.01)

Ex-Al cmol(+) kg^{-1}

Mean		Country			Area			Sites			Plot		
2.6	(1.27)	China	2.9	(3.21)	Jinyunshann, Chongqing	4.3		1. Jinyunshann	4.3	(10.80)	1	5.1	(0.45)
											2	3.4	(0.83)
					Jiwozi, Xi'an	0.0		2. Dabagou	0.0	(0.00)	1	0.00	(0.02)
											2	0.00	(0.01)
					Xiaoping, Xiamen	4.3		3. Xiaoping	4.3	(1.27)	1	4.40	(1.20)
											2	4.20	(0.26)
					Zhuxiandong, Zhuhai	2.9		4. Zhuxiandong	2.9	(1.86)	1	2.90	(0.38)
											2	2.20	(0.67)
											3	3.70	(1.11)
		Indonesia	3.3		Serpong	3.3		5. Bogor Research Forest	3.3		1	3.30	(0.64)
		Japan	5.1	(4.45)	Ijira	5.4		6. Lake Ijira	5.4	(0.80)	1	4.9	(2.46)
											2		
											3	5.4	(1.60)
											4	5.9	(0.45)
					Banryu	4.7	(20.96)	7. Banryu-2	3.1	(0.64)	1	3.1	(0.29)
											2	3.0	(0.55)
								8. Iwami "rinku" FP	6.4	(10.80)	3	5.5	(0.49)
											4	7.2	(1.72)
		Malaysia	-		Pasoh	-		9. Pasoh-1&2	-		1		
											2		
								10. Pasoh-3	-		1		
		Phippines	2.6		Los Banos	2.6	(24.14)	11. Mt. Makiling,	0.7	(8.89)	1	1.40	(1.37)
											2	0	(0.00)
								12. UP Quezon	4.5	(7.62)	1	3.90	(0.29)
											2	5	(0.51)
		Republic o	3.1		Imsil	3.1		13. Mt. Naejang	3.1	(1.27)	1	3.2	(0.25)

Table A-3.4.5 Analysis of variance of pH(H_2O), pH(KCl), and exchangeable Ca and Al in the multi-stage sampling system

pH(H_2O) - Surface soil

Factor		Sum of square	Degree of freedom	Mean square
Country	A	65.4	7	9.34
Area	B(A)	46.4	5	9.29
Site (Soil type)	C(AB)	35.1	6	5.86
Plot	D(ABC)	4.4	15	0.29
Subplot	E(ABCD)	4.4	127	0.03
	Total	155.7	160	

Variance	Estimated value	Contribution(%)	CV(%)	Total mean
σA^2	0.11	11	6.90	4.9
σB^2	-0.01	0	-	
σC^2	0.85	81	18.91	
σD^2	0.05	5	4.73	
σE^2	0.03	3	3.83	
	1.05	100		

pH(H_2O) - Subsoil

Factor		Sum of square	Degree of freedom	Mean square
Country	A	43.1	7	6.16
Area	B(A)	41.0	5	8.21
Site (Soil type)	C(AB)	32.2	6	5.36
Plot	D(ABC)	4.7	15	0.31
Subplot	E(ABCD)	5.5	127	0.04
	Total	126.5	160	

Variance	Estimated value	Contribution(%)	CV(%)	Total mean
σA^2	-0.01	0	-	4.9
σB^2	-0.03	0	-	
σC^2	0.77	89	17.88	
σD^2	0.06	6	4.82	
σE^2	0.04	5	4.25	
	0.87	100		

pH(KCl) - Surface soil

Factor		Sum of square	Degree of freedom	Mean square
Country	A	59.6	7	8.52
Area	B(A)	25.1	5	5.03
Site (Soil type)	C(AB)	21.7	6	3.62
Plot	D(ABC)	2.6	15	0.17
Subplot	E(ABCD)	4.7	127	0.04
	Total	113.7	160	

Variance	Estimated value	Contribution(%)	CV(%)	Total mean
σA^2	0.25	30	12.15	4.1
σB^2	-0.06	0	-	
σC^2	0.53	62	17.55	
σD^2	0.03	3	4.06	
σE^2	0.04	4	4.63	
	0.84	100		

pH(KCl) - Subsoil

Factor		Sum of square	Degree of freedom	Mean square
Country	A	23.9	7	3.41
Area	B(A)	16.2	5	3.24
Site (Soil type)	C(AB)	20.4	6	3.40
Plot	D(ABC)	2.6	15	0.17
Subplot	E(ABCD)	5.6	127	0.04
	Total	68.6	160	

Variance	Estimated value	Contribution(%)	CV(%)	Total mean
σA^2	0.07	10	6.23	4.1
σB^2	-0.17	0	-	
σC^2	0.49	78	17.04	
σD^2	0.03	4	3.95	
σE^2	0.04	7	5.08	
	0.63	100		

Ex-Ca - Surface soil

Factor		Sum of square	Degree of freedom	Mean square
Country	A	8855.8	6	1475.97
Area	B(A)	335.2	5	67.04
Site (Soil type)	C(AB)	1965.2	5	393.04
Plot	D(ABC)	221.2	14	15.80
Subplot	E(ABCD)	634.4	124	5.12
	Total	12011.8	154	

Variance	Estimated value	Contribution(%)	CV(%)	Total mean
σA^2	69.10	54	134.78	6.2
σB^2	-39.27	0	-	
σC^2	51.44	40	116.29	
σD^2	2.14	2	23.70	
σE^2	5.12	4	36.67	
	127.80	100		

Ex-Ca - Subsoil

Factor		Sum of square	Degree of freedom	Mean square
Country	A	3891.3	6	648.55
Area	B(A)	225.0	5	44.99
Site (Soil type)	C(AB)	1329.9	5	265.98
Plot	D(ABC)	197.3	14	14.09
Subplot	E(ABCD)	219.7	124	1.77
	Total	5863.2	154	

Variance	Estimated value	Contribution(%)	CV(%)	Total mean
σA^2	30.60	44	123.61	4.5
σB^2	-26.48	0	-	
σC^2	34.35	50	130.96	
σD^2	2.46	4	35.08	
σE^2	1.77	3	29.75	

Ex-Al - Surface soil

Factor		Sum of square	Degree of freedom	Mean square
Country	A	651.4	6	108.56
Area	B(A)	289.3	5	57.87
Site (Soil type)	C(AB)	198.3	5	39.66
Plot	D(ABC)	46.5	13	3.57
Subplot	E(ABCD)	45.4	120	0.38
	Total	1230.9	149	

Variance	Estimated value	Contribution(%)	CV(%)	Total mean
σA^2	2.65	30	49.65	3.3
σB^2	0.32	4	17.34	
σC^2	4.92	55	67.66	
σD^2	0.64	7	24.39	
σE^2	0.38	4	18.76	
	8.91	100		

Ex-Al - Subsoil

Factor		Sum of square	Degree of freedom	Mean square
Country	A	347.2	6	57.86
Area	B(A)	127.6	5	25.51
Site (Soil type)	C(AB)	144.4	5	28.88
Plot	D(ABC)	32.5	13	2.50
Subplot	E(ABCD)	55.9	120	0.47
	Total	707.6	149	

Variance	Estimated value	Contribution(%)	CV(%)	Total mean
σA^2	1.75	28	46.71	2.8
σB^2	-1.14	0	-	
σC^2	3.60	58	66.91	
σD^2	0.41	7	22.50	
σE^2	0.47	7	24.08	

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