Fourth Report for Policy Makers: Towards Clean Air for Sustainable Future in East Asia through Collaborative Activities

Acid Deposition Monitoring Network in East Asia (EANET)

November 2019

EANET

Fourth Report for Policy Makers: “Towards Clean Air for Sustainable Future in East Asia through Collaborative Activities”

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This report has been prepared based on available reports, scientific data from the EANET monitoring, assessment and research activities, supplemented by information obtained from various sources which are duly acknowledged.

The contents of the report do not necessarily reflect the views, policies, or opinions of any participating country and organization.

The term East Asia in this report refers to the Northeast Asia and Southeast Asia regions unless otherwise stated.

Acid deposition, as defined in the “Instrument for Strengthening the Acid Deposition Monitoring Network in East Asia (EANET)” adopted at the Twelfth Session of the Intergovernmental Meeting (IG12) on the EANET in 2010, means deposition of major acidifying species and related chemical substances.

Fourth Report for Policy Makers: Towards Clean Air for Sustainable Future in East Asia through Collaborative Activities

Acid Deposition Monitoring Network in East Asia (EANET)

Foreword

The Twentieth Session of the Intergovernmental Meeting (IG20) on the Acid Deposition Monitoring Network in East Asia approved the final draft of Fourth Report for Policy Makers (RPM4) – Towards Clean Air for Sustainable Future in East Asia through Collaborative Activities submitted by the Secretariat for the EANET by the end of 2018.

Similar reports developed by EANET every four or five years aims to help policy makers of the participating countries of EANET in accessing scientific-based recommendations during the decision-making process. In making such recommendations for the policy makers, the Report made use of the relevant updated reports produced by the EANET, such as the Third Periodic Report on the State of Acid Deposition in East Asia.

In each edition, the Report for Policy Makers highlighted a specific issue that considered crucial to be informed to the policy makers in the region. In this fourth edition, the Report is focusing on efforts to create synergy through closer collaboration and partnership and global initiatives to tackle air pollution problems in the region and beyond.

This Report was finalized based on collaborative efforts from many parties. I would like to express my appreciation as the Chairperson of the IG20 to all colleagues of the EANET for their valuable input starting from the development of outline to the final revision of the Report. I also thank the members of the Scientific Advisory Committee of the EANET for their technical and scientific advice during the development and revision of the Report. My special thanks go to Asia Center for Air Pollution Research as the Network Center for the EANET as well as UN Environment as the Secretariat for the EANET for getting this Report done.

Last but not least, I would like to encourage all participating countries to use the Report as a reference for making our air better.

Mr. Thalearngsak Petchsuwan
Chairperson of the IG20


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Preface

The Acid Deposition Monitoring Network in East Asia (EANET) is an intergovernmental initiative established to promote cooperation among countries in Northeast and Southeast Asia, in addressing acid deposition and other related atmospheric pollutants.

Since the commencement of its regular phase activities in 2001, the EANET, through its monitoring and research activities, has been providing valuable scientific inputs to assist policy makers in decision making for mitigating the adverse effects of air pollution and other related environmental issues. Policy makers play a crucial role in safeguarding the environment through the implementation of sufficient legislative and policy tools and ensuring that there is compliance with environmental laws and regulations.

For conveying crucial scientific information directly to the policy makers of the participating countries, the EANET produced the series of Report for Policy Makers (RPM) once in every four to five years. The first issue of the Report for Policy Makers (RPM1) was published in November 2005 to announce the EANET's achievements during the first five years of operation and its plans.

The Second Report for Policy Makers (RPM2) published in November 2009 promoted timely action to attain better air quality management by integrating prevention and mitigation of air pollution and acid deposition. The Third Report for Policy Makers (RPM3) published in 2014 updated on progress and activities of the EANET, highlighted trends of the regional environment and provided information on emerging issues concerning the situation.

The Fourth Report for Policy Makers (RPM4) was developed in 2018 in line with the third Medium Term Plan for the EANET (2016-2020) adopted at the Seventeenth Session of the Intergovernmental Meeting (IG17) on the EANET in November 2015 and Work Programme and Budget of the EANET in 2017 and 2018 which were approved at the Eighteenth Session of the Intergovernmental Meeting (IG18) in 2016 and the Nineteenth Session of the Intergovernmental Meeting (IG19) in 2017 on the EANET, respectively.

This Report informs policymakers of the results from analysis of monitoring during the period 2010-2014 and trends in the past 15 years as reported in the Third Periodic Report on the State of Acid Deposition in East Asia (PRSAD3). In addition, it highlights the adverse impacts of acid deposition and air pollution on human health and the economy and reports on new developments related to air pollution management especially ozone and particulate matter (PM).

It also introduces strategic initiatives to achieve cleaner air including challenges in air quality management and motivation for an integrated approach, significant achievements by the participating countries of the EANET, and the way forward for sustainable development goals (SDGs) to promote healthy, safe and sustainable life as well as to protect terrestrial ecosystems.


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Ambient Air Quality Monitoring Mobile Unit
EURO3

Executive Summary

Air pollution is a severe public health crisis in the Asia Pacific that jeopardizing over four million lives due to exposure from outdoor and household air pollution. The more significant numbers of the victims are the vulnerable ones: women, children, the elderly, and the poor.

Bad health condition caused by poor air quality reduces productivity, increases the social welfare costs, and ultimately, takes away the rights of people to have a better life. Besides particulate matter (PM), other pollutants such as carbon monoxide (CO), nitrogen oxides (NOx), sulphur oxides (SOx) and ground-level ozone formed in the atmosphere as a secondary pollutant from CO, NOx, and volatile organic compounds are among air pollutant sources that could harm human health.

Moved by this situation, a global call to action on air quality has been made during the first and the third United Nations Environment Assembly (UNEA). As the highest level of decision-making body on the environment with 193 UN Member States, the UNEA resolutions on air quality were made by involving countries, UN organizations, specialized agencies, inter-governmental organizations, civil society, and the private sectors. UNEA3 resolution on air quality is focusing on preventing and reducing air pollution to improve air quality globally.

The Resolution acknowledged that air pollution affects several aspects of society, such as human health, economy, ecosystems, and climate. The recommendation calls on Member States to pursue a shared response and identify solutions to address air pollution, including by strengthening inter-governmental cooperation to address and reduce the negative impacts of air pollution. The improvement of global air quality is expected to contribute to the achievement of the Sustainable Development Goals (SDGs). It requires collective efforts to prevent the adverse impact of air pollution at all levels, from individual efforts to global efforts.

The Report discusses the current state and trend of acid deposition and air pollution in East Asian region and the current key of environmental issues. The linkages were made between air pollution as the source of the problems with various aspects of human lives, such as health, ecosystem and economy. To achieve a better result, the potential contributions of EANET from its monitoring and research activities to the region was discussed linked with strategic initiatives to achieve cleaner air in the region.

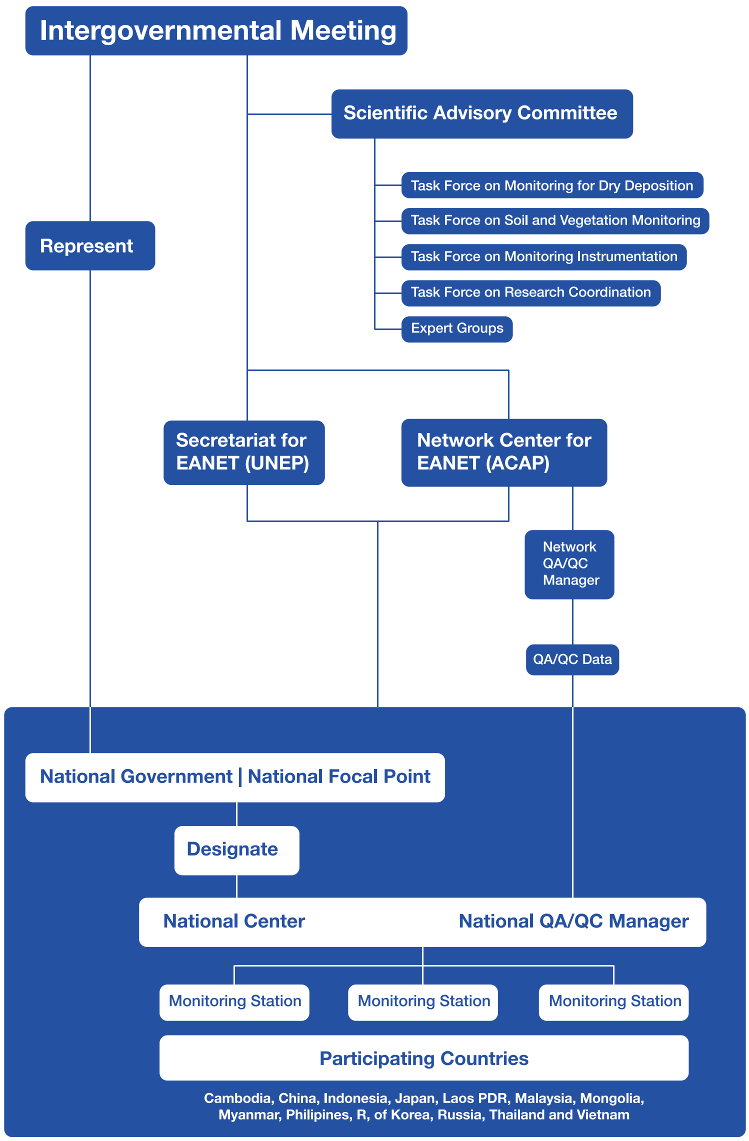
Brief Info - EANET

The Acid Deposition Monitoring Network in East Asia (EANET) is an intergovernmental regional network established in 1998 for promoting cooperation among countries in East Asia to address acid deposition problems. EANET aims to provide policymakers with credible data and scientifically assessed information for decision-making and policy formulation on air pollution issues.

EANET has three objectives:

1. To create a common understanding of the state of acid deposition problems in East Asia.
2. To provide useful inputs for decision-making at local, national and regional levels aimed at preventing or reducing adverse impacts on the environment caused by acid deposition.
3. To contribute to cooperation on the issues related to acid deposition among the participating countries.

Institutional Framework of the EANET



EANET acid deposition monitoring sites

EANET Secretariat:
United Nations Environment Programme (UNEP)
Asia and the Pacific Office, Bangkok, Thailand

Network Center:
The Asia Center for Air Pollution Research (ACAP),
Niigata, Japan

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1 Acid deposition and EANET

1.1 Acid deposition and air pollution

Acid deposition is a potentially critical environmental threat in countries with fast-growing economies and high dependence on fossil fuels consumption. Despite increased attention given to low-carbon sources of energy, over the last 25 years, consumption of oil, coal and natural gas has remained stable accounting for 81% of the global energy fuel use. Nitrogen oxides (NOx) and sulfur dioxide (SO_2) emissions from fossil fuels consumption, together with ammonia are the primary precursors of acid deposition.

Addressing acidification problems is challenging due to its transboundary nature. The pollutants are causing measurable adverse effects to human health, soil, lakes, forests, materials and cultural heritage often originate from long distance sources and are transported by atmospheric systems to the affected areas. A comprehensive understanding of the origins of the primary pollutants, their chemical and physical transformations in the atmosphere, transport processes, and deposition (wet and dry), as well as the impacts on human health and ecosystem, is essential to pave the way for effective policy efforts to tackle acidification and related air pollution problems.

The East Asian region has lately become the region with the most massive air pollutant emissions in the world, surpassing those from Europe and North America [EANET RSAP 2015]. Currently, there are serious concerns that the high levels of acid-forming pollutants emitted from human activities, in particular, energy production, could lead to potential acidification problems as well as other related air pollution issues affecting the region. The Acid Deposition Monitoring Network in East Asia (EANET), established in 1998, is a regional intergovernmental cooperative initiative to address acid deposition and related air pollution problems in East Asia for environmental sustainability.

Figure 1: Pollutants involved in the acid deposition process

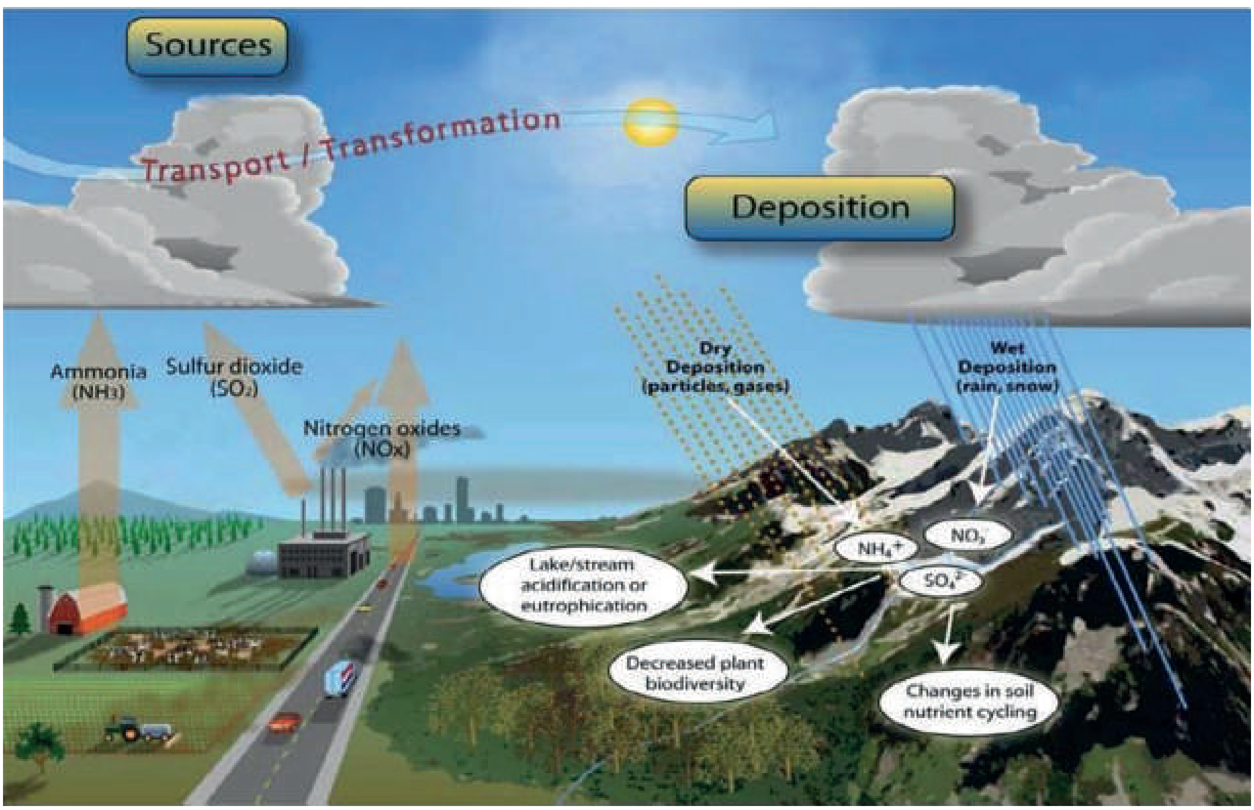
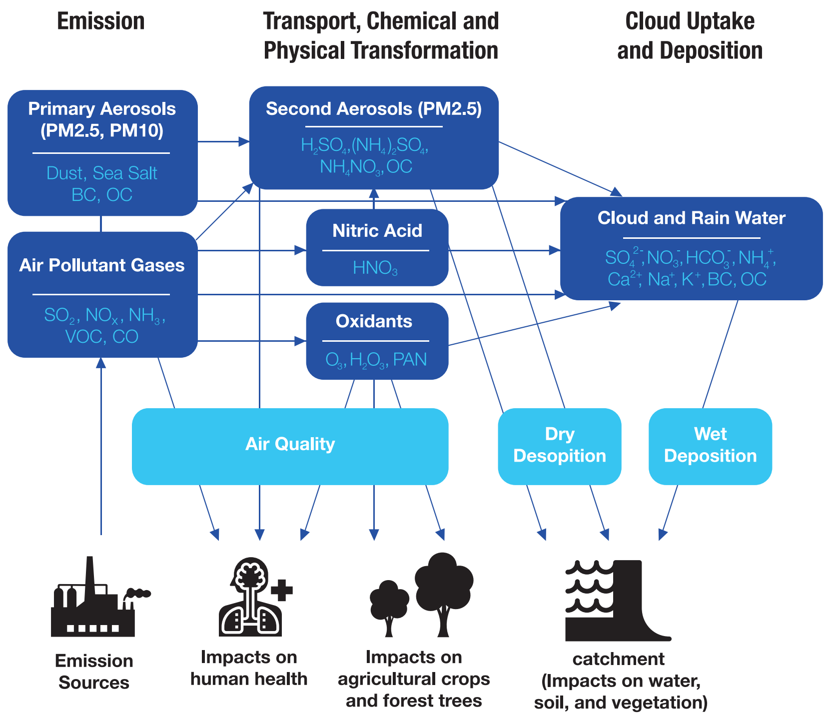


Figure 2: Schematic chart of air pollution showing emissions, atmospheric transport and transformation, cloud uptake, wet and dry depositions and environmental impacts



Other prominent transboundary issues that are of concern in the East Asian region are the episodic outbreaks of dust/haze associated with high levels of fine particles and the regional ozone problem. In the case of ozone, the primary contributing sources may originate both from outside/inside of the East Asian region. The concentration of ozone at any location can be affected by local precursor emissions, geography and weather variables. The weather has multiple effects, as sun and temperatures influence the ozone producing reactions, while wind can transport ozone over vast distances and rainfall affects ozone deposition. As a result, ozone concentrations usually are higher in suburban and rural areas compared to urban areas.

Regional haze episodes are usually caused by accumulated emission and unfavorable meteorological conditions, resulting in extremely high concentrations of fine particles, secondary aerosols, and other hazardous toxic components. In Northeast Asia, increasing desertification of the Gobi Desert contributes large amounts of dust aerosols which are transported by wind to regions far away from its source affecting parts of China, R. of Korea, Japan and even remote North Pacific. In the case of episodic haze due to widespread biomass burning in Southeast Asia, the concentration of haze particles usually is highest near its source, but the particles may spread over a vast area and remain in the atmosphere for several days to weeks. In cities, pollutants from urban activities combine with the haze pollutants from transboundary sources leading to an escalation of visibility, health, and economic problems.

Solving transboundary air pollution problems requires regional cooperation and steadfast commitment. In Europe, abatement measures under the 1979 Convention on Long-range Transboundary Air Pollution (CLRTAP) and its protocols, have successfully achieved sharp declines in emissions, especially for sulfur, and decoupling economic growth and trends in air pollution. It also halted soil acidification, and lakes and forests have since recovered. In Southeast Asia, the governments of 10 ASEAN member countries have signed the ASEAN Agreement on Transboundary Haze Pollution in a collective effort to tackle persistent haze pollution from land and forests fires in Southeast Asia.

1.2 EANET activities to address acid deposition in East Asia

The major activities being implemented by the EANET are:

- Acid deposition (major acidifying species and ozone/PM) monitoring including QA/QC;
- Compilation, verification, evaluation, storage and provision of data and relevant information;
- Organization of EANET meetings;
- Communication with participating countries and related organizations;
- Technical support and capacity building;
- Research activities;
- Public awareness activities.

To provide guidance for the implementation of the activities in the period 2016 to 2020, the Medium-Term Plan for the EANET (2016-2020) was developed and adopted at the Seventeenth Session of the Intergovernmental Meeting in November 2015. Of interest is the inclusion of the following extended activities in the Medium-Term Plan:

Strengthening current monitoring activities

- Promotion of the monitoring of ozone and PM2.5 including research cooperation and communication on the results as appropriate;
- Capacity building activities especially for ozone and PM2.5 monitoring;
- Increasing number of EANET monitoring sites; and
- Strengthening understanding and capacity for monitoring of meteorological parameters and on these as appropriate.

Promotion of activities other than monitoring

- Promotion of information exchange
- Information exchange on clean air technologies and regional impact assessment through workshops, seminars, etc.
- Promotion of research and technical cooperation on emission inventory to support the capacity building
  - Research on technical guidelines on emission inventory to support capacity building; and
  - Capacity building for emission inventories
- Promotion of research activities
  - Research activities on regional impact assessment to plants and ecosystem; and
  - Research activities on measurement methodology for elemental carbon (EC) and organic carbon (OC).

A significant achievement in recent years is the development of the Third Periodic Report on the State of Acid Deposition in East Asia (PRSAD3) published in 2016. PRSAD3 consists of three parts, Part I: Regional Assessment Report, Part II: National Assessment Report, and Part III: Executive Summary. The PRSAD3 provides useful information to member countries for developing air pollution policies by understanding the state of acid deposition in the region based on scientific analysis of accumulated monitoring data.

A new arrangement on the provision of the EANET Secretariat under UN Environment was completed in 2016. It was marked by the formal appointment of a Coordinator for the Secretariat for the EANET and adoption as well as the signing of the Framework

Agreement between UNEP and the EANET during the Eighteenth Session of the Intergovernmental Meeting (IG18) on EANET. The Chairperson of the Session, on behalf of the thirteen participating countries, signed the Framework Document on the Arrangement of the Secretariat for the Acid Deposition Monitoring Network in East Asia (EANET) between UNEP and EANET.

2

Current state and trend of acid deposition and air pollution in East Asia

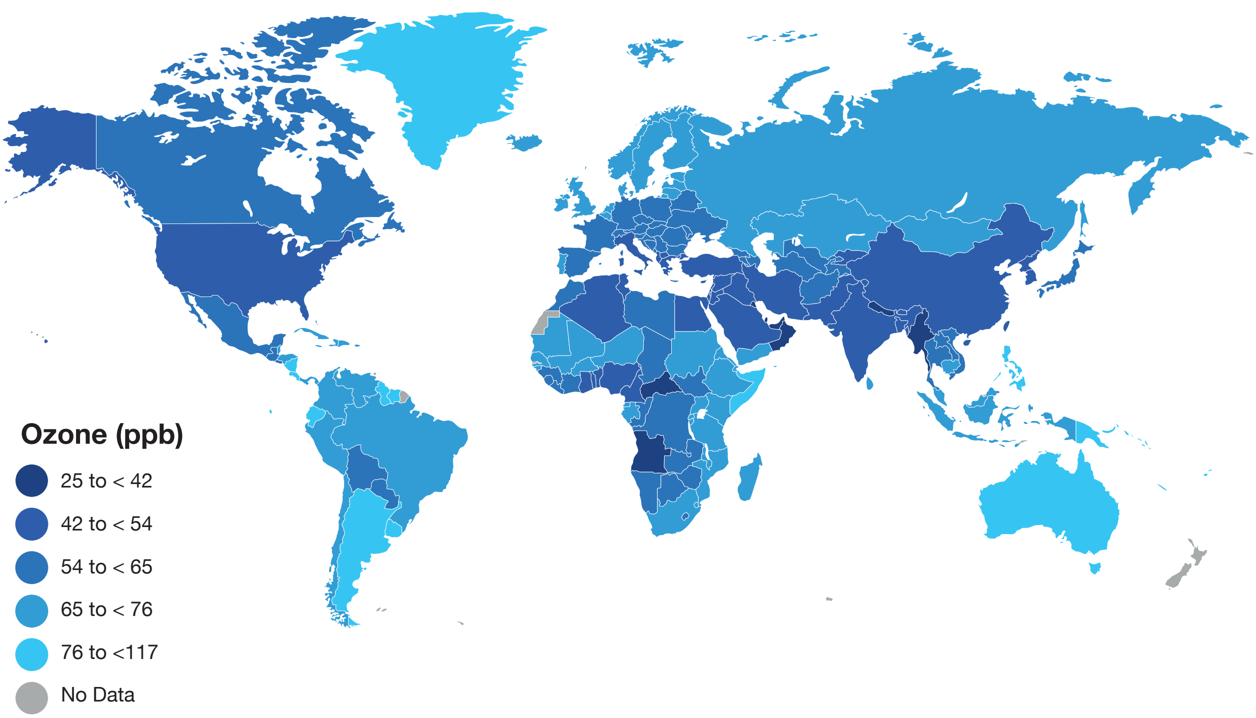
2.1 Key environmental issues

Tropospheric Ozone and PM2.5

In recent times tropospheric ozone (O3) and PM2.5 have become the focus of concern due to their severe health and environmental impacts. They are found to be more toxic than other air pollutants affecting human health as well as vegetation even at low concentrations. Ozone is not emitted directly by an emission source. It is a secondary pollutant formed at ground level through complex chemical reactions from pollutant precursor gases such as NOx and volatile organic compounds (VOCs) under sunlight. NOx is mainly emitted by motor vehiles, industry, and other combustion processes while VOCs are released from solvents and petroleum products. Photochemical smog, a common phenomenon in many large cities, is caused by the accumulation of ozone, fine particles and other gaseous pollutants in the atmosphere.

Between 1990 and 2013, emissions of ozone precursor gases (NOx, VOCs, CO and methane) declined by more than 40% in Europe and North America but increased by 20-30% in the rest of the world, and by 50% in emerging economies such as China and India. The Convention on Long -range Transboundary Air Pollution (CLRTAP) Task Force on Hemispheric Transport of Air Pollution (TF HTAP) simulations indicate that ozone concentrations may start increasing after 2020-2030, progressively driven by methane. The scenarios also suggest that contributions of methane to global air pollution from East Asia, South Asia and the rest of the world are increasing, reaching to almost 80% of global emissions for all scenarios by 2050 [UNECE, 2016]. The global map of seasonal average population -weighted ozone concentrations around the world indicates that ozone concentrations are higher in Asia, Middle East, Africa and North America. (Figure 3)

Figure 3: Seasonal average population-weighted ozone concentrations in 2015



Source: HEI/IHME State of Global Air 2017

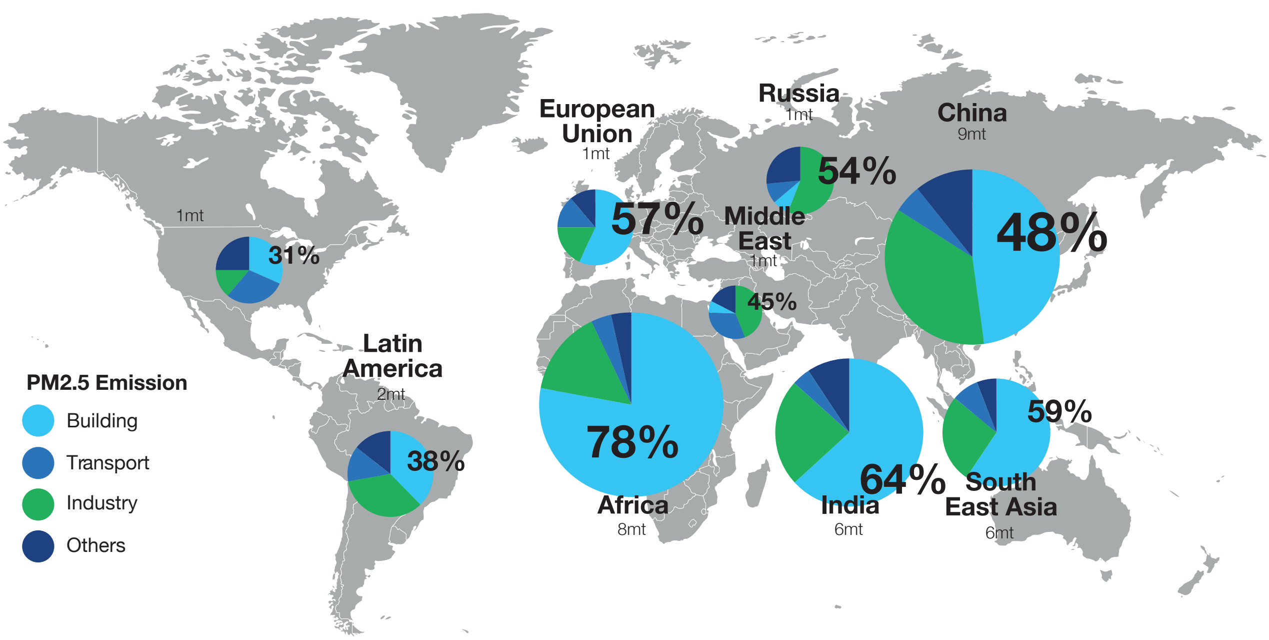
PM2.5 refers to fine particulate matter defined as particles with diameter < 2.5 micrometers. They may compose of primary and secondary particles. The primary particles may be carbonaceous (black carbon, organic carbon from incomplete combustion) or non-carbonaceous (fly ash, soil, road dust, sea salt). The secondary particles are inorganic aerosols produced in the atmosphere through chemical reactions between gaseous precursor emissions. The primary sources of PM2.5 in the East Asian region are from power stations, large and small industrial installations, road vehicles, household stoves and heating (Figure 4). In Southeast Asia, another primary source of PM2.5 comes from the agricultural sector involving the open burning of agricultural wastes and forest and peat fires.

Warming of the global climate system due to human influence is occurring, and all nations face its consequences on the environment. In 2016, a new temperature record was set, carbon dioxide levels reached new highs, an unprecedented drop in global sea-ice extent was observed, and global sea levels rose strongly making new records [WMO, 2017]. There were significant economic losses from hurricanes, flooding in parts of Asia and droughts in parts of Africa and Central America. Although addressing climate change issues is not under the purview of EANET, scientific research has shown that climate change significantly affects air quality and vice versa. Understanding the interactions between air pollution and climate issues is essential for the development of mitigation measures and preparation of adaptation strategies for future environmental changes. Moreover, co-benefits can be obtained from co-controls of common pollutants.

Ozone, black carbon and methane belong to a group of pollutants, called short-lived climate pollutants (SLCPs), that persists in the atmosphere for short periods ranging from days to decades and cause strong warming effects. Reducing emissions of these pollutants can produce health benefits directly from reduced air pollution and related ill-health as well as indirectly decreasing extreme weather and safeguarding agricultural production related to food security. The health gains and weather benefits of reducing SLCPs occur near to where mitigation action is taken, thus directly benefiting the communities within the decision-making jurisdictions [WHO/Climate & Clean Air Coalition, 2016]. Promoting policies for mitigating actions to reduce ozone and black carbon emissions for health benefits which can also obtain benefits for SLCP reduction is an indicative example of the co-benefits approach.

Figure 4: Energy -related PM2.5 emissions by region and sector, 2015

This map is without prejudice to the status of or sovereignty over any territory, to the delimitation of international frontiers and boundaries, and to the name of any territory city or area.



Source: World Energy Outlook Special Report

Urbanization and Population Increase

The Asian continent is one of the fastest growing continents in the world with increasing urbanization and high growth rates for cities. Asia today is home to 53% of the urban population in the world [UN, 2014]. By mid-century, the urban population of Asia is likely to increase by 61%, and 52% of the urban population of the world will be concentrated in Asia, mainly contributed by China. Tokyo is the world's largest metropolitan area with a population of 39.8 million (2017 estimate) while China has the largest number of megacities.

In Southeast Asia, due to the region's rapid growth and population increase (Figure 5), multiple and varied emission sources, the absence of stringent air quality policies and strong dependence on fossil fuels for energy, air pollution has become a significant health concern. The region's economy has doubled in size since 2000 while the energy demand has grown by about 55% since 2000, coal and natural gas each accounting for around 30%, oil 27% and bioenergy 10%, of the energy demand [International Energy Agency 2016]. Combustion of coal for power generation and industrial processes are the most significant sources of energy-related SO_2 emissions accounting for about three-quarters of the total 3.9 million tonnes of SO_2 emissions in 2015, about half of which occurs in Indonesia. Energy-related NOx emissions total 5.7 million tonnes, around two thirds, were the result of oil combustion, primarily in the transport sector.

Figure 5: Population projection in millions

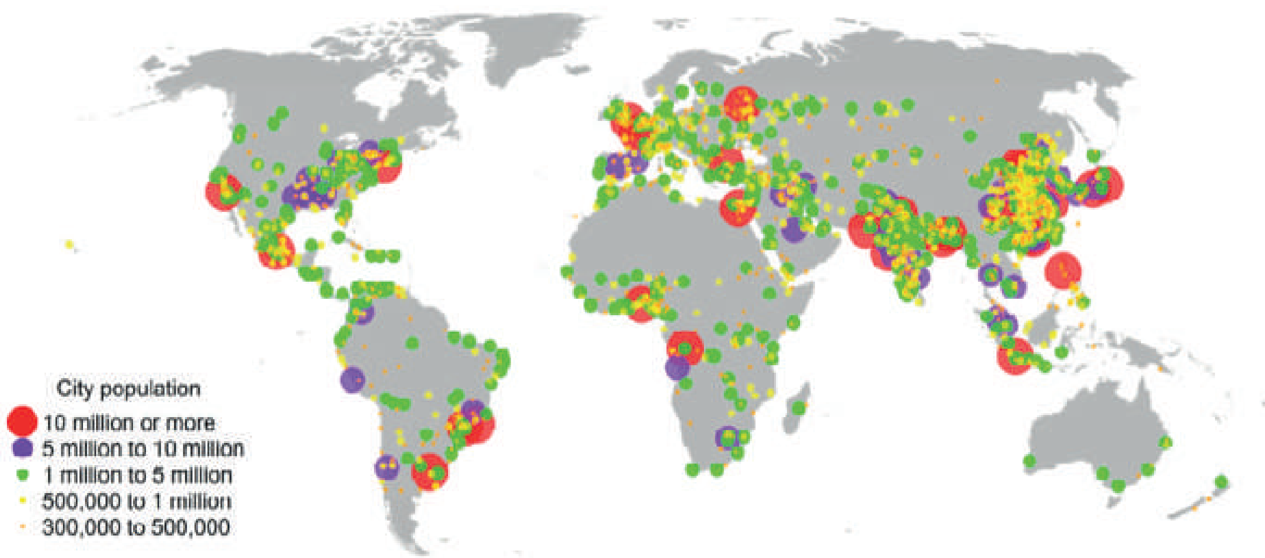
	2015	2020	2030	2050
North East Asia				
China	1,402	1,433	1,453	1,385
Japan	127	125	120	108
Mongolia	2.92	3.11	3.39	3.75
Republic of Korea	50	51	52	51
Russia	142	140	134	121
South East Asia				
Brunei Darussalam	0.43	0.45	0.50	0.55
Cambodia	16	17	19	23
Indonesia	256	269	293	321
Lao PDR	7.02	7.65	8.81	10.60
Malaysia	31	33	37	42
Myanmar	54	56	59	59
Philippines	102	110	128	157
Singapore	5.62	6.05	6.58	7.06
Thailand	67	68	68	62
Viet Nam	93	97	102	104

Source: UN World Urbanization Prospects: The 2014 Revision

Urbanization is one of the major trends currently shaping Southeast Asian economies. With more than half of its population living in urban areas, the Southeast Asian region comprises some of the fastest growing cities in the world (Figure 6).

In the cities, the combination of population growth and a sharp increase in demand for energy, transportation, and manufacturing has resulted in significant repercussions on environmental quality, in particular, air quality. With cities responsible for the bulk of anthropogenic emissions and the majority of the population exposed to air pollution, environmental sustainability must be addressed to build urban resilience.

Figure 6: Cities by size class of urban settlement in 2014



Source: UN World Urbanization Prospects: The 2014 Revision

2.2 Results and trends from EANET monitoring

The results from EANET monitoring are consistent with the scenarios described for East Asia in various regional and international publications. The following sections summarize the main outputs reported in the PRSAD3.

Data Quality

Since the start of EANET monitoring, quality assurance and quality control (QA/QC) programs have been implemented covering four areas (wet deposition, air concentration (dry deposition), soil chemistry and inland aquatic environment) to ensure a high level of data quality. The resulting EANET dataset is considered of good quality, but there is still room for improvement. In the latest Inter-Laboratory Comparison project for wet deposition, the percentage of data within the data quality objectives (DQOs) has increased from the range (75 – 78) % in 1998 to (76 – 91) % in 2016 (Figure 7). The percentage of flagged data has gradually decreased. Overall improvements were also recorded from the dry deposition, inland water, and soil inter-comparison projects.

Figure 7: Overall comparisons of 1st to 19th Inter-Laboratory Comparison projects for wet deposition (high and low concentration samples)

Source: EANET/Report on the Inter-laboratory Comparison Project 2016

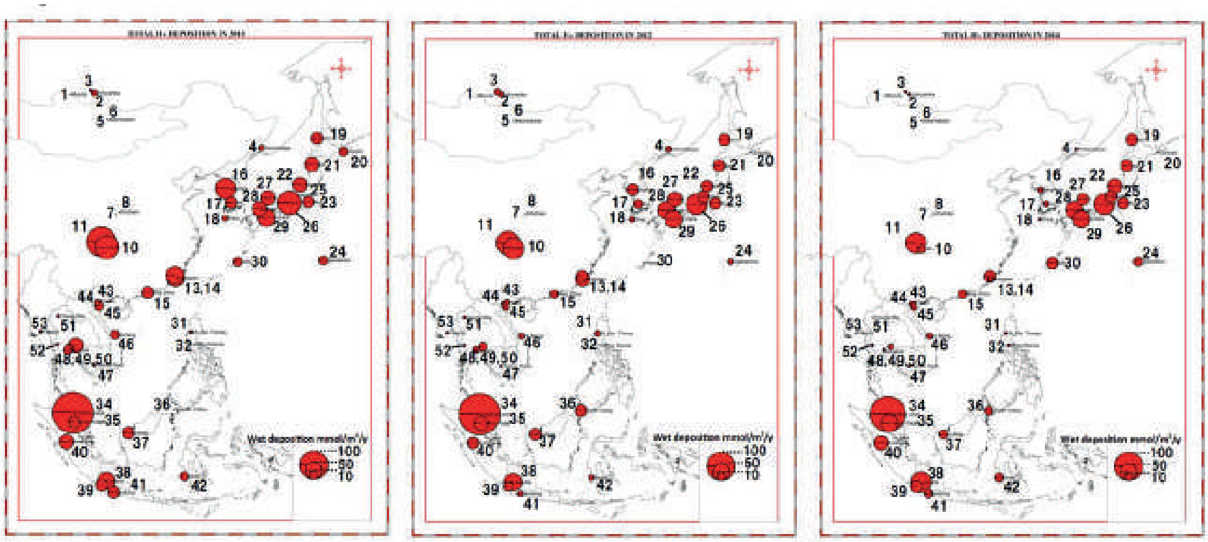
Distribution of Hydrogen (H^+), Non-seasalt Sulfate (nss-SO_4^{2-}) and Nitrate (NO_3-) ions in annual wet deposition

EANET monitors the wet deposition by collecting and chemically analyzing rainwater from 55 sites comprising of urban, rural and remote sites. The mean pH or acidity of rainwater from all sites averaged over the period 2010-2014 ranged from a minimum value of 3.94 at a rural site in China to 7.12 at a remote site also in China. The H^+ levels in wet deposition have remained relatively uniform across most sites and have not changed from previous 5-year periods (Figure 8). Exceptions are some sites in China, Malaysia, Japan and Indonesia that have high levels of H^+ that vary from year to year. A decreasing trend was observed in recent years for the sites with high H^+ levels.

The deposition levels of nss-SO_4^{2-} differ from site to site (Figure 9). Some sites with low levels (< 30 mmol m^{-2} y^{-1}) have insignificant variation while those with high levels of nss-SO_4^{2-} (60-120 mmol m^{-2} y^{-1}) in China, Indonesia, Malaysia, Philippines, and Viet Nam exhibited significant fluctuations in each year. In particular, some sites in Indonesia showed a clear increasing trend. NO_3- deposition was also varied (Figure 10). At sites in China, Indonesia, Japan, Malaysia, Philippines, Thailand and Viet Nam NO_3- deposition was very high (50-100 mmol m^{-2} y^{-1}) while at other sites the deposition was below 50 mmol m^{-2} y^{-1}. Some sites with high values, particularly in Indonesia, China and Viet Nam showed a dramatically increasing trend of NO_3- deposition.

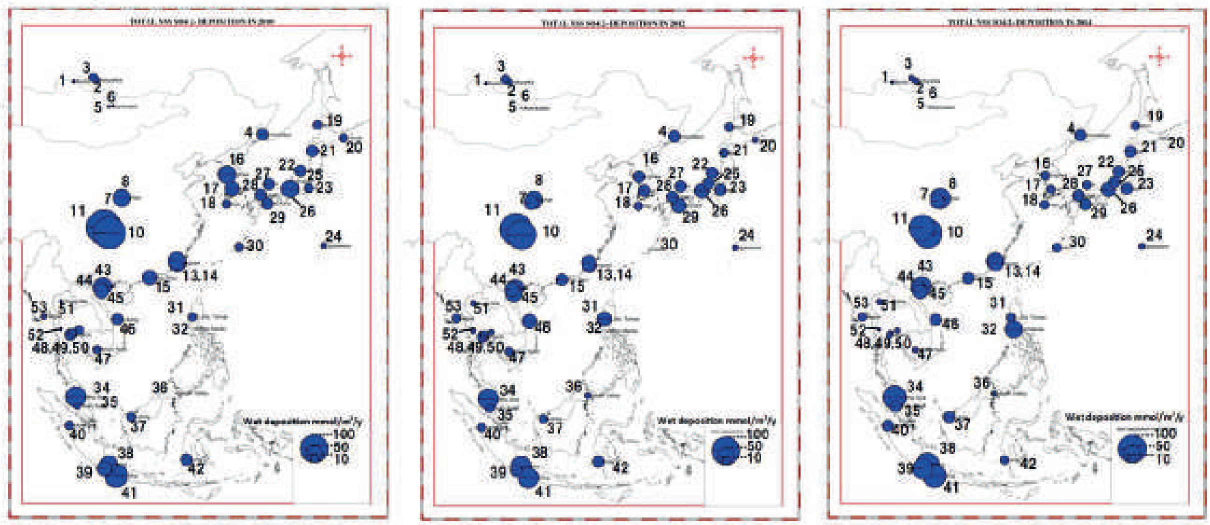
In the analysis of spatial distribution, data from 13 out of 20 remote sites were selected considering spatial representativeness of each remote site. Spatial distribution of the primary anions and cations in precipitation did not much different compared to the 2000-2004 and 2005-2009 periods, exhibiting high calcium concentrations near the desert areas and high sulfate concentrations near the industrial areas. Sulfate ion was also the primary anion in 2010-2014, exceeding the nitrate ion at all the remote sites. The calcium ion is a major cation in 4 out of the 13 sites exceeding the ammonium ion, mainly attributed to the effect of desert dust. At the other nine sites, concentrations of ammonium ion were higher than calcium indicating the influence of agricultural activities.

Figure 8: Distribution of H^+ annual wet deposition in recent years (2010, 2012 and 2014 from left to right)



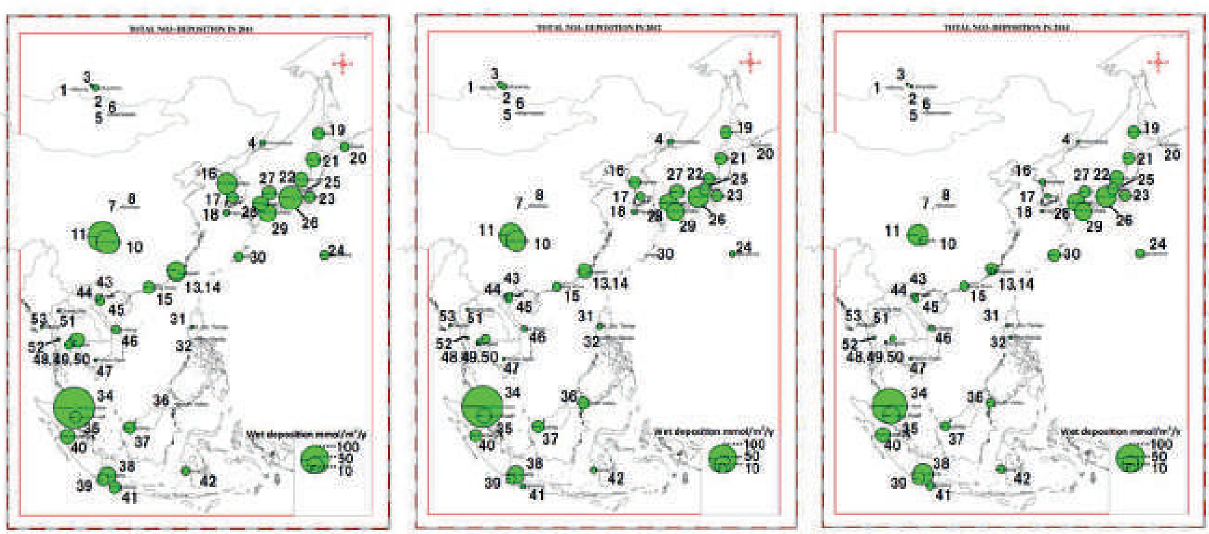
Source: EANET/Third Periodic Report on the State of Acid Deposition in East Asia

Figure 9: Distribution of nss-SO_4^{2-} annual wet deposition in recent years (2010, 2012 and 2014 from left to right)



Source: EANET/Third Periodic Report on the State of Acid Deposition in East Asia

Figure 10: Distribution of NO_3^- annual wet deposition in recent years (2010, 2012 and 2014 from left to right)



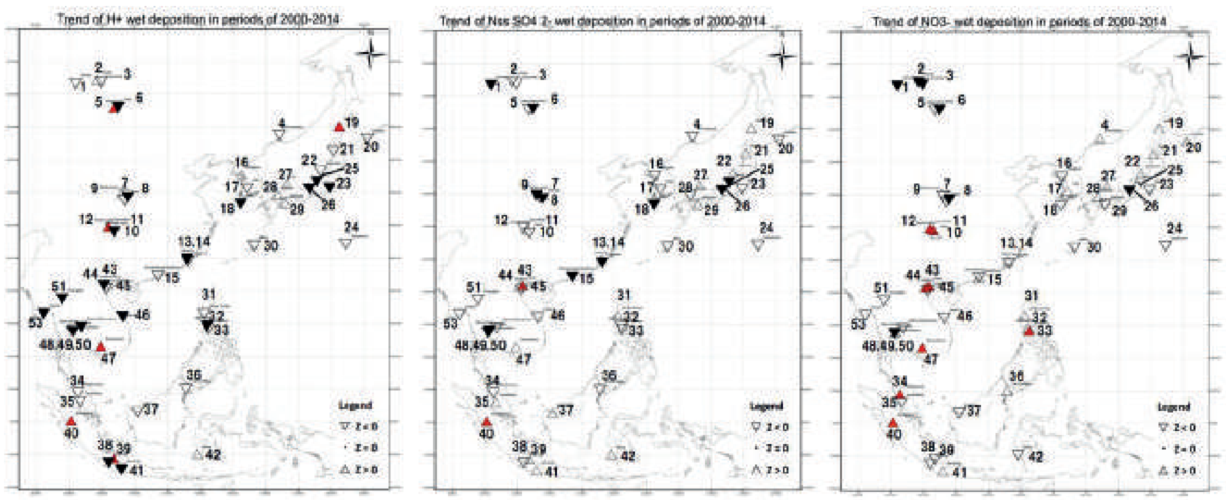
Source: EANET/Third Periodic Report on the State of Acid Deposition in East Asia

Temporal trends of Hydrogen (H^+), Non-seasalt Sulfate ($nss^-SO_4^{2-}$), and Nitrate (NO_3^-) ions in wet deposition from 2000 to 2014

The wet deposition of H+ and nss-SO42- generally have the same decreasing trend over most of the East Asia region except for several sites in Southeast Asia which showed an increasing trend (Figure 11).

However, for NO_3^- concentrations in wet deposition, two distinct trends are detected, namely a decreasing trend in Northeast Asian sites and an increasing trend in Southeast Asian sites. The decreasing trend could be an indication of the effectiveness of policies and emission control measures recently implemented in some countries while the increasing trend in Southeast Asia may be due to the rapid growth of road transport and other factors.

Figure 11: Map of variation trend of H^+ (left), $nss^-SO_4^{2-}$ (center) and NO_3^-(right) wet deposition in the period 2000-2014



Note: Up triangle illustrates an increasing trend and down triangle a decreasing trend. Filled triangle means the trend with significance level of $p < 0.05$.

Source: EANET/Third Periodic Report on the State of Acid Deposition in East Asia

*Names and numbers of the sites corresponding to Figure 8 - 11

1	Mondy	12	Guanyinqiao	23	Tokyo	34	Petaling Jaya	45	Cuc Phuong
2	Irkutsk	13	Xiaoping	24	Ogasawara	35	Tanah Rata	46	Da Nang
3	Listvyanka	14	Site name	25	Happo	36	Danum Valley	47	Phnom Penh
4	Primorskaya	15	Xiangzhou	26	Ijira	37	Kuching	48	Bangkok
5	Ulaanbaatar	16	Kanghwa	27	Oki	38	Jakarta	49	Pathumthani
6	Terelj	17	Imsil	28	Banryu	39	Serpong	50	Samutprakarn
7	Shizhan	18	Cheju	29	Yusuhara	40	Kototabang	51	Chiang Mai
8	Jiwozi	19	Rishiri	30	Hedo	41	Bandung	52	Kanchanaburi
9	Weishuiyuan	20	Ochiishi	31	Mt. Sto. Tomas	42	Maros	53	Yangon
10	Haifu	21	Tappi	32	Metro Manila	43	Hanoi		
11	Jinyunshan	22	Sado-seki	33	Los Ba–os	44	Hoa Binh		

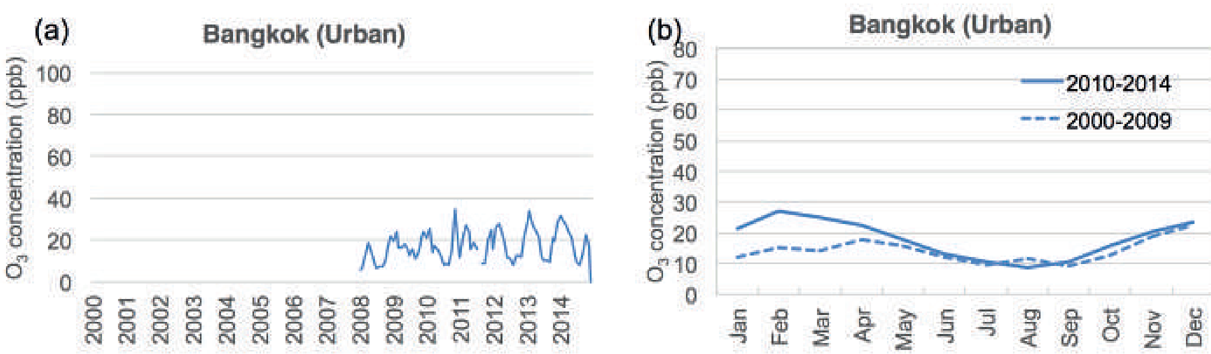
Trace gas and aerosol concentrations from monitoring of Dry Deposition (2010-2014)

EANET conducts continuous monitoring of priority gaseous air pollutants and particulate matter components. At almost all sites in the Northeast Asia region, gaseous sulfur dioxide (SO_2) concentrations show distinct seasonal cyclical pattern, low in the mid-summer and high during winter, indicating high energy utilization of coal during the colder period. Concentrations are high in China, Mongolia and Russia, and at some sites in R. of Korea, and Japan. Other sites in Northeast Asia recorded declining trend of SO_2 concentrations. All urban sites in Southeast Asia showed significant improvement in concentrations of SO2 since 2000, which could be attributed to pollution reduction policies. Despite the clear decreasing trend of sulfur dioxide concentrations, not many sites show decrease trend of sulphate. Almost all sites show a decreasing trend in HNO_3 concentration. No clear seasonal trend was detected. Ammoniumion concentrations generally declined throughout the region with larger declines noted in the northern regions.

Ozone (O_3) concentrations

A common seasonal trend of ozone concentrations was observed in all the monitoring sites, namely, higher in spring, lower in summer and slightly higher in autumn. Ozone concentrations at higher latitude locations are low in winter. At sites near the southern Pacific Ocean concentrations were very low in summer due to prevailing clean Pacificair mass. Some sites in Japan and Russia showed decreasing concentrations, but three sites in R. of Korea, showed an increasing tendency. All monitoring sites in Southeast Asia showed an increasing trend of ozone concentrations with particularly high values recorded in Thailand (Figure 12).

Figure 12: Temporal variations of O_3 in Bangkok, Thailand (a) Time series variation and (b) Seasonal average



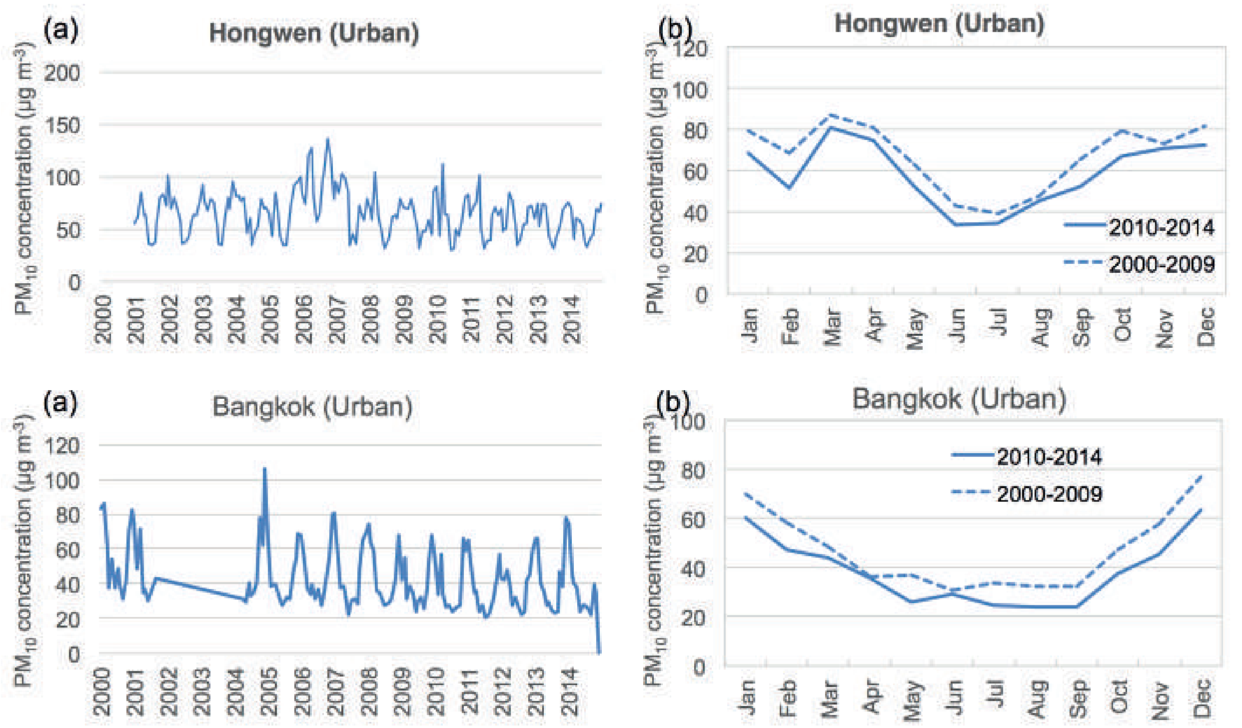
Source: EANET/Third Periodic Report on the State of Acid Deposition in East Asia

PM10 concentrations

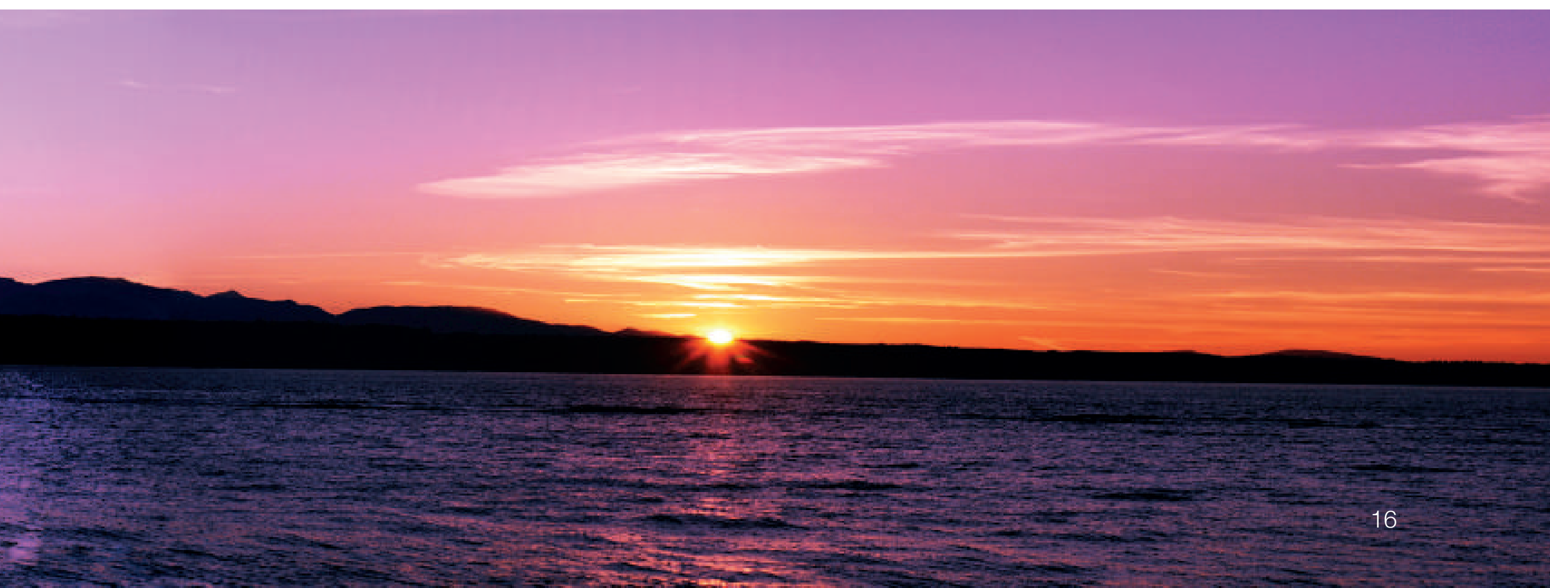
PM10 concentrations were comparatively higher at sites in Southeast Asia than in Northeast Asia. Most of the sites in R. of Korea, Japan, and SoutheastAsia showed a decreasing tendency.

While concentration levels at all sites in China remained at high levels, a decreasing trend was observed from 2000 (Figure 13).
A site in Thailand and Malaysia showed comparatively large increasing values.

Figure 13: Temporal variations of PM10 concentrations in Hongwen, China and Bangkok, Thailand (a) Time series variation and (b) Seasonal average



Source: EANET/Third Periodic Report on the State of Acid Deposition in East Asia



Monitoring the impacts on ecosystems

Since 2000, the EANET has been conducting monitoring of soil chemical properties, forest vegetation conditions such as tree growth, understory vegetation and tree crown conditions, and inland water chemistry to determine whether there are impacts from acidification on ecosystems in East Asia. The 15-year monitoring data revealed significant decreases in soil pH and soil buffering capacity at some sites in China, Indonesia and Russia suggesting possible acidification of soils. However, no clear effect on tree growth was observed in these sites.

Acidification of inland water, characterized by a decline of pH and alkalinity with an increase of SO_4^{2-} and/or NO_3^- was also noted in some sites in China and Russia, whereas recovery from acidification was observed at sites in Japan and Malaysia. These trends correlated with observations from wet deposition monitoring. Due to ecosystem resilience, there are no direct impacts have been noted for forest vegetation thus far.

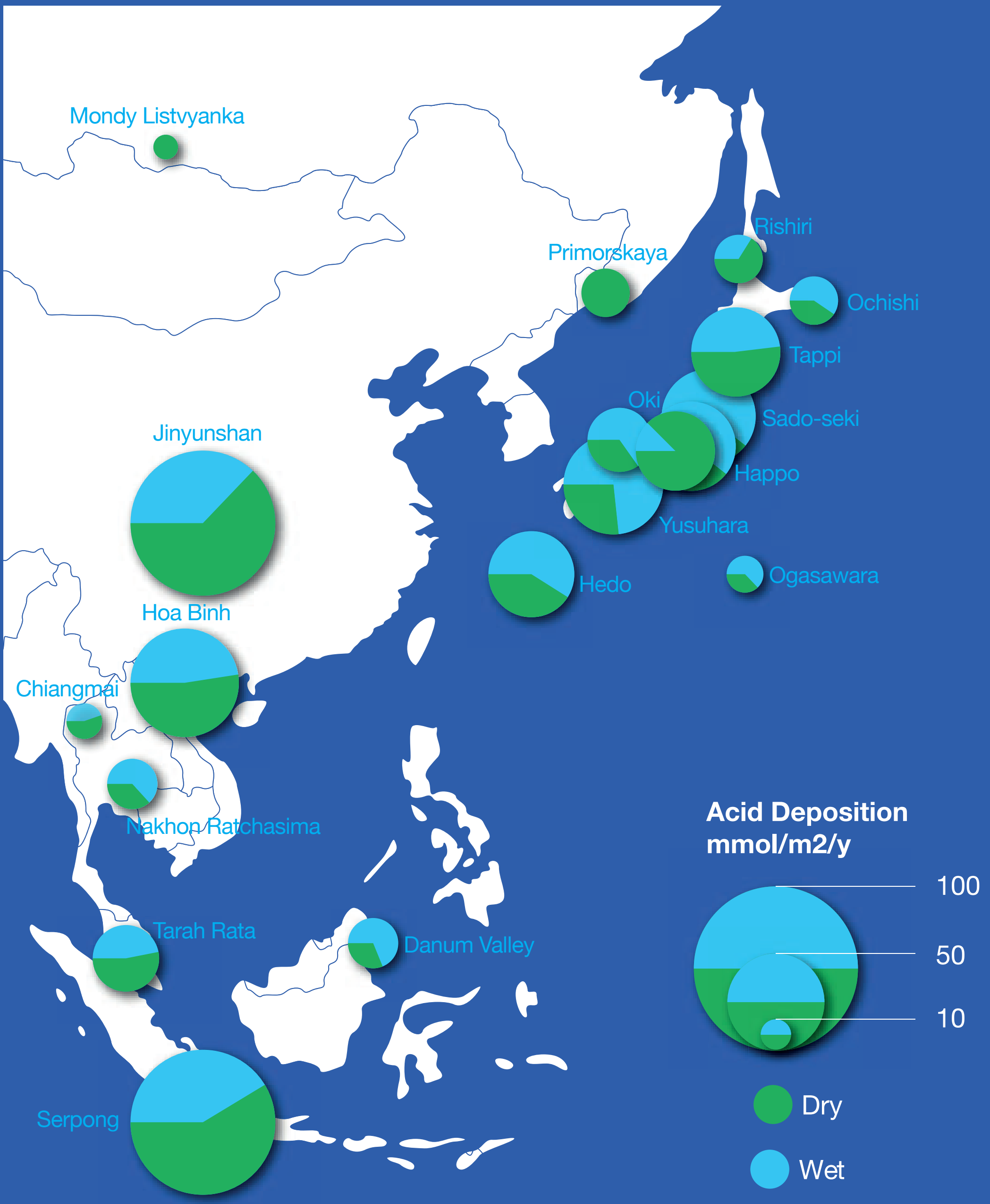
Catchment-scale monitoring at Lake Ijira, Japan, where the soil was acidified significantly in the 1980s and 1990s, indicated recovery from acidification and nitrogen saturation since 2000. The joint catchment-scale research projects in Japan, Thailand and Malaysia has clarified the input-output budget of major ion constituents. While atmospheric sulfur may be the major factor in the Japanese site, geological sulfur input may affect the water chemistry in Malaysia while in Thailand biologically fractionated sulfur may have flowed into the stream water.

Importance of supplementing the existing network of monitoring sites

The EANET activities cover a vast region. Currently, the network has 55 wet deposition monitoring sites, 47 dry deposition monitoring sites, 31 soil and vegetation monitoring sites, 19 inland aquatic monitoring sites and 1 catchment-scale monitoring site. The small number of monitoring sites may not be able to provide sufficient density of measurements and the coverage required for comprehensive studies on seasonal variations and annual trends of acid deposition and air pollution and tracking long-range transboundary pollution.

The number of sites conducting continuous measurements of particulate PM2.5 and all the recommended gaseous species, (with data meeting the data requirement conditions), and submitting the necessary meteorological parameters for estimation of dry deposition flux, is presently limited. The dry deposition estimates of gaseous and particulate species are essential for the calculation of total deposition of acids to be used for studies on the potential impacts of acid deposition in the region. Figure 14 shows the limited number of sites where there is sufficient data for estimation of total acid deposition in 2014. Most of these sites are in Japan. The EANET continues to try to encourage member countries to establish more monitoring sites, particularly in data-sparse areas and regions with sensitive ecosystems.

Figure 14: Total Acid Deposition in 2014 (wet and dry deposition of sulfur and nitrogen compounds)



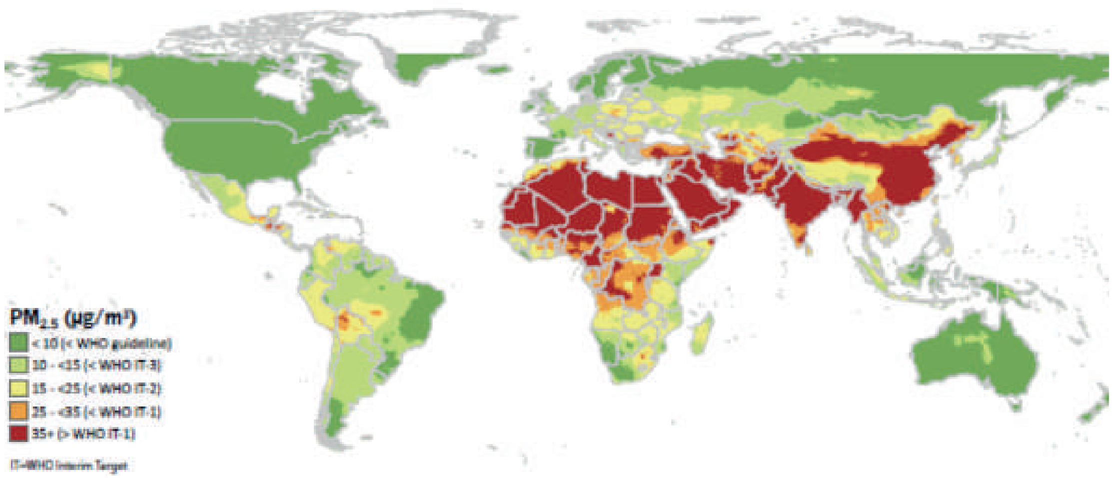
Source: EANET/Third Periodic Report on the State of Acid Deposition in East Asia **

Satellite and remote sensing data, and chemical transport model simulations are essential to supplement the ground observations for a more comprehensive understanding of the air pollution mechanism, particularly in assessments of ozone and PM2.5 risks. Satellite observations have been widely used for trend analysis and seasonal variation of particles given its benefit of long-term data availability, comprehensive coverage and the ability to detect changes in the Earth's vegetation, atmospheric trace gas content, sea state, etc.

Data from environmental monitoring satellites such as TERRA, AQUA satellites of NASA which carries the Multi-angle Imaging Spectroradiometer (MISR) and Moderate Resolution Imaging Spectroradiometer (MODIS) instruments respectively, have greatly expanded opportunities for data integration, analysis, modelling and map production.

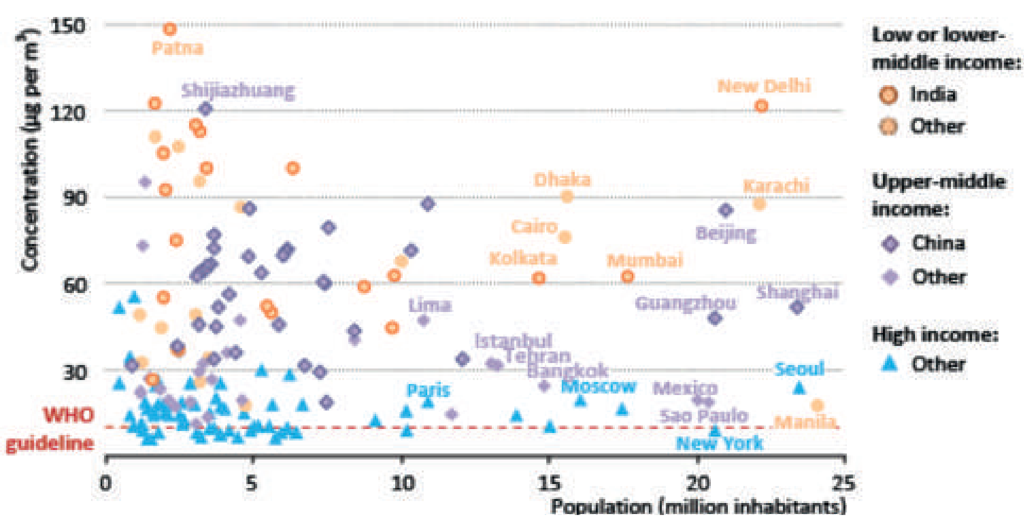
Comparison of annual average PM2.5 concentrations in 2015 with WHO Air Quality Guidelines is shown in Figure 15. High concentrations of PM2.5 are found in parts of China, northern India and parts of Southeast Asia. Average annual outdoor PM2.5 concentrations in selected urban areas including East Asian cities are also shown in Figure 16. A high concentration of PM2.5 was also recorded in many East Asian cities.

Figure 15: Comparison of annual average PM2.5 concentrations in 2015 with WHO Air Quality Guidelines



Source: HEI/IHME State of Global Air 2017

Figure 16: Average annual outdoor PM2.5 concentrations in selected urban areas



Source: World Energy Outlook Special Report based on WHO (2016) Global Ambient Air Pollution Database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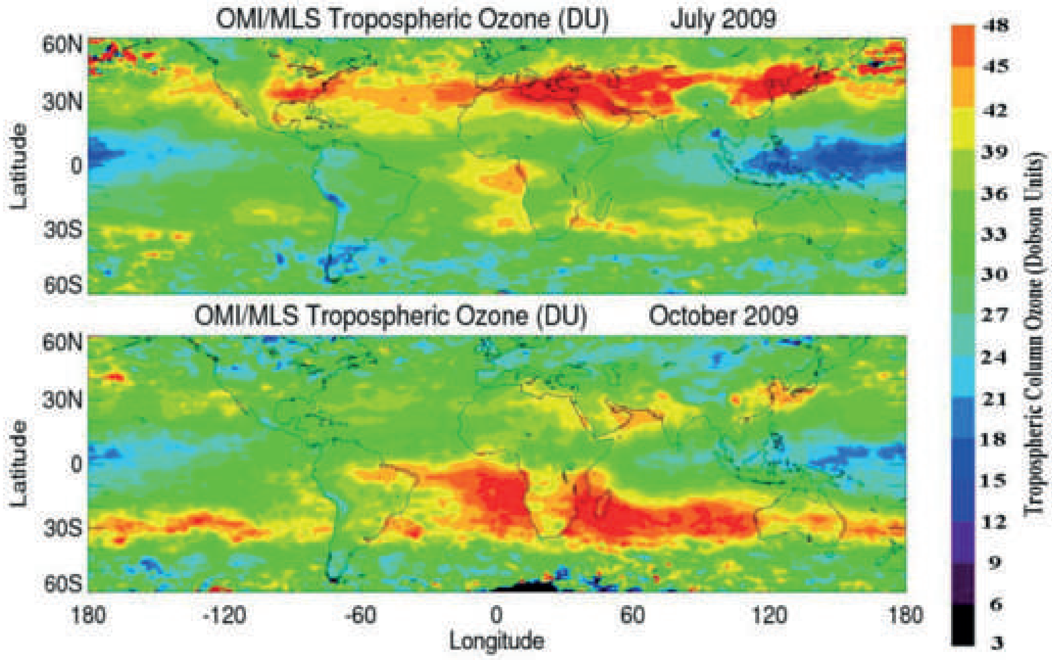
Global and regional scale chemical transport model simulations together with an updated emission inventory have been successfully applied to describe the seasonal and spatial variability of O_3 in Northeast Asia (Figure 18). Source-receptor modelling is a useful tool for characterizing atmospheric deposition in each country and identifying possible sources of pollutants, whether from local emissions or long-range transboundary transport.

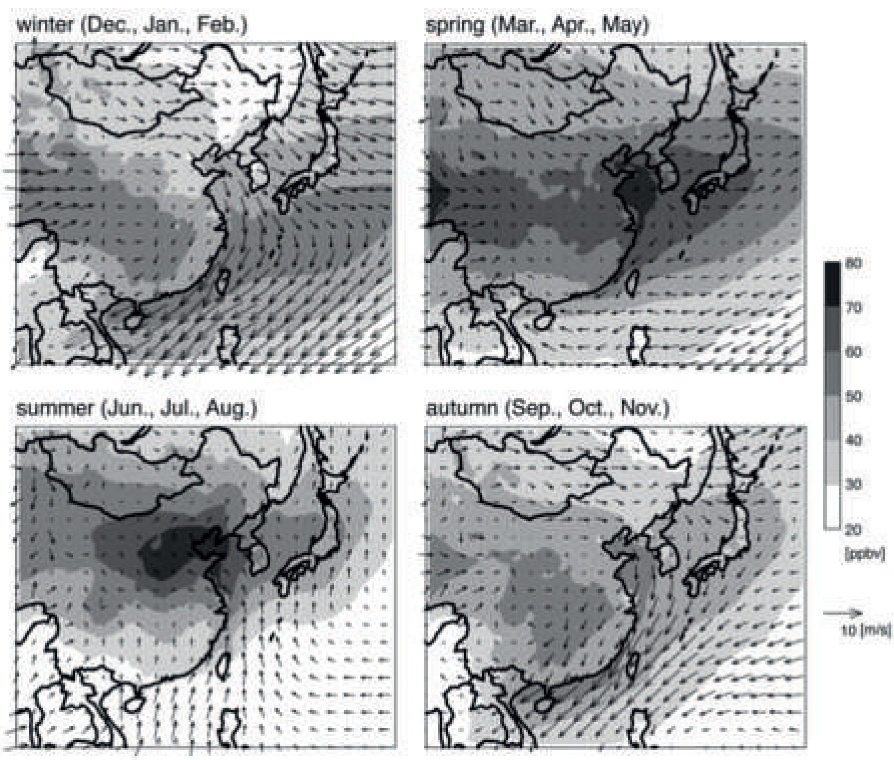
A UNECE Task Force on Hemispheric Transport of Air Pollution (TF HTAP) study on the contribution of foreign sources (Europe, North America and South Asia) to concentrations of surface ozone in East Asia revealed that emissions originating from within the region have the largest influence, and a reduction in anthropogenic O_3 precursor emissions within East Asia would result in significant improvement in concentrations of surface ozone (TF HTAP 2010). Therefore, it is very important to study source-receptor relationships between sub-regions in East Asia using appropriate global chemistry transport models.

Figure 17: Tropospheric ozone columns determined by the residual from OMI observations of total column O_3 and MLS observations of stratospheric O_3



Source: EANET RSAP (Figure taken from HTAP 2010 report Figure 2.3)

Figure 18: Spatial distribution of simulated O_3 concentrations in 4 seasons. Vectors denote the wind field.



Source: EANET RSAP

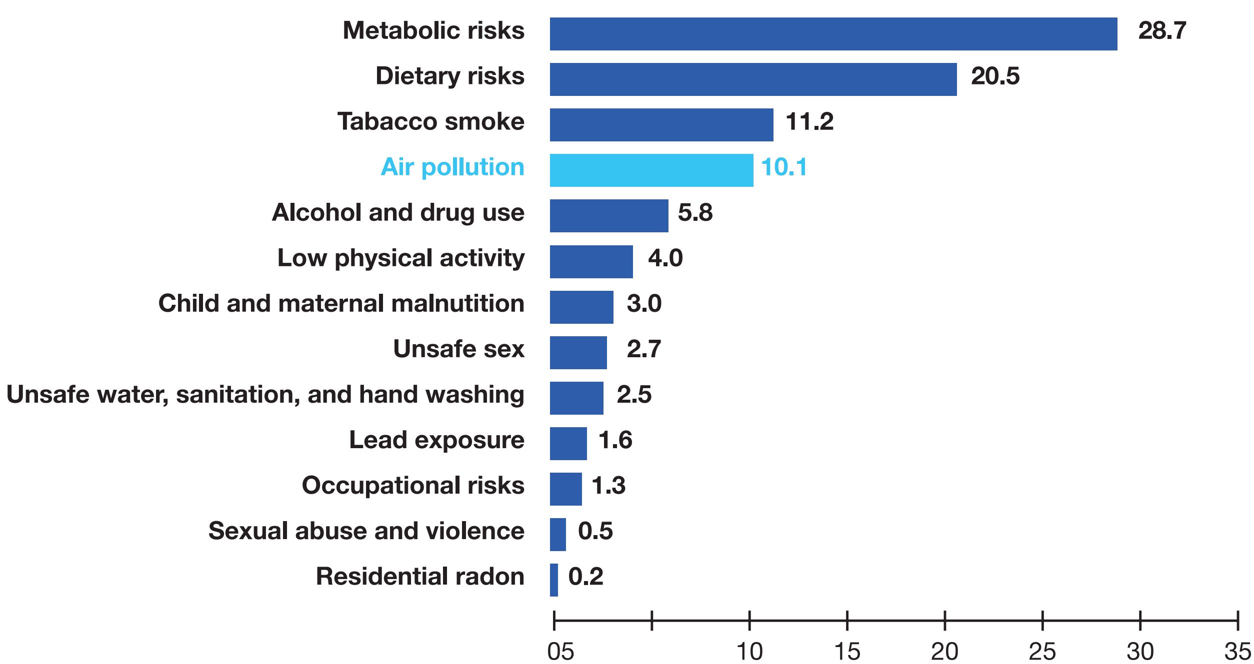
2.3 Adverse effects of air pollution on human health, ecosystem and economy

As countries around the globe continue to develop and become wealthier, millions of tons of air pollutants from industries, construction, agricultural practices, vehicular transportation, and combustion of fossil fuels are emitted into the atmosphere. In Northeast Asia, although emissions of SO_2 and PM2.5 decreased by 15% and 11% respectively from 2005 to 2010, mainly achieved by policy interventions and large-scale deployment of efficient removal technologies in China, the emissions of NOx and non-methane volatile organic compounds increased by 25% and 15%. In Southeast Asia, driven by rapid growth and robust economy, SO_2 and NOx emissions are projected to each grow by some 45% through to 2014. The harmful effects of air pollution on human health and ecosystems are therefore a serious concern in East Asia.

Air Pollution and Human Health

A collaborative study between the World Bank and the Institute for Health Metrics and Evaluation (IHME) at the University of Washington, Seattle showed that air pollution is now the fourth leading fatal health risk worldwide (Figure 19).

Figure 19: Percentage of Attributable Deaths by Risk Factor: Globally, 2013

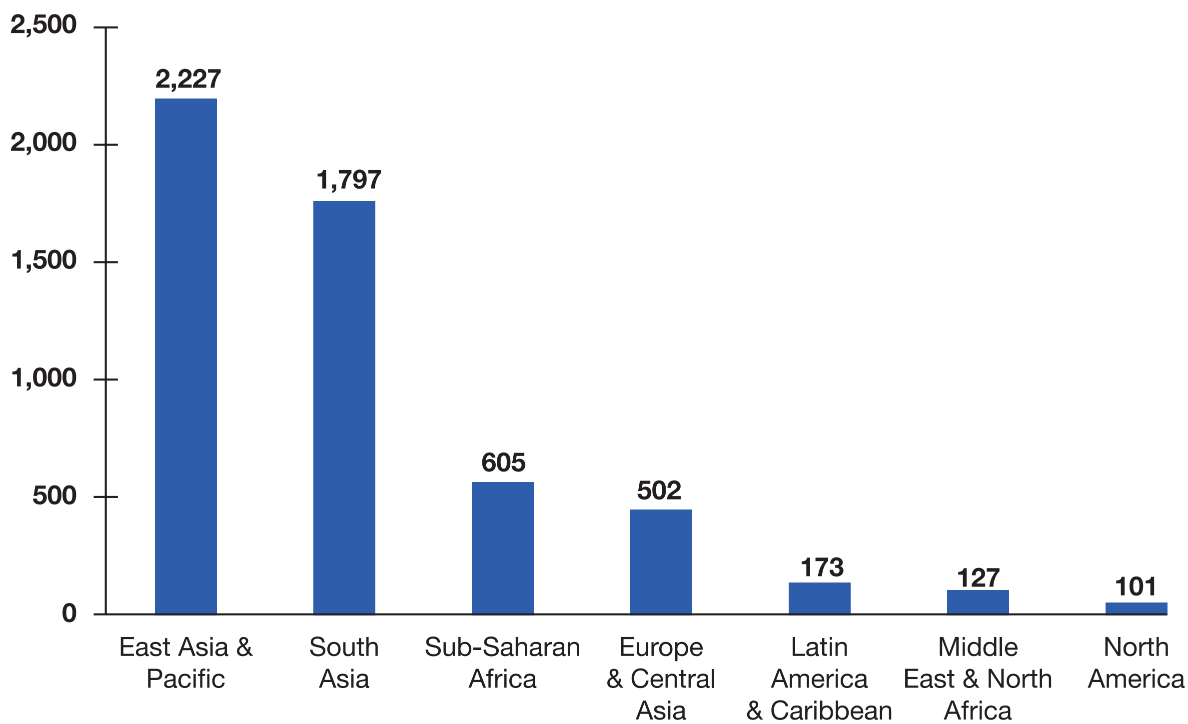


Source: World Bank/IHME, 2016

Exposure to air pollution increases a person's risk of contracting a disease such as lung cancer, stroke, heart disease, acute respiratory infections and chronic obstructive pulmonary diseases. According to IHME's estimates, in 2013, 5.5 million premature deaths worldwide, or 1 in every 10 total deaths, were attributable to air pollution. Air pollution levels are highest in developing countries and can be particularly severe in fast-growing urban centers where greater economic activity is contributing to higher levels of pollution and to greater exposure. The very young and older adults remain particularly vulnerable. In 2013 about 5 percent of premature deaths of children under 5 and 10 percent of deaths among adults over 50 were attributable to air pollution, compared with less than 1 percent among young adults. Among all ages, a larger proportion of men than women have died prematurely of air pollution related illness. Since 1990, the number exposed to ambient air pollution has grown in most countries with the greatest increases in heavily populated, fast growing region.

Within Asia more than half of the population are exposed to air that exceeds the World Health Organization (WHO) Interim Target Level 1 of 35 μg m^{-3}. Less than 8% of the population breathe air that conforms to the WHO Air Quality Guideline value of 10 μg m^{-3} for PM2.5.

Figure 20: Total Deaths from Air Pollution by Region, 2013



Source: World Bank/IHME

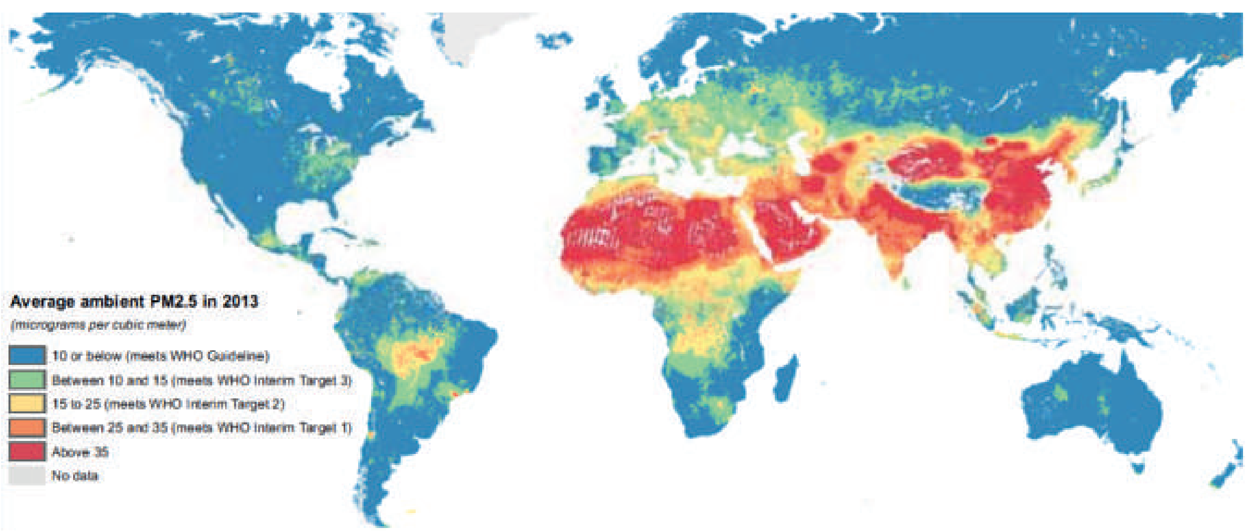
Due to its large population and because of high exposure levels, the majority (40 percent) of the 5.5 million premature deaths attributed to air pollution occurred in East Asia and the Pacific, amounting to about 2.2 million (Figure 20). The South Asia region was next highest accounting for 33 percent of the premature deaths from air pollution. About 14 percent of total deaths in the East Asia and Pacific region were attributed to air pollution. Since 1990 there has been a slight decline in the mortality rate. Deaths per 100,000 people from air pollution dropped to 99 per 100,000 in 2013. However, the total number of air pollution deaths has grown substantially with a percentage of male deaths higher than female deaths, and a similar increase in the percentage of deaths of children under 5 years of age.

One of the most damaging pollutants in the air is PM2.5 which is a very fine particulate matter (PM). Due to its small size these particulates can penetrate deep into the lungs where, depending on their source and chemical composition, they may have different health effects. Based on World Bank estimates, in 2013 about 87 percent of the world's population lived in areas that exceeded the World Health Organization's Air Quality Guideline of an annual average of 10 micrograms per cubic meter (μg m^{-3}) for PM2.5. About 35 percent of the global population lives in areas with concentrations above the WHO Interim Target 1 of an annual average of 35 μg m^{-3} for PM2.5.

Nearly all population that experienced the extreme values (> 65 μg m-3) are concentrated in China and India. The highest concentrations of PM2.5 can be found in North Africa, the Middle East (due to emissions of windblown mineral dust) and in China and India, mainly due to combustion emissions from multiple sources (Figure 21). With PM2.5 concentrations that could reach up to 80 μg m^{-3}, far exceeding the WHO threshold that will have considerable effects on human health, Asia has become one of the most polluted continents in the world.

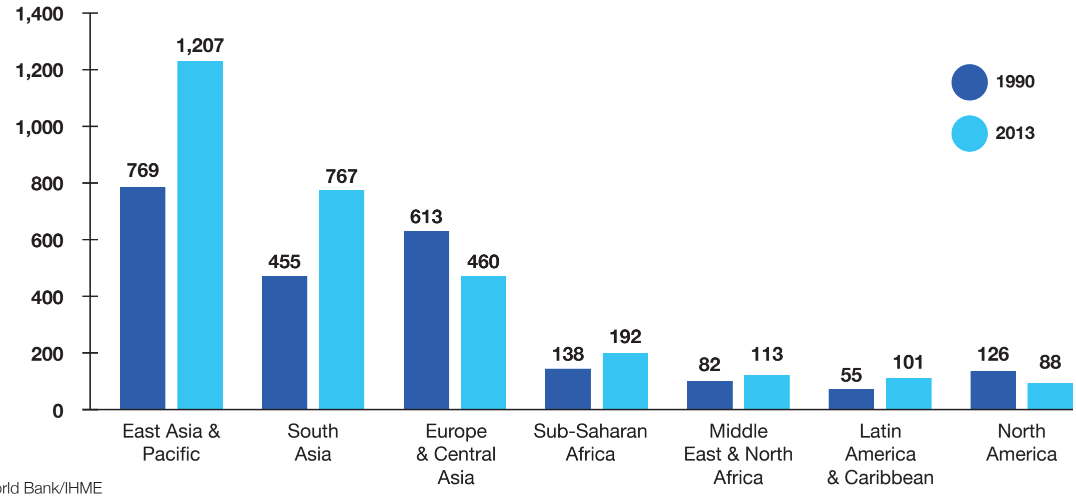
In their most recent update, the IHME Global Burden of Disease (GBD) project estimated that 4.2 million deaths occurred in the year 2015 from PM2.5 exposure [HEI/IHME, 2017].

Figure 21: Locations Where 2013 Annual Average PM2.5 Concentrations (μg m^{-3}) Meet or Exceed World Health Organization's (WHO) Air Quality Guideline or Exceed Interim Targets



Source: World Bank/IHME

Figure 22: Total Deaths from Ambient PM2.5 Pollution by Region, 1990 and 2013

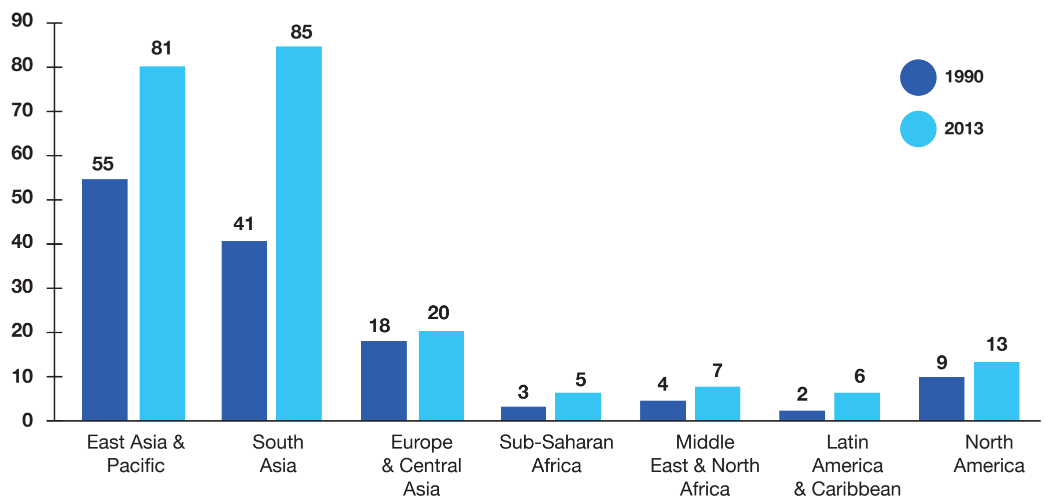


Source: World Bank/IHME

Global exposure to PM2.5 has not improved over the last 23 years. The main outcome of PM2.5 risk is cardiovascular disease, including ischemic heart disease (IHD) and stroke, and cancers. Ambient PM2.5 was responsible for more than 2.9 million deaths in 2013, a 30 percent increase from 1990. Due to the high population and higher exposure levels in East Asia and Pacific region, the highest number of total deaths from ambient PM2.5 was recorded in this region, driven largely by China. The number of total deaths increased from 770 thousand in 1990 to 1.2 million in 2013 (Figure 22), and the number of deaths per 100,000 people increased from 42 to 54 for the region.

A rising trend in total deaths from ambient ozone pollution was also noted worldwide, with the East Asia and Pacific region recording the second highest values. When inhaled, ozone causes shortness of breath, chest pain and throat irritations, inflames and damage airways and aggravates lung diseases such as asthma, emphysema and chronic bronchitis leading, in some cases, to respiratory mortality. Although the numbers of deaths from exposure to ambient ozone are much smaller than those attributable to ambient PM2.5 it contributed to a total of 217,000 premature deaths in 2013 worldwide with the highest numbers from the East Asia and Pacific and South Asia regions. In East Asia and Pacific region, the number of deaths rose from 55 in 1990 to 81 in 2013 (Figure 23).

Figure 23: Total Deaths from Ambient Ozone Pollution by Region, 1990 and 2013

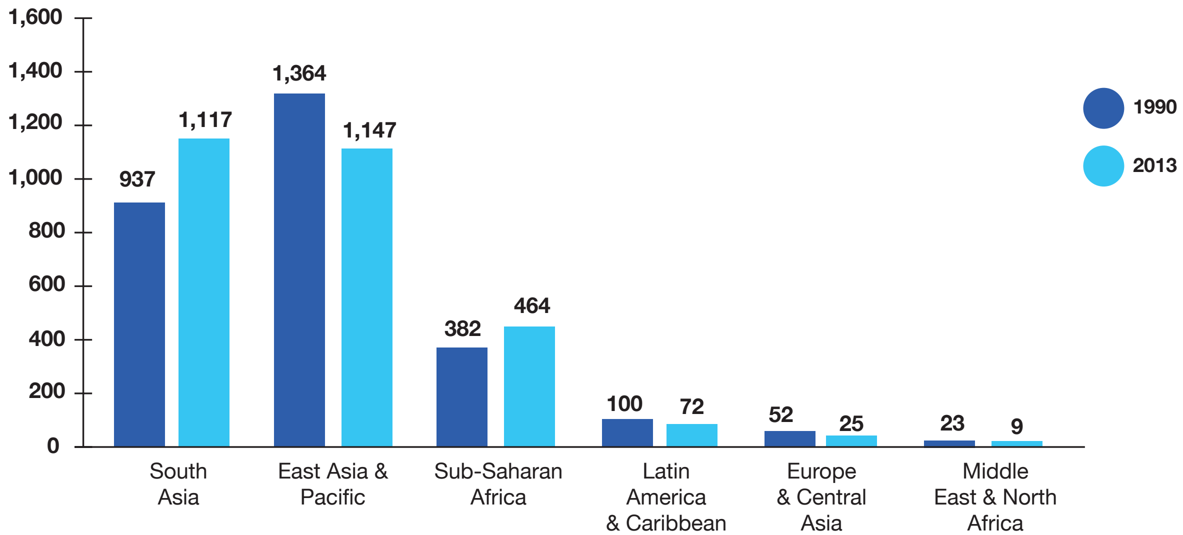


Source: World Bank/IHME

Although indoor air pollution or household pollution has been a topic of many health studies, this major health risk has not been given sufficient attention in the East Asian region. The World Bank and IHME report estimated that 42.2 % of the world's population, mainly those in the low and middle income countries that rely on solid fuels for cooking and heating purposes, are exposed to indoor air pollution. Among the regions considered, the East Asia and Pacific region has the second highest number of deaths due to indoor air pollution in 2013. Although a total number of deaths in East Asia and the Pacific has declined from 1.4 million in 1990 to 1.1 million in 2013 (Figure 24), indoor air pollution is still regarded as a major health threat in the region as many households in the developing countries still rely on solid fuels for cooking and household heating.

Some 6.5 million people die prematurely every year from exposure to outdoor and indoor air pollution, and 9 in 10 people breathe outdoor air polluted beyond the acceptable World Health Organization guideline levels

Figure 24: Total Deaths from Household Air Pollution by Region, 1990 and 2013



Source: World Bank/IHME

Air Pollution and Ecosystems

Atmospheric deposition of pollutants can acidify soils and reduce the diversity of plant species and the productivity of grasslands. Fertilizer use in crop fields is a major contributor to ammonia emissions, which react in the atmosphere with other pollutants such as sulfur dioxide (SO_2), nitrogen oxides (NOx) and volatile organic compounds (VOCs) to form PM2.5. The resultant pollutants may adhere to plant surfaces and reduce the amount of sunlight reaching crops stunting their growth. Experimental studies in Japan and China on the effects of ozone on crops found that high concentrations of ozone reduce photosynthetic rate, and stomatal activity resulting in a reduction in grain yield. More experimental and field studies are needed in Asia to evaluate ozone effects on crops, particularly in Southeast Asia where information is lacking.

The adverse impact of acid deposition and air pollution on forests has been well investigated and documented in Europe and North America. In East Asia, atmospheric deposition of pollutants was reported to have acidified soils and reduced the productivity of grasslands in Mongolia where many people rely on pastoral livelihoods. [Chen et al. 2013/World Bank/IHME, 2016]. It was also found that high levels of ozone can adversely affect growth and physiological functions of some sensitive forest tree species by reducing carbon absorption and dry matter production. Ozone is considered to be one of the major environmental stress relating to tree dieback and forest decline observed in Mt. Tateyama and Tanzawa Mountains in Japan. However, the insufficient information is available and further investigations are needed on the effects of ozone on growth and physiological functions of forests species in all Asian countries.

The detrimental effects of air pollutants on aquatic ecosystems include the loss of biota sensitive to increased acidity of surface waterways as well as increased phytoplankton and algal growth, which contributes to the eutrophication of waterways, causing dead zones and harmful algal blooms that hurt fisheries, water-based recreational activities and tourism.

Air Pollution and the Economy

Existing studies of the economic impacts of air pollution differ in many respects due to geographic and sectoral coverage, methodology and other factors but it can be generally concluded that the costs of inaction are very large and far outweigh the cost of taking mitigating actions. The economic costs of pollution are many – from lowering productivity of workers to reducing crop yields to loss of income from a reduction of tourists visiting places that have become polluted. The Global Burden of Disease study estimates of air pollution exposure and health impacts provide a basis for assessing the economic costs of pollution for the world's economies.

Besides being a health risk, air pollution is an economic burden. By causing illness and premature deaths, pollution reduces the quality of life. By causing a loss of productive labour, pollution reduces input and incomes in the countries. It was found that premature deaths due to ambient and indoor air pollution in 2013 cost the global economy about $225 billion in lost labour income and about $5.11 trillion in welfare losses worldwide. Pollution related income loss is greatest in East Asia and the Pacific region where premature mortality costs reached the equivalent of 7.5% of gross domestic product (GDP) in 2013 and welfare losses from air pollution climbed to $2.306 trillion (Figure 25). Labour income losses, while being lower than welfare losses, were nevertheless substantial amounting to the equivalent of 0.25 percent of GDP in East Asia and the Pacific region in 2013. In South Asia, the labour loss was much higher totaling more than $66 billion, the equivalent of nearly 1 percent of GDP.

Globally, the development burden has also increased over time. Welfare losses from ambient air pollution have increased by nearly 300 percent between 1990 and 2013, growing from $2.18 trillion to $3.55 trillion. Welfare losses increased in about two-thirds of all countries. Welfare losses from indoor air pollution increased by 63 percent between 1990 and 2013 despite declines in the percentage of households that rely on solid fuels for cooking. The increase can be attributed to population growth, aging and rising incomes, which led to more deaths and higher costs of welfare services.

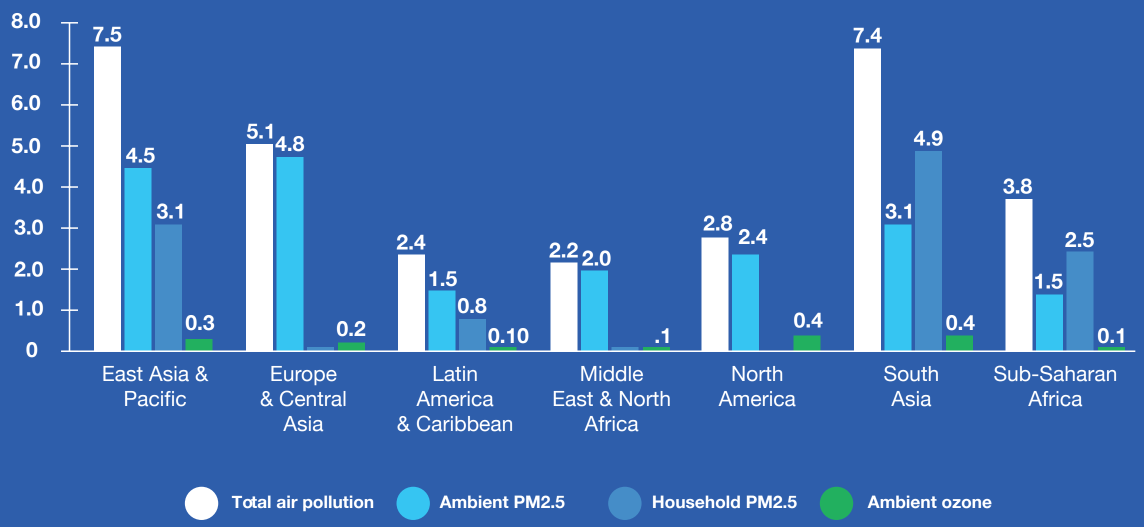
Sector-wise, in OECD countries, the road transport sector has been estimated to account for around half of the total health-related economic cost of ambient air pollution of about $865 billion in 2010 [OECD, 2014], On the other hand, in developing countries, power generation and industry are the sectors that make the most significant contributions to the economic cost of pollution. In China it was estimated at around $85-280 billion in 2003 while in India an estimate of the cost of air pollution was around $160 billion in 2009 [World Bank, 2013].

There are also economic losses from crop losses attributable to air pollution. High concentrations of some pollutants, such as ozone and black carbon affect the productivity of agricultural crops causing a loss of income, affecting global food security. The most significant losses are felt in developing countries that have both large-scale crop production and relatively high pollution levels. It has been estimated that the annual losses due to ozone pollution to agriculture in India has been around 3.5 million tonnes of foregone wheat production and 2.1 million tonnes of rice, sufficient to feed over 90 million people [Ghude, et al., 2014]. In China, surface ozone had reduced yields of summer wheat by an estimated 21-25%.

The World Bank and the Chinese environmental authority estimate the cost of acid rain and SO_2 pollution on agricultural output in China at 30 billion yuan a year (2013 prices) [World Bank-SEPA (2007) /World Bank/IHME, 2016]. Another study of four staple crops (wheat, soybeans, rice and maize) estimated that current ozone levels cause yield losses of 3-16%, depending on crop and modelling assumptions. Present day global relative yield losses are estimated to range between 7-12% for wheat, between 6-16% for soybean, between 3-4% for rice and between 3-5% for maize [EANET RSAP, 2015]. This impact may increase food insecurity among low-income populations in affected regions.

Air pollution episodes, besides being a major source of pollutants, also reduce visibility and produce odours discouraging tourism. The episodic severe haze from peat fires and biomass burning affecting Southeast Asian countries in past years have cost the economies of the affected countries billions of dollars. Total economic costs cover over all aspects of life – lost productivity, lost tourism, lost workdays due to respiratory illness as well as higher prices of fresh food products. The Asian Development Bank estimated regional business losses from the 1997-1998 episode at over $9 billion. The losses from the 2015-2016 episode are still being counted. Although estimates could vary due to coverage and methodologies used in estimating damages, none are below $16 billion and could be as high as $47 billion, according to the Indonesian government’s estimate.

Figure 25: Welfare Losses Due to Air Pollution by Region, 2013



Source: World Bank/IHME

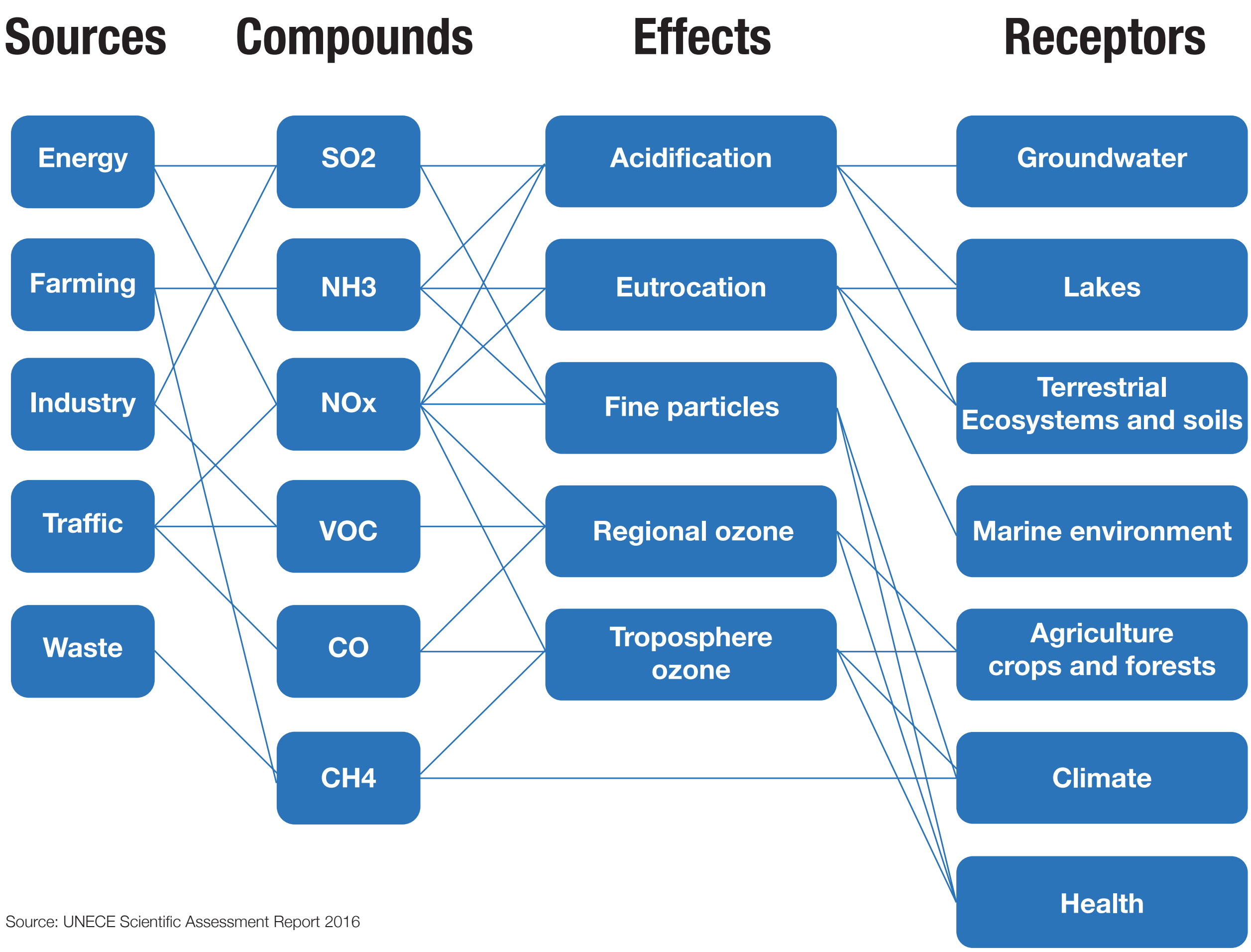
3 Strategic initiatives to achieve cleaner air

3.1 Links between acid deposition, air pollution and other environmental issues

Air pollutants from various sources interact within the atmosphere leading to combined effects and impacts on human health and ecosystems. Some forms of air pollution are interlinked (Figure 26). Acid deposition is linked to tropospheric ozone and to fine particles. It shares precursor emissions with ozone and thus measures to mitigate this phenomenon can also be expected to benefit the suppression of other air pollution, both directly and indirectly.

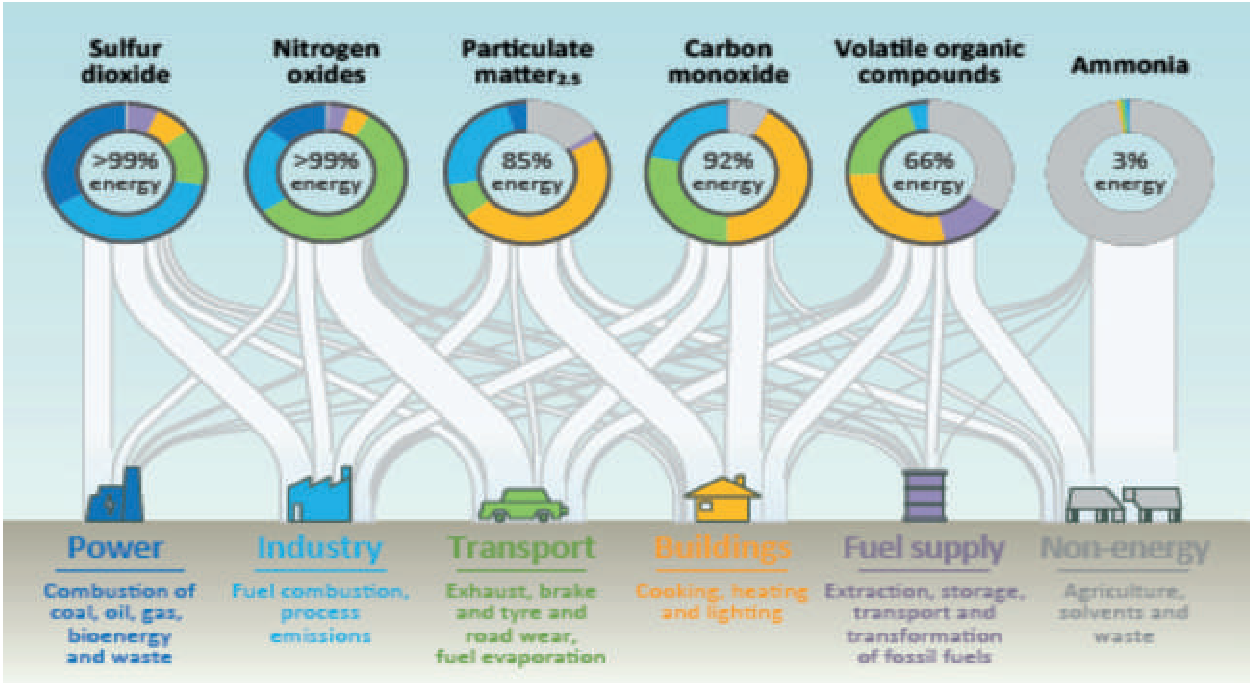
Energy production and use account for most of the air pollutant emissions from human activities. Air pollutants are emitted at every stage; primarily from the combustion of fossil fuels but also during extraction, industrial activities, processing and transportation of coal and natural gas and oil refining. As shown in Figure 27, sulfur dioxide (SO_2) and nitrogen oxides (NOx) emissions are almost entirely attributable to energy production and use while 85% of PM2.5 emissions are attributable to energy production and use. Of the 80 million tonnes of SO_2 emissions from the energy sector, 45% is from industry and about 33% is from the power sector.

Figure 26: Relationship between sources and receptors of air pollution



Source: UNECE Scientific Assessment Report 2016

Figure 27: Selected primary air pollutants and their sources, 2015



Source: International Energy Agency

3.2 Challenges in air quality management and motivation for an integrated approach

The current pollution abatement measures at the national level may be able to maintain the decline in concentrations of some pollutants such as SO_2 in the region but may not be sufficient to bring about a significant improvement in the environment and achieve cleaner air for sustainable growth in East Asia. Much greater efforts are needed to reverse the increasing trends of concentrations of air pollutants that are presently on the rise and to accelerate the decline of those that have started to decrease in recent years. Innovative and strategic policy actions should be implemented to bring about further reductions in emissions from the major sources as well as other sources that have not been targeted in earlier efforts.

An integrated approach to air quality management

An effective air quality management plan will require global, multi-stakeholder effort including intergovernmental bodies, business leaders, civil society and individuals to facilitate synergies. Building alliances with global and regional partners are also essential. The international co-operative approach includes an interaction between scientific community and policy makers, providing a good basis for exploring synergies between air pollution and climate change, agriculture and biodiversity and energy and public health policies on the urban, national, continental and hemispheric scale. International collaboration and coordination of air pollution science will harmonize methods for estimating emissions, monitoring air quality and impacts and identifying cost effective measures.

Global and regional environmental agreements can provide a framework for pollutant reduction particularly when there is scientific evidence of risk to health or ecosystems. Many countries have adopted a national policy and legal frameworks to implement the agreements, some of which are target-based, some are time-based, while others cover compliance -related actions, monitoring and reporting. Multilateral environment agreements have been successfully applied in Europe in the reduction of some targeted pollutants.

Many air pollution abatement measures have co-benefits for greenhouse gas emissions and climate change. Air pollution controls increase energy efficiency and reduce consumption of fossil fuels resulting in a reduction of CO_2 emissions. With increasing costs of air pollution controls a win-win situation can be achieved by adopting strategies that simultaneously produce both health and climate co-benefits.

The air pollutant climate approach was introduced as a new policy tool to mitigate near-term climate change and improve air quality simultaneously. From the acid deposition and air quality improvement side, stringent control of emissions of ozone precursors and fine particles/black carbon can be achieved with less cost when combined with other air pollution reduction policies. Justification of SLCPs control from a climate change mitigation perspective is that, while the CO_2 emission reduction is essential for alleviating long-term global warming and climate change, it does not help for the near-term mitigation due to its long atmospheric lifetime. Mitigation of near-term climate change can only be achieved by reducing emissions of SLCPs. Co-controls measures on some SLCPs such as ozone, fine particles/black carbon and methane therefore provide co-benefits to climate and air quality, including acid deposition mitigation. In a study by UNEP and the WMO, it was estimated that implementing a small suit of SLCP mitigation actions could prevent 2.4 million premature deaths annually, mainly targeting black carbon [WHO/Climate & Clean Air Coalition, 2016].

There is need for a holistic, comprehensive and global system that integrates and builds on current efforts to tackle air pollution. It is timely that the UN Environment Assembly is considering a Framework for actions on pollution to curb pollution around the world, with a reduction of air pollution among the main targets [UNEP, 2017].

Actions Required for Air Pollution Mitigation

1. Develop air quality policies and strategies at the subnational, national and regional levels to comply with World Health Organization air quality guidelines

2. Invest in air quality monitoring networks, assessment systems, institutional capacity and information disclosure to the wider public to address gaps in capacity, data, information and awareness

3. Reduce emissions from major industrial and manufacturing sources

4. Adopt and enforce advanced vehicles emissions standards

5. Develop and adopt electric and hybrid vehicles

6. Provide access to public transport and non-motorized transport infrastructure in cities

7. Increase investment in renewable energy and energy efficiency

8. Improve access to clean cooking fuels and green technologies for residential heating

9. Protect and restore ecosystems to avoid erosion, fires and dust storms

3.3 Creating synergy through closer collaboration and partnerships with regional and global initiatives

EANET has consistently promoted communication and cooperation with relevant environment-related organizations and regional programmes and networks related to acid deposition and air pollution such as Asia Pacific Clean Air Partnership (APCAP), United Nations Economic Commission for Europe, Convention on Long-range Transboundary Air Pollution (UNECE CLRTAP) and its programmes including the Cooperative Programme for Monitoring and Evaluation of the Long Range Transmission of Air Pollutants in Europe (EMEP), North-East Asian Sub-regional Programme for Environmental Cooperation (NEASPEC), Climate and Clean Air Coalition to Reduce Short-Lived Climate Pollutants Initiative (CCAC), the World Meteorological Organization (WMO), Regional Forum on Environment and Health, etc.

The cooperation with WMO was further enhanced with the signing of a Letter of Arrangement (LoA) between EANET and the Global Atmosphere Watch (GAW) programme of WMO to provide additional scientific expertise and strengthen research and service activities of both EANET and WMO/GAW. The benefits to the EANET are:

- Easier access to the WMO/GAW and EANET data and stations information by users
- EANET can access further information from the WMO/GAW network which covers additional regions, vertical regimes, monitoring parameters
- EANET representative will participate in the Scientific Advisory Group (SAG) for Total Atmospheric Deposition and can shape the GAW Programme
- Additional opportunities for training at the GAW Training and Education Centre
- Increased potential for collaboration with other members of the GAW community to improve the quality of observation and potential for joint research

Modelling research is an essential tool for improving the understanding of acid deposition processes in the region. Due to the limited coverage of ground-based measurements, chemical transport models and remote sensing techniques have been used to map spatial distribution and seasonal variation of aerosols and ozone at the regional, hemispheric and global scale. The Joint Research Activities on Model Inter-comparison Study in East Asia (MICs-Asia) is an EANET related activity to promote modelling research for the East Asia region. The MICs-Asia program brings together atmospheric modelers from around the region to interact and carry out joint studies and provide opportunities for modelers to present and discuss their simulated results, make comparisons with other methods and share information at workshops held annually.

The Asia Center for Air Pollution Research (ACAP), the Network Center for EANET, will host the Acid Rain 2020 conference in mid-October 2020 in Niigata city, Japan. This conference is one of the historical international conferences related to acid deposition and has been held basically every 5 years at various venues. EANET has plans to hold special events during the conference to commemorate its 20th anniversary since the start of its regular -phase activities in 2001. The Acid Rain 2020 conference offers further opportunities for scientists of the region who have conducted acid deposition related research studies to present their findings and for conference participants to be updated on the latest developments in this field.

4

Significant achievements of the region

4.1 Progress made by the participating countries in addressing acid deposition and air pollution issues

Much has been achieved by the EANET network since the start of monitoring activities in 2000. Of importance, all participating countries have established and are operating national monitoring sites following the EANET technical manuals and guidelines and are submitting data regularly to the network for regional assessment. Through the EANET training courses and national workshops, the knowledge on acid deposition and air pollution has been passed on to other stakeholders.

The progress of countries in addressing acid deposition and air pollution issues varies from country to country depending on national priorities and capacities and severity of air pollution in the country. The activities in the participating countries relating to air quality management in recent years as summarized below.

No negative impact from acid deposition is evident in **Cambodia** although the effect of acid deposition on the ancient remains (Angkor Wat) is doubted. However, the General Directorate of Environmental Protection which has a responsibility for environmental protection is in the process of revising the environmental quality standards at the national level including air quality standards.

The State Council of **China** adopted the "National 12th Five-Year Plan for Environmental Protection" in December 2011 which plans to further double the efforts in sulfur dioxide and nitrogen oxides emissions reduction, and to cut sulfur dioxide emissions and nitrogen oxides emissions in 2015 by 8% and 10% respectively compared with 2010. The main requirements are i) continuously facilitate emission reduction of power industry ii) accelerate desulfurization and denitrification of other industries iii) control NOx emissions from vehicles and ships.

The Ministry of Environmental Protection issued the revised "Ambient Air Quality Standards" (GB 3095-2012) in February 2012 and determined the phase-based implementation plan. After implementation by stages in selected areas and cities, the "Ambient Air Quality Standards" was adopted nationally after January 1, 2016. Compared with the pre-revised version, the new standard adds annual and 24-hour average concentration limit of PM2.5 and 8-hour average concentration limits of ozone and tightens PM10 and NO_2 concentration limits.

The State Council issued the "Air Pollution Prevention and Control Action Plan" in September 2013. It proposes that: "After five years' efforts, the overall national air quality shall be improved. Heavily polluted days shall be reduced dramatically. Regional air quality in Beijing-Tianjin-Hebei, Yangtze River Delta and Pearl River Delta will be turned better. Through another five years' or even longer efforts, heavily polluted days shall gradually be eliminated, and the national air quality shall be improved significantly". 35 specific measures in 10 categories have been identified and specific indicators will be used to track achievements.

Indonesia does not have specific national measures against acid deposition. To control the emission of air pollutants there are some regulations of stationary emission standard, vehicle emission standard and ambient standard. The Ministry of Environment Republic of Indonesia has company's environmental performance rating program as an alternative compliance instrument. This program does not directly reduce the emission of sulfur dioxide and nitrogen oxides which are the main cause of acid deposition but there is an assessment of compliance with the requirement of air pollution regulation. One of the main sources of acid pollution comes from excessive amounts of acid emitted during forest fires. The government of Indonesia has established in 2015 an Agency for Peatland Restoration to mitigate peatland fires and established the moratorium for peatland conservation and palm oil plantation until further policy changes.

In accordance with the Air Pollution Control Law, the state of air pollution is constantly monitored throughout **Japan** by prefectural and ordinance

- designated municipal governments. Though the atmospheric concentration of NO_2 and SO_2, suspended particulate matter (SPM) and CO are decreasing or stable almost below the Environmental Quality Standards (EQS) levels, photochemical oxidant and fine particle (PM2.5) are keeping relatively high level over EQS these years. Based on the monitoring results, the Ministry of the Environment (MoE) will further enhance the comprehensive efforts to achieve EQSs through taking measures for emission reduction from factories and business establishments, automobile exhaust gas, dissemination of low-emission vehicles, etc.

In **Lao PDR**, where air pollution levels from industrial sources are relatively low, the agency responsible for environment quality protection has been identified and activities related to climate change at the national level are being implemented. The "National Environmental Standard" for air, water and soil quality and emission sources from factories and in-use motor vehicles has been prepared and the Sustainable Transport Strategy and National Environment Strategy have been developed up to the year 2020.

With its history of air quality management, **Malaysia** has a well-developed monitoring network and its national ambient air quality standards generally comply with the WHO interim targets and environmental clean air quality regulations. The Environmental Strategic Plan for 2011-2020 has a requirement to maintain good air quality. Currently, several research projects are being undertaken to study the physico-chemical properties of forest litter compost and use of co-composited forest to improve soil nutrient retention.

Air quality monitoring instrument malfunctions can occur due to harsh winter conditions in **Mongolia** resulting in a gap in the dataset. The major sources of air pollution are emission from coal burning for heating accounting for the higher concentrations of SO_2, NOx, CO and PM during the winter.

The Law on Air (2010), the Law on Air Pollution Payment (2010), the National Program for Reducing Air and Environmental Pollution (2017), and the Action Plan for Implementation of the National Program for Reducing Air and Environmental Pollution (2017) have been issued. The revised Law on Air of 2012 is a main legal instrument aimed at air protection and pollution prevention, mitigation and control. The National Program for Reducing Air and Environmental Pollution is used as the most detailed and comprehensive document dealing with air quality improvement. It envisages 60 measures; among them, over 50 measures are focused on air pollution.

A Master Plan for decreasing air pollution in Ulaanbaatar city has been approved in 2018. As a part of actions to reduce the air pollution in Ulaanbaatar city, the Government has approved a regulation to cut electricity night tariff for ger (Mongolian traditional housing unit) district households to zero, from 9 pm to 6 am during the cold period that is from 15 October to 31 March. Moreover, the Government issued the order for a prohibition of raw coal use in Ulaanbaatar city which will be implemented starting from 15 May 2019.

No negative impacts from acid deposition have been identified in **Myanmar**. The Department of Meteorology and Hydrology will continue the relevant environmental monitoring activities. Some other government agencies such as the Yangon/Mandalay City Development Committee, Department of Health, Department of Atomic Energy, Irrigation Department, and Water Resources Utilization Department etc. are also carrying out monitoring of water and air quality. In 2014, the Environmental Conservation Department has also installed a PM2.5 monitoring equipment for air concentration measurement.

The **Philippines** Clean Air Act of 1999 is used as a comprehensive guiding air pollution control policy in air quality management, intervention and programs. As 70-80% of air pollution comes from mobile and industry sources, measures for mitigating air pollution include enforcement of motor vehicles and stationary/industrial sources standards and enforcement on open burning to comply with the provisional ambient air quality guideline value of 50 μg m^{-3} for short term and 25 μg m^{-3} for long term PM2.5 effective from 1 January 2016.

The Government of the **Republic of Korea** has taken comprehensive measures to reduce air pollutant emissions for the last three decades or so as it recognized the seriousness of air pollution caused by industrialization since the 1960s. A national air monitoring program was initiated in the mid-1970s. Then, photochemical assessment stations and hazardous air monitoring stations were added to the network in early 2000. Adverse effects of long range transport of air pollutants have a long history in R. of Korea Since its first record over six hundred years ago, the occurrence of Asian dust and its harmful effects have been constantly reported. As Northeast Asia has been experiencing extensive industrialization for the last half century, long range transport of air pollutants has become a great public concern along with natural air pollutants and Asian dust. Recognizing that international collaboration is required to effectively cope with transboundary air pollution,R. of Korea has actively promoted and participated in many regional initiatives which have objectives and methods to addressing long range transport of air pollutants and other regional air quality problems.

In East Siberia of **Russia**, SO_2 predominates among other small gaseous admixtures in the atmosphere at all monitoring sites with stronger inter-annual variations being mostly depended on air temperature in winter months: the colder the winter, the higher the average concentration, as recorded in East Siberia in 2005-2006 and 2009-2013 due to cold winters. Annual average concentrations of SO_2 at Primorskaya site was lower compared to that in East Siberia, and despite of cooler air temperature in 2012-2014, SO_2 content in the atmosphere at Primorskaya site was less than in the previous cold years of 2004-2005 and 2010.

That could be attributed to the transition of power/heat production in region from coal to gas consumption. Ozone concentrations at all monitoring sites of East Siberia have similar seasonal dynamics like many remote areas of the Northern Hemisphere, and it is likely correspondent to global atmospheric chemistry and dynamics. However, its shorter-term fluctuations (of several days) at Mondy during a cold period are associated with regional synoptic conditions: changes of atmospheric pressure and regional transport by winds. Diurnal fluctuations of ozone are maximal in spring and summer and minimal in December and January. The acidity of atmospheric precipitation increases in the areas away from regional industrial sources in East Siberia. Lower acidity (pH <5.0) has been registered in the 47% precipitation samples at Listvyanka, of 24% at Primorskaya, and around 14% in Irkutsk. These numbers were less than those in 2005-2009, desirable together with the reduction of sulfur and nirogen oxide emissions from large regional coal power plants. The experience of European countries shows that it is possible to solve this problem by improving abatement devices or by using natural gas instead of coal.

Thailand has categorized its air pollution sources under i) general sources including transportation, domestic and industrial fuel combustion for power generation and consumption and ii) specific sources including a fire in landfills, haze and smog resulting from the open burning of agricultural land and forests. Emission standards for new and in-used vehicles have been implemented including inspection and maintenance programme and promotion of Ecology car. To solve the problem of haze and smoke, the National Master Plan on Open Burning Control focusses on forest fires prevention and rehabilitation of traditional crops land preparation with programs based on the preservation and protection of nature.

Faced with increasing air pollution in recent years, the government of Viet Nam has made efforts in institutional and policy related to air quality management and air pollution controls. The government departments/agencies involved in air quality management have been consolidated and their responsibilities clarified. In addition, many legislation documents have been issued such as Laws, Decrees, Circular, plans and national technical standards on air emission control.

4.2 Activities for improving understanding of acid deposition and air pollution

The EANET has gained international recognition for its success in promoting regional cooperation on acid deposition monitoring in East Asia and facilitating inter-regional exchange on measurement data and assessments of the state of acid deposition.

The EANET periodically publishes scientific assessment reports on the state of acid deposition in East Asia. The Third Periodic Report on the State of Acid Deposition in East Asia (PRSAD3) describes the outcome of EANET monitoring activities from 2010 to 2014. The following activities within the current scope of the EANET were identified in PRSAD3 for improvement and strengthening of the EANET:

- Improvement of acid deposition monitoring, including consideration of other relevant components such as ozone and particulate matter, with increased transparency
- Extended assessment of the state of acid deposition, including consideration of other relevant atmospheric pollutants
- Promotion of research activities, including the development of modelling and emission inventories
- Establishment of an epistemic community and promotion of public awareness to achieve a common understanding of atmospheric pollution
- Enhancement of policy relevant activities related to the provision of policy advice and information based on sound science and assessment
- Strengthening of technological support and capacity by enhancing cooperative efforts among participating countries
- Preview of the present status of the atmospheric environment in East Asia and Feasibility study on the expansion of the scope of the EANET
- Feasibility study on the establishment of a new Network Center (NC) for the EANET
- Enhancement of collaboration with organizations outside the region

PRSAD3 further made recommendations for improving the understanding of acid deposition and related air pollution issues in East Asia as follows:

1. Particulate Matter and Haze- The number of monitoring sites should be increased, particularly in locations with the highest human activities. More comprehensive monitoring data focusing on atmospheric chemistry should be submitted to the EANET. Carbonaceous aerosol measurement should be added as it plays a dominant role in the formation of haze. More investigations on health effects attributed to transboundary particulate matter pollution are needed as the chemical composition of PM varies in different areas. Epidemiological research such as cohort study specifically designed for evaluating air pollution effects of PM should be conducted in East Asia.

2. Tropospheric Ozone- More studies on inter-annual variations and long-term trends are needed. Monitoring of ozone precursors and tracers need to be enhanced and the impacts of climate change on source-receptor relationships need to be further studied. Multi-country collaboration for studies with consistent methodology is necessary including a sufficient number of cities which are affected and not affected by ozone. Experimental and field studies are needed to ascertain the effect on crops for consideration of efficient control measures for the protection of agricultural production as well as sensitive forest ecosystems in the region.

3. Acidification and Eutrophication- Conduct more field observations in sensitive forested ecosystems and increase the number of sites conducting long-term inland water chemistry measurements. Regional scale evaluation of acidification and nitrogen leaching are necessary.

4. Air Toxics – Increase the number of monitoring sites for Persistent Organic Pollutants (POPs) to gather more data in the East Asia region in order that a detailed emission inventory can be prepared taking into consideration transboundary pollution and to establish control measures

5. Emission Inventories – Improve the estimation of natural and anthropogenic emissions in particular biogenic volatile compounds (VOC) emissions. Conduct more research studies including continuous studies to evaluate the fundamental model and key parameters of biogenic emissions estimates for a better understanding of Asian dust an biomass burning emissions. Verification, improvement and updates of anthropogenic and natural emission inventories based on ground and satellite observations, chemical transport modelling and inverse modelling are essential to reduce uncertainties.

4.3 Consideration on the future direction of the EANET

In a study conducted on possible expansion of scope of the EANET, many participating countries expressed support for the strengthening of the Network Center including expansion of its activities, considering various factors such as emerging air pollution issues, needs and interests of the participating countries, available financial resources and mandate from the next Medium-Term Plan of the EANET (2021-2025).

The potential new activities identified for consideration by member countries are:

- Monitoring of VOCs
  To address regional air pollution from PM2.5, ozone and NOx which causes serious health issues, it is necessary to include VOCs to complete the list of important pollutants to be monitored
- Monitoring using environmental satellite data
  Data from satellites such as SCHIAMACHY, MODIS, OMI, etc. can provide useful information, particularly spatial distribution of air pollutants, to supplement the EANET monitoring data.
- Emission inventories
  Conduct research and capacity building on the development of emission inventories, a basic key element for establishing sound policy decisions on air pollution mitigation, and compile the government-based emission inventories from each participating country
- Clean air technology
  Although information exchange on clean air technology is currently implemented, research on various clean air technologies and identification of the best available technologies (BAT) for reducing emissions of SO_2, NOx, VOCs and PM2.5 is useful for improvement of air quality
- Modelling
  The adoption of suitable chemical transport model(s) for use in the EANET region and promoting the application of the model results for decision making on mitigation measures
- Open Laboratory for scientific research
  The Open Laboratory, as one of the functions of the Network Center, might facilitate joint research, exchange of scientific data and information among participating countries, that might lead to improvement of the quality of research and understanding of acid deposition issue

The Nineteenth Session of the Intergovernmental Meeting decided that the proposal to establish new network center for activities not currently carried out by the Network Center will be further studied and, considering future development of the EANET, taking account of the situation, the needs, and priorities, it may be considered during the development of the next Medium-Term Plan.

There is an urgent need within EANET to strengthen linkages between science and policy makers, to expand and improve existing channels of communication with policy makers in order that results of EANET monitoring and research activities as well as the latest scientific findings can be shared with policy makers and effectively applied in decision making.


The Second Intergovernmental Meeting of EANET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5 The way forward

5.1 Role of policy makers

Air pollution policy can make a significant contribution to the Sustainable Development Goals (SDGs) particularly those to promote healthy life and well-being in the world, to achieve food security and sustainable agriculture, to have safe and sustainable cities, to promote access to sustainable and modern energy sources and to protect terrestrial ecosystems. To realize the SDGs, decision makers need to integrate sustainability into national development plans and policies. In particular policy makers need to incorporate health impacts of air pollution into the cost-benefit analysis of any economic projects and activities and address the findings on Global Burden of Disease (GBD) for the region. Points to note:

- Greater action on air pollution will require greater uptake by decision makers of the scientific and economic findings on the impacts of pollution. Efforts are being made by the scientific community to improve uptake by communicating policy-relevant findings in a clear, effective and credible way.

- Air pollution hurts the environment in many ways that can have lasting effects of future productivity – human mortality, morbidity, degradation of natural ecosystems etc. Estimates of costs are complicated due to many uncertainties and differences among countries. Current estimates of losses need further work. There is a need to link exposure and health impacts to pollution sources to support policy actions and to provide subnational estimates to help prioritize areas within countries.

- Ground-based monitoring is a critical component of any air pollution management approach, particularly at the city level, and countries need to enhance ground-level monitoring networks to tackle air pollution issues. However, with ground based monitoring alone it is hard to achieve spatial and temporal coverage. For global assessments of air pollution burden, it is necessary to combine satellite-based observations with data from ground-based monitoring. Such information should be fully utilized for country -level assessments and air quality planning.

- Measurements of disease burden are being improved regularly by the relevant agencies, with better data and improved methods leading to improved accuracy. The estimates of GBD are updated yearly. The results of research and studies on effects of air pollution on other diseases, health impacts of other pollutants such as nitrogen oxides from transport emissions, natural wind-blown dust will provide better estimates of disease burden and economic costs and be valuable information to decision makers.

- Although reduction of air pollution is a costly, considering huge impacts on human health especially for children and elderly people, it is essential to implement clean air measures in consideration of a co-benefit approach to achieve SDGs. As air pollution is a major health risk and an economic burden, policy-makers should assign high priority to the implementation of national air pollution control measures aimed at reducing health risks. Among others, appropriate measures to reduce fine particles (PM) and ozone are the most important in East Asia. Reduction of exposure to fine particles would not only require a reduction in emissions of primary particles in cities but also precursor (SO_2, NOx, NH_3, VOCs) emissions in a much wider area. Region-wide emission reductions are essential to meet the WHO guideline levels for air pollution.

- With its existing region-wide monitoring network, and a pool of scientists engaged in research on acid deposition and air pollution, EANET has a major role in assessing the state of air pollutants in the region and its impacts on the ecosystem and delivering credible data and information to policy makers to be used for policy formulation and setting of priorities. EANET, through its training programs, can also assist in capacity building.

5.2 Regional actions

The Third Session of UN Environment Assembly (UNEA3) held in Nairobi from 4-6 December 2017 under the theme "Towards a pollution-free planet", called on leaders of Member States to take decisive actions to eliminate anthropogenic pollution that degrades ecosystems, harms human health and well-being and impacts the functioning of all living species. A number of tangible commitments to end the pollution of air, land, waterways and oceans and to safely manage our chemicals and waste was delivered among which is a resolution on "Strengthening health and environmental action in Asia and the Pacific and supporting the initiatives of the Asia-Pacific regional forum on health and environment".The 2030 Agenda provides Governments an opportunity to accelerate regional, national and local actions on pollution towards meeting the Sustainable Development Goals (SDGs).

The Asia Pacific Clean Air Partnership (APCAP) was established in response to the global call to action of air quality from the UNEA. Currently engaging with 14 regional networks, APCAP seeks to promote better air quality management in the Asia Pacific and reduce air pollution and premature mortality, improve agricultural productivity, and contribute to other co-benefits such as conservation of biodiversity and climate change mitigation through voluntary partnerships with other networks and countries. To date, 16 countries from East Asia, South Asia, Southeast Asia, and Oceania & Pacific have officially joined the partnership. In response of calls from UN Environment to prepare regional assessment reports on air quality issues, APCAP has jointly developed the Air Pollution Solutions Report. The Report, presented at the 2nd Asia Pacific Clean Air Partnership (APCAP) Joint Forum in March 2018, targeted professionals, practitioners and policy makers, provided practical and effective solutions to improve air quality benefitting human health, crop yields, climate, environment and socio-economic development and the scale of financing needed to implement priority air quality actions, including the identification of financing sources and mechanism for access.

Given its potential role in the region, EANET could make use of its long-term monitoring data to explore impacts due to exposure to acid deposition and air pollutants and more focus on solutions to acidification and other air pollutant problems that have caused adverse effects. EANET could continuously increase intergovernmental collaboration with outside network, of which APCAP could be one of a regional Asia and the Pacific platform and consider an effective regional network such as EMEP as a model to adopt for enhancement of EANET programme. Lastly, it is crucial for the EANET to enhance the promotion of information exchange, development of policy-relevant reports and publications, as well as the promotion of public awareness.


B5

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