CHALLENGE OF EAST ASIAN COUNTRIES AGAINST ACID RAIN AND AIR POLLUTION

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Abstract

In recent years, the East Asian region has been facing increasing risks of problems related to excess deposition of acidic substances as a result of rapid industrialization. To obtain common understanding on the state of the acid deposition, East Asian countries launched the Acid Deposition Monitoring Network in East Asia (EANET) in 2001 on regular basis. Ten countries in the region including China and Japan are participating in the network. Acid deposition monitoring activities cover four environmental media – wet deposition (e.g. SO_4^{2-}, NO_3^-, Cl^-, NH_4^+, Na^+, K^+, Ca^{2+}, and Mg^{2+} in precipitation), dry deposition (e.g. SO_2, NO_X, O_3 and PM in air), soil and vegetation (e.g. soil chemical properties and degree of decline of trees), and inland aquatic environments (e.g. acidification of lakes and marshes). The network is the first attempt of international cooperation in the region, particularly in the field of acid deposition. Initial data of the network indicated that a wide concentration range of acidic substances existed depending on the location of monitoring sites, and it is expected to provide useful information to describe the present status of acid deposition and transportation of pollutants in the near future.

Air pollution is still the main focus in some countries in East Asia, especially in regions where energy supply is supported by coal combustion without sophisticated treatment facilities. Various air pollution monitoring networks on regular and temporal basis are on-going in the region. Some examples of the output of networks emphasizing hazardous elements included in the fine portion of atmospheric particulate matter are introduced in this paper.

INTRODUCTION

The first intergovernmental meeting on the Acid Deposition Monitoring Network in East Asia (EANET) held in March 1998 agreed to implement the preparatory-phase activities of the Network on an interim basis aimed at facilitating common understanding of the state of acid deposition in the region. Ten participating countries – China, Indonesia, Japan, Malaysia, Mongolia, Philippines, Republic of Korea, Russia, Thailand, and Vietnam – have been carrying out monitoring on wet deposition, dry deposition, soil and vegetation, and inland aquatic environment, based on their own national monitoring plans. The Network developed its operation on regular basis from 2001, and participating countries are accumulating their monitoring data.

Elemental concentration represents status of air, such as emission of heavy metals from industries and municipal incinerators, transportation of soil derived elements more than thousands of kilometers, and so on. These monitoring data obtained by neutron activation analysis can be a cue to evaluate environment problems. Japanese government launched National Air Surveillance Network (NASN) employing neutron activation analysis in 1974, and the data has been accumulated at about twenty sampling sites. As a result of mitigation measure of air pollution sources, concentrations of elements that have anthropogenic sources decreased particularly at the beginning of the monitoring period. However, even now, concentrations of these elements reflect the characteristics of each sampling site, e.g. industrial/urban, rural, and remote. Soil derived elements have a seasonal variation because of the contribution of continental dust transported by strong westerly winds prevailing in winter and spring season.

The health effects associated with trace elements in particulate matter have not been well characterized. However, there is increasing evidence that particulate air pollution, especially fine portion of particles in many different cities is associated with acute mortality.

METHODOLOGY

EANET activities

There are 38 monitoring sites for wet deposition monitoring in the preparatory phase activities of EANET. These monitoring sites cover a vast area of East Asia between lat.51 ° N to lat.6 ° S across ten participating countries. Monitoring sites are classified into three categories depending on the characteristics of individual site. There are 16 remote sites, 7 rural sites, and 15 urban sites. Most countries have at least one urban and one remote site. Geographical distribution of EANET is described in Fig.1. It can be seen that there is a lack of sites in Southeast Asian countries like Cambodia, Laos, and Myanmar. The number of sites in Northern countries like Russia and Northern part of China is also few.

Other than wet deposition monitoring, activities of each monitoring site are limited. About ten sites are equipped with filter packs and about twenty sites with automatic monitor to measure air concentration of atmospheric pollutants. At the vicinities of about ten sites, monitoring for soil/vegetation and inland aquatic environment is carried out.

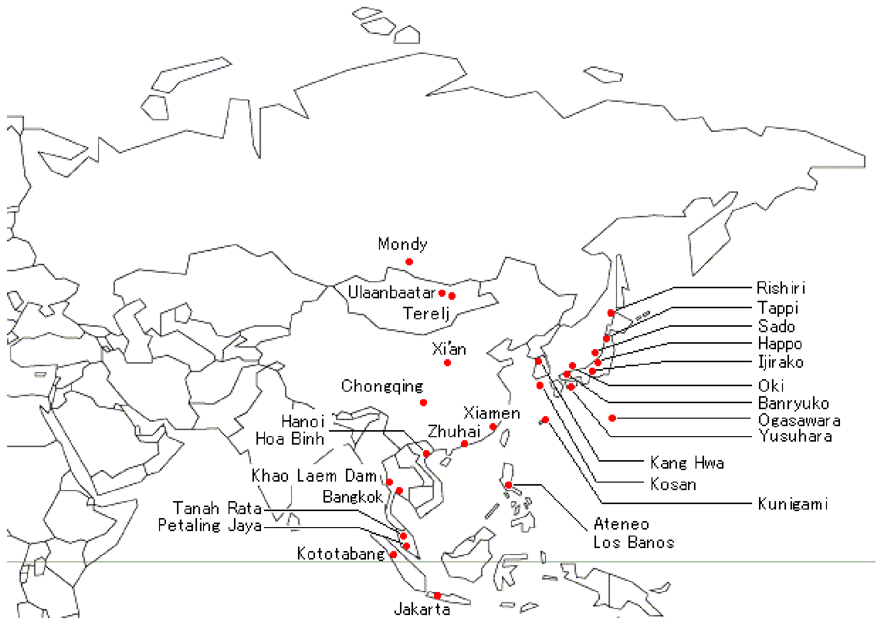

Figure 1: Locations of EANET monitoring sites during the preparatory-phase

(Note: "Xi'an" includes 3 sites, and "Chongqing", "Xiamen", "Zhuhai" include 2 sites respectively. "Jakarta" includes also nearby "Serpong" and "Bandung" sites, and "Bangkok" includes also nearby "Samutprakarn" and "Patumthani" sites. "Ateneo"/"Los Banos" and "Hanoi"/"Hao Binh" are described as one point respectively.)

Monitoring components during the preparatory phase are as follows:

Wet deposition monitoring

Major ions related to acidification such as SO_4^{2-}, NO_3^-, Cl^-, NH_4^+, Na^+, K^+, Ca^{2+}, Mg^{2+}, and pH and electric conductivity of precipitation samples are measured.

Dry deposition monitoring

Air concentration monitoring is carried out as the first step of the dry deposition monitoring:

1st priority: NO_2(urban), SO_2, O_3, and NO and particulate mass concentration;

2nd priority: NO_2(rural and remote), HNO_3, NH_3, particles (SO_4^{2-}, NO_3^-, NH_4^+, and Ca^{2+})

Along with wet and dry deposition monitoring, meteorological parameters such as wind direction, wind speed, temperature, humidity, precipitation amounts, and solar radiation have been measured at the same site or nearby meteorological observatory.

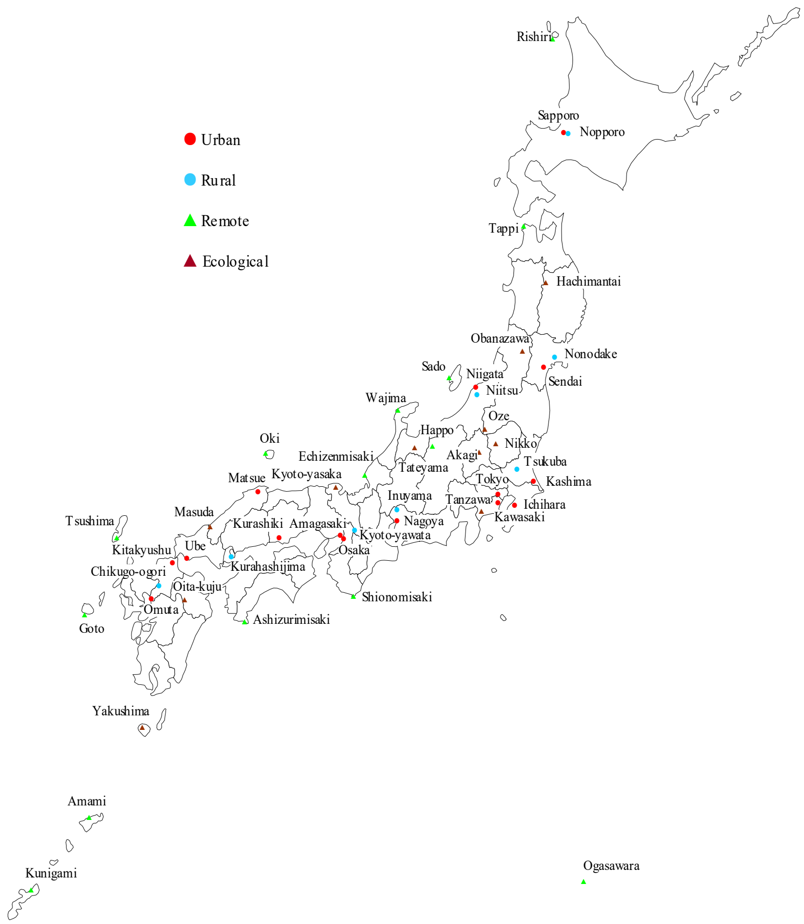

Figure 2 : Site map of national acid deposition monitoring network in Japan

Particulate Matter (PM) Monitoring

The National Air Surveillance Network (NASN) was established in 1965 to measure air quality throughout Japan. In 1974, instrumental neutron activation analysis (INAA) was first applied to PM samples collected at the Network for the determination of trace elements. Since then, air concentration data of 16 monitoring sites has been accumulated for more than 20 years. A brief description of the activities follows.

-PM sample: PM sample was collected every month on nitrocellulose membrane filter by low-volume air sampler (flow rate of 20 liter/m) for 25 days. The sampler was designed to collect particles less than 10 micrometer in diameter.

-INAA and X-ray fluorescence (XRF) method: A quarter of filter was irradiated at reactor for the measurement of short-lived nuclides, e.g. Al, Br, Ca, and another quarter of filter was irradiated for the measurement of medium-lived nuclides, e.g. As, K, Na, and long-lived nuclides, e.g. Cr, Fe, Zn. The rest of the filter was used for the determination of Cd, Ni and Pb by XRF method. In total, 31 elements in PM sample were determined.

RESULTS AND DISSCUSSION

Acid deposition in Japan

In Japan, the Committee on Acid Deposition was first established by the Environment Agency, and the First Survey on National Acid Deposition Monitoring was started among 17 sampling sites from fiscal 1983. However, the sampling device mainly used for the chemical analysis of the survey was the bulk sampler with separating filter. The Second Survey on National Acid Deposition Monitoring among 23 sampling sites was started from fiscal 1988, employing sampling equipment almost the same as the present wet-only samplers. During the Second Survey, 6 monitoring stations located at remote islands had been added to the monitoring network year by year. These newly established monitoring stations at remote areas were the prototype of the present Japanese monitoring stations which are participating in the EANET. The report of the Second Survey concluded the following:

i) pH and deposition amount of precipitation in Japan were virtually the same level as in Western countries. There have been no significant fluctuations since the first survey.

ii) pH values of most lakes and marshes were around 7, and more than 90% of pH values of rivers were between pH7 to pH8. However, there were several lakes and marshes with low pH values.

iii) As regards to the impacts of acid deposition on soil, there had been no evidence of acidification of soil caused by acid deposition, though the existence of acidic soil and soil which is highly sensitive to acid deposition was recognized.

iv) To evaluate these results, clear indication of adverse effect by acid deposition on the ecosystem such as inland aquatic environments, soil and vegetation was not found, though acid precipitation same as western countries was widely observed. However, adverse effect on the ecosystem can appear in the future if acid precipitation continues at the present level.

The Third Survey on National Acid Deposition Monitoring was started from fiscal 1993 among 29 sampling stations. More than ten sampling stations were added in fiscal 1994 and the present monitoring network consists of 48 sites as described in Fig.2. Sampling frequency of the wet precipitation was daily to monthly depending on the site. However for newly built sampling stations and renewal of old samplers, daily sampler was given priority to be introduced to the sites. Properties of collected samples were investigated by measurement of pH and EC, and determination of major anions and cations. Annual average pH of all sites of the Third Survey was from pH4.7 to pH4.9 and that was almost the same as the overall average pH value of the Second Survey (pH4.8). Concentrations of nss(non sea salt)-SO_4^{2-} and nss-Ca^{2+} in wet precipitation samples of the Third Survey were slightly decreased compared with the Second Survey. The average concentration ratio of (NO_3^-/nss-SO_4^{2-}) in equivalent weight increased from 0.44 in 1993 to 0.53 in 1997. It showed the contribution of nitrate to the acidification was becoming larger in recent years. Trends of deposition amount of ions were almost the same as the trends of concentrations; i.e., nss-SO_4^{2-} and nss-Ca^{2+} deposition amounts decreased.

Concerning the spatial variation of the acid deposition, both nss-SO_4^{2-} and NO_3^- deposition amount was larger along the western coast, particularly the South China Sea side. For nss-SO_4^{2-}, it was caused by the higher concentration and larger precipitation amount along the western coast during winter season.

In the Third Survey of National Wet Deposition Monitoring, 29 lakes and marshes were investigated, and several ponds with low pH and low alkalinity values were found. Possibility of a adverse effect by acid precipitation should be considered, because these ponds were not affected by volcanoes or other anthropogenic pollution sources. Evaluating the trend of physicochemical properties of the soil such as "cations/Al ratio" in continuously observed areas from the Second Survey, there has been no significant change by acid precipitation. Regarding the impact of acid deposition on vegetation, decline of the forest was observed at about half of monitoring areas. Most of the cause of decline was identified such as damage by harmful insects, and strong wind and so on. On the other hand, the cause was not identified in some areas. In these areas, most of the soil types were classified into the "moderately sensitive" soil to acid deposition, and the relationship between decline cause of the forest and the acid deposition was not still clear.

Preparatory-phase monitoring data of EANET

Example of the wet deposition monitoring result of EANET during the preparatory phase activities is shown in Table1(Interim Scientific Advisory Group of EANET, 2000). Targeted summary period was from June to August 1999, because maximum numbers of monitoring sites were in operation during the period. In remote sites, pH values of precipitation samples were around five. However, in rural and urban sites, lower pH values were observed particularly with high concentration of SO_4^{2-}. These sites located in China and other Southeast Asian countries might be affected by coal or petroleum combustion. On the other hand, in some countries like Mongolia and Vietnam, Ca^{2+} and other cations neutralized precipitation and made pH value more than five. More detailed monitoring data of regular phase are expected to describe the present status of acid deposition in East Asian region.

Table 1 Characteristics of precipitation sample of EANET
(June1999-August1999, range of weighted average across sites)

	pH			$nss\text{-}SO_4^{2-}$ (umol/L)			Ca^{2+} (umol/L)		
Country	(Remote)	(Rural)	(Urban)	(Remote)	(Rural)	(Urban)	(Remote)	(Rural)	(Urban)
China	5.0-6.7	3.9-6.9	4.3-6.2	17-115	81-99	15-146	6-148	31-111	3-162
Indonesia	-	4.3	-	-	38	-	-	7.3	-
Japan	4.7-5.3	4.5	4.9	1.4-8.8	13	5.2	0.5-5.1	7.4	0.4
Korea	5.4	5.2	-	-	3.5	-	3.9	4.4	-
Malaysia	5.0	-	4.3	5.0	-	23	3.0	-	4.5
Mongolia	5.6	-	6.0	12	-	16	17	-	25
Philipp-ines	-	3.6	5.0	-	9.8	12	-	2.7	3.4
Russia	5.1	-	-	5.3	-	-	3.5	-	-
Thai-land	5.8	5.1	5.5	1.6	21	17	1.7	13	13
Vietnam	-	5.6	6.3	-	5.3	5.3	-	8.2	21

Particulate matter data in Japan

Atmospheric concentration of PM and elements are quite varied among sites in large/industrialized cities, sites in small/rural cities, and sites located in remote areas. As shown in Fig.3, elements such as Cr, Fe, and Ni, which have anthropogenic emission sources in Kawasaki (typical industrialized city) were higher concentration than that of Sapporo (rural) and Nopporo (remote). As shown in Fig.4, the annual average concentration of As in Kawasaki declined clearly compared to Sapporo and Nopporo. Similar trend of concentration change of elements emitted mainly from anthropogenic sources can be seen. Decrease of the concentrations was steep during the first half of the monitoring period, but more gradual during the second half of the period.

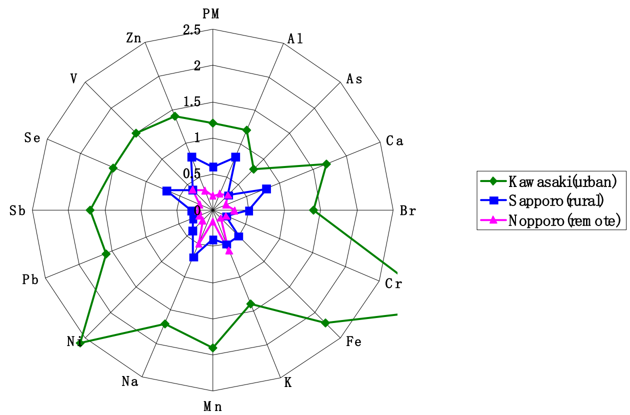

Fig.3 Relative average concentrations in several NASN sites (1996)

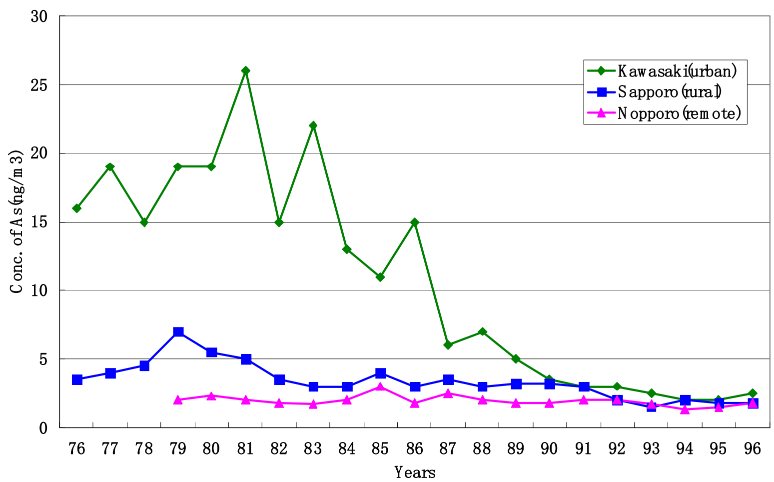

Fig.4. Annual average concentration of As in several NASN sites (1976-1996)

Adverse effects of fine particles on human health

It is well known that during the London smog incident of December 4-8 1952, serious air pollution including over 1.0 mg/m^3 concentrations of sulfur dioxide and PM caused more than 4000 human deaths above the expected figures. Pollutants of coal combustion emitted from both industrial and domestic sources were the main cause of the tragedy. Size distribution of PM is also important parameter regarding human health. In general, fine particles less than 10 micrometers (＜10μ m) may pass through the nose and be collected in the lower respiratory tract. Therefore, ambient air quality standard for PM was first set up in 1971 by U.S. EPA as "total suspended particulate" (TSP), and then revised in 1987 to focus on protecting against adverse effects to health associated with exposure to ambient "PM less than 10 micrometers" (PM_{10}). Based on the latest scientific information on adverse effects on human health, a new standard of "PM less than 2.5 micrometers" ($PM_{2.5}$) was promulgated in 1997 together with the modified PM_{10} standard (US.EPA., 2001). As shown in Fig.5, "PM_{10}" includes a part of coarse particles and all of fine particles, and "$PM_{2.5}$" represents simply fine particles. Major components of fine particles are heavy metals, semi-volatile compounds such as ammonium nitrate, and certain organic substance including carcinogens emitted directly from combustion sources or secondary particles. Transition metals including iron, vanadium, nickel, manganese, zinc, and copper can promote the production of reactive oxygen species, and may be implicated in mortality effects of PM. Other important aspects of fine particles are PM associated acid and hazardous organic compounds and so on. On the other hand, most coarse particles originate from natural sources or mechanical emission sources.

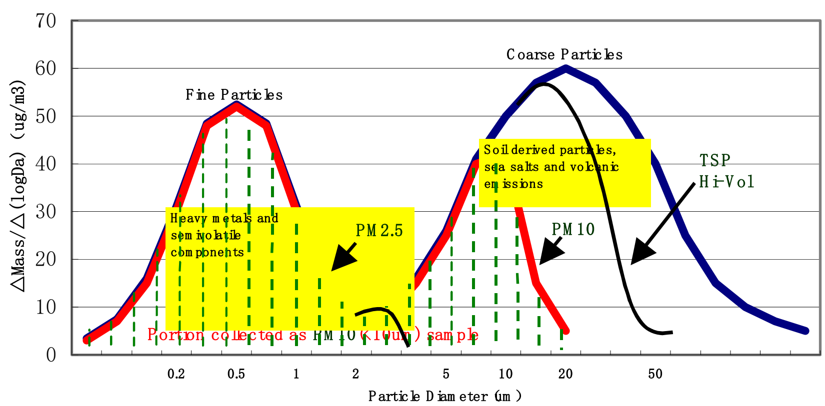

Fig.5 Idealized size distribution of PM in air and portion collected by various samplers

CONCLUSION

Present status of acid deposition monitoring in East Asia and Japan was introduced. The Acid Deposition Monitoring Network in East Asia (EANET) started its preparatory-phase activities in 1998. Ten participating countries are now accumulating monitoring data concerning wet-deposition, dry-deposition, soil and vegetation, and inland aquatic environment. Environment Agency of Japan carried out several national surveys on acid deposition monitoring. The states of the acid precipitation observed in Japan are almost the same as in western countries. Precipitation amount of nss-SO_4^{2-} is decreasing, while the contribution of the NO_3^- to the acidification became larger in these years. Preparatory-phase monitoring data on EANET show variety of acid deposition in the East Asian region.

The Japanese PM monitoring Network employing INAA technique was introduced. Importance of size distribution of PM in terms of its components and human health was also discussed.

Through the monitoring activities described in this paper, East Asian countries are expected to develop international cooperative efforts for preventing or reducing adverse environmental impacts of acid deposition and air pollution.

REFERENCES

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