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Third Periodic Report on the State of Acid Deposition in East Asia

Part II National Assessments

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

Acid Deposition Monitoring Network
in East Asia (EANET)

The Third Periodic Report on the State of Acid Deposition in East Asia

Part II: National Assessments

Edited by:

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Preface

The present report is the National Assessments, Part II of Third Periodic Report on the State of Acid Deposition in East Asia (PRSAD3).

The National Assessments of PRSAD3 was prepared by each participating country according to the format for national assessments that prepared by the Drafting Committee of the PRSAD3. The Acid Deposition Monitoring Network in East Asia (EANET) data and other domestic data of each participating country were used for the national assessments. The period of monitoring data to be analysed is 2010 - 2014. While for its own needs, data in 2000 - 2009 has also been used for trend analysis.

Four chapters are included in this national assessment report, i.e. Basic Information on National Monitoring Activities, State of Acid Deposition in Each Participating Country, Review of National Air Quality Management including Acid Deposition and Conclusion or Summary. Thirteen participating countries, namely Cambodia, China, Indonesia, Japan, Lao PDR, Malaysia, Mongolia, Myanmar, Philippines, Republic of Korea, Russia, Thailand, and Vietnam, shared the progress of their national monitoring activities, state of acid deposition in their respective country and the national measures implemented.

As a detailed complementary of Regional Assessment, the report includes the national information on acid deposition. This is a unique output of an assembling report on East Asia countries in the area of acid deposition during 2010 - 2014.

National Assessment on Acid Deposition in Cambodia

Chapter 1. Base Information on National Monitoring Activities

1.1 Outline of the activities on acid deposition and National Monitoring Plan

The acid deposition is regarded as a global issue and has been highly concerning in many regions in the world. Therefore, Cambodia participated in East Asia Acid Deposition Network (EANET) in 2001 and implemented regular monitoring activities together with twelve other countries. The national monitoring plan developed in 2006 for wet deposition monitoring, dry deposition monitoring has started from February 2010 and the monitoring of inland aquatic environment has started from June 2011.

1.2 Monitoring Station

Sites	Characteristics	Latitude	Longitude	Altitude
Dry Phnom Penh	Urban	11° 33' 21.00"N	104° 55' 52.88" E	15 m
Wet Phnom Penh	Urban	11° 33' 21.00"N	104° 55' 52.88" E	15 m
Inland Sras Srang Kirirom	Remote	11° 32' 88.83" N	104° 03'13.30" E	800m

1.2.1 Wet Deposition

Wet Monitoring, use automatic rain sampler, (Sampling, pH analysis, Electric Conductivity, Ion Chromatography), sampling weekly, Measurement of parameters : pH, EC, SO_4^{2-}, NO_3^-, Cl^-, NH_4^+, Na^+, K^+, Ca^{2+}, Mg^{2+} . Sample amount, conductivity and pH should be measured as soon as possible after sample arrival, and checking agreement of samples and sample list. After conductivity and pH measurement, all samples should be filtered with clean membrane filters (pore size: 0.45µm). Filters should be well washed and be free from contamination. After filtration, samples should be refrigerated at 4ºC . Effort should be made to start analysis of the other parameters within a week of sample arrival in the laboratory and to complete the data sets by measuring EC, pH and all other chemical parameters.

Figure 1.2.1.1 Pictures of Monitoring Station in Phnom Penh from 2006 to 2015

1.2.2 Dry Deposition

Cambodia was installed dry deposition monitoring in February 2010 in Phnom Penh city (11° 33' N, 104° 55' E). Used the four-stage filter pack method , Filter pack method is available for the measurement of SO_2, HNO_3, HCl, NH_3, and particulate component (SO_4^{2-}, NO_3^-, Cl^-, Na^+, K^+, NH_4^+, Ca^{2+}, Mg^{2+}). The four-stage filter pack method can measure all of these parameters at the same time. Sampling intervals: sample is collected for every two weeks, 1. Preparation of filter pack, 2. Sampling, 3. Extraction and chemical analysis, 4. Calculation of results.

Figure 1.2.2.1 Pictures of Dry Deposition Monitoring

Stage	Reaction	Collected specie
1st (F0)	Filtration	Aerosols SO_4^{2-},NO_3^-,Cl^-, Na^+, NH_4^+,K^+, Ca^{2+}, Mg^{2+}
2nd (F1)	Adsorption	HNO_3, partial SO_2, partial HCl SO_4^{2-},NO_3^-,Cl^-, NH_4^+
	Neutralization by collected acid gases	partial NH_3
3rd (F2)	Neutralization by alkali impregnated cellulose filter	SO_2, HCl , SO_4^{2-}, Cl^-
4th (F3)	Neutralization by acid impregnated cellulose filter	NH_3 , NH_4^+

1.2.3 Inland aquatic environment Monitoring

Cambodia has started the monitoring of inland aquatic environment from June 2011 , named SRAS SRANG at KIRIRUM national Park, Kampong Speu province, about 110 km from Phnom Penh city (11º 19' N104º 03' E) , water sample take 2 times a year , monitoring items : Temperature, Alkalinity, pH, EC, SO_4^{2-}, NO_3^-, Cl^-, Na^+, K^+, NH_4^+, Ca^{2+}, Mg^{2+}.

Figure 1.2.3.1 Pictures of inland aquatic environment

Chapter 2. State of Acid Deposition in Cambodia

2.1 State of wet deposition

Acid deposition, more commonly known as acid rain, occurs when emissions of sulfur dioxide (SO_2) and nitrogen oxides (NO_X) react in the atmosphere (with water, oxygen, and oxidants) to form various acidic compounds. These acidic compounds then fall to earth in either a wet form (rain, snow, and fog) or a dry form (gases, aerosols, and particles). Prevailing winds transport the acidic compounds hundreds of miles, often across state and national borders. At certain levels the acidic compounds, including small particles such as sulfates and nitrates can cause many negative human health and environmental effects.

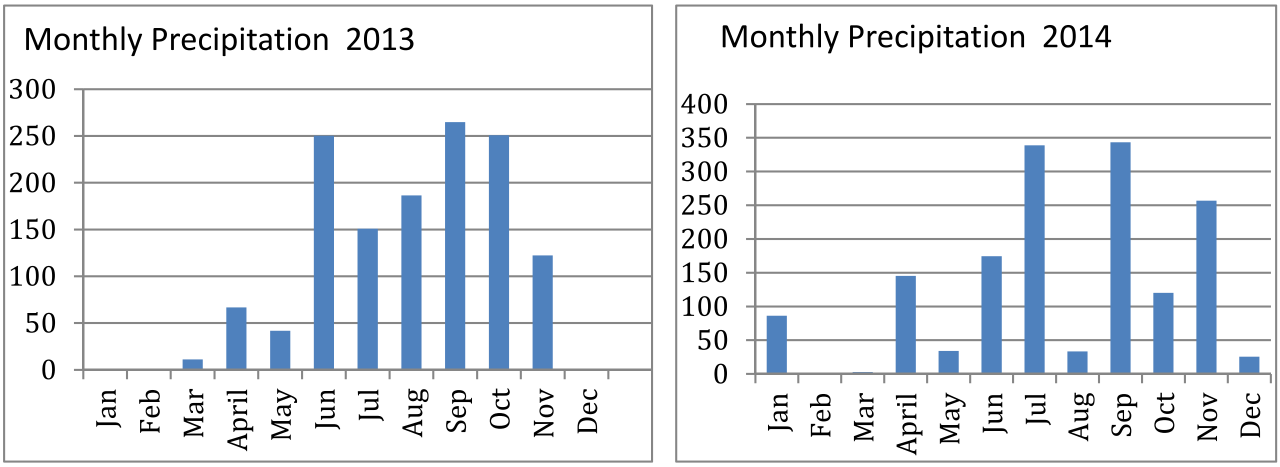


Figure 2.1.1 monthly precipitation (mm)

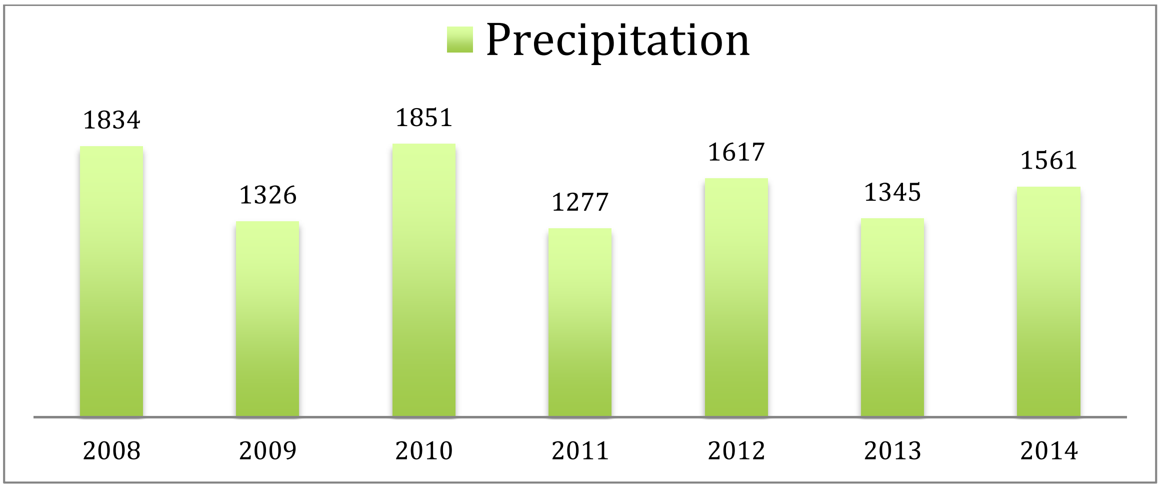


Figure 2.1.2 Yearly precipitation (mm)

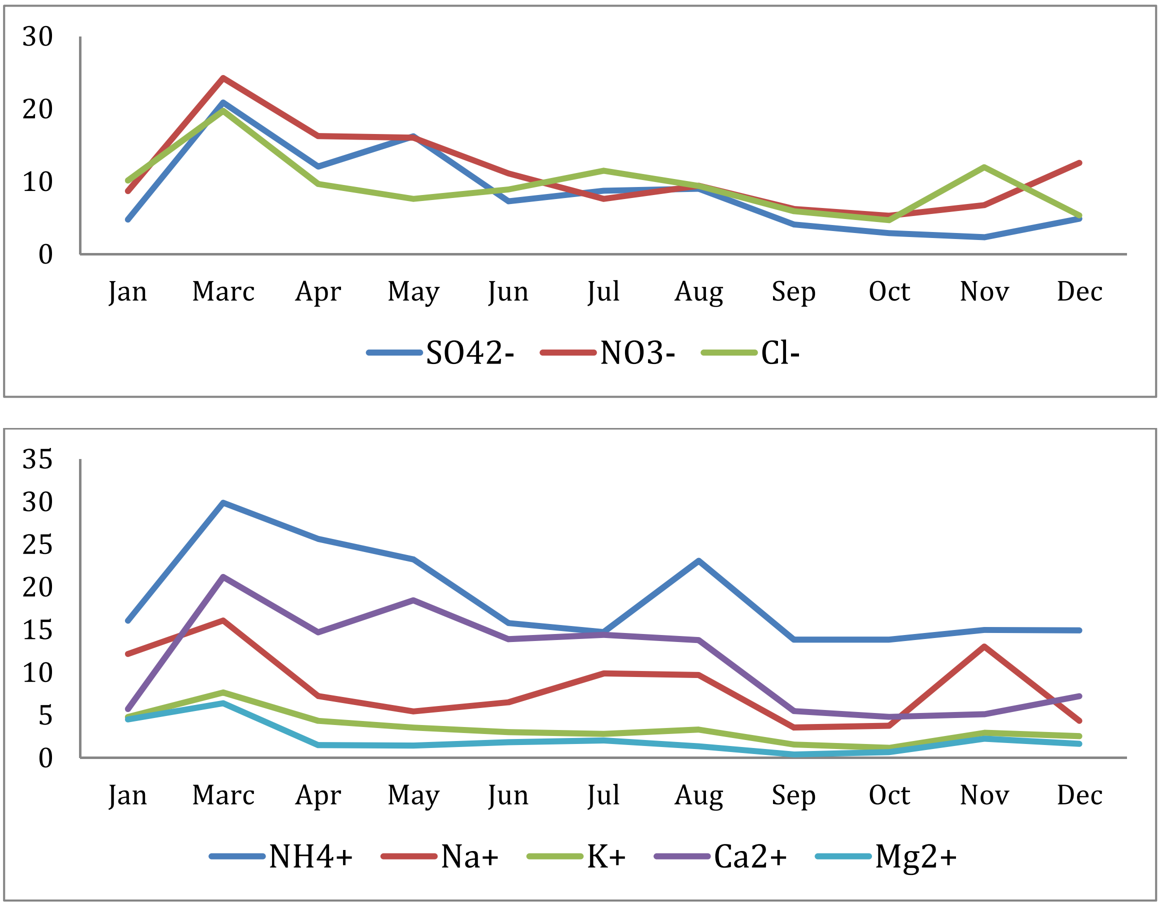
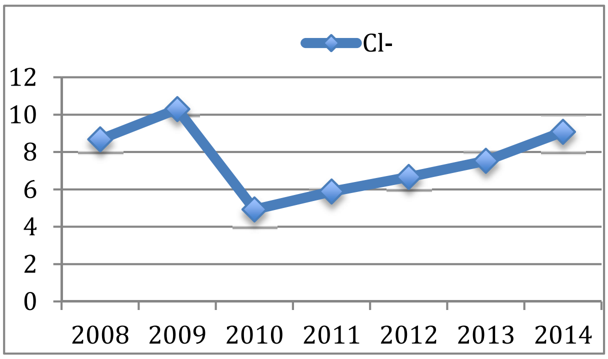
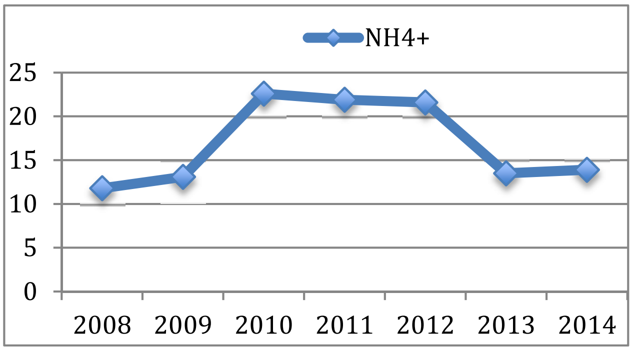


Figure 2.1.3 Monthly Concentrations of Wet in 2014 (umol/l)





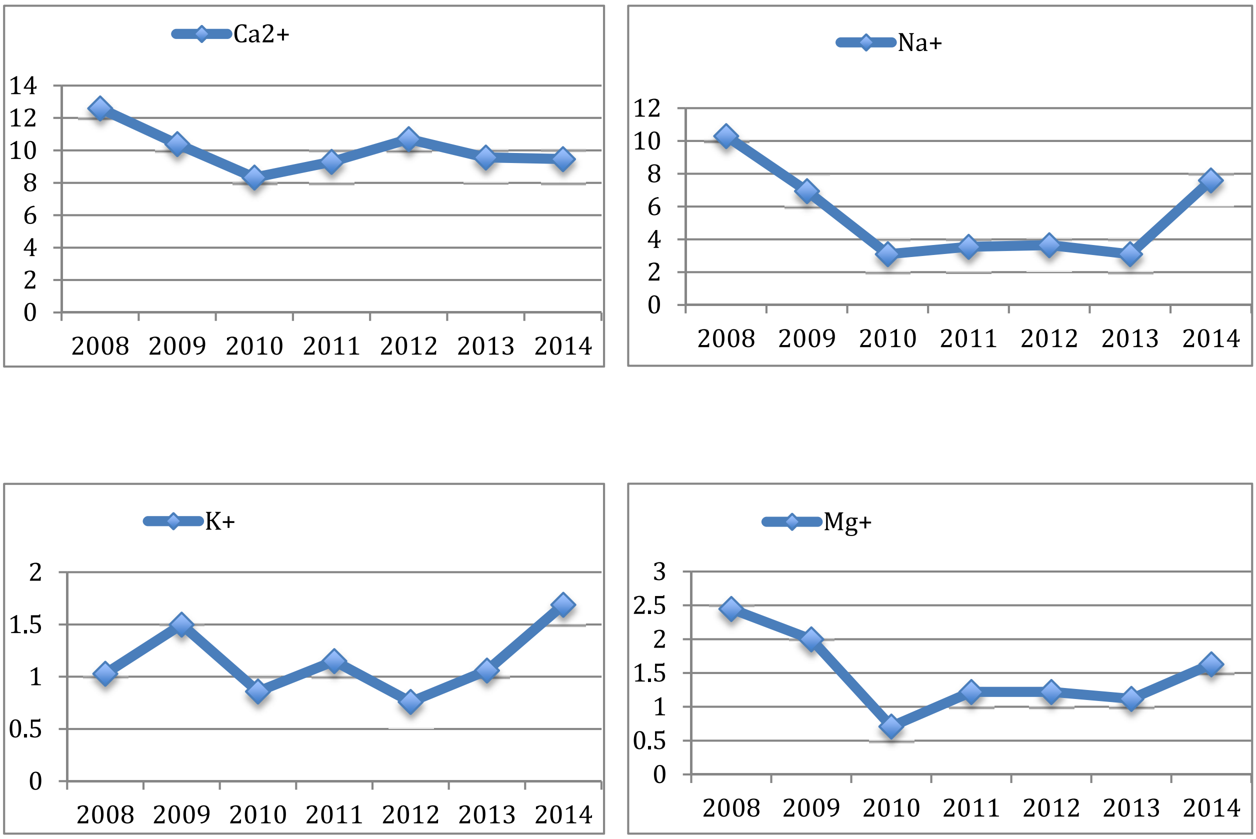
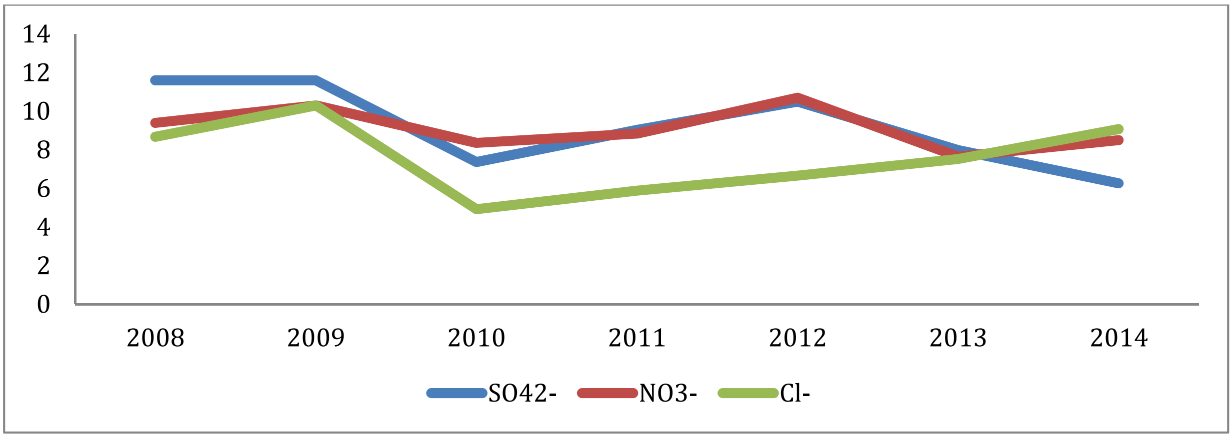


Figure 2.1.4 Yearly Concentrations of Anon and Cation , Wet deposition (umol/l)



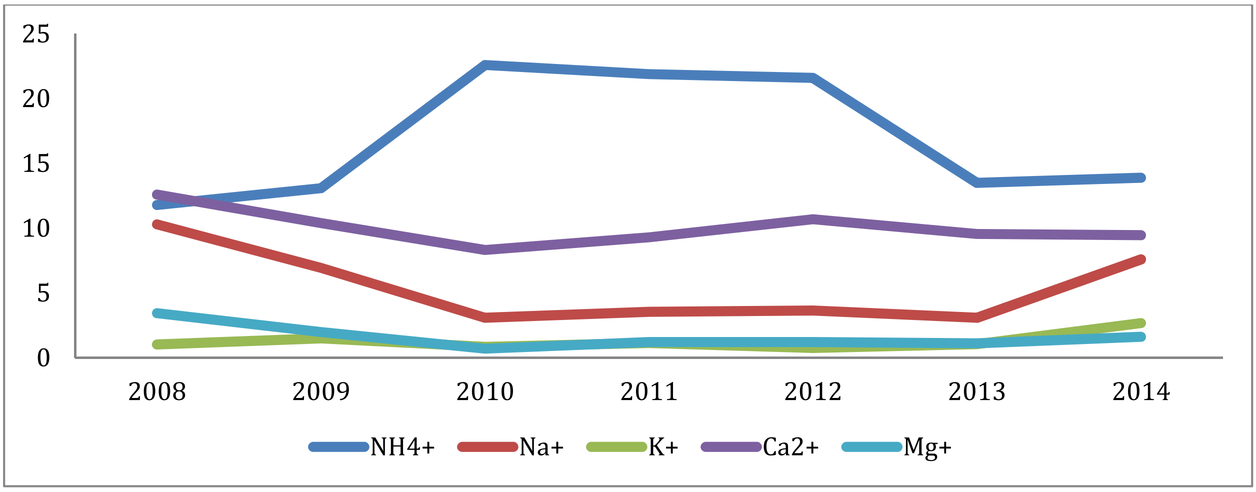


Figure 2.1.5 Yearly Concentrations of Wet deposition (umol/l)

2.2 State of dry deposition

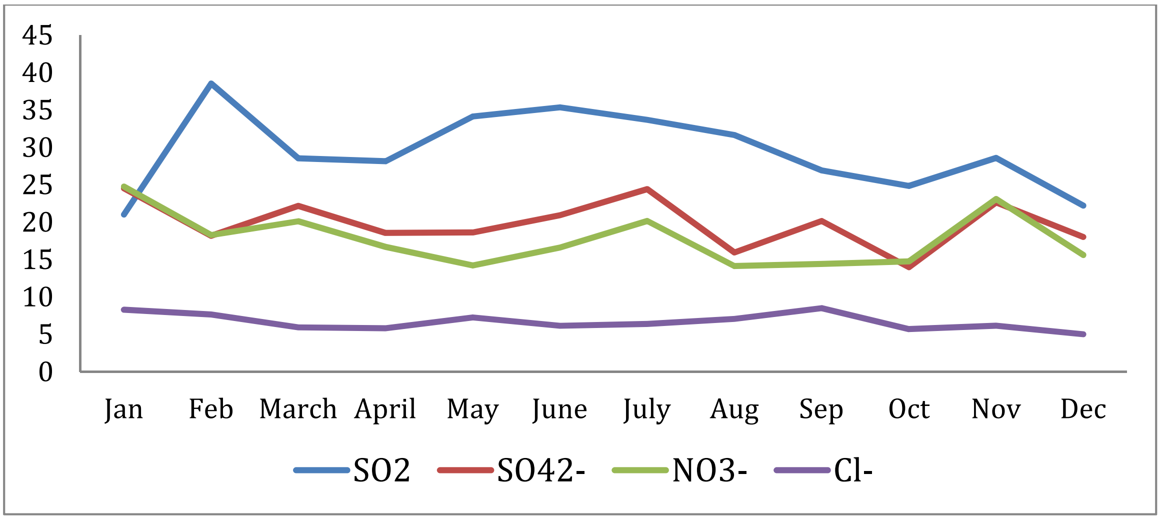


Figure 2.2.1 Monthly Concentrations of Anion (Particle) for dry in 2014 (nmol/m^3)

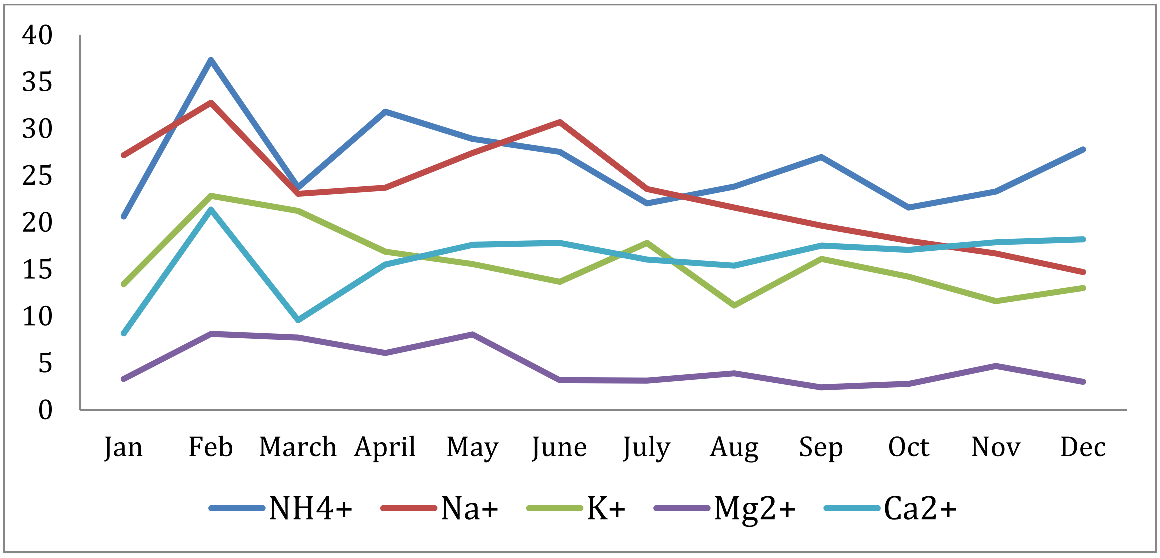
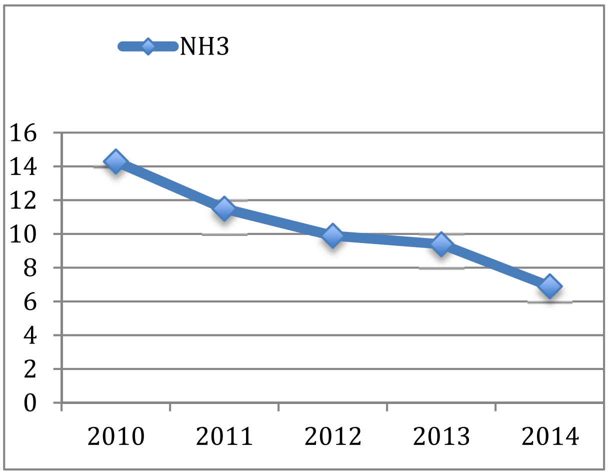
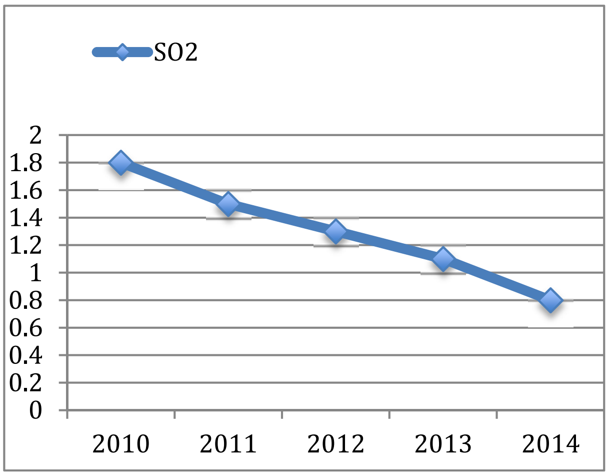
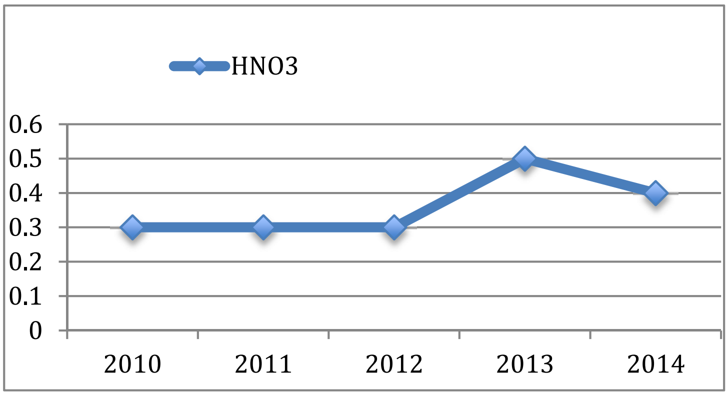


Figure 2.2.2 Monthly Concentrations of Cation (Particle) for dry in 2014 (nmol/m^3)







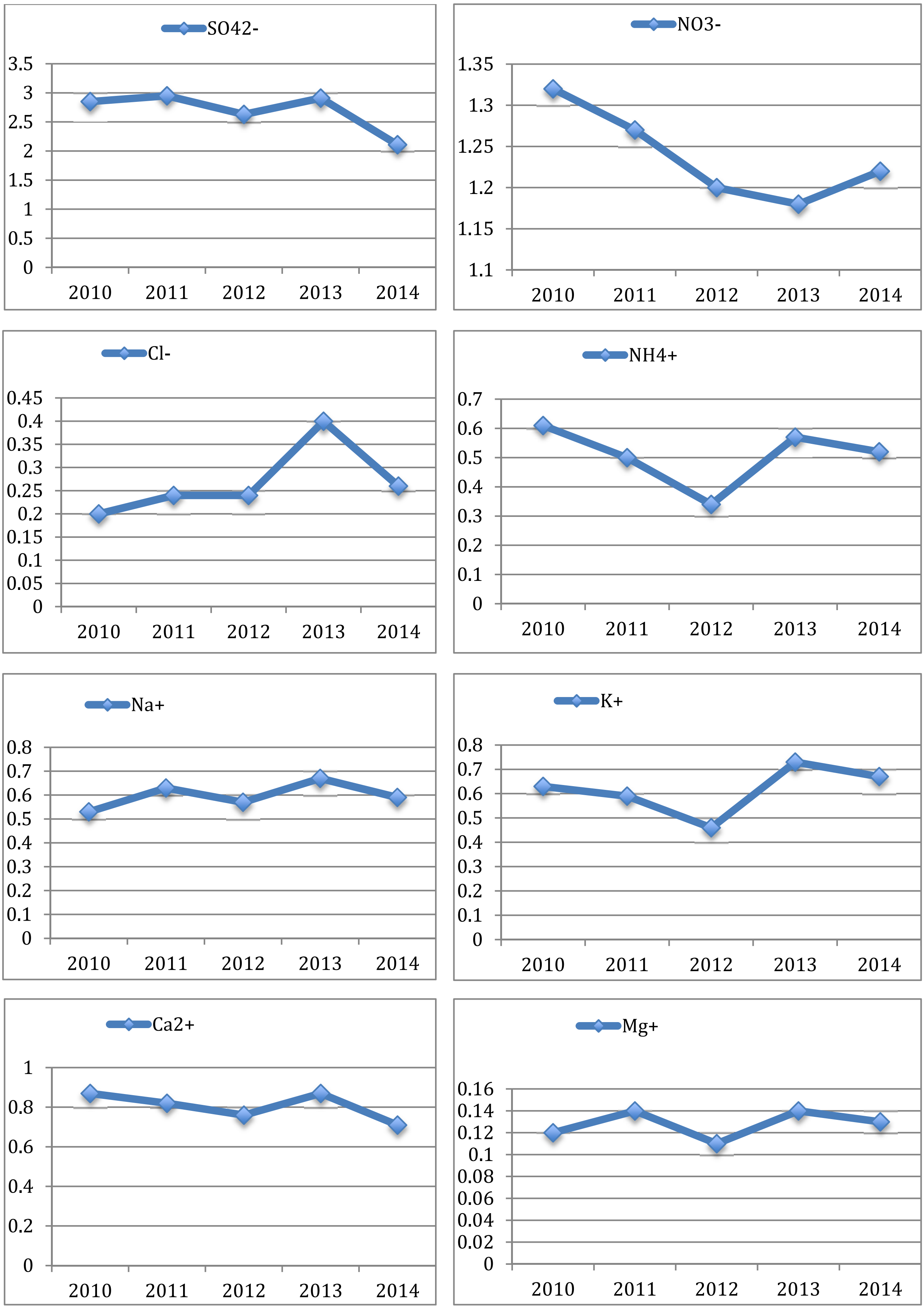
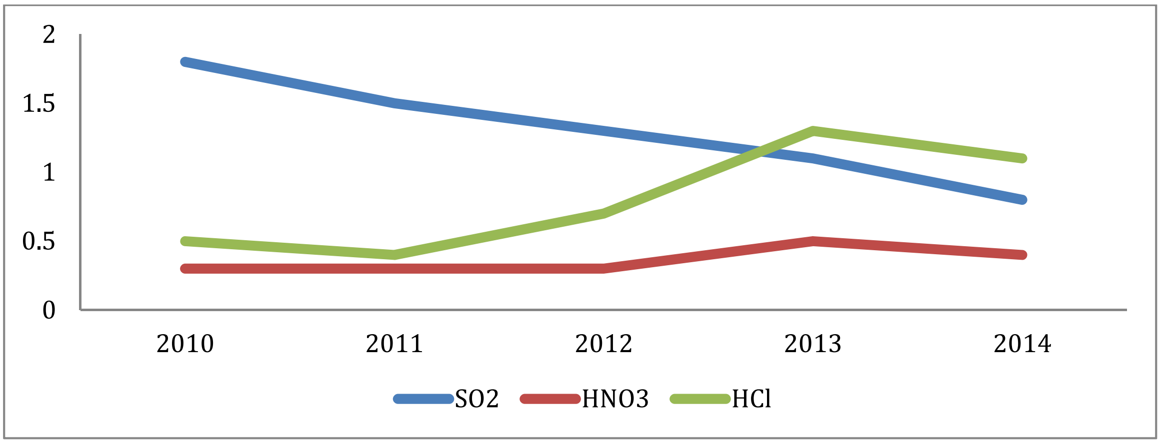


Figure 2.2.3 Yearly Concentrations of Anion and Cation for dry from 2010 to 2014 (nmol/m^3)



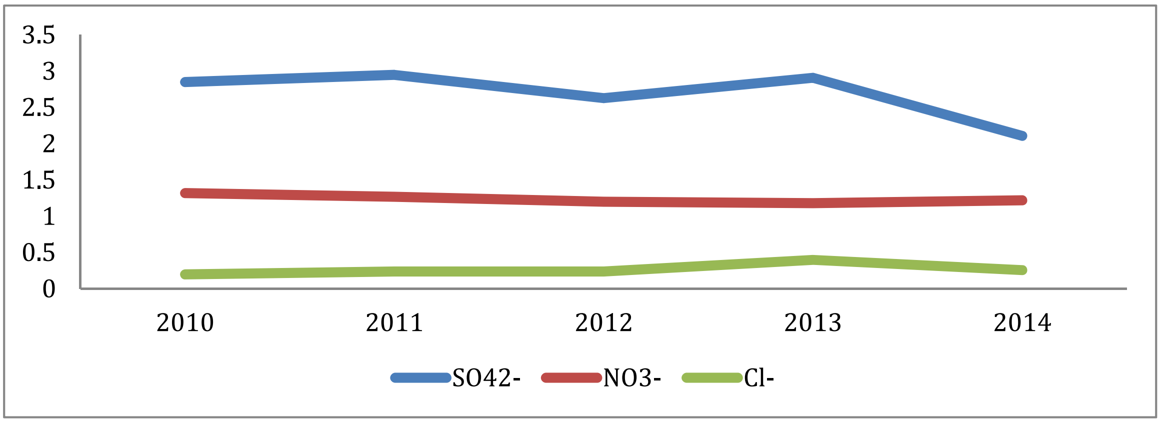


Figure 2.2.4 Yearly Concentrations of Anion for dry from 2010 to 2014 (nmol/m^3)

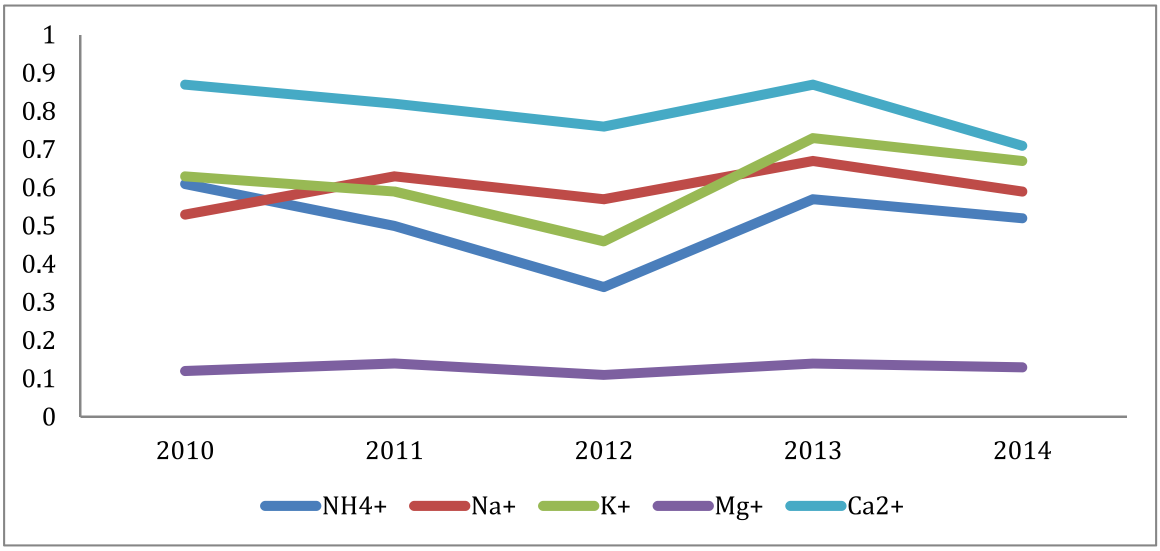


Figure 2.2.5 Yearly Concentrations of Cation for dry from 2010 to 2014 (nmol/m^3)

2.3 State of inland aquatic environment

Table 2.3.1 Concentrations of inland aquatic environment

Items	2012	2013	2014
pH	5.87	5.74	5.84
EC	0.88	0.93	0.96
Alkalinity meq L^{-1}	0.037	0.034	0.035
SO_4^{2-} mg L^{-1}	0.08	0.05	0.06
NO_3^- mg L^{-1}	0.36	0.28	0.60
Cl^- mg L^{-1}	1.65	1.39	1.38
NH_4^+ mg L^{-1}	0.04	0.02	0.12
Na^+ mg L^{-1}	0.94	0.94	1.03
K^+ mg L^{-1}	0.13	0.12	0.31
Ca^{2+} mg L^{-1}	0.27	0.29	0.26
Mg^{2+} mg L^{-1}	0.16	0.13	0.12

2.4 Conclusion

Based on monitoring result of wet deposition, dry monitoring and inland aquatic environment from 2010-2014, The state of acid deposition, its negative impacts has not yet evidenced in Cambodia. However, General directorate of Environmental Protection has responsible for environmental protection is in the process of revising environmental quality standards at the national level included air quality standards.

National Assessment on Acid Deposition in China

China National Environmental Monitoring Center (CNEMC)

Chapter 1 An Overview of EANET China's Acid Deposition Monitoring Activities

1.1 EANET China's Overall Acid Deposition Monitoring and National Monitoring Plan

EANET is a monitoring network mainly aimed to monitor and understand the status and impact of acid deposition in East Asia. As one of EANET member states, China has carried out continuous monitoring activities over acid deposition as required since its formal operation in 2001.

EANET China includes Chongqing, Xiamen, Xi'an and Zhuhai these four member units, covering wet deposition, dry deposition, inland water, soil and vegetation monitoring. As the sub-center in China, China National Environmental Monitoring Center (CNEMC) develops national monitoring plans each year according to EANET's technical guidelines, guides monitoring activities of EANET China, and conducts statistical summary and quality control over the monitoring data of all member units.

Xiamen began dry deposition monitoring and studies with multi-layer filter membrane sampling since 2007, and due to the failure of multi-layer filter membrane sampling device in 2012 which could not be repaired in China, the monitoring activities came to a stop accordingly.

1.2 Monitoring Sites

Since the participation in EANET, most sites of EANET China can carry out ongoing monitoring, and only certain specific sites stop monitoring or are altered, for they fail to meet the standards of EANET due to surrounding environment changes. The information of monitoring sites in Chongqing, Xi'an, Xiamen and Zhuhai these 4 member units of EANET China is presented in the following table.

Table 1.2.1The information of monitoring sites of EANET China

City Name	Site class	Site Name	Longitude	Latitude	altitude(m)
Chongqing	Rural site	Jinyunshan	106°22′	29°49′	800
	Urban site	Haifu	106°30′	29°37′	317
Xi'an	Urban site	Shizhan	108°57′	34°14′	400
	Remote site	Jiwozi	108°48′	33°50′	1800
Xiamen	Urban site	Hongwen	118°08′	24°28′	50
	Remote site	Xiaoping	118°02′	24°51′	686
Zhuhai	Urban site	Xiangzhou	113°34′	22°16′	40
		Zhuxiandong	113°31′	22°12′	45

1.2.1 Chongqing:

In 2010-2014, Chongqing had Haifu (urban site) and Jinyunshan (rural site) these two sites to carry out acid deposition monitoring. Guanyinqiao (urban site) stopped its monitoring in 2008 because of the relocation of its environmental monitoring building to Haifu (urban site) which began to carry out acid deposition monitoring in 2008. The basic information of these two sites is as follows:

Jinyunshan: The monitoring site is located in Beibei District of Chongqing, with a longitude of 106°22' E, latitude of 29°49' N, about 40 kilometers from downtown. Jinyunshan is the key nature reserve of Chongqing. It extends about 16 km from northwest to southeast along the western margin of paralleled ridge-valley of East Sichuan. The altitude is between 700 and 900 meters, with a maximum of 952 meters, low mountain landscape. The area has significant hot and cold changes, abundant rainfall, high soil and air humidity, which is conducive to plant growth, and the main vegetation is mixed vegetation communities dominated by evergreen trees, structurally stable and relatively well-preserved. As a nature reserve, it has no industry, but a small number of farm homes, nursing homes, resorts, and microwave stations. In recent years, a number of new cement plants have been built in northern part, and the residential quarters in southern part also witnessed certain expansion, which may affect the air quality of Jinyunshan.

Haifu: Guanyinqiao site stopped its monitoring at the end of 2007 due to the relocation of the building of Chongqing Environmental Monitoring Center in 2007. To ensure the continuity of EANET’s monitoring, a new precipitation monitoring site, namely, Haifu monitoring site (Qingsong Road No. 1, Yubei District, Chongqing; 106°30' E by longitude, 29°37' N by latitude, 317 meters by altitude) was selected, and it was 6 kilometers north by west of the original Guanyinqiao site, and located on the roof of a five-floor building. There is no major source of pollution around, bordering Zhaomushan Botanical Garden in the north and 1 kilometer north of the inner ring highway around Chongqing. The precipitation monitoring at the site was officially started in January 2008.

1.2.2 Xi'an:

In 2010-2014, Xi'an had Shizhan (urban site) and Jiwozi (remote site) to carry out acid deposition monitoring. As the changes in surrounding circumstances brought new pollution sources and major transportation routes, the previous Weishuiyuan (rural site) no longer met EANET’s technical requirements for rural sites, and stopped the monitoring in 2007. The basic information of these two sites is as follows:

Shizhan: The site is located in the southern suburbs of Xi'an, with a longitude of 108°57' E, latitude of 34°14', and altitude of 400 meters. It is mainly surrounded by residential areas, commercial areas and transportation routes.

Jiwozi: The site is located in the southern mountainous area of Chang'an County of Xi'an, about sixty kilometers from downtown, low in northeast and high in southwest. It has a longitude of 108°48' E, latitude of 33°50' N, and altitude of 800-2000 meters. It is in warm temperate zone, with an annual average temperature of 13.2℃, extreme maximum temperature of 43.4℃, minimum -17.1℃, annual average rainfall of 687mm. The temperature is relatively lower, and the frost-free period is about 150 days. The area is rocky, dominated by shrubs with sparsely distributed tall trees. The soil is fertile, mainly in brown. It boasts a large number of artificial forests, mainly Pinus armandi, dahurian larch and Pinus tabuliformis

1.2.3 Xiamen:

In 2010-2014, Xiamen City had Hongwen (urban site) and Xiaoping (remote site) these two monitoring sites to carry out acid deposition monitoring. The basic information of two sites is as follows:

Hongwen: The site (longitude 118°8’ E, latitude 24°28' N, latitude 50 meters) is located in the middle of Xiamen Island, under the jurisdiction of the New Town of Xiamen at first and now a part of downtown Xiamen. The island has Yunding Peak in the southern part, the highest peak of the island, with vegetation coverage rate of over 90%, and the reservoir in the north is largest reserve water for the island. Accompanied by the development of urban construction, a number of transport routes such as Lianqian Road pass along the monitoring site.

Xiaoping: The site is located in the heart of remote forest areas of Xiamen, far away from highways, railways, urban areas and human activities. Its coordinates are longitude 118°2’ E, latitude 24°51' N, and latitude 686 meters.

1.2.4 Zhuhai:

In 2010-2014, Zhuhai City had Xiangzhou (urban site) and Zhuxiandong (urban site) to carry out acid deposition monitoring. However, Zhuxiandong stopped the monitoring in 2013, because its conditions are not suitable for acid deposition monitoring.

Xiangzhou: The monitoring site (113°34’ E, and 22°16' N) is on the roof of the building of Zhuhai Environmental Monitoring Center in downtown Zhuhai. The main area is the location of government offices and departments, with no industrial point sources of pollution in surroundings. The main pollution comes from motor vehicles and residents’ living sources. The site adjoins transport corridor Northern Haibin Road, 40 meters above sea level.

Zhuxiandong: The monitoring site (113°31'E, 22°12'N) is located in Zhuxiandong scenic tourist area of Nanping Township, about 15 kilometers from the city. It borders Lizhi Mountain in the south and Nanwan Road in the north, 45 meters above sea level. As the reservoir dam was strengthened in 2012, it was not suitable for acid deposition monitoring during the construction period, and thus the monitoring was suspended.

Table1.2.2 The information of the monitoring sites

City Name	Site class	Site Name	Wet deposition	Dry deposition	Soil and vegetation	Inland water
Chongqing	Rural site	Jinyunshan	√	√	√	√
	Urban site	Haifu	√			
Xi’an	Urban site	Shizhan	√			
	Remote site	Jiwozi	√	√	√	√

Xiamen	Urban site	Hongwen	√	√		
	Remote site	Xiaoping	√		√	√
Zhuhai	Urban site	Xiangzhou	√	√		
		Zhuxiandong	√		√	√
		Haibin-park		√		

1.3 Monitoring plans in 2010-2014

CNEMC develops national monitoring palns each year, and these four cities carry out monitoring work according to EANET's technical guidelines, and submit data to CNEMC as required.

1.3.1 Wet deposition monitoring

Wet deposition monitoring covers: rainfall, pH of rainfall, EC, SO_4^{2-}, NO_3^-, Cl^-, NH_4^+, Na^+, K^+, Ca^{2+} and Mg^{2+} ions. The monitoring cycle is 24 hours, from 9:00 am to 9:00 am the next day.

1.3.2 Dry deposition monitoring

Each of the four member units of EANET China selects 1 site for dry deposition monitoring at a frequency of one hour, covering SO_2, NO_2 and PM_{10} in the air. Among them, Hongwen monitoring site of Xiamen City carried out four stage filter pack method sampling for dry deposition. The Network Center provided Xiamen Environmental Monitoring Center with four stage filter pack sampling devices in September 2006, which was installed and run by the end of 2006. The sampling period is once a week, with air flow rate of 1 l/min. The monitored items include gaseous pollutants (SO_2, HCl, HNO_3 and NH_3) and chemical compositions in particulate matters (NH_4^+, Na^+, K^+, Ca^{2+}, Mg^{2+}, SO_4^{2-}, NO_3^- and Cl^-). In 2012, the monitoring was stopped due to device failure which cannot be repaired in China.

1.3.3 Inland water monitoring

Inland water monitoring covers pH, EC, SO_4^{2-}, NO_3^-, Cl^-, NH_4^+, Na^+, K^+, Ca^{2+}, Mg^{2+} ions and alkalinity, and the monitoring frequency is once every 3 months. Moreover, color, transparency, COD, NO_2^- and PO_4^{3-} are monitored once a year.

1.3.4 Soil and vegetation monitoring

In 2001, the environmental monitoring center of Zhuhai and Xi'an carried out soil monitoring respectively. In 2003, according to the revised national monitoring plan, soil monitoring and vegetation survey shall be conducted once every three years, and in 2010-2014, all the 4 member cities of EANET China carried out soil and vegetation monitoring.

Soil monitoring covers: pH(H_2O), pH(KCl), exchangeable Na^+, K^+, Ca^{2+}, Mg^{2+}, EC (valid cation exchange capacity), exchangeable acidity, P, T-N, T-C.

Vegetation monitoring covers: description of trees, understory vegetation survey, observation of tree decline, etc. According to the revised EANET planning, the frequency of observation of tree decline was changed to once per year after 2008.

Table1.3.1 Monitoring Parameters and Frequency of EANET China

Content	Monitoring Parameters	Frequency
Wet deposition	pH, EC, rainfall, SO_4^{2-}, NO_3^- ,Cl^-, NH_4^+, Na^+, K^+, Ca^{2+}, $Mg^{2+,}$	24h, 09:00-09:00
Dry deposition	SO_2, NO_2, PM_{10}	1h
Inland water	pH, EC, SO_4^{2-}, NO_3^- ,Cl^-, NH_4^+, Na^+, K^+, Ca^{2+}, Mg^{2+}, alkalinity	Four times per year
	Water color, transparancy, COD, NO_2^-, PO_4^{3-}	Once per year
Soil	pH(H_2O), pH(KCl), exchangeable Na^+, K^+, Ca^{2+}, Mg^{2+}, ECEC(valid cation exchanging ability), exchangeable acidity, P, T-N, T-C	Once three years
Vegetation	description of trees, understory vegetation survey	Once three years
	observation of tree decline	Every year

1.4 Sample Collection and Sample Analysis

1.4.1 Sample Collection and Preservation

Each monitoring site of EANET China uses acid rain autosamplers to collect rain samples. The monitoring frequency is one rainwater sample every 24 hours, from 9:00 am to 9:00 the next morning.

After collecting samples with acid rain autosamplers, the staff weigh the rainwater at the scene weight, and record it. After testing EC and pH of rainwater, the remaining samples are collected in special acid rain sampling bottles, stored in a refrigerator at 4℃ for ion analysis. The information of sampling devices used at each monitoring site of EANET China is shown in Table 1.4.1.

Table 1.4.1 Sampling method, instrument information of the monitoring sites

City name	Monitoring site	Sampling method	Instrument information	Note
Chongqing	Jinyunshan	auto	ZJC-V(Hangzhou Hengda)	
	Haifu	auto	US-320H (Ogasawara)	
Xi’an	Shizhan	auto	DSSI(Xuanhui, Qingdao)	
	Jiwozi	auto	XHARS30A(Hebei Sailhero)	

Xiamen	Hongwen	auto	ZJC-Ⅱ(Hengda,Hangzhou)	
	Xiaoping	auto	ZJC-Ⅱ(Hengda,Hangzhou)	
Zhuhai	Xiangzhou	auto	US-320H (Ogasawara)	
	Zhuxiandong	auto	ZJC-III (Hengda,Hangzhou)	

1.4.2 Sample analysis

The relevant information of samples must be recorded in detail at sampling sites, and transferred to laboratory analysts. The samples are filtered with 0.45 micron membrane for ion analysis which should be completed within a week.

Table 1.4.2 Measurement method, instrument information of the laboratory

City name	Monitoring parameters	Measurement method	Instrument information
Chongqing	pH	Glass electrode method	METTLER TOLEDO 320
	EC	electrode method	TOA-DKK
	F^- Cl^- NO_{3-} SO_4^{2-}	IC	DX-1100
	Na^+ NH_4^+ K^+ Mg^{2+} Ca^{2+}	IC	DX-500
Xi'an	pH	Glass electrode method	Rex Electric PHSJ-4A
	EC	electrode method	Rex Electric DDSJ-308A
	NH_4^+, Na^+, K^+ Mg^{2+}, Ca^{2+}, Cl^- NO_3^-, SO_4^{2-}	IC	DIONEX ics-5000
Xiamen	pH	Glass electrode method	Mettler Toledo
	EC	electrode method	Mettler Toledo
	Cl^- NO_{3-} SO_4^{2-}	IC	DX-320
	Na^+ NH_4^+ K^+ Mg^{2+} Ca^{2+}	IC	DX-320
Zhuhai	pH	Glass electrode method	ORION 420A
	EC	electrode method	Rex Electric
	NH_4^+, Na^+, K^+ Mg^{2+}, Ca^{2+}, Cl^- NO_3^-, SO_4^{2-}	IC	DX-ICS-1000

1.4.3 QA/QC of wet deposition monitoring

According to EANET's requirements for QA and QC of wet deposition monitoring, all the four member units of EANET China adhere strictly to QA and QC requirements in all aspects of monitoring. The analysis laboratories of the four cities have participated into inter-laboratory comparison tests of EANET each year since 2000 (covering wet deposition, dry deposition, soil and inland water), and achieved satisfactory results.

The pass rates of ion equilibrium test parameters R1 and EC test parameters R2 in rainfall analysis of the four cities of EANET China in 2010-2014 are listed in Figure 1.4.1 and 1.4.2. The pass rates of R1 and R2 remained stable between 2010 and 2014 and saw much improvement relative to those at the beginning of participation into EANET.

PH standard buffer solution should be used for calibration before testing the pH value of rainfall each time. Since the pH values of most rainfall samples range between 3.0 and 7.5, the standard buffer solution with a pH of 4.0-7.0 is generally used for calibration. Standard buffer solution should be preserved in 4℃ refrigerator, and changed regularly (usually every 2-3 months).

EC meter is calibrated with multi-point calibration method. Before measuring the EC of rainfall samples, deionized water is used to dilute 0.01md/L KCl standard solution into 0.0001, 0.0005 and 0.001md/L KCl solution to calibrate EC meter, and the EC of deionized water also needs to be measured. When conditions permit, the sample and standard solution should be measured at 25°C water bath conditions. Standard calibration solution should be changed regularly (once a quarter). In analyzing rainfall ion composition through ion chromatography, a calibration curve connecting at least 5 concentration points is drawn each time, and blank sample should be measured in each test, and 5% of actual amount of samples are selected for parallel double measurement.

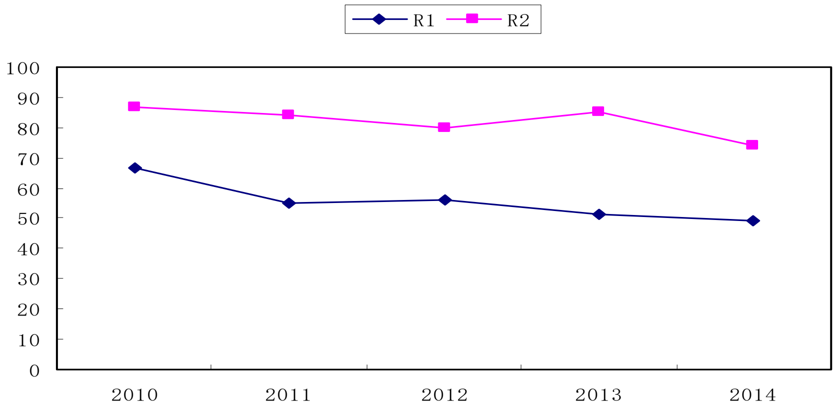


Figure1.4.1 Comparison of R1 and R2, all sites of EANET China from 2010 to 2014

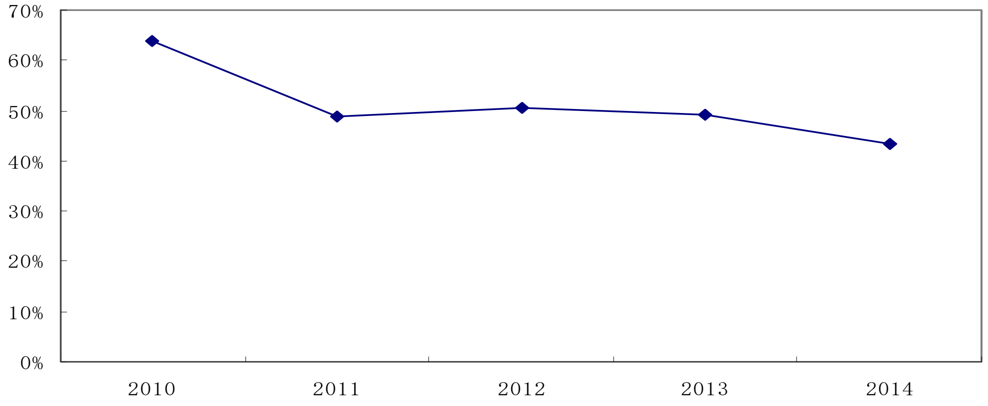


Figure 1.4.2 The average of Comparison both R1 and R2, EANET China from 2010 to 2014

Chapter 2 Current Situation of Acid Deposition of EANET China

2.1 Atmospheric deposition

2.1.1 Wet deposition of EANET China

2.1.1.1 EC and pH of wet deposition of EANET China in 2010-2014

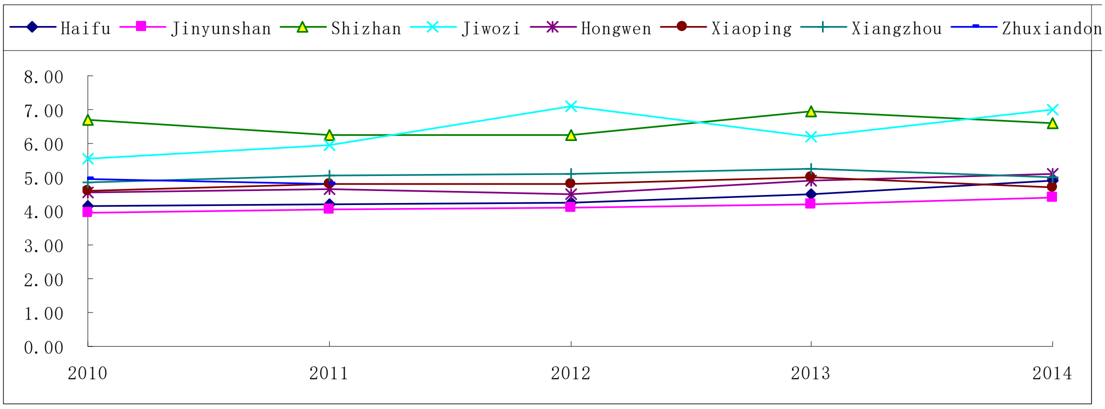
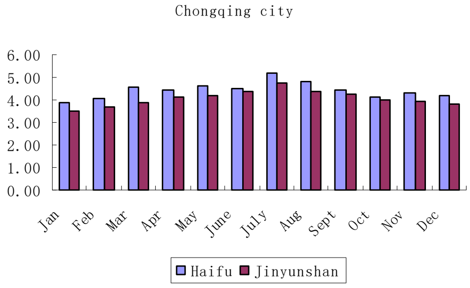
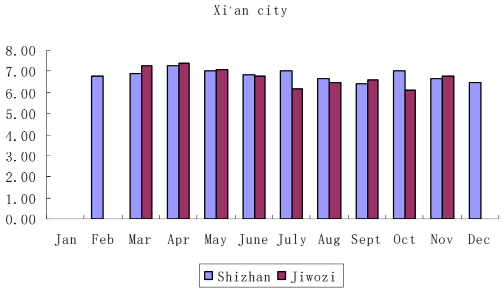


Figure 2.1.1 Trends of annual average pH of all monitoring sites, EANET China, 2010-2014





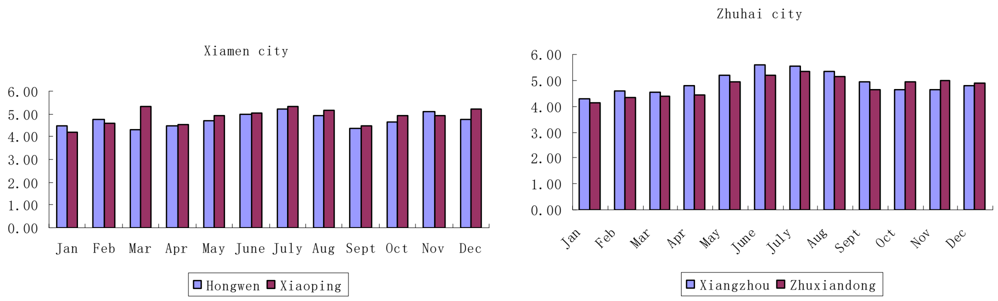


Figure2.1.2 Trends of monthly averages pH of four cities, EANET China about 2010-2014

The monthly and annual average pH values of all the 8 acid deposition monitoring sites in 4 cities in 2010-2014 are shown in Figure 2.1.1 and Figure 2.1.2. According to the trend of annual average, Xi'an in western China has a significantly higher annual average pH than the other 3 cities, and Chongqing in southwest China has the lowest annual average pH, and Xiamen and Zhuhai in southern coastal areas are close to each other in this regard. From a longer perspective, the change in annual average pH of EANET China is not very obvious, but from 2010 to 2014, it showed an overall upward trend. According to the trend of monthly average in 2010-2014, the monthly pH values of country sites and remote sites of the 4 member units were all lower than those of urban sites. From a seasonal point of view, Chongqing, Xiamen and Zhuhai have a similar trend that the monthly average pH is the highest in summer, followed by spring, and lowest in autumn and winter. Xi’an, however, is high in spring and low in summer.

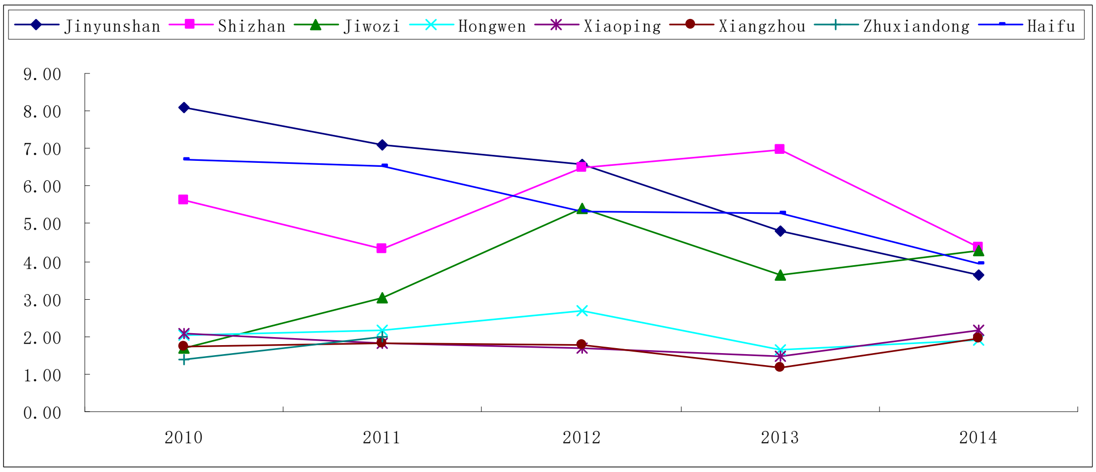


Figure2.1.3 Trends of annual average of EC all monitoring sites, EANET China, 2010-2014 (unit: mS m^{-1})

The trends of annual average EC of all the 8 acid deposition monitoring sites in 4 cities in 2010-2014 are shown in Figure 2.1.3. It can be found that the annual average EC values of Chongqing and Xi’an are significantly greater than those of Xiamen and Zhuhai, and present relatively larger inter-annual fluctuations. The annual average EC values of Xiamen and Zhuhai are relatively lower, with small inter-annual fluctuations, and have remained relatively stable since 2010. It also can be seen that the annual average EC values of Jinyunshan and Haifu monitoring sites in Chongqing showed a relatively clear downward trend between 2010 and 2014

2.1.1.2 Concentrations of major ions of wet deposition of EANET China in 2010-2014

The annual average SO_4^{2-}, NO_3^- and Cl^- ion concentrations of wet deposition monitoring sites in 2010-2014 are shown in Figure 2.1.4-2.1.6. Geographically, Xi'an in the northwest and Chongqing in the southwest have significantly higher SO_4^{2-} and NO_3^- ion concentrations than Xiamen and Zhuhai in southern coastal areas, but regarding Cl^- ion concentration, the former is lower than the latter, and this is because the wet deposition of the later is affected by sea salt particles. Moreover, of all monitoring sites, SO_4^{2-}, NO_3^- and Cl^- ion concentrations of country sites and remote sites are relatively lower than those of urban sites. From a temporal perspective, SO_4^{2-}, NO_3^- and Cl^- ion concentrations of Haifu and Jinyunshan monitoring sites demonstrated a significant decline from 2010 to 2014, but other sites did not see prominent variations over this period.

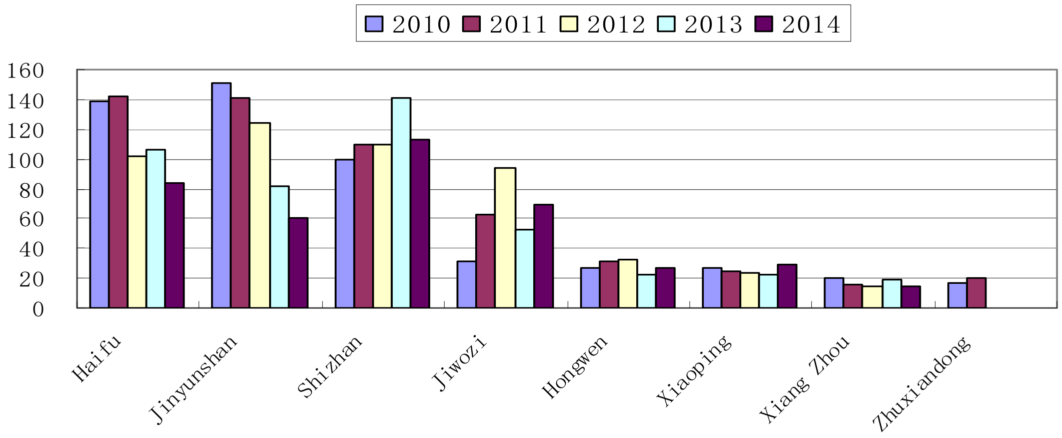


Figure 2.1.4 Trends of annual average of SO_4^{2-} concentration of all monitoring sites, EANET China, 2010-2014 (unit: μmol L^{-1})

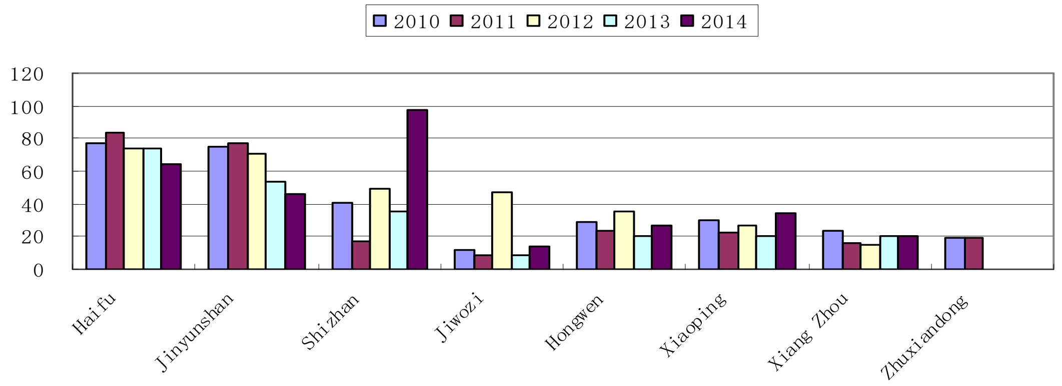


Figure 2.1.5 Trends of annual average NO_3^- concentration of all monitoring sites, EANET China, 2010-2014 (unit: μmol L^{-1})

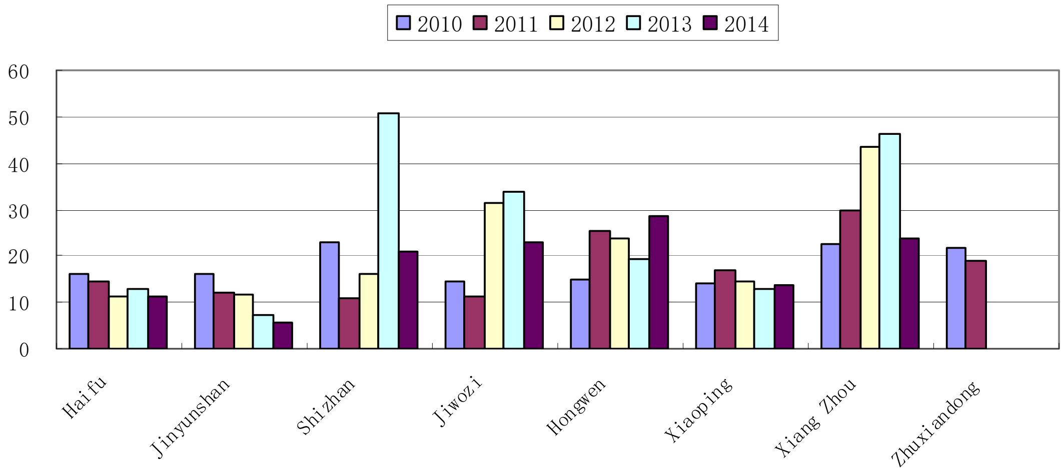


Figure 2.1.6 Trends of annual average Cl^- concentration of all monitoring sites, EANET China, 2010-2014 (unit: µmol L^{-1})

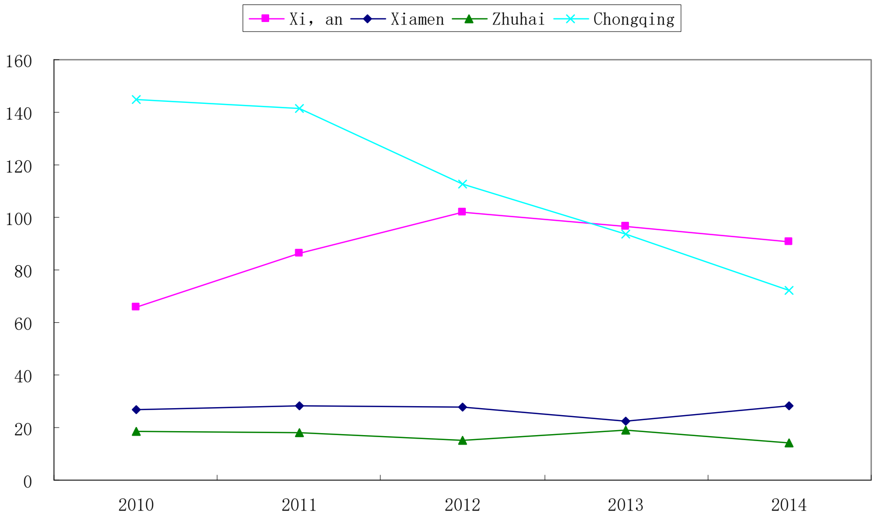


Figure 2.1.7 Trends of annual average SO_4^{2-} concentration of four cities, EANET China, 2010-2014 (unit: µmol L^{-1})

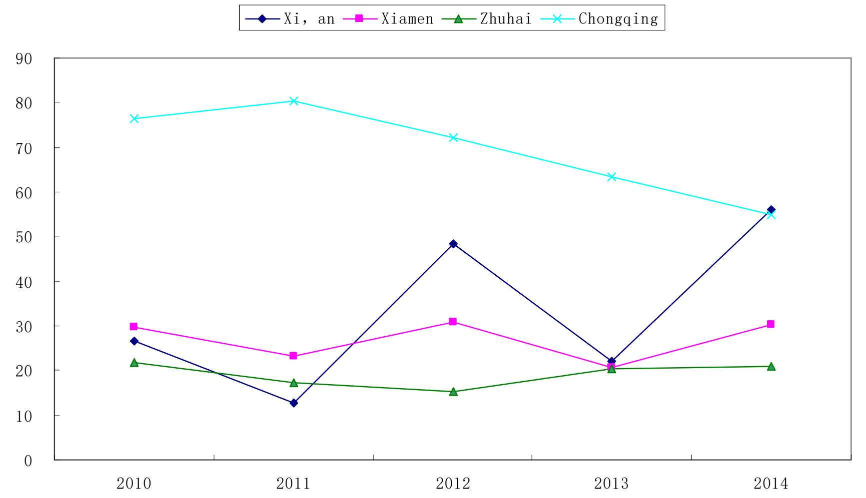


Figure 2.1.8 Trends of annual average NO_3^- concentration of four cities, EANET China, 2010-2014 (unit: µmol L^{-1})

SO_4^{2-} and NO_3^- ions are the major acidic ions in wet deposition, and the annual concentrations of the two major acidic ions of the 4 cities in 2010-2014 are shown in Figure 2.1.7 and Figure 2.1.8. Overall, the SO_4^{2-} ion concentration of Chongqing exhibited a prominent decreasing trend in 2010-2014. The annual average NO_3^- ion concentrations of Xiamen and Zhuhai remained relatively stable, while Chongqing and Xi'an witnessed significant fluctuations.

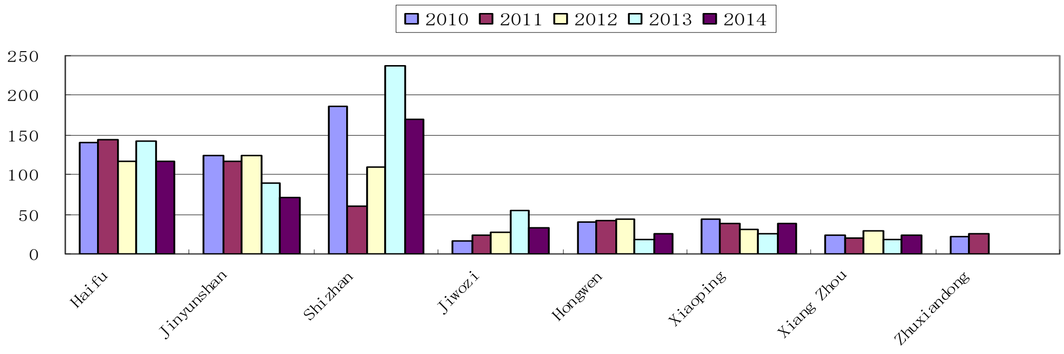


Figure 2.1.9 Trends of annual average $NH4^+$ concentration of all monitoring sites, EANET China, 2010-2014 (unit: µmol L^{-1})

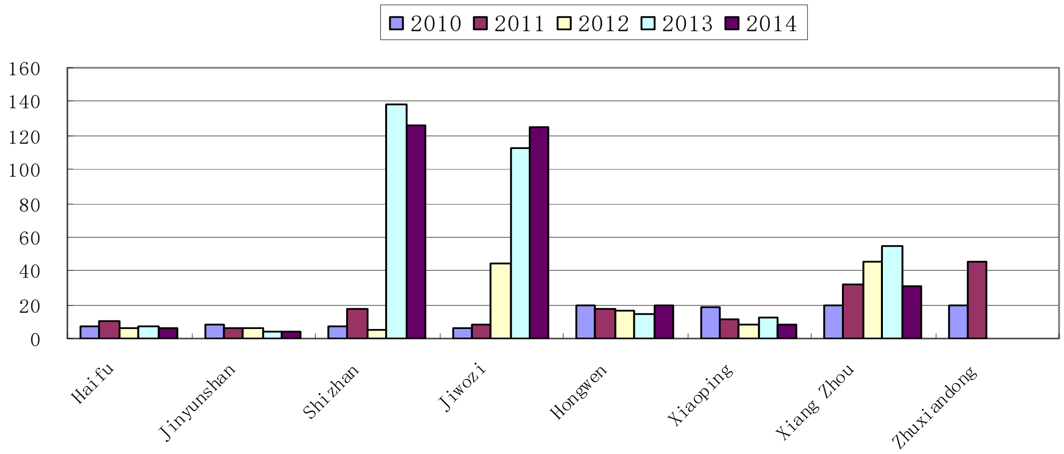


Figure 2.1.10 Trends of annual average Na^+ concentration of all monitoring sites, EANET China, 2010-2014 (unit: µmol L^{-1})

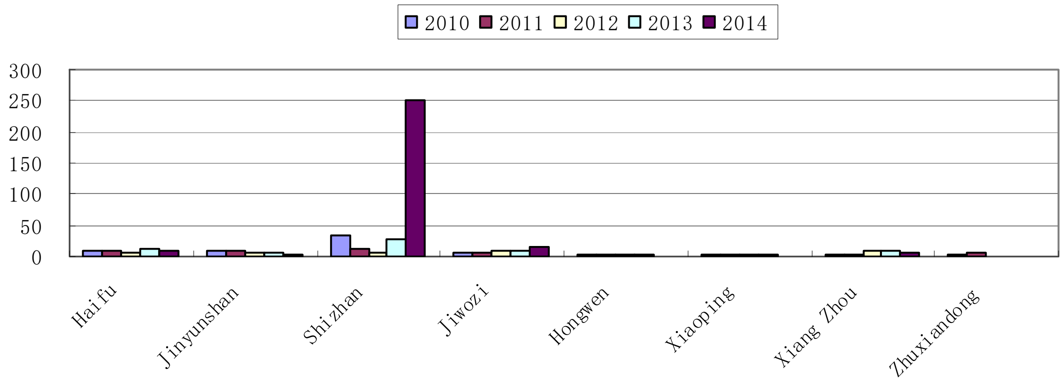


Figure 2.1.11 Trends of annual average K^+ concentration of all monitoring sites, EANET China, 2010-2014 (unit: µmol L^{-1})

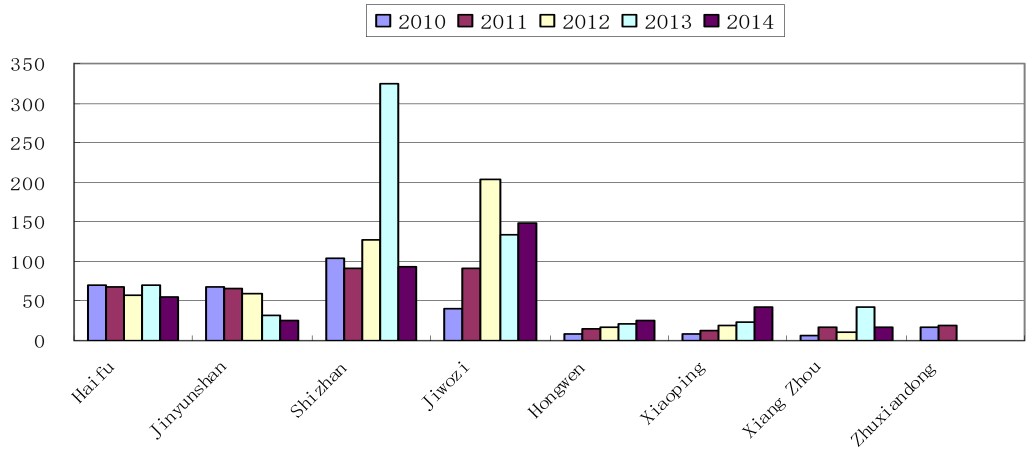


Figure 2.1.12 Trends of annual average Ca^{2+} concentration of all monitoring sites, EANET China, 2010-2014 (unit: µmol L^{-1})

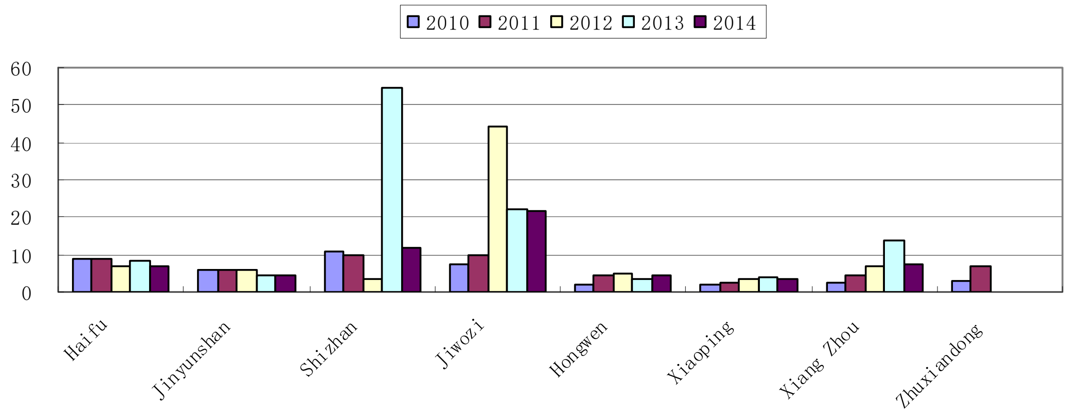


Figure 2.1.13 Trends of annual average Mg^{2+} concentration of all monitoring sites, EANET China, 2010-2014 (unit: µmol L^{-1})

The annual average concentrations of NH_4^+, Na^+, K^+, Ca^{2+} and Mg^{2+} ions in wet deposition during 2010-2014 are shown in Figure 2.1.9-2.1.13. From a temporal perspective, the annual averages of these ions experience no significant variations. Geographically, the annual averages of Na^+ in wet deposition of Xiamen and Zhuhai these two coastal cities were significantly higher than that of Chongqing and Xi'an these two inland cities, which should be affected by the ocean.

2.1.2 Dry deposition of EANET China

Jinyunshan of Chongqing, Hongwen of Xiamen and Xiangzhou of Zhuhai these 3 monitoring sites started dry deposition monitoring in 2001. Weishuiyuan site carried out dry deposition monitoring from 2001 to 2006, but stopped later, because its surrounding environments no longer met the requirements for country sites. Therefore, EANET China had Jinyunshan, Hongwen and Xiangzhou three sites for dry deposition monitoring in 2010-2014, covering SO_2, NO_2 (or NO, NO_X) and PM_{10}, and they all adopted automatic air monitoring at a frequency of 1 hour.

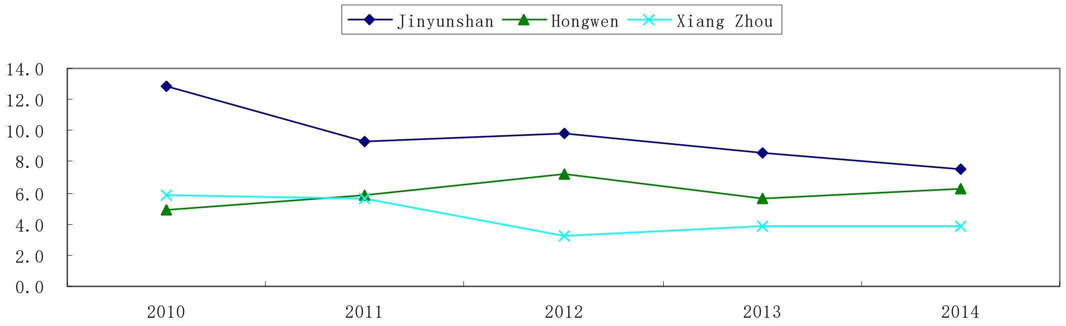


Figure 2.1.14 Trends of annual average of SO_2 concentration of EANET China, 2010-2014 (unit: ppb)

Figure 2.1.14 shows the annual average concentration of SO_2 at four dry deposition monitoring sites in 2010-2014. As can be seen, Chongqing had a relatively higher annual average than Xiamen and Zhuhai, and all sites, especially Xiangzhou site of Zhuhai and Jinyunshan site of Chongqing, saw a significant decline in annual average concentration of SO2 in 2010-2014.

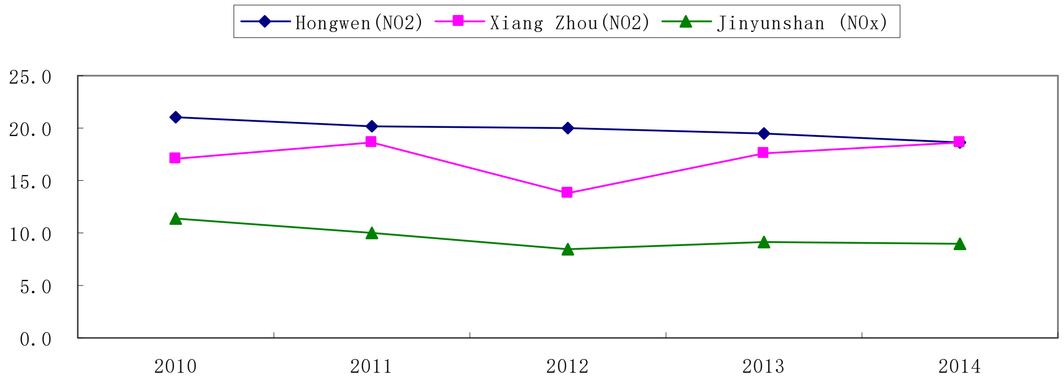


Figure 2.1.15 Trends of annual average of NO_2, NO_X concentration of EANET China, 2010-2014 (unit: ppb)

Figure 2.1.15 shows the annual average concentration of NO_2 or NO_X at four dry deposition monitoring sites in 2010-2014. As can be seen, Hongwen and Jinyunshan witnessed a slightly downward trend in annual average concentration of NO_2 or NO_X in 2010-2014, and for Xiangzhou, there was no significant variation.

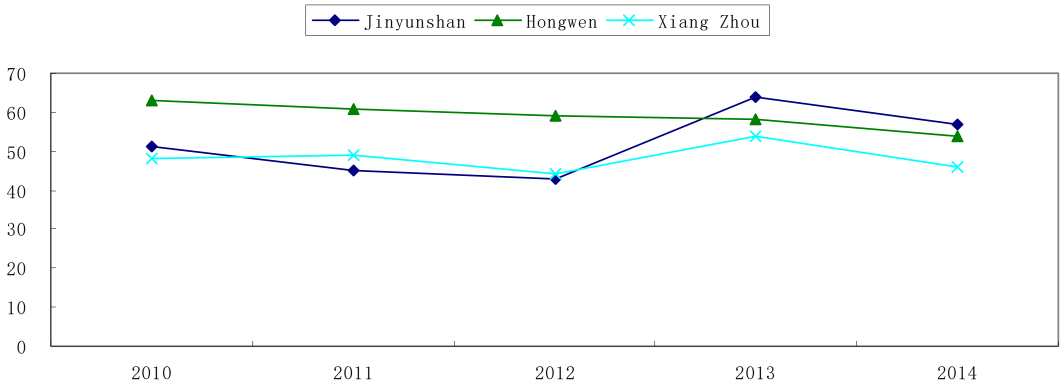


Figure 2.1.16 Trends of annual average of PM_{10} concentration of EANET China,2010-2014(unit: ppb)

The annual average concentrations of PM_{10} at four dry deposition monitoring sites in 2010-2014 are presented in Figure 18. Hongwen, which was in downtown, had relatively higher annual average concentration of PM_{10} than the other two monitoring sites before 2013, but saw a certain downward trend in 2010-2014. The annual average concentrations of PM_{10} of Jinyunshan and Xiangzhou underwent no obvious variations over this period.

2.2 Inland water

The 4 cities began inland water monitoring in Jinyunshan, Jiwozi, Xiaoping and Zhuxiandong these 4 monitoring sites in 2001, and still kept the monitoring in 2010-2014, covering monitoring factors of two different monitoring frequencies. pH, EC, SO_4^{2-}, NO_3^-, Cl^-, NH_4^+, Na^+, K^+, Ca^{2+} and Mg^{2+} are sampled and analyzed on a quarterly basis, while color, transparency, COD, NO_2^- and PO_4^{3-} are sampled and analyzed once a year.

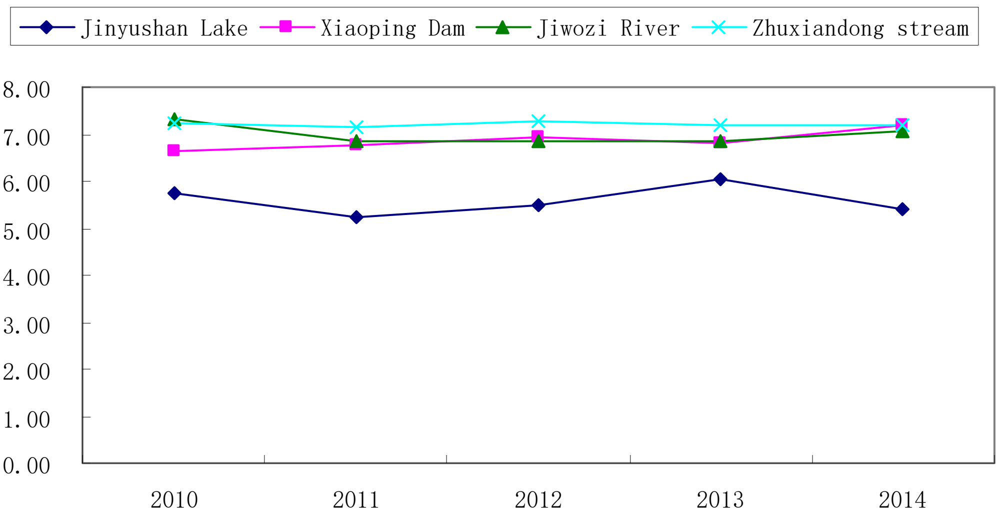


Figure 2.2.1 Trends of annual average of pH at the inland aquatic environment monitoring sites

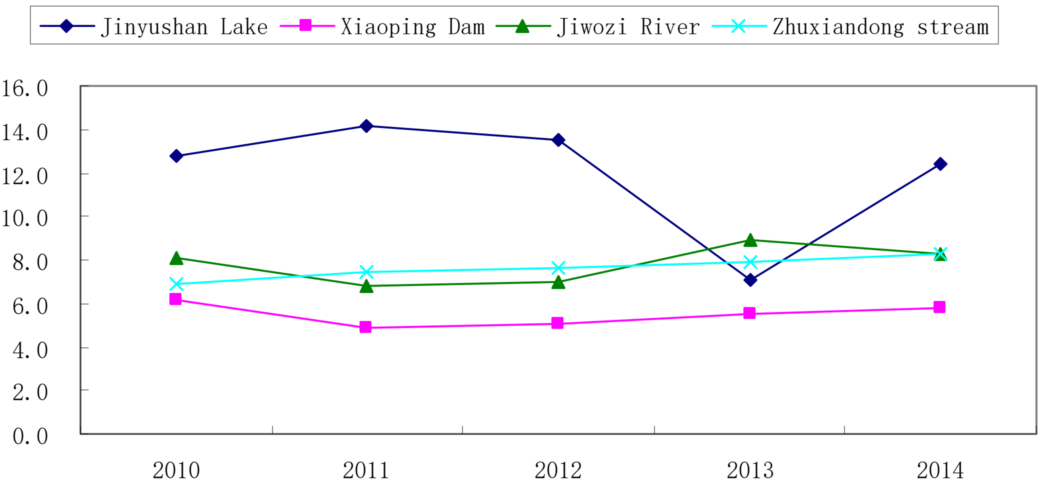


Figure 2.2.2 Trends of annual average of EC at the inland aquatic environment monitoring sites (unit: mS/m)

The annual average pH and EC values of EANET China’s four inland water monitoring sites in 2010-2014 are shown in Figure 2.2.1-2.2.2. Inland water at Jinyunshan site had a relatively low annual average pH and high annual average EC. The annual average pH and EC values of the other three sites were quite close and exhibited no prominent inter-annual volatility, hence no obvious variations from a temporal view.

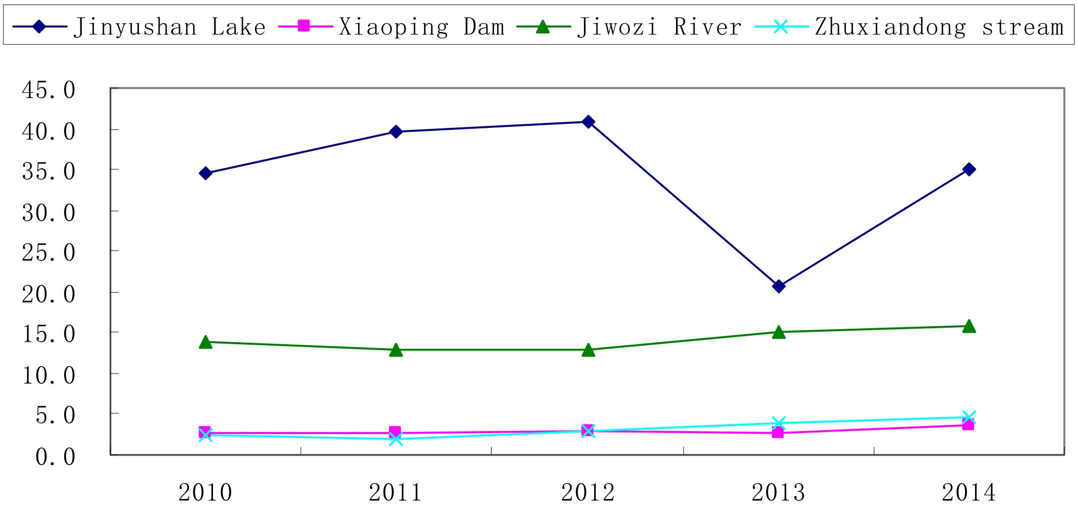


Figure 2.2.3 Trends of annual average of SO_4^{2-}at the inland aquatic environment monitoring sites (unit: mg/L)

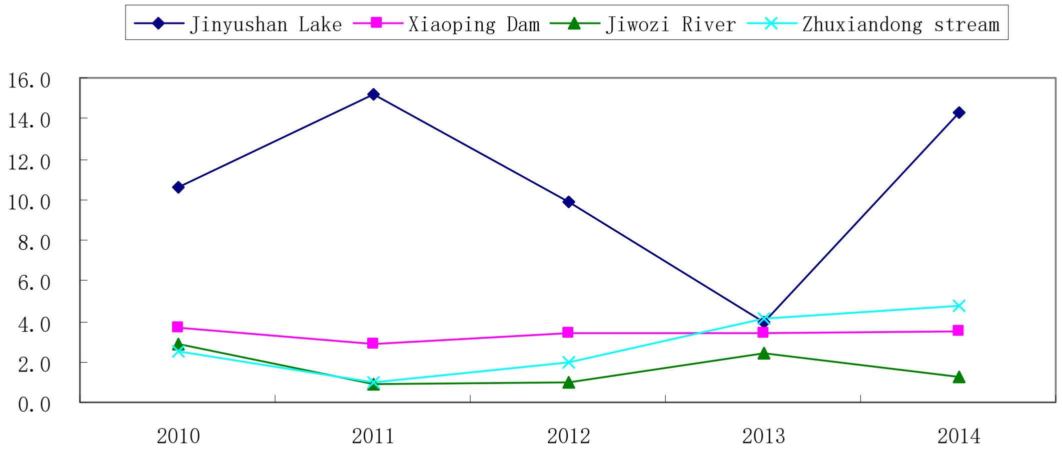


Figure 2.2.4 Trends of annual average of NO_3^-at the inland aquatic environment monitoring sites (unit: mg/L)

The annual average concentrations of major acidic ions SO_4^{2-} and NO_3^- at EANET China's four inland water monitoring sites in 2010-2014 are shown in Figure 2.2.3-2.2.4. The SO_4^{2-} ion concentrations in inland water of Chongqing and Xi'an these two inland cities were significantly higher than Xiamen and Zhuhai these two coastal cities. The NO_3^- ion concentration of Chongqing was relatively higher than the other three cities. All these four inland water monitoring sites experienced no obvious variations from 2010 to 2014.

2.3 Overall analysis

Overall, the annual average concentrations of EC, SO_4^{2-} and NO_3^- in rainfall of Chongqing and Xi'an these two inland cities were higher than coastal city Xiamen and Zhuhai, while the later had higher Na^+ and Cl^- concentrations than the former. From 2010 to 2014, EANET China's four cities saw an overall slightly upward trend in pH value, and the annual average EC remained relatively stable. The annual average concentration of SO_4^{2-} in wet deposition witnessed a certain decline, and NO_3^- concentration remained relatively stable. At Haifu and Jinyunshan monitoring sites in Chongqing, the annual average concentrations of EC, SO_4^{2-} and NO_3^- showed a relatively significant decline in 2010-2014.

In terms of dry deposition, Chongqing had higher annual average concentration of SO_2 than Xiamen and Zhuhai. From 2010 to 2014, all three dry deposition monitoring sites, Jinyunshan of Chongqing and Xiangzhou of Zhuhai in particular, witnessed a relatively significant decline in annual average concentration of SO_2, which may be attributed to national SO_2 emissions reduction. NO_2 at Hongwen and Xiangzhou also exhibited a little downward trend between 2010 and 2014. The annual average concentration of NO_X in Chongqing and PM_{10} in all three monitoring sites remained relatively stable and underwent no great change in 2010-2014.

Chapter 3 Review of China's Acid Deposition Policies

1. Implementing "National 12th Five-Year Plan for Environmental Protection"

The State Council adopted "National 12th Five-Year Plan for Environmental Protection" in December 2011. In planning, it is required to further double the efforts in sulfur dioxide and nitrogen oxides emission reduction, and cut sulfur dioxide emissions and nitrogen oxide emissions in 2015 by 8% and 10% respectively compared with 2010. The main requirements are as follows:

Continuously facilitate emission reduction of power industry. Any new coal fueled generating unit will simultaneously install sulfur and nitrogen removal facilities. Any existing coal-fueled generating units without desulphurization facilities should be phased out as soon as possible or install desulphurization facilities. The smoke desulphurization facilities should eliminate flue gas bypass according to requirement. We will accelerate low-nitrogen combustion technical reform of coal-fueled generating units and installation of smoke denitrification facilities. All coal fueled generating units with capacity at and over 300,000 kW must install denitrification facilities. We will strengthen supervision on the operation of sulfur and nitrogen removing facilities. Any generating unit failing to steadily meet emission standard should make corrections within a given period of time.

Accelerate desulphurization and denitrification of other industries. We will facilitate total SO_2 emission control of iron & steel industry and remove the sulfur in the smoke of sintering machines in an all-round way. Any new sintering machine should construct supporting sulfur and nitrogen removing facilities. We will strengthen the control of SO_2 and NO_x emissions of industries such as cement, petroleum, petrochemicals and coal chemicals. Industrial furnaces in industries such as petrochemicals, non-ferrous metals and building materials will carry out desulphurization reform. NSP kiln system should conduct low-nitrogen technical reform. New cement production lines should install denitrification facilities with efficiency no less than 60%. Treatment of the flue gas from coal fueled boilers should be conducted based on local conditions; new coal fueled boilers should install desulphurization and denitrification facilities, existing coal fueled boilers should remove sulfur in their flue gas. All existing coal fueled boilers in eastern part of China should also install low-nitrogen combustion devices.

Control NO_x emissions from vehicles and ships. We will carry out environmental label management for vehicles. We will accelerate the phasing out of old vehicles, locomotives and ships. It is planned that by the end of 2015, all “yellow label vehicles” with operation registration before 2005 will be basically phased out. We will impose stricter environmental access to vehicles and strengthen check on production consistency. The production, sale and registration of vehicles failing to meet emission standard shall be banned. New energy powered vehicles will be encouraged. We will implement national Stage IV emission standard for vehicles across the country. The regions with appropriate conditions will implement stricter emission standard. We will improve the quality for vehicle fuel, encourage the application of new types of clean fuel, and supply vehicle oil meeting national Stage IV standard across the country. We will actively develop urban public transport and explore appropriate ways to regulate in-service amount of automobiles in very large and big cities.

2. Revising “Ambient Air Quality Standards”

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. In 2012, the revised “Ambient Air Quality Standards” is scheduled to be implemented in Beijing-Tianjin-Hebei, the Yangtze River Delta, Pearl River Delta as well as municipalities and provincial capital cities in 2012, and expanded to 113 key environmental protection cities and national environmental protection model cities in 2013; all prefecture-level cities would implement new air quality standards in 2015; and it is scheduled to be adopted nationally after January 1, 2016.

Compared with the pre-revised version, the new standard adds annual and 24-hour average concentration limits of $PM_{2.5}$ and 8-hour average concentration limits of ozone (O_3), and tightens PM_{10} and NO_2 concentration limits.

3. Implementing “Air Pollution Prevention and Control Action Plan”

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.”

Specific indicators: By 2017, the urban concentration of Particulate Matters (PM_{10}) shall decrease by 10% compared with 2012; annual number of days with fairly good air quality will gradually increase. Concentration of fine particulate matter ($PM_{2.5}$) in Beijing-Tianjin-Hebei, Yangtze River Delta and Pearl River Delta region shall respectively fall by around 25%, 20% and 15%. Fine particulate matter annual concentration in Beijing shall be controlled below 60 micrograms per cubic meter.

To achieve the goal, the “Plan” puts forward 35 specific measures in 10 categories, including: (1) increase effort of comprehensive control and reduce emission of multi-pollutants; (2) optimize the industrial structure, and promote industrial restructure; (3) accelerate the technology transformation, and improve the innovation capability; (4) adjust the energy structure and increase the clean energy supply; (5) strengthen environmental thresholds and optimize industrial layout; (6) better play the role of market mechanism and improve environmental economic policies; (7) improve law and regulation system, and carry on supervision and management based on law; (8) establish the regional coordination mechanism and the integrated regional environmental management; (9) establish monitoring and warning system, and cope with heavy pollution weather; (10) clarify the responsibilities of the government, enterprise and society, and mobilize public to participate in environmental protection.

National Assessment on Acid Deposition Indonesia

by

Edvin Aldrian and Retno Puji Lestari

1. Basic Information on National Monitoring Activities

1.1. Outline of the activities on acid deposition and national monitoring plan

The monitoring of acid deposition in Indonesia is carried out by observing wet deposition, dry deposition, and attempted in assessing the impacts by observing soil, vegetation and inland aquatic water. These tasks are conducted by various related national institutions where Ministry of Environment as National Focal Point and Pusarpedal-KLH (EMC) of the Ministry of Environment as the National Center. The participating institutions are Meteorological Climatological and Geophysical Agency (BMKG), National Institute of Aeronautics and Space (LAPAN) for wet and dry deposition monitoring. Research Center for Water Resources (RCWR) for inland aquatic, Soil Research Institute (SRI) of the Ministry of Agriculture and Forest for soil monitoring and Forestry Research and Development Center - Ministry of Forestry and Environment for vegetation monitoring.

1.2. Monitoring program of acid deposition from 2010-2014

The progress on acid deposition monitoring program during year 2010–2014 is to continue the existing monitoring and to increase the site number of monitoring stations on wet deposition, dry deposition and inland aquatic. The monitoring sites located in the western part of Indonesia and not represent the national vast territory. Therefore in 2007, wet deposition monitoring was established at Maros, South Sulawesi in eastern Indonesia.

Ideally wet deposition station monitoring conducted in parallel with dry deposition. This condition has been applied in Serpong Stations. Therefore in the beginning of 2007, Jakarta and Kototabang stations have started to monitor dry deposition by means of passive sampler method for SO_2 and NO_2 as well as Bandung and Serpong in year 2008. In 2014, Jakarta and Bandung stations carried out dry deposition monitoring by filter pack method. The inland aquatic monitoring expanded when a new site conducted at Situ Gunung Sukabumi in year 2007.

To improve the laboratory competency, EMC conducted training for analysts in the field of sampling and analysis of wet and dry deposition, inland aquatic, soil and vegetation monitoring.

1.3. Monitoring stations

Table 1.1. EANET monitoring stations in Indonesia.

Station name	Laboratory/Institution	Type of monitoring	Classification of site	Latitude/Longitude	Altitude (m)	Height of sampling point (m)
Serpong	EMC – KLH	WD, DD	Rural	S 6° 21' 2.347" E 106° 39' 52.527"	46 m	3 m
Bandung	LAPAN	WD, DD	Urban	S 6° 53' 39.401" E 107° 35' 5.143"	743 m	13 m
Jakarta	BMKG	WD, DD	Urban	S 6° 9' 21.755" E 106° 50' 22.203"	7 m	2.5 m
Kototabang	BMKG	WD, DD	Remote	S 0° 11' 55.618" E 100° 19' 2.267"	864 m	12 m
Maros	BMKG	WD	Rural	S 4° 59' 47.904" E 119° 34' 21.133"	11 m	1,2 m
Situ Patengang	RCWR	IA	Rural	S 7° 10' 3.361" E 107° 21' 13.053"	1600-1700 m	-
Situ Gunung	RCWR	IA	Rural	S 6° 50' 14.903" E 106° 55' 6.181"	1600 m	-
Dramaga Research Forest	SRI and MoF	SV	Rural	S 6° 33' 14.274" E 106° 45' 14.525"	244 m	-

1.4. Sampling and measurement

a. Wet deposition monitoring

The sampling frequency of wet deposition was carried out in every precipitation event (Serpong station), daily (Bandung station), weekly (Jakarta, Kototabang and Maros stations). Parameters of pH, EC, SO_4^{2-}, NO_3^-, CI^-, NH_4^+, Na^+, K^+, Ca^{2+} and Mg^{2+} were analyzed by glass electrode cell, conductivity cell, and ion chromatography methods.

b. Dry deposition monitoring

Sampling of SO_2, HNO_3, HCl, NH_3, SO_4^{2-}, Cl^-, NO_3^-, Na^+, K^+, Ca^{2+}, Mg^{2+} and NH_4^+ in gas and aerosol by filter pack method were conducted biweekly in all sites (Serpong, Bandung, and Jakarta). These parameters were analyzed by ion chromatography.

Monitoring of SO_2 and NO_2 by passive sampler were carried out biweekly in Bandung, Jakarta and Kototabang stations. SO_2 was analyzed by ion chromatography and NO_2 by spectrophotometry method.

Meteorological parameters such as wind direction, wind speed, air temperature, humidity, and precipitation amount are measured as well using meteorological automatic instrument in Serpong and Jakarta stations.

c. Monitoring of inland aquatic

Quarterly monitoring was conducted for inland aquatic. Measurements were done on twelve parameters as follows: temperature, pH, EC, alkalinity (at pH 4.8 baseline), SO_4^{2-}, NO_3^-, Cl^-, NH_4^+, Na^+, K^+, Ca^{2+} and Mg^{2+}. And also for mandatory parameters such as transparency, water color, COD, NO_2^-, and PO_4^{3-} were analyzed by glass electrode cell, conductivity cell, titration, ion chromatography, spectrophotometry, secchi disk, and AAS methods.

d. Monitoring of soil and vegetation

The acid deposition observation for soil and vegetation has been made in Dramaga Forest Research. Soil samples were collected and analyzed for moisture content, pH (H_2O and KCI), organic matter (organic carbon), kjedahl nitrogen, cation exchange capacity (CEC), exchangeable cation, base saturation, exchangeable acidity and effective CEC (ECEC) were calculated. This monitoring frequency is about every three until five years. Indonesia has four times monitoring of soil in year 2001, 2007, 2009 and 2014. Meanwhile, the first understory vegetation survey and the observation of tree decline were conducted in year 2008.

2. State of Acid Deposition

2.1. State of wet deposition

Wet deposition monitoring data in four locations in Indonesia in year 2010 to 2014 are analyzed to indicate rainwater chemistry characteristics. Rainwater chemistry compositions are mapped to assess precipitation location characteristic. Acid and base concentrations are analyzed to indicate their roles in determining rainwater acidity. Rain impact to ion concentrations are assessed by relation between rain numbers and major acid and base concentrations. Ratio between concentrations of sulphates to nitrates in rainwater contents is analyzed to study gas emission characteristics. Monthly and annual averages values are analyzed to study acid deposition trend.

2.1.1. Distribution of precipitation pH

The average weighted pH of precipitation for the period from year 2010 to 2014 is show in Figure 2.1. Rainwater with low pH indicates that precipitation were acidic i.e. rainwater contains high H+ ion concentration. Average pH values in Indonesia are between 4.5- 5.6. In Jakarta average pH value was 4.6 ± 0.3. Because there is only little different between rainwater pH in Jakarta and Serpong therefore, we also need to consider acid deposition contents dissolved in rainwater and months of precipitation. It is because of Jakarta is an urban area with relatively higher density of transportation compared with Serpong which is considered as a rural area. Rainwater pH values were less than 5.0 in Jakarta shows influence of other acids such as Cl^- except sulfuric and nitric acids that is originated from seasalts that reduce pH.

Bandung as an urban area has monthly average rainwater pH 5.6 ± 0.8. In the other hand, Kototabang as a remote area has average pH 5.0 ± 0.4. pH values in Bandung are higher compared with three other locations as a result of higher degree of neutralization as a present of high concentration of ammonium base compounds. Kototabang with pH values were less than 5.0 indicates lower base neutralization influence compared with acid compounds. As forest fires in North Sumatra and Riau that often occur during dry seasons and contribute CH_3Cl, aerosol nitrates to the atmosphere.

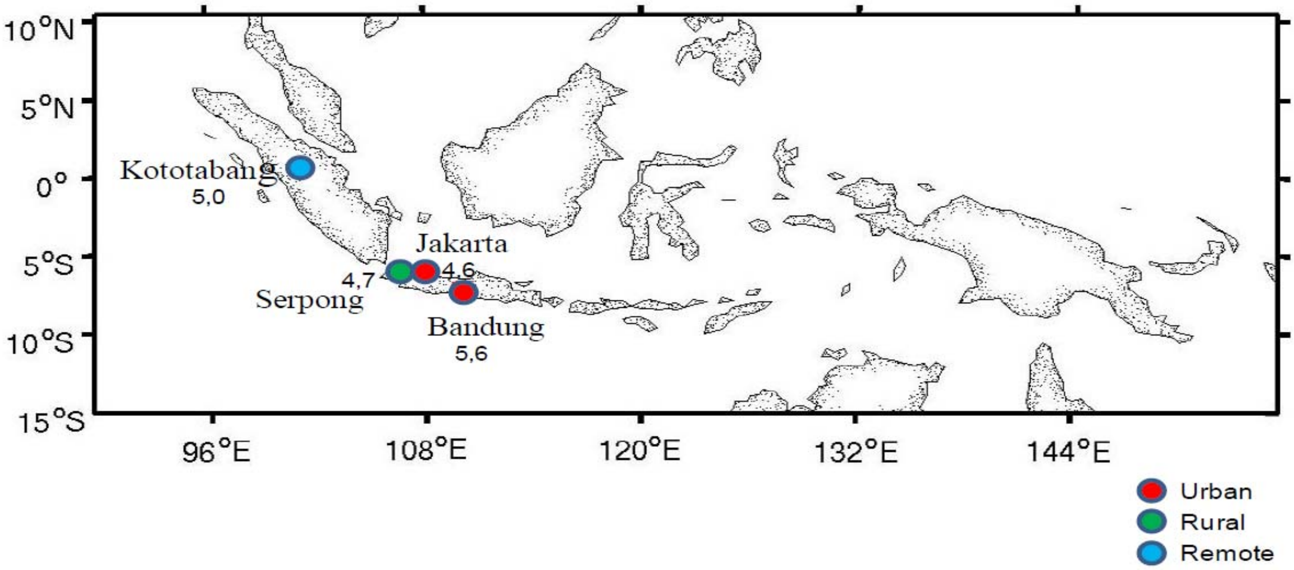


Figure 2.1. Distribution of pH level, 2010-2014.

Based on monthly average pH from year 2010 to 2014 precipitation events with pH less than 5.6 shows that Bandung has lowest rank compared with the other three locations. In the other hand Jakarta as an urban area shows highest precipitation events with rainwater pH less than 5.6. Therefore during year 2010-2014 those 4 cities have experienced acid rains as shown by event frequency.

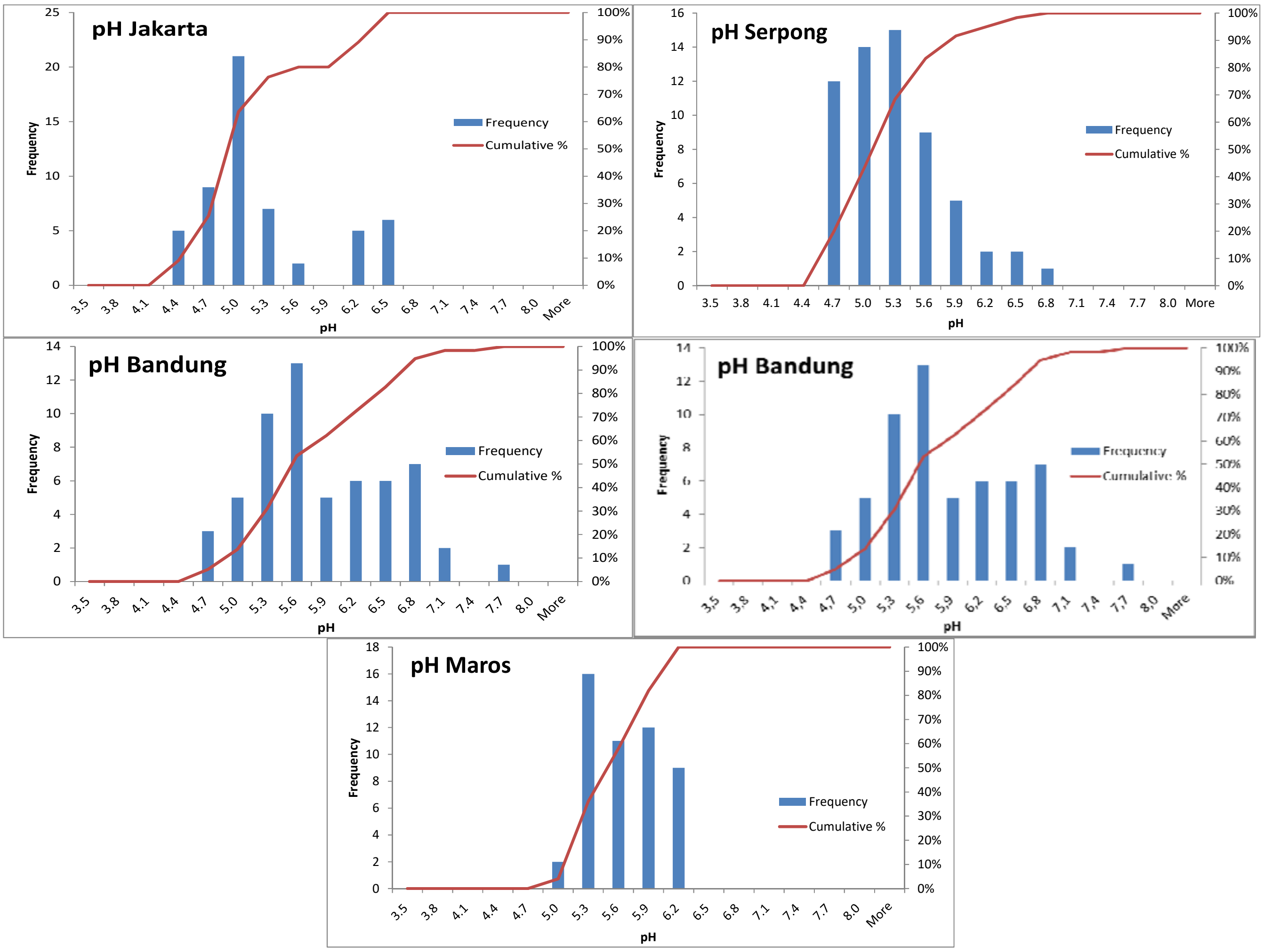
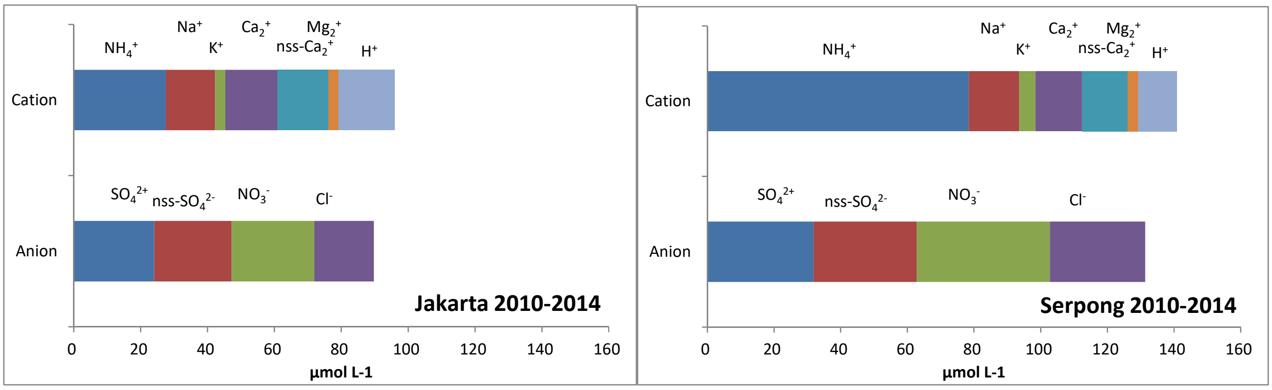


Figure 2.2. Rainwater pH distribution in Jakarta, Serpong, Bandung, Kototabang and Maros from year 2010 to 2014.

2.1.2. Chemical composition of rainwater

Rainwater is composed of dissolved anions and cations as a result of union between gases and aerosol in ambient air. Anions and Cations are SO_4^{2-}, NO_3^-, Cl^-, NH_4^+, Na^+, K^+, Ca^{2+}, Mg^{2+}, and H^+. Non sea-salts (nss) SO_4^{2-} and Ca^{2+} are also measured theoretically. Based on rainwater chemistry composition we can study characteristics of rainwater locations as shown in Figure 2.3.



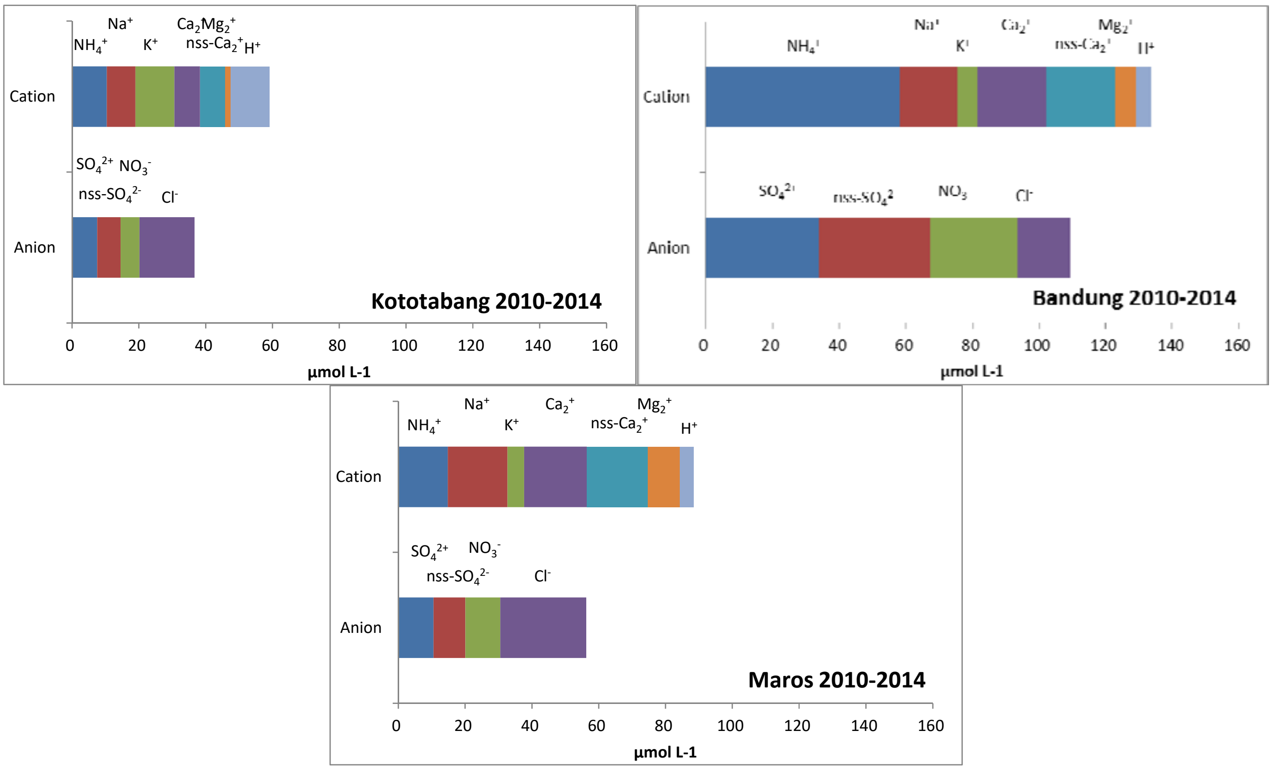


Figure 2.3. Anions and cations concentrations contents of rainwater at the EANET Indonesia's monitoring site in Jakarta, Serpong, Bandung, Kototabang and Maros from 2010 to 2014.

Figure 2.3 shows the characteristics of chemical rainwater in Jakarta, Serpong, Bandung, Kototabang and Maros from monthly averaged from year 2010 to 2014. The characteristics in Jakarta indicated major anions such as nitrates (NO_3^-) and nss-sulphates (nss-SO_4^{2-}). Sea-originated ions such as Cl^- and Na^+ are high, as an indication of coastal area. Different cases were found in Bandung, Serpong and Kototabang which is dominated by ammonium (NH_4^+). Bandung as an urban area and Serpong as a rural area have many vegetation that release ammonia (NH_3). In dry season $(NH_4)_2SO_4$ and NH_4NO_3 in soil dust will increase the concentration of NH_4^+ in rainwater. Major anions such as nitrates (NO_3^-) and nss-sulphates (nss-SO_4^{2-}) originated from fossil fuel combustion were relatively higher and dominant in Serpong.

Bandung has also high major anions such as nitrates (NO_3^-) and nss-sulphates (nss-SO_4^{2-}) as indication of strong anthropogenic source influence. Kototabang as a remote area has a higher concentration of ammonium (NH_4^+) in that indicates biomass burning. Land forest fires contributions to atmospheric NH_3 during dry seasons that are often occurred in another province, Riau.

Jakarta has the highest NO_3^- ion concentration as related to a huge transportation number and also high nss-SO_4^{2-} compared to other parameters. The concentration of Cl^- and Na^+ indicates a significant relationship as coastal areas (Figure 2.3).

Figure 2.4 shows a correlation between $[NH_4^+]/[2.\text{nss-}Ca^{2+}]$ in Jakarta indicating these parameter significantly affect the pH value. Meanwhile, the value of $[NH_4^+]/[2.\text{nss-}Ca^{2+}]$ in Serpong is higher than 1 in every season. The situation indicated NH_4^+ as a major ion with averaged value of pH below 5. It almost similar to the situation in Bandung, but in the dry season $[NH_4^+]/[2.\text{nss-}Ca^{2+}]$ has raised the pH value, caused by particulates containing NH_4NO_3 and $[NH_4]_2SO_4$ dissolved in precipitation. In Kototabang pH varied from 0 to 10, with a tendency to below 1 in the rainy season. This indicates that nss-Ca^{2+} as major cation is more important than NH_4^+. In the months SON from year 2010 to 2014, frequent forest fires and soil dust due to dry season is relatively a lot.

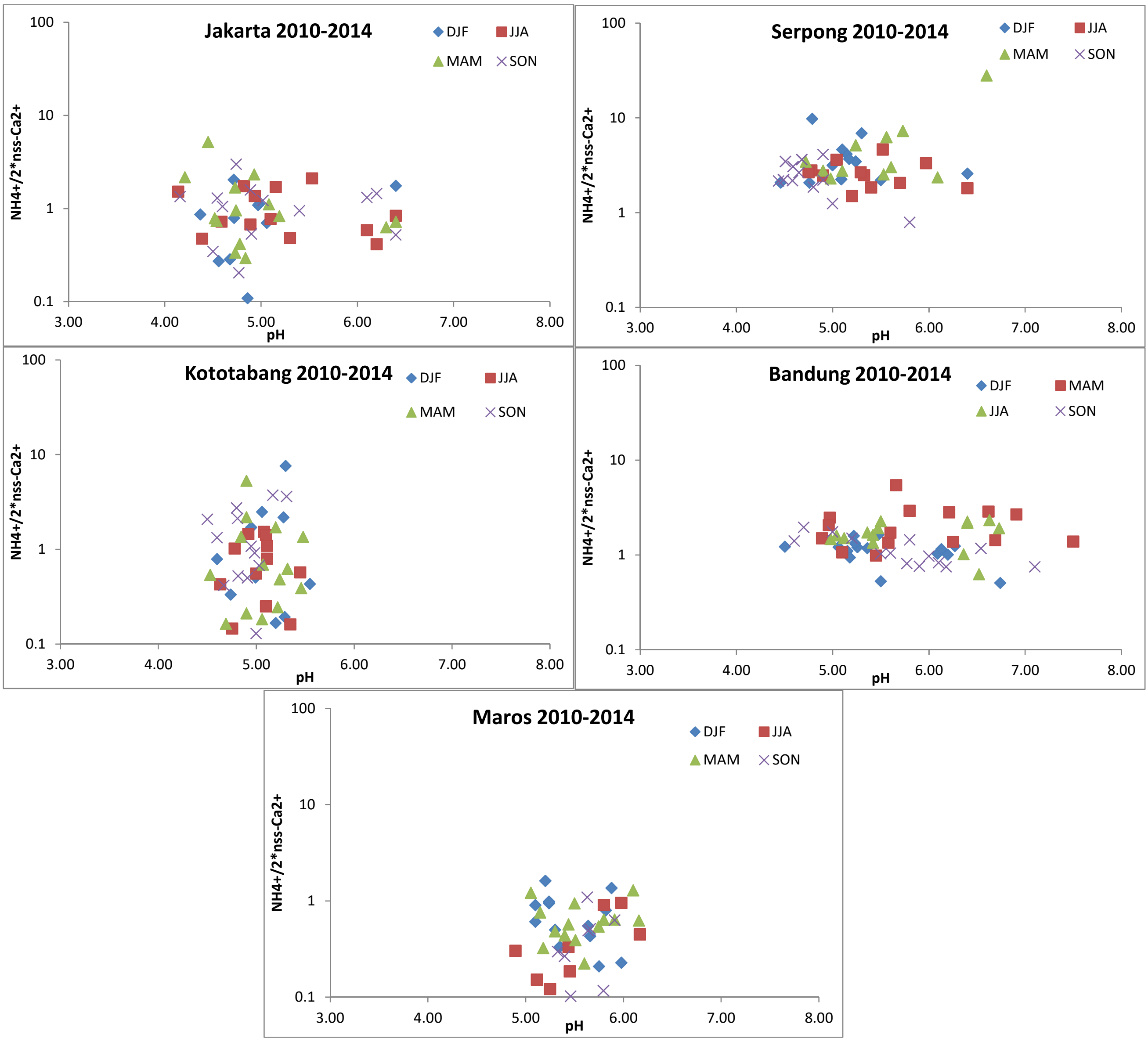
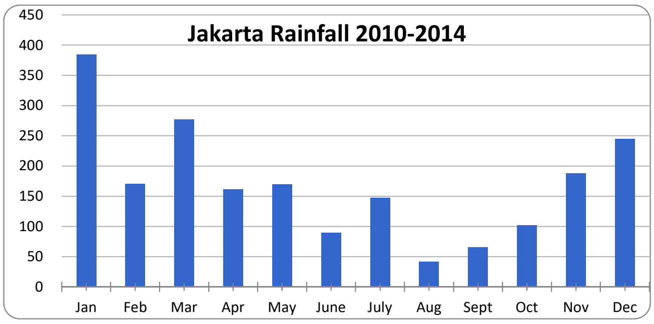
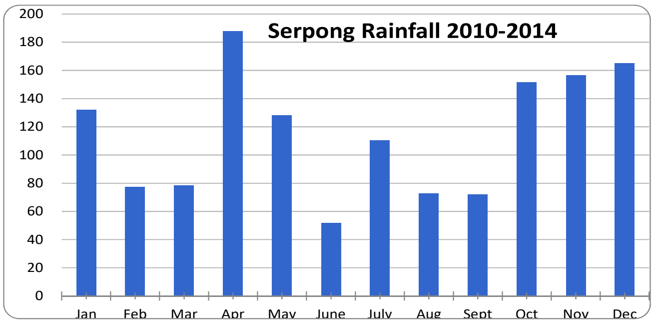


Figure 2.4. Measured $[NH_4^+]/[2.nss\text{-}Ca^{2+}]$ versus pH at Jakarta, Serpong, Bandung, Kototabang and Maros in Indonesia (2010 to 2014).

2.1.3. Rainfall variation





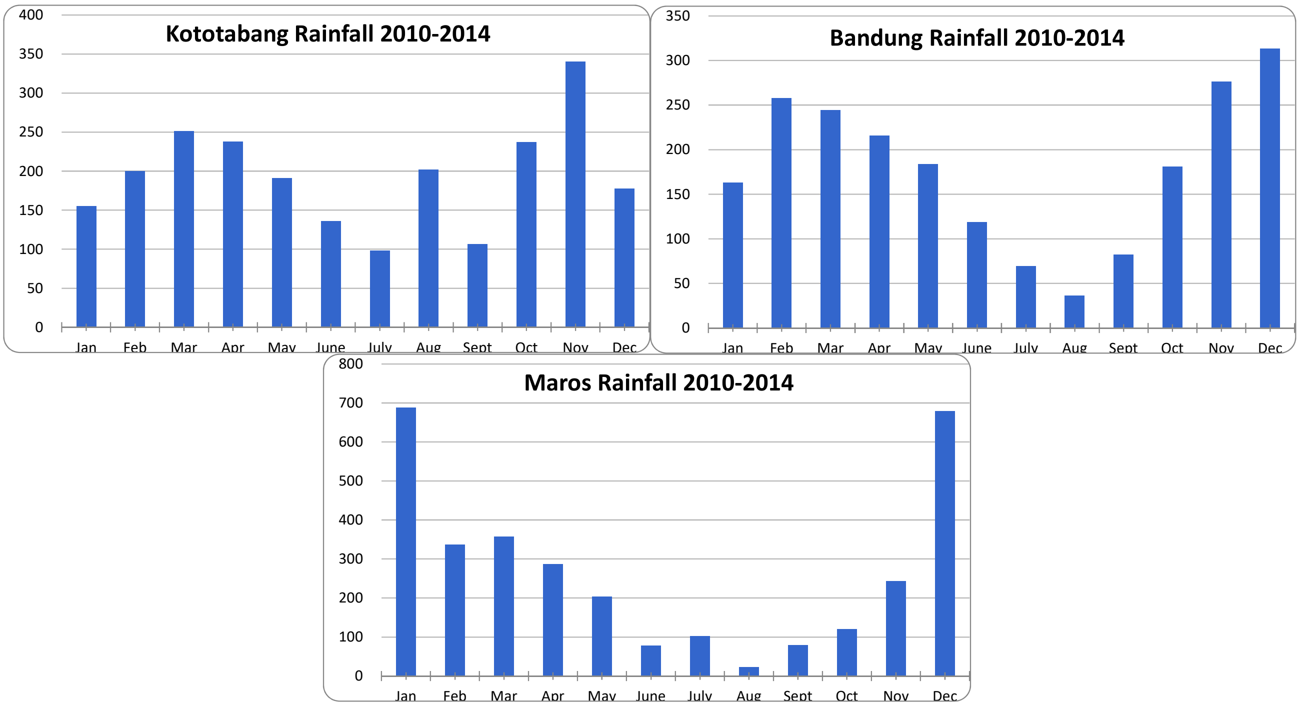


Figure 2.5. Monthly averaged precipitation amounts (mm) at Jakarta, Serpong, Bandung, Kototabang and Maros for 2010 to 2014.

The range of rainfall (30 – 390 mm) seems very large compared to other climate elements. Rainfall is one of the important elements of climate.

Wet deposition precipitation in Indonesia varied due to differences in the amount of annual rainfall. Table 2.1 below shows the mean of annual wet deposition of major ions (meq.m^{-2}.yr^{-1}) and precipitation (mm.yr^{-1}) in every monitoring site at year 2010 to 2014. The highest total annual average rainfall 2,420.1 mm.yr^{-1} of Kotatabang has also average annual deposition of major ions nss-SO_4^{2-} compared to other ions in Jakarta, Serpong and Bandung.

Table 2.1. Annual mean wet deposition of major ions (meq.m^{-2}.yr^{-1}) and precipitation (mm.yr^{-1}) at Indonesia monitoring site for 2010 to 2014.

	SO_4^{2-}	nss-SO_4^{2-}	NO_3^-	Cl^-	NH_4^+	Na^+	K^+	Ca^{2+}	nss-Ca^{2+}	Mg^{2+}	H^+	Precip.
	μmol L^{-1}											mm month^{-1}
Jakarta	24.01	23.15	24.81	17.81	27.08	14.68	3.10	15.54	15.22	3.11	16.85	162.05
Serpong	31.85	30.94	39.96	28.65	78.42	15.16	4.85	13.95	13.64	3.26	11.55	140.37
Kototabang	7.51	7.51	7.51	7.51	7.51	7.51	7.51	7.51	7.51	7.51	7.51	197.07
Bandung	34.18	33.16	26.36	15.75	58.39	16.98	6.06	20.86	20.56	6.32	4.54	176.66
Maros	10.56	9.54	10.44	25.73	14.81	17.91	4.94	18.72	18.35	9.56	4.16	259.05

2.2. State of dry deposition

Dry deposition consists of gas and particle, where the gas which is consisted of SO_2, HNO_3, HCl and NH_3 contribute to form acid deposition. On the other hand, the aerosol which is consisted of anion and cation also contribute to form acid deposition. The dry deposition monitoring resulted during period 2010 to 2014 for gas and aerosols can be described in Figures 2.6 and 2.7.

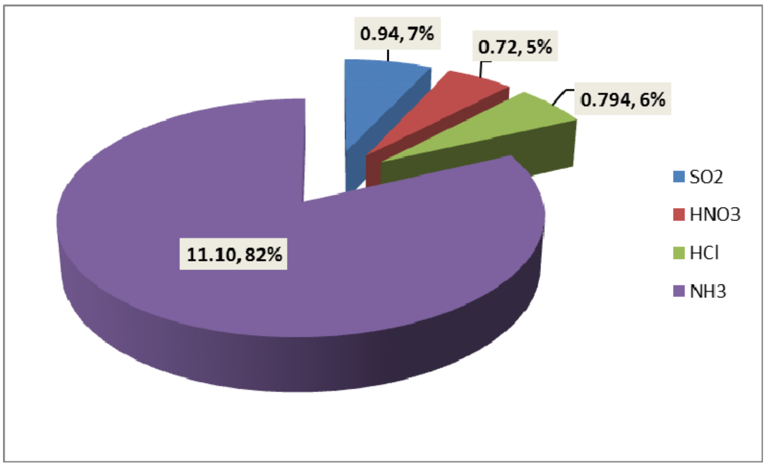


Figure 2.6. Average chemical composition of gas SO_2, HNO_3, HCl and NH_3 at Serpong station during year 2010 to 2014.

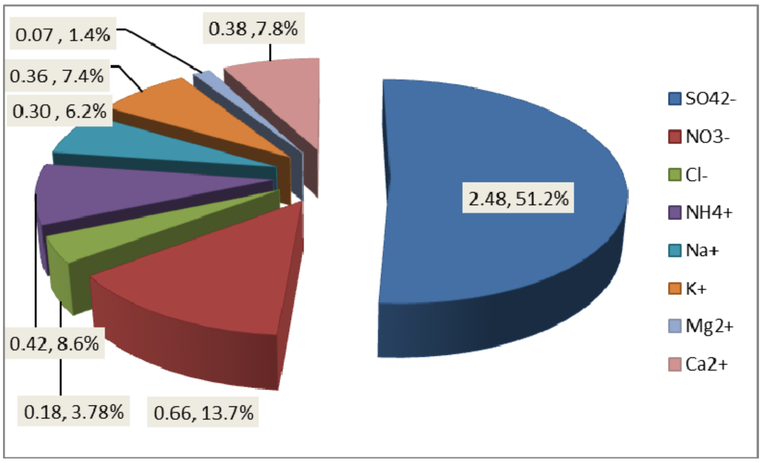


Figure 2.7. Average chemical composition of anion- cation in aerosol at Serpong station during year 2010 to 2014.

NH_3 concentration is the highest compare to other gases in dry deposition (Figure 2.6), where as SO_2 followed at the second order. Source of NH_3 gas could be generated from poultry, plantation, fertilizer, and domestic waste around Serpong station. While source of HCl could be generated from industrial activities around Serpong and Tangerang city; and SO_2 and HNO_3 could be generated from transportation.

The highest composition for anion and cation in aerosol were SO_4^{2-} followed by NO3- and Cl- (Figure 2.7). Higher composition for SO_4^{2-} and NO_3^- could be generated from fossil fuel combustion around the area; as for Cl^-, the contribution would probably come from sea salt at Northern part of Java Island as well as from industrial activity around Tangerang city.

Variability of gas and aerosols in dry deposition can be described in Figures 2.8 and 2.9 as follow:

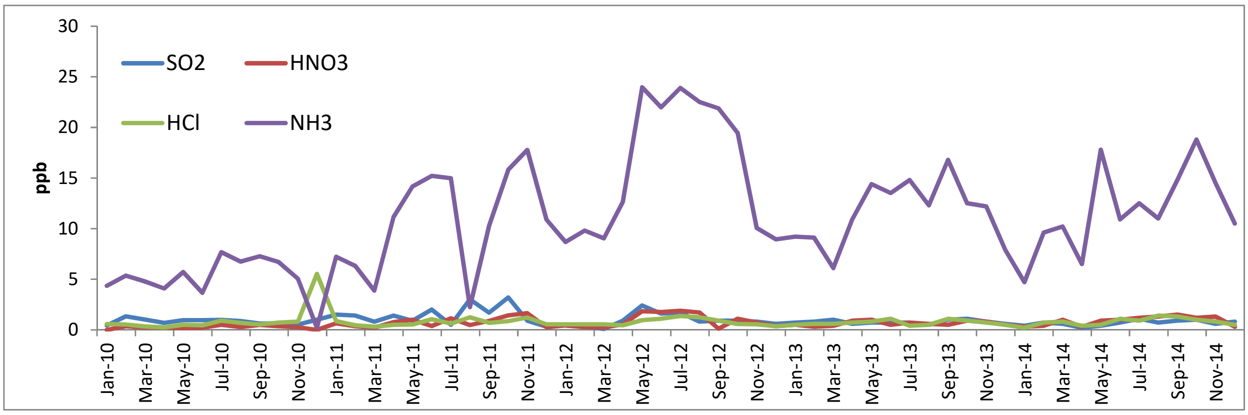


Figure 2.8. Monthly variation for gas in dry deposition at Serpong station during year 2010 to 2014.

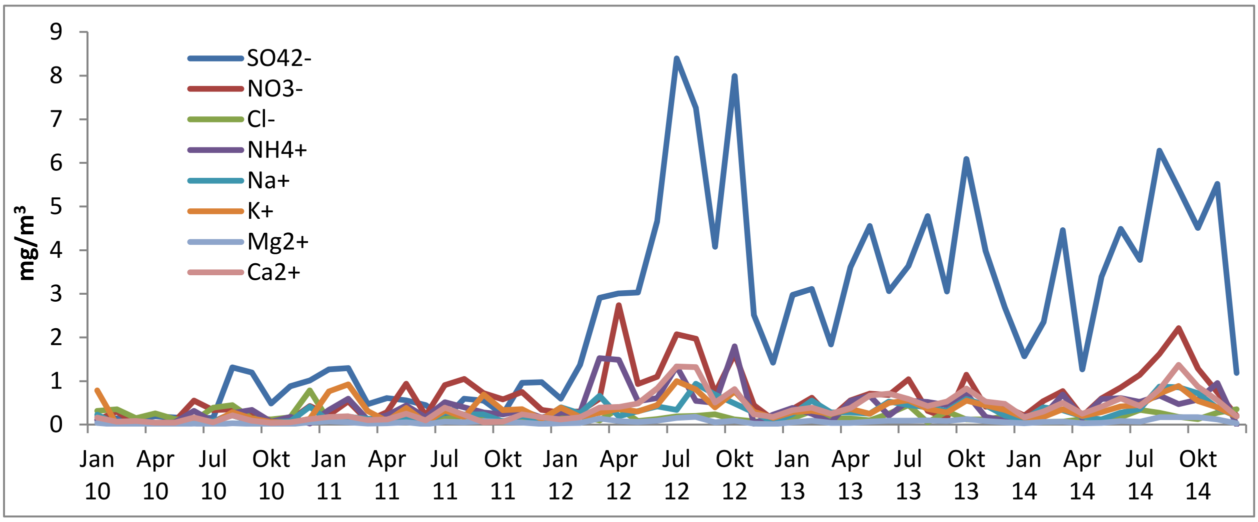


Figure 2.9. Monthly variation for aerosol in dry deposition at Serpong station during year 2010 to 2014.

Figure 2.10 describes the higher trend for NO_2 concentration in Jakarta station compare to Bandung and Kototabang station, although Bandung station shows stagnant concentration at the last tri year in year 2011 and 2014. While Figure 3.2.11 describes the higher trend for SO_2 concentration in Jakarta station compares to Bandung and Kototabang stations, although Bandung station shows the highest concentration during September to December year 2010-2014 while Kototabang station shows the highest concentration during October to December year 2013.

The trend for NO_2 and SO_2 concentrations in Jakarta, Bandung and Kototabang stations describes in Figures 2.10 and 2.11.

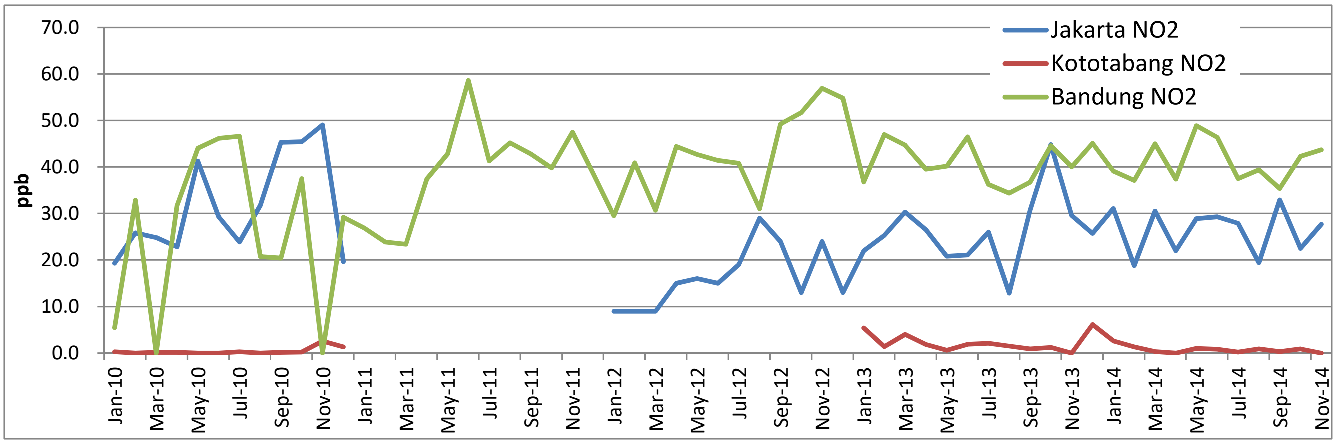


Figure 2.10. NO_2 in Jakarta, Bandung and Kototabang (year 2010 to 2014).

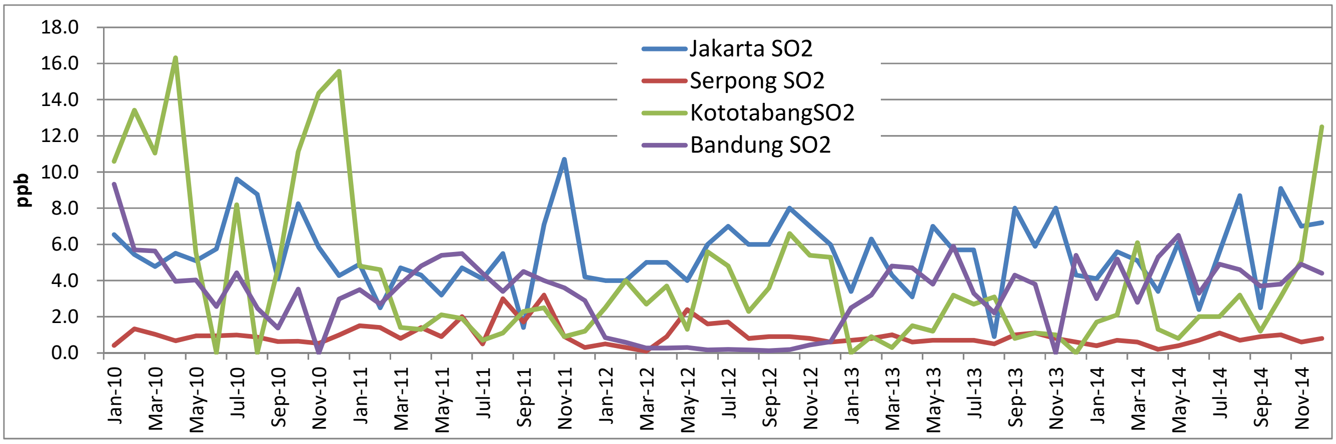


Figure 2.11. SO_2 in Jakarta, Bandung dan Kototabang (year 2010 to 2014).

2.3. State of inland aquatic environment

In year 2007, Situ Gunung was established as a new site of inland aquatic monitoring. Located 14 km Northwest of Sukabumi, at Kadudampit district, Sukabumi regency, West Java province, Indonesia. It is a nature conservation area, a nature tourism park based on the Decree of the Minister of Agriculture dated 27 November 1975 within area of 120 ha consisting of the territorial waters of a lake area 9.34 ha Geographically situated between 060 50' 01" South latitude and 1060 55' 24.4" East longitude, at an altitude of 1,600 – 1,700 m asl. The depth of the deepest lake is below 10 m. The elevation around 950 – 1,150 m asl. Rainfall ranges were from 3,500 – 4,000 mm.yr-1 and the temperature was around 16°C-28°C.

Situ Gunung can follow two tracks: Jakarta - Bogor - Cisaat - Situ Gunung (123 km) and Bandung - Sukabumi - Cisaat (108 km). Mileage from Cisaat to Situ Gunung (7 km) is a road passable by wheeled vehicles 2 or 4 wheels and 6 wheels. Dominant trees species around the Gunung Lake are amber, flower, and Saninten Rasamala. The source of lake water comes from the waterfall Cimanaracun Mountain, a distance of 1.5 km from there and can be reached by foot.

Figure 2.12. Situ Gunung (Lake), Sukabumi (left) and Situ Patenggang (Lake) (right), West Java.

The pH range of Situ Patengang is 7.14–7.0, and in Situ Gunung is 6.69-6.73. The value of electrical conductivity in Situ Patenggang and Situ Gunung is seen that there is still showed a good value for acid deposition monitoring site selection in inland aquatic because its value is still below 10 mS.m-1. The alkalinity value has exceeded the maximum limit (>0.2 meq.l^{-1}). The highest of alkalinity value is alleged the existence of the positive influence of anions and cations in the water. An increased in levels of nitrite caused by the decayed vegetable and animal matter, fertilizer use, domestic effluents sewage sludge disposal to land, and atmospheric washout all contribute to these ions in water sources. Fluctuations in sulfate levels allegedly associated with the composition of cations and anions to reach the ion balance.

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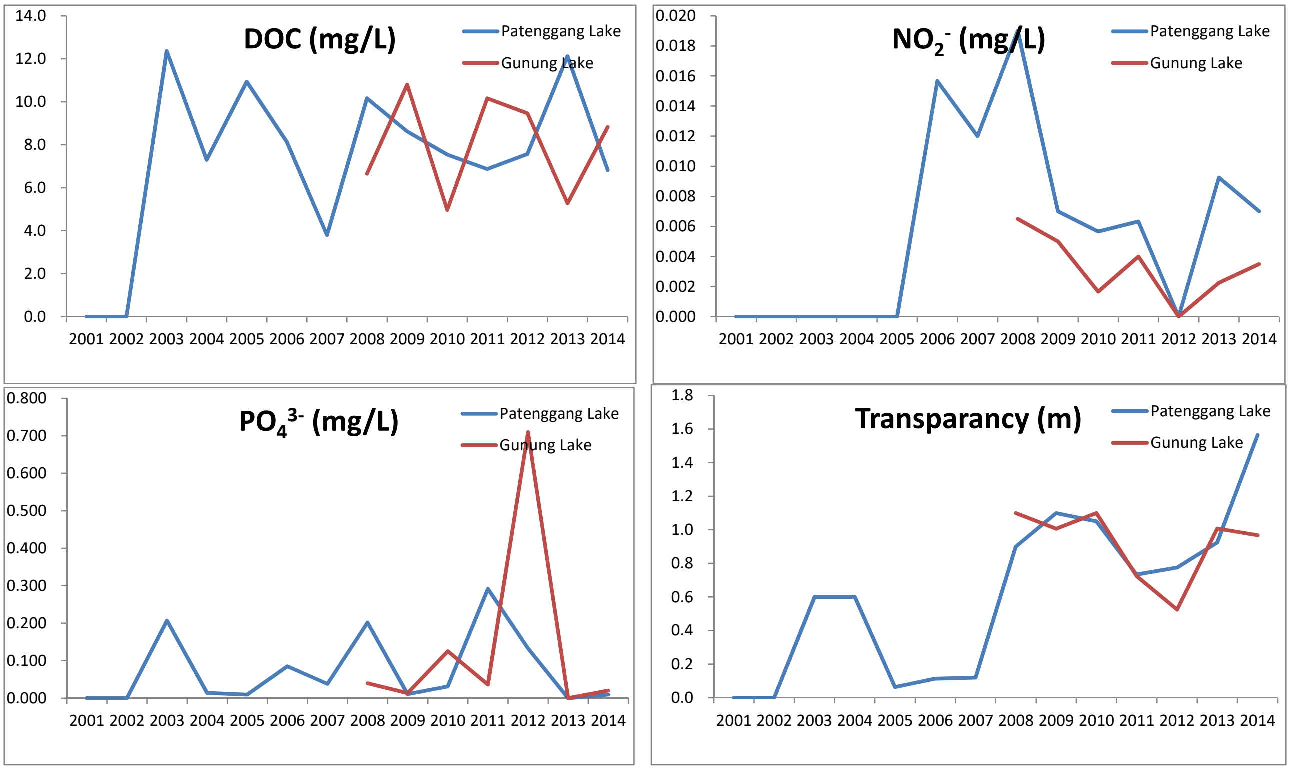
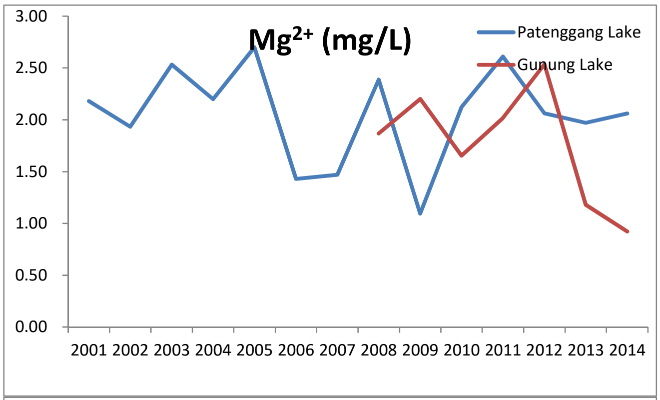
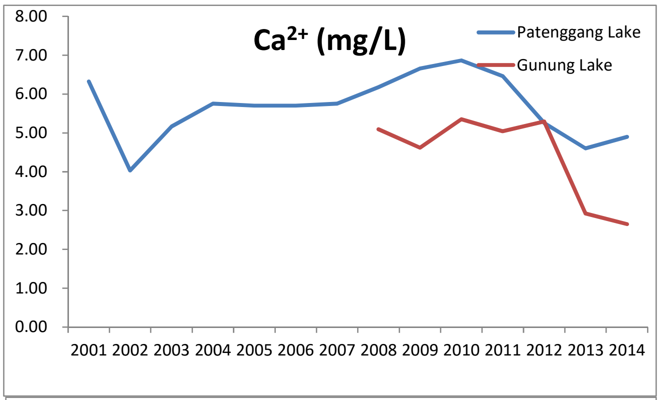
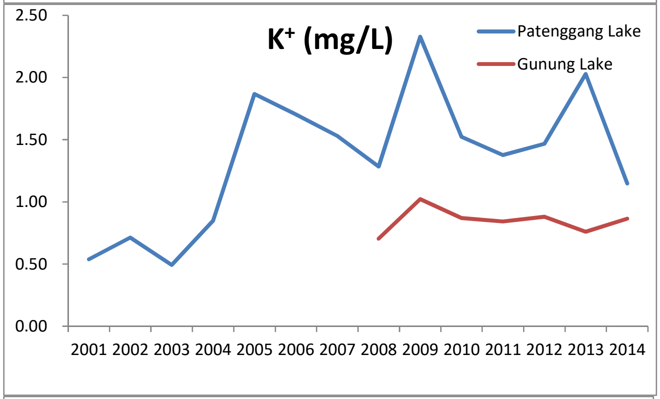
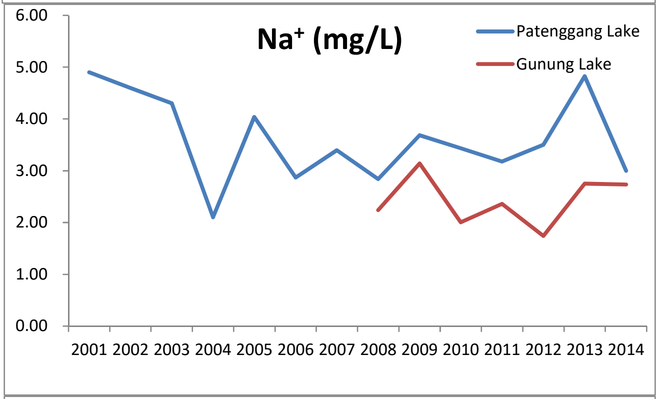


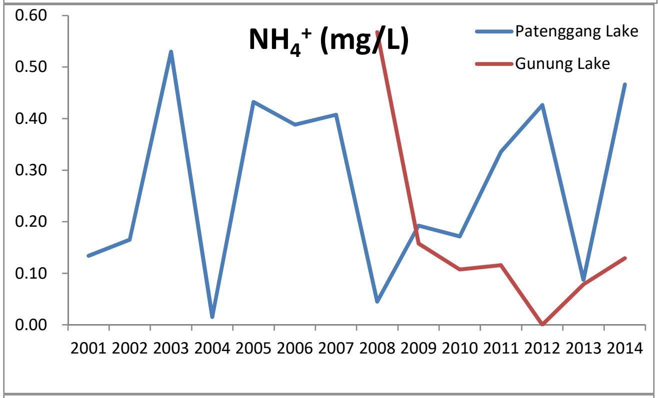
Figure 2.13. The values of mandatory parameter once a year of transparency, NO_2^-, PO_4^{3-} and DOC in Situ Patenggang and Situ Gunung.

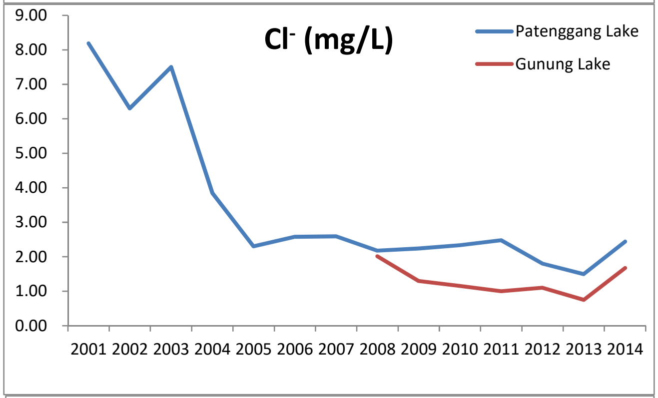

Mg^{2+} (mg/L)
Patenggang Lake
Gunung Lake
3.00
2.50
2.00
1.50
1.00
0.50
0.00
2001 2002 2003 2004 2005 2006 2007 2008 2009 2010 2011 2012 2013 2014

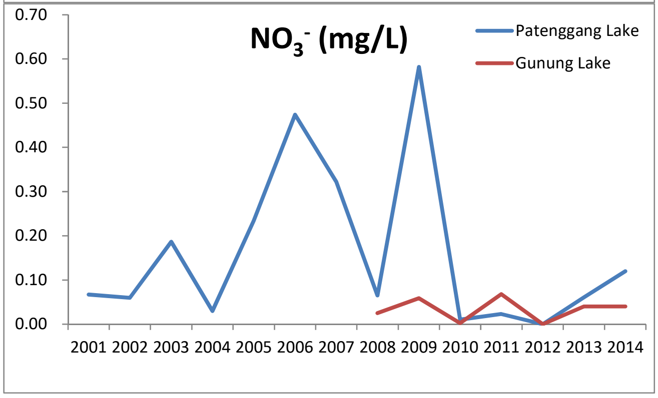

Ca^{2+} (mg/L)
Patenggang Lake
Gunung Lake
8.00
7.00
6.00
5.00
4.00
3.00
2.00
1.00
0.00
2001 2002 2003 2004 2005 2006 2007 2008 2009 2010 2011 2012 2013 2014

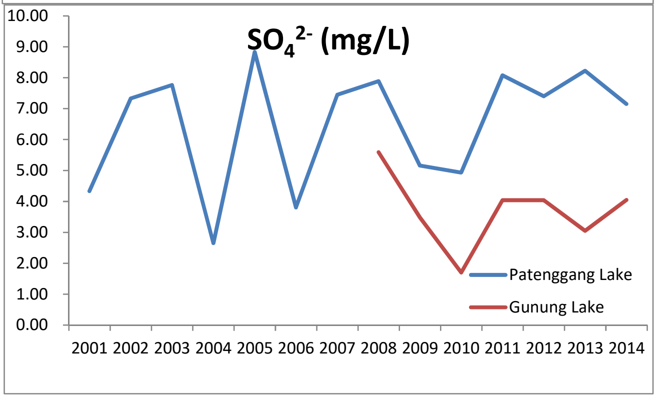

K^{+} (mg/L)
Patenggang Lake
Gunung Lake
2.50
2.00
1.50
1.00
0.50
0.00
2001 2002 2003 2004 2005 2006 2007 2008 2009 2010 2011 2012 2013 2014


Na^{+} (mg/L)
Patenggang Lake
Gunung Lake
6.00
5.00
4.00
3.00
2.00
1.00
0.00
2001 2002 2003 2004 2005 2006 2007 2008 2009 2010 2011 2012 2013 2014


NH_4^{+} (mg/L)
Patenggang Lake
Gunung Lake
0.60
0.50
0.40
0.30
0.20
0.10
0.00
2001 2002 2003 2004 2005 2006 2007 2008 2009 2010 2011 2012 2013 2014


Cl^{-} (mg/L)
Patenggang Lake
Gunung Lake
9.00
8.00
7.00
6.00
5.00
4.00
3.00
2.00
1.00
0.00
2001 2002 2003 2004 2005 2006 2007 2008 2009 2010 2011 2012 2013 2014


NO_3^{-} (mg/L)
Patenggang Lake
Gunung Lake
0.70
0.60
0.50
0.40
0.30
0.20
0.10
0.00
2001 2002 2003 2004 2005 2006 2007 2008 2009 2010 2011 2012 2013 2014


SO_4^{2-} (mg/L)
Patenggang Lake
Gunung Lake
10.00
9.00
8.00
7.00
6.00
5.00
4.00
3.00
2.00
1.00
0.00
2001 2002 2003 2004 2005 2006 2007 2008 2009 2010 2011 2012 2013 2014

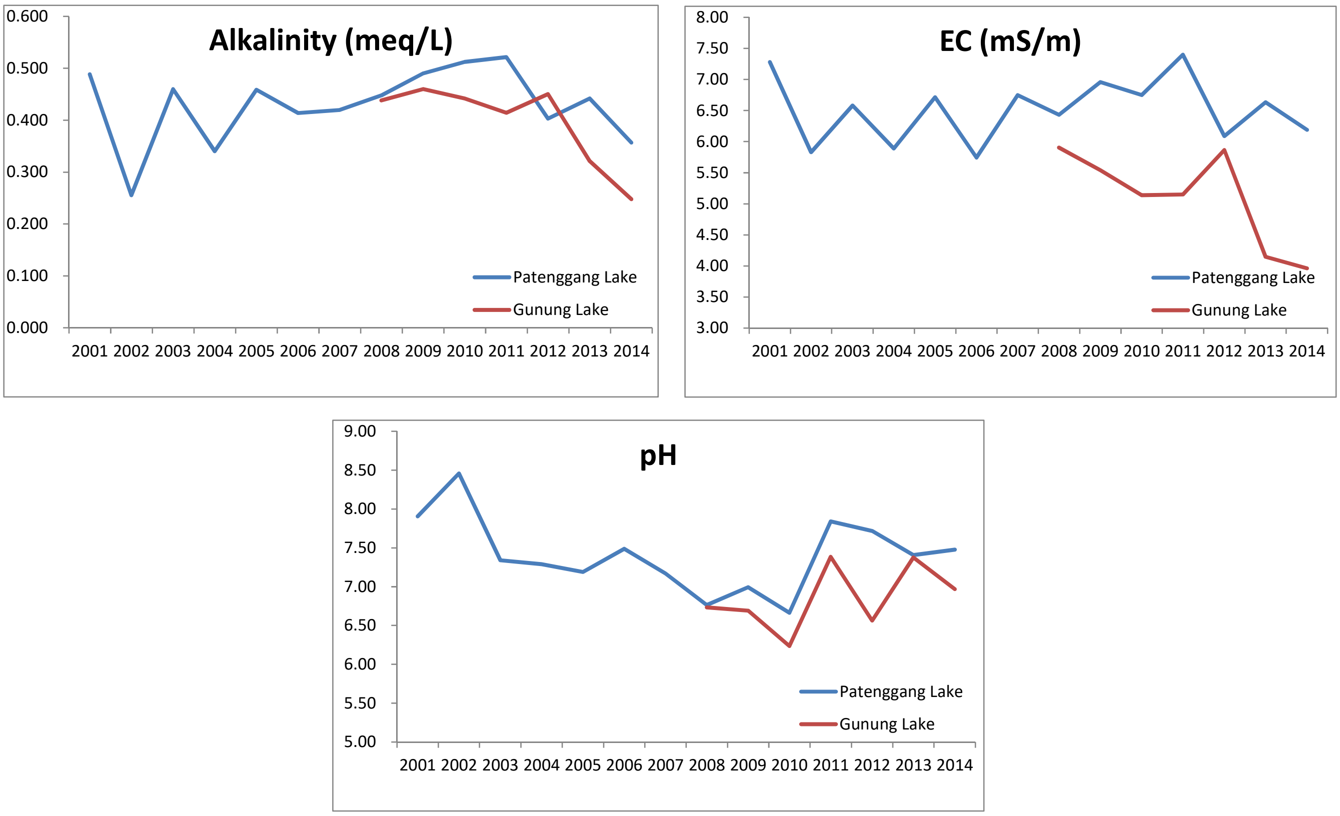


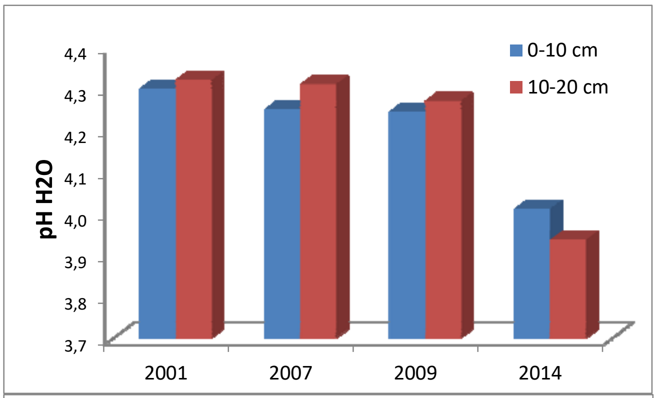
Figure 2.14. The values of mandatory parameter four times a year of EC, pH, alkalinity, NO_3^-, NH_4^+, SO_4^{2-}, Cl^-, Na^+, K^+, Mg^{2+} and Ca^{2+} in Situ Patenggang and Situ Gunung.

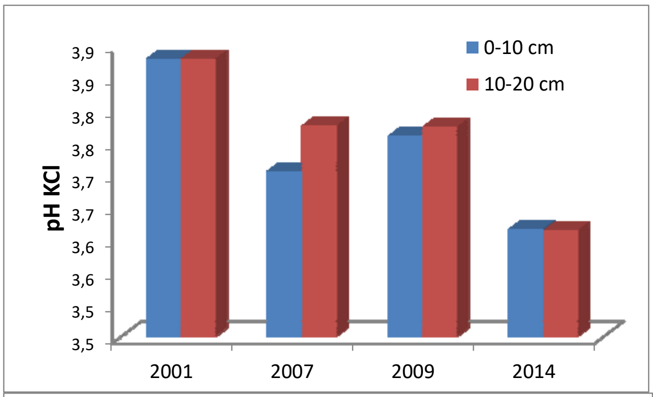
2.4. State of soil and vegetation

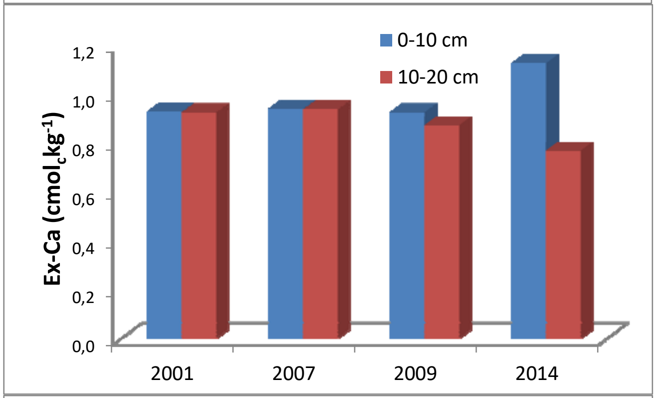
Soil and vegetation observations have been made in Dramaga Forest Research, Bogor. This forest is 40 years old man made type with Hopea mengarawan the major tree species and managed by Forestry Research and Development Center, Ministry of Forestry of Republic Indonesia as experimental forest.

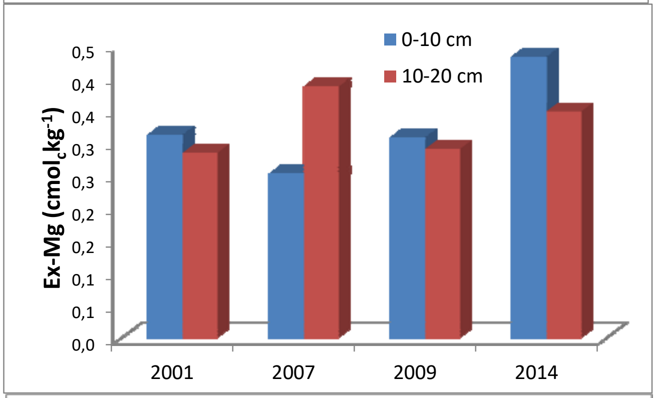
2.4.1. State of soil

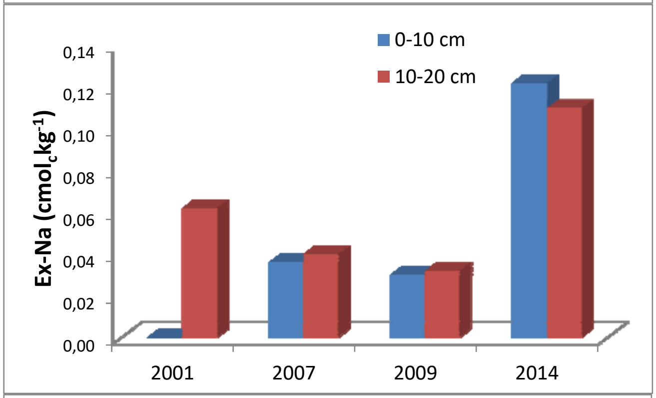
Soil chemistry monitoring in Dramaga Experimental Research, Bogor, Indonesia in the period of observation in 2002, 2007, 2009 and 2014 showed the acidity soil symptoms as decreasing soil pH, base saturation and higher acid saturation. The type of soil has a very acid pH, low organic matter, exchangeable-cation and cation exchange capacity (CEC), so it is considered as poor soil.

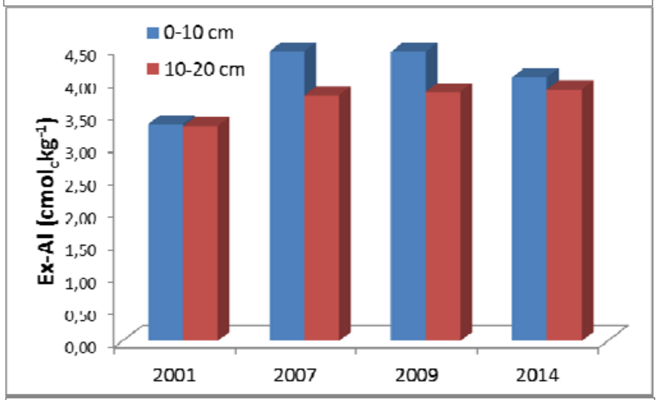

pH H2O
4,4
4,3
4,2
4,1
4,0
3,9
3,8
3,7
2001
2007
2009
2014
0-10 cm
10-20 cm

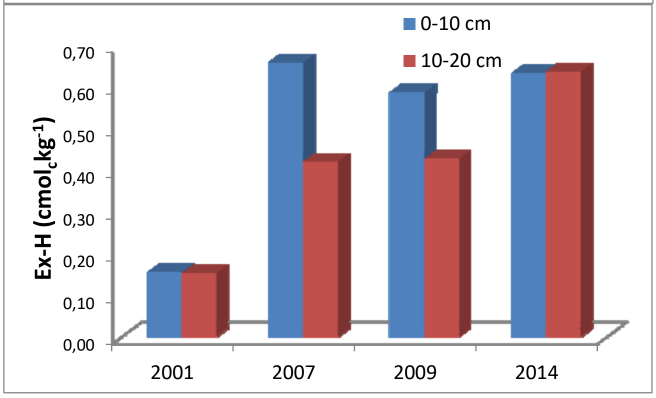

pH KCl
3,9
3,9
3,8
3,8
3,7
3,7
3,6
3,6
3,5
3,5
2001
2007
2009
2014
0-10 cm
10-20 cm

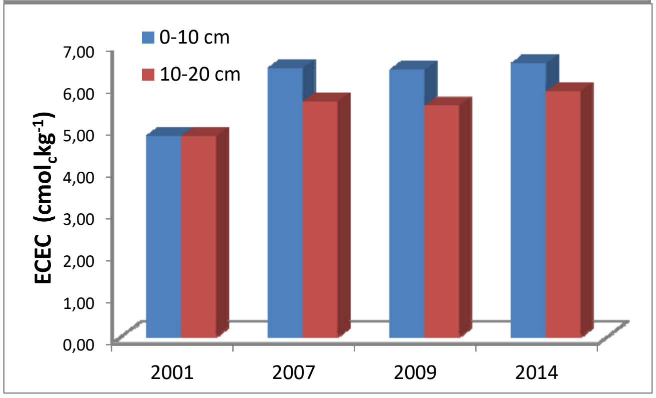

Ex-Ca (cmol$_c$kg^{-1})
1,2
1,0
0,8
0,6
0,4
0,2
0,0
2001
2007
2009
2014
0-10 cm
10-20 cm


Ex-Mg (cmol$_c$kg^{-1})
0,5
0,4
0,4
0,3
0,3
0,2
0,2
0,1
0,1
0,0
2001
2007
2009
2014
0-10 cm
10-20 cm


Ex-Na (cmol$_c$kg^{-1})
0,14
0,12
0,10
0,08
0,06
0,04
0,02
0,00
2001
2007
2009
2014
0-10 cm
10-20 cm


Ex-Al (cmol$_c$kg^{-1})
4,50
4,00
3,50
3,00
2,50
2,00
1,50
1,00
0,50
0,00
2001
2007
2009
2014
0-10 cm
10-20 cm


Ex-H (cmol$_c$kg^{-1})
0,70
0,60
0,50
0,40
0,30
0,20
0,10
0,00
2001
2007
2009
2014
0-10 cm
10-20 cm


ECEC (cmol$_c$kg^{-1})
7,00
6,00
5,00
4,00
3,00
2,00
1,00
0,00
2001
2007
2009
2014
0-10 cm
10-20 cm

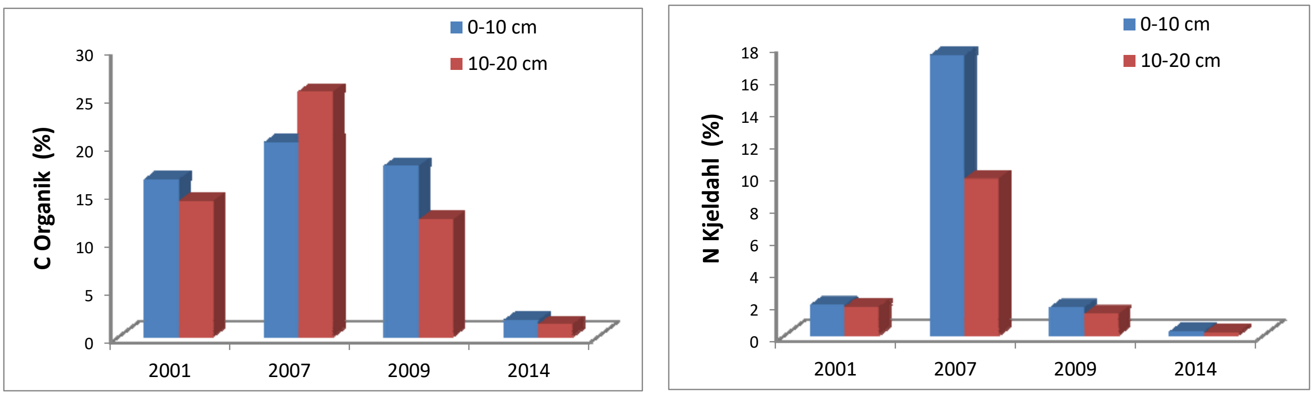


Figure 2.15. The values of pH (H_2O), pH (KCl), C - organic, N – Kjeldahl, Ex-cations, base saturation, CEC, Ex-Al, and Ex-H at depth 0 - 10 cm and 10 – 20 cm.

The soil pH in Dramaga station tends to be extremely acidic (<4.5). Figure above shows the gradual change of pH-H_2O at 10 cm upper part of soil layer (top soil) and 10 cm underneath for several times observation during year 2001 to 2014.

Both soil layers tend to decrease in pH even in small scale (< 0.1 pH unit). The topsoil has lower pH-H2O and pH-KCl than the lower layer. It is also a similar pattern for gradual change in pH-KCl. The lower pH of soil at the top layer was caused by some sources of acid (H+) above ground, that could be generated from organic decomposition or from rain water.

Level of organic matter in topsoil is higher than the layer underneath as it commonly found in natural soils. C-organic content in the topsoil tends to increase. The bottom layer shows a decreasing level from year 2002 to 2007 and to 2014. The same pattern was shown in Nitrogen level for the second soil layer. C/N ratio of soil organic material represents the level of decomposition of organic material.

Exchangeable cations in soil samples was dominated by exchangeable-Ca (Ex-Ca), followed by exchangeable – Mg (Ex-Mg) and exchangeable-Na (Ex-Na) is the smallest such as generally normal land. There has been no change during the observation in year 2001-2014. The second soil layer shows elevated level of exchangeable-Al (Ex-Al) and exchangeable-H (Ex-H) during observation.

2.4.2. State of vegetation

Vegetation monitoring has been done in 2014. As a whole, it has not indicated the impact of acid deposition on observed vegetation. Some existing vegetation experienced disturbances such as pests and diseases are more due to the high density stands (11,755 trees.ha-1). High-density stands causing micro-climate in the observation plot are very conducive for pest and disease outbreaks. Meanwhile, the impact of acid deposition is not clear whether it is the color of the leaf and canopy structure. To see the impact of acid deposition in detail and valid, required an in-depth micro-analysis of physiological plant leaves, especially on the leaves tissue.

This activity was done in Dramaga Experimental Forest which one of the experimental forest managed by Forestry Research and Development Center, Ministry of Forestry of Indonesia. This forest has high density from seedlings until trees about 11755 trees/ha. The condition information of that forest and the results of the survey are shown as below:

Figure 2.16. Dramaga Forest Research, Bogor.

From the tree measurement in 2014 as shown in Table 2.2 there are some dead trees. Estimated cause of decline: pest and very dense, tree no. 1 (71), 12 (269) and 16 (113) was fallen due to hard rain and strong wind

Figure 2.17. Samplig location tress: Plot: 106 44' 55.1 E and 6 33' 7'' S

Tabel 2.2 Measurement of trees in 2014

Individual No.	1 (71)	4 (27)	5 (279)	6 (280)	8 (282)	12 (269)	16 (113)	21 (83)	23 (146)	27 (175)	28 (232)	31 (264)	33 (266)	34 (267)	39 (275)	42 (278)	44 (287)	46 (289)	49 (292)	51 (294)
Direction	N	N	N	N	N	E	E	E	E	E	S	S	S	S	S	W	W	W	W	W
Plant Name	*Hopea mengarawan*	*Hopea mengarawan*	*Hopea mengarawan*	*Hopea mengarawan*	*Hopea mengarawan*	*Hopea mengarawan*	*Hopea mengarawan*	*Hopea mengarawan*	*Hopea mengarawan*	*Hopea mengarawan*	*Hopea mengarawan*	*Hopea mengarawan*	*Melia excelsa*	*Maesopsis emenii*	*Hopea mengarawan*	*Hopea odorata*	*Khaya grandifolia*	*Hopea mengarawan*	*Hopea mengarawan*	*Hopea mengarawan*
Relative height																				
Tree height (m)	28,0	33,0	40,0	43,0	45,0	30,0	24,0	47,0	31,0	7,5	42,0	10,0	6,5	5,8	43,0	30,0	45,0	42,0	35,0	40,0
DBH (cm)	Dead					Dead	Dead													
Vitality of tree				1								1	2	1						
Form of tree		1		2	2			3		1	1		3	1	1	1	2	1	1	1
Branch growth		1		1	1			3	2	1	2		2	2	1	1		1	2	2
Dieback of stem		1			1				1					1	1	1		1	1	
Defoliation of crown		1		1	1			1	1	1			1	1	1	1		1	1	1
Deformation of leaves				1																
Size of leaves									1											
Discoloration of leaves				1					1	1		1	1	1	1	1		1		1
Injury of leaves				1					1	1		1	1	1	1	1		1		1
Damage class				1					1	1			1	1	1	1		1		1

3. Review of National Measures Againts Acid Deposition

Indonesia does not have the specific national measures against acid deposition. To control the emission of air pollutant 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 is not directly reduced the emission of sulfur dioxide and nitrogen oxide which is the main cause of acid deposition, but there is an assessment of compliance to the requirement of air pollution regulation.

One of the major sources of acid pollution comes from the excessive amount of acid emitted during the forest fire. The government of Indonesia has established in 2015 an Agency for Peatland restoration to mitigate the peatland fire. The government also has established the moratorium for peatland conservation and palm oil plantation until further policy changes. Whenever the forest fire broke, the government has installed measured against air pollution with fire extinguisher by weather modification, PM_{10} detection, fire danger rating system and trajectory modeling.

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National Assessment on Acid Deposition in Japan

Chapter 1. Basic Information on National Monitoring Activities

1.1 Outline of the activities on acid deposition and National Monitoring Plan

There is a large concern of various air pollution problems with rapid economic growth, and it will be prevailing in East Asia. In 1983, the Environment Agency of Japan, which was reorganized as the Ministry of the Environment (MOEJ) in January 2001, brought up the adverse impact of acid deposition in Japan and established the Committee for Acid Deposition Measures consisting experts on air pollution, soil, vegetation and inland aquatic environments. Then, the 1st survey of Japan Acid Deposition Survey (JADS) was launched. By analyzing the monitoring data from 1983 to 2002, the Summary Report of JADS was published in June 2004. This report demonstrated that pH in precipitation was as low as that in Europe and North America, and that acid components is higher in winter season.

In order to implement long-term and nationwide acid deposition monitoring, the continuous monitoring of acid deposition has been started based on the long term monitoring plan for acid deposition by the MOEJ in 2003. By analyzing the monitoring data from 2003 to 2007, the Report of the Long Term National Acid Deposition Monitoring in Japan (JFY2003-2007) was published in March 2009. This report described acidification in Lake Ijira catchment, the necessity of transboundary air pollution monitoring integrating ozone, aerosol and acidic deposition data.

With the heightening concern toward transboundary air pollution issues, the long term monitoring plan for transboundary air pollution and acid deposition was established in March 2009, in order to clarify watching transboundary air pollution to monitor not only acid deposition but ozone and aerosol. The objective of new monitoring plan is to acquire long term trend and long range transportation of acidic substances and other air pollutants and to promptly grasp and predict the impact of transboundary air pollution and acidic deposition. The monitoring plan is aimed to implement atmospheric monitoring and ecological monitoring for a long period in cooperation with EANET activity. By analyzing the monitoring data from 2008 to 2012, the Report of the Long Term Transboundary Air Pollution and Acid Deposition Monitoring in Japan (JFY2008-2012) was published in March 2014. Chapter 2 includes the summarized results of this report.

The long term monitoring plan for transboundary air pollution and acid deposition was revised in March 2014. According to the revised plan, domestic monitoring stations for atmosphere and ecology were reorganized, and the number of $PM_{2.5}$ monitoring stations were increased. For the impact study, the intensive monitoring in high potential risk area of acidification and pilot monitoring of the impact of ozone on plants were launched.

The QA/QC activities for atmospheric and ecological monitoring have been also conducted to get the internationally comparable, high precision and high accuracy data by monitoring data verification and implementation of site audit and inter-laboratory comparison survey.

1.2 Monitoring program in 2010 – 2014

1.2.1 Background

The economic activities in East Asian region have been developing rapidly with the severe environmental issues such as air pollution and so on. The transboundary air pollution including acid deposition becomes more serious in the near future.

MOEJ launched the first survey for the measure against acid rain in 1983, and then the acid deposition monitoring on the field of ambient air, soil and vegetation, and inland aquatic environment have been conducted more than 30 years.

As the accumulated result of these surveys, it was confirmed that the situation of the acid deposition in Japan was almost same as that in European countries and the tendency of increasing the acidic components in the Japan sea coastal area in winter season. The effect of acid deposition on ecological systems was not clear, but the effect may be revealed in future if the situation of acidic deposition is not changed.

Based on these backgrounds, MOEJ is promoting *long term monitoring of transboundary air pollution and acid deposition* and *study on the investigation of the measure against acid deposition in East Asia* under the Acid Deposition Monitoring Network in East Asia (EANET) and international corroboration. MOEJ also established the *Long term monitoring plan for transboundary air pollution and acid deposition* which was renamed from the *Long term monitoring plan for acid deposition* in 2009 and revised in 2014. This plan was prepared to indicate the middle and long-term direction of Japan for continuous implementation of wide-area and long-term monitoring of acid deposition.

Based on the monitoring results from 2003 to 2007, with the addition of catchments survey and the reviewing of wet deposition monitoring sites, and on the view point of clarification of the monitoring for transboundary air pollution not only on acid deposition, but also ozone and aerosol, this plan was revised partly in 2009. In 2014, domestic monitoring stations were reorganized, and the number of $PM_{2.5}$ monitoring stations were plan to increase.

1.2.2 Objectives

The objectives of the long-term monitoring of transboundary air pollution and acid deposition are grasping the long-range transboundary transportation and long-term trend, etc. of air pollutants, such as acid rain causing substances, ozone and so on. The long-term air monitoring and ecological impact monitoring would be implemented with EANET activities.

1.2.3 Structure for the implementation of long–term monitoring of transboundary air pollution and acid deposition

a) Components of the structure

The long-term monitoring consists *Ambient Air Monitoring* and *Ecological Impact Monitoring*. Ambient Air Monitoring includes *Wet Deposition Monitoring* by measuring the components in the precipitation and *Air pollutants Monitoring* by measuring the components in gas and aerosol phase. Dry deposition of acidic substances is included in the Air pollutants Monitoring. The Ecological Impact Monitoring consists *Soil and Vegetation Monitoring*, *Inland Aquatic Environment Monitoring* and *Catchment-scale Monitoring*. The schematic structure is shown in Figure 1.1.

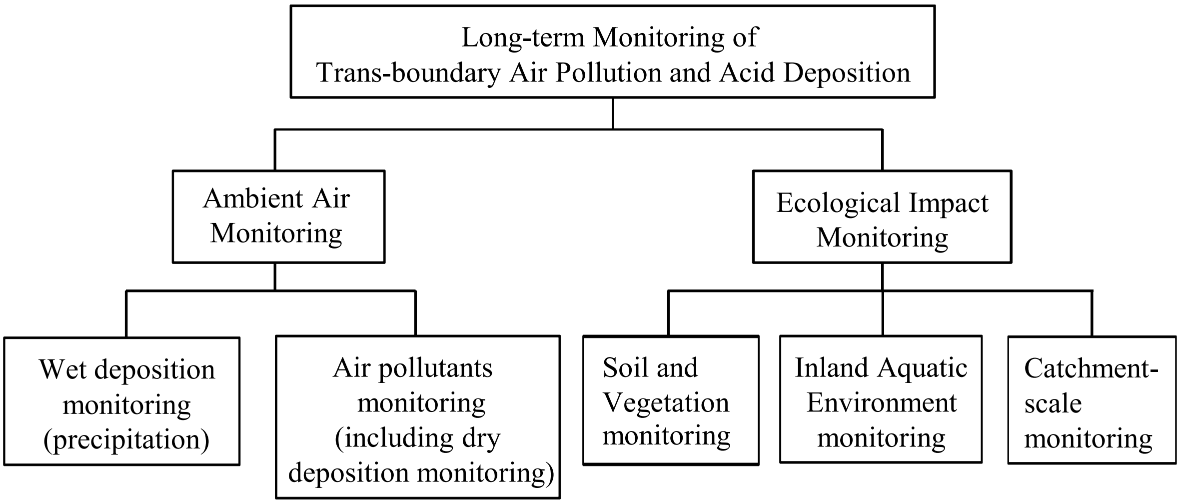

Figure 1.1. Schematic structure of long–term monitoring.

b) Implementing organizations

The task on the long-term monitoring is implemented by following organizations.

Tasks	Implementation organizations
Planning and arrangement	MOEJ Asia Center for Air Pollution Research (ACAP)*, Japan Environmental Sanitation Center (JESC)
Sample collection	Local governments and other organizations contracted with MOEJ
Analysis	Local governments, ACAP and other organizations contracted with MOEJ
Quality control and assurance	ACAP and other organizations contracted with MOEJ
Data compilation, analysis and evaluation	MOEJ ACAP

** ACAP is designated as the Network Center for EANET and the National Center of Japan.*

c) Objectives of the ambient air monitoring

The objectives of the ambient air monitoring are implemented to assess the state of concentration and deposition of acidic substances and air pollutants such as ozone and so on. The targets of the assessment are whole ecosystem including, 1) coastal and plane region in the remote area, 2) mountain region in the remote area, 3) rural area, 4) suburban area, 5) urban area, 6) special emission sources area such as volcano, and 7) area for forest and inland aquatic environment assessment.

d) Objectives of the ecological impact monitoring

The soil and vegetation monitoring is conducted for the establishment of the baseline data of soil and forest in representative forests in Japan and for detecting effects of acid deposition/air pollution in early stage. The inland aquatic environment monitoring is conducted for detecting effects of acid deposition on inland aquatic environments in early stage. The catchment-scale monitoring is conducted for evaluating acidic substances burden in the catchment area by using material balance between inflow and outflow.

Table 1.1. The monitoring sites for the ambient air monitoring.

#	Site name	Prefecture	Classification of climate	Site classification	Wet deposition	Sampling interval	Air Pollutants						Notes
							FP	SO_2	O_3	NOx	PM_{10}	$PM_{2.5}$	
1	Rishiri	Hokkaido	Hokkaido	Remote	✓	daily	✓	✓	✓	✓	✓	✓	EANET*1
2	Sapporo	Hokkaido	Hokkaido	Urban	✓	weekly		✓	✓	✓		✓	
3	Cape Ochiishi	Hokkaido	Hokkaido	Remote	✓	daily	✓	✓	✓	✓	✓	✓	EANET
4	Cape Tappi	Aomori	N of Japan Sea	Remote	✓	daily	✓	✓	✓	✓	✓	✓	EANET
5	Nonodake	Miyagi	Pacific Ocean	Rural	✓	weekly		✓	✓	✓		✓	
6	Akagi	Gunma	Pacific Ocean	Rural	✓	weekly			✓				
7	Tokyo	Tokyo	Pacific Ocean	Urban	✓	daily	✓	✓*5	✓*5	✓*5	✓*5	✓*5	EANET
8	Ogasawara	Tokyo	Pacific Ocean	Remote	✓	daily	✓	✓	✓	✓	✓	✓	EANET
9	Sado–Seki	Niigata	N of Japan Sea	Remote	✓	daily	✓	✓	✓	✓	✓	✓	EANET
10	Niigata–Maki	Niigata	N of Japan Sea	Rural	✓	daily		✓	✓	✓	✓*5	✓*5	
11	Happo–one	Nagano	N of Japan Sea	Remote	✓	daily	✓	✓	✓	✓	✓	✓	EANET
12	Cape Echizen	Fukui	N of Japan Sea	Remote	✓	daily			✓				
13	Lake Ijira	Gifu	Pacific Ocean	Rural	✓	weekly	✓	✓	✓	✓	✓	✓	EANET
14	Amagasaki	Hyogo	Seto-uchi	Urban	✓	weekly		✓	✓	✓		✓	
15	Oki	Shimane	San'in	Remote	✓	daily	✓	✓	✓	✓	✓	✓	EANET
16	Lake Banryu	Shimane	San'in	Urban	✓	weekly	✓	✓	✓	✓	✓	✓	EANET
17	Yusuhara	Kochi	Pacific Ocean	Remote*2	✓	daily	✓	✓	✓	✓	✓	✓	EANET
18	Chikugo–Ogori	Fukuoka	East China Sea	Rural	✓	weekly			✓				
19	Tsushima	Nagasaki	East China Sea	Remote	✓	daily			✓		✓	✓	TBP*3
20	Goto	Nagasaki	East China Sea	Remote					✓				TBP
21	Oita–Kuju	Oita	Seto–uchi	Rural	✓	weekly			✓				
22	Ebino	Miyazaki	East China Sea	Remote*2	✓	daily		✓	✓				Volcano
23	Yakushima	Kagoshima	Nansei Islands	Remote*2	✓	Weekly		✓	✓				WH*4
24	Cape Hedo	Okinawa	Nansei Islands	Remote	✓	Daily	✓	✓	✓	✓	✓		EANET

**1: Designated as EANET site, *2: Belonging to Remote with the influence of volcano, *3: possibilities of the effect by transboundary pollution, *4: World Heritage, *5: To be installed near future*

Table 1.2. Soil and vegetation monitoring sites.

Classification	Name of forest area	Targeted tree species or soil types	Remarks Nearest sites for ambient air monitoring
Area focusing on impacts on trees (focusing on natural forests)	Shiretoko National Park (Hokkaido Pref.)	*Abies sachalinensis*	Cape Ochiishi
	Shikotsu–Toya National Park (Hokkaido Pref.)	*Betula ermanii*	Sapporo
	Towada–Hachimantai National Park (Iwate Pref.)	*Abies mariesii*	Hachimantai
	Bandai–Asahi National Park (Niigata Pref.)	*Fagus crenata*	Niigata–Maki
	Nikko National Park (Tochigi Pref.)	*Fagus crenata*	Akagi
	Chubu–Sangaku National Park (Toyama Pref.)	*Fagus crenata*	Happo–one
	Hakusan National Park (Ishikawa Pref.)	*Fagus crenata*	Cape Echizen
	Yoshino–Kumano National Park (Nara Pref.)	*Fagus crenata*	Shionomisaki
	Daisen–Oki National Park (Tottori Pref.)	*Fagus crenata*	Oki
	Ishizuchi Quasi–National Park (Kochi Pref.)	*Fagus crenata*	Yusuhara
	Aso–Kuju National Park (Oita Pref.)	*Fagus crenata*	Oita–Kuju
	Yakushima National Park (Kagoshima Pref.)	*Criptomeria japonica,* glossy–leaved forest	Yakushima
Area focusing on impacts on soil	Sekidozan and Horyuzan (Ishikawa Pref.)	red soil, brown forest soil	Cape Echizen
	Hodoji and Amanosan (Osaka Pref.)	yellow soil, yellowish brown forest soil	Amagasaki
	Shimofuritake and Tokusagamine (Yamaguchi Pref.)	yellow soil, black soil	Lake Banryu
	Kashiigu and Koshosan (Fukuoka Pref.)	reddish brown forest soil, brown forest soil	Chikugo–Ogouri
EANET sites (focusing on relationship with inland water)	Lake Ijira area (Ijira and Yamato) (Gifu Pref.)		Lake Ijira
	Lake Banryu area (Banryu and Iwami–rinku factory park) (Shimane Pref.)		Lake Banryu

Table 1.3. Monitoring sites for inland aquatic environment.

	Lake or ponds	Location	Remarks
1	Imagamio-ike	Yamagata Pref.	
2	Karikom-iko	Tochigi Pref.	
3	Futago-ike	Nagano Pref.	

4	Ohata-ike	Ishikawa Pref.	
5	Yashaga-ike	Fukui Pref.	
6	Ijira-ko	Gifu Pref.	EANET site
7	Sawano-ike	Kyoto Pref.	
8	Banryu-ko	Shimane Pref.	EANET site

1.3 Monitoring stations

The ambient air monitoring is conducted at the 24 sites as shown in Table 1.1. Soil and vegetation monitoring and inland aquatic environment monitoring are conducted at the 18 and 8 sites, as shown in Table 1.2 and 1.3, respectively.

1.4 Sampling and Measurements

1.4.1 Ambient air monitoring

a) Monitoring items, interval and method

i) Wet deposition (precipitation)

- Monitoring items: electrical conductivity (EC), pH, sulfate ion (SO_4^{2-}), nitrate ion (NO_3^-), chloride ion (Cl^-), ammonium ion (NH_4^+), sodium ion (Na^+), potassium ion (K^+), calcium ion (Ca^{2+}) and magnesium ion (Mg^{2+})
- Sampling intervals: Daily sampling for EANET sites and monitoring sites for transboundary air pollution. Weekly sampling for ecological impact monitoring sites and other domestic sites.
- Monitoring methods:

Precipitation samples should be collected by a wet-only sampler and analyzed by the following methods.

Item	Analytical instrument (principle of the analytical method)
Electrical conductivity	electrical conductivity meter (electric conductivity cell method)
pH	pH meter (glass electrode method)
SO_4^{2-},NO_3^- and Cl^-	ion chromatograph
NH_4^+	ion chromatograph or spectrometer (Indophenol method)
Na^+, K^+, Ca^{2+} and Mg^{2+}	ion chromatograph or atomic adsorption

ii) Air pollutants (gas and aerosol) by automatic monitor

- Monitoring items: sulfur dioxide (SO_2), ozone (O_3), nitrogen oxides (NO/NO_2 or NOx*), particulate matter (<10 μm) (PM_{10}) and particulate matter (<2.5 μm) ($PM_{2.5}$)
- Sampling intervals: continuous monitoring and summarized as hourly data
- Monitoring methods:

Item	analytical method
SO_2	ultraviolet fluorescence method (high sensitivity type)
O_3	ultraviolet adsorption method
NOx*	chemiluminescence method (high sensitivity type)
PM_{10}, $PM_{2.5}$**	TEOM method and β-ray adsorption method

** NOx monitors at rural and remote sites should selectively measure* NO_2*.*

**** $PM_{2.5}$ *monitors should be equivalent to the standard (filter weight) method.*

iii) Air pollutants (gas and aerosol) by manual monitoring

- Monitoring items: gaseous components: SO_2, HNO_3, HCl and NH_3
  aerosol components: SO_4^{2-}, NO_3^-, Cl^-, NH_4^+, Na^+, K^+, Ca^{2+} and Mg^{2+}
- Sampling intervals: sample is collected for two weeks. The sampling period at high concentration sites is designed as one week.
- Monitoring methods: filter-pack method

iv) Dry deposition

Dry deposition at EANET sites are estimated by inferential method according to “Technical Manual on Dry Deposition Flux Estimation in East Asia".

1.4.2 Ecological impact monitoring

a) Monitoring items, interval and method

i) Soil and vegetation monitoring

Forest vegetation monitoring:

- Monitoring items: Mandatory: General description of forest (description of trees (species name, diameter at breast height (DBH) and height of tree), understory vegetation survey), observation of tree decline.
  Optional: photographic records of tree decline and estimation of decline cause.
- Sampling frequency: Every five years for general description of forest, once a year for survey of tree decline.
- Monitoring methods: Observation plots are established in the selected forest areas:
  - Area focusing on impacts on trees (national parks): one plot.
  - Area focusing on impacts on soil: one plot respectively for two soil types (two plots in total).
  - EANET sites: one plot respectively for two soil types (two plots in total).

Soil monitoring:

- Monitoring items: Mandatory: Moisture content, pH (H_2O), pH (KCl), exchangeable base cations (Ca, Mg, K, and Na), exchangeable acidity, exchangeable Al, exchangeable H, effective cation exchange capacity (ECEC), carbonate content (calcareous soils only).
  Optional: total N, total C, available P, Sulphate, soil physical properties (fine earth bulk density, penetration resistance).
- Sampling frequency: Every five years.
- Monitoring methods: Sampling plots are established in the selected forest areas:
  - Area focusing on impacts on trees (national parks): two plot.
  - Area focusing on impacts on soil: two plots respectively for two soil types (four plots in total).
  - EANET sites: two plots respectively for two soil types (four plots in total).
- Analytical methods:

Item	Analytical instrument or method (principle)
Moisture amount	electrical conductivity meter

pH (H_2O), pH (KCl)	pH meter (glass electrode method)
Exchangeable base (Ca, Mg, K, Na)	After extracting with ammonium acetate, atomic absorption spectrometer (AAS), ICP/AES, ICP/MS
Exchange acidity	After extracting with KCl aq., titrimetry
Exchangeable Al and H	After extracting with KCl aq., titrimetry
ECEC	Total of exchangeable cations
Carbonate content	Volume calcimeter

ii) Inland aquatic environment monitoring

➢ Monitoring items:

- ✓ Water sample:
  - a) Mandatory: water temperature, pH, EC, alkalinity (pH 4.8), NH_4^+, Ca^{2+}, Mg^{2+}, Na^+, K^+, SO_4^{2-}, NO_3^-, Cl^-, Chlorophyll a, Dissolved oxygen (DO)
    Optional: Plankton
  - b) Mandatory: transparency, water color, DOC, NO_2^-, PO_4^{3-}
    Optional: total dissolved Al, COD
- ✓ Sediment sample:
  - ● Mandatory: NO_3^-, NH_4^+, and SO_4^{2-} of pore water
    Optional: organisms other than plankton, sediment (Pb, Pb–210, and stable isotope of S)

➢ Sampling frequency:

- ✓ Water sample: 4 times (for four seasons) a year for the items (a) shown above, and once (in spring) to 4 times a year for the items shown (b) above
- ✓ Sediment sample: every five years

➢ Monitoring methods:

Water sample:

Parameters	Analytical instruments or methods
Electric conductivity (EC)	Conductivity meter (electric conductivity cell)
pH	pH meter (glass electrode)
Alkalinity	Titration by Burette or Digital burette with pH meter
NO_3^-, NO_2^-, PO_4^{3-}, SO_4^{2-}	Ion chromatography (preferably with suppressor) or Spectrophotometry
PO_4^{3-}	Spectrophotometry (Molybdenum blue method)
Cl^-	Ion chromatography or Titration
NH_4^+	Ion chromatography or Spectrophotometry (Indophenol blue)
Na^+, K^+, Ca^{2+}, Mg^{2+}	Ion chromatography or Atomic absorption/Emission spectrometry
Chlorophyll a	SCOR/UNESCO method
DO	DO Meter method or Winkler–modified sodium azide method
Transparency	Secci disk method
Water color	Observation
DOC	Combustion–Infrared method or Wet–oxidation method
Plankton	Water column sampling method (for phytoplankton), Plankton net sampling (for zoo plankton)
Total dissolved Al	Atomic absorption spectrometry with graphite furnace, ICP Emission spectrometry or ICP/MS
COD	Acidic potassium permanganate method

Lake sediment and their pore water:

Parameter	Analytical methods
SO_4^{2-}	Ion chromatography
NO_3^-	Ion chromatography or Spectrophotometry
NH_4^+	Ion chromatography or Spectrophotometry (Indophenol blue)
Pb	Atomic absorption spectrophotometry with graphite furnace after acid extraction, ICP emission spectrophotometry or ICP/MS
Sedimentation dating	Pb–210 method (Pb–210 : γ–radiation spectrometry)
S (stable isotopes ratio)	Isotope mass spectrometry by ionization

iii) Catchment-scale monitoring

- Input–output budget of acid substances is estimated based on the strengthened surveys on inflowing rivers to Lake Ijira (Kamagatani River and Kobora River) to monitor effects of acid deposition impacts in the acidified catchment.

Outline of the catchment monitoring

Items		Methods
Estimate of input (total deposition)	Precipitation distribution	Rain gauges at three different slope positions: upper, middle (Ijira Station), and lower.
	Wet deposition	EANET data at Lake Ijira site, taking account of the precipitation distribution above
	Dry deposition	WANET data at Lake Ijira site, taking account of dry deposition flux by Inferential method
	Total deposition	Sum of wet and dry deposition above
Estimate of output (material discharge)	Discharge	H–Q curve method based on the water level data
	Water chemistry	Biweekly sampling Parameters: water temperature, pH, EC, alkalinity (pH4.8 endpoint and Gran's Plot titration methods), NH_4^+, Ca^{2+}, Mg^{2+}, Na^+, K^+, SO_4^{2-}, NO_3^-, Cl^-, TOC, total dissolved Al, SiO_2
	Material discharge	Based on the amount of flow and the water quality of the river described above, the periodic outflow amount in every two weeks is estimated.

1.4.3 Other ecological surveys

i) Intensive monitoring in the area to be monitored for acidification risk

The areas, whose soil or geology have low acid neutralizing capacity and in which acid deposition is large, may have a large risk of acidification and should be monitored intensively. The high-risk areas for acidification were identified based on the cumulative acid loads for the 25 years from the 1980s to the middle of the 2000s and spatial distribution of soil and geology. In the high-risk areas, the intensive monitoring utilizing stable isotopic analysis is implemented to evaluate effects of atmospheric deposition including trans-boundary air pollution. Moreover, possibility of setting a new catchment-monitoring site is discussed.

- Monitoring items

  Stable isotopic ratio of sulfur, which is useful to evaluate dynamics of sulfur in ecosystems and its emission source, is measured for rainwater, soil solution and river/lake water. Other stable isotopic analyses, such as nitrogen and oxygen in nitrate and metal elements, are also implemented as possible, which may be useful to evaluate effects of atmospheric deposition.

Item	Note

Stable isotopic ratio of sulfur ($\delta^{34}S$)	Useful to evaluate retention/release time of atmospheric sulfur in ecosystems with its emission source information
Stable isotopic ratio of nitrogen and oxygen in nitrate, and metal elements	Useful to evaluate dynamics of atmospheric deposition in a catchment

- Monitoring sites

  The areas to be monitored are distributed mainly in Chubu region of Central Japan, the coastal area of the Sea of Japan, and western part of Kyushu Island. This includes Lake Ijira catchment and other areas, in which acidification and nitrogen saturation have been previously reported. The intensive monitoring is conducted in Lake Ijira catchment, in which effects of domestic emission sources are relatively large and the regular catchment monitoring has been conducted. Additionally, taking possibility of the future catchment monitoring into consideration, the areas, in which effects of trans-boundary air pollution are relatively large and/or long-term monitoring data have already been accumulated, may become the candidates for the monitoring sites.

ii) Monitoring on effects of ozone on plants

Recently ozone concentrations in Japan have been increasing gradually and warning for photochemical oxidants has been issued in wider areas. Therefore, to monitor effects of ozone on ecosystems, the pilot monitoring is conducted in the somma of Lake Mashu-ko, Hokkaido Prefecture, Mt. Hakkai-san, Niigata Prefecture, and Mt. Hiko-san, Fukuoka Prefecture, for the future regular monitoring. For a while, a field measurement of ozone concentrations in forest/mountainous area and a collection of the information on tree conditions nearby are implemented. Then, the monitoring methods to evaluate effects of ozone on plants are discussed. Moreover, to elucidate combined effects of air pollution and other factors, such as disease and insect attack, conditions of the damage are surveyed in such potentially affected areas.

Chapter 2. State of Acid Deposition in Japan

2.1 State of acid deposition and transboundary air pollution

2.1.1 State of wet deposition/precipitation chemistry

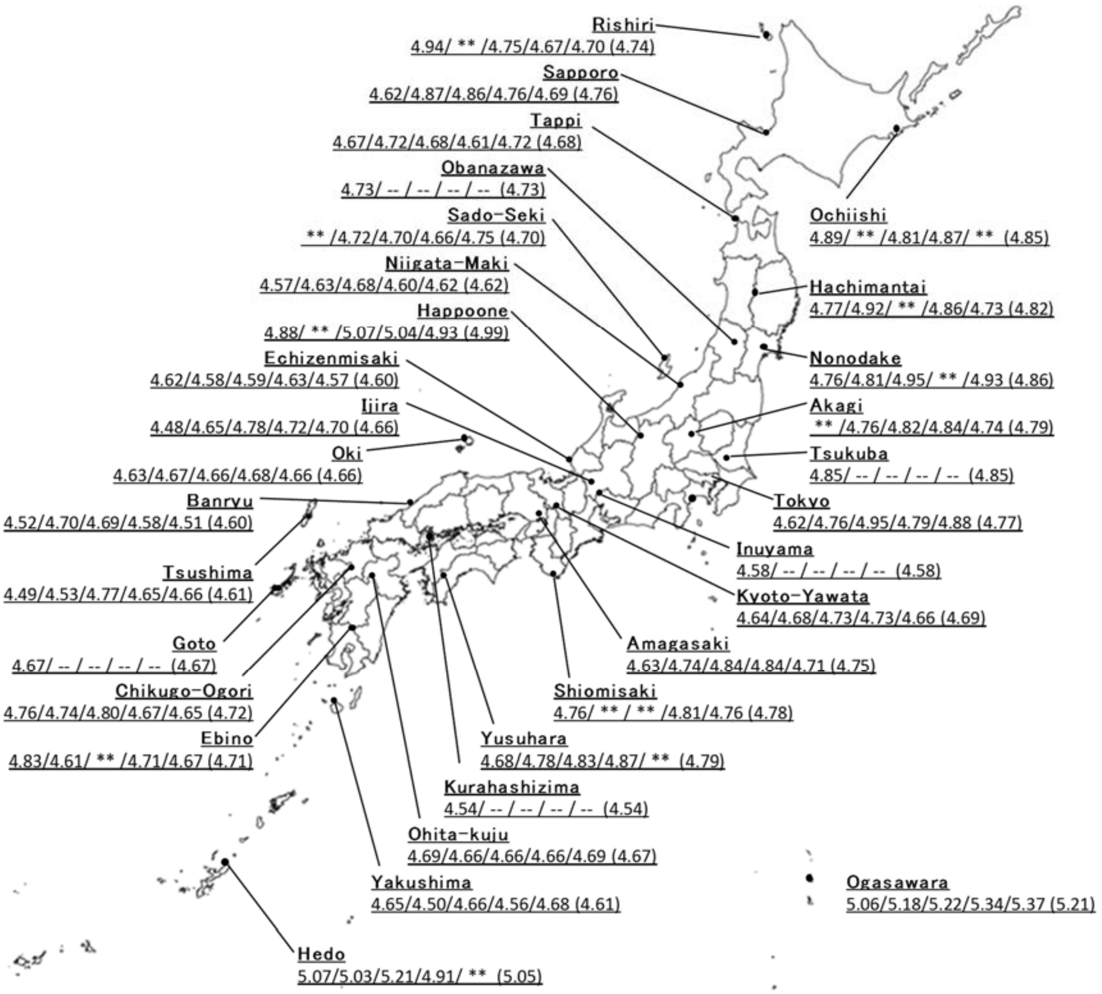

Figure 2.1.1.1 Distribution of pH in Japanese sites (JFY 2008-2012)

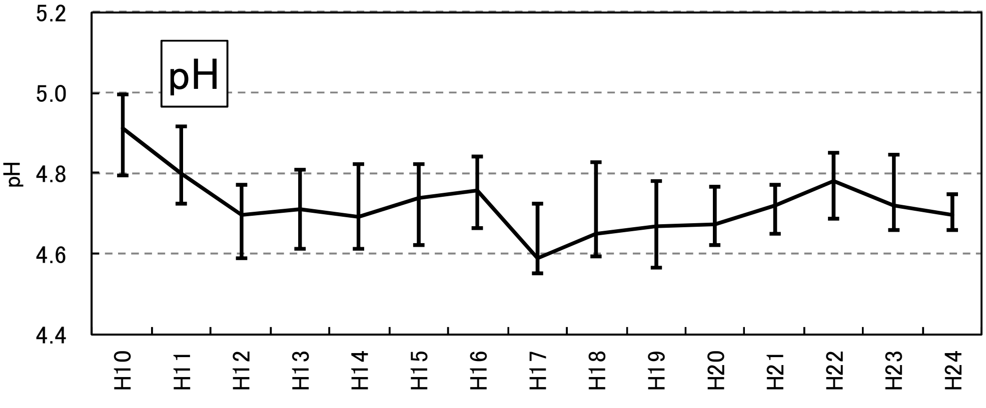

Figure 2.1.1.2 Inter annual variation of pH in precipitation

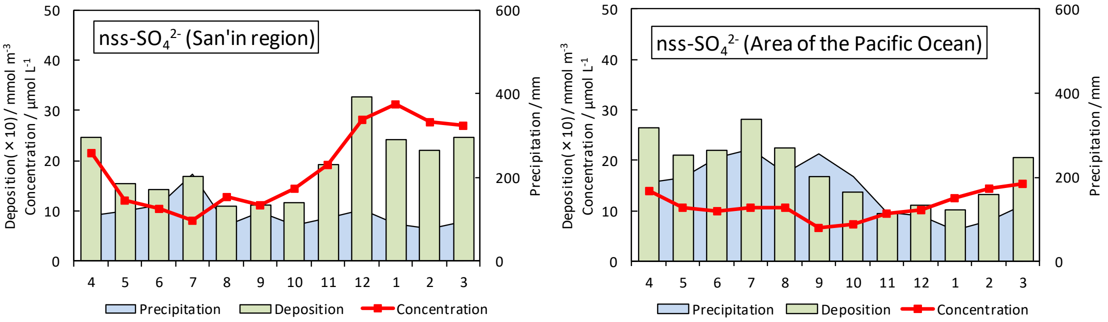

Figure 2.1.1.3 Seasonal variation of nss-SO$_4^{2-}$ concentration, wet deposition and precipitation amount (Average of JFY 2008-2012)

2.1.2 State of dry deposition/air pollutant concentration

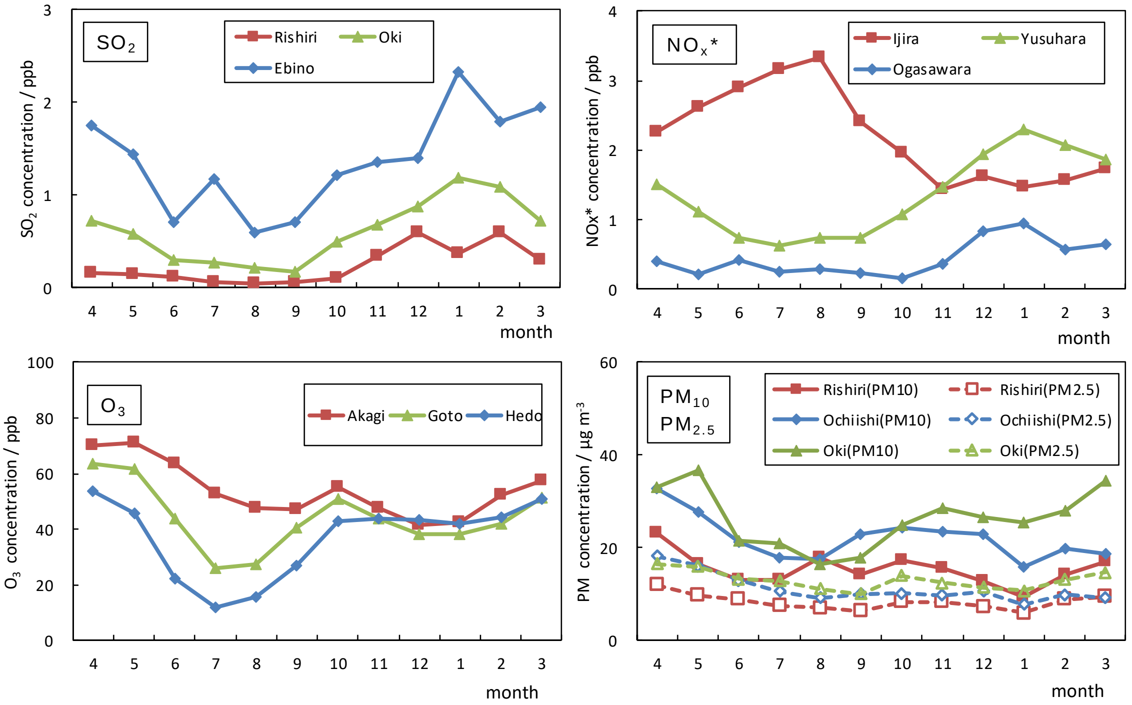

Figure 2.1.2.1 Seasonal variation of SO$_2$, NOx*, O$_3$, PM$_{10}$ and PM$_{2.5}$ concentrations (Average of JFY 2008-2012)

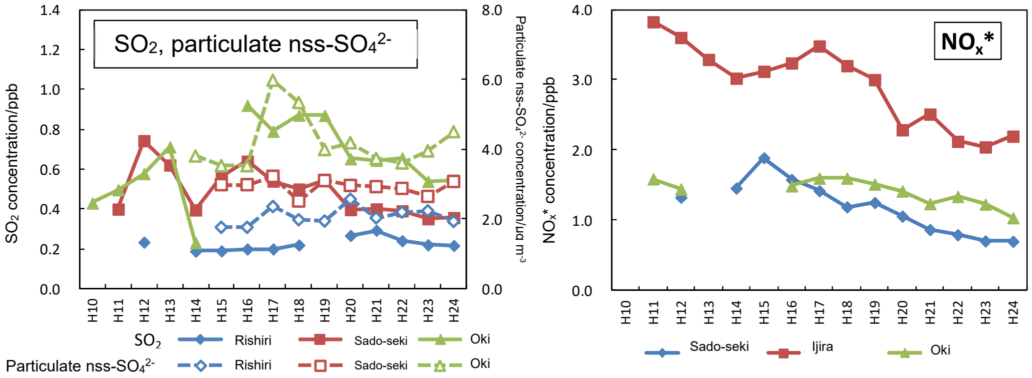

Figure 2.1.2.2 Inter annual variation of SO$_2$, particulate nss-SO$_4^{2-}$ and NOx* concentrations

2.2 State of ecological impact monitoring

2.2.1 State of soil, vegetation and inland aquatic environment

Significant trends of soil and inland water chemical properties, such as decline of pH, were observed in several monitoring sites, which seemed to be related to atmospheric deposition. Although changes in vitality of trees were observed in some part of the monitored trees, part of them could be attributed to effects of natural factors. In terms of tree growth, decline of a forest as a whole was not observed in most of the cases.

- Soil chemical properties were monitored in 25 forests in Japan. In many sites, soil was very acidic and its pH was lower than 4.5. The soil pH declined and increased significantly in 10 and 3 forests, respectively, at least 1 plots out of 2 plots, which were established in the respective forests (Figure 2.2.2.1).
- In four national parks, namely Bandai-Asahi, Daisen-Oki (Tottori Prefecture), Towada-Hachiman (Iwate Prefecture), and Yoshino-Kumano, abnormality was detected for several tree conditions, such as growth of branches, defoliation rate, changes in leaf color, etc. Some of them seemed to be attributed to natural factors, such as disease and insect attack. In terms of tree growth, decline of a forest as a whole was not observed in most of the cases.
- The pH and alkalinity were low in some of the monitoring lakes, which were considered as acid sensitive. In particular in Lake Yashaga-ike in Fukui Prefecture, central Japan, pH and alkalinity declined significantly over the last decade, which indicated progress of acidification (Figure 2.2.2.2).

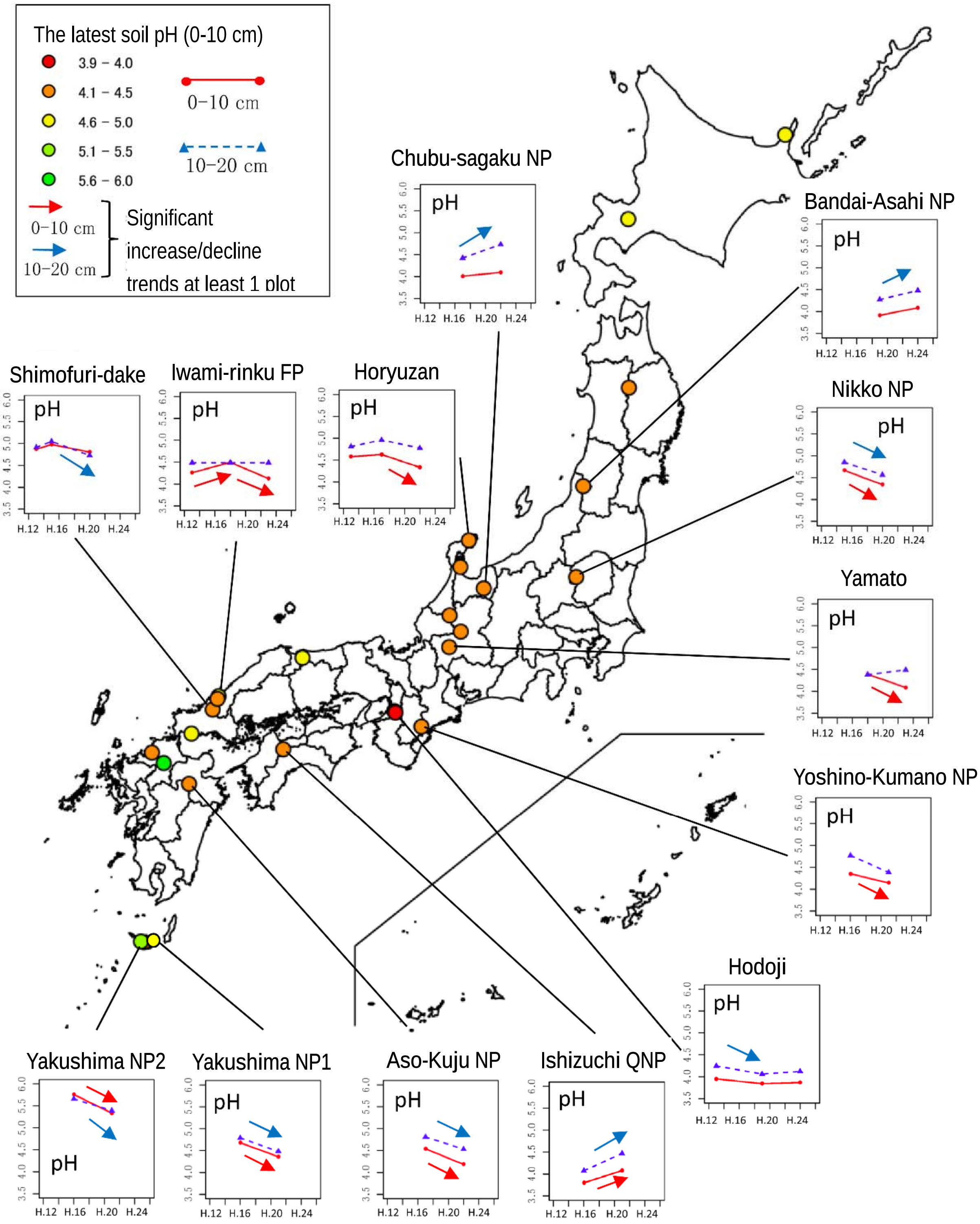

Figure 2.2.2.1 Distribution of soil pH (H_2O) and the temporal variation in the monitoring forests for soil and vegetation. NP, National Park; QNP, Quasi-national Park; Two plots were established in each forest; The data show mean values of 2 plots. In Iwami-rinku FP, the pH in one plot declined continuously and those in another plot once increased and then declined. H, Heisei era in Japan; H12, H16, H20, and H24 in the X-axis correspond to JFY2000, 2004, 2008, and 2012, respectively.

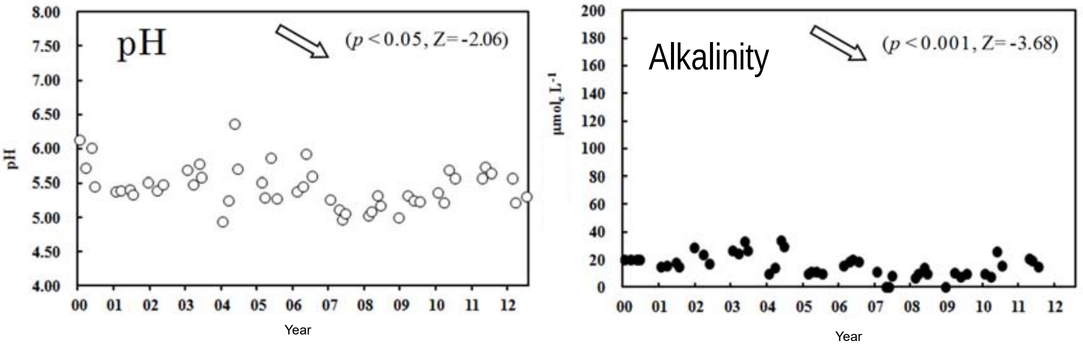

Figure 2.2.2.2 Trends of pH and alkalinity in surface water of Lake Yashaga-ike, Fukui Prefecture, Central Japan. The arrows indicate significant trends, which were assessed by seasonal Mann-Kendall test. The negative Z score statistics indicate declining trends.

2.2.2 State of catchment monitoring

Soil acidification and nitrogen saturation have been reported in Lake Ijira catchment. Although the symptoms of recovery were observed temporarily, it was still not clear.

- The output of SO_4^{2-} from the river exceeded the input from the atmosphere. It was suggested that sulfur accumulated in soil surface of the catchment in the past has been leaching.
- Concentrations of NO_3^- in the river water were still high even in summer, when nitrogen uptake by forest vegetation appeared to be active. Recovery from nitrogen saturation is still not clear. Consequently, it is important to monitor the catchment more carefully hereafter.

(The data on the catchment monitoring in Lake Ijira are also discussed in the Regional Assessment of PRSAD3. Please refer to Chapter 6 of the Regional Assessment.)

2.2.3 Identification of high-risk areas for acidification

High-risk areas for acidification of soil and inland water were identified as the “areas to be monitored”.

- The areas having a high potential risk of acid substances were identified as the “areas to be monitored” for acidification risk. The forest areas, whose soil and/or geology are acid-sensitive and in which cumulative acid loads derived from atmospheric deposition are high, may have a high risk of acidification for soil and/or inland water. Based on the hypothesis above, three risk factors, namely “soil sensitivity”, “sensitivity of geology”, and “cumulative acid loads for 25 years”, were weighted and overlapped on the map, and then the high-risk areas were identified for soil and inland water (Figure 2.2.3.1).
- The high-risk areas were found mainly in the coastal area of the Sea of Japan in western Japan, western part of Kyushu Island, and Chubu region in central Japan. Within the high-risk areas, Lake Ijira catchment, Lake Sawano-ike, and northern part of Niigata were included, where the scientific papers previously reported acidification of soil and/or inland water. Horyuzan, Iwami-rinku FP, and Lake Yashaga-ike, which were reported above as acidified, were also included in the high-risk areas.

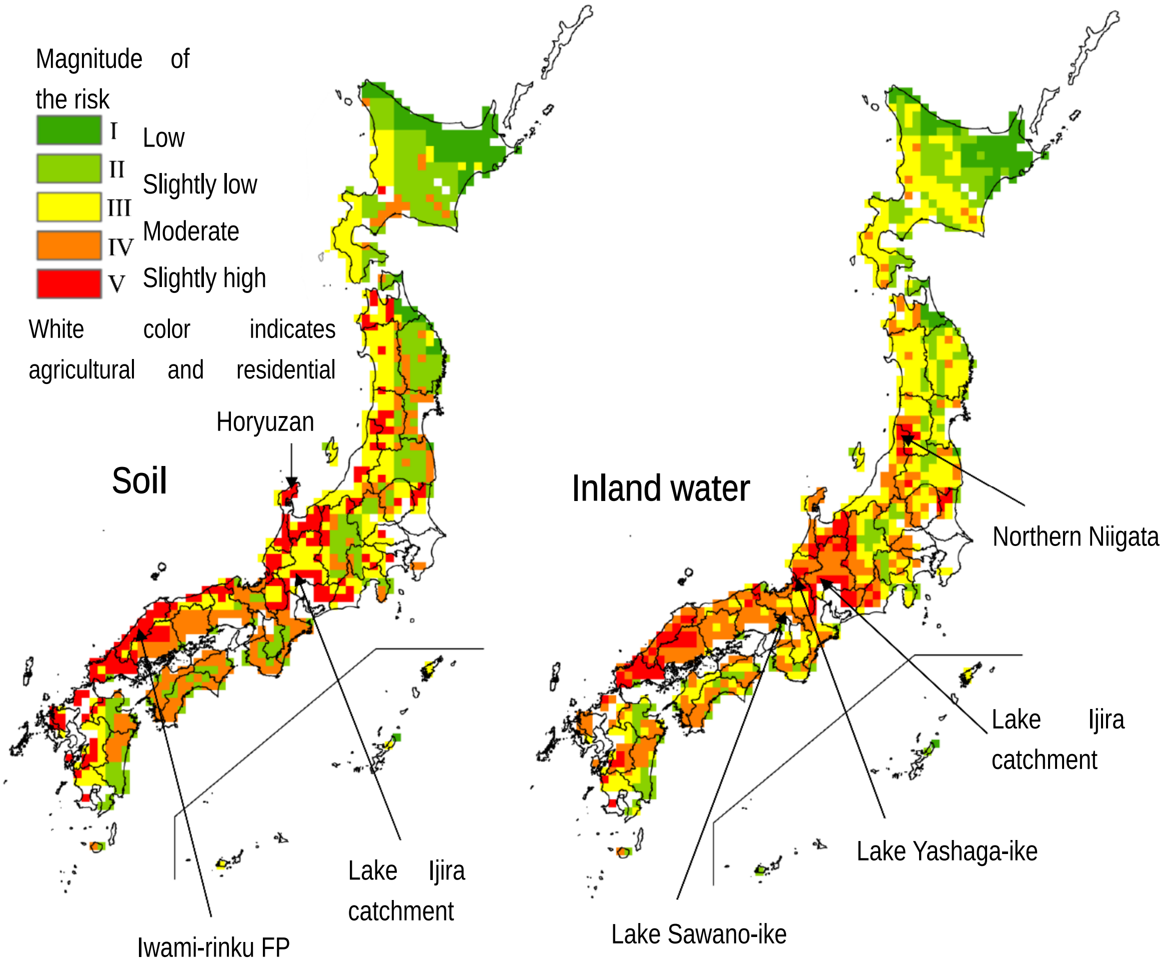

Figure 2.2.3.1 Risk map for acidification of soil (left) and inland water (right). In the locations indicated in the map, acidification of soil/inland water due to acid deposition was suggested by the monitoring results or previous studies.

2.3 Analysis on ozone and particulate matters

2.3.1 Long-term trends on ozone concentrations

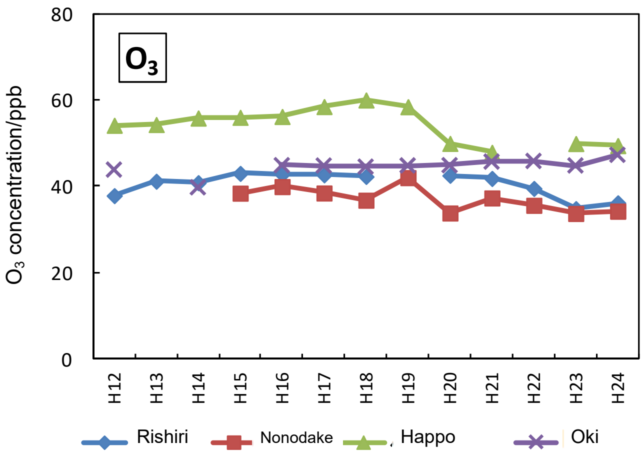

Figure 2.3.1.1 Inter annual variation of ozone concentration during JFY 2000-2012

2.3.2 Long-term trends on concentrations of particulate matters (PM_{10} and $PM_{2.5}$)

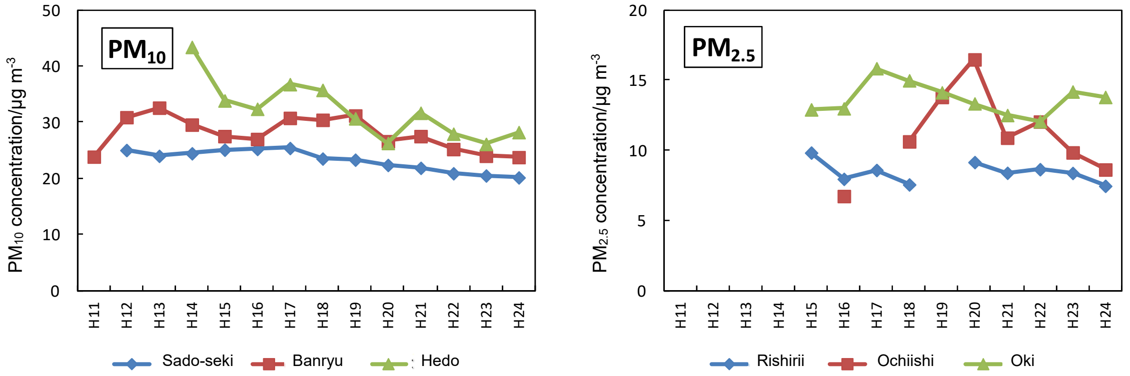

Figure 2.3.2.1 Inter annual variation of PM10 and PM2.5 concentrations during JFY 2000-2012

2.3.3 Identification of high-risk areas for effects of ozone on Japanese tree species

The areas to be monitored for evaluation of ozone effects on plants were identified for representative Japanese tree species.

- The areas, in which plants potentially suffer from effects (damage) due to exposure to tropospheric ozone, were identified as the “areas to be monitored”. In the areas, where ozone concentrations are high and plant species highly sensitive to ozone are distributed, the species suffer from the damage. Based on the hypothesis above, a reduction rate (%) of tree growth was estimated in the case that the growth with no ozone exposure was 100%.
- The growth reduction rate was estimated for 6 Japanese tree species, namely Japanese cedar (*Cryptomeria japonica*), Japanese red pine (*Pinus densiflora*), Japanese larch (*Larix kaempferi*), Japanese beech (Fagus crenata), Japanese oak (Quercus serrata), Itaji Chinkapin (*Castanopsis sieboldii*). As an index of ozone concentration, AOT40 (Accumulated exposure Over a Threshold of 40 ppb) was simulated by using a model (Figure 2.5.3.1). For the respective tree species, formulas for estimation of growth reduction due to exposure to ozone were developed by exposure tests and the results were published in scientific papers. The simulated AOT40 was applied to the formula of each tree species, and the estimated reduction rates were visualized on the map taking account of distribution of each species. The maps for beech and larch were shown in Figure 2.5.3.2.
- The high-reduction rates were found in Hokuriku region and Niigata Prefecture in Central Japan, and northern/western parts of Kanto region for Japanese beech, in Kanto, Chubu and Kansai regions and part of Seto Island Sea region for Japanese red pine, in Kanto-Koshin region (including Yamanashi and Nagano prefectures) for Japanese larch, and in northern part of Kyushu Island for Itaji Chinkapin.

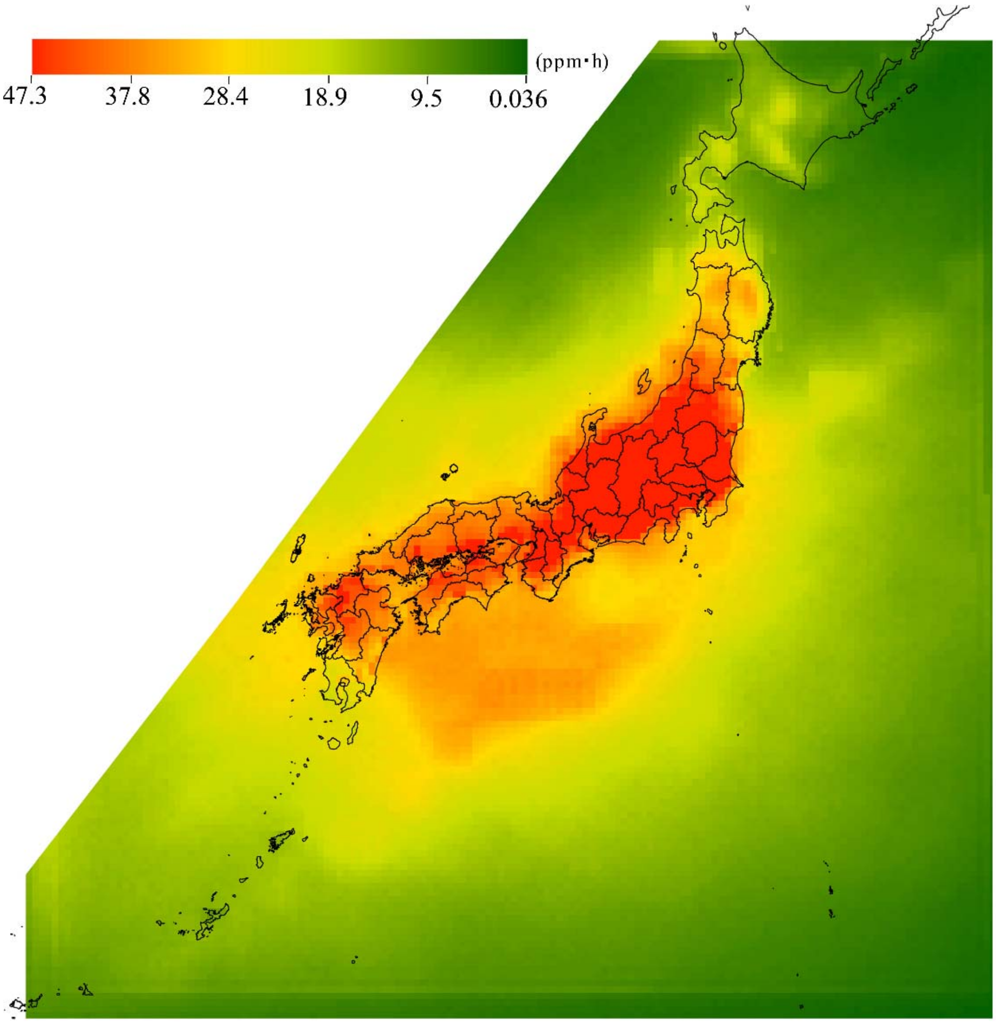

Figure 2.3.3.1 Simulated AOT40 (Accumulated exposure Over a Threshold of 40 ppb) of ozone in Japan. The emission inventory in 2009 and the meteorological condition in 2011 were used for the simulation. The results are accumulated values from April to September, 2011.

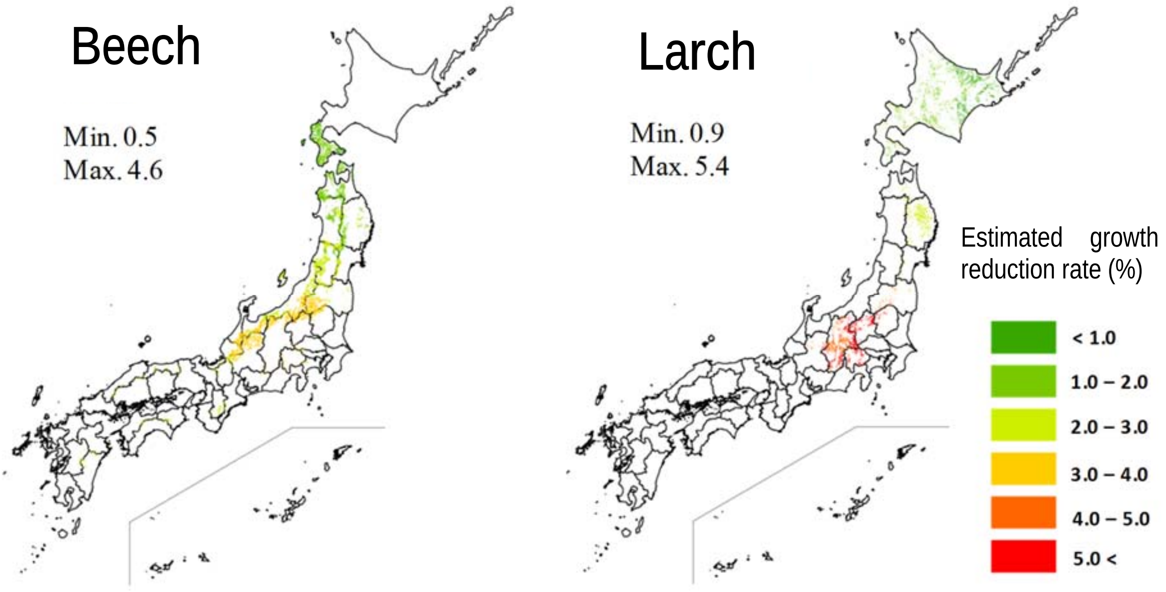

Figure 2.3.3.2 Estimated growth reduction rate of Japanese beech (left) and Japanese larch (right) trees due to ozone. The simulated AOT40 of ozone (shown in Figure 2.5.3.1) was used for the estimation. The reduction rate (%) was calculated based on the case that the growth with no ozone exposure was 100%. The map was developed based on 1 km × 1 km grid vegetation data. The white colored part indicates the area in which target species were not distributed.

2.3.4 Pilot monitoring of ozone effects on plants

In the pilot monitoring sites for ozone effects on plants, ozone concentrations were high and mortality and decline of trees were observed. It is possible that tree growth has been suppressed due to exposure to high concentrations of ozone.

- The pilot monitoring of ozone effects on plants has been conducted in Hokkaido, Niigata and Fukuoka prefectures (Figure 2.3.4.1). In Mt. Hiko-san, Fukuoka Prefecture, AOT40 was higher than the standard values (critical levels) suggested in Europe/US and Japan (Table 2.3.4.1), and mortality and decline of Japanese beech were also reported. It was suggested that tree growth has been suppressed due to exposure to high concentrations of ozone.

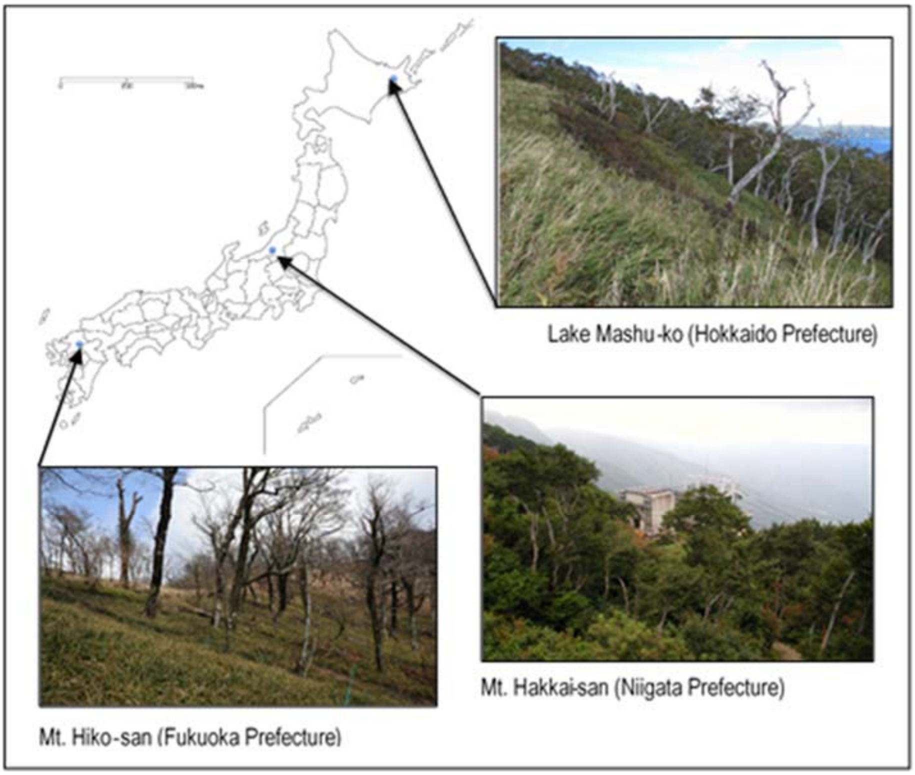

Figure 2.3.4.1 Pilot monitoring sites for evaluation of ozone effects on plants in mountainous area. Altitude: the somma of Lake Mashu-ko, 555 m; Mt. Hakkai-san, 1,165 m; Mt. Hiko-san, 790 m,

Table 2.3.4.1 Outline of ozone concentrations during the plant growing season in 2012

	Lake Mashu-ko[*1]	Mt. Hakkai-san	Mt. Hiko-san
Monitoring period	1 May – 31 October	21 June – 9 November	1 May – 31 October
Mean (ppb) [*2]	27 (29)	41	45
Median (ppb) [*2]	27 (29)	40	46
95 percentile (ppb) [*2]	45 (47)	60	77
5 percentile (ppb) [*2]	11 (13)	25	17
AOT40 (ppm·h)[*3]	1.2 (1.9)	4.7	21.8

*1 Values in parentheses indicate those of “potential ozone (PO)”, which take effects of nitrogen oxides into account.

*2 Values among all the data including those in nighttime.

*3 Accumulated exposure over a threshold of 40 ppb, during 12 hours of a day (AM6:00-PM6:00) for the monitoring periods.

Chapter 3. Review of National Air Quality Management including Acid Deposition

3.1 National Air Quality Monitoring

- In accordance with the Air Pollution Control Law, state of air pollution is constantly monitored throughout Japan at about 1,900 monitoring stations by prefectural and ordinance-designated municipal governments. There are about 1,500 ambient air pollution monitoring stations (APMSs) including national stations and about 400 roadside air pollution monitoring stations (RAPMSs) including national stations.
- Though the atmospheric concentration of nitrogen dioxide (NO_2), sulfur dioxide (SO_2), suspended particulate matter (SPM) and carbon monoxide (CO) are decreasing or stable almost below the Environmental Quality Standards (EQSs) levels, photochemical oxidant (Ox/Ozone) and fine particle ($PM_{2.5}$) are keeping relatively high level over EQSs these years. Sometimes the concentration in the high level of Ox is observed in metropolitan areas and the high level of $PM_{2.5}$ is observed in western Japan and metropolitan areas.
- 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.

3.2 The research study of strategic research and development area of the Environment Research and Technology Development Fund (ERTDF): S7

- The research study of strategic research and development area of the Environment Research and Technology Development Fund (ERTDF): S7 was carried out from 2009 to 2013 headed by Dr. Hajime Akimoto.
- The Source-Receptor (S-R) relationship for surface O_3 in East Asia is estimated for recent years utilizing the tagged tracer method with a global chemical transport model. The estimation shows the importance of intra-continental transport of O_3 inside East Asia as well as the transport of O_3 from distant source regions. In the warm season (April to September), most of the surface O_3 is attributed to O_3 created within East Asia in most areas of East Asia.

  Intensive field observation was conducted at Fukue Island in May 2009. Observation items included ozone and its precursors, as well as aerosol chemical species, size distribution, mass concentrations and optical properties. Oxidized nitrogen species ($NO_z = NO_y - NO_x$) were well correlated with O_3, suggesting that variations of surface O_3 at Fukue were controlled by photochemical processes.
- The top-down method for estimation of the long-term trend and monthly variations of NO_x emissions using satellite observation data and chemical transport model is developed. The factor analysis formula including economic growth ratio, industrial structures, plant renewal, fuel change, desulfurization facilities is proposed for quantitative analysis of driving factors of SO_2 emissions. For the purpose of linking the IPCC scenario with atmospheric chemistry science scenario, the sensitivity analysis is conducted by transplanting the benchmark emission datasets on CH_4, SO_2 and NO_x for Asian 6 countries in the AIM/CGE [Global] from the RCP (Representative Concentration Pathways) datasets to the REAS (Regional Emission inventory in ASia) in order to quantify the range of future emission scenarios due to the difference of the benchmark emission inventory.
- As for consensus building processes, it has been found that there are barriers such as low

political priority on transboundary air pollution issues to expand the scope of existing regional network. Principles of a possible framework may include step-by-step approach, Asian style gradual consensus building, emphasis on ownership by all nations, flexibility for future change/amendments etc. Incentive approach such as co-benefits approach is more realistic rather than regulatory approach, which was adopted in Europe. Two emerging initiatives, the Joint Forum on Regional Atmospheric Pollution in Asia and the Pacific, and an Asian Co-benefits Partnership were identified to be promising tools to develop a cooperative regional framework.

3.3 The research of acid deposition and air pollution in whole Japan by the Environmental Laboratories Association

- The Environmental Laboratory Association consisted of the municipal environmental laboratories of Japan has implemented the cooperative research on acid deposition in whole Japan from 1991. The data obtained in more than 150 monitoring sites by this research project were used as the fundamental data for development of the simulation modelling.
- After the research project, the association has been contributing to promotion of the research study of acid deposition of Japan through the assessment of the transboundary air pollution using the backward trajectory analysis, adoption of wet-only sampler in the world-wide standard, development/improvement of method of the concentration of gas and particles, assessment of dry deposition. Especially, Filter Pack method for monitoring of gas and particles developed/improved through this research project were adopted by EANET as the standard method.
- In recent years, the research of the Ministry of Environment, Japan stresses on the monitoring of acid deposition and long-range transportation of its precursors at the remote area from the international and global view point, the research project of the Environmental Laboratory Association stresses on the assessment of acid deposition in rural and urban area in the view point of local environment protection considering the transboundary air pollution from near countries.
- The research projects of the Environmental Laboratory Association had been carried out in the time span of 3 to 6 years, however, the 5th research project has no time-limitation involving the more accurate estimation of deposition of nitrogen element and background ozone concentration in addition to the monitoring and assessment of wet/dry deposition. The monitoring sites are: 66 of wet deposition, 34 of dry deposition of gas/particles by FP method, 36 of passive sampling method for gas concentration. The various analysis results have been obtained from the data of the research project such as long-range transportation of air pollutants and deposition in each area, and the information is openly provided through the journal of the Environmental Laboratory Association and the Japan Society for Atmospheric Environment. The information is released on the website of Global Environmental Database of Center for Global Environmental Research, National Institute for Environmental Research (http://db.cger.nies.go.jp/portal/overviews/index?lang=eng).

Chapter 4. Conclusion or Summary

4.1 Promotion of domestic activities

- It is necessary to carry out the comprehensive, long-term and continuous monitoring in line with the change of monitoring items to be stressed. Therefore the timely review of the monitoring activities is necessary such as reinforcement of the monitoring of $PM_{2.5}$ etc.
- It is indispensable to develop the precise simulation modeling so that the transboundary air pollution by acid deposition and ozone etc. can be analyzed and assessed totally and accurately. Especially, since the simulation modelling of $PM_{2.5}$ with enough accuracy has not been developed, the research study should be promoted.
- It is necessary to continue the comprehensive analysis including the effect of atmospheric deposition since the mechanism of effect on ecosystem is expected primarily to be clarified in the areas where the risk of acidification is high (high-risk areas for acidification). The stable isotope analysis can contribute to elucidate the relationship between atmospheric deposition and acidification/saturation of nitrogen in inland aquatic environment, the research study using such method is expected to be promoted.
- It is necessary to continue the pilot monitoring of the ozone effects on the plant and establish the methodology of assessment of ozone effects on the plant, gather the information on the assessment using absorption flux (the amount of ozone absorbed though stomata of leave) and phenomena of complex effects by air pollution and other (e.g. damage by insect pests).

4.2 Promotion of international activities

- It is necessary to improve the monitoring activities by motivating participating countries of EANET since the monitoring of ozone and PM have not been implemented sufficiently in EANET.
- In order to share the clean air among Asian countries, it is necessary to strengthen the regional cooperation, and consider and deploy various activities in cooperation with international organizations, networks and programs that have outstanding experiences in the field.
- It is firstly expected for solving internationally the regional (transboundary) air pollution problems in Asia that the perception on the scientific facts among Asian scientists is shared and the mechanism which provides appropriate counter-measure to policy makers can work effectively based on the perception-sharing. For the sake of that, it is also necessary to consider the establishment of framework in which scientists can discuss and send message to policy makers.

National Assessment on Acid Deposition in Lao PDR

by

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Ministry of Resources and Environment (MONRE)

1.1. Basic Information on National Monitoring Activities

1.1.1. Outline of the activities on acid deposition and national monitoring plan

Lao People's Democratic Republic (Lao PDR) is a landlocked country surrounded by Myanmar, Cambodia, China, Thailand and Viet Nam. The total land area of the country is 236,800 km^2 with a largely mountainous topography. Vientiane is the capital city, however lies on a plain. The country is bordered on the West by the Mekong River, making the river an important artery for transportation, communication and trade with other countries sharing tributaries of Mekong River.

The country has a tropical monsoon climate, characterized mainly by a rainy season (May to October) and dry season (November to April) and temperatures ranging from 5ºC to 40ºC depending on altitude. Humidity is generally high in the 70% to 80% range.

Acid Deposition issues are a fairly new phenomenon for Lao PDR and the interest in the prevention of this problem is still gaining momentum. There is lack of knowledge on various aspects of sulfur and nitrogen pollution including emissions, atmospheric transport and deposition, direct impacts of gases on human health, vegetation and corrosion of monuments and indirect impacts via changes in the soil.

Realizing the need to protect the country from the acid deposition problem, Lao PDR became one of the participating countries of EANET in November 2002. Since then, in order to ensure the monitoring activities of acid deposition in Lao PDR, the country has nominated the National Center for developed and implementing the nation monitoring plan as well as collecting the national monitoring data, promoting national QA/QC activities, public awareness raising through the acid deposition brochure and dealing with technical matters on the network activities in the country.

The national monitoring activities on acid deposition monitoring was established and started monitoring wet deposition in Vientiane capital city by collecting daily sample (during rainy season) and established the dry deposition monitoring at the same site of wet deposition monitoring. The activities also were surveyed the appropriate monitoring site for inland aquatic at the Namhum lake and collected samples and analysis for observed data.

All activities were carried out by to Environment Quality Monitoring and Hazardous Chemical Center (EQMHCC), the National Center under Water Resources and Environment Research Institute (WERI) of Water Resources and Environment Administration (WREA) until 2011 was changed its name Environment Quality Monitoring Center (EQMC), under Natural Resources and Environment Institute (NREI), Ministry of Natural Resources and Environment (MONRE).

1.1.2. Monitoring program from 2010-2015

The national monitoring plan covers the generation of the relevant data and activities, operation and maintenance of field and laboratory facilities and conduct of QA/QC activities.

- For wet deposition monitoring to collecting daily sample and analyzed was conducted at the Department of Meteorological and hydrological stations. Ministry of Natural Resources and Environment (MONRE). Measurement parameters: Precipitation amount, pH and Electric Conductivity (EC). Anion: SO_4^{2-}, NO_3^-, Cl^- and Cation: Na^+, NH_4^+, K^+, Ca^{2+}, Mg^{2+} by using Ion Chromatometry.

- For dry deposition monitoring, surveyed and established monitoring site at the Department of Meteorological and hydrological, Ministry of Natural Resources and Environment (MONRE) in Vientiane (2009) and start to collecting weekly sample in 2010. Measurements were done 12 parameters as follows: SO_2, HNO_3, HCl, NH_3, SO_4^{2-}, NO_3^-, Cl^-, NH_4^+, Na^+, K^+, Ca^{2+}, Mg^{2+} by using the Ion Chromatography.

- For ambient air quality monitoring established monitoring site at the Department of Meteorological and hydrological, Ministry of Natural Resources and Environment (MONRE) in Vientiane Capital (2013) and start to analyses by using the automated. Measurements were done 2 parameters: NO_x and PM_{10}.

- For ambient air quality monitoring mobile unit established monitoring at prime minister 'office (PMO) and Ministry of Natural Resources and Environment (MONRE) in (2014). Measurement parameters: NO, NO_2, NO_x, PM_{10}, SO_2, O_3, CO and VOCs.

- For inland aquatic monitoring to survey monitoring site at Namhum lake and collected sample in 2010 and analyses follow the EANET manual parameters: pH, EC, Alkalinity. Anion: SO_4^{2-}, NO_3^-, Cl^-, PO_4^{3-} and cation: Na^+, NH_4^+, K^+, Ca^{2+}, Mg^{2+}, by using IC.

- For raising awareness and training on acid deposition to conducted national awareness workshop on acid deposition for relevant ministries and for the primary school teacher and student from National University of Laos (NUOL) especially Faculty of Science and Faculty of Environmental Science.

- To participant the activities analysis samples of inter-laboratory comparison project on acid deposition: Wet and Dry and Inland.

1.1.3. Monitoring stations

The acid deposition station in Lao PDR

Table 1.1.1. Acid deposition monitoring sites in Lao PDR.

Site category	Site classification	Location
Acid deposition monitoring Site: Wet deposition	Urban	Vientiane capital (Department of Meteorological and hydrological, Ministry of Natural Resources and Environment (MONRE)
Acid deposition monitoring Site: Dry deposition	Urban	The same as the wet deposition monitoring site
Ambient Air Quality Monitoring Station	Urban	The same as the wet deposition monitoring site
Ambient Air Quality Monitoring Site: Mobile Unit	Urban	Prime minister ‘office (PMO) and Ministry of Natural Resources and Environment (MONRE)
Ecological survey site: Inland aquatic monitoring	Rural	Namhum lake Vientiane capital
Ecological survey site: Soil and Vegetation monitoring	not start yet	

Figure 1.1.1. Monitoring station for wet and dry deposition.

Figure 1.1.2. Ambient Air Quality Monitoring Mobile Unit.

Figure 1.1.3. Ambient Air Quality Monitoring Station

1.1.4. Sampling and measurements

Rainwater samples for wet deposition monitoring were collected by the "Wet only sampler" installed on site. Gas and aerosol samples for dry deposition monitoring were collected by filler pack. Lake water samples were collected directly to the sample containers. The analytical methods were following by the EANET manuals. For the ambient air quality monitoring, mobile unit and station its real-time measurement.

1.2. State of Acid Deposition in Lao PDR

1.2.1 Atmospheric deposition

The global climate is changing. All witness changes are in average temperatures, shifts in seasons and an increasing intensity of extreme weather events. In Lao PDR, the effects of climate change are already visible and will become more evident in the future. Currently accurate predictions of the potential changes in climatic conditions and resulting adverse impact of such changes have not been developed nationally by the Lao PDR but some indication can be taken from preliminary regional level predictions.

1.2.1.1. State of wet deposition

For the period 2010-2015, a total of 111 wet deposition sample were collected in the Vientiane monitoring station and analyzed for pH, Electrical conductivity, Anion and Cation.

Table 1.2.1. Annual mean of pH and EC.

Station	Year	pH			EC (mS.m^{-1})		
		Max	Min	Annual mean	Max	Min	Annual mean
Vientiane capital monitoring site	2010	5.66	5.32	5.47	0.86	0.30	0.55
	2011	-	-	-	-	-	-
	2012	7.65	5.52	6.66	1.26	0.16	0.48
	2013	7.40	5.95	6.61	4.46	0.22	1.46
	2014	6.94	5.05	5.79	2.10	0.30	0.76
	2015	7.23	5.16	6.17	3.60	0.40	1.51

The pH values were of the range 5.05 – 7.65. The overall mean pH values were 5.47 ± 6.66. It is observed that the mean pH values were lower in 2010 and higher in 2012, the time series concentration show that there were slightly decrease and increase value in 2013-2015.

The electrical conductivity values were of the range 0.16 - 4.46 mS.m^{-1}. The overall mean electrical conductivity was 0.48 ±1.51 mS.m^{-1}. It is observed that the mean EC value higher in 2013 and lower in 2010, the time series concentration show that there were slightly decreased and increase value in 2013-2015.

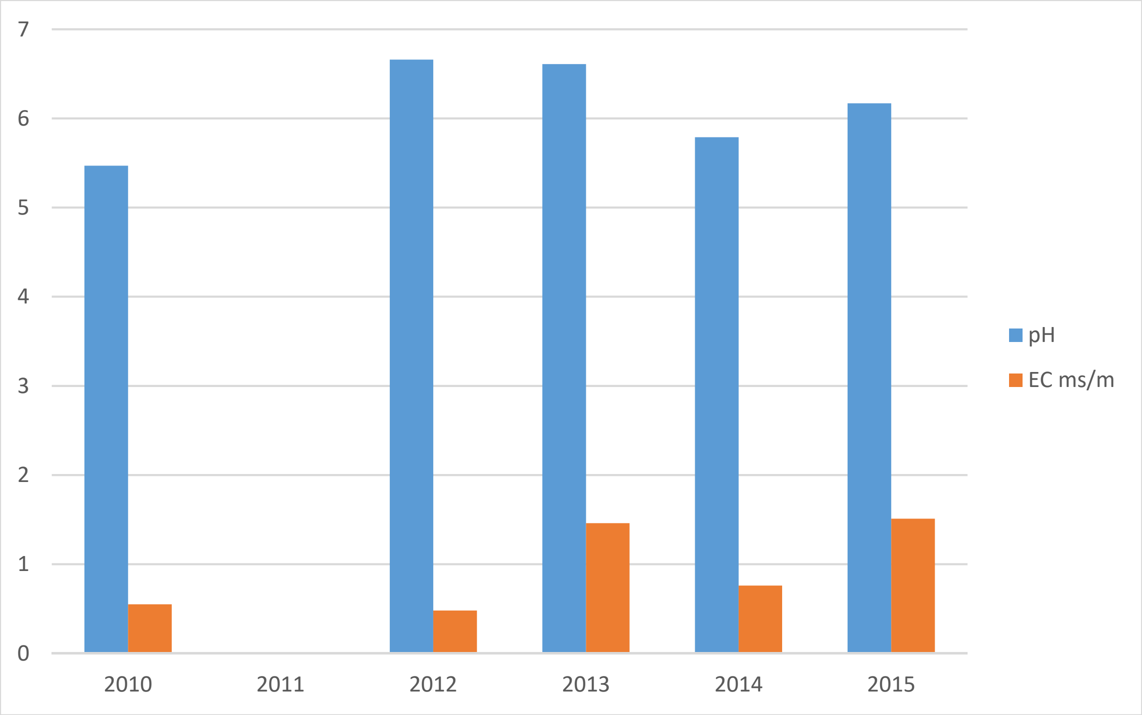

Figure 1.2.1. The values of pH and EC.

For Anions and Cations period 2010-2015, a total of 56 and 29 samples were collected in Vientiane monitoring station and analyzed for Sulfate (SO_4^{2-}), Nitrate (NO_3^-), Chloride (Cl^-), Ammonium (NH_4^+), Sodium (Na^+), Potassium (K^+), Calcium (Ca^{2+}) and Magnesium (Mg^{2+}) by using Ion Chromatography.

Table 1.2.2. The mean concentrations of anion and cation for 6 years' period in Vientiane capital city monitoring station.

Year	SO_4^{2-} $\mu mol.L^{-1}$	NO_3^- $\mu mol.L^{-1}$	Cl^- $\mu mol.L^{-1}$	NH_4^+ $\mu mol.L^{-1}$	Na^+ $\mu mol.L^{-1}$	K^+ $\mu mol.L^{-1}$	Ca^{2+} $\mu mol.L^{-1}$	Mg^{2+} $\mu mol.L^{-1}$
2010	-	-	-	-	-	-	-	-
2011	-	-	-	-	-	-	-	-
2012	2.25	3.70	4.36	-	-	-	-	-
2013	-	-	-	12.87	9.12	0.93	5.51	0.69
2014	-	-	-	-	-	-	-	-
2015	3.30	4.67	4.53	7.72	3.59	2.52	4.48	0.80

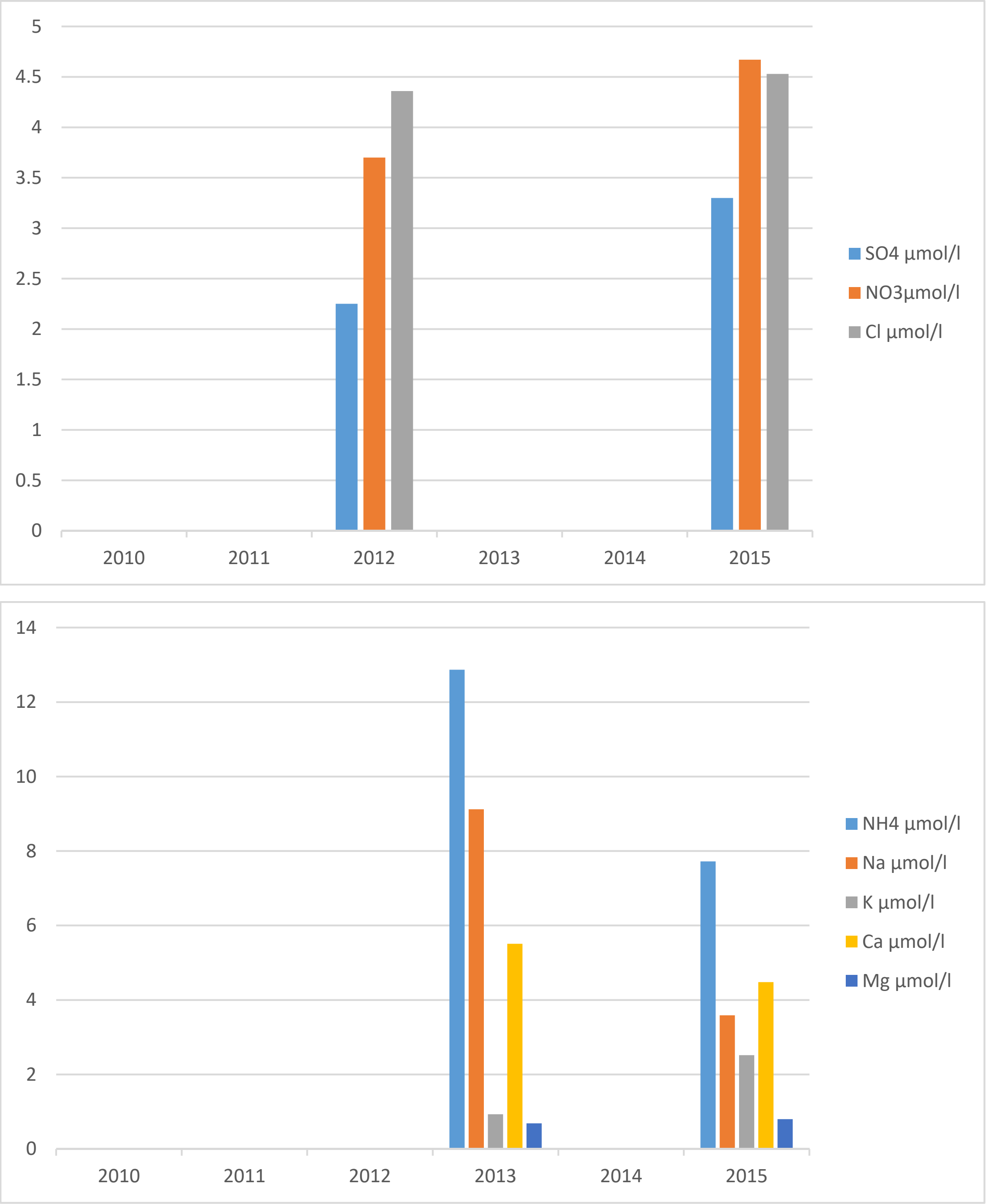

Figure 1.2.2. The values of sulfate, nitrate and chloride, ammonia, sodium, potassium, calcium and magnesium.

1.2.1.2. State of dry deposition

Lao PDR established the dry-deposition monitoring station in Vientiane (same as the wet deposition monitoring site) at the end of 2009 and will start collecting sample and analyses in 2010. But the results not available because It has some problem about the Instrument Ion Chromatography System Since 2010-2014.

Table 1.2.3. The mean concentrations of Gas and Particle for 2015 in Vientiane capital city monitoring station.

	Gas (ppb)				Particle ($\mu g/m^3$)							
2015	SO_2	HNO_3	HCl	NH_3	SO_4^{2-}	NO_3^-	Cl^-	NH_4^+	Na^+	K^+	Mg^{2+}	Ca^{2+}
Jan	0.47	0.35	0.29	2.70	7.96	0.33	0.03	0.19	0.29	0.84	0.08	0.35
Feb	0.58	0.64	0.33	3.50	7.05	0.15	0.02	1.76	0.60	0.72	0.07	0.20
Mar	0.52	0.76	0.44	3.60	6.09	0.53	0.03	1.64	0.36	0.60	0.08	0.23
Apr	0.41	0.36	0.39	3.40	3.92	0.49	0.02	1.24	0.27	0.42	0.03	0.09
May	0.35	0.19	0.43	2.90	2.15	0.59	0.08	0.60	0.22	0.18	0.09	0.16
Jun	0.52	0.20	0.20	2.80	2.61	0.51	0.08	0.86	0.24	0.13	0.06	0.25
Jul	0.2	0.14	0.27	2.40	2.34	0.70	0.14	0.71	0.26	0.12	0.06	0.33
Aug	0.21	0.11	0.25	2.40	1.95	0.76	0.14	0.59	0.36	0.14	0.04	0.25
Sep	0.27	0.19	0.18	2.00	4.00	0.16	0.02	1.26	0.12	0.17	0.02	0.18
Oct	0.15	0.12	0.34	1.50	5.35	0.41	0.07	1.65	0.17	0.21	0.03	0.17
Nov	0.47	0.26	0.22	1.70	10.19	0.71	0.08	3.09	0.23	0.46	0.05	0.33
Dec	0.13	0.20	0.34	2.70	3.34	0.27	0.03	1.09	0.22	0.30	0.04	0.15
Annual	0.36	0.29	0.31	2.63	4.75	0.47	0.06	1.22	0.28	0.36	0.05	0.22

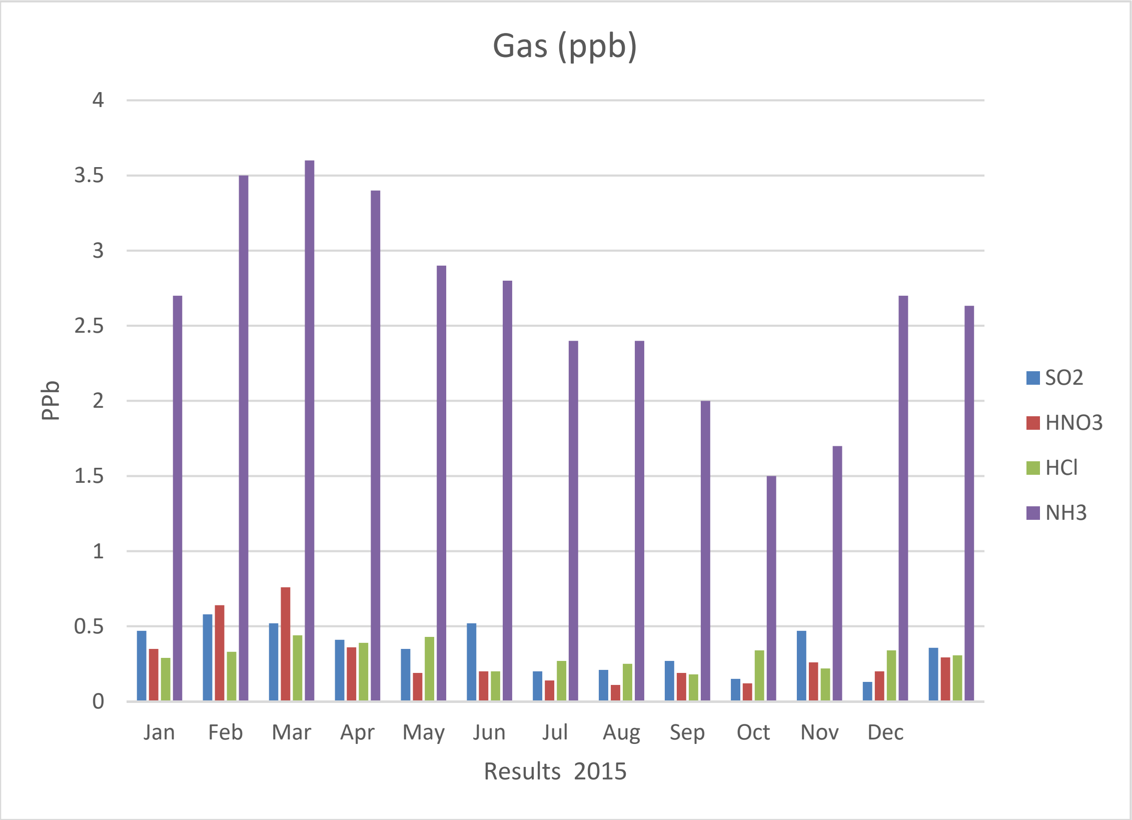

Figure 1.2.3. The values of Gas (ppb) in 2015 Sulfur dioxide, Nitric Acid, Hydrochloric Acid and Ammonia,

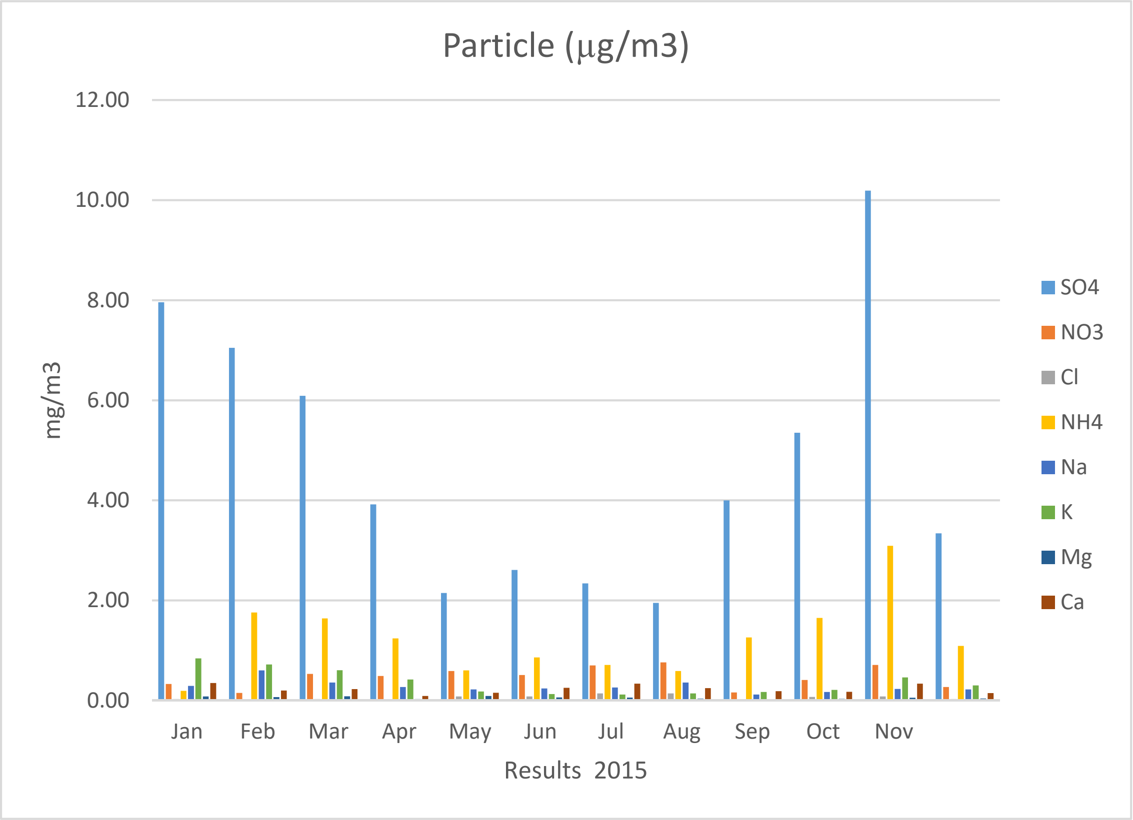

Figure 1.2.4. The values of Particulate matter (mg/m^3) in 2015

1.2.2. State of inland aquatic environment

For inland aquatic in Lao PDR were surveyed for candidate sites in Vientiane in 2005 at Namhum lake and collected sample and analyzed at the end of 2009 for observed data to consider Namhum lake as the monitoring site for inland aquatic environment. In 2010 Lao PDR started to collect sample and analyzed the parameters as the EANET manual, but the result not available because the quality of deionized water and It has some problem about the Instrument Ion Chromatography System Since 2010-2013.

Table 1.2.4. The mean concentrations of inland aquatic 2014- 2015 in Vientiane capital city monitoring station.

year	pH	EC (ms/m)	Alk (meq/L)	SO_4^{2-} (mg/)	NO_3^- (mg/)	Cl^- (mg/)	NH_4^+ (mg/)	Na^+ (mg/)	K^+ (mg/)	Ca^+ (mg/)	Mg^{2+} (mg/)	PO_4^{-3} (mg/)	DO (mg/)	COD (mg/)
2014	6.93	4.50	0.47	-	-	-	-	-	-	-	-	0.02	6.50	20.40
2015	7.08	3.68	0.45	3.02	0.03	0.77	0.01	0.80	0.43	1.34	2.28	0.03	6.50	22.71

Figure 1.2.5. View of Namhum lake monitoring site

1.2.3. State of soil and vegetation

Lao PDR has not yet decided for soil and vegetation monitoring activities at this time due to constraints for instruments and capacity building. However, the national center will consider conducting soil and vegetation monitoring in the future.

1.3. Review of National Air Quality Management

1.3.1. Air Quality Monitoring

Air quality monitoring is still not a routine practice in the country. Monitoring of the concentrations of pollutants in the air remains to be on an ad-hoc project basis. The most recent monitoring conducted was in March to April 2004 in 3 sites in Vientiane. Prior to this, a DANIDA-funded study also monitored air quality in 2003 to 2004 in 7 different sites in Vientiane.

On 09 August 2013, Lao MONRE started to monitor ambient air quality with a collaboration and supported by Pollution Control Department, Ministry of Natural Resources and Environment Thailand and Installed an onsite ambient Air Quality Monitoring station at the Department of Meteorology and Hydrology in Vientiane Capital on 08 March 2014.

NREI has a 1 monitoring station and 1 Mobile Unit (continuous and automatic) which measures pollutant (NO, NO_2, NO_x and PM_{10}) including meteorological parameters: wind speed and direction, temperature, radiation (solar and net), humidity, precipitation, pressure and rain. For the one Mobile Unit can measures all criteria pollutants (SO_2, NO_x, CO, O_3,
PM_{10} and VOCs).

1.3.2. Air quality data

The Ambien air quality monitoring station has been conducted automatic on only at most 24 h per day at Department of Meteorology and Hydrology, MONRE and air quality data results are insufficient for comparison with annual guidelines of WHO, USEPA and Lao National Environmental Standard but can only be compared with 24 hour standards.

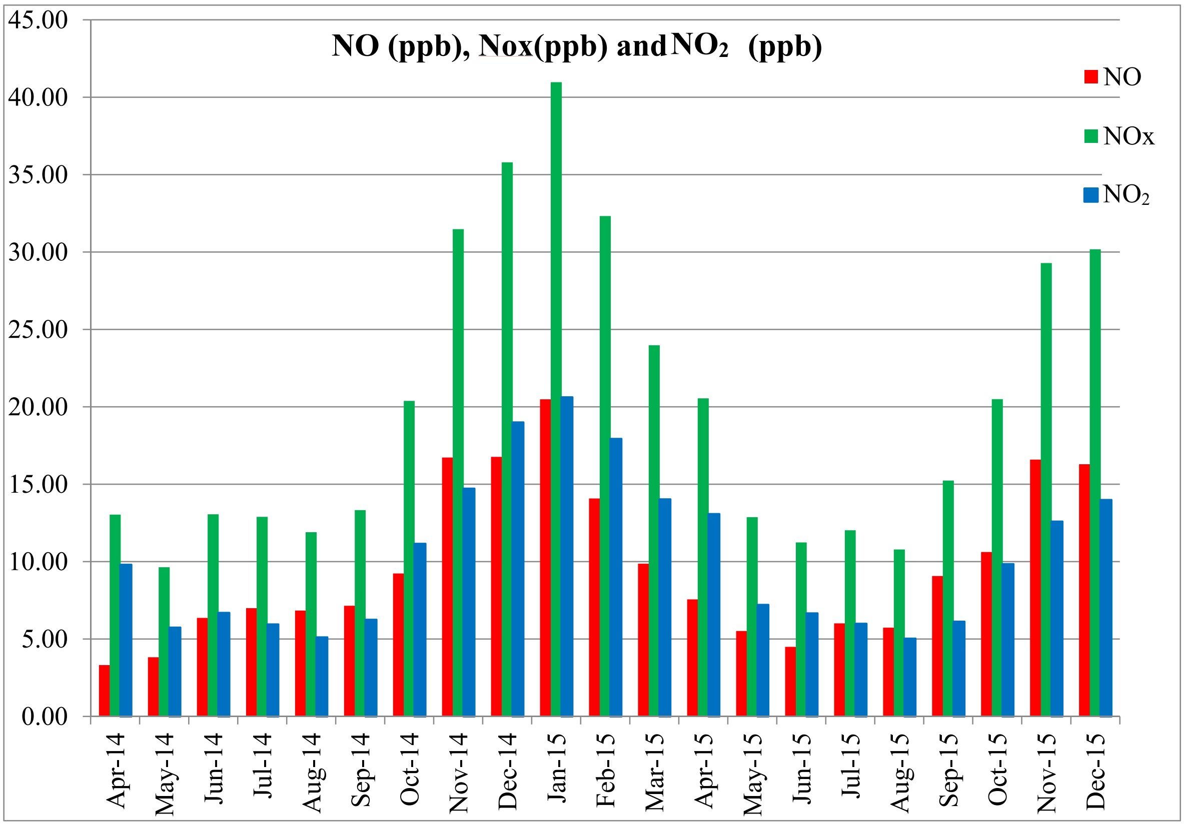

Figure 1.3.1 NO_2 monitoring results at Department of Meteorology and Hydrology in Vientiane Capital, 2014-2015

NO_2 measurements in Vientiane Capital are generally very low having only a maximum reading of 20µg/m^3. WHO does not have 24-hour guidelines for NO_2 but only has a 40µg/m^3 annual guideline and a 200µg/m^3 hourly guideline and USEPA National Ambient Air Quality Standards (NAAQS) identified 53 µg/m^3 annuals**.** Considering that most of the NO_2 readings (80.46%) in Vientiane Capital are below 10.36 µg/m^3, NO_2 is not a problem in the City (figure 1.2.5)

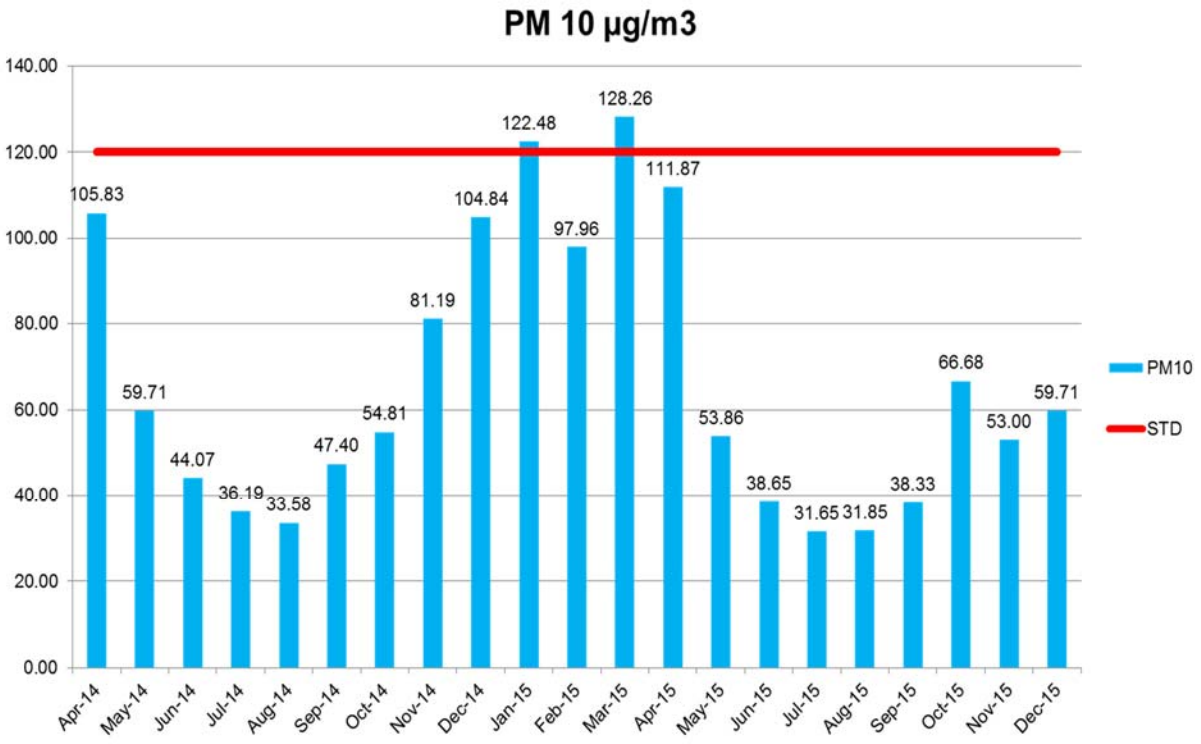

Figure 1.3.2 PM10 monitoring results at Department of Meteorology and Hydrology in Vientiane Capital, 2014-2015

PM10 monitoring results in Vientiane Capital showed a range of concentrations between 31.65µg/m^3 to 128.26µg/m^3 and an average of all 21 measurements at 66.76µg/m^3 (Figure 1.2.6). If the measurements are compared with the Lao National Environmental Standard in 2010 (120µg/m^3), only 44.37% of the measurements comply to the standard. This also suggest that PM10 is a problem pollutant for Vientiane Capital

1.3.3. Air Quality Management

1.3.3.1 Legislation and Mandate

There is no specific air pollution control act or law that provides a legal framework for air quality management in the country. Article 27 of the Lao PDR's Constitution (2013) has a provision for Lao National Environmental Standard as the basis for the environmental monitoring and pollution control on water, soil, air and noise. "all organizations and citizens must protect the environment and the natural resources: land, underground, forests, fauna, water sources and the atmosphere"

In addition to the Constitution, the Environmental Protection Law (EPL) 2013 is the main environmental legislation relevant to Lao PDR at the national level. The EPL mandates the Ministry of Natural Resources and Environment (MONRE) responsible for environmental protection. Nevertheless, MONRE and MPWT still have the decree and implemented some programs below to protect environment:

- Decree on the National Environmental Standard No. 2734/PMO.WREA dated 7 December 2009
- Decree on The Vehicles Technical Standard and Vehicles Accessory, Permit, import to register in Lao PDR No. 4312/MPWT dated 11 November 2002
- Decree on The Protection and Vehicles Facilitation No. 12302/ MPWT dated 7 September 2009

1.3.3.2. Ambient Air Quality standards

Lao PDR has not adopted ambient AQ standards but monitoring results are often compared with some standards which are much more lenient than WHO guidelines (see Table 1.3.1).

Table1. 3.1 Ambient AQ standards used for comparison with monitoring results in Lao PDR Pollutant

Parameter	Lao National Environmental Standard	WHO Standard	USEPA
PM_{10}, 24-hr	0.12 mg/m^3	0.05 mg/m^3 (WHO, 2005)	0.15 mg/m^3
NO_2, 24-hr	-	-	-
NO_2, 1 Year	-	-	0.053 mg/m^3

1.3.3.3. Management of Mobile Sources

There is no specific regulation that controls the emissions of pollutants from mobile sources. The EPL also does not stipulate any specific provisions on this sector. The Transport Policy however of the Ministry of Public works and Transport (MPWT) has also set forth policy objectives and statements strongly supporting cleaner transport technology and mode shifting to more sustainable modes. The main environmental objectives of the MPWT include reduction of emissions from vehicles, reduction of noise as well as reduction of accidents. The MPWT also has adopted the following strategies (Table 1.3.2):

Table 5.2. MPWT transport strategies

Area	Strategy
Non-motorised transport	Promotion of non-motorised transport
	Improve safety and security
Public transport	Improve comfort
	Reduce walking distances to public transport
	Decrease travel times
	Increase service frequency
	Improve reliability and punctuality
	Provide customer information systems
	Introduce convenient fare systems
	Introduce high-capacity vehicles, where appropriate
	Integrate public transport fully with other modes
	Use cleaner fuels for public transport
	Integrate land-use and public transport planning
	Establish appropriate institutional structures for managing public transport
Private vehicle restriction measures	Provide priority for public transport in road space
	Reduce private vehicle usage through internalisation of impacts
	Introduce greater parking restrictions
	Examine potential for higher vehicle import taxation and petrol taxation

Although there is a vehicle registration system in place in Lao PDR, compliance with any emissions standards does not seem to be a legislated requirement.

Considering that the fuel for automobile use in the country is imported, it is highly probable that the automotive gasoline in use in Lao PDR is lead-free.

1.3.3.4. Management of Stationary Sources

Although Lao PDR does not have a large number of large industries, industrial air pollution from stationary sources are also managed by MONRE and the Ministry of Industry and Commerce. Stack monitoring of industries such as cement factories are also being conducted to ensure that these industries do not pollute the atmospheric environment of the country.

The environmental impact assessment (EIA) system requirements of the country for industries and establishments also are a way to monitor and regulate air pollution from the industry. The EIA system utilized in Lao PDR however is still informal and ad hoc in nature (Tan, 1998).

1.4. Conclusion

Acid deposition status and its negative impact still can be accepted in Lao PDR. However, the Water Resources and Environment (MONRE) as the agency responsible for environment quality protection at the national level. Furthermore, the government has established and implemented some programs below:

- Accessed the United Nations Framework Convention on Climate Change (UNFCCC) in 1995 and is also a signatory to the Kyoto Protocol which it was accessed in 2003.
- Completed the "National Environmental Standard" in January 2010. The standard covers ambient air, water and soil quality and emissions sources from factories and in-use motor vehicles.
- Set up the Climate Change Steering Committee, Technical Working Group and established Climate Change Office.
- Set up the Cleaner Production Project and operated by Ministry of Industry and Handicraft;
- Formulated the Sustainable Transport Strategy up to the year 2020.
- Developed the National Environment Strategy up to the year 2020 and National Environment Policy.

As a least, developed economy which is still highly agriculture based, Lao PDR's environmental challenges are just beginning. Most of these problems however relate mostly to exploitation of natural resources in the rural areas. These problems include deforestation, solid degradation and loss of biodiversity and forest cover.

Since Lao PDR has still only small urban coverage, and industrial pollution is still generally negligible, addressing urban environmental problems is still not a priority for the government. Even in the urban centers, the major environmental challenges are not directly air quality management related – water, sanitation and solid waste.

Despite the general perception that air quality in the country is still generally good and an air quality management system is still not major requirement, results of limited monitoring conducted in Vientiane already suggest that the city has PM pollution problems. The lack of technical scientific understanding on the status of air quality and their specific sources in the country will make it difficult for the government to address this PM problem. There is thus a need to start air quality management with at least a basic understanding of the country's air pollution problem through air quality monitoring and compilation of emissions inventory even on ad hoc project basis. Moreover, the Lao PDR should participate the Acid Deposition in East Asia (EANET) in order to steadily and effectively manage its air quality, specifically in the key urban areas, which would contribute to the Program implementation.

1.5. References

EANET. 2000. Technical Document for Wet Deposition, Dry Deposition and Inland Aquatic Monitoring. Niigata, Japan

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Tan, 1998. Preliminary Assessment of Lao PDR's Environmental Law. Available: http://sunsite.nus.edu.sg/apcel/dbase/Lao PDR/reportl.html

National Assessment Report on Acid position in Lao PDR 2009

National Assessment on Acid Deposition in Malaysia

Chapter I : Basic Information On National Monitoring Activities

1.1 Outline of the activities on the acid deposition and national monitoring plan

Malaysia participated in the preparatory phase of the Acid Deposition Monitoring Network in East Asia (EANET) during 1998 – 2000 and jointly implemented EANET activities on a regular basis since 2001. The Environmental Management and Climate Change Division under the Ministry of Natural Resources and Environment was appointed as the National Focal Point whereas Malaysian Meteorological Department under the Ministry of Science, Technology and Innovation as the National Center for EANET. Acid deposition monitoring in Malaysia covers 5 environmental media: wet and dry deposition, soil and vegetation and inland aquatic environment. The measured parameters and monitoring intervals are tabulated below:

Table 1.1 Measurement parameters and monitoring interval.

Items	Measurement parameters	Monitoring interval
Wet deposition	pH, EC, NH_4^+, Na^+, K^+, $Ca^{2+,}$ Mg^{2+}, SO_4^{2-}, NO_3^-, Cl^-, CH_3COO^-, $HCOO^-$, $C_2O_4^{2-}$	Weekly
Dry deposition	Gas: SO_2, HNO_3, NH_3, HCl, Components in PM: NH_4^+, Na^+, K^+, Ca^{2+}, Mg^{2+}, SO_4^{2-}, NO_3^-, Cl^-	Weekly / Biweekly
Soil	pH(H2O), pH(KCl), exchangeable (Na^+, K^+, Ca^{2+}, Mg^{2+}, Al^{3+}, H^+), exchangeable acidity	3 – 5 years
Inland aquatic environment	Water Temp, pH, EC, alkalinity, NH_4^+, Na^+, K^+, Ca^{2+}, Mg^{2+}, SO_4^{2-}, NO_3^-, Cl^-, PO_4^{3-}	4 times a year

1.2 Monitoring programme from 2010 – 2014

1.2.1 Wet and dry deposition monitoring

There are 4 monitoring sites for wet deposition and 3 monitoring sites for dry deposition in Malaysia which are designated as EANET monitoring sites. These are Tanah Rata Regional GAW Station in Pahang, Petaling Jaya Regional GAW Station in Selangor, Danum Valley Global GAW Station in Sabah and Kuching Meteorological Station in Sarawak. The monitoring activity at all sites is conducted by Malaysian Meteorological Department (MetMalaysia).

The Department of Chemistry Malaysia (DOC) conducted the chemical analysis for wet and dry deposition as well as inland aquatic samples. From 2010 to 2014, the laboratory has actively participated in the inter-laboratory comparison study conducted by EANET.

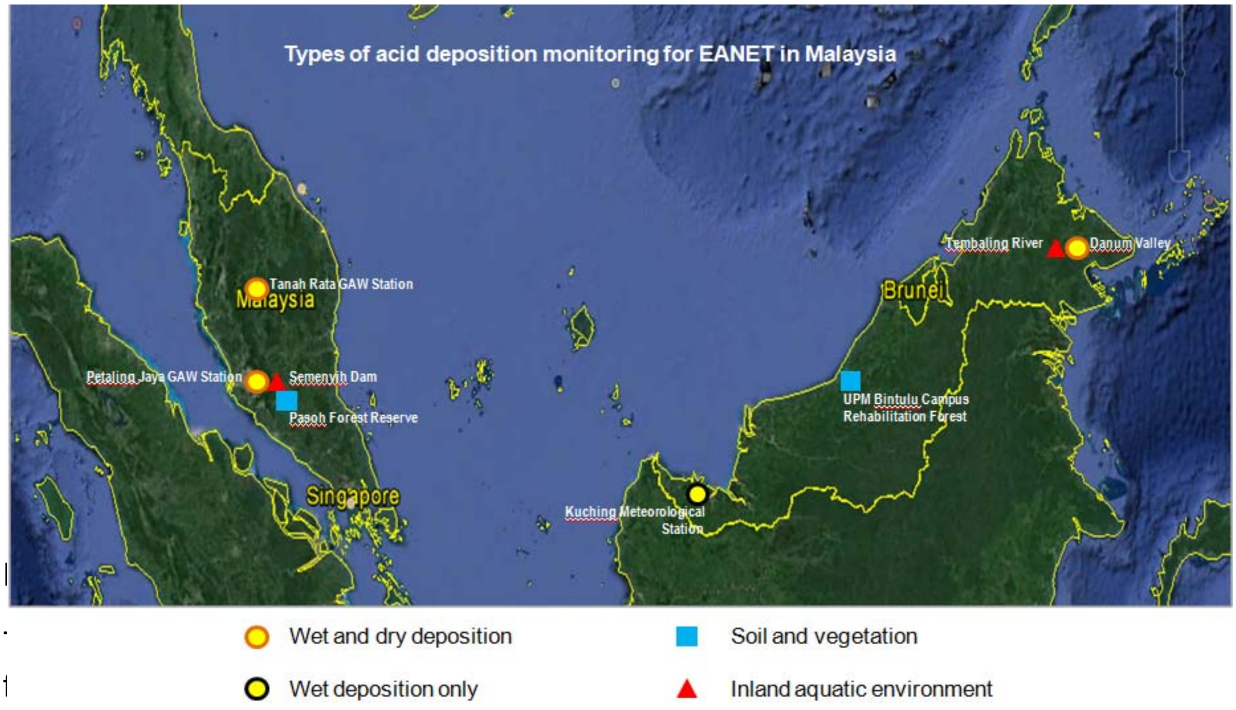
1.2.2 Soil and vegetation monitoring

Forest Research Institute Malaysia (FRIM) has undertaken the soil and vegetation monitoring at Pasoh Forest Reserve, Negeri Sembilan, while the monitoring in UPM Bintulu Campus Rehabilitation Forest in Sarawak is conducted by Universiti Putra Malaysia Bintulu Campus. The chemical analysis of the samples is conducted at the respective surveyors' laboratory facilities.

1.2.3 Inland aquatic environment monitoring

There are 2 designated EANET monitoring sites for inland aquatic environment monitoring. The monitoring activities at Semenyih Dam in Selangor is conducted by Universiti Teknologi MARA (UiTM), while at Sungai Tembaling in Sabah is conducted by MetMalaysia. The chemical analysis for the samples is conducted by DOC.

1.3 Monitoring Stations



a. Wet and dry deposition monitoring

   i. Tanah Rata Regional GAW Station (rural site)

   ii. Petaling Jaya Regional GAW Station (urban site)

   iii. Danum Valley Global GAW Station (remote site)

   iv. Kuching Meteorological Station (urban site)

b. Soil and vegetation monitoring

   i. Pasoh Forest Reserve

   ii. UPM Bintulu Campus Rehabilitation Forest

c. Inland aquatic monitoring

   i. Semenyih Dam

   ii. Sungai Tembaling (Danum Valley)

1.4 Sampling and Measurements

1.4.1 Wet deposition sampling and analytical methodologies

The wet deposition sample at all sites was collected using the wet-only sampler. The rainwater sample was collected on weekly basis and stored in polyethylene bottles. Biocide (thymol) was used to retard the degradation of organic compounds as well as ammonium and nitrate ions. The samples were then sent to DOC for chemical analysis of the principal anions and cations.

The analytical method used has fulfilled the requirements of the technical manual and is shown in Table 1.2.

Table 1.2 Measurement and analytical methods.

Parameter	Measurement/analytical methods	Manufacturer/Type of equipment	Detection limit
pH	Glass electrode	Mettler Toledo Education Line EL20	-
EC	Conductivity cell	Mettler Toledo SevenEasy	0.06 uS/cm
SO_4^{2-}	Ion Chromatography	DIONEX USA / DX-600 and ICS-2000 Anion System	0.04 umol/L
NO_3^-			0.03 umol/L
Cl^-			0.20 umol/L
CH_3COO^-			0.05 umol/L

$HCOO^-$			0.10 umol/L
$C_2O_4^-$			0.07 umol/L
NH_4^+	Ion Chromatography	DIONEX USA / DX-600 and ICS-2000 Cation System	0.20 umol/L
Na^+			0.40 umol/L
K^+			0.08 umol/L
Ca^{2+}			0.50 umol/L
Mg^{2+}			0.40 umol/L

1.4.2 Dry deposition sampling and analytical methodologies

The dry deposition sample was collected using the filter pack at all 3 sites. Sampling in Tanah Rata and Petaling Jaya was done weekly whereas in Danum Valley it was done biweekly due to the remote locality of the station as well as low concentration of acid deposition at the surrounding area.

For 2010 to 2014, monitoring activities using the passive sampler was still conducted at the same sites as the filter pack. All samples from filter pack and passive sampler sampling was sent to DOC for analysis.

The measurements and analytical methods are tabulated in Table 1.3.

Table 1.3 Measurement and analytical methods.

Parameter	Measurement/analytical methods	Manufacturer/Type of equipment	Detection limit
SO_4^{2-}	Ion Chromatography	DIONEX USA / DX-600 and ICS-2000 Anion System	0.010 mg/L
NO_3^-			0.006 mg/L
Cl^-			0.009 mg/L
NH_4^+	Ion Chromatography	DIONEX USA / DX-600 and ICS-2000 Cation System	0.003 mg/L
Na^+			0.010 mg/L
K^+			0.003 mg/L
Ca^{2+}			0.020 mg/L
Mg^{2+}			0.010 mg/L

1.4.4 Soil sampling and analytical methodologies

Pasoh Forest Reserve is in the centre of the southern Peninsular Malaysia and towards the southern end of the main range. It is a mixed dipterocarp forest with a gentle topography and homogeneous terrain. A part of the Pasoh Forest Reserve was once logged under the Malaysian Uniform System (MUS) in the 1950s. The core area of the forest reserve is a residual unlogged forest that exhibits a typical structure and specis composition of lowland dipterocarp forest. The logged area of the forest reserve is a relict area of regenerating lowland forest.

Pasoh Forest Reserve is one of the most extensive researched forest in Malaysia with many researchers both from national and international programmes. A 50 ha long term ecological plot has been established since 1985 with 5 year intervals of floristic census. It is located within the primary forest of the Pasoh Forest Reserve.

Florist composition

It is reported that greater density of semi-medium (6-10 cm in diameter) and medium trees (10-30cm), a higher density of canopy forming trees with relatively smaller crowns and a higher density of non-commercial canopy forming trees in the regenerating forest (Okuda, et al, 2003). MUS aims to encourage uniform forest structure with large number of sound commercial timber trees by removing non timber trees. Okuda et al (2003) also argued that this was not done due to the high-density canopy forming trees. It is a closed canopy forest with mean canopy height of about 27.4m.

Euphorbiaceae, Dipterocarpaceae, Annobaceae, Rubiaceae and Burseraceae are the five most abundant families in the primary forest (Kochummen, 1997; Manokaran et al 1999). Cumulatively, these families' accounts for more than 40% of the total stem density of the forest (Okuda et al 2003).

Soil types and chemistry

Yamashita et al (2003) reported that the soil type consists four groups with 11 types of soil. Group 1 has one soil type, Bungor, a well-drained soil developed from shale. Group 2 has Terap, Gajah Mati, which are lateritic materials while Group 3 consists of four soil type. They are Tebok, Tebok, medium sand variants and Tawar, a series of moderately well or well drained soil. Group 4 is alluvial or riverine area with Awang, Alma, Kampong Pasu and Kampong Pusu coarse sand series. Most of the soil type are Ultisols and dominant in Group 1,2 and 3 while Group 4 is Aquults and Aquic Paleudults (Yamashita et al, 2003)

Table 1.4 shows the chemical properties of the soil in Pasoh Forest Reserve, which was reported to EANET in 2015. The values have not changes significantly from the previously reported values. Al availability is higher while available P is lower in the soils. The CEC and Al are inversely correlated to P. When the former is higher, the later gets lower and resulting in a P deficiency (Attiwill and Adams, 1993)

Table 1.4: Chemical properties in Pasoh Forest Reserve

Sample No	Location	Soil type	Plot No	Sub Plot	Layer (cm)	pH	pH (KCl)	Ca	Mg	K	Al	Na	CEC	Base Sat (%)	C	N	Av-P mgkg^{-1}
								cmol(+)kg^{-1}							Total (%)		
1	Pasoh FR	Orthoxic Tropudults	1	1	0-10	4.5	3.41	0.49	0.61	0.31	2.37	0.13	5.17	29.8	2.29	0.16	3.9
2				2	0-10	4.4	3.48	0.05	0.23	0.08	3.21	0.09	7.67	5.9	0.83	0.07	1.4
3				3	0-10	4.5	4.54	0.49	0.61	0.32	2.40	0.10	5.2	29.8	2.27	0.15	3.5
4				4	0-10	4.5	3.61	0.45	0.58	0.33	2.33	0.12	5.12	29.1	2.00	0.10	3.8
1	Pasoh FR	Orthoxic Tropudults	1	1	10-20	4.7	4.02	0.08	0.10	0.14	3.58	0.18	5.35	9.4	0.42	0.06	0.9
2				2	10-20	4.7	4.06	0.05	0.07	0.10	3.59	0.12	5.94	5.7	0.42	0.04	0.5
3				3	10-20	4.6	4.05	0.03	0.06	0.10	3.28	0.09	6.45	4.2	0.31	0.04	0.3
4				4	10-20	4.6	4.01	0.08	0.07	0.09	3.62	0.10	11.56	2.9	0.23	0.03	0.4
1	Pasoh FR	Plinthic Kandiaquults	2	1	0-10	3.9	3.47	0.12	0.14	0.10	2.99	0.10	6.42	7.2	1.76	0.16	2.5
2				2	0-10	4.1	3.57	0.02	0.03	0.03	3.42	0.03	8.01	1.4	1.03	0.08	1.6
3				3	0-10	4.2	3.51	0.02	0.0.2	0.03	3.40	0.10	7.9	1.2	2.27	0.15	3.5
4				4	0-10	4.0	4.02	0.11	0.14	0.10	2.13	0.12	6.2	7.3	2.00	0.10	3.8
1	Pasoh FR	Plinthic Kandiaquults	2	1	10-20	4.5	4.06	0.03	0.04	0.02	3.31	0.03	518	2.3	0.35	0.04	0.9
2				2	10-20	4.5	3.54	0.08	0.00	0.03	3.46	0.02	5.08	2.6	0.24	0.03	0.3
3				3	10-20	4.7	4.1	0.15	0.04	0.03	3.70	0.04	6.00	4.3	0.24	0.03	0.4
4				4	10-20	4.6	4.1	0.04	0.01	0.02	4.38	0.04	10.38	1.1	0.16	0.03	0.3

1.4.5 Inland aquatic sampling and analytical methodologies

Surface water samples were collected at 30 cm depth using a grab sampler 4 times a year. The sampling point was at the center of Semenyih Dam, while for Sungai Tembaling, the sampling point was at the estuary. pH, electric conductivity and temperature were measured in situ. The water samples were collected in polyethylene bottles and sent to DOC for analysis.

The parameters to be measured for inland samples are listed in Table 1.5.

Table 1.5 Measurement and analytical methods.

Parameter	Measurement/analytical methods	Manufacturer/Type of equipment	Detection limit
pH	Glass electrode	Mettler Toledo Education Line EL20	-
EC	Conductivity cell	Mettler Toledo SevenEasy	0.06 uS/cm
Alkalinity	Titration by burette with pH meter	Eutech Instrument pH1500 CyberScan	0.01 meq/L
SO_4^{2-}	Ion Chromatography	DIONEX USA /ICS-1000 Anion System	0.03 mg/L
NO_3^-			0.02 mg/L
Cl^-			0.004 mg/L
PO_4^{3-}			0.02 mg/L
NH_4^+	Ion Chromatography	DIONEX USA / DX-600 and ICS-2000 Cation System	0.003 mg/L
Na^+			0.01 mg/L
K^+			0.003 mg/L
Ca^{2+}			0.020 mg/L
Mg^{2+}			0.01 mg/L
COD	Spectrophotometry	HACH	1.0 mg/L

1.4.6 Submission of data to the Network Center

The monitoring data from the respective agencies were submitted to MetMalaysia. MetMalaysia compiled, validated and submitted the data to National Focal Point for approval before submission to the Network Center.

Malaysia also participated in the Inter-laboratory comparison (ILC) project on wet deposition, dry deposition, soil and inland aquatic environment.

The ILC project is a round-robin test which involves 4 analytical laboratories as Table 1.6 below.

Table 1.6 The Inter-Laboratory Comparison Project for Malaysia

Department	Code	Type of ILC project			
		Wet	Dry	IAE	Soil
Division of Environmental Health, Department of Chemistry (DOC)	MY01	/	/	/	
Faculty of Applied Science, University Technology Mara (UiTM)	MY03			/	
Universiti Putra Malaysia, Campus Bintulu (UPMKB)	MY04				/
Soil Laboratory, Forest Research Institute Malaysia	MY05				/

Chapter II : State of Acid Deposition in Malaysia

2.1 Atmospheric deposition

This assessment examines the wet deposition of sulphate and nitrate and the gaseous substances such as sulphur dioxide (SO_2) and nitric acid (HNO_3) at Petaling Jaya, Tanah Rata, Kuching and Danum Valley from 2010 to 2014.

2.1.1 State of Wet Deposition for Sulphate and Nitrate

Figure 2.1 – Figure 2.4 show the time series of monthly wet deposition of sulphate and nitrate from 2005 to 2014 for Petaling Jaya, Tanah Rata and Danum Valley sites and the time series from 2008 to 2014 for Kuching site respectively.

The highest monthly wet deposition for sulphate and nitrate at all sites was recorded as mostly occurring during the inter-monsoon seasons (April – May and September – October) every year. At Tanah Rata, the monthly wet sulphate and nitrate deposition for 2010 – 2014 maintained at lower than 5 $mmol.m^{-2}$, which is similar with the 2005 – 2009 observation. At Danum Valley, the monthly wet sulphate and nitrate deposition for 2010 – 2014 is generally below 2 $mmol.m^{-2}$, which is lower than the 2005 – 2009 observation, except for May 2013 where it recorded 3.05 and 2.97 $mmol.m^{-2}$ for SO_4^{2-} and NO_3^- deposition, respectively.

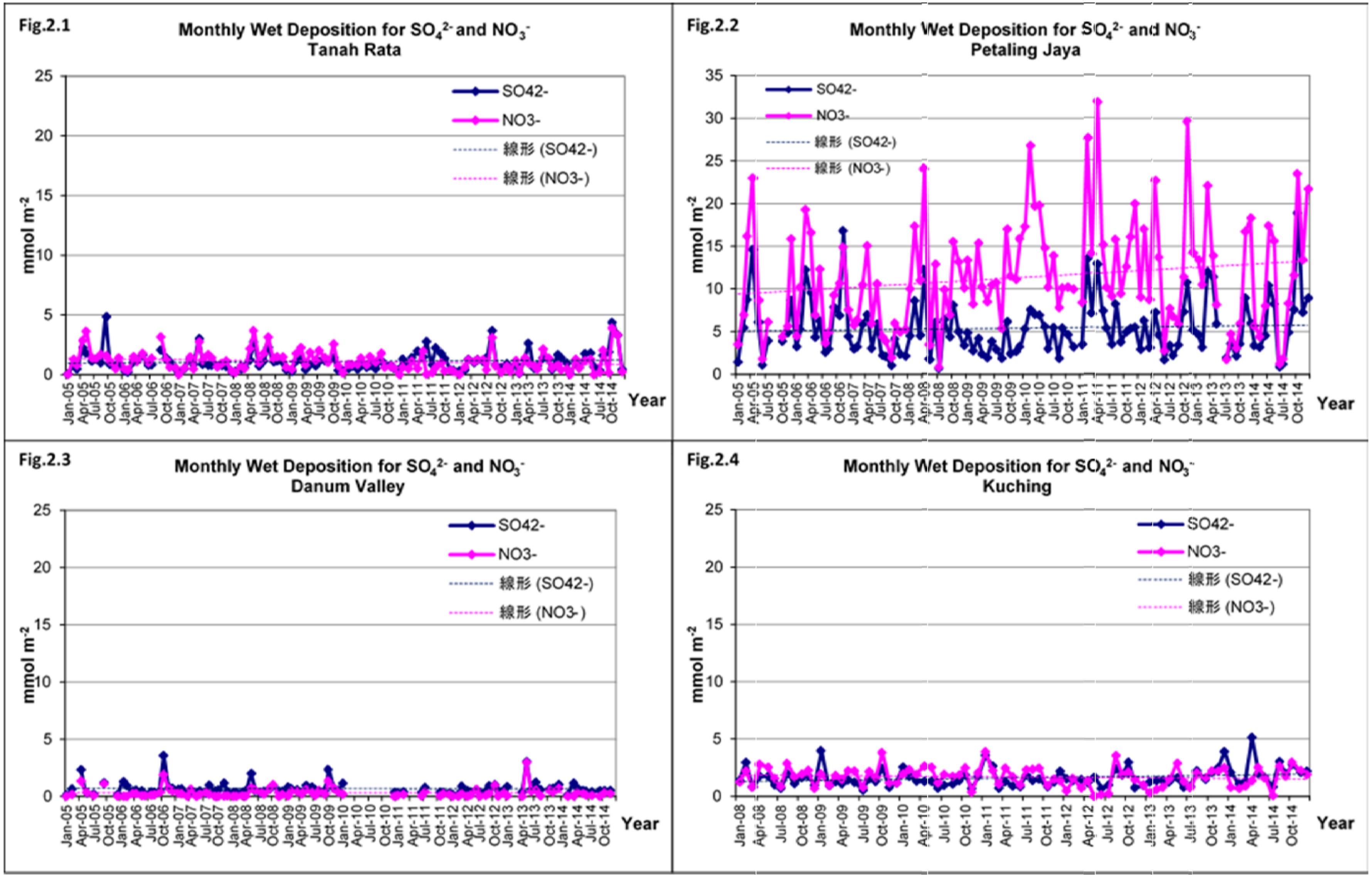


Figure 2.1 – Figure 2.4 show the time series of monthly wet deposition of sulphate and nitrate for Petaling Jaya, Tanah Rata, Danum Valley and Kuching sites.

At Kuching, the monthly wet deposition for sulphate and nitrate in 2010 – 2014 also maintains at lower than 5 mmol.m^{-2}, which is similar with the 2005 – 2009 observation, except in April 2014 where it recorded 5.14 mmol.m^{-2} for SO_4^{2-} deposition. The highest monthly sulphate and nitrate deposition at Petaling Jaya is recorded during October 2014 (18.9 mmol.m^{-2}) and April 2011 (31.9 mmol.m^{-2}), respectively.

The sulphate deposition showed a slightly increasing trend for Petaling Jaya, Kuching and Tanah Rata sites. Meanwhile, the nitrate deposition showed a slightly decreasing trend at Tanah Rata and Kuching sites. At Petaling Jaya, the nitrate deposition has been slightly increasing. At Danum Valley, there was not much change in trend recorded during the observation period.

Figures 2.5 and 2.6 show the annual wet deposition of sulphate and nitrate at all 4 sites.

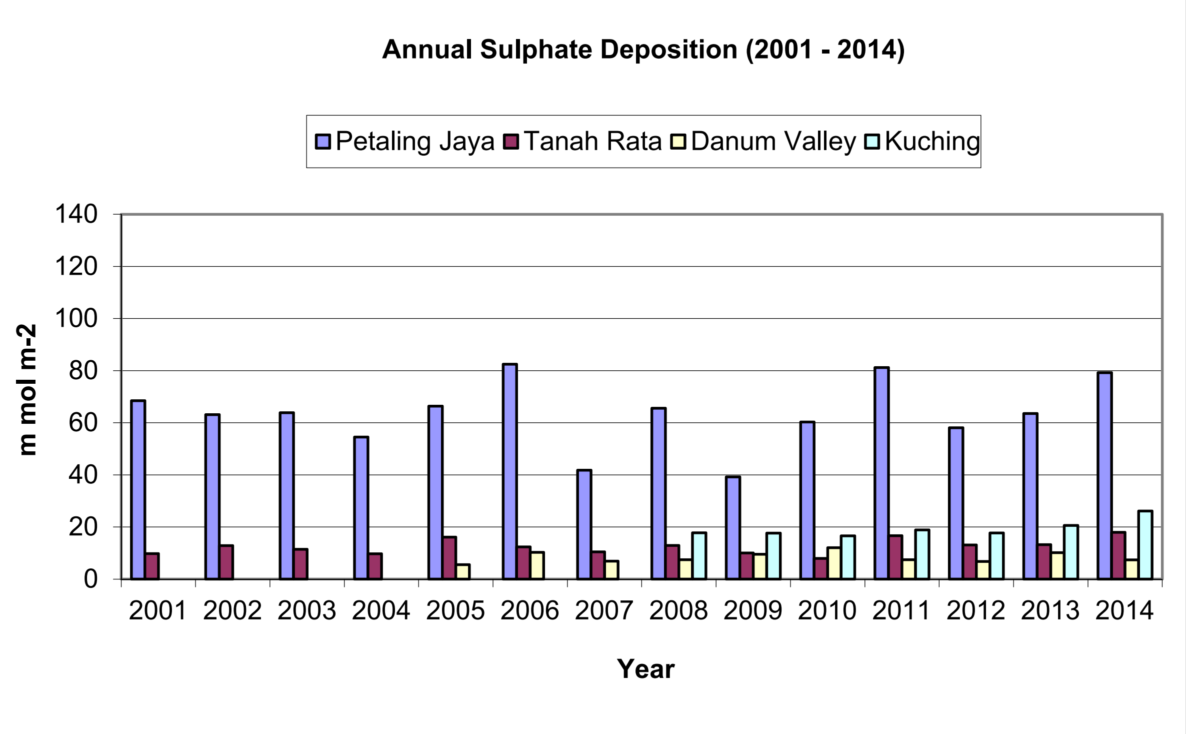


Figure 2.5 Annual sulphate deposition from 2001 – 2014

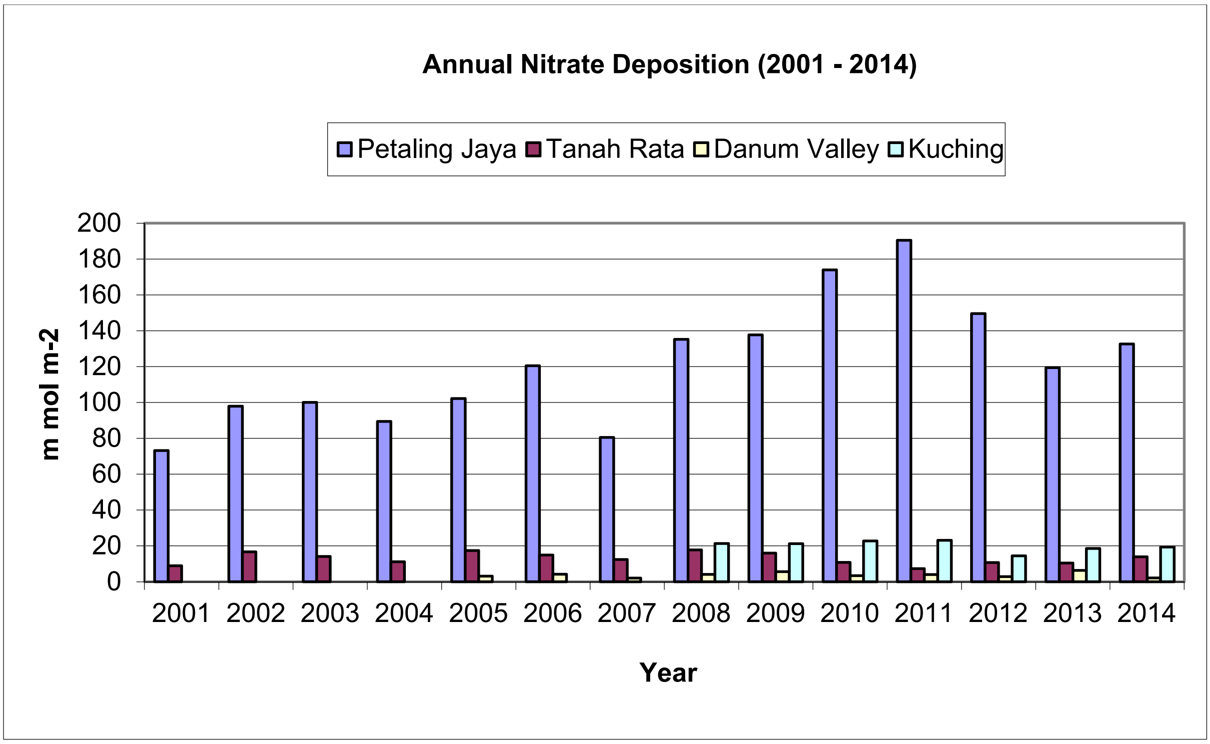


Figure 2.6 Annual nitrate deposition from 2001 – 2014

From all of the figures, it is observed that Petaling Jaya showed a much higher concentration as compared to the other sites for both sulphate and nitrate. This might be due to the Petaling Jaya monitoring station located at the urban area near the Kuala Lumpur city centre and surrounded by industrial areas with active development activities and high traffic density.

Petaling Jaya had much higher nitrate deposition compared with the sulphate deposition. As compared to nitrate, Tanah Rata, Kuching and Danum Valley had higher sulphate deposition, with small differences between the two elements.

2.1.2 State of dry deposition for Sulphur Dioxide and Nitric Acid

The filter pack method was used in Tanah Rata, Danum Valley and Petaling Jaya sites to monitor the dry deposition fluxes in Malaysia. The ambient air concentration of gaseous substances, SO_2 and HNO_3 are presented and discussed.

Fig.2.7

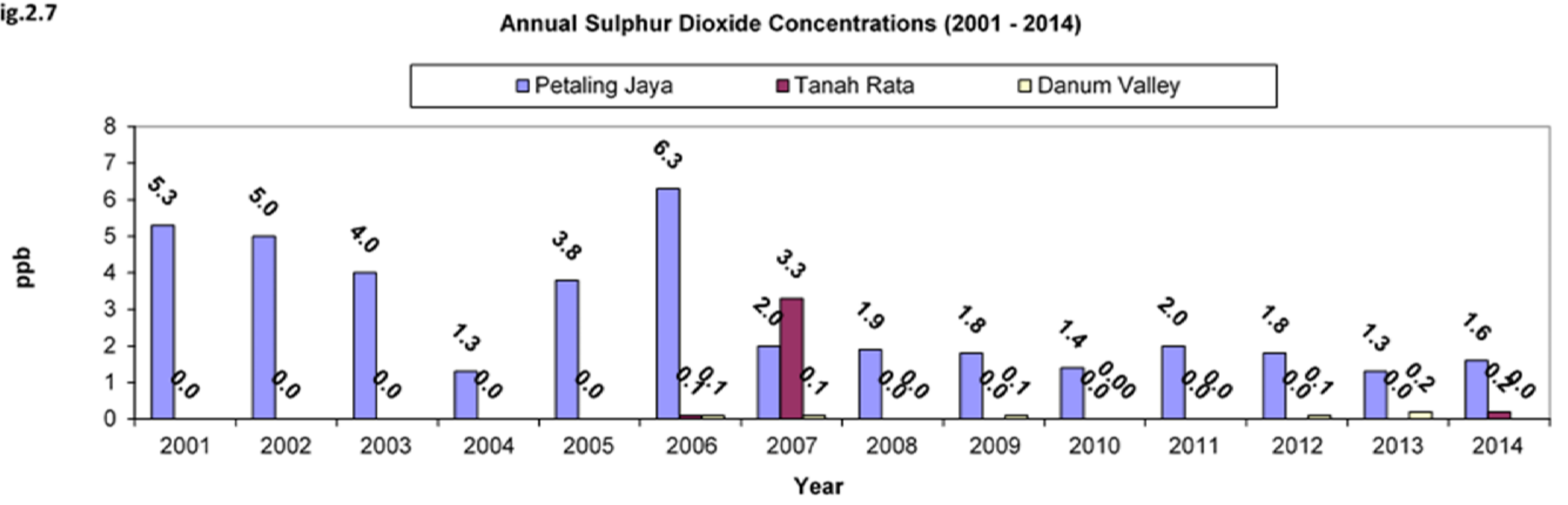


Fig.2.8

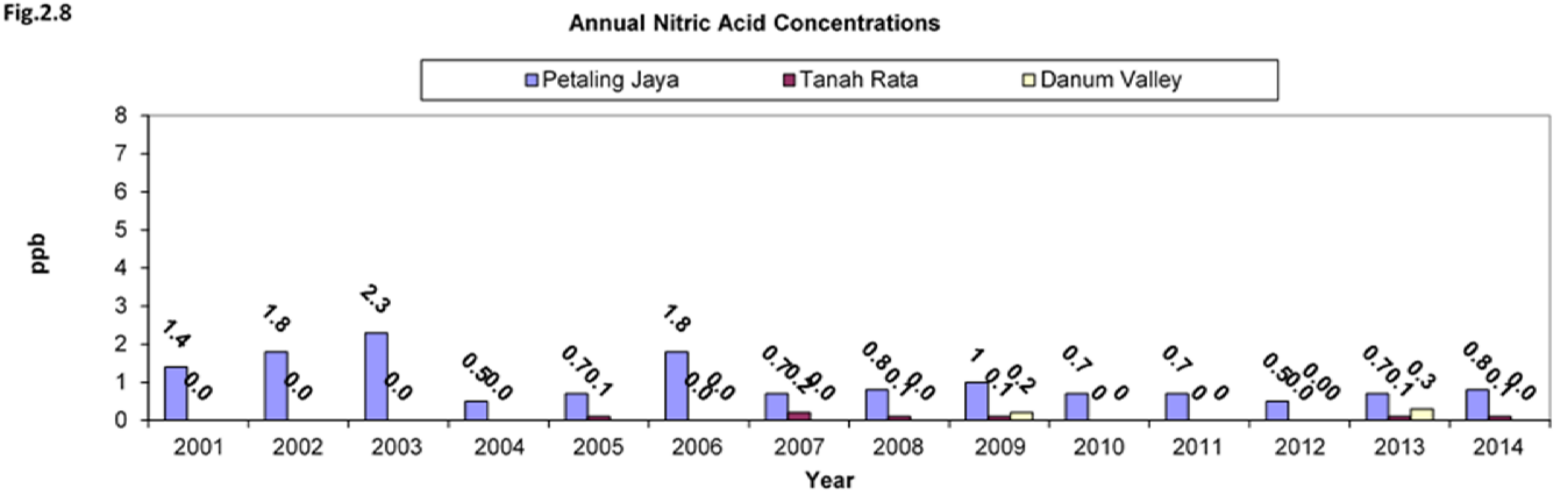


Figure 2.7 – Figure 2.8 show the annual SO_2 and HNO_3 depositions for Petaling Jaya, Tanah Rata and Danum Valley sites from 2001 – 2014.

Data under the detection limit are depicted as 0.0 in Figures 2.7 and 2.8. From these figures, Petaling Jaya has a higher deposition for both elements as compared to Tanah Rata and Danum Valley.

For SO_2, the deposition from 2010 – 2014 at Petaling Jaya showed a decreasing trend from the past 9 years' observation with concentration range between 1.3 ppb and 2.0 ppb. The concentration at Tanah Rata and Danum Valley were 0.2 ppb and below. For HNO_2, the annual concentration at Tanah Rata and Danum Valley were mainly 0.1 ppb and below while the concentration at Petaling Jaya ranged between 0.5 ppb and 0.8 ppb.

2.2 State of inland aquatic environment monitoring

2.2.1 Sampling site

The 2 sampling sites selected for inland aquatic environment monitoring are Semenyih Dam in Selangor and Sungai Tembaling in Sabah. The geographical characteristics and location are summarized in Table 2.2.

Semenyih Dam is 25 km from Kajang town and 20 km from Bangi town. Beranang, Seremban and Nilai are also located within 25 km from Semenyih Dam while Shah Alam is 80 km away. All of these towns have industries, businesses and residential areas, which could contribute to anthropogenic pollution. There is also an agricultural area located on the western side of the reservoir and forest areas on the eastern side.

Tembaling River is located in the Danum Valley Conservation Area, a protected forest reserve area. It is a remote area within the Lahad Datu district of Sabah.

Table 2.2 Geographical characteristics and location of sampling sites.

	Semenyih Dam	**Tembaling River**
Location	Selangor, Malaysia	Danum Valley, Sabah
Lat/long	03° 04.574' N 101° 53.058' E	04° 57' N 117° 48' E
Altitude	230 m a.s.l.	427 m a.s.l.
Origin	Dam	Natural stream
Type of site	Semi urban	Remote

Fig.2.9

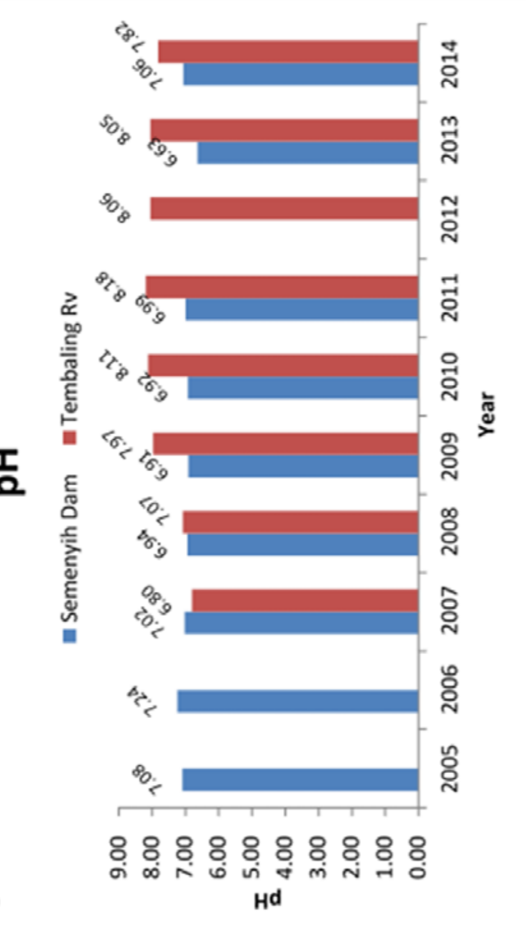


Fig.2.10

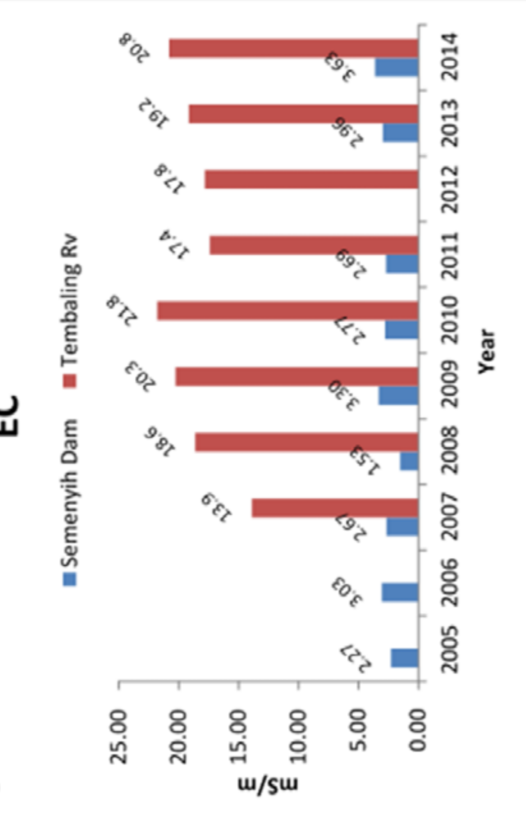


Fig.2.11

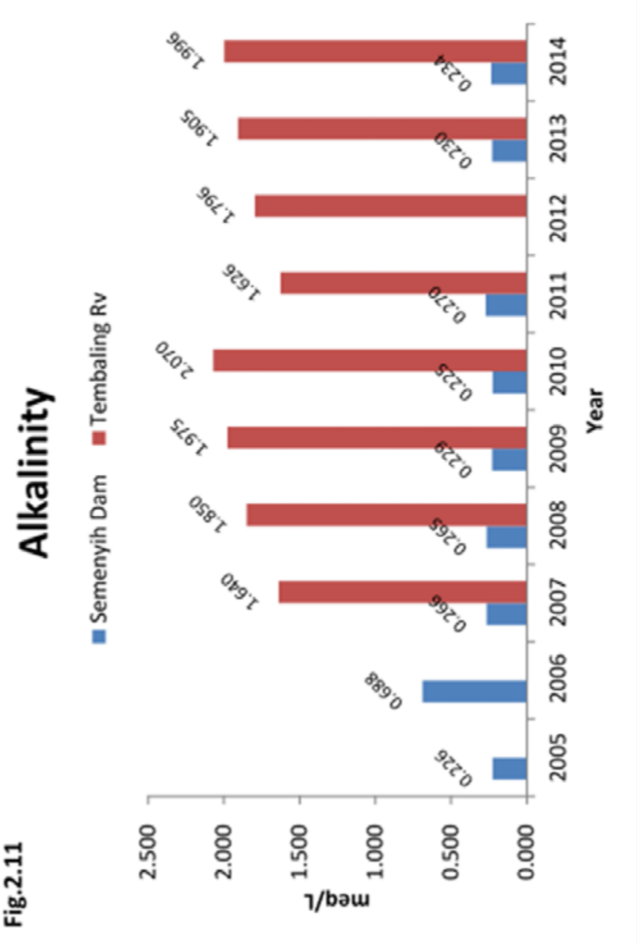


Fig.2.12

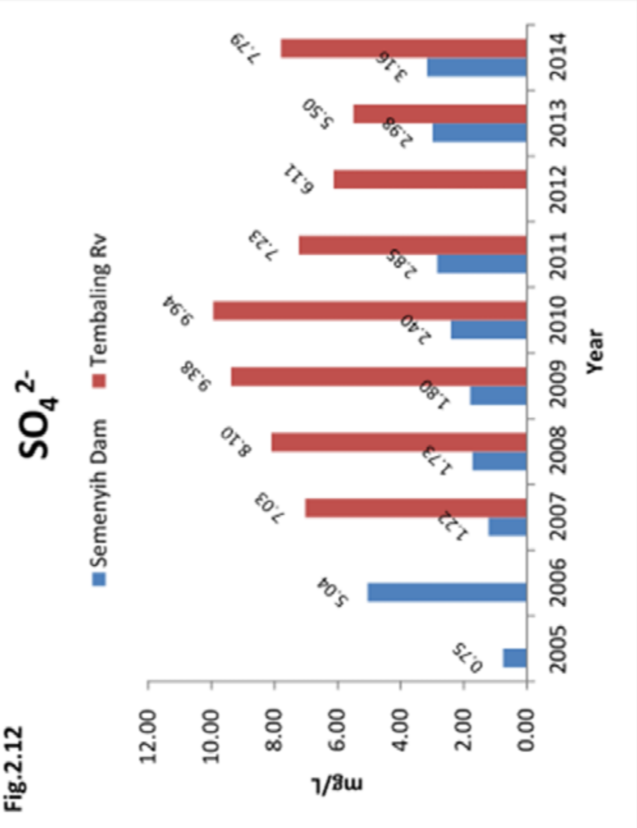


Fig.2.13

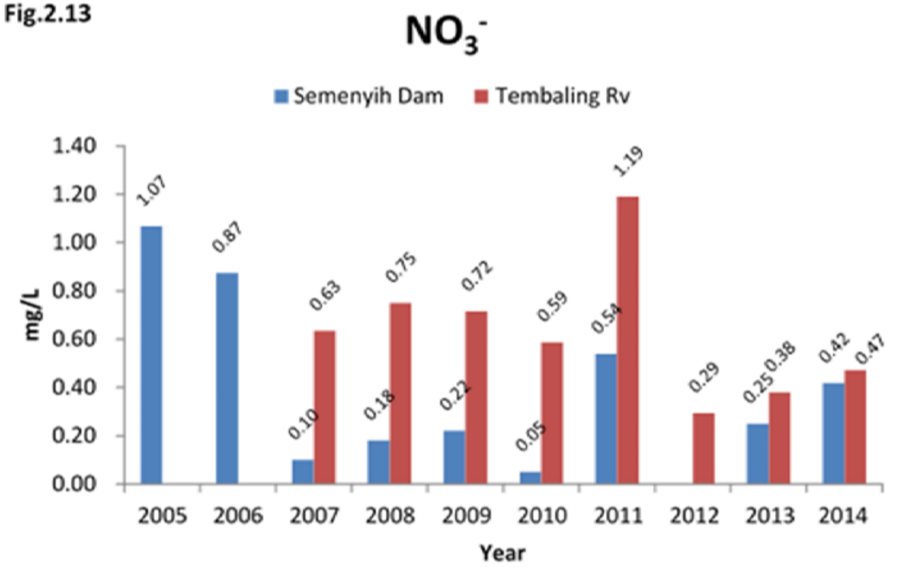


Fig.2.14

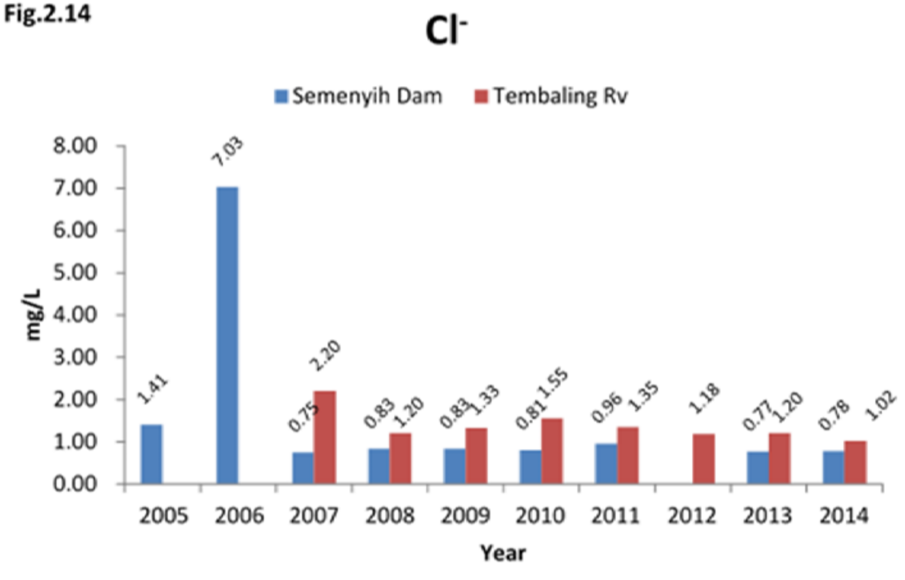


Fig.2.15

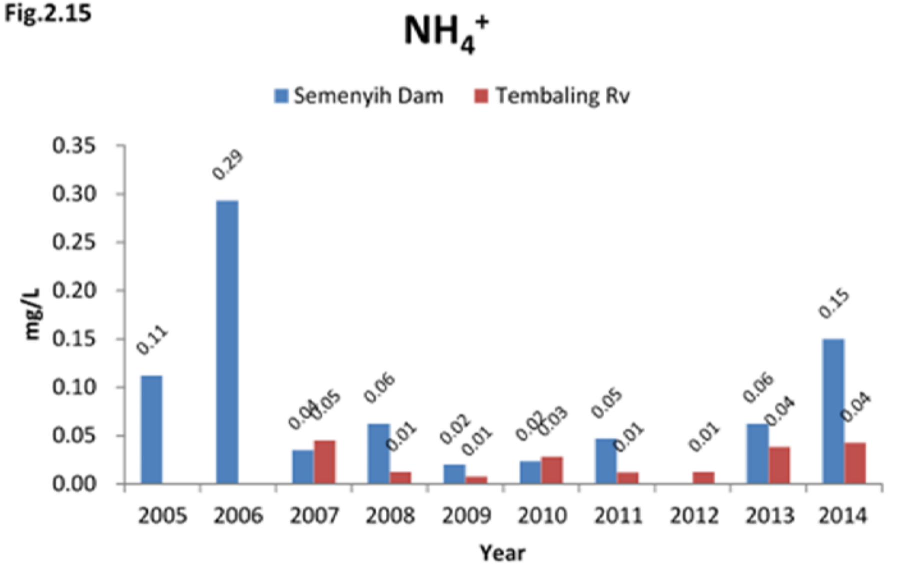


Fig.2.16

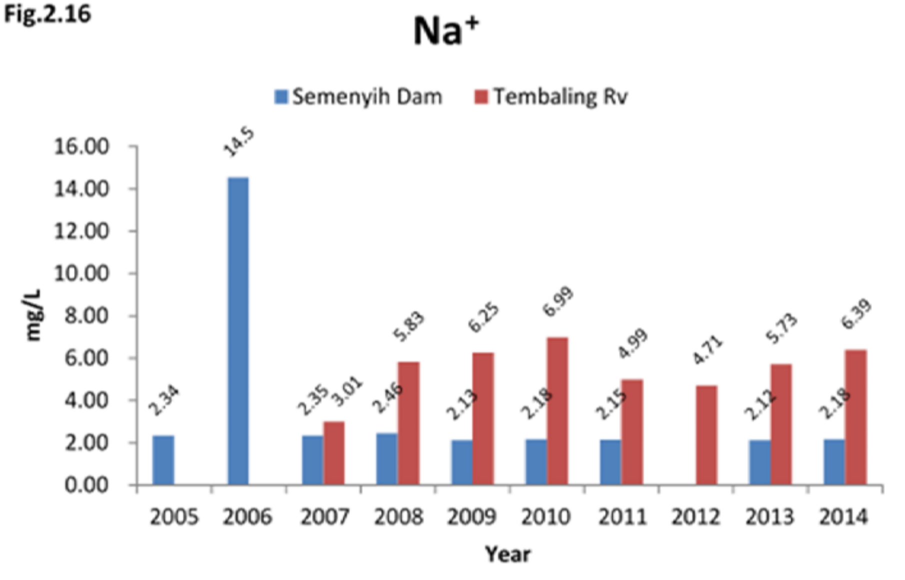


Fig.2.17

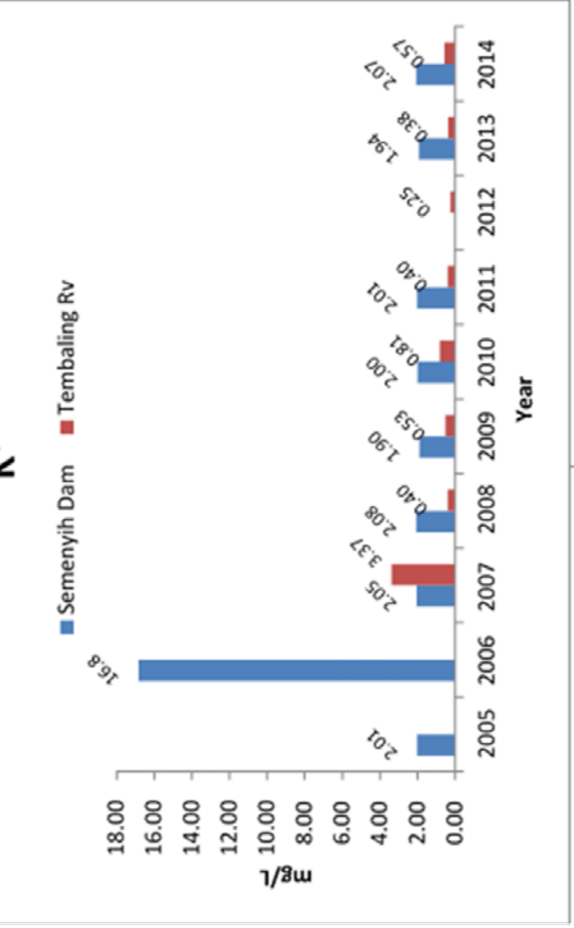


Fig.2.18

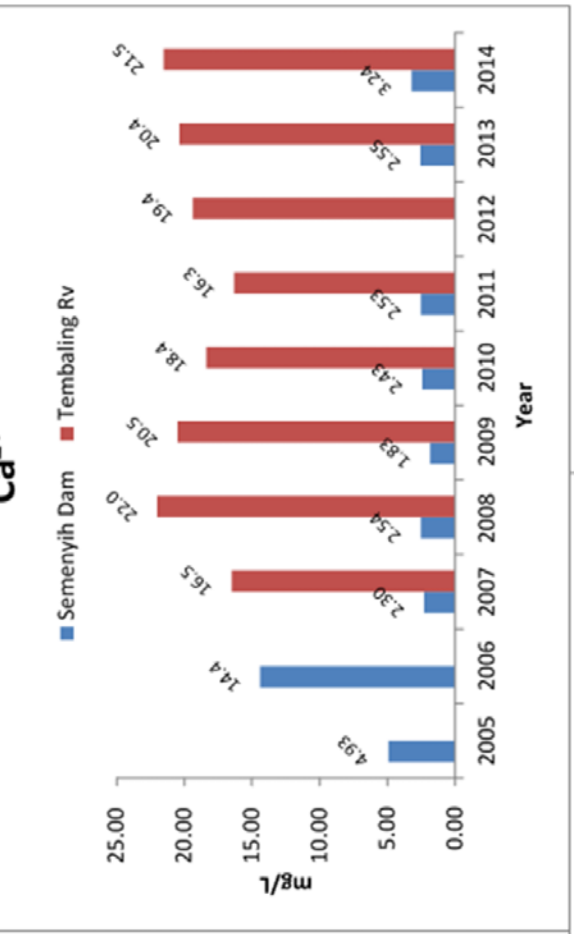
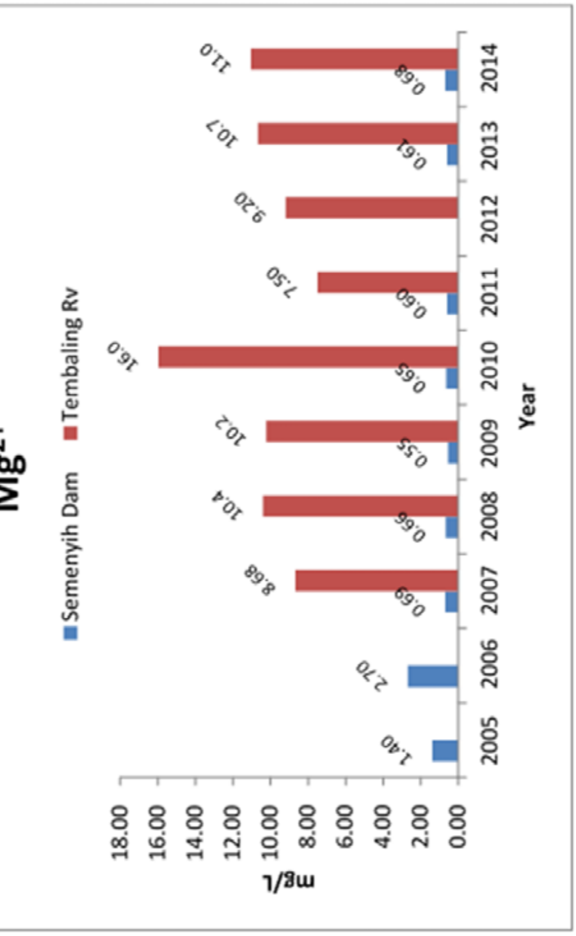


Fig.2.19



2.2.2 Analysis of monitoring parameters

The graphs presented in Figures 2.9 – 2.19 are explained as follows,

a. pH

Figure 2.9 shows that from 2010 – 2014, the pH values were mostly ≥ 7.0 at Semenyih Dam and ≥ 8.0 at Tembaling River. For the record between 2005 – 2014, the lowest annual mean pH recorded were 6.6 for Semenyih Dam in 2013 and 6.8 for Tembaling River in 2007. These pH values indicate that the water of the 2 sites are not threatened by acidic compositions deposition.

b. Electric Conductivity

Figure 2.10 shows that Sungai Tembaling has higher conductivity than Semenyih Dam.

c. Alkalinity

Figure 2.11 indicates that Tembaling River contained more basic ions compared to Semenyih Dam, thus the consistent alkaline pH values throughout the monitoring period. In contrast, the alkalinity of Semenyih Dam was relatively much less than Tembaling River, and this is reflected in lower pH in 2013.

d. Anions

Overall, the concentrations for SO_4^{2-}, NO_3^- and Cl^- (Figures 2.12 – 2.14) were higher in Tembaling River as compared with Semenyih Dam for the period of 2010 – 2014. For NO_3^- (Figure 2.13), there had been a 101% increase in concentration from 2010 to 2011 and then a 76% decrease from 2011 to 2012. There were no significant changes for other anions during 2010 – 2014.

e. Cations

For the period of 2010 – 2014, the concentrations of NH_4^+ and K^+ (Figures 2.15 and 2.17) were generally higher in Semenyih Dam as compared with Tembaling River. However, the reverse could be said with Na^+, Ca^{2+} and Mg^{2+} (Figures 2.16, 2.18 and 2.19).

Chapter III: Review of National Air Quality management including Acid Deposition

Forest Litter Compost as Organic Amendment and Compound Liquid Fertilizer

Background of study

Tropical soil despite being infertile for crop production support diverse tree species with tight canopy of 60-90 ft with most available nutrients in the plant biomass (Boerner, 1982). The tropical forest of Malaysia is composed of 15,500 species of higher plants. It is estimated to produce approximately 79.78 to 128.87 million ton ha^{-1} of litter fall annually (FAO Global Forest Resources Assessment, 2010). Approximately about 423 million m^3 of bioenergy from the forest is to be used by EU Member States in their National Renewable Energy Action Plans (NREAPs) for 2020. However, there is limited information on litter uses for agriculture purposes. Some scientists are of the view that collecting forest litter will deplete the organic matter content of the forest as well as the soil nutrients. They might be right but the question is - does the forest also loss its organic matter content and soil nutrients when there is forest fires? Example of this forest fires was in 1997 to 1998 when Malaysia experienced severe forest fires and about 64,499 ha of forest areas were burnt where Sarawak and Sabah were mostly affected (Thai, 1998). Other countries across the world also experienced wild forest fires and among those affected places in the eighties include New Brunswick where 160 people killed with 1,200,000 ha destroyed in 1825, and Wisconsin where over 1700 people were killed and 490,000 ha destroyed in 1871. In the nineties Florida where 4899 fires occurred, 342 homes were burned and destroying $390 million wealth of timber with 205,000 ha in 1998 and of recent, British Columbia where 66,600 ha and 40,000 ha were destroyed in 2009 and 2010, respectively. In Washington, 102,000 ha and 122,306 ha were destroyed in 2014 and 2015, respectively. The latest forest fires were recorded in Alberta – Saskatchewan where 593,670 ha were destroyed in 2016 and in Kansas –Oklahoma where 148,770 ha were destroyed in 2016. This severed forest fires were only few that has been reported and this fires happen very year all over the world. This fires are fueled by of huge amount of forest litterfall which affect the physical, chemical, mineralogical, and biological properties of the soil. Additionally, the rapid loss of soil organic matter content and soil nutrients through leaching into our rivers (Schlesinger, 1997; Boerner, 1982) as a result of high rainfall in the tropic especially in Sarawak which have about 3000 mm height of rain annually compounds the problem. The use of this litterfall for bioenergy might not be a suitable way of recycling forest litter resources because it does not benefit the agriculture soils but rather deplete the soil completely those nutrients lock up in the forest litter. Hence, this study proposes that forest litterfall should be properly managed for the benefit of the forest and our agriculture land instead of allowing it management completely to the forest. In order to determine how effective forest resources can be managed, this research proposes the recycling of forest litter for agriculture purposes only.

Purpose of study

This study seeks to effectively utilize forest litterfall resources through recycling of nutrients for agriculture purposes only. This study focuses on determining the quality of forest litter as organic amendment to improve chemical fertilizer use efficiency, effectively extraction of the lock up nutrients in forest litterfall into liquid compound fertilizers which is more uniform in mixture of nutrients and very effective than the use of granular chemical fertilizers, and evaluation of the products in improving crops yield by reducing fertilizer usage.

- Research -

3.1 SELECTED PHYSICO-CHEMICAL PROPERTIES OF FOREST LITTER COMPOST

The objective of this study was to compost forest litter and determine some of its selected physic-chemical properties by comparing their nutrients content, humic acid, and toxicity level to those of leucaena, chicken litter, and cow dung.

Findings and conclusion

The results indicates that, forest litterfall compost was higher in humic acid with minimum toxicity level but similar in physical and chemical properties to those of leucaena, chicken litter, and cow dung making it suitable and easily accessible organic amendment for crop product.

Litterfall collection

Air dry and grinded litterfall

Product after composting

3.2 IMPROVING EXTRACTION OF NUTRIENTS LOCK UP IN FOREST LITTER FOR LIQUID COMPOUND FERTILIZER

The objective of this study was to extract liquid compound fertilizer from composted forest litter using distil water and NaOH solution.

Findings

Results indicates that, NaOH solution effectively extracted K, P, Ca, and Na nutrient elements as compared with distil water. The humic acid content of the extractant using NaOH solution was higher than the use of waster making NaOH solution a suitable solution in extracting compound liquid fertilizers from organic substances. Solution type and shaking methods had no significant effect on N concentration. However, it is recommended that the liquid compound fertilizer from forest litter should be fortified with N, P, and K fertilizers base on the test crop requirement.

Liquid fertilizer extraction

Filtering

Some of the products after extraction

3.3 IMPROVING SOIL CHEMICAL PROPERTIES, NUTRIENTS USE EFFICIENCY, AND RICE GRAIN YIELD THROUGH CO-COMPOSTED FOREST LITTER ON TROPICA ACID SOIL

The objectives of this study was to increase paddy plant growth variable and grain yield by reducing use of N, P, and K chemical fertilizers use

Findings

The use of composted forest litter as organic amendment improved the soil chemical properties, increased rice plant dry matter yield, plant height and grain yield to about 10 t ha^{-1} compared with the normal practice which is about 5 t ha^{-1}. Additionally, the use of chemical fertilizer was reduced for N by 25%, P by 100%, and K by 64.37%. This confirm the suitability of the use of forest litter as organic amendment in Research 1 above.

Rice plant at 20 days after transplanting

Rice plant at 80 days after transplanting

Note: T1 = soil only, **T2** = Normal fertilization, **T3** = co-composted forest litter

3.4 IMPROVING SOIL CHEMICAL PROPERTIES, NUTRIENTS USE EFFICIENCY, AND *Zea mays* L. GRAIN YIELD USING COMPOUND LIQUID FERTILIZER EXTRACTED FROM FOREST LITTER COMPOST

The objectives of this study was to determine the effects and suitable rate of liquid compound fertilizer extracted with NaOH solution from composted forest litter on the growth variable and grain yield of *Zea mays* L.

Findings

The suitable rate of the liquid compound fertilizer was 160 mL per plant. This rate increases plant growth variables and yield to about 4 t ha^{-1} which was similar to that of the normal fertilization. This rate could be used to substitute the use of chemical fertilizers in *Zea mays* production. The liquid fertilizer was also found to be low in K based on maize requirement and this affected the yield of treatments with liquid fertilizers. However, this K deficiency can be corrected by supplementing it with K fertilizers.

Note: Plants are 30 days after sowing. **T1**= Normal fertilization, **T5** and **T5** liquid compound fertilizer was use at different rates

3.5 LABORATORY EVALUATION OF CO-COMPOSTED FOREST LITTER AND CHEMICAL FERTILIZERS INTERACTION IN PADDY FIELD

The objectives of this study was to evaluate how co-composted forest litter will interact with the applied N and K chemical fertilizer when used in paddy field.

This study have been completed but the analysis is yet to be done.

3.6 LABORATORY EVALUATION AMMONIA GAS MITIGATION EFFECT OF CO-COMPOSTED FOREST LITTER IN PADDY FIELD

The objectives of this study was to evaluate how co-composted forest litter will mitigate the evolution of ammonia gas when urea is applied in paddy field.

This study have been completed, the gas data have been collected but the soil is yet to be analysed.

3.7 LABORATORY EVALUATION SOIL NUTRIENTS RETAINTION OF CO-COMPOSTED FOREST LITTER IN PADDY CULTIVATION

The objectives of this study was to evaluate how co-composted forest litter will retain soil nutrients when chemical fertilizers are applied in paddy field.

This study still ongoing, the leachate data collection is ongoing too.

3.8 FIELD EVALUATION LIQUID COMPOUND FERTILIZER FROM COMPOSTED FOREST LITTER TO IMPROVE PADDY GROWTH AND YIELD THROUGH FOLIA APPLICATION

The objectives of this study was to evaluate how liquid compound fertilizer from composted forest litter will increase rice plant growth and grain yield when applied as folia fertilizer
This study is ongoing

Rice plant at 20 days after transplanting

Rice plant at 88 days after transplanting

Note: Plants are 30 days after sowing. **T1**= Soil only, **T2**= Normal fertilization, **and T7** = Treatment with folia application at different rates

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National Assessment on Acid Deposition in Mongolia

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1. Basic information on National Monitoring Activities

Geographically, Mongolia is landlocked, highly elevated, approximately 1500 m above the sea level, surrounded by high mountains and consists of taiga forest, steppe, semiarid, arid and desert.

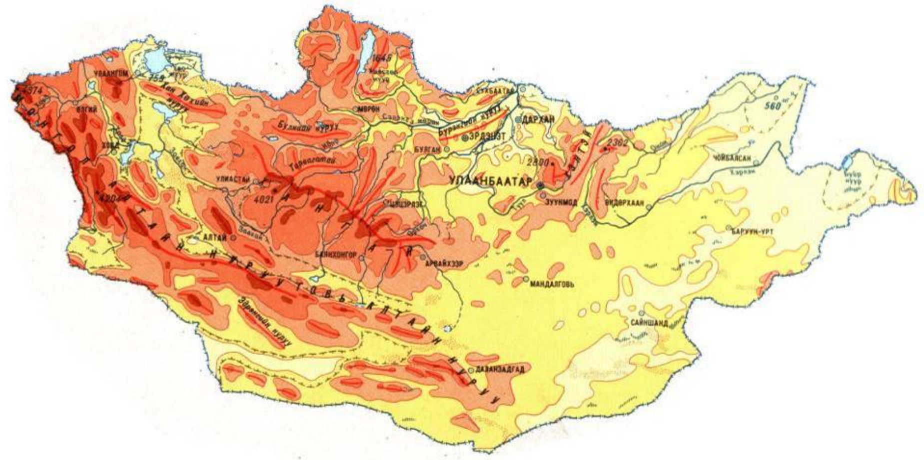


Figure 1.1. Map of Mongolia

Generally, Mongolian climate is dry and cold continental, which is characterized by small precipitation and huge diurnal range of temperature. Annual mean temperature varies from 8 to -10^{0}C, precipitation falls from 50 to 500 mm in the year.

According to 1940-2013 data air тtemperature has increased by 2.1^{0}C, for winter 2.6^{0}C, for summer 1.4^{0}C and precipitation is decreased by 4%, for summer by 7%, for winter it has increased by 24% [IRIMHE, 2014].

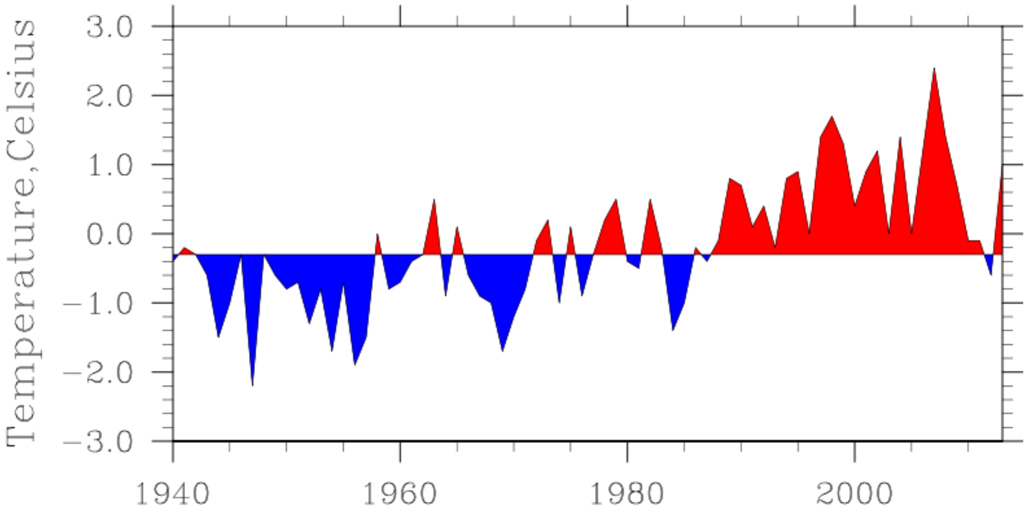


Figure 1.2. Air temperature of Mongolia

The annual precipitation is decreased during the periods since 1960 to 1980 and from the middle of 1990 to 2000. The annual precipitation has increased from 1980 to middle of 1990, except Govi area of Mongolia [P.Gomboluudev, 2014].

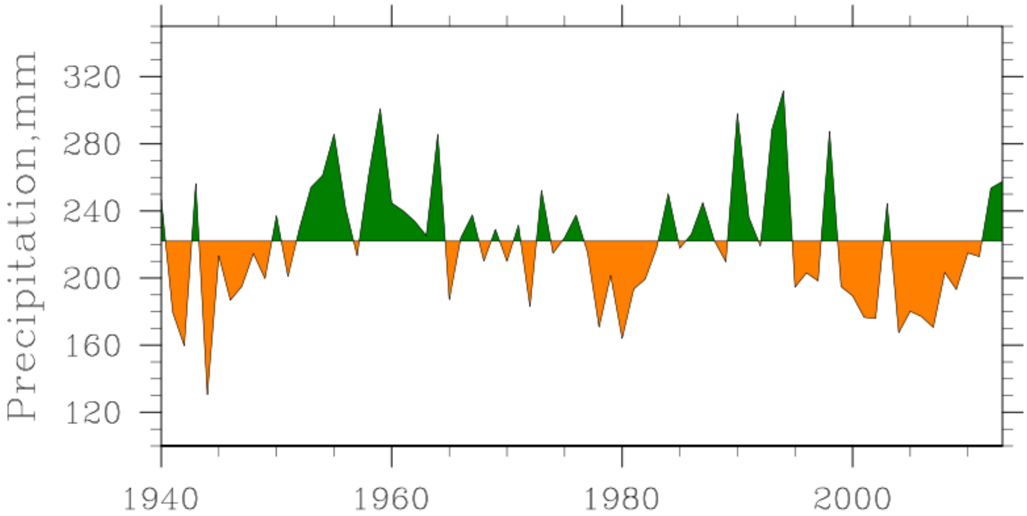


Figure 1.3. Precipitation of Mongolia

Extreme hot days are increased by 8 days. The daily maximum surface air temperature for the period from 1980 to 2000 was 23.0^{0}C in the 1980s, 24.1^{0}C in 1990s and 25.5^{0}C in 2000s. In the last three decades, the decadal slope of increasing for the peak of daily maximum surface air temperature is 1.1^{0}C to 1.4^{0}C, which tells that Mongolian area is getting warmer. Heat wave duration is increased by 11 days. The widespread HW was a rare event in the beginning of the study period, a total of 14 days accounts in the 1990s and none in the 1980s. Along with increasing HW, widespread HW accounted 20 days for 2002 only and total 64 days were observed in the 2000s, in which HW is more frequent and severe and occurred almost every three years [E.Enkhbat, 2015].

Extreme cold days is decreased by 5 days. The cold wave is decreased by 8 days. Growing season length is extended by 14 days. Even cases dust storm in the autumn and beginning of winter in Govi region of Mongolia. In last 2 decades, the frequency of extreme events has doubled [IRIMHE, 2014].

The impacts of climate change in Mongolia are visible and clear through environmental degradation.

1.1. Monitoring program

Wet and dry depositions monitoring at the urban site Ulaanbaatar has been carried out only from May to October every year and it has been suspended during the cold season due to a technical problem caused by climate conditions. The monitoring program is presented in Table 1.

Table 1.1.1. The monitoring program

Items	Monitoring site	Monitoring period	Monitoring interval	Monitoring parameters
Wet deposition	Terelj Ulaanbaatar	2010-2014	Daily (May to October)	pH, EC, SO_4^{2-}, NO_3^-, Cl^-, NH_4^+, Na^+, K^+, Ca^{2+}, Mg^{2+}
Dry deposition	Terelj Ulaanbaatar	2010-2014	Biweekly Weekly	Gases: SO_2, HNO_3, HCl, NH_3 Aerosol: SO_4^{2-}, NO_3^-, Cl^-, NH_4^+, Na^+, K^+, Ca^{2+}, Mg^{2+}
Inland aquatic environment	Terelj river	2010-2014	6 times per a year	pH, EC, alkalinity, SO_4^{2-}, NO_2^-, NO_3^-, Cl^-, NH_4^+, Na^+, K^+, Ca^{2+}, Mg^{2+}, PO_4^{3-}
Soil	Ulaanbaatar	2010-2014	Every 3-5 years	pH (H_2O), pH (KCI) Exchangeable acidity

1.2. Monitoring stations

a. Wet and dry deposition monitoring sites:

Ulaanbaatar-urban site, 47^{0}55'N, 106^{0}54'E, 1275 m ASL (above sea level).

The site is situated in the center of capital city Ulaanbaatar (on the building roof of the National Agency of Meteorology and Environmental Monitoring) and well isolated from intensive stationary sources of air pollution. Ulaanbaatar is a capital city of Mongolia. The city is located on the bank of the Tuul River and surrounded by four mountains.

Terelj – remote site, 47^{0}59'N, 107^{0}27'E, 1550 m ASL.

This site is located in the central part of Mongolia, in the western part of the Khentei mountain ranges and away from major industrial polluting sources. The nearest major city is Ulaanbaatar, which is 50 km far to the southwest.

1.3. Sampling and Measurements

a. Sampling method and sample handling:

The wet-only sampler with refrigerator (collection diameter is 357 mm) manufactured by Ogasawara Co.Ltd installed for rain sampling. The equipment is uninstalled once a year before frost time and kept in the store during the winter season because it does not meet the operation conditions under the cold weather. After the winter season, the equipment is installed again and samples are collected on a daily basis. During winter, a plastic basket with 395 mm diameter was used for snow sample (bulk) collection at the Terelj site.

The sampler with four-stage filter packs MB-01T manufactured by Tokyo Dylec Co.Ltd was used for the dry deposition monitoring. The first membrane filter collects particles, the second cellulose filter is designed for absorption of SO_2, HCl, HNO_3, and the third alkaline impregnated filter is for residual SO_2, HCl, and the fourth acid impregnated filter-for NH_3 absorption.

Wet and dry deposition samples at Terelj remote site are collected and transported to the analytical laboratory twice per month by local staffs and then analyzed by the Central Laboratory of Environment and Metrology (CLEM). Samples at Ulaanbaatar urban site are handled by CLEM.

b. Measurements:

Table 1.3.1. Analytical methods and equipment

Items	Monitoring parameters	Measuring method	Equipment
Wet deposition	pH	pH-meter	HM-30V, TOA
	EC	EC-meter	DS-12, Horiba
	SO_4^{2-}, NO_3^-, Cl^-, NH_4^+, Na^+, K^+, Ca^{2+}, Mg^{2+}	Ion chromatography	ICS-1600, Dionex
Dry deposition	Gases: SO_2, HNO_3, HCl, NH_3	Ion chromatography	ICS-1600, Dionex
	Aerosol: SO_4^{2-}, NO_3^-, Cl^-, NH_4^+, Na^+, K^+, Ca^{2+}, Mg^{2+}		
Inland aquatic environment	SO_4^{2-}, NO_3^-, Cl^-, NH_4^+, Na^+, K^+, Ca^{2+}, Mg^{2+}	Ion chromatography	ICS-1600, Dionex
	Alkalinity	Titration	Titration with 0.02n H_2SO_4
	PO_4^{3-}	Colorimetric	Using ammonium molibdate
	NO_2^-	Colorimetric	Using Griss reagent

2. State of Acid Deposition in Mongolia

2.1 Atmospheric deposition

2.1.1 State of wet deposition

The state of acid rain and chemical composition of rainwater is presented in this report for the central part of Mongolia during the period 2004-2014 since the acid deposition monitoring sites are located in central area of the country and the monitoring period was extended only from May to October every year.

pH: The pH of rainwater was in the range from 3.68 to 7.32 in remote site Terelj. At urban site Ulaanbaatar city, the pH varied from 4.69 to 8.74 and the rain with pH below 5.0 was observed several times for the period between 2004 and 2014. The annual mean values of pH for the period 2004-2014 are given in Table 2.1.1. Ten years changes of wet deposition pH for Ulaanbaatar and Terelj are shown in Figure 2.1.1.

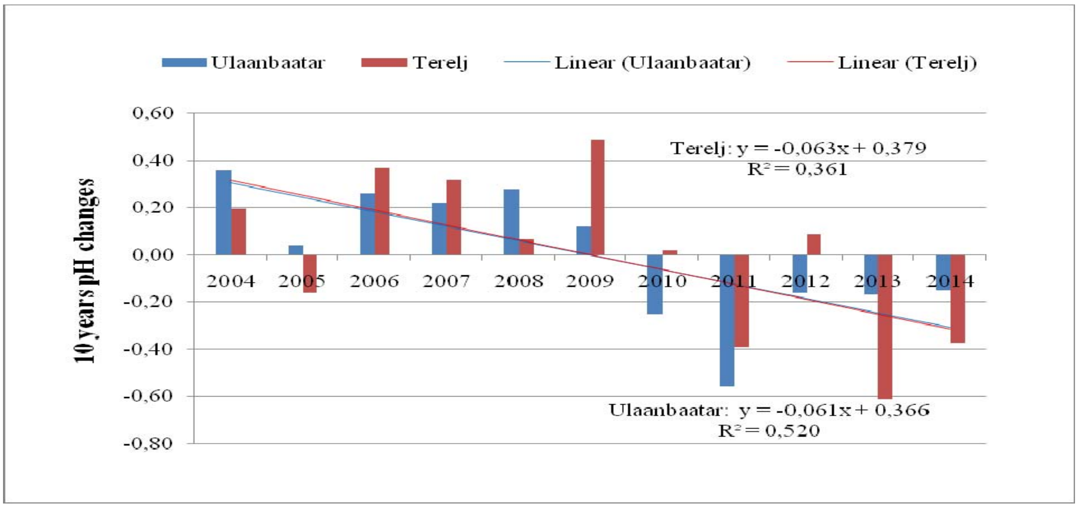


Figure 2.1.1. The changes of wet deposition pH at Ulaanbaatar and Terelj sites

According to the graph we can see the significant decreasing trend for *pH* values at Ulaanbaatar (slope=-0.061, $P<0.05$) and Terelj (slope= -0.063 and, $P=0.06$) sites. The average value of pH for the period 2004-2014 is 6.51 and 5.90 for Ulaanbaatar and Terelj, respectively.

Electrical conductivity (EC): For the period 2004-2014, a total of 199 and 282 samples from Ulaanbaatar and Terelj, respectively, were collected and analyzed for electrical conductivity. EC values were of the range 0.38-16.79 mS/m and 0.27-31.20 mS/m at Ulaanbaatar and Terelj, respectively. The annual EC for the period 2004-2014 is presented in Table 2.1.1.

Table 2.1.1. Annual means of the wet deposition pH and EC

Station	**Year**	**pH**			**EC, mS/m**		
		Annual mean	**Min**	**Max**	**Annual mean**	**Min**	**Max**
Ulaanbaatar	2004	6.87	6.13	7.61	2.82	0.82	6.16
	2005	6.55	4.80	8.29	2.42	0.61	8.67
	2006	6.77	5.36	7.66	3.00	0.61	11.60
	2007	6.73	5.73	**8.74**	2.75	0.65	8.70
	2008	6.79	5.43	7.92	3.65	0.64	9.53
	2009	6.63	5.54	7.79	3.15	0.78	11.61
	2010	6.26	5.33	7.32	2.88	**0.38**	14.26
	2011	5.95	4.76	6.77	3.09	0.53	10.18
	2012	6.35	**4.69**	7.22	2.42	0.42	9.19
	2013	6.34	5.35	7.86	4.30	0.69	**16.79**
	2014	6.36	5.23	7.11	2.82	1.08	6.27
Terelj	2004	6.10	5.14	6.91	1.35	0.38	5.03
	2005	5.74	4.28	7.20	1.48	0.22	5.54
	2006	6.27	3.80	**7.32**	2.17	0.39	12.35
	2007	6.22	**3.68**	7.13	3.67	0.49	28.90
	2008	5.97	4.22	7.14	2.39	**0.21**	12.49
	2009	6.39	5.45	7.09	2.37	0.48	16.66
	2010	5.92	4.63	7.29	3.34	0.35	**31.20**
	2011	5.51	4.20	6.40	1.64	0.47	8.37
	2012	5.99	4.57	6.68	1.97	0.27	14.79
	2013	5.29	4.17	6.65	2.06	0.27	8.11
	2014	5.53	4.30	6.29	1.37	0.28	4.77

In the case of EC, we could not see any significant trend for 2 sites. But in 2007, EC was increased up to 1.5 mSm-1. However, the 10 years average is 2.16 mSm-1 at Terelj station (Fig 2.1.2). Generally, the EC has increased during the period from 2007 to 2010, especially in Terelj site.

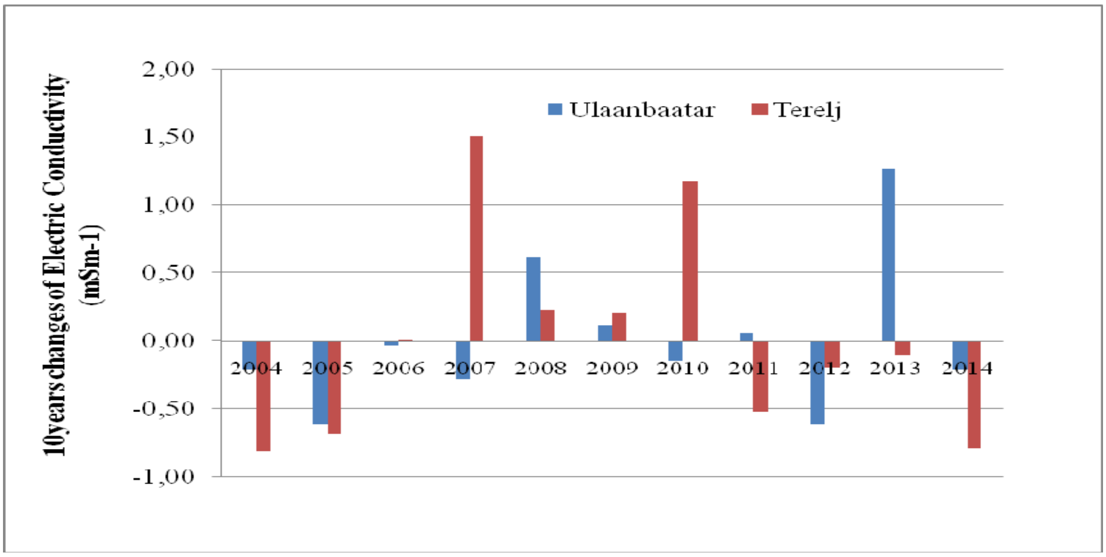


Figure 2.1.2. Precipitation electric conductivity (EC) changes relative to the 10 years average for remote (Terelj) and urban (Ulaanbaatar) area, Mongolia

Anions: Rainwater samples were collected in the period from 2004 to 2010 and have analyzed for sulphate, nitrate and chloride ions using ion chromatography and the annual mean value is showed in the next table.

Table 2.1.2. Annual mean anion flux

Station	Year	SO_4^{2-}, µeq L^{-1}	NO_3^-, µeq L^{-1}	Cl^-, µeq L^{-1}
Ulaanbaatar	2004	61.8	23.8	12.0
	2005	54.3	19.4	7.7
	2006	35.2	16.3	7.2
	2007	74.2	26.0	9.4
	2008	37.7	20.4	10.2
	2009	40.4	19.7	9.9
	2010	51.6	24.6	9.8
	mean	**50.7**	**21.4**	**9.4**
Terelj	2004	23.6	19.0	11.3
	2005	28.7	13.4	6.6
	2006	27.5	11.6	9.2
	2007	40.7	16.8	11.7
	2008	32.4	19.2	9.8
	2009	32.5	20.2	9.1
	2010	69.8	35.7	12.5
	mean	**36.4**	**19.4**	**10.0**

According to the analysis, the contribution of sulphate to precipitation acidity was much higher than nitrate (Table 2.1.2). Except for 2010 sulphate concentration was much higher at Ulaanbaatar than in Terelj, it might be depending on coal combustion usage and high density of population in the capital city of Mongolia.

Cations: The rain water samples (2004-2010) were collected and analyzed for ammonia, sodium, potassium, calcium and magnesium ions using ion chromatography and their annual mean has shown in table 2.1.3.

Table 2.1.3. Annual mean cation flux

Station	**Year**	**NH_4^+ µeq L^{-1}**	**Na^+ µeq L^{-1}**	**K^+ µeq L^{-1}**	**Ca^{2+} µeq L^{-1}**	**Mg^{2+} µeq L^{-1}**	**H^+ µeq L^{-1}**
Ulaanbaatar	2004	57.3	11.0	5.5	104.8	15.8	-
	2005	54.6	7.1	4.4	96.6	11.2	1.1
	2006	45.8	7.8	4.3	74.7	7.5	0.4
	2007	91.6	9.6	3.8	97.8	12.4	0.5
	2008	51.3	6.0	5.0	63.0	10.4	0.5
	2009	48.4	4.7	2.5	83.9	9.7	0.8
	2010	68.1	7.2	4.5	92.7	9.4	-
	mean	**59.6**	**7.6**	**4.3**	**87.6**	**10.9**	**0.7**
Terelj	2004	39.4	8.3	5.4	39.6	11.7	-
	2005	29.8	9.4	5.4	38.9	9.1	3.4
	2006	40.0	13.5	8.0	61.3	11.2	1.5
	2007	55.8	25.2	10.4	79.4	10.7	1.8
	2008	55.2	10.5	12.5	56.2	10.7	2.9
	2009	39.1	6.4	3.7	74.5	11.3	0.6
	2010	43.2	18.0	6.4	97.9	16.8	-
	mean	**43.2**	**13.0**	**7.4**	**64.0**	**11.6**	2.0

Ammonium and calcium ions mostly have predominated among the cations in the precipitation water.

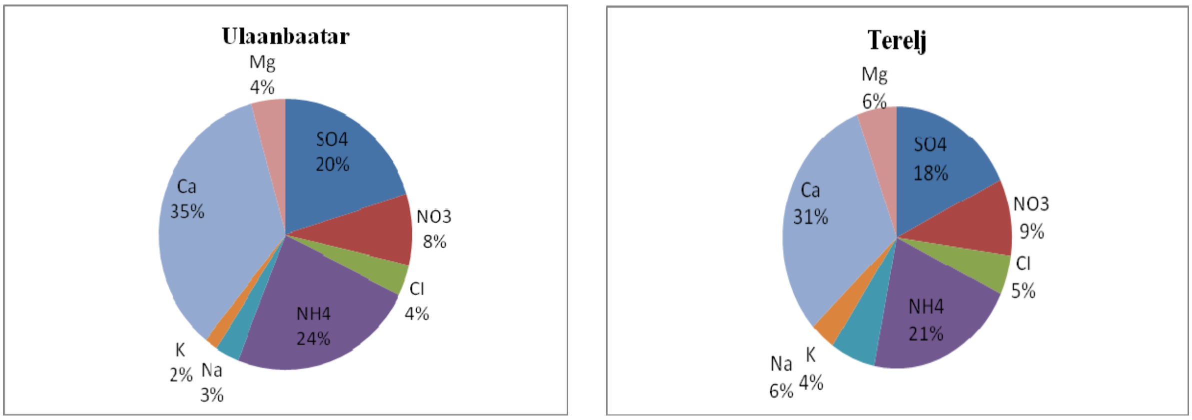


Figure 2.1.3. Major ions composition of wet deposition, 2004-2010, %

The dominant ions such as Ca^{2+}, NH_4^+, SO_4^{2-}, NO_3^- were and Ca^{2+}(35%), followed by NH_4^+(24%), SO_4^{2-}(20%) and NO_3^- (8%) in the wet deposition of Ulaanbaatar. The dominant ions (Ca^{2+}, NH_4^+, SO_4^{2-}, NO_3^-, Mg^{2+}) were and Ca^{2+}(31%), followed by NH_4^+(11%), SO_4^{2-}(21%), NO_3^- (9%) and Mg^{2+}(6%) in the wet deposition of Terelj.

2.1.2 State of dry deposition

The mean annual concentrations of sulphur dioxide, nitric acid, hydrogen chloride and ammonia in the atmosphere of the urban site Ulaanbaatar have ranged 0.32-257.61 µg m^{-3}, 0.03-4.94 µg m^{-3}, 0.04-14.90 µg m^{-3}, and 0.30-47.80 µg m^{-3}, respectively. The mean annual concentrations of sulphur dioxide, nitric acid, hydrogen chloride and ammonia in the atmosphere of the remote site Terelj have ranged 0.07-31.86 µg m^{-3}, 0.01-1.27 µg m^{-3}, 0.02-5.00 µg m^{-3}, and 0.03-6.09 µg m^{-3}, respectively. The mean annual concentrations of gaseous compounds in the atmosphere of Ulaanbaatar and Terelj are presented in figure 2.1.4.

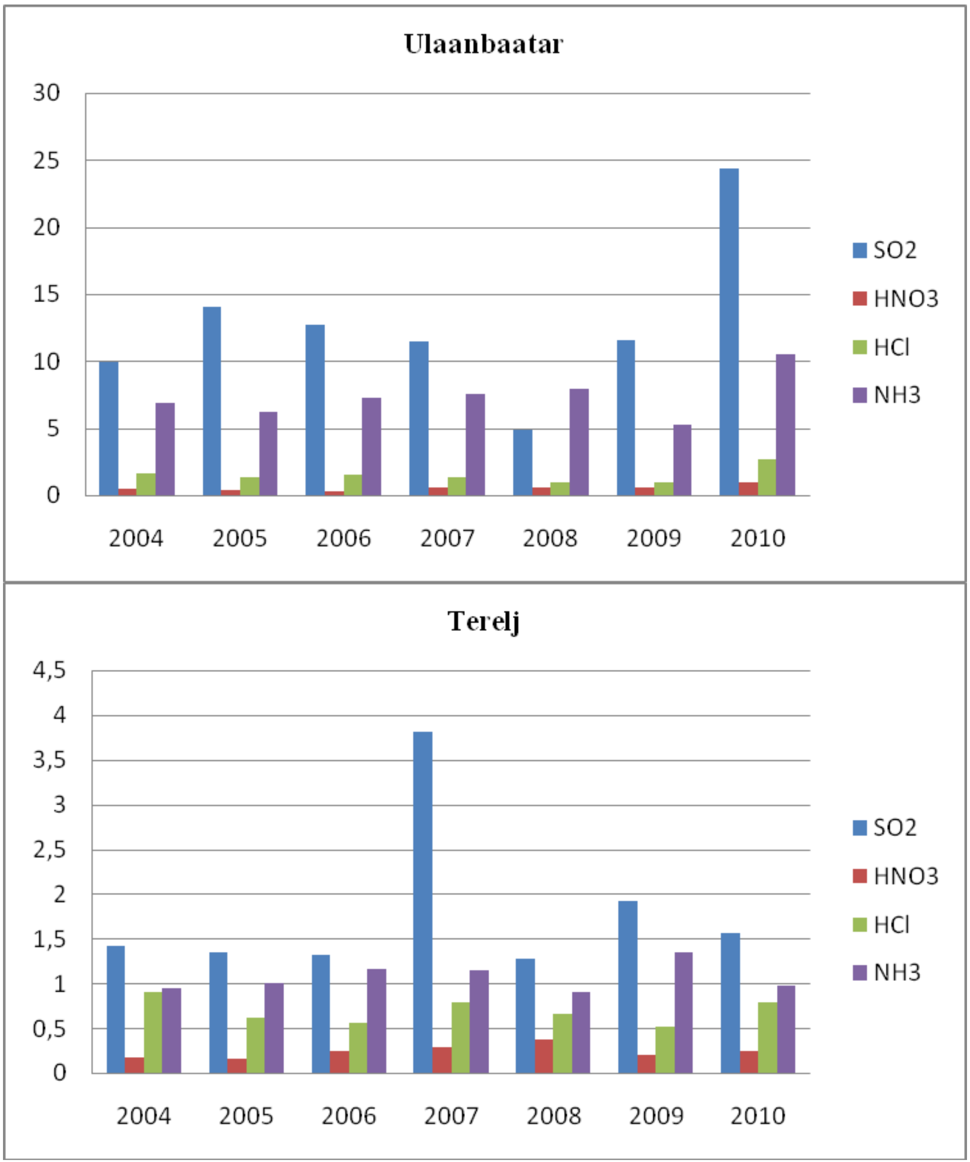


Figure 2.1.4. The mean annual concentrations of gaseous compounds, µg m^{-3}

The average (2004-2010) of sulphur compounds in the atmosphere of Ulaanbaatar and Terelj are presented in Figure 2.1.5.

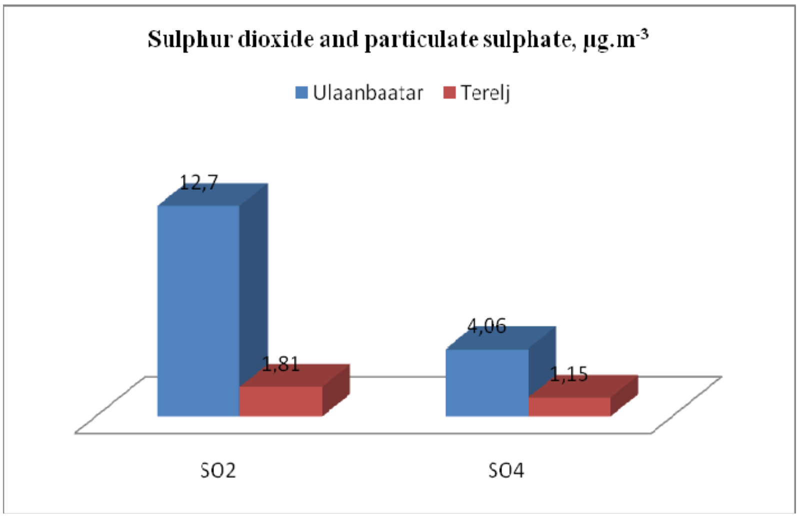


Figure 2.1.5. The average of sulphur dioxide and particulate sulphate in the atmosphere, µg m^{-3}, 2004-2010

Dry deposition filters from 2012 to 2015 were saved in the refrigator due to the problem of cation column of Ion chromatography. Therefore we contracted with Abacus company and ordered 4 mm column, guard column, and suppressors in 2016.

At the national level in Ulaanbaatar are 6 automatic monitoring sites based on influencing emission sources and activities: roadside (UB02), urban (UB04, UB05), industrial (UB01, UB07) and background (UB08).

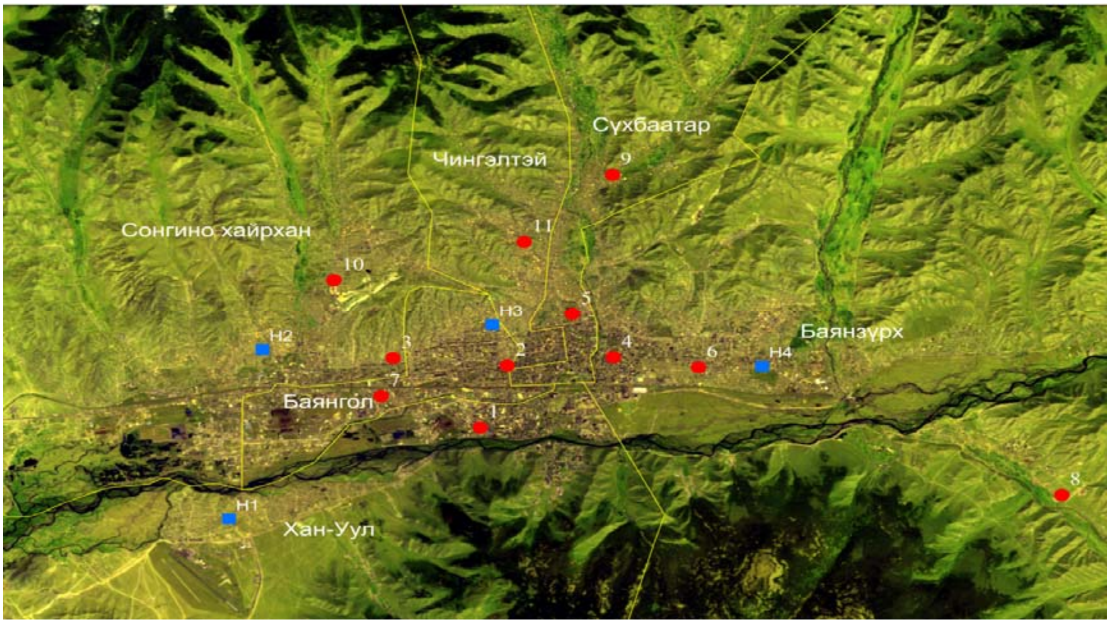


Figure 2.1.6. The location of sites in Ulaanbaatar, Mongolia

Sites	Established	Latitude	Longitude
UB01	May 1977	47°53'38.44" N	106°52'57.54" E
UB02	22 Nov 1977	47°54'55.46" N	106°53'39.60" E
UB03	January 1985	47°55'04.03" N	106°50'53.02" E
UB04	January 1996	47°55'02.65" N	106°56'14.97" E
UB05	6 Nov 2008	47°55'58.45" N	106°55'16.96" E
UB06	9 Jan 2009	47°54'48.42" N	106°58'19.31" E
UB07	12 June 2010	47°54'20.22" N	106°50'32.97" E
UB08	11 June 2010	47°51'57.43" N	107°07'05.77" E
UB09	January 2011	47°58'54.89" N	106°56'05.84" E
UB10	20 January 2011	47°57'23.45" N	106°49'39.34" E
UB11	2 January 2011	47°57'05.15" N	106°54'14.66" E

The air pollution is a very serious problem in Ulaanbaatar in the cold (winter) season. There is a big diurnal, seasonal, annual variation defending on air pollutant's characteristics and emission sources.

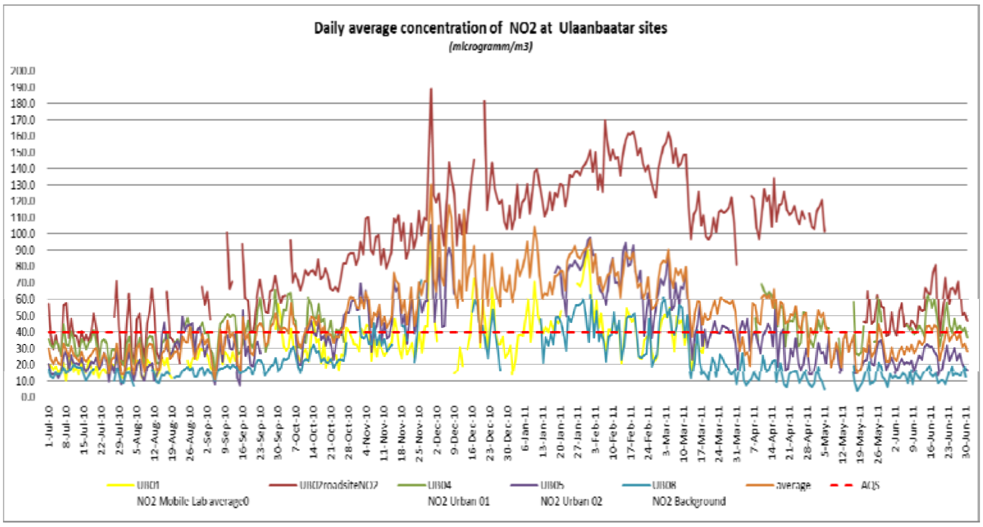


Figure 2.1.7. Surface NO_2 concentration in Ulaanbaatar

The NO_2 concentrations are higher than air quality standard of Mongolia (AQS) at all sites in winter. The highest concentration observed at the roadside station a whole year.

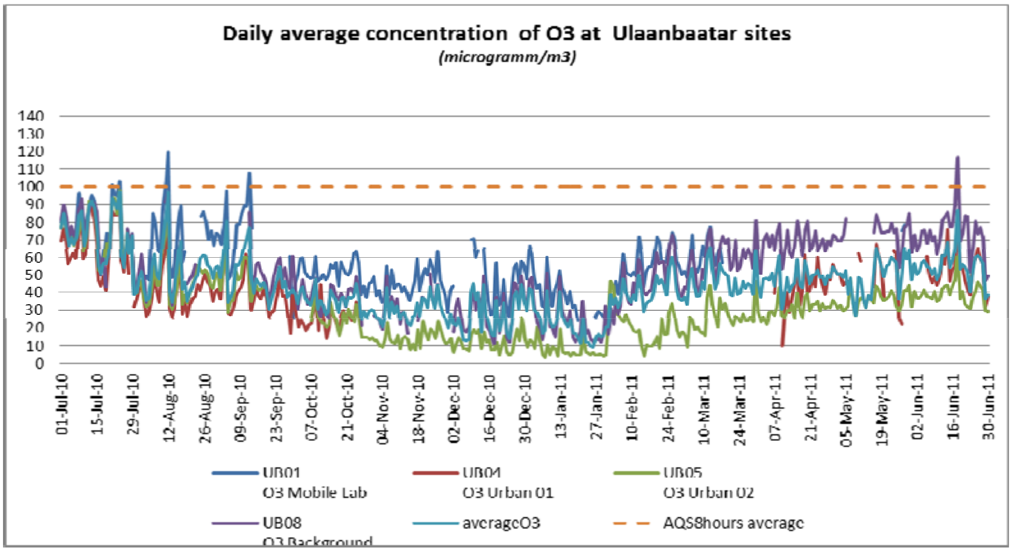
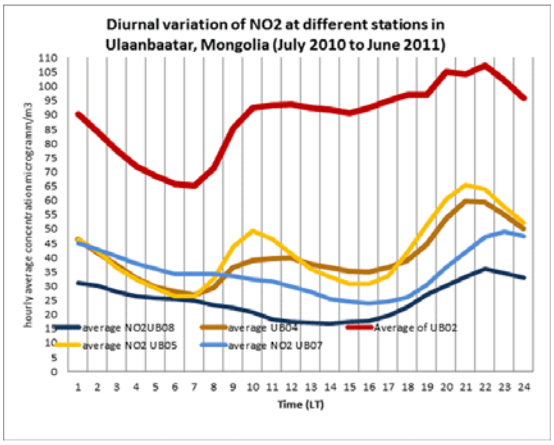
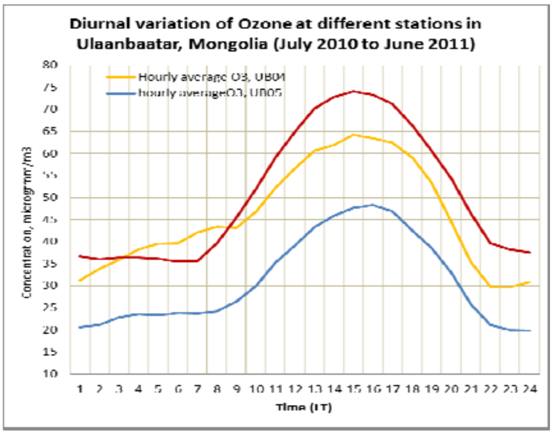


Figure 2.1.8. Surface ozone concentration in Ulaanbaatar

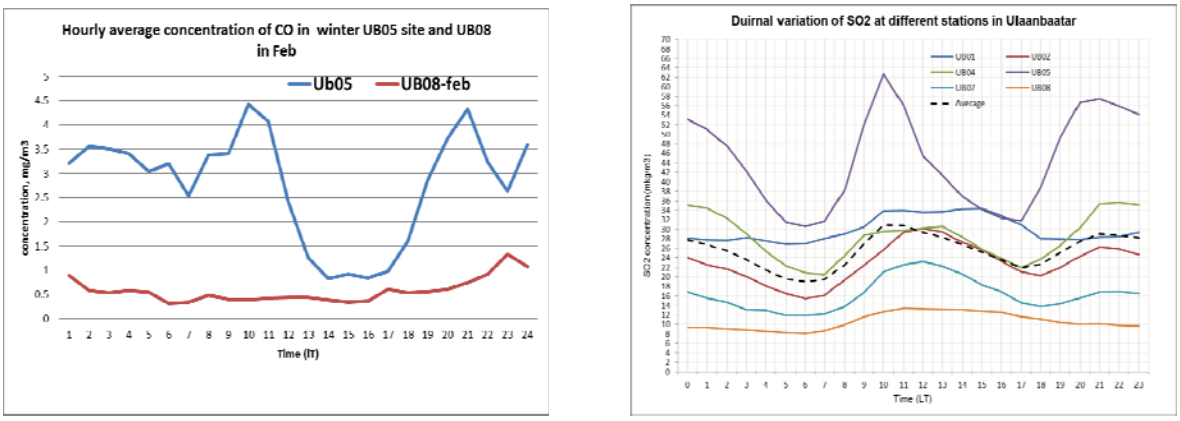
Surface ozone (O_3) concentrations are shown opposite seasonal variation of NO_2. In the summer, a few days surface ozone exceeded by AQS.



a)



b)

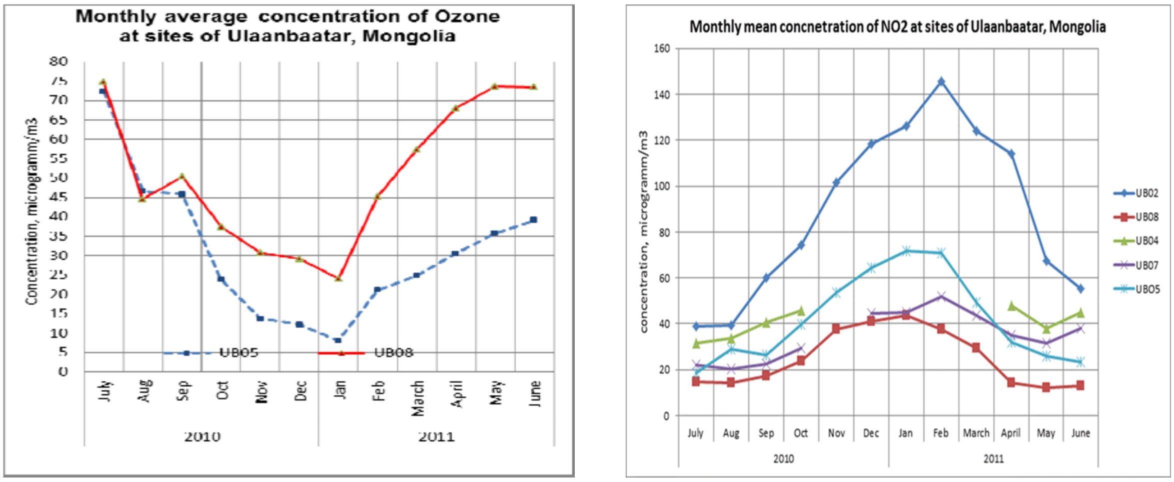


c) d)

Figure 2.1.9. Diurnal variations of pollutants: a) NO_2; b) O_3; c) CO; d) SO_2

The ozone precursors (NO_2, CO) and SO_2 show an almost opposite diurnal variation pattern to O_3 (Figure 2.1.9 a), b), c), d)) characterized by high concentrations during night and morning and low concentrations during the daytime, especially noon and afternoon. The UB08 station is located eastside of Ulaanbaatar city and close to the main central road. The daytime west and Northwest wind dominated at the site. The pollution and some formed ozone in the central city transported to the UB08 station.

Each pollutant has two main peak concentration levels; the first peak appears in the morning rush hours (9:00 - 11:00AM); the second peak appears around evening (8:00 - 10:00PM), but for CO the second peak appears around (8:00 - 9:00PM). The peaks caused by coal burning in the ger area for a heating period in the cold season. The morning rush hour peak is mainly caused by traffic at the near roadside exclude SO_2. These precursors and SO_2 reach their minimum values at around 6:00 - 7:00AM and at around 2:00 - 4:00PM when ozone O_3 reaches its high values.



a) b)

Figure 2.1.10. Annual variations of pollutants: a) O_3; b) NO_2;

The seasonal variations of O_3, NO_2 (figure 2.1.10) are shown a well-defined seasonal variation. The low values appear in late autumn and winter for ozone, in summer for NO_2, while the high values appear in late spring, summer and early autumn for ozone, in winter for NO_2. This common behavior of ozone was justified by the dominant photochemical production process of ozone due to the presence of its precursors and intense solar radiation.

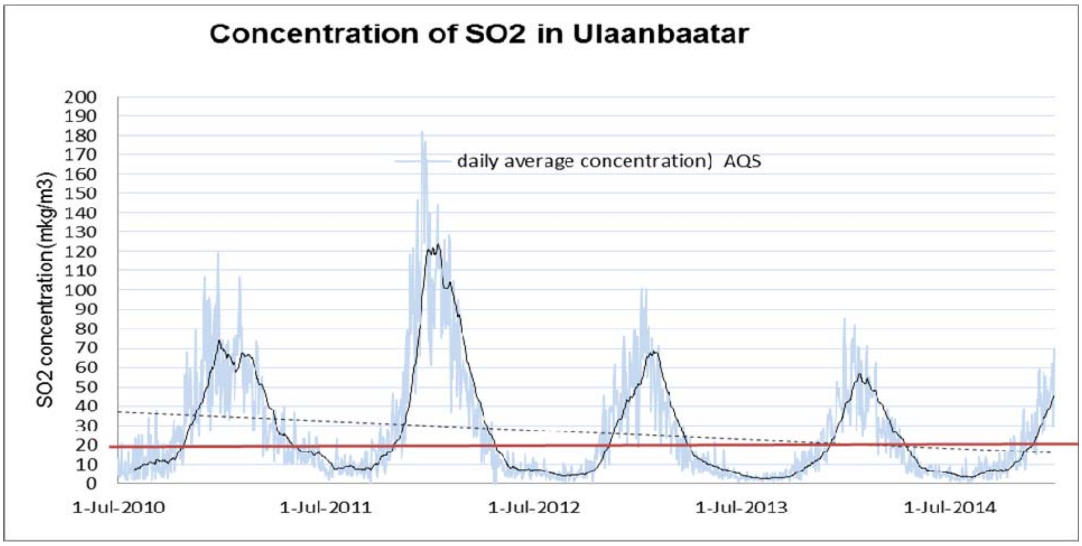


Figure 2.1.11. Trend of SO_2 in Ulaanbaatar

Sulphur dioxide is produced by fossil fuel *combustion*. In the heating season, a daily average of SO_2 concentration almost higher than AQS in Ulaanbaatar. Last 3 years general trend of SO_2 is decreased. It has indicated some results of air pollution reduction measures. But the concentration of SO_2 is still higher than AQS.

2.2 State of inland aquatic environment

Terelj river has been selected for the inland aquatic environment monitoring purpose because its water has quite low electric conductivity. The river starts at the western slope of Khentei mountain range and flows into the Tuul river. Terelj river water has very low mineralization with electric conductivity in the range of 43.2-65.9 µS$^{\cdot}$cm^{-1} and pH variations within 6.40-7.40. The average chemical composition of the Terelj river water for the period 2004-2014 is presented in Table 2.2.1.

Table 2.2.1. The mean annual concentration of the Terelj river, mg$^{\cdot}$ l^{-1}.

	pH	**EC** mS/m	**Alk.**	**SO_4^{2-}**	**NO_3^-**	**Cl^-**	**NH_4^+**	**Na^+**	**K^+**	**Ca^{2+}**	**Mg^{2+}**
2004	7.03	4.44	-	2.75	0.70	0.54	0.04	1.60	0.72	5.93	0.89
2005	6.94	4.84	0.367	3.18	0.82	0.56	0.05	1.95	0.68	8.90	1.04
2006	7.05	5.07	0.327	3.60	0.79	0.46	0.11	2.07	0.62	9.04	1.07
2007	7.01	5.06	0.340	3.18	0.79	0.57	0.37	2.22	0.56	8.63	1.03
2008	7.12	6.59	0.280	3.82	1.33	0.73	-	1.93	0.60	13.70	1.00
2009	7.15	4.70	0.331	3.47	0.48	0.42	-	1.65	0.58	5.40	0.75
2010	6.79	5.57	0.380	4.46	0.86	0.81	0.13	2.17	1.19	7.52	1.15
2011	6.40	4.45	-	3.88	0.67	0.72	0.08	1.43	0.70	6.46	0.73
2012	7.40	4.43	0.315	-	-	-	-	-	-	-	-
2013	6.91	4.32	0.294	2.81	0.46	0.37	-	1.46	1.01	6.13	0.83
2014	6.75	4.77	0.307	-	-	-	-	-	-	-	-

The composition of the major ions in the Terelj river water is illustrated in Figure2.2.1. The main dominated ions were the calcium.

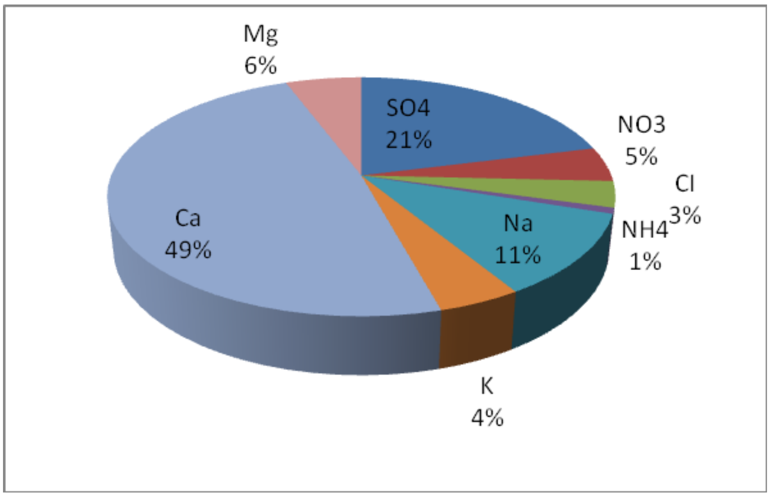


Figure 2.2.1. Major ions composition of Terelj River water, 2004-2014, %

The dominant ion (Ca^{2+}, SO_4^{2-}, Na^+, Mg^{2+}) was Ca^{2+}(49%), followed by SO_4^{2-}(21%), Na^+(11%) and Mg^{2+}(6%) in the river water of Terelj.

3. Review of National Measures against Acid Deposition

- Due to the cold season (harsh winter) and equipment problems had a gap in the dataset.
- pH has decreased, sulphate to precipitation acidity was much higher than nitrate, and ammonium and calcium ions mostly have predominated among the cations in the precipitation water.
- The concentrations of SO2, NOx, CO were highest during the winter (heating period) in Ulaanbaatar. The major sources are emission from coal burning for heating.
- Since 2010 in Mongolian Gobi are going on a lot of mining activities and also Mongolia has getting transboundary pollution from the industrial area of China and Russia (Siberia). Therefore, we need to have 1 or 2 more EANET sites in Mongolian Gobi in the near future.

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National Assessment on Acid Deposition in Myanmar

1. Basic Information on National Monitoring Activities

1.1 Outline of activities on acid deposition and national monitoring plan

The rapid industrialization in the East Asian countries has helped in achieving economic growth. Along with industrialization, energy consumption such as coal, oil and natural gas has also rapidly increased in East Asia. The combustion of these fossil fuels is the main source of air pollutants such as HNO_3, H_2SO_4. The emission of air pollutants will increase, if there is no proper management to control it efficiently. For this reason there is a need for a better understanding in these problems in Myanmar. To protect the country from the acid deposition problem, it is required to monitor the state of acid deposition in the country. So, Myanmar had joined Acid Deposition Monitoring Network in East Asia (EANET) in November 2005. After Myanmar became member country of EANET, Department of Meteorology and Hydrology (DMH) is designated as National Center for EANET. DMH have carried out its responsibility by wet deposition monitoring and then the following are some relevant activities and program that are currently implemented:

- Developed National Monitoring Plan for EANET
- Developed Standard Operating Procedures(SOPs)
- Upgrading for the laboratory progress
- Capacity building of staffs in Myanmar on acid deposition
- Participation in the inter-laboratory comparison on wet deposition
- Carrying out public awareness activities in Myanmar in coordination with the Secretariat and the Network Center(NC) for EANET
- Fully equip the urban site to provide all the required data for wet & dry deposition monitoring by the use of Ion chromatography

1.2 Monitoring Program in 2010-2014

After Myanmar became one of EANET member countries, DMH, the national center of EANET is carrying out its responsibility by acid deposition monitoring site, Yangon (Kaba-Aye). According to the capacity of the Myanmar, wet deposition monitoring was conducted with measuring pH, EC and amount of precipitation. In November 2011, ACAP had provided two instruments, Filter Pack Method System for dry deposition and Distilled Water Generator. During November 2011, Filter Pack Method System was installed at the site of Yangon (Kaba-Aye) and Distilled Water Generator was installed at the Laboratory of DMH. After installing, DMH has started to analyze the ion contents such as Cation NH_4^+,Na^+, K^+, Ca^{2+},$Mg^{2+}$and Anion SO_4^{2-}, NO_3^-,Cl^- by Ion Chromatograph. Then in March 2014, our Department DMH had bought two instruments of water purification system (RO-DI 30l(s) and RO-DI 15l(s)). And then in November 2014, DMH has bought two instruments of Voltex Shakers. The measurement of pH & EC of the collected rain water have been done by Horiba pH/COND meter. Result of all analysis data (pH, EC, Ions) could be sent to ACAP from started up to now.

1.3 Monitoring Stations

In Myanmar, one monitoring site, Yangon (Kaba-Aye) was chosen for wet deposition monitoring site for EANET. It was classified into urban site following the technical manual of EANET as shown in Table 1.1. At that chosen site wet only sampler was installed on the roof of Hydrology section building in June 2007 and then Filter Pack Method for dry deposition monitoring was installed at the same place of wet sampler in November 2011. The geographical location and picture of the station were shown in Figure 1.1 and Figure 1.2.

Table 1.1 The location of monitoring site in Myanmar

Name of site	Site Classification	Latitude	Longitude	site Category
Yangon (Kaba-Aye)	Urban	16.5˚ N	96.11˚ E	Wet Deposition and Dry Deposition

Figure 1.1 The geographical location of EANET site in Myanmar.

Figure 1.2 Picture of wet & dry deposition monitoring site at Yangon (Kaba-Aye) in Myanmar

1.4 Sampling and Measurements

Rainwater samples for wet deposition monitoring were collected daily by the wet only sampler and weekly composite analysis since 2008. Dry deposition monitoring sampling interval is biweekly and ion analysis since November, 2011.We measured amount of precipitation, pH and EC by pH meter (pH/ COND meter Horiba) and analyzed ion contents by Ion Chromatograph following the technical manual for wet & dry deposition monitoring analysis adopted by EANET as shown in Table 1.2.

Table 1.2 Monitoring Parameters and Method for wet deposition and Dry Deposition

Monitoring Parameters		Method
Wet Deposition	**Dry Deposition**	
Electric Conductivity(EC)	-	Conductivity cell Method
pH	-	Glass electrode Method
Cl^-, NO_3^-, SO_4^{2-}	Cl^-, NO_3^-, SO_4^{2-}	Ion chromatography (preferably with suppressor)
NH_4^+, Na^+, K^+, Ca^{2+}, Mg^{2+}	NH_4^+, Na^+, K^+, Ca^{2+}, Mg^{2+}	Ion chromatography

2. State of acid deposition in Myanmar

2.1 Atmospheric Deposition

2.1.1 State of wet deposition

Acid deposition monitoring in Myanmar has been carried out according to the common methologies specified in the "Technical Documents for wet deposition monitoring in East Asia". Precipitation samples are collected by Wet only Sampler on daily basis at Yangon (Kaba-Aye). Collected samples are carried to laboratory. And then measurement and analysis of the rain water samples have been done according to the technical manual. Annual mean of pH and EC were shown in Table 2.1.1 and Annual mean of Ion Concentration Analysis were shown in and Table 2.1.2 Also meteorological parameters such as temperature, relative humidity, wind speed, wind direction, precipitation amount and sunshine hours were observed at Yangon (Kaba-Aye) station, and it was shown in Table 2.2.

Table 2.1.1 Annual means of pH and EC on wet deposition at Yangon (Kaba-Aye)

Station	Year	pH			EC mS/m			Precipitation amount (mm) from wet sampler			
		Min	Max	Mean	Min	Max	Mean	Min	Max	Mean	Total
Yangon (Kaba-Aye)	2010	5.75	6.85	6.49	0.36	8.75	1.13	7.5	192.2	88	2279.6
	2011	6.20	7.09	6.52	0.30	5.28	0.94	3.9	245.8	102	3150.5
	2012	5.83	7.10	6.60	0.31	4.50	1.54	2.7	246.4	78	2570.0
	2013	6.06	6.99	6.61	0.42	8.30	1.62	2.0	269.8	96	2690.5
	2014	6.00	6.98	6.69	0.42	5.73	1.28	3.9	295.4	103	2872.2

Table 2.1.2 Annual mean ion concentration for wet deposition at Yangon (Kaba-Aye)

Years	NH_4^+ µmol/l	Na^+ µmol/l	K^+ µmol/l	Ca^{2+} µmol/l	Mg^{2+} µmol/l	SO_4^{2-} µmol/l	NO_3^- µmol/l	Cl^- µmol/l
2010	16.82	13.65	3.09	8.12	2.01	5.86	9.16	14.03
2011	23.70	15.10	2.50	12.40	3.70	9.20	12.70	16.30
2012	34.10	25.00	7.70	15.70	6.30	13.10	18.50	27.00
2013	24.60	29.90	6.30	3.00	54.20	16.40	25.50	44.40
2014	35.65	9.24	26.13	30.88	4.66	12.08	5.95	37.43

Table 2.2 Monthly means Meteorological Data at Yangon (Kaba-Aye) in 2010 -2014

Year	Month	Temperature (˚C) Mean		Relative humidity (%) (Mean)	Wind speed (m/s) (Mean)	Wind direction	Total Precipitation amount(mm)	Total Sunshine (hours)
		Max	Min					
2010	Jan	34.4	15.8	70.0	1.6	NE	0	240.8
	Feb	35.8	18.1	64.0	1.6	NE	0	255.3
	Mar	37.2	23.1	73.0	1.4	SE	0	231.3
	Apr	39.2	25.6	66.7	1.7	SW	0	290.6
	May	37.2	25.9	70.0	1.9	SW	308	211.7
	June	32.6	25.4	83.0	1.9	SW	529	67.8
	July	32.5	25.0	85.0	1.5	SE	367	96.8
	Aug	31.0	24.6	86.4	1.7	SE	467	63.4
	Sep	32.1	24.3	83.0	1.6	SW	402	97.2
	Oct	32.7	24.1	80.3	2.0	SE	367	156.0
	Nov	34.6	22.0	68.0	2.0	NE	7	264.6
	Dec	33.0	19.3	66.4	1.8	NE	33	255.0

Year	Month	Temperature (˚C) Mean		Relative humidity (%) (Mean)	Wind speed (m/s) (Mean)	Wind direction	Total Precipitation Amount (mm)	Total Sunshine (hours)
		Max	Min					
2011	Jan	32.3	18.2	66.0	1.7	NE	48	247.8
	Feb	34.8	19.5	63.0	1.7	NE	0	260.1
	Mar	33.7	21.6	71.1	2.1	SE	127	210.3
	Apr	36.5	24.4	68.9	1.4	SE	5	238.8
	May	33.0	24.7	81.7	1.7	SW	412	123.0
	June	31.7	24.7	86.9	2.0	SW	567	54.6
	July	31.2	24.0	88.1	1.6	SW	574	80.0
	Aug	30.5	23.7	87.7	1.7	SW	615	51.8
	Sep	31.2	23.6	87.9	1.8	SW	538	64.5
	Oct	33.0	23.5	81.8	1.7	SE	178	162.1
	Nov	34.2	21.4	70.3	1.4	NE	0	266.9
	Dec	33.3	19.7	67.0	2.2	E	0	242.8

Year	Month	Temperature (˚C) Mean		Relative humidity (%) (Mean)	Wind speed (m/s)	Wind direction	Total Precipitation Amount (mm)	Total Sunshine (hours)
		Max	Min					
2012	Jan	33.5	17.1	63.2	1.7	NE	0	277.3
	Feb	36.0	18.8	70.0	1.5	SE	0	242.7
	Mar	36.9	21.9	69.6	1.3	SW	0	253.4
	Apr	37.9	24.4	65.8	1.6	SW	8	252.3
	May	34.8	24.5	76.6	1.3	SW	167	136.0
	June	31.7	23.6	85.9	1.6	SW	450	56.2
	July	31.1	22.8	87.9	1.3	SW	717	43.0
	Aug	30.2	22.4	89.5	1.4	SW	864	45.7
	Sep	32.0	22.6	84.5	1.4	SW	379	115.2
	Oct	33.8	22.7	80.0	1.6	NE	69	202.8
	Nov	33.9	22.1	78.4	2.1	SE	115	192.5
	Dec	32.6	17.3	97.9	2.4	NE	002	258.3

Year	Month	Temperature(˚C) Mean		Relative humidity (%) (Mean)	Wind speed (m/s)	Wind direction	Total Precipitation Amount (mm)	Total Sunshine (hours)
		Max	Min					
2013	Jan	32.7	15.8	70.8	2.2	NE	6	276.6
	Feb	36.6	19.2	70.0	2.4	SE	0	243.8
	Mar	37.1	20.0	67.6	2.1	SE	0	277.0
	Apr	38.6	21.9	66.9	2.1	SW	0	276.2
	May	35.5	22.4	78.0	2.8	SE	125	172.5
	June	31.4	22.1	88.6	2.1	SW	551	71.7
	July	30.4	24.0	89.2	2.0	SW	630	53.1
	Aug	30.9	24.2	89.9	2.2	SW	464	68.0
	Sep	31.2	23.9	89.2	1.7	SW	612	84.3
	Oct	32.6	23.7	81.2	1.9	SE	371	174.0
	Nov	34.1	22.9	75.0	2.8	NE	13	228.3
	Dec	30.9	17.6	73.8	1.8	NE	3	241.3

Year	Month	Temperature(˚C) Mean		Relative humidity (%)(Mean)	Wind speed (m/s)	Wind direction	Total Precipitation Amount (mm)	Sunshine (hours)
		Max	Min					
2014	Jan	32.3	16.1	71.0	1.8	NE	0	283.1
	Feb	34.0	17.8	69.5	1.4	NE	0	254.4
	Mar	37.4	20.0	66.5	1.6	SE	0	288.6
	Apr	38.1	23.8	70.6	1.3	SW	0	220.5
	May	35.9	23.7	75.0	1.5	SW	0	243.7
	June	32.1	22.8	87.3	1.4	SW	701	48.6
	July	31.0	21.8	90.6	1.6	SW	818	26.5
	Aug	31.1	21.3	89.0	1.6	SW	575	52.7
	Sep	31.9	21.0	83.0	1.4	SW	197	79.1
	Oct	33.6	22.6	76.3	1.7	SE	224	194.5
	Nov	33.4	21.9	77.2	0.8	SE	300	203.0
	Dec	33.8	19.5	66.0	0.9	NE	26	259.6

In the year 2010, it was recorded minimum of pH =5.75 (lowest acidic value), EC= 0.36 mS/m and the maximum of pH =6.85, EC= 8.75mS/m as shown in **Figure 2.1** and **Figure 2.2**

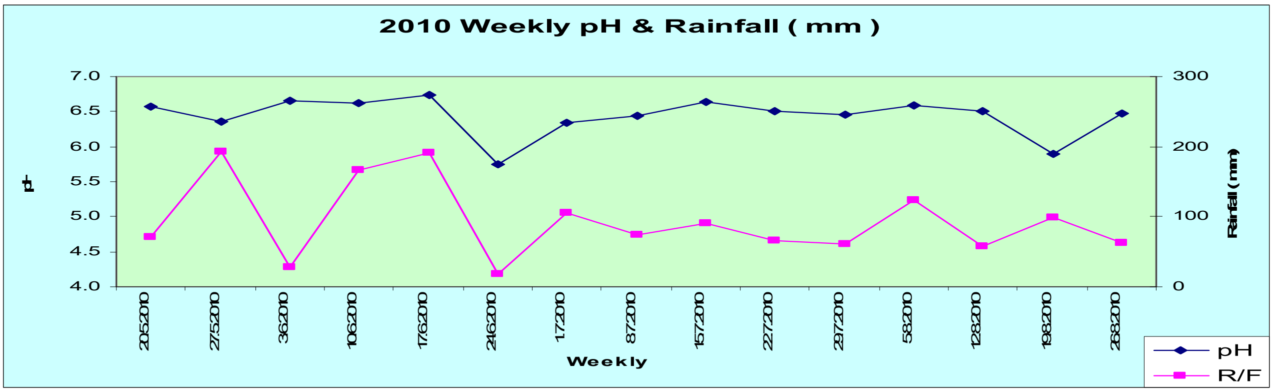


Figure 2.1 Weekly pH and Rainfall (mm) at Yangon (Kaba-Aye) in 2010

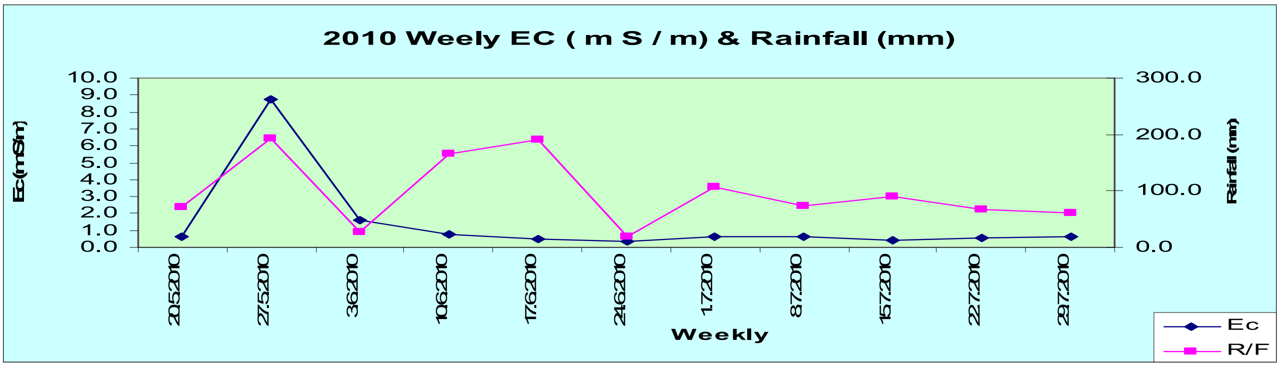


Figure 2.2 Weekly EC (mS/m) and Rainfall (mm) at Yangon (Kaba-Aye) in 2010

In the year 2011, it was recorded minimum of pH =6.20, EC= 0.30 mS/m and the maximum of pH=7.09, EC= 5.28 mS/m as shown in **Figure 2.3 and 2.4.**

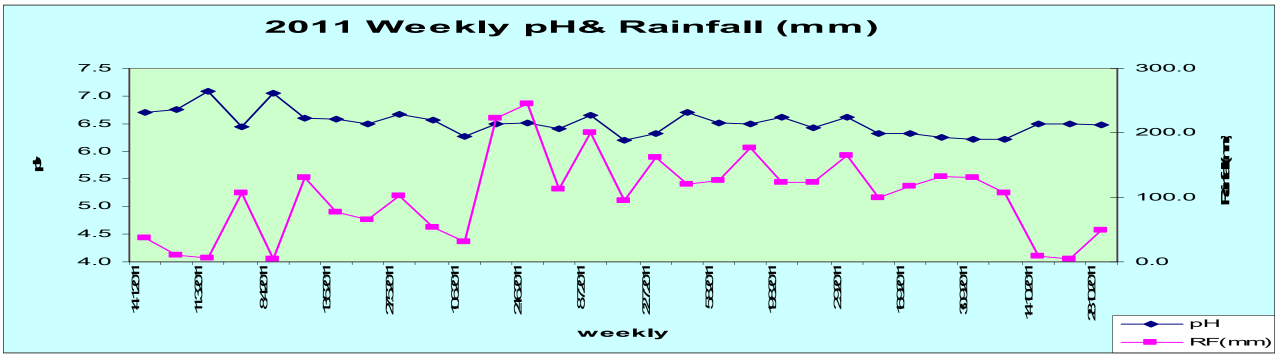


Figure 2.3 Weekly pH and Rainfall (mm) at Yangon (Kaba-Aye) in 2011

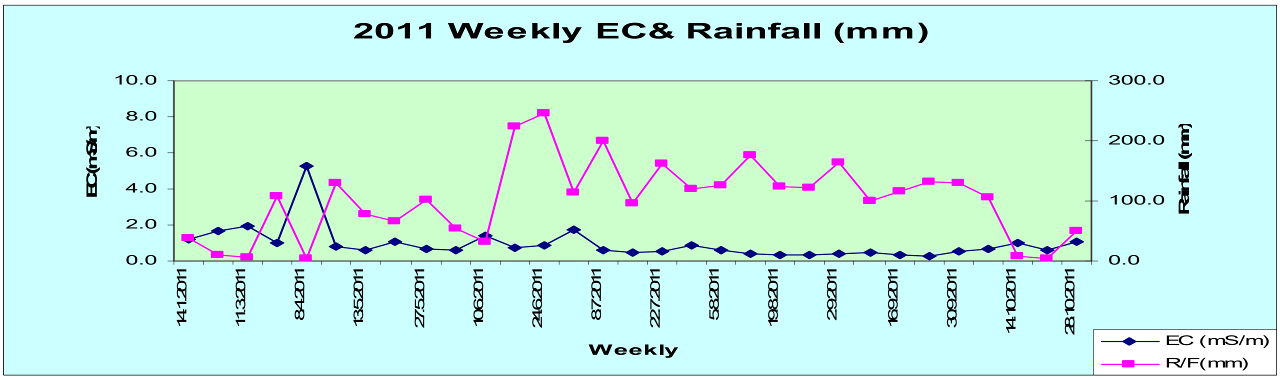


Figure 2.4 Weekly EC (mS/m) and Rainfall (mm) at Yangon (Kaba-Aye) in 2011

In the year 2012, it was recorded minimum of pH =5.83 (lowest acidic value), EC = 0.31 mS/m and the maximum of pH = 7.10, EC = 4.50 mS/m as shown in **Figure 2.5 and 2.6**

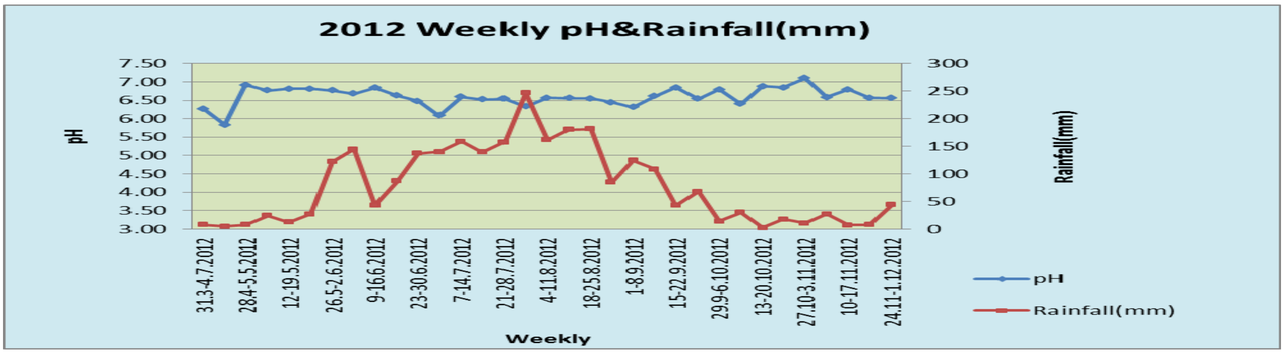


Figure 2.5 Weekly pH and Rainfall (mm) at Yangon (Kaba-Aye) in 2012

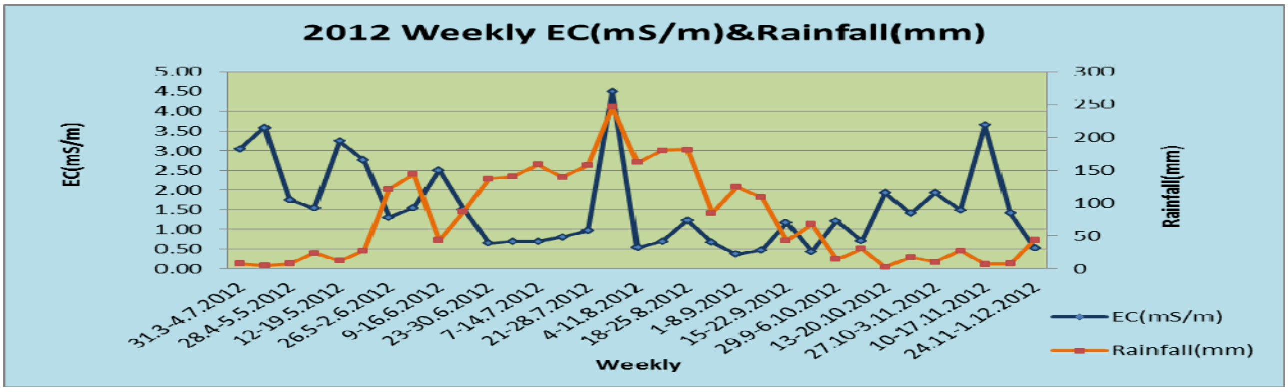


Figure 2.6 Weekly EC (mS/m) and Rainfall (mm) at Yangon (Kaba-Aye) in 2012

In the year 2013, it was recorded minimum of pH =6.06, EC = 0.42 mS/m and the maximum of pH = 6.99, EC = 8.30 mS/m as shown in **Figure 2.7 and 2.8**

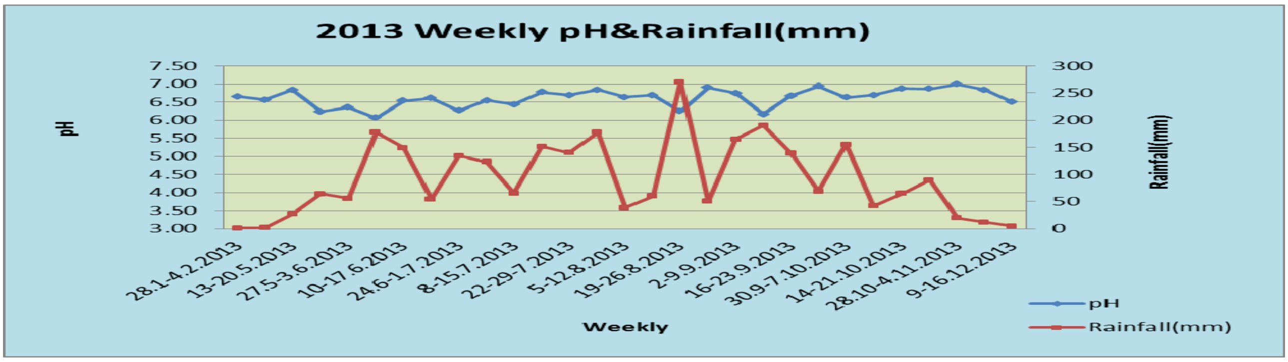


Figure 2.7 Weekly pH and Rainfall (mm) at Yangon (Kaba-Aye) in 2013

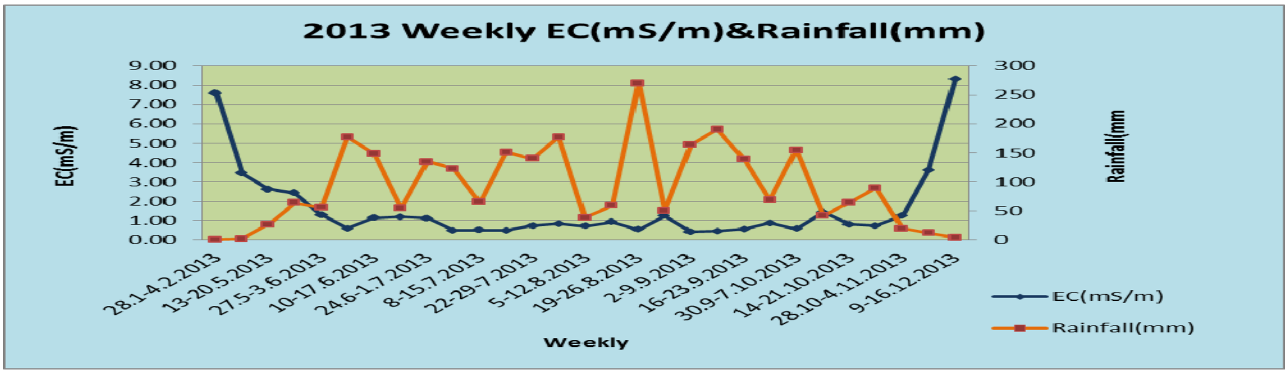


Figure 2.8 Weekly EC (mS/m) and Rainfall (mm) at Yangon (Kaba-Aye) in 2013

In the year 2014, it was recorded minimum of pH =6.00 , EC = 0.42 mS/m and the maximum of pH = 6.98, EC = 5.73 mS/m as shown in **Figure 2.9 and 2.10**

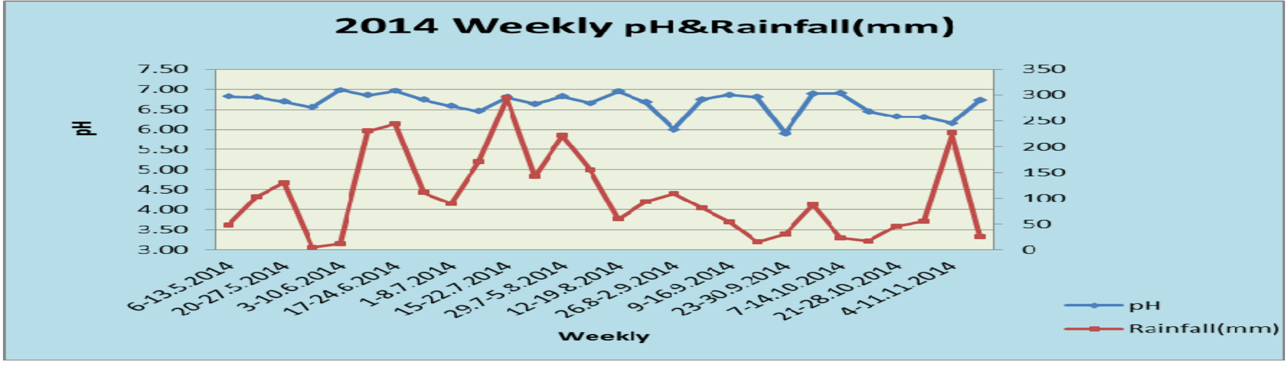


Figure 2.9 Weekly pH and Rainfall (mm) at Yangon (Kaba-Aye) in 2014

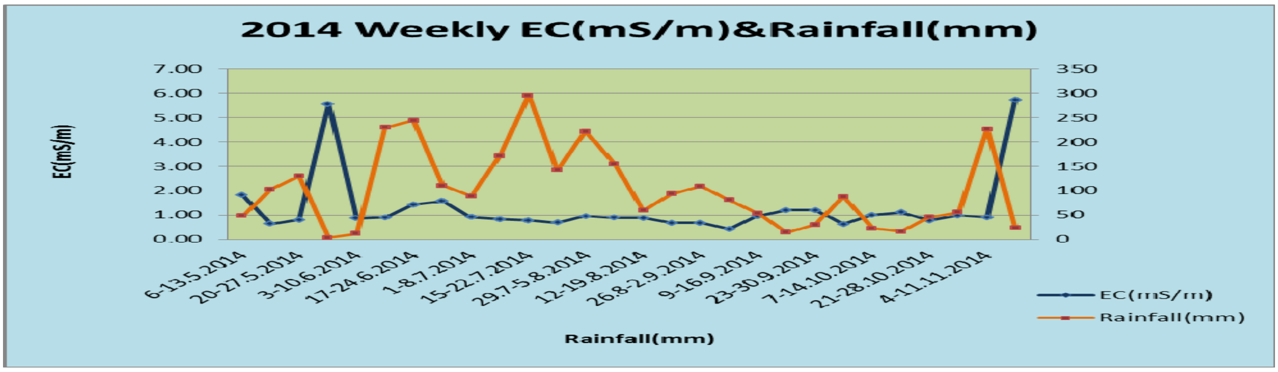


Figure 2.10 Weekly EC (mS/m) and Rainfall (mm) at Yangon (Kaba-Aye) in 2014

In the year 2010, it was recorded minimum of Anion Cl^- = 4.49µmol/l , NO_3^-= 0.0µmol/l , SO_4^{2-}= 0.02µmol/l,' the minimum of Cation NH_4^+ = 4.21µmol/l, Na^+= 4.87µmol/l, K^+= 0.59µmol/l, Ca^{2+},= 2.67µmol/l,Mg^{2+} = 0.66 µmol/l as shown in **Figure 2.11**

In the year 2010, It was recorded maximum of Anion Cl^- = 28.29µmol/l , NO_3^- = 96.21 µmol/l ,SO_4^{2-}=18.46 µmol/l , the Maximum of Cation NH_4^+ = 70.51µmol/l, Na^+= 33.41µmol/l, K^+ = 20.46 µmol/l, Ca^{2+},= 40.17µmol/l, Mg^{2+} = 5.55µmol/l as shown in **Figure 2.12**

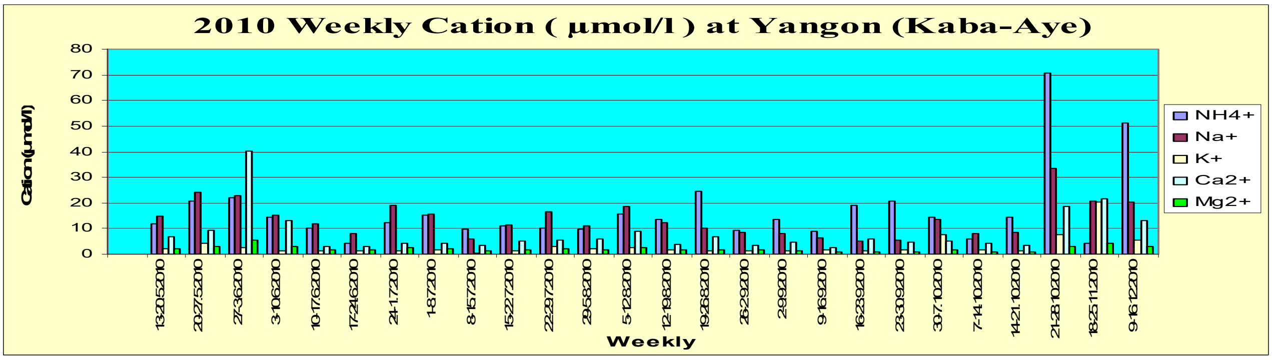


Figure 2.11 Weekly Analysis of Cation at Yangon (Kaba-Aye) in 2010

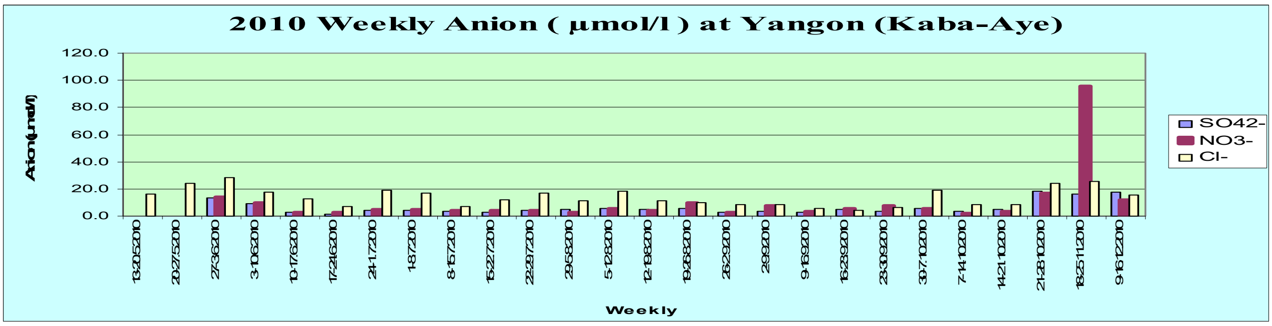


Figure 2.12 Weekly Analysis of Anion at Yangon (Kaba-Aye) in 2010

In the year 2011, it was recorded minimum of Anion Cl^- = 4.71µmol/l , NO_3^-= 1.76µmol/l ,SO_4^{2-} =2.68µmol/l' the minimum of Cation NH_4^+ = 0.89µmol/l, Na^+= 0.39µmol/l, K^+= 0.28µmol/l, Ca^{2+},= 0.77µmol/l, Mg^{2+} = 0.08 µmol/l as shown in **Figure 2.13**

In the year 2011, it was recorded maximum of Anion Cl^- = 58.50µmol/l , NO_3^- = 106.40 µmol/l ,SO_4^{2-}=53.30 µmol/l , the Maximum of Cation NH_4^+ = 98.50µmol/l, Na^+= 50.20µmol/l, K^+= 10.30µmol/l, Ca^{2+},= 132.40µmol/l, Mg^{2+} = 24.70µmol/l as shown in **Figure 2.14**

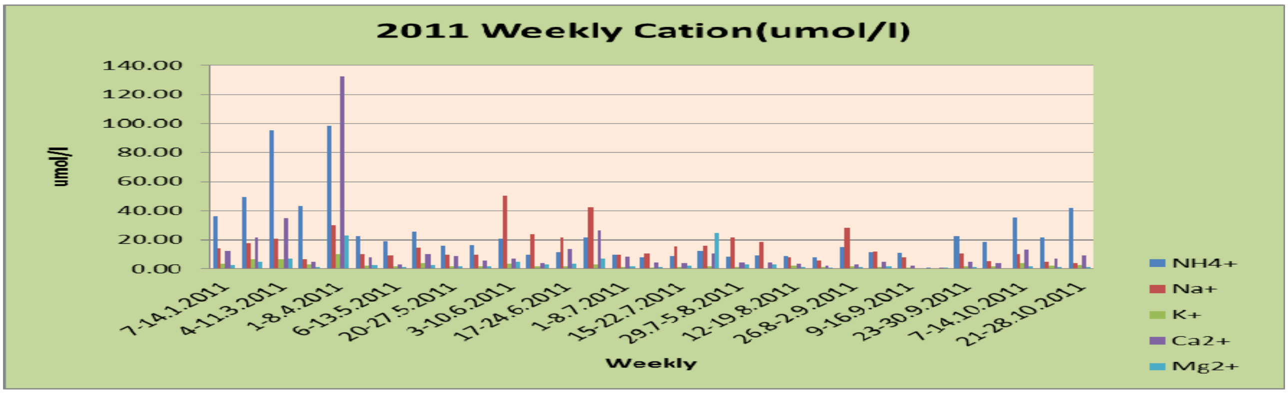


Figure 2.13 Weekly Analysis of Cation at Yangon (Kaba-Aye) in 2011

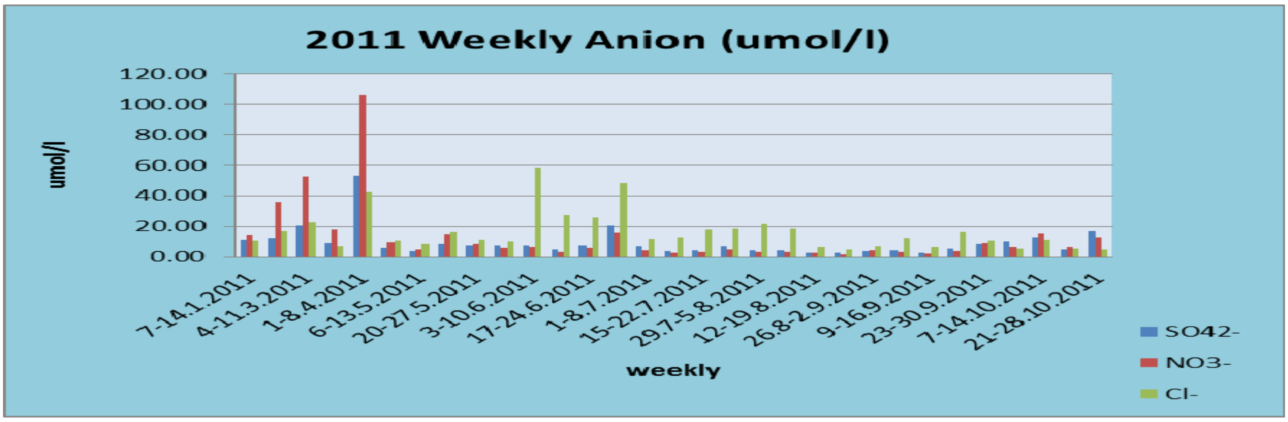


Figure 2.14 Weekly Analysis of Anion at Yangon (Kaba-Aye) in 2011

In the year 2012, it was recorded minimum of Anion Cl$^-$ = 2.45µmol/l , NO$_3$ $^-$= 2.19µmol/l ,SO$_4^{2-}$ =1.88µmol/l, the minimum of Cation NH$_4^+$ = 7.76µmol/l, Na$^+$= 5.79µmol/l, K$^+$= 1.00µmol/l, Ca^{2+},= 0.02µmol/l, Mg^{2+} = 0.16 µmol/l as shown in **Figure 2.15**

In the year 2012, it was recorded maximum of Anion Cl$^-$ = 95.10 µmol/l , NO$_3$ $^-$ = 76.40 µmol/l , SO$_4^{2-}$=43.70 µmol/l , the Maximum of Cation NH$_4^+$ = 116.50µmol/l, Na$^+$= 95.70µmol/l, K$^+$= 30.10µmol/l, Ca^{2+},= 57.90µmol/l, Mg^{2+} = 21.0µmol/l as shown in **Figure 2.16**

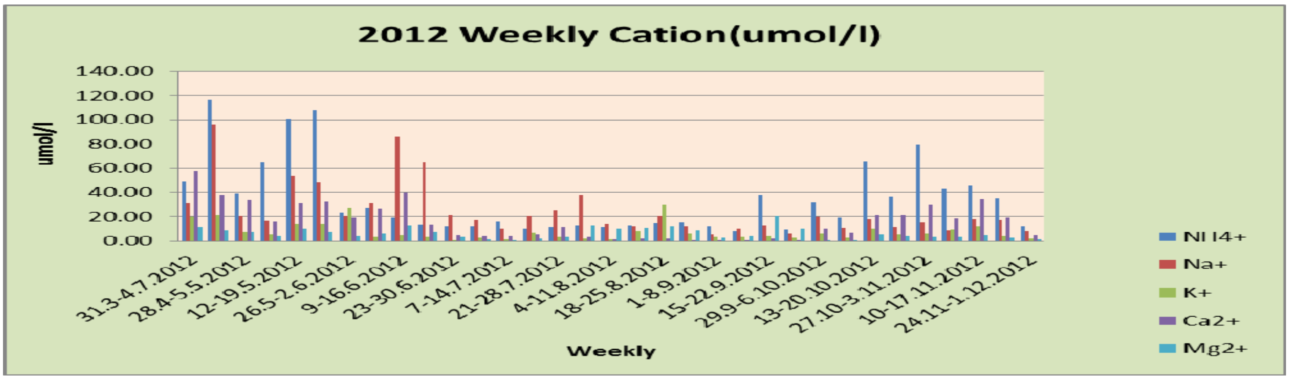


Figure 2.15 Weekly Analysis of Cation at Yangon (Kaba-Aye) in 2012

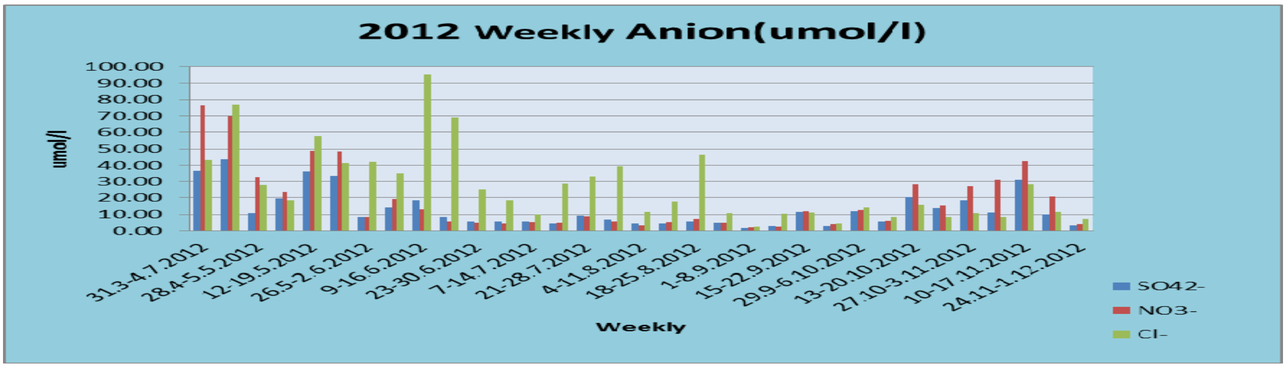


Figure 2.16 Weekly Analysis of Anion at Yangon (Kaba-Aye) in 2012

In the year 2013, it was recorded minimum of Anion Cl^- = 3.98μmol/l , NO_3^-= 0.06μmol/l ,SO_4^{2-}= 0.0μmol/l, the minimum of Cation NH_4^+ = 0.55μmol/l, Na^+= 0.04μmol/l, K^+= 0.08μmol/l, Ca^{2+},= 0.05μmol/l, Mg^{2+} = 0.41 μmol/l as shown in **Figure 2.17**

In the year 2013, it was recorded maximum of Anion Cl^- = 254.90μmol/l , NO_3^-= 300.0 μmol/l ,SO_4^{2-}=73.40 μmol/l , the Maximum of Cation NH_4^+ = 106.60μmol/l, Na^+= 354.40μmol/l, K^+= 31.70μmol/l, Ca^{2+},= 25.10μmol/l, Mg^{2+} = 824.0μmol/l as shown in **Figure 2.18**

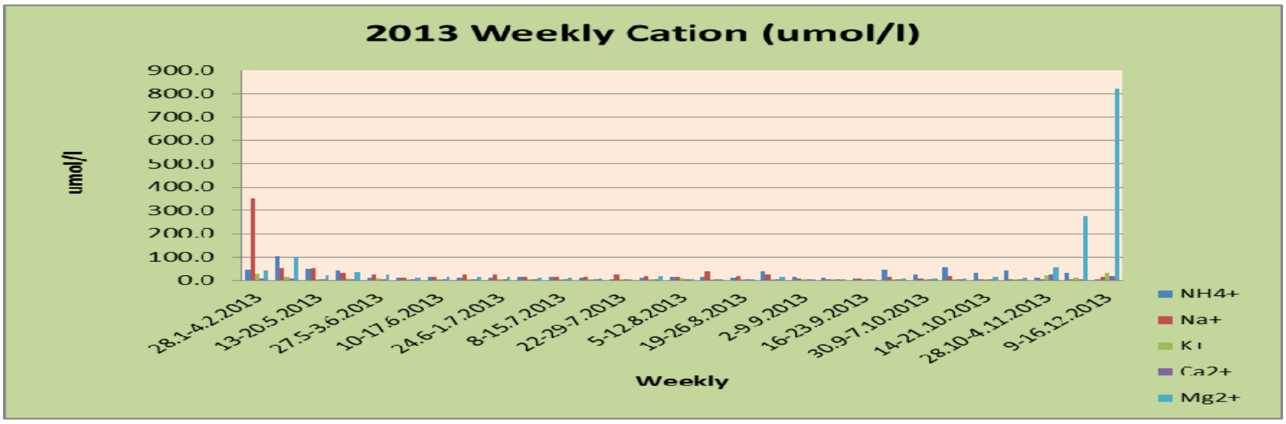


Figure 2.17 Weekly Analysis of Cation at Yangon (Kaba-Aye) in 2013

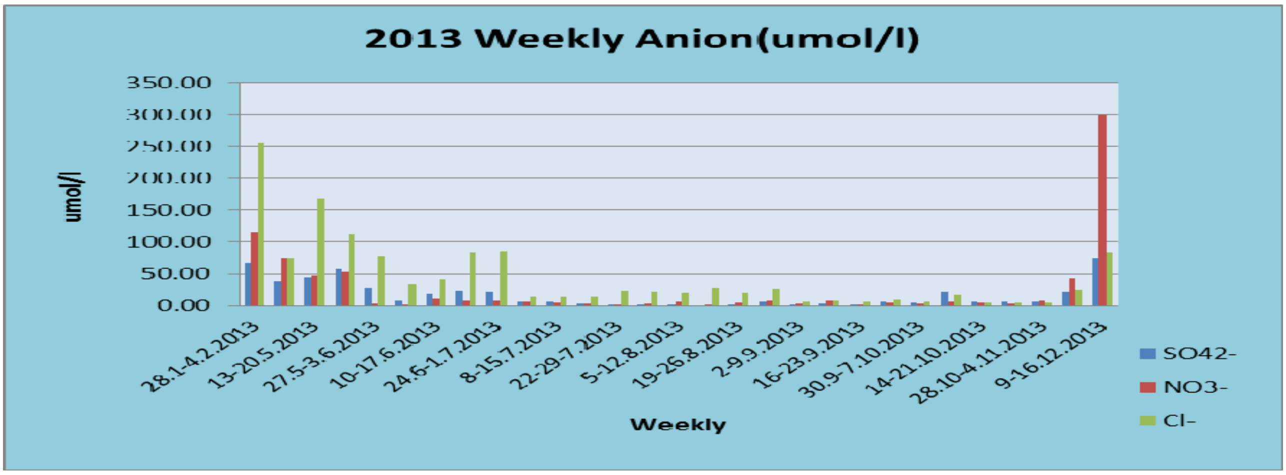


Figure 2.18 Weekly Analysis of Anion at Yangon (Kaba-Aye) in 2013

In the year 2014, it was recorded minimum of Anion Cl^- = 4.40 µmol/l, NO_3^-= 0.21 µmol/l, SO_4^{2-}= 0.90 µmol/l' the minimum of Cation NH_4^+ =0.78 µmol/l, Na^+= 1.04 µmol/l, K^+= 1.94 µmol/l, Ca^{2+},= 3.52 µmol/l, Mg^{2+} = 1.03 µmol/l as shown in **Figure 2.19**

In the year 2014, it was recorded maximum of Anion Cl^- = 398.62 µmol/l , NO_3^-= 43.93 µmol/l ,SO_4^{2-} =35.93µmol/l , the Maximum of Cation NH_4^+ =304.82 µmol/l, Na^+= 47.24 µmol/l, K^+=527.70 µmol/l, Ca^{2+},=197.48 µmol/l, Mg^{2+} = 38.26 µmol/l as shown in **Figure 2.20**

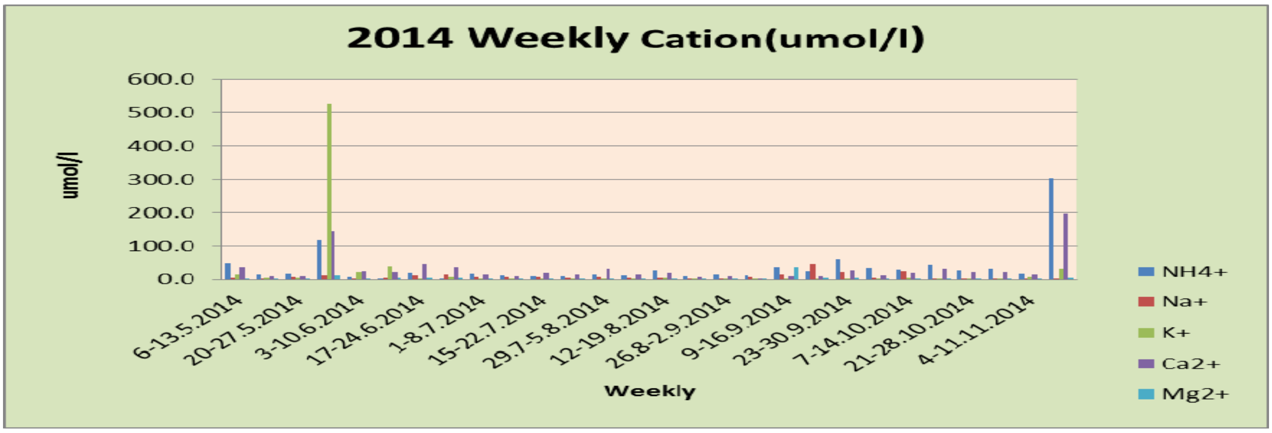


Figure 2.19 Weekly Analysis of Cation at Yangon (Kaba-Aye) in 2014

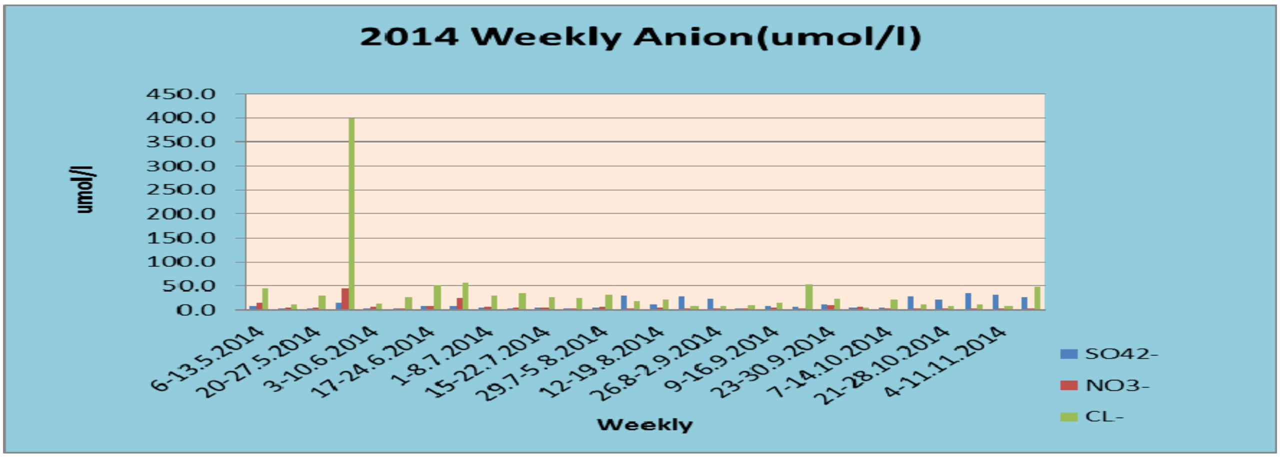


Figure 2.20 Weekly Analysis of Anion at Yangon (Kaba-Aye) in 2014

2.1.2 State of Dry Deposition

Myanmar has been carrying out according to the common methologies specified in the "Technical Documents for dry deposition monitoring in East Asia". Dry samples are collected by Filter Pack Simpler System in biweekly basic at Yangon (Kaba-Aye). Collected samples are carried to laboratory and stored in the refrigerator at 4 ^{0}C to preserve the sample composition. And then analysis for ions has done by Ion Chromatography machine. The maximum value of ion analysis for Dry Deposition Monitoring was shown in following **Table 2.4** and **figures 2.21 to 2.26** show the biweekly Analysis of Cation and Anion for Dry Deposition .

Table 2.4 Maximum values of Ions Analysis for dry deposition monitoring (2012-2014)

Year	Anion (nmol/m3)			Cation (nmol/m3)				
	Cl^-	NO_3^-	SO_4^{2-}	NH_4^+	Na^+	K^+	Ca^{2+}	Mg^{2+}
2012	41.86	56.01	118.68	75.17	79.64	65.30	80.45	13.06
2013	44.29	23.00	90.17	90.42	54.76	23.02	24.69	6.94
2014	68.62	10.35	210.75	167.68	59.46	123.64	171.83	33.10

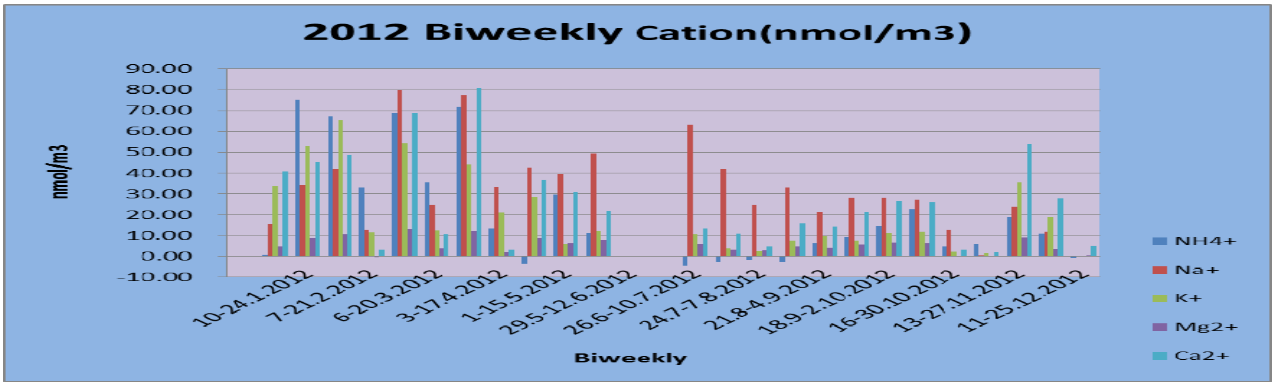


Figure 2.21 Biweekly Analysis of Cation at Yangon (Kaba-Aye) in 2012

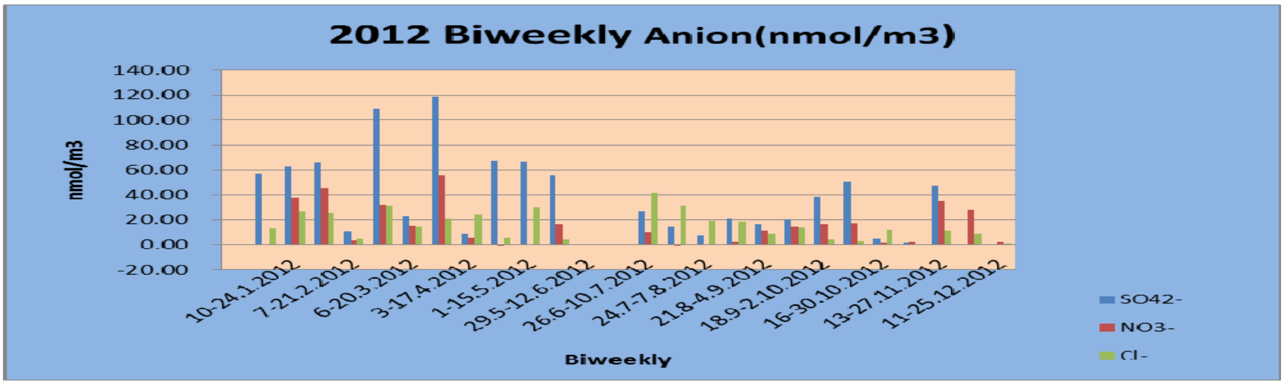


Figure 2.22 Biweekly Analysis of Anion at Yangon (Kaba-Aye) in 2012

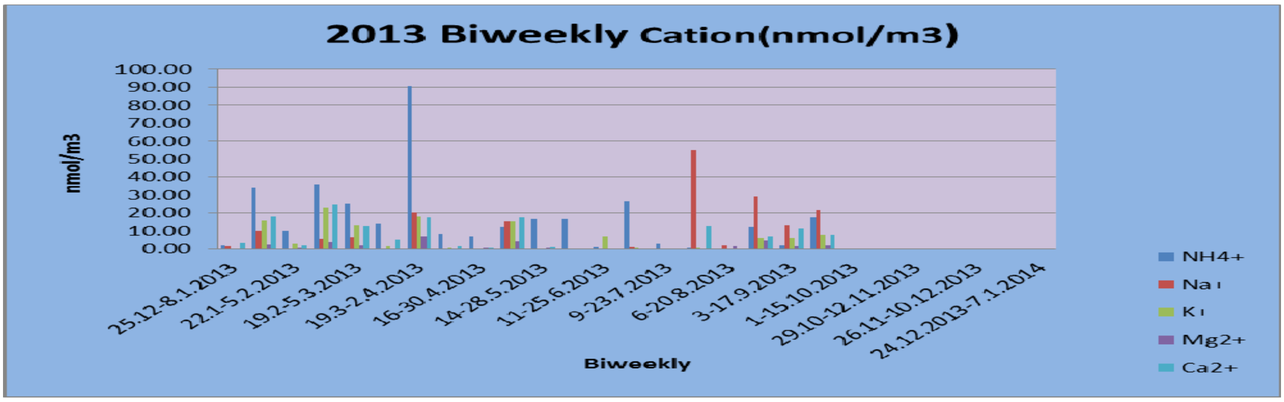


Figure 2.23 Biweekly Analysis of Cation at Yangon (Kaba-Aye) in 2013

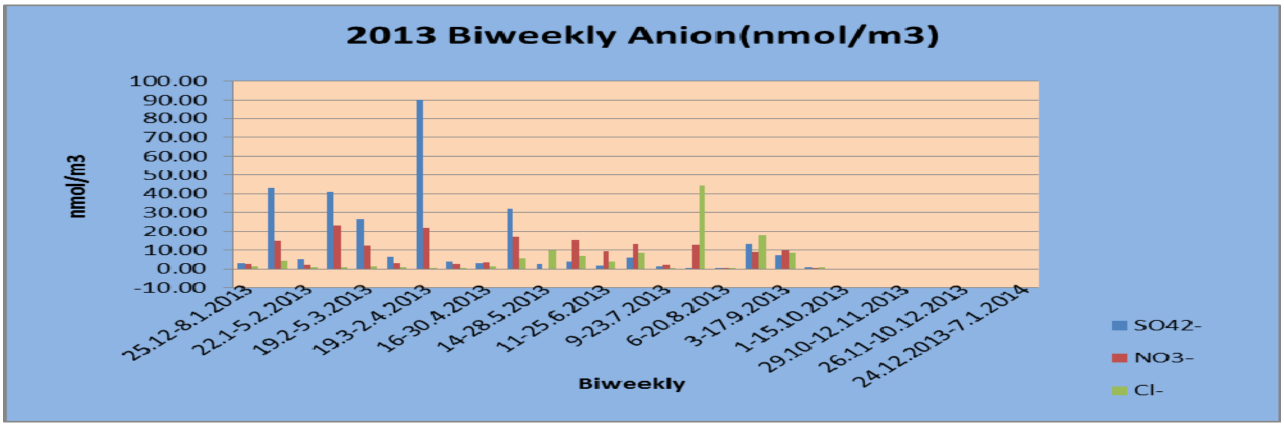


Figure 2.24 Biweekly Analysis of Anion at Yangon (Kaba-Aye) in 2013

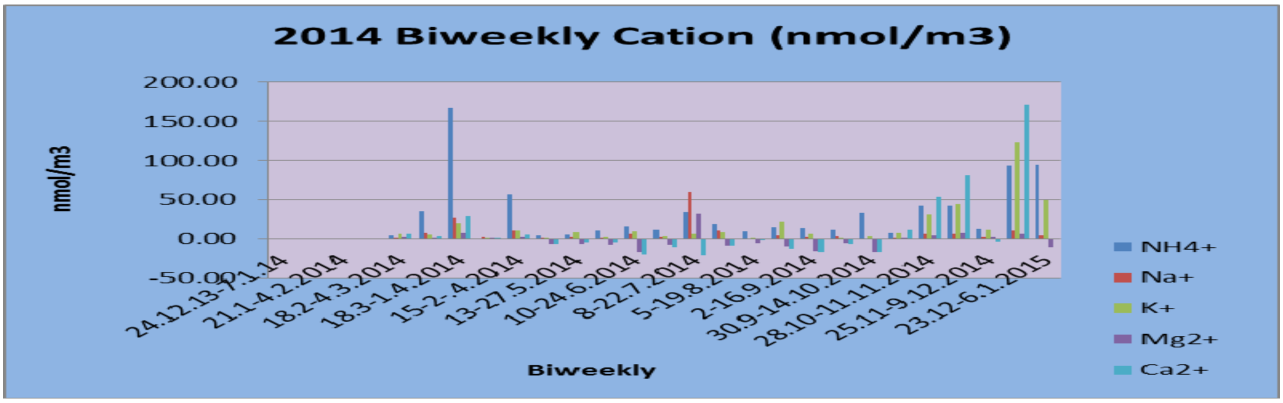


Figure 2.25 Biweekly Analysis of Cation at Yangon (Kaba-Aye) in 2014

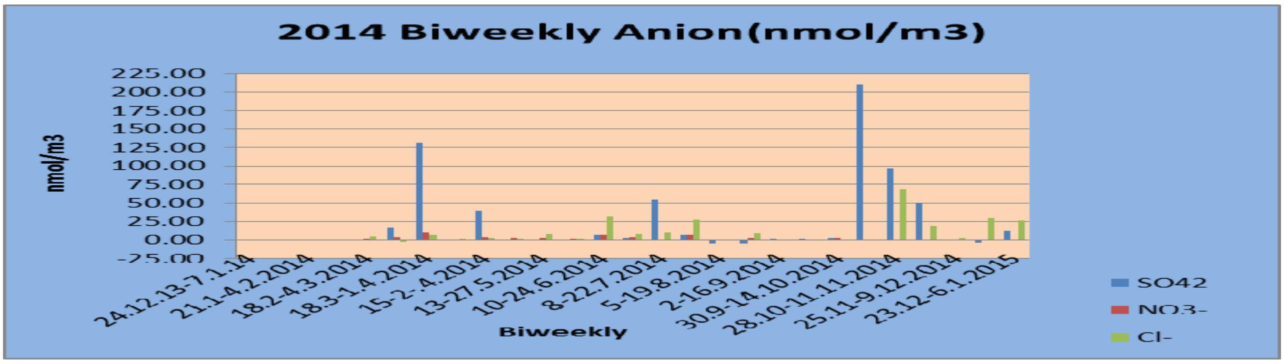


Figure 2.26 Biweekly Analysis of Anion at Yangon (Kaba-Aye) in 2014

2.2 State of inland and aquatic environment

Myanmar will initiate the monitoring of inland and aquatic environment in the near future in order to fulfill the requirements of EANET activities.

2.3 State of soil and vegetation

The activities for soil and vegetation monitoring are not yet decided now in Myanmar due to constraints for instrument supply and capacity building. However, the national center will make plan to conduct soil and vegetation monitoring in the future.

2.4 Overall analysis

By the analysis of water quality monitoring in Myanmar, among the observed data (rain water sample) from Yangon (Kaba-Aye) urban site, minimum pH value for 2010, 2011, 2012, 2013 and 2014 were 5.75, 6.20, 5.83, 6.06 and 6.00 respectively; most of the measured pH values throughout the year were between 5.75 and 6.2, which is within the desirable range for drinking water from **national drinking water quality standard** (6.5 -8.5) and **Maximum permissible range of WHO standard** (6.5 -9.2). Hence, it can be generally concluded that acid deposition is not significant in Myanmar. Regarding the value of EC, the maximum of 8.75 mS/m was recorded on 27 May 2010 but it is under the acceptable level. It was the early monsoon season in 2010, and there could be some contaminants in that rain water sample. From the data recorded in 2010 to 2014, the overall analysis describes the average concentrations of pH and EC receptivity, which are still within the acceptable levels. Most of the analysis ions values throughout the year were under maximum permissible value which are also still within the acceptable level. Meteorological data such as wind direction, wind speed, temperature and humidity and sunshine hours are also observed together with precipitation at the site. Based on monitoring result of Acid deposition from 2010 to 2014, the status of Yangon rain is not acidic and its negative impacts has not identified yet in Myanmar.

3. Review of National Measure against Acid Deposition

Based on monitoring result of Acid deposition from 2010 to 2014, the status of Yangon rain is not acidic and its negative impacts has not identified yet in Myanmar. As the National Monitoring Center for EANET, the Department of Meteorology and Hydrology will continue the relevant environmental monitoring activities. Apart from DMH, there are some governmental agencies such as: Yangon/ Mandalay City Development Committee, Department of Health, Department of Atomic Energy, Irrigation Department, Water Resources Utilization Department etc., which monitor water and air qualities. Environmental Conservation Department also installed the $PM_{2.5}$ for air concentration in 2014. Regarding acid deposition monitoring, wet and dry deposition have been monitored. The National Center will seek the possible opportunities to extend the inland aquatic monitoring to follow the examples of other participating countries of EANET.

References

1. Acid Deposition Monitoring Network in East Asia: 2000, Technical Documents for Acid Deposition Monitoring in East Asia.
2. Network Center for EANET: Periodic Report on the State of Acid Deposition in East Asia
3. Network Center for EANET: 2002, Data Reporting, Data Quality Assessment, and Data Treatment of Wet Deposition Monitoring for EANET Textbook.
4. Acid Deposition Monitoring Network in East Asia: FACT SHEETS

National Assessment on Acid Deposition in Philippines

Environmental Management Bureau
Department of Environment and Natural Resources

1.0 Basic Information on National Monitoring Activities

1.1 Outline of the activities on acid deposition and National Monitoring Plan

The Philippines has been a participant in the preparatory phase in 1998 to 2000 and up to this date in the Acid Deposition Monitoring in East Asia (EANET) and the National Monitoring Plan was developed in 1999 after the basic monitoring infrastructure was set up with the assistance of the Government of Japan. This was based on the guidelines for acid deposition monitoring developed by the Environment Agency.

Acid deposition activities in the Philippines include the following:
1) Implementation of the National Monitoring Plan through the conduct of monitoring of wet deposition, dry deposition, soil, vegetation, and inland aquatic;
(2) Participation in inter-laboratory comparison exercises for wet deposition, soil, and inland aquatic environment; and
(3) National training capacities for enforcers and inspectors of emission sources relative to emission inventories, sulfur oxides stack testing and ambient sulfur dioxide sampling.
(4) Conduct of public awareness activities through the preparation of the acid deposition brochures, conduct of seminar-workshops for stakeholders and lectures on acid deposition.

At the regional level, the Philippines also participates in sessions of the (1) Senior Technical Managers that discuss the results of monitoring and quality assurance/quality control (QA/QC) activities; (b) Scientific Advisory Committee that provides advice from the scientific and technical viewpoints; and (3) Intergovernmental Meeting (IG) that sets the policy and makes decisions relative to EANET budget and operations as well as Working Groups on Future Development of EANET to discuss specific concerns/issues directed by the IG.

1.2 Monitoring program from 2010 to 2014

The National Monitoring Plan covers the generation of the relevant data, operation and maintenance of field and laboratory facilities and equipment, and conduct of QA/QC activities.

For wet deposition monitoring, weekly monitoring was conducted in the Metro Manila , Los Baños and Mt. Sto. Tomas stations. Measurements were done on ten (10) parameters as follows: pH, electrical conductivity, sulfate (SO_4^{2-}), nitrate (NO_3^-), chloride (Cl^-), ammonium (NH_4^+), sodium (Na^+), potassium (K^+), calcium (Ca^{2+}), and magnesium (Mg^{2+}).

For dry deposition monitoring, weekly monitoring was conducted in the Metro Manila, Los Baños and Mt. Sto. Tomas stations. Measurements were done for four (4) gases, i.e., sulfur dioxide (SO_2), nitric acid (HNO_3), hydrogen chloride (HCl), and ammonia (NH_3), and for eight (8) parameters in aerosol, i.e., sulfate (SO_4^{2-}), nitrate (NO_3^-), chloride (Cl^-), ammonium (NH_4^+), sodium (Na^+), potassium (K^+), calcium (Ca^{2+}), and magnesium (Mg^{2+}). For remote site, sampling in Sto. Tomas started on 2009.

For soil monitoring, soil samples were collected and analyzed for pH (H_2O), pH (KCl), exchangeable base cations (Ca^{2+}, Mg^{2+}, K^+, Na^+), and exchangeable acid cations (Al, H). Exchangeable acidity and ECEC were calculated. Study sites for soil vegetation are the Mt. Makiling Forest Reserve at the University of the Philippines at Los Baños in Laguna and the U.P. Quezon Land Grant in Quezon (Figure 8.2). The prescribed monitoring frequency for soil monitoring is 3-5 years.

For vegetation monitoring, investigations were made on the trees in the sampling plots (species, diameter at breast height/DBH, height) and understorey vegetation in terms of species. Indicators of tree damage were also noted. Study sites for vegetation monitoring are the Mt. Makiling Forest Reserve at the University of the Philippines in Laguna and the U.P. Quezon Land Grant located in Quezon. The prescribed monitoring frequency for vegetation monitoring is 3-5 years.

For inland aquatic monitoring, quarterly monitoring was conducted in Pandin Lake in Laguna and Ambulalakao Lake in Itogon, Benguet for the period 2010-2014. Measurements were done on twelve (12) parameters as follows: temperature, pH, electrical conductivity, alkalinity, sulfate (SO_4^{2-}), chloride (Cl^-), phosphate (PO_4^{3-}), ammonium (NH_4^+), sodium (Na^+), potassium (K^+), calcium (Ca^{2+}), and magnesium (Mg^{2+}).

1.3 Monitoring Stations

Figure 1 Monitoring sites of wet and dry deposition, inland aquatic, soil and vegetation

Table 1 List of Monitoring Stations

Site Category	Site Classification	Location
Wet deposition/ Dry deposition	Urban	Metro Manila (Manila Observatory,Ateneo de Manila University Campus, Quezon City)
	Rural	Los Banos (Pag-asa, Agromet, University of the Philippines Campus, Los Banos, Laguna)
	Remote	Mt. Sto. Tomas, Tuba, Benguet
Ecological survey site Soil and Vegetation	Rural	Makiling Forest Reserve Los Banos, Laguna
		UP Quezon-Laguna Land Grant Laguna
	Urban	La Mesa Watershed Quezon City
	Remote	Environmental Research and Development Sector, DENR Itogon, Benguet
Inland Aquatic	Rural	Pandin Lake San Pablo City
	Remote	Ambulalakao Lake Itogon, Benguet

1.4 Sampling and Measurements

Rainwater samples for wet deposition monitoring were collected by the "wet-only" samplers installed on site. Gas and aerosol samples for dry deposition monitoring were collected by the filter pack. Soil samples were collected by soil augers. Lake water samples were scooped directly into the sample containers.

Analytical methods for the measurement of specific parameters are the methods recommended in EANET manuals. Data in Metro Manila for 2010 and 2012 did not meet the EANET criteria , % PCL <80% while Los Banos for years 2010, 2012, 2013 and 2014 due to breakdown of equipment, laboratory rehabilitation and forging of Memorandum of Agreement (MOA) with partner agency was installed until this day.

2.0 State of acid deposition in the Philippines

2.1 Atmospheric Deposition

2.1.1. State of trace gas and aerosol concentration

Mt. Sto. Tomas annual data of dry deposition monitoring are presented below. There were no data for Metro Manila and Los Banos due to dry deposition equipment broke down and problems of forging of MOAs with partner agencies..

Table 2. Dry Deposition Monitoring at Sto. Tomas in ppb

	SO_2	HNO_3	HCl	NH_3
2010	1.1	0.4	1.2	2.5
2011				
2012	0.2	0.2	0.2	1
2013	0.1	<0.1	0.2	1.1
2014	0.1	0.1	0.2	2.2

Table 2.1 Annual ions in PM concentration, ug/cu.m.

	SO_4	NO_3	Cl	NH_4	Na	K	Mg	Ca
2010	1.4	0.78	0.32	0.1	0.52	0.15	0.06	0.5
2011								
2012	0.15	0.19	0.05	<0.01	0.07	0.01	0.03	0.35
2013	0.17	0.14	0.04	0.01	0.1	0.01	0.04	0.29
2014	0.38	0.26	0.1	0.1	0.31	0.07	0.03	0.39

2.1.2 State of precipitation

Figures 2.1 shows the annual average precipitation for the three sites for 2010-2014 where 2012 has the highest rainfall in Metro Manila and Mt. Sto. Tomas. The highest annual rainfall was in Mt. Sto. Tomas with 5,730 mm in 2012. At rural site in Los Banos, the range was at 2068-2394 mm for the five year period.The ionic composition of waters is presented in figures 2.2 to 2.4. The balance of anions and cations at different monitoring sites was shown. The anions deficiency was observed at the three sites.

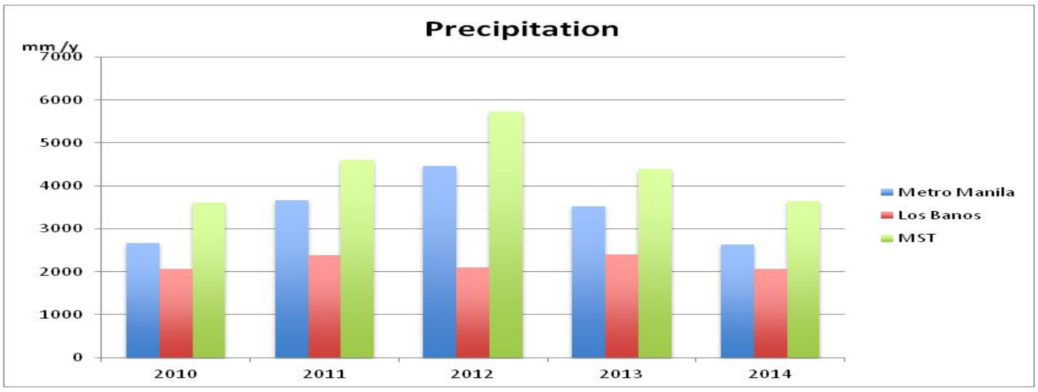


Figure 2.1 Annual Precipitation from 2010-2014

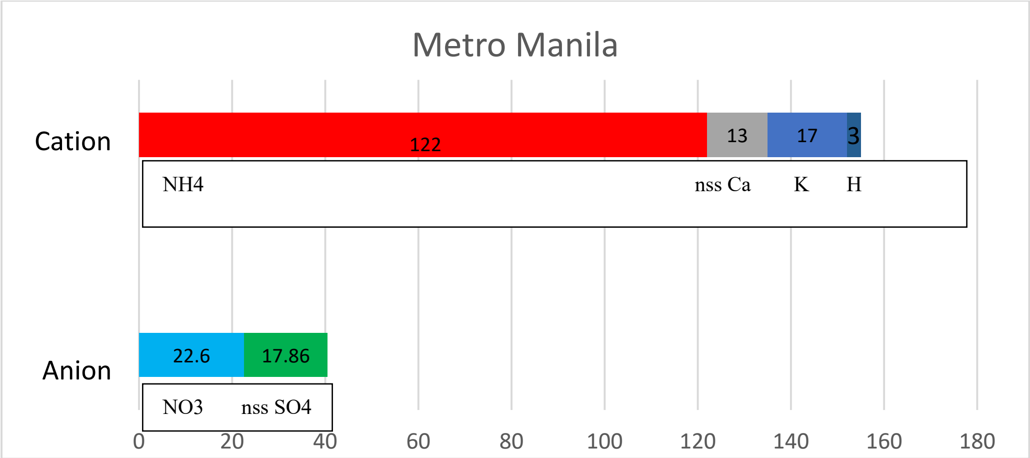


Figure 2.2 Ionic composition of rain waters at Metro Manila 2010-2014

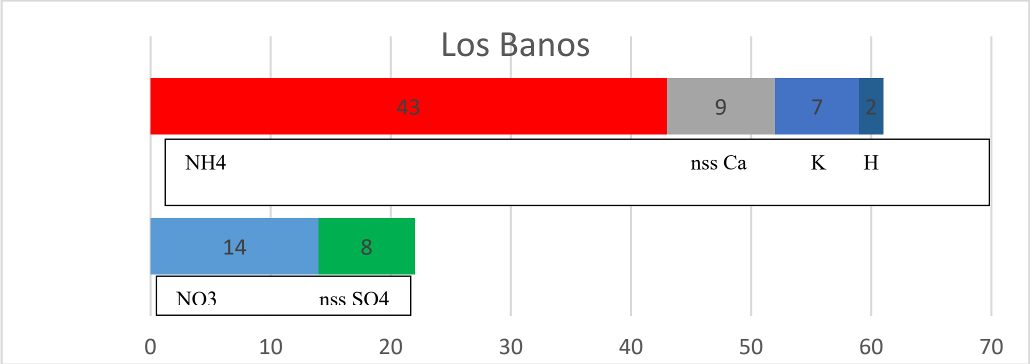


Figure 2.3 Ionic composition of rain waters at Los Banos

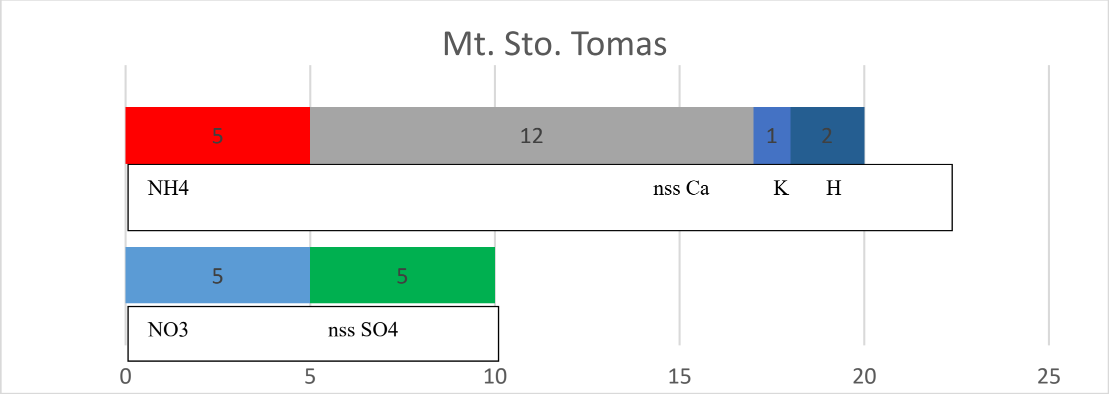


Figure 2.4 Ionic composition at Mt. Sto. Tomas

2.1.3 State of wet and dry deposition

The pH of rainwater in urban site was in the range from 5.52 to 6.13 for the monitoring years of 2010-2014. In Los Banos, rural site , pH ranged from 5.57 to 5.88, Mt. Sto. Tomas, the remote site has a range of 5.35 to 6.70 and data in Metro Manila has 5.22-6.13. Figures 2.7 to 2. 17 show the annual averages of cation and anion deposition from 2010-2014. The highest deposition of cation was NH_4 in Metro Manila, urban site in 2012. NO_3 was also high in 2010 and has decreased from 2012-2014 in Metro Manila.

1) Ion concentrations and composition of precipitation

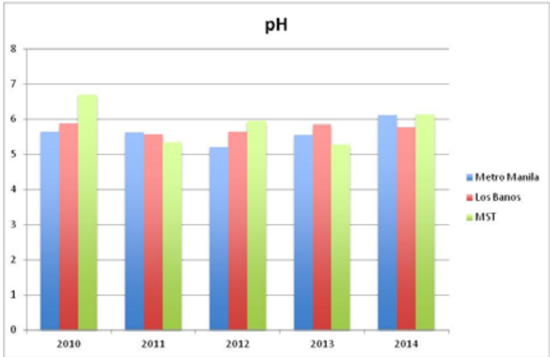


Figure 2.5 Annual pH from 2010-2014

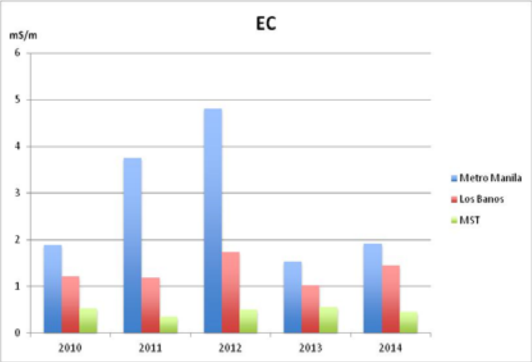


Figure 2.6 Annual EC from 2010-2014

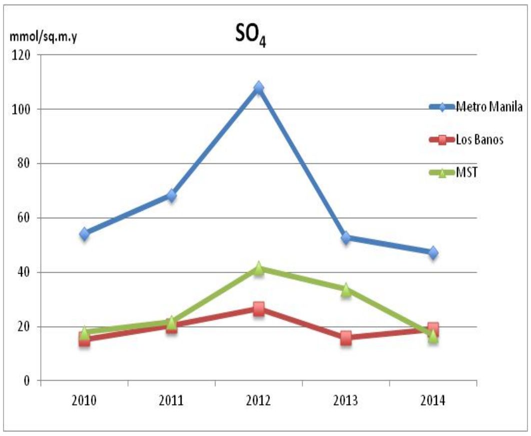


Figure 2.7 Annual SO_4 deposition from 2010-2014

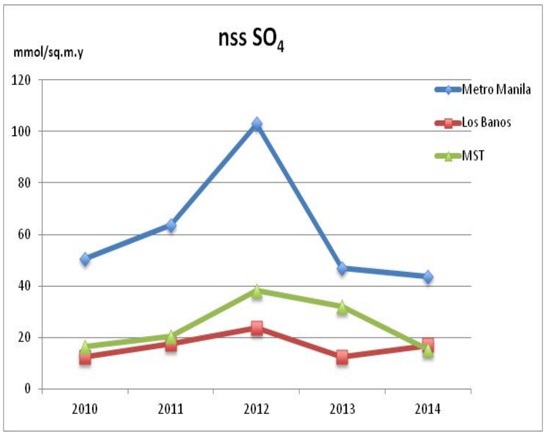


Figure 2.8 Annual nss SO_4 deposition from 2010-2014

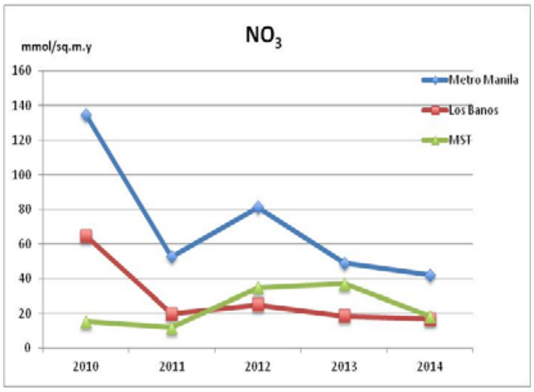


Figure 2.9 Annual NO_3 deposition from 2010-2014

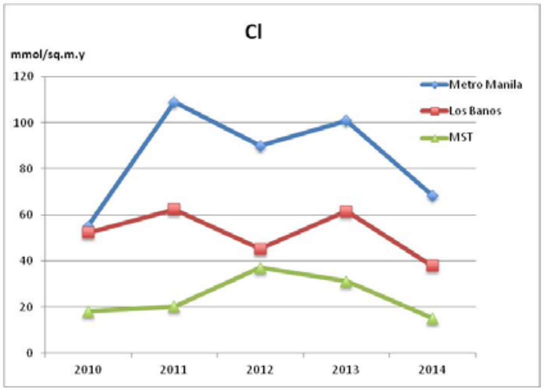


Figure 2.10 Annual chloride deposition from 2010-2014

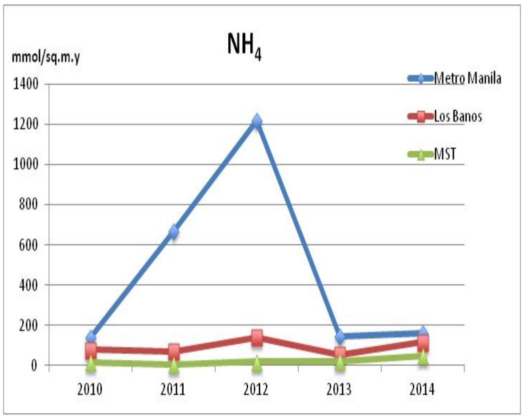


Figure 2.11 Annual NH_4 deposition from 2010-2014

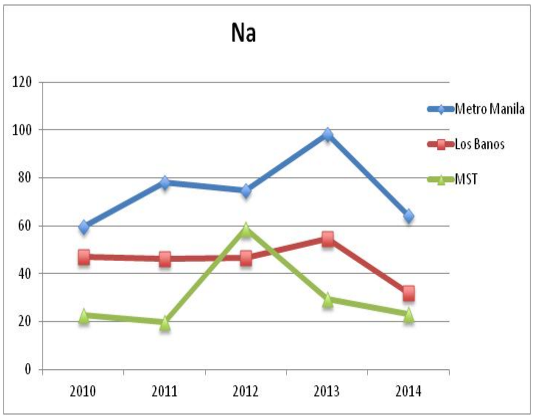


Figure 2.12 Annual Na deposition from 2010-2014

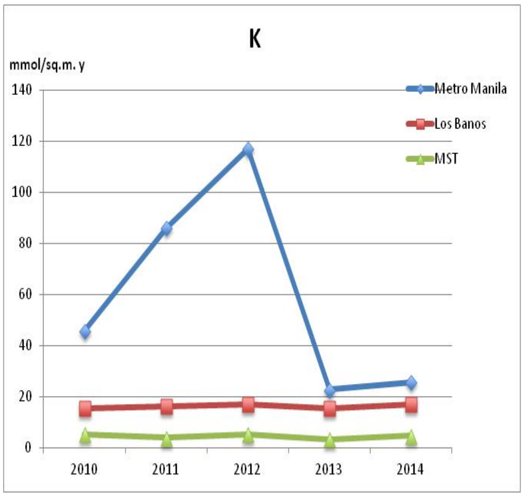


Figure 2.13 Annual K deposition from 2010-2014

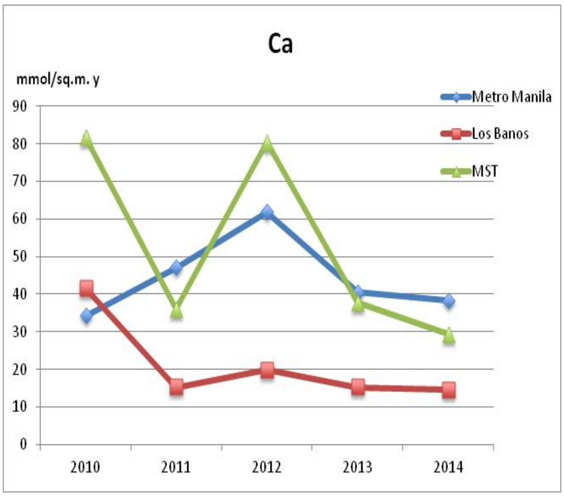


Figure 2.14 Annual Ca deposition from 2010-2014

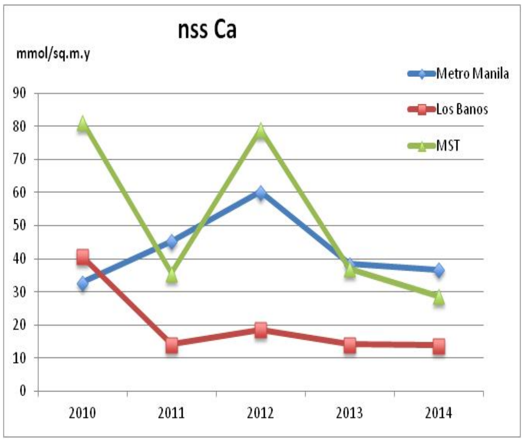


Figure 2.15 Annual nss Ca deposition from 2010-2014

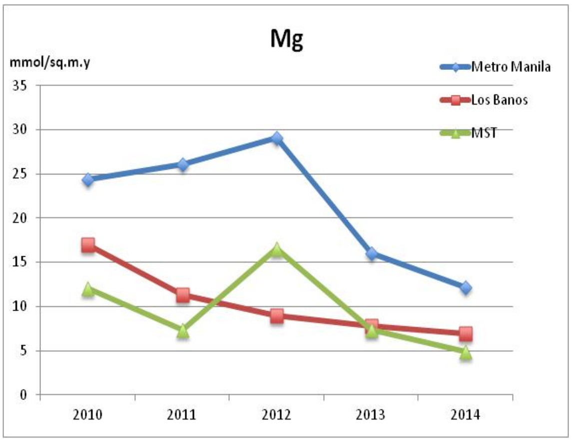


Figure 2.16 Annual Mg deposition from 2010-2014

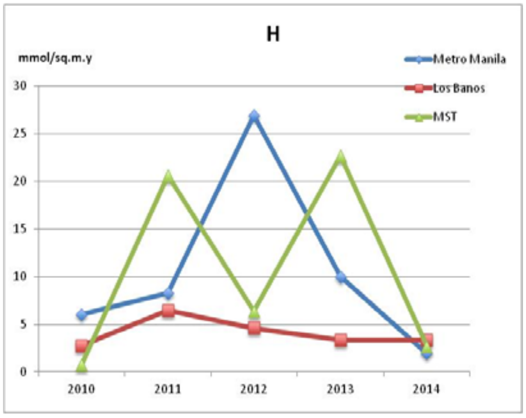


Figure 2.17 Annual H deposition from 2010-2014

2.2 State of inland aquatic environment

Monitoring results in Pandin Lake and Ambulalakao Lake are presented in figures for pH , EC and ionic concentration. Pandin Lake monitoring started in 2004 and conducted four times a year while in Ambulalakao , categorized a remote site, monitoring started on 2005 and conducted two times a year. Other parameters monitored include ammonium, nitrate, chloride, sodium, potassium, calcium, magnesium, phosphate and nitrate.

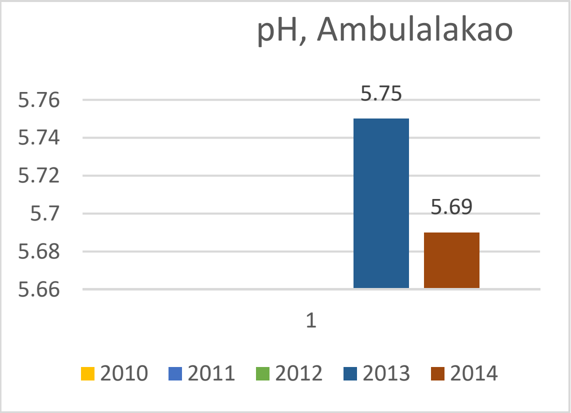


Figure 2.17 Annual pH for remote, Ambulalakao Lake 2010-2014

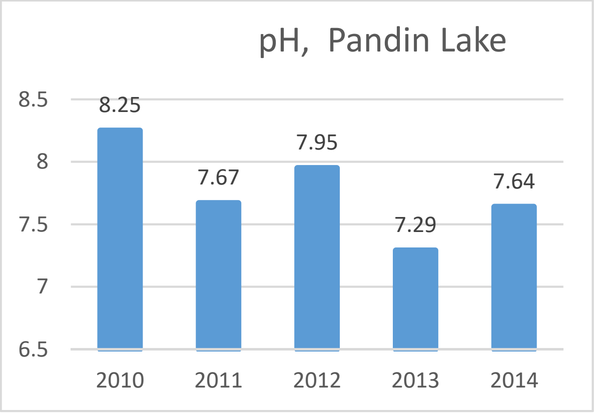


Figure 2.18 Annual pH for rural Pandin Lake, 2010-2014

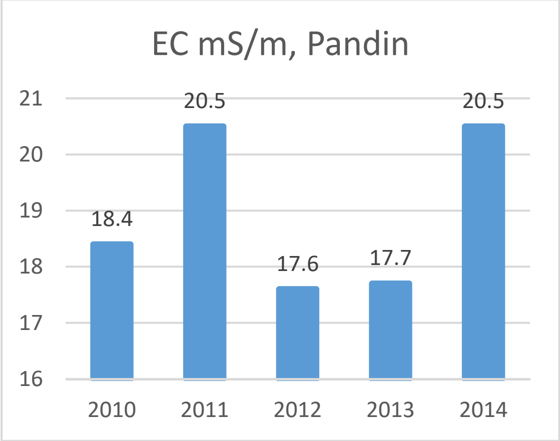


Figure 2.19 Annual EC for rural Pandin

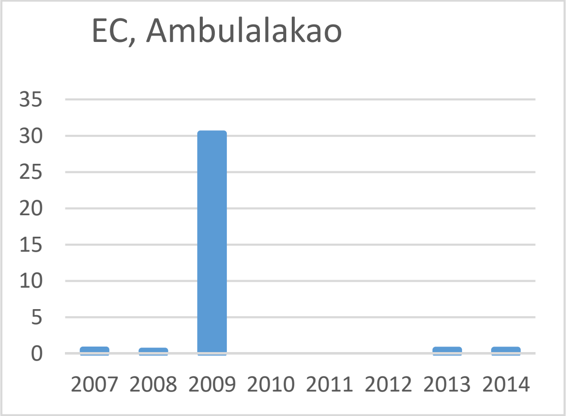


Figure 2.20 Annual EC for remote Ambulalakao

Table 3 Annual mean values of each parameters from 2010-2014 at Pandin Lake

	Alkalinity meq/L	SO_4 mg/L	NO_3 mg/L	Cl mg/L	NH_4 mg/L	Na mg/L	K mg/L	Ca mg/L	Mg mg/L	PO_4 mg/L
2010	1.837	0.34	3.36	3.28		8.79	5.59	13.1	8.49	0.06
2011	1.738	0.49	2.08	3.29	0.17	7.99	4.14	14.9	7.58	0.086
2012	1.683	1.53	0.48	3.45	0.06	8.17	4.43	14.1	7.59	
2013	1.725	0.56	0.16	3.19	0.1	7	4.24	15.6	7.89	0.004
2014	2.145	0.22	0.14	2.54	0.04		3.7	19.1	9.09	

Table 3.1 Annual mean values of each parameter from 2010-2014 at Ambulalakao Lake

	Alkalinity meq/L	SO_4 mg/L	NO_3 mg/L	Cl mg/L	NH_4 mg/L	Na mg/L	K mg/L	Ca mg/L	Mg mg/L	PO_4 mg/L
2010										
2011										
2012										
2013	0.06	*	*	0.39	*1	0.56	0.13	0.49	0.11	
2014	0.023	0.11	*	0.2	0.21	0.46	0.35	0.59	0.12	

Figures 2.17 and 2.18 show the annual pH for Pandin and Ambulalakao Lake. Ionic concentrations for Ambulalakao Lake exhibited lower trends compared with Pandin Lake, although, in the year 2009 data for Ambulalakao Lake were considerably high for some parameters.

3.0 Review of National Air Quality Management including Acid Deposition

3.1 Air Quality

The Philippine Clean Air Act of 1999 or Republic Act 8749 is the comprehensive guiding air pollution control policy in air quality management, interventions and programs. Under the Clean Air Act, publication of National Air Quality Status Report is required to report the extent of air pollution, per type of pollutant and per type of source. It includes an analysis of the current situation and identifies trends in air pollution. It identifies critical areas, activities or projects, which need closer monitoring or regulation.

Measures for mitigating air pollution include strategies for:

a) Enforcement on motor vehicles standards;
b) Enforcement on stationary/industrial sources standards;
c) Enforcement on open burning;
d) Shift to cleaner fuels
e) Public awareness

Mobile sources

Emission testing is required to all in-use vehicles prior to annual registration. The in-use emission standards for gasoline-fed are hydrocarbons and carbon monoxide. For diesel-fed, the standard for smoke opacity expressed in terms of light absorption coefficient, k)

Private Emission Testing Centers are authorized and accredited by the government to conduct compliance emission testing prior to registration. The Land Transportation Office conducts emission testing of privately owned motor vehicles for public utility vehicles in their Motor Vehicle Inspection Center.

Certificate of Conformity is issued by the DENR, through the EMB, to a motor vehicle manufacturer, assembler or importer certifying that a new motor vehicle type complies with the emission limits adopted under Euro 2/II regulations.

Issuance of Certificate of Compliance to Emission Standards (CCES): For rebuilt or second hand-CBU imported into the country or pre-registered vehicles retrofitted with second hand engines shall not be allowed registration or renewal without a valid Certificate of Compliance to Emission Standard (CCES) issued by the DOTC-LTO. (No data from LTO)

Department Administrative Order (DAO) 2015-04 on the Implementation of Vehicle Emission Limits for Euro 4/IV and In-use Vehicle Emission Standards Effective July 1, 2015”. Under this DAO, all motor vehicle types except MC/TC shall comply with Euro 4/IV new emission standards effective January 1, 2016. (Euro 3).

Department of Energy issued the mandatory sale, manufacture and import of Euro IV gasoline and diesel fuel oils with 50 ppm sulfur content nationwide effective January 1, 2016.

Stationary Sources

All sources of air emissions are required to secure a Permit to Operate prior to operation upon compliance with air quality standards (emission and ambient). Industries or firms that emit air pollutants are required to submit to EMB a self-monitoring reports (SMR) that demonstrates their compliance with environmental regulations. The SMR which is submitted on a quarterly basis, contains monitoring of effluents/discharges, air emissions and solid waste disposal.

Major industrial plants such as power plants, cement, oil refineries among others are required to install continuous emission monitoring system. The regulated pollutants are sulfur oxides, oxides of nitrogen, particulate matter, carbon monoxide, metals etc.

Department Administrative Order (DAO) on Revised Guidelines for DENR Accreditation of Third Party Source Emission Testing Firms **(DAO No. 2013-26).**This DAO provides assurance to stakeholders, regulators and the public of the reliability of source emission test results; and ensures that accredited firms are fully capable of conducting source emission tests in accordance with the procedures set in the National Emission Standards for Source Specific Air Pollutants (NESSAP) Table 2 of the Implementing Rules and Regulations of RA 8749 (DAO 2000-81).

3.2 Ambient Air Quality Monitoring

EMB has a total of twenty one (21) monitoring stations (continuous/ automatic) which measures criteria pollutants (SO_2, NO_x, O_3, CO, PM) including meteorological parameters (i.e. wind speed, wind direction, temperature, relative humidity, global radiation and pressure. Twenty seven (27) particulate matter 10/2.5 air monitor are also located nationwide.

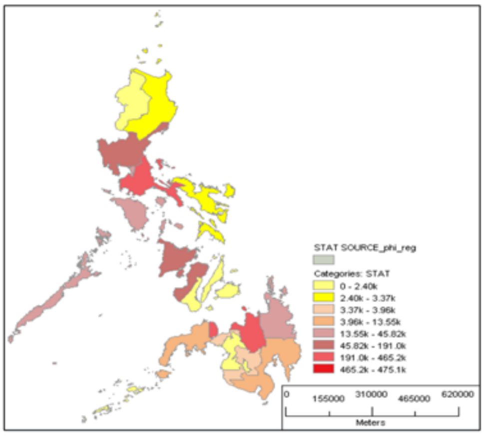
Issuance of the Department Administrative Order (DAO) on $PM_{2.5}$ Emission Standard **(DAO No. 2013-13).**This Order establishes provisional ambient air quality guideline values for PM 2.5 necessary to protect public health and safety and general welfare by adopting the World Health Organization (WHO) guidelines. The values shall be 50 and 25ug/Ncu.m for short-term and long-term, respectively effective January 1, 2016.

Emission Inventory:

Figure 3.2 Emission inventory national and Metro Manila, 2012

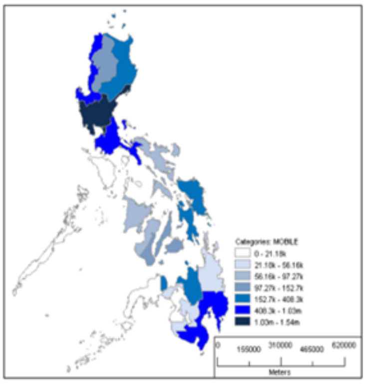
It was estimated that 80% of the pollutants came from mobile sources, in Metro Manila where the urban site is located. There are 4,599 sources or firms and mostly small and medium. Region 4A where Los Banos . the rural site is located, there are 3,734 of medium and large industries. In Cordillera Autonomous Region (CAR), Mt. Sto Tomas, the remote site, 1,639 industries of small and medium categories.

Spatial distribution of pollutants in Metro Manila, Los Banos and Mt. Sto. Tomas is presented in Figures 3.3- 3.10.



No.4 Regional Spatial Distribution for Stationary Source Emission Inventory in (Tons/Year)Arc GIS

Figure 3.3 Stationary Source distribution in tons/ year



No.5 Regional Spatial Distribution for Mobile Source Emission Inventory in (Tons/Year) Arc GIS

Figure 3.4 Mobile Source distribution in tons/year

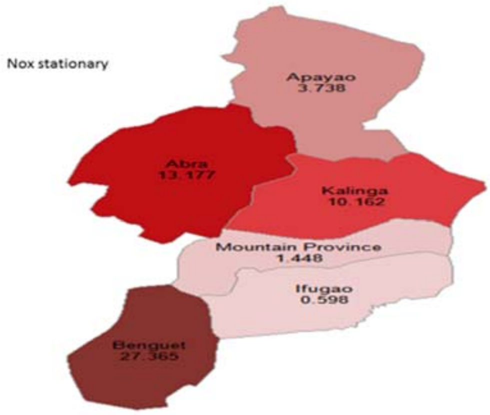


Figure 3.5 Oxides of nitrogen, tons/year in CAR

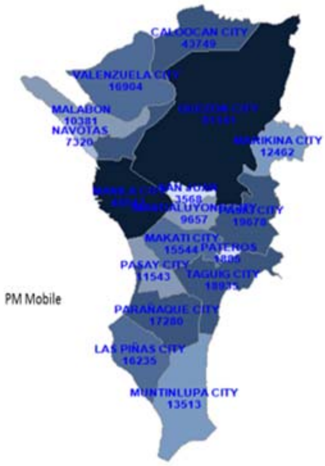


Figure 3.6 Particulate Matter from mobile in Metro Manila

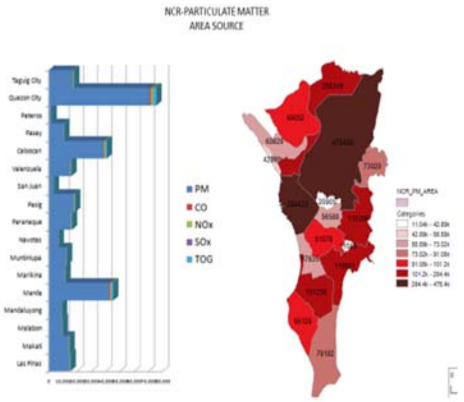


Figure 3.7 Particulate Matter from Area in Metro

Figure 3.8 SO_x from stationary sources in Metro Manila

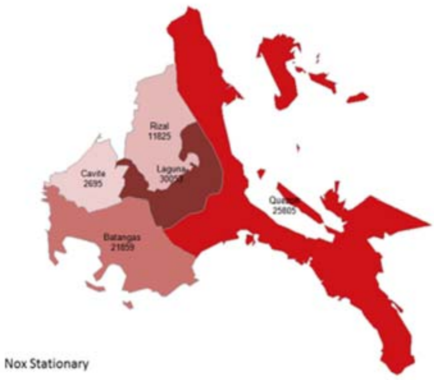


Figure 3.9 NO_x from Stationary in Region 4A (Laguna-Los Banos)

Figure 3.10 PM from Stationary in Region 4A

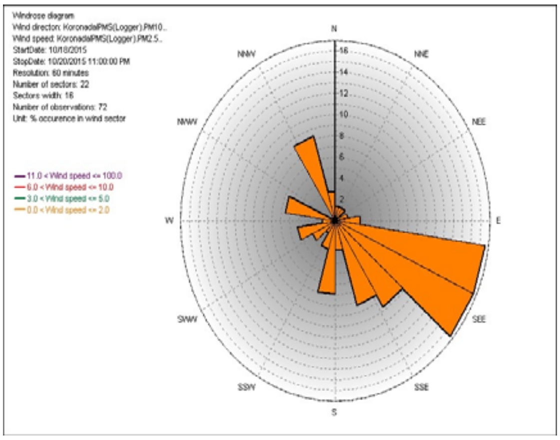
Cleaner Fuels

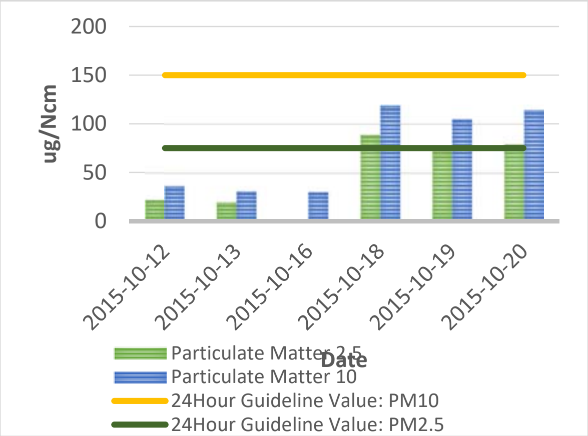
Improved Fuel Quality

Sulfur content of automotive diesel is 0.05% by wt. (0.05%) while phase out of leaded gasoline had been effected in December 2000. The Technical Committee on Petroleum Products and Additives (TCPPA) has set fuel quality specifications for conventional fuels (diesel and unleaded gasoline) and bio-fuels (Fatty Acid Methyl Ester (FAME) and Ethanol. 2% bio-diesel blend and 10% ethanol gasoline blend (E10) are available in all refilling stations nationwide. Fuel specifications for auto LPG and CNG were also set.

Haze Episode

The first episode of haze was felt on September 30, 1-2 October, 2015 in Cebu, southern part of Philippines.. On October 18, 2015, it was reported that haze occurred in Koronadal City, in Mindanao. The wind direction is predominant in southeast east and east. The 2015 haze incident was reported on the 11th Meeting of the Committee Under the Conference of Parties to the ASEAN Agreement on Transboundary Haze Pollution last October 27, 2015.





WATER QUALITY

Republic Act 9275 or Philippine Clean Water Act of 2004 provides for a comprehensive water quality management program. It also provides the framework for sustainable development to achieve a policy of economic growth in a manner consistent with the protection, preservation and revival of the quality of fresh, brackish and marine water.

PUBLIC AWARENESS

With the help of different agencies and sectors, raised public awareness about air quality and air pollution thru different campaigns such as:

Development, production and dissemination of information, education and promotional materials for cleaner air, cleaner water etc;

Conduct of fora on the following: (i) Anti-Smoke Belching Campaign Action Plan and Communication Strategies for LGU Enforcement Teams; (ii) Clean Air for Public Transport Companies; and (iii) EDSA Bus Operators' Forum on Environment-friendly; and Cost-Effective Vehicle Handling and Maintenance;

National Assessment on Acid Deposition in Korea

National Institute of Environmental Research

1.1 Basic Information on National Monitoring Activities

1.1.1 Outline of the activities on acid deposition and National Monitoring Plan

Korean government 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 1960's. That is why the country initiated a national air monitoring program in the middle of the 1970's. Then, photochemical assessment stations and hazardous air monitoring stations were added to the network in early 2000. As of 2004, there are 213 urban sites, 11 rural sites, 5 remote sites, 22 traffic sites under the national monitoring network and 31 monitoring sites for acid deposition shows that Korea is deeply aware of its importance.

Adverse effects of long range transport of air pollutants have a long history in Korea. Since its first record over six hundred years ago, the occurrence of Asian dusts and its harmful effects have been constantly reported. More importantly, North East Asia, one of the most populated regions in the world, has been experiencing extensive industrialization for the last half century and, consequently, a long range transport of air pollutants became a great public concern along with natural air pollutants and Asian dusts. As a result, rural sites and remote sites were established to evaluate the effect of long range transport on the air quality with the implementation of the acid deposition monitoring network.

Recognizing that international collaboration is required to effectively cope with trans-boundary air pollutants, Korea has actively promoted to and, if allowed, participated in regional endeavors such as LTP (Long range Transport Project), NEASPEC (North East Asian Sub-regional Program of Environmental Cooperation), EANET (Acid Monitoring Network in East Asia), NOWAP (Northwest Pacific Action Plan), and ACE-ASIA (Asian Pacific Regional Aerosol Characterization Experiment). Each of these has its own objectives and methods in addressing long range transport of air pollutants and other regional air quality problems.

EANET has become a leading acid deposition monitoring network in East Asia region since it was launched in 2001. As a founding member of EANET, Korea has been actively involved in various efforts of EANET; preparation of technical manuals; participation of QA/QC program; and regular monitoring of wet deposition, dry deposition, soil and vegetation. Monitoring data has been submitted to Network Center of EANET helping and used as the scientific information for the evaluation of both acid depositions and its impacts on ecosystems in East Asia. This year's national report covers characteristics of monitoring stations for EANET as well as preliminary analysis of monitoring data.

1.1.2 Monitoring Stations

Korea selected Ganghwa, Imsil, and Jeju as the acid deposition monitoring sites for EANET. Ganghwa and Jeju were classified into "rural site", and Imsil, "remote site" according to the Technical Manual of EANET as summarized in Table 1.1.1. The locations and pictures of the stations are shown in Figure 1.1.1 and Figure 1.1.2, respectively. Ganghwa and Jeju sites are located near the coast to minimize anthropogenic emissions. Meanwhile, Imsil site is located near the mountain, which is subjected to soil and vegetation monitoring.

With the exception for those measured by automatic instruments, as noted in Table 1.1.2, NO_X, SO_2, O_3 and PM_{10} mass were monitored using air monitoring devices, and $PM_{2.5}$ compositions and the gaseous species, with filter pack. Together with chemical species, meteorological parameters such as wind speed, wind direction, air temperature, relative humidity, and solar radiation were observed at automatic weather stations in each site or nearby meteorological observatories.

Table 1.1.1. The characteristics and location of monitoring sites in Korea

Name of sites	Site classification	Latitude	Longitude	Heght above the sea level
Ganghwa	Rural	37° 42' N	126° 17' N	102 m
Imsil	Remote	33° 18' N	126° 10' N	50 m
Jeju	Rural	35° 36' N	126° 11' N	67 m

Table 1.1.2. The selected monitoring parameters and methods in Korea

Name of sites	Wet dep.	Dry dep.			
		Automatic			Filter pack
		SO_2, NO_2	O_3	PM	
Ganghwa	O	O	O	O	O
Imsil	O	O	O	O	O
Jeju	O	O	O	O	O

Figure 1.1.1. The geographical Location of EANET sites in Korea

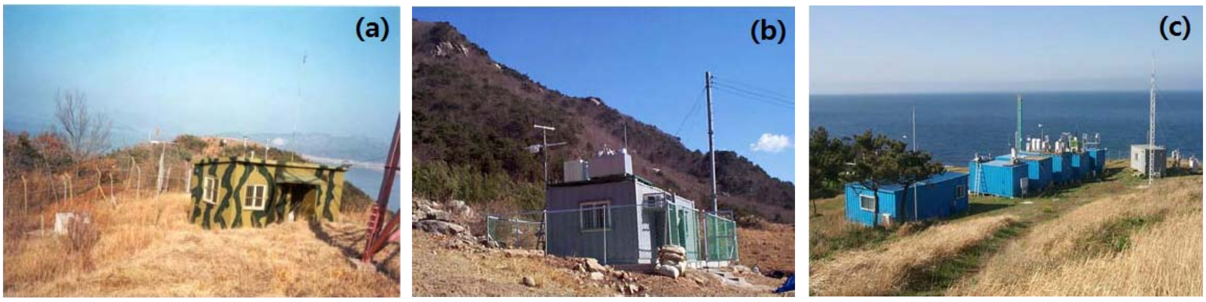


Figure 1.1.2. Pictures of monitoring sites in Korea ((a) Ganghwa, (b) Imsil, (c) Jeju)

1.1.3 Sampling and Measurements

1.1.3.1 Wet Deposition Monitoring

Acid deposition monitoring in Korea has been carried out according to the common methodologies specified in the “Technical Documents for Wet deposition Monitoring in East Asia” (hereafter denoted as Manual) in order to obtain the equivalent quality of monitoring data. Figure 1.1.3 shows wet-only samplers used for monitoring work. Precipitation samples were collected on a daily basis at 3 sites as listed in Table 1.1.3. Collected samples without biocides were shipped to laboratories and stored in a cooling box to preserve the sample composition. Rainwater major constituent were analyzed in line with the Manual as shown in Table 1.1.4. Ion Chromatography is a major analytical method for chemical analysis of anions and cations. All the data were checked using ion balance and conductivity agreement by calculating ion balance (R_1) and conductivity agreement (R_2). If a sample or individual datum has problems including "insufficient sample volme" or "low precision", the flags corresponding to the problems were attached to the data, following "Quality Assurance/Quality Control (QA/QC) Problem for Wet Deposition Monitoring in East Asia" (2000).

Figure 1.1.3. Wet deposition monitoring samplers

Table 1.1.3. Sampling method for wet deposition monitoring in Korea

Name of sites	**Site**	**Sampling frequency**	**Starting month**
Ganghwa	Rural	Daily	March '99
Imsil	Remote	Daily	April '99
Jeju	Rural	Daily	January '99

Table 1.1.4. Sampling method for wet deposition monitoring in Korea

Name of sites	**Site classification**	**Anion analysis**	**Cation analysis**
Ganghwa	Rural	IC	IC
Imsil	Remote	IC	IC
Jeju	Rural	IC	IC

(Note) IC : *Ion Chromatography*

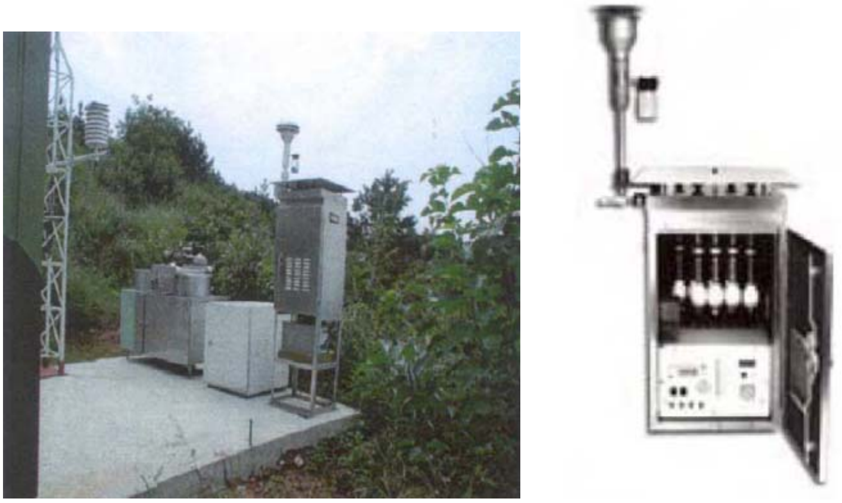
1.1.3.2 Dry Deposition Monitoring

SO_2, NO_2, O_3 - based-on the priority of the chemical species - and PM_{10} mass were monitored by automatic instruments as directed by "QA/QC Program for the Air Concentration Monitoring in East Asia (2001)" as noted in Table 1.1.5. Three-stage $PM_{2.5}$ filter pack sampler, shown in Figure 1.1.4, was used to monitor gaseous acids and bases, HNO_3, HCl, NH_3, and particulate components (SO_4^{2-}, NO_3^-, Cl^-, Na^+, K^+, NH_4^+, Ca^{2+} and Mg^{2+}).

Table 1.1.5. Sampling method and parameter for dry deposition monitoring

Name of sites	Characteristics of site	Method	Parameter
Ganghwa	Rural	AT	SO_2, NO_2, O_3, PM_{10}
		FP	PMC in $PM_{2.5}$
Imsil	Remote	AT	SO_2, NO_2, O_3, PM_{10}
		FP	PMC in $PM_{2.5}$
Jeju	Rural	AT	SO_2, NO_2, O_3, PM_{10}
		FP	PMC in $PM_{2.5}$

(Note) AT: Automatic monitor, FP: Filter pack, PMC: Particulate matter components



URG(3 state $PM_{2.5}$ Sequential Sampler, USA)

Figure 1.1.4. Instruments used for dry deposition monitoring

1.2 State of Acid Deposition in the Korea

1.2.1 State of wet deposition

The reliability of data was assessed based on the consistency between the measured electrical conductivity of precipitation and calculated one. If the balance of between cation and anion is not good, it means that there are errors in sampling or conducting chemical analysis or that there is one or more missed compositions in the precipitation. As presented in Figure 1.2.1., both regression and correlation analysis showed that the slope of the regression line is 0.9791, the coefficient of determination is 0.9937, and the balance between cation and anion was relatively good.

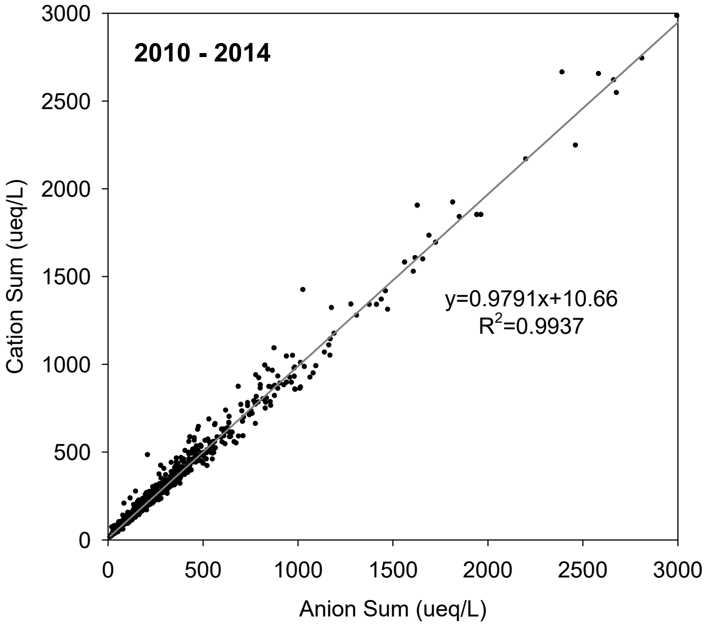


Figure 1.2.1. Relationship between total cation and anion in precipitation

The EC of weak solution can be calculated using the equivalent conductance, and the result should be consistent with the EC value of samples, which can be calculated using the following equation.

ECcalc (μS.cm-1) =

$\{349.7\times10^{(6\text{-}pH)} + 80.0\times2[SO_4^{2-}] + 71.5[NO_3^-] + 76.3[Cl^-] + 73.5[NH_4^+] + 50.1[Na^+] + 73.5[K^+]$

$+ 59.8\times2[Ca^{2+}] + 53.3\times2[Mg^{2+}]\ \} / 1000$

According to regression and correlation analyses of calculated conductivity and measured conductivity, as presented in Figure 1.2.2., the slope of the regression line is 1.0686 and the coefficient of determination is 0.9860.

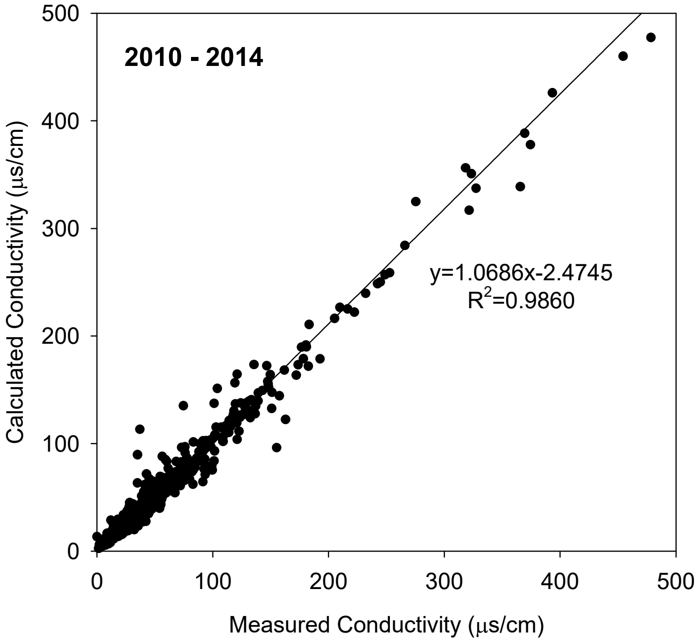


Figure 1.2.2. Relationship between the EC_{meas} and EC_{cal}

Figure 1.2.3 presents the sum of major anion and cation ratio and SO_4^{2-} and NO_3^- ratio (2010-2014). NH_4^+ and Ca^{2+} were selected as major cations, and SO_4^{2-} and NO_3^- were selected as major anions. The sum of SO_4^{2-} and NO_3^- concentrations appeared to be slightly larger than the sum of NH_4^+ and Ca^{2+}. The ratios of major anions and cations were constantly checked as a key parameter for the ion balance and for rain water characteristics of sulfur and nitrogen containing species and checked together with major anion and cation ratios.

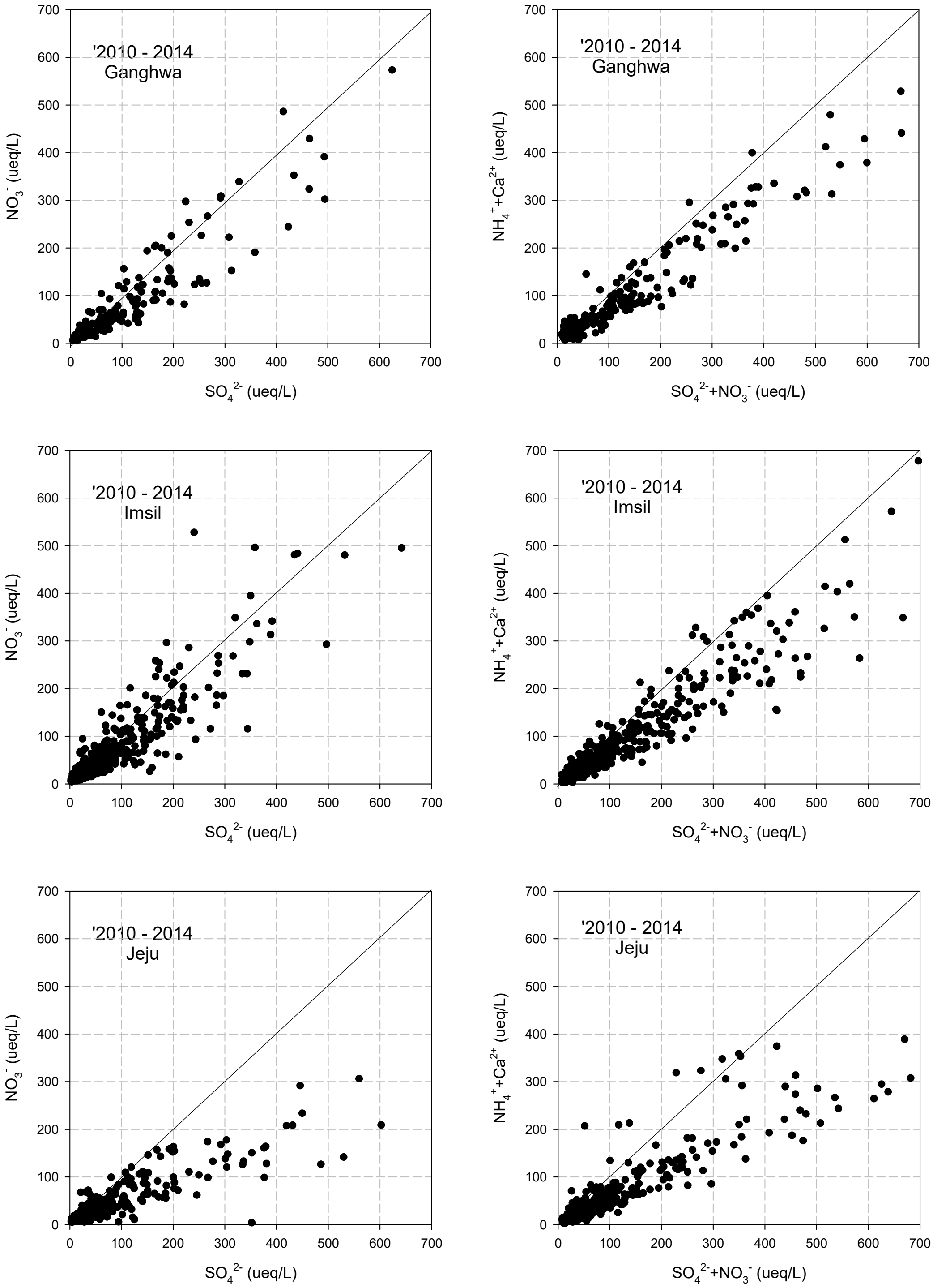


Figure 1.2.3. Ion balance check in Ganghwa, Imsil and Jeju (Unit: μeq/L)

pH is regarded as a major parameter characterizing acid rain mainly because it determines the acidity of rain waters. The annual mean pH was 4.8 in 2010, 5.0 in 2011, 5.0 in 2012, 5.1 in 2013 and 5.3 in 2014 while the annual precipitation was 1,405 mm, 1,348 mm, 1116 mm, 918 mm and 907 mm, respectively. Rainfall decreased, pH level was increased. Figure 1.2.5 shows the frequency and volume of precipitation in the three EANET sites in Korea from 2010 to 2014. pH level of Ganghwa was most frequently at pH 4.1~5.0. Imsil and Jeju showed most frequency value at pH v6.1~6.5.

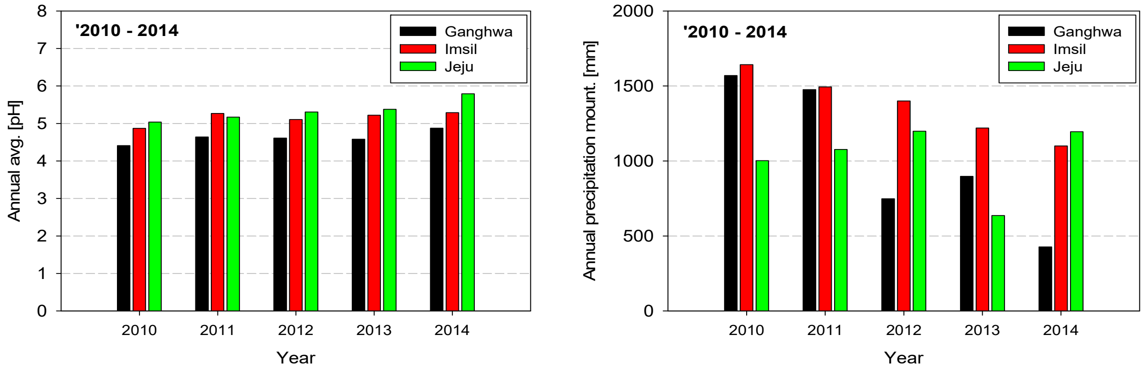


Figure 1.2.4. The annual average pH and annual precipitation mount in each site (2010 – 2014)

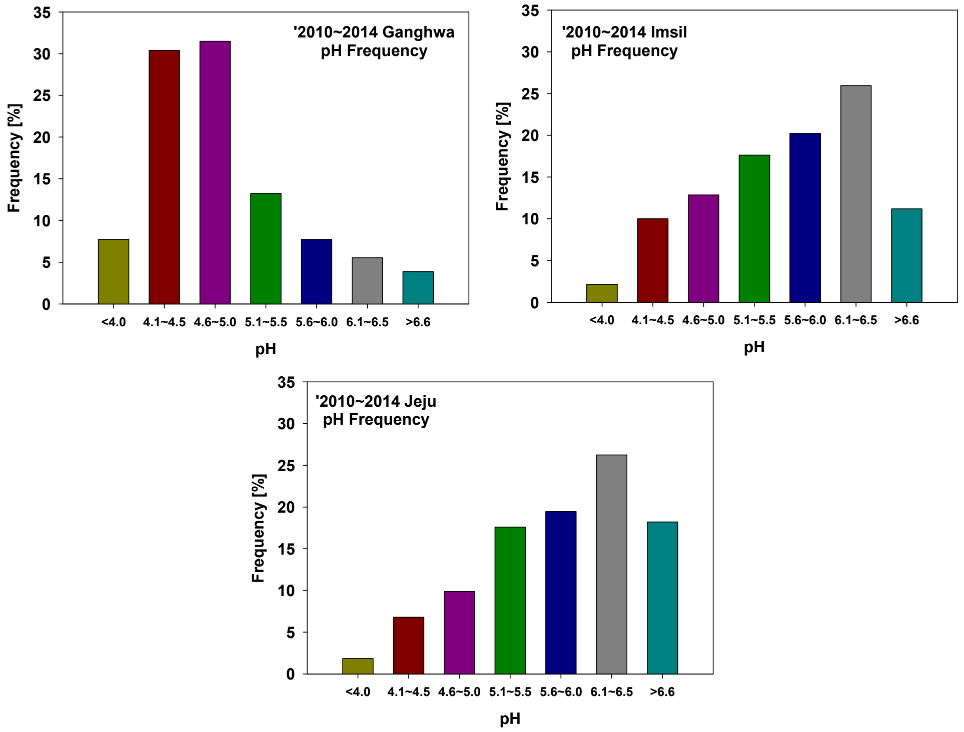
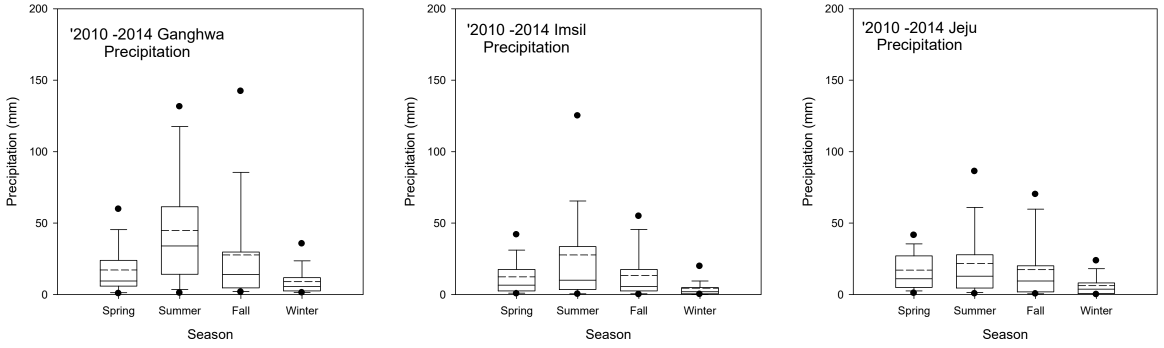


Figure 1.2.5. pH frequency and the amount in each site (2010 – 2014)

Seasonal variations of precipitation, EC, and pH are shown in 1.2.6. Precipitation concentrates on summer, rainy season in Korea. As we can see in the five-year results, the summer is not always the season with highest pH and lowest EC. EC concentration showed high level at the whole region in winter. Gannghwa and Imsil showed high pH level in spring, the precipitation rate was similar with summer.



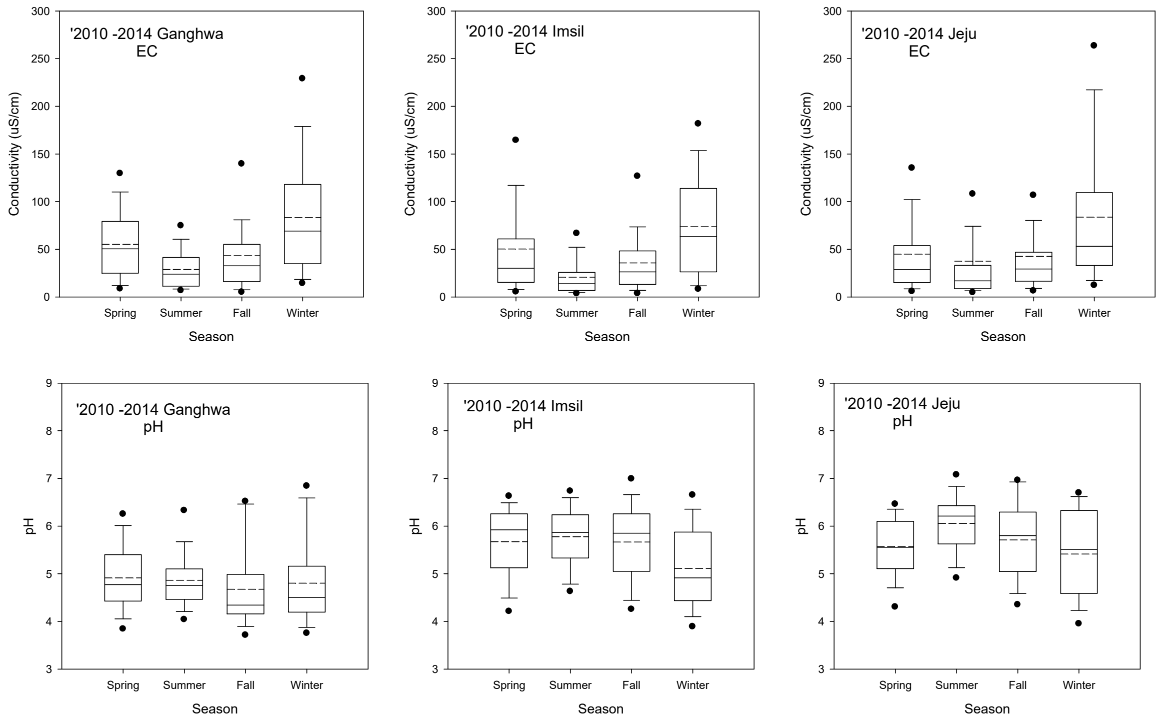
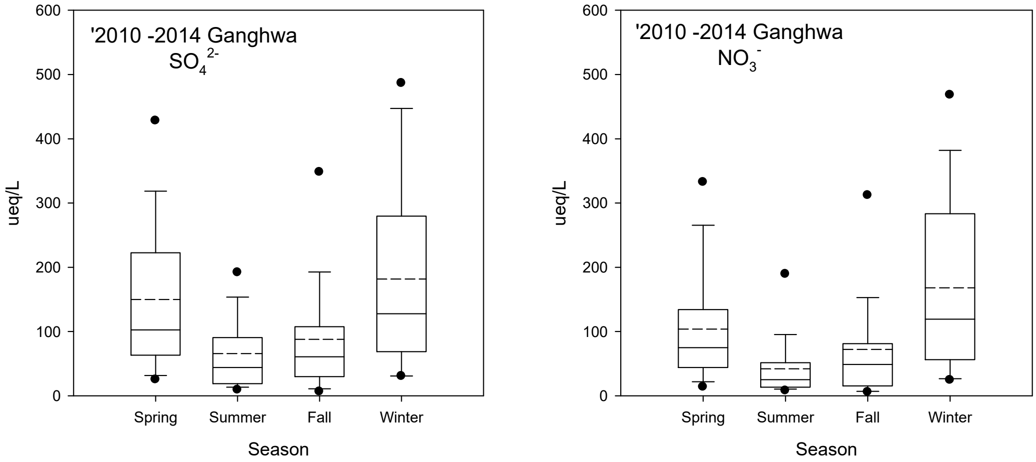


Figure 1.2.6. Seasonal variation of precipitation, electronic conductivity and pH

Figures 1.2.7, 1.2.8, and 1.2.9 show seasonal variations of major ionic species concentrations and the amount of wet depositions at each site. The heavy precipitation during summer as discussed above diluted ionic species concentrations for rain waters, leading to the lowest concentration in summer. Despite the lowest ionic concentrations, the volume of wet depositions was still the largest in summer thanks to the heavy precipitation. The SO_4^{2-} and NO_3^- concentrations were high in winter due to high fuel demand for heating in Imsil and Jeju. This influence of heating appeared less distinctive in Ganhwa, indicating existing of industrial influence. Ca^{2+} concentration in spring in Gangwha and Imsil exhibited considerable variability in spring due to Asian dust as noted earlier.



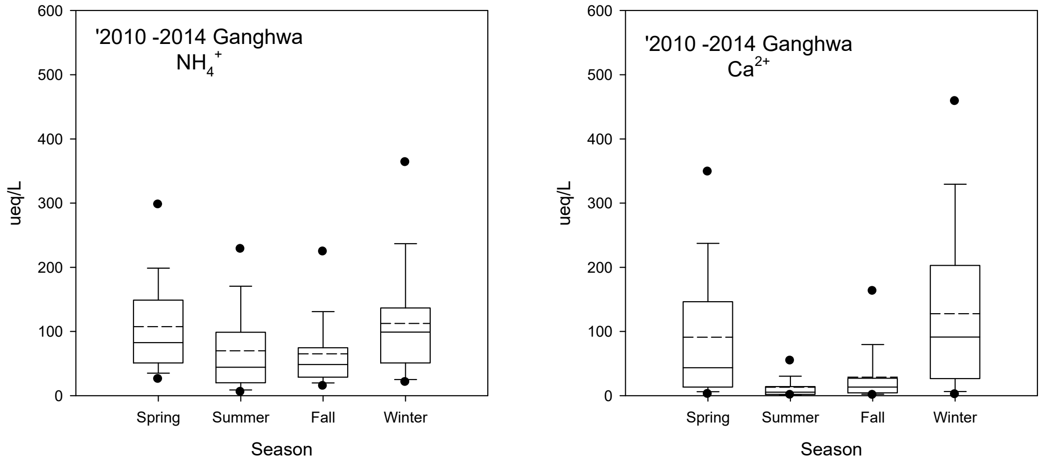


Figure 1.2.7. Seasonal variation of wet deposition (equivalent concentration), Ganghwa

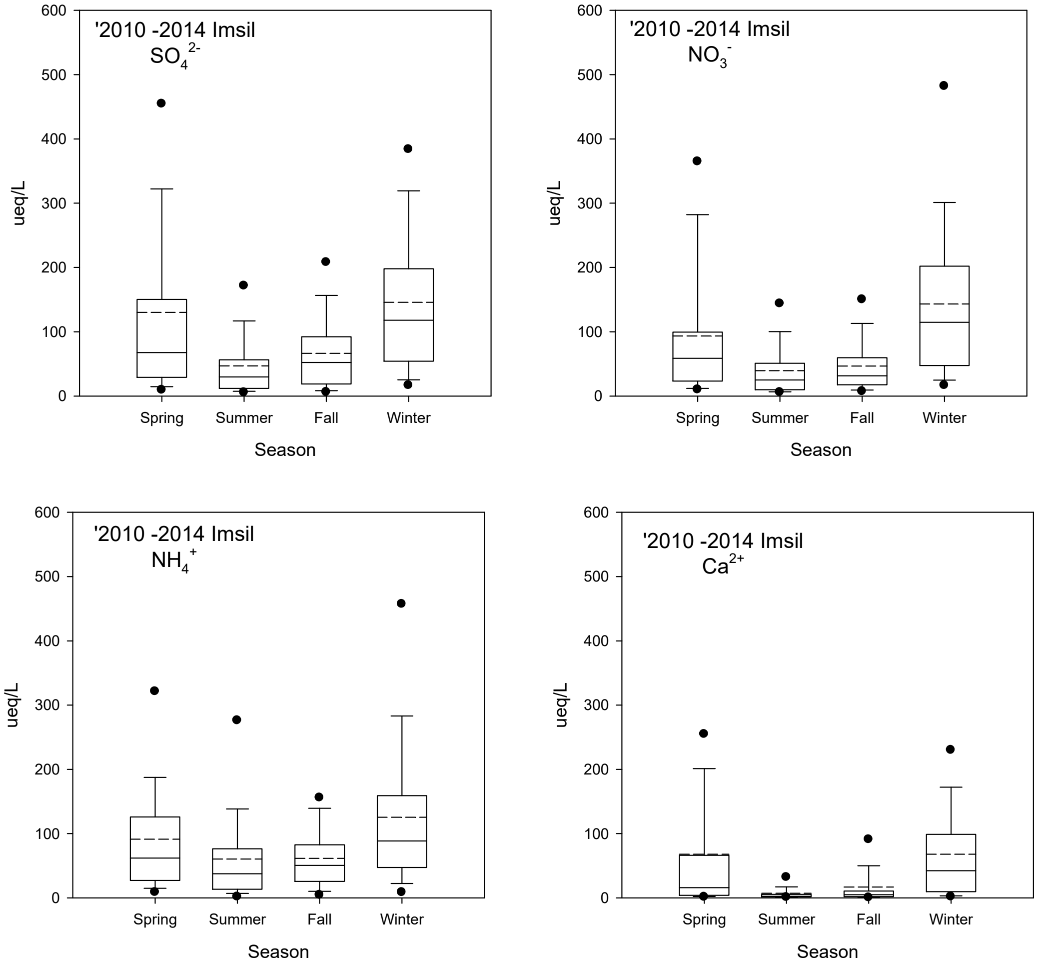


Figure 1.2.8. Seasonal variation of wet deposition (equivalent concentration), Imsil

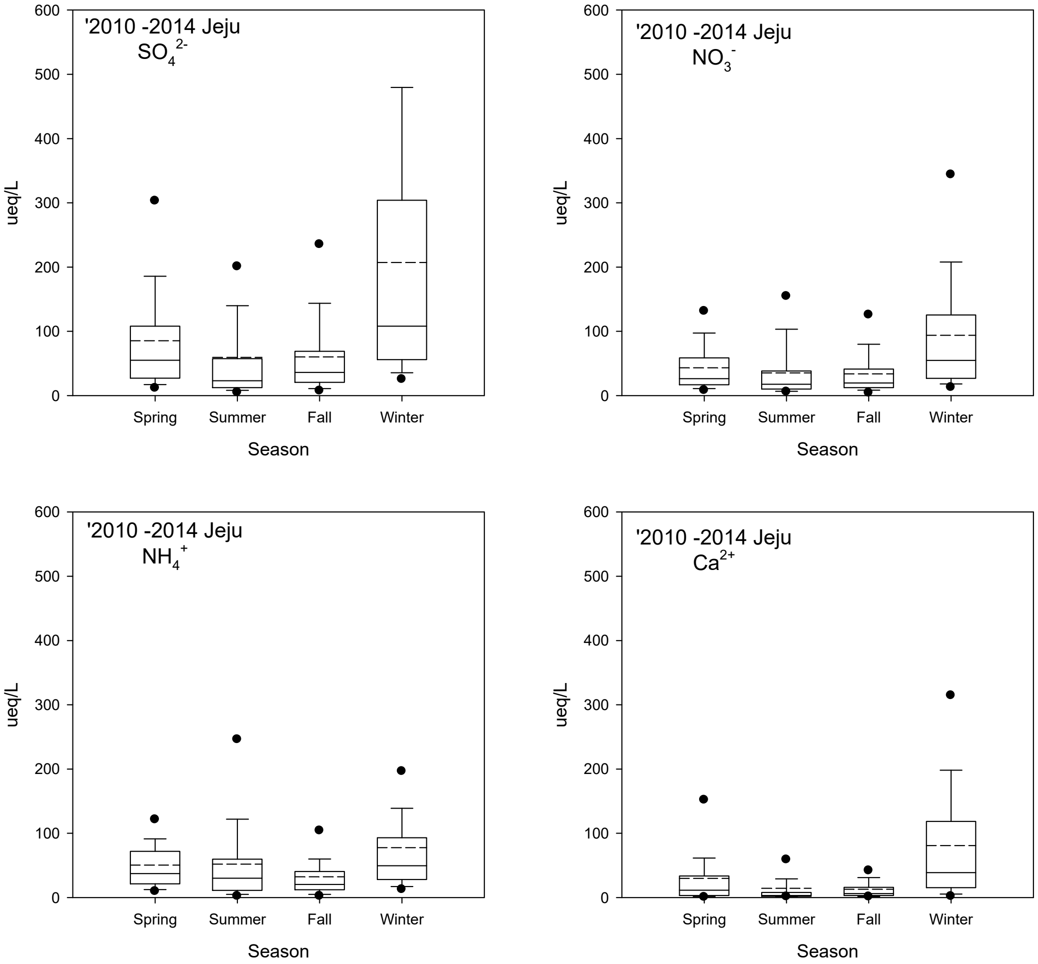


Figure 1.2.9. Seasonal variation of wet deposition (equivalent concentration), Jeju

1.2.2 State of dry deposition

The equivalent conductance, as shown in Figure 1.2.10, was calculated using the same method for wet deposition monitoring results. The result shows that the balance between cation and anion is relatively good with 0.9623 of the coefficient of determination. In this case, based-on the review of the ion balance, samples with reliability problem were reanalyzed or excluded from data analysis.

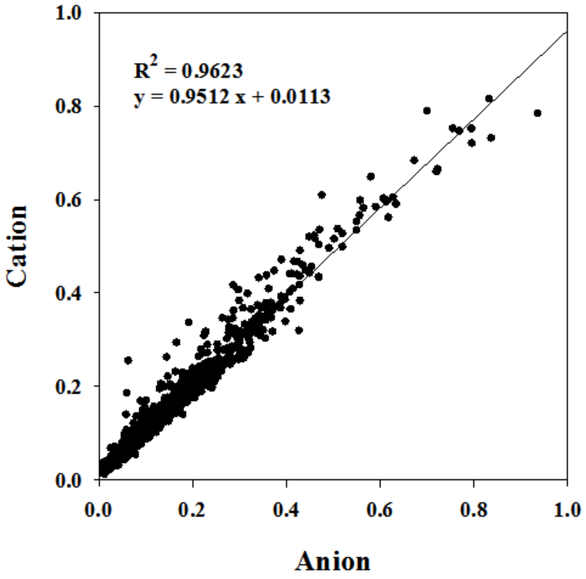
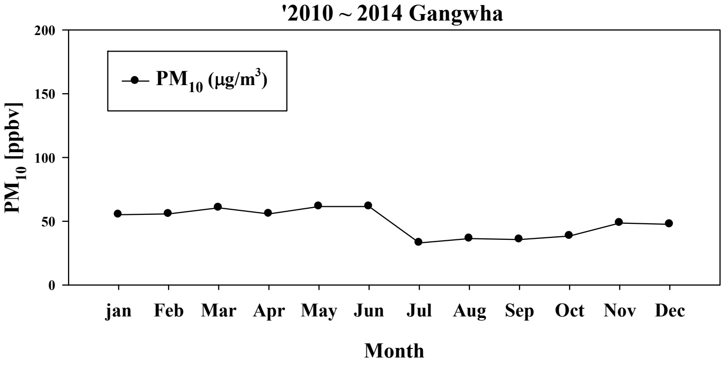
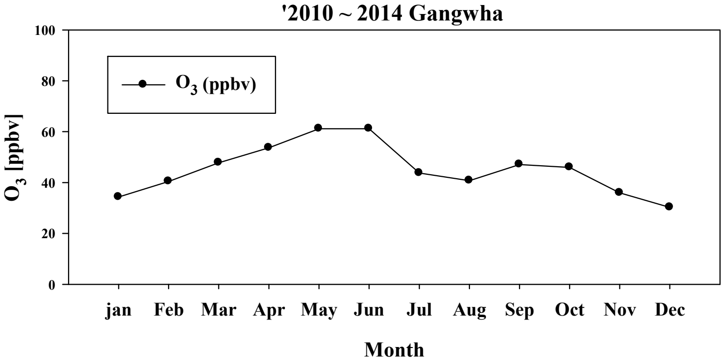


Figure 1.2.10. Relationship between total anion and cation

Figures 1.2.11, 1.2.12, and 1.2.13 present the average monthly concentrations of SO_2, NO_2, O_3, and PM_{10} mass from 2010 to 2014. The average concentration of PM_{10} ranges from 24 ㎍.m^{-3} to 65 ㎍.m^{-3}. PM_{10} concentrations were observed to be high mainly in March or May, a period of Asian dust. The average monthly concentration of O_3 measured to be high in April and June. In case of SO_2, the increase trend in winter was observed. The highest concentration levels were Ganghwa usland. But SO_2 and NO_2 levels were less than 0.64 ppbv and 4.05 ppbv in Jeju, one of the most remote sites, with one exception of January.





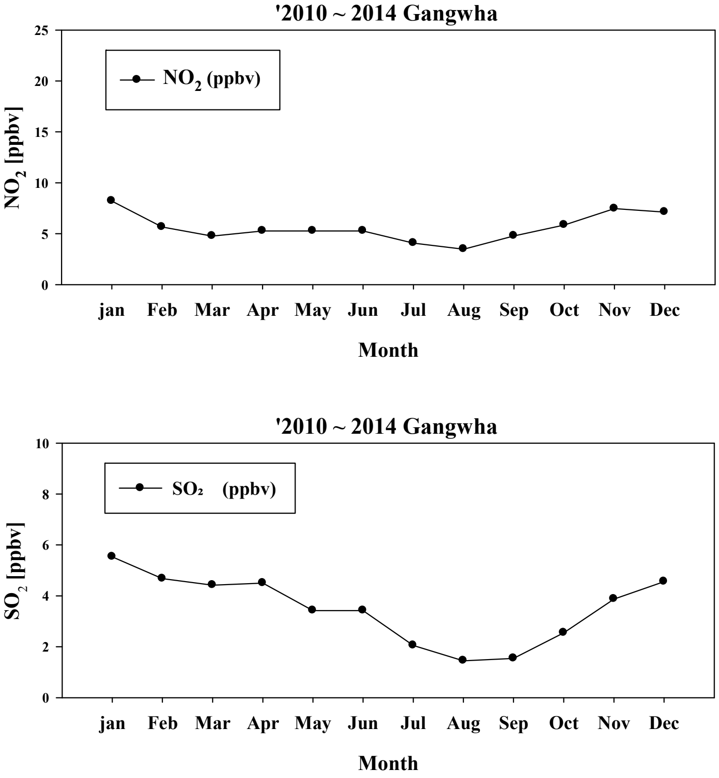
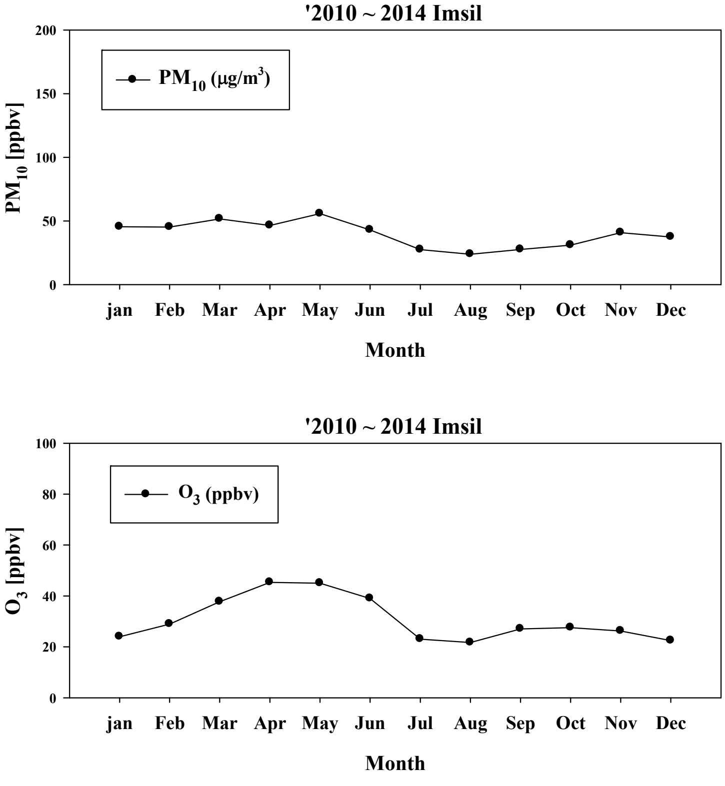
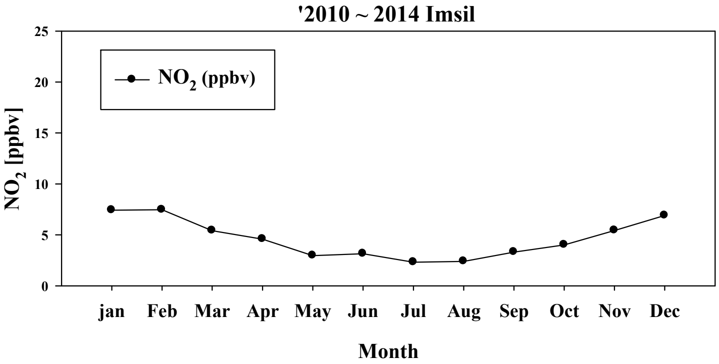


Figure 1.2.11. Average monthly concentrations of SO_2, NO_2, O_3 and PM_{10} at Ganghwa





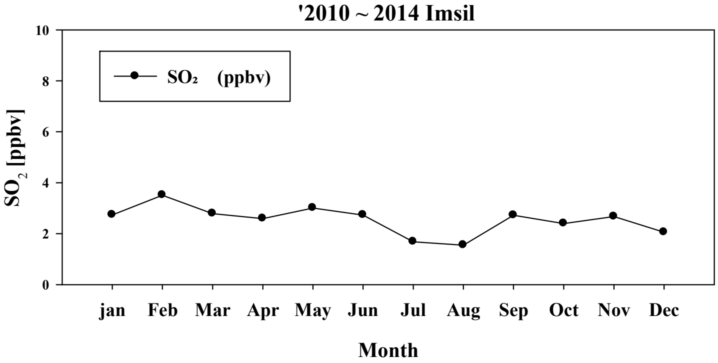
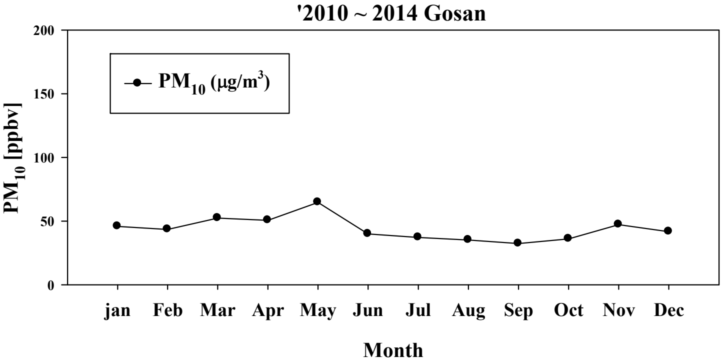
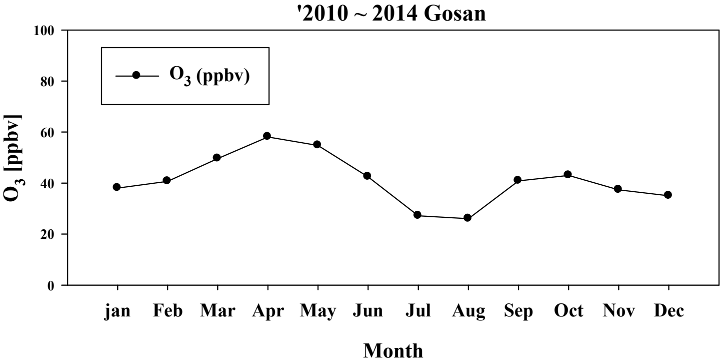
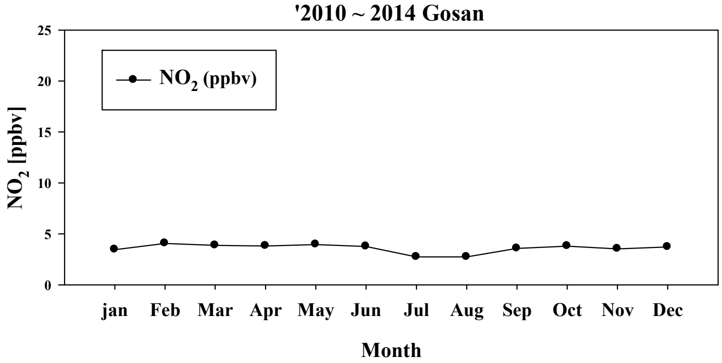


Figure 1.2.12. Average monthly concentrations of SO_2, NO_2, O_3 and PM_{10} at Imsil







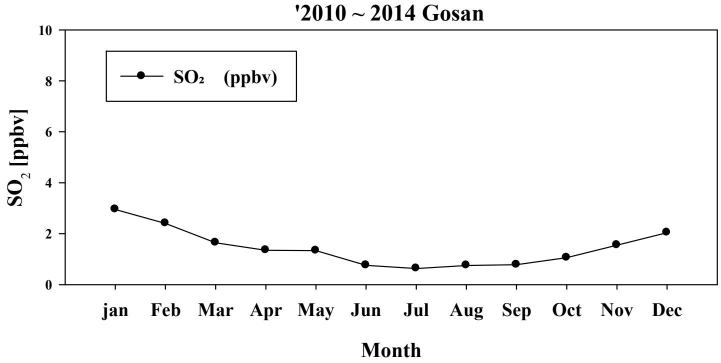


Figure 1.2.13. Average monthly concentrations of SO_2, NO_2, O_3 and PM_{10} at Jeju

Chemical composition analysis of $PM_{2.5}$ found that SO_4^{2-} and NH_4^+ were major chemical constituents for Ganghwa, Imsil and Jeju sites. Except for Jeju, NO_3^- was significantly increased in winter. But SO_4^{2-} did not showed clear seasonal trend. As shown in Figure 1.2.14, the seasonal average concentrations of SO_4^{2-}, NH_4^+ and NO_3^- varied among the three sites and therefore this suggests there is a need for further studies to on their causes.

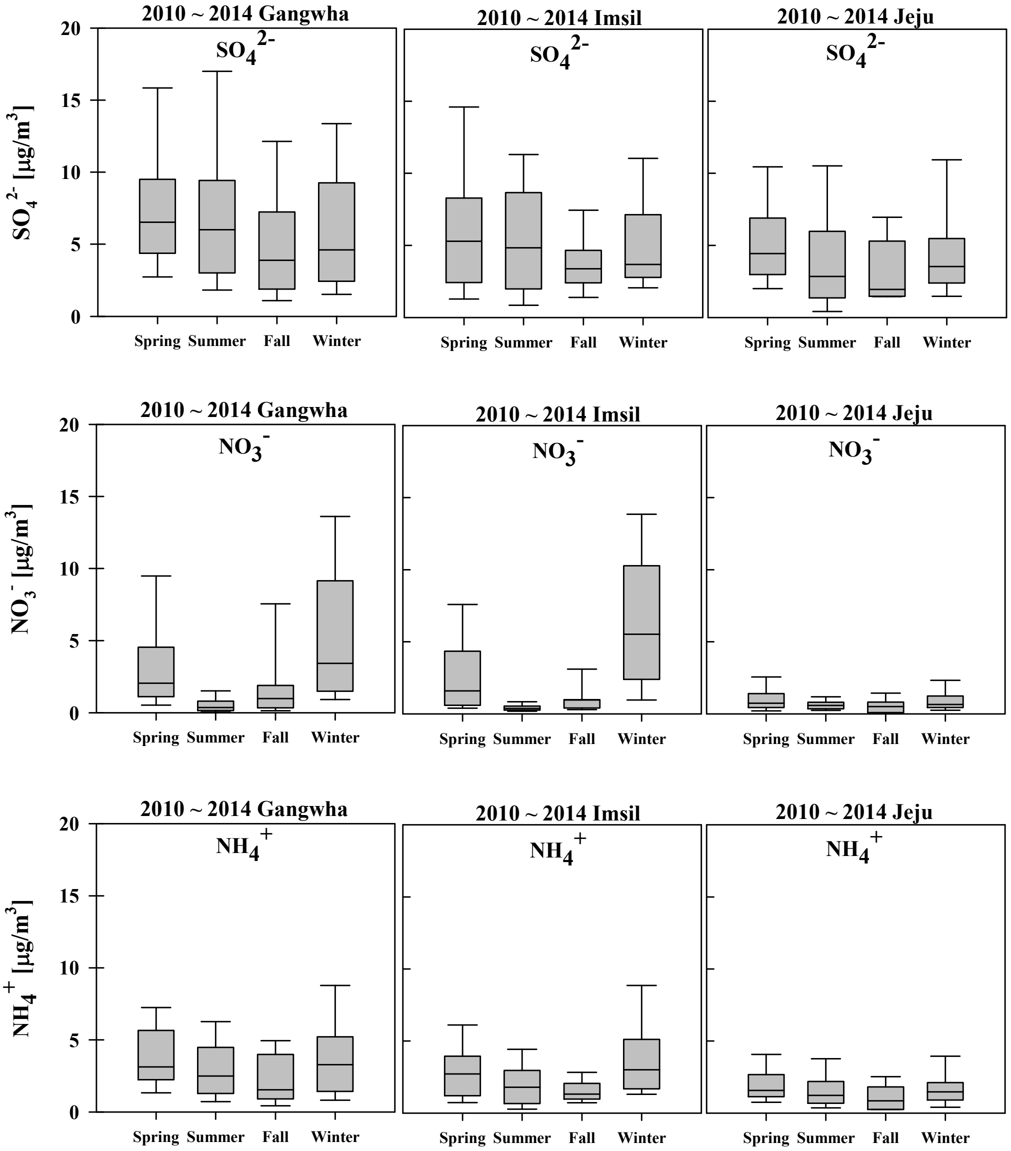


Figure 1.2.14. Seasonal variations of major chemical species concentrations in $PM_{2.5}$ at sites

National Assessment on Acid Deposition in Russia

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1. Basic information on National Monitoring Activities of EANET.

Russian Federation has been participating in EANET since the 1998 with start of activities during the preparatory phase and further continuation at the regular phase from 2000. Russian Federal Service for Hydrometeorology and Environmental Monitoring (ROSHYDROMET) was designated as the National Focal Point for EANET and took responsibility on coordination of all activities. The research Institute of Global Climate and Ecology (IGCE) of Roshydromet and Russian Academy of Sciences (RAS), Moscow contributes as Russian National EANET Activity Center and Limnological Institute of RAS (LIN), Irkutsk was designated as National EANET Data Center.

All Russian EANET monitoring sites were established in the southeast of the Asian part of Russia, mostly in Baikal lake region and Russian Far East. Also there are more than ten stations of national precipitation chemistry network operating under the Roshydromet within that territory which conduct measurements on atmospheric deposition of major ions (MGO, 2015). The long term monitoring results of the national network were presented together with other international and national network data in global assessment prepared by WMO GAW SAG on Precipitation Chemistry (Vet et al., 2014) and independently with current updates in annual reports (Roshydromet, 2015; IGCE, 2015).

The most of acidic substances, their precursors and related pollutants are released into lower troposphere from anthropogenic sources providing an effect on extension and intensity of acid deposition. Coal power plants (PPs) being the main facilities for heat and electricity supply in cities, industrial regions and towns of Siberian with its cold climate are large sources of emissions of anthropogenic sulphur and nitrogen oxides in region. In a contrast with densely populated areas in Europe, the relative amounts of industrial emissions of anthropogenic substances in Siberia are comparatively low with regard to its vast territory. However, their negative effect on the natural ecosystem of certain areas should not be ignored.

Irkutsk area with a set of big cities (Irkutsk, Angarsk, and Shelekhov) is the one of the developed industrial centres in East Siberia. Several large coal PPs are located in this region to the west from Baikal Lake, whose annual emissions are over 100,000 tonnes of SO_2 and approximately 60,000-80,000 tonnes of NO_x. Due to release from tall chimneys (up to 200 m and higher) their emissions can be transported downwind for tens to several hundred kilometres. The southern and south-eastern parts of Lake Baikal, which are located about 100 km from the Irkutsk-Angarsk industrial complex, are subject to atmospheric impact of large regional coal power plants whose emissions are transported towards the lake by prevailing north-western winds.

Together with the products of their transformation during the transmission these acidified pollutants are deposited onto the watersheds of lakes and rivers, thus causing gradual changes of soil chemistry and acidification of natural waters. Such phenomenon had been already observed in a number of regions of Europe and North America (Husar et al., 1991; Galloway, 2001; Campbell, Lee, 1996). Small lakes and rivers in the Scandinavian countries had been acidified under the effect of long-range transport of sulphur and nitrogen from Central Europe (Abrahamsen et al, 1983), as well as due to regional transport in the area of the Kola Peninsula in Russia (Moiseenko, 1996). Not much attention has been paid by decision makers and industrial management in Siberia to this problem.

1.1. Monitoring EANET sites.

At the preparatory phase of EANET three sites of national network were established in East Siberia (Baikal Area, Irkutsk region and Buryatia): Irkutsk (urban), Listvyanka (rural), and Mondy (remote), which have been working since the 1998. These sites are of considerable differerence in physical and geographical conditions as well as in the level of anthropogenic emission effects into the surrounding atmosphere. However, the EANET activities was proposed to expand on other regions of the East Asian part of Russia. Among the possible areas the one monitoring site in the Russian Far East (near Ussuriysk, Primorsky Krai) and was established during the regular phase in 2002 (Figure 1.1.1).

Figure 1.1.1The location of the Russian EANET monitoring sites

According to the EANET principles and methodology, two soil and vegetation monitoring sites (sensitive and control) were established around (within the radius of 50 km) each atmospheric deposition sampling sites. The measurements were conducted in 2013-2014 being organized with schedule of once per 3-5 years.

Two water objects (small river) for inland aquatic environment monitoring (one in East Siberia, Pereemnaya river, Baikal lake basin, and other, Komarovka river, Sikhote-Alin area in the Far East) were also selected for regular monitoring (Table 1.1.1).

Table 1.1.1. Some geographical characteristics of the Russian EANET monitoring sites

Region, site name, classification and geographical position.	**Topography and landscape**	**Dry/wet deposition**	**Soil and vegetation**	**Inland Aquatic**
East Siberia (Irkutsk region):				
1. Mondy (remote) (51°40' N; 101° 00' E; 2005 m)	Upper slope (N) of mountain; forest	+	+	-
2. Listvyanka (rural) (51° 51' N, 104°54' E, 700 m)	Hilly terrain, top of the hill; forest.	+	+	+
3. Irkutsk (urban) (52° 14' N; 104°15' E; 400 m)	Slope (NE) of broad river valley, city.	+	+	-
Far East (Primorsky region)				
4. Primorskaya (rural) (43° 42' N; 132° 07', E; 84 m)	Plane, forest	+	+	+

Irkutsk, an urban site, is located in Irkutsk city, a large industrial centre in the south of East Siberia, with the population of over 600,000 people. The city possesses 180 industrial and municipal boiler plants and a large Heat Electric Power Plant (HEPP). The contribution of these sources is 80% of total atmospheric emission released within whole urban area. EANET observations were performed at the southern end of the city out of industrial areas. The data obtained from this site characterize the conditions of industrial regions of Siberia.

Listvyanka, a rural site, is located on the south-western coast of Lake Baikal, 70 km to southeast of Irkutsk, near the outlet source of the Angara River. The site is located beyond the settlement Listvyanka with population of approximately 3,000 people, at the top of the hill, 250 m above the lake surface. For the past years, tourism has been intensely developed in this area. A few point sources of pollution are located in the settlement such as small boiler plants and stove heating. Moreover, the atmosphere in this area is periodically enriched by pollutants due to atmospheric transport of emissions from such large regional cities as Irkutsk and Angarsk of 70-100 km far to the north-west.

Mondy, a remote site, is situated in the background region (a mountain area near the Russian-Mongolian border), on Mount Chasovye Sopki (the plateau between the East Sayan and Khamar-Daban ridges, 2,005 m above sea level). This area is not affected by any local sources of atmosphere pollution, being at a distance of 250 km from industrial enterprises of the region. This site corresponds to regional background conditions of atmosphere and could trace a global transfer of atmospheric pollutants. Main sources of substances are soil-erosion processes, vegetation and forest fires. Dust storms from the arid zone of Mongolia, whose frequency has appeared for the recent years, are the powerful source of alkaline components in aerosol.

Primorskaya, a rural site, was established in the Far East region in 2002 at the long-term meteorological station, and is capable to monitor an effect of long-range pollutant transport at the edge of the Asian part of Russia towards the Pacific. Primorskaya site is situated on the western slope of branch of the Southern Sikhote-Aline Ridge, in the valley of Komarovka river, 25 km southeast of Ussuriysk, at the surround protected area of the Ussuriysky Biosphere Reserve.

1.2. Sampling and measurement

1.2.1. Sampling

Wet deposition. Automatic wet-only samplers are used to collect precipitation during the period of rainfall. However, during winter season an automatic wet-only sampler has low sampling efficiency (for solid snow precipitation). Therefore, manual sampling is the only way to collect precipitation. Snow is sampled every precipitation event as well as rain. Measurement parameters for rain and snow water are the same: pH, EC, NH_4, Na^+, K^+, Ca^{2+}, Mg^{2+}, SO_4^{2-}, HCO_3^-, NO_3^-, and Cl^- (Table 1.2.2).

Dry deposition. A four-stage filter pack method is used for sampling. At urban and rural sites samples are collected weekly; at the remote site (Mondy) – bi-weekly. Air flow rate is about 1-2 L min. Measured substances are gases (SO_2, HC1, HNO_3, and NH_3) and water-soluble fraction of particulates (NH_4^+, Na^+, K^+, Ca^{2+}, Mg^{2+}, SO_4^{2-}, NO_3^- ,HCO_3^-, and Cl^-). Besides the above-mentioned parameters, ozone is also measured at Mondy and Listvyanka sites using Dylec 1006-AHJ with sampling interval of 10 minutes (Table 1.2.2). Meteorological parameters such as air temperature and humidity, wind direction and velocity are observed directly at sampling sites or obtained from the nearest meteorological station.

Soil and vegetation. Soil and vegetation are sampled once every 3-5 years with measurement of:
- for soil: pH (H_2O), pH (KC1), exchangeable Na^+, K^+, Ca^{2+}, Mg^{2+}, Al^{3+}, H^+, exchangeable acidity, ECEC , carbonate, T-C, and T-N;

- for vegetation: observation of tree decline, description of trees, under-story vegetation survey and photographic record..

Inland aquatic environment. Monitoring are conducted at two rivers: the Pereemnaya River (East Siberia) and the Komarovka River (Far East). Measurement parameters are water temperature, pH, EC, alkalinity, NH_4^+, Na^+, K^+, Ca^{2+}, Mg^{2+}, SO_4^{2-}, NO_3^-, HCO_3^-, Cl^-, transparency, water colour, DOC, NO_3^-, and PO_4^{3-}. Sampling interval: four to five times a year depending on hydrological regime.

Table 1.2.2 Sites and monitoring parameters

Site	Monitoring environment	Frequency	Sampling method	Monitoring parameters
Irkutsk	Wet deposition	Every day	Wet only	pH, EC, NH_4^+, Na^+, K^+, Ca^{2+}, Mg^{2+} SO_4^{2-}, NO_3^-, Cl^-, HCO_3^-
	Air concentration	Weekly	Filter pack	Gases: SO_2, HNO_3, HCl, NH_3 Aerosols: NH_4^+, Na^+, K^+, Ca^{2+}, Mg^{2+} SO_4^{2-}, NO_3^-, Cl^-, HCO_3^-
Listvyanka	Wet deposition	Every day	Wet only	pH, EC, NH_4^+, Na^+, K^+, Ca^{2+}, $Mg^{2+}SO_4^{2-}$, NO_3^-, Cl^-, HCO_3^-
	Air concentration	Weekly Hourly	Filter pack Automatic (ozone)	Gases: SO_2, HNO_3, HCl, NH_3 O_3, Aerosols: NH_4^+, Na^+, K^+, Ca^{2+}, Mg^{2+} SO_4^{2-}, NO_3^-, Cl^-, HCO_3^-
Mondy	Wet deposition	Every day	Wet only	pH, EC, NH_4^+, Na^+, K^+, Ca^{2+}, $Mg^{2+}SO_4^{2-}$, NO_3^-, Cl^-, HCO_3^-
	Air concentration	Bi-weekly	Filter pack Automatic (ozone)	Gases: SO_2, HNO_3, HCl, NH_3, O_3 Aerosols: NH_4^+, Na^+, K^+, Ca^{2+}, Mg^{2+} SO_4^{2-}, NO_3^-, Cl^-, HCO_3^-
Primorskaya	Wet deposition	Every day	Wet only	pH, EC, NH_4^+, Na^+, K^+, Ca^{2+}, Mg^2, $SO_4^{2-}SO_4$ $NO_3{}^-$ Cl^-, HCO_3
	Air concentration	Weekly	Filter pack	Aerosols: NH_4^+, Na^+, K^+, Ca^{2+}, Mg^{2+} SO_4^{2-}, NO_3^-, Cl^-, HCO_3^-
Pereemnaya River	Inland (surface) waters	Four times/year	Plastic bottles	pH, EC, NH_4^+, Na^+, K^+, Ca^{2+}, Mg^{2+} SO_4^{2-}, NO_3^-, Cl^-, HCO_3^-, PO_4^{3-} Transparency, Water colour, DOC
Komarovka River	Inland (surface) waters	Five times/year	Plastic bottles	pH, EC, NH_4^+, Na^+, K^+, Ca^{2+}, Mg^{2+} SO_4^{2-}, NO_3^-, Cl^-, HCO_3^- Transparency, Water colour, DOC

1.2.2. Measurement

Two chemical laboratories analyse collected samples: 1) Laboratory of Hydrochemistry and Atmospheric Chemistry of Limnological Institute SB RAS, Irkutsk (all mandatory items) and 2) Primorsky Monitoring Centre of Russian Hydrometeorological Service, Vladivostok (wet deposition and surface water samples).

The following analytical methods are used in Limnological Institute for measuring ion/element concentrations in atmospheric precipitation, inland water, extracts from aerosols, and soils in South-East Siberia: HC and atomic absorption and flame spectrophotometry for Ca^{2+}, Mg^{2+}, Na^+, K^+; spectrophotometry for NH_4^+, high-performance liquid chromatography (HPLC) and HC- for anions SO_4^{2-}, Cl^-, and NO_3. Spectrophotometry, titration, and atomic absorption are used at Primorsky Monitoring Centre.

1.2.3. QA/QC activities

QA/QC programmes are carried out at all stages of monitoring activities. Validity of the analytical data was regularly controlled by means of ion balance calculations and by comparison of measured and calculated conductivities (EANET, 2000).

The laboratories are involved in the EANET inter-laboratory comparison projects (on wet deposition, dry deposition, soil and inland aquatic environment monitoring (See Vol.1, Chapter 2). Another inter-laboratory comparison projects (on wet and dry deposition and inland aquatic environment monitoring) were participated within the framework of WMO Global Atmospheric Watch (GAW) and UN ECE CLPTAR (ICP-Waters and EMEP). The discrepancy between the results obtained and control values did not exceed 5-10%, which attested to the data validity.

2. State of atmospheric acid deposition in the EANET region of Russia

2.1. Overview of emissions

The main sources of emission of pollutants on the territory of South-East Siberia and Far East are enterprises of heat-power production, industry, and motor vehicles. The presence of pollutants in the atmosphere at sites of East Siberia depends, firstly, on emissions of contaminants into atmosphere from stationary sources of the Irkutsk-Angarsk industrial complex, including several cities and areas of forest fires (Fig. 2.1.1).

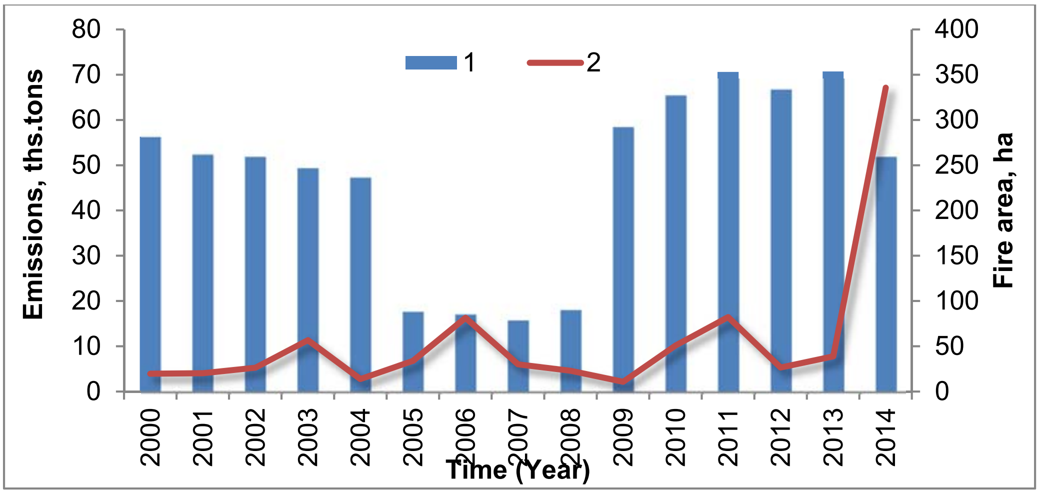

Figure 2.1.1. Multiyear dynamics of annual pollutant emissions into atmosphere from stationary sources in Irkutsk (1), of average area of a forest fire in the Irkutsk region (2)

The reduction of emission in Irkutsk in 2005-2008 was associated with integration of large thermal power plants (TPP) into a single system as well as with the decrease of production output at industrial enterprises because of deterioration of the economy. Atmospheric emissions of pollutants increased subsequently in 2009-2013. The main contributors of emission in Irkutsk city were motor vehicles with up to 60% of total amount of all pollutants. The number of motor vehicles increased from 2000 to 2014 by 80% with an annual growth of over 10,000 vehicles (Rosstat, 2016).

The emission from stationary sources in the Primorsky Kray for the last 3 years was considerably lower than in 2010-2012 due to recent transition of thermal power enterprises from coal to gas (Table 2.1.1). Emissions of pollutants into atmosphere in the Primorsky Kray from motor vehicles amount to 51% of total emission (Rosstat, 2016).

Table 2.1.1. Inter-annual dynamics of emissions of pollutants into atmosphere from stationary sources in the Primorsky Kray

Pollutants	Emissions, thousand tons per year								
	2006	2007	2008	2009	2010	2011	2012	2013	2014
Total, including:	237	227.5	242.5	226	232.8	224.9	208.7	180.9	189.5
SO_2		80.2	78.8			76.9	62.7	56.1	56.5
NO_x		22.9	23.6			25.0	25.5	24.4	24.3

Forest fires have effects significantly on concentrations of atmospheric pollutants in the southeast of the Asian part of Russia. Annual average area of a single forest fire on the territory of South-East Siberia is shows in Figure Fig. 2.1.1 as well as total number of fires. The most intense forest fires were recorded in 2003, 2004, 2006, 2010-2012, and 2014 (Minprirody of Russia, 2016). Maximal burned area of forests in the Primorsky Kray was recorded in 2008-2009 (Fig. 2.1.1).

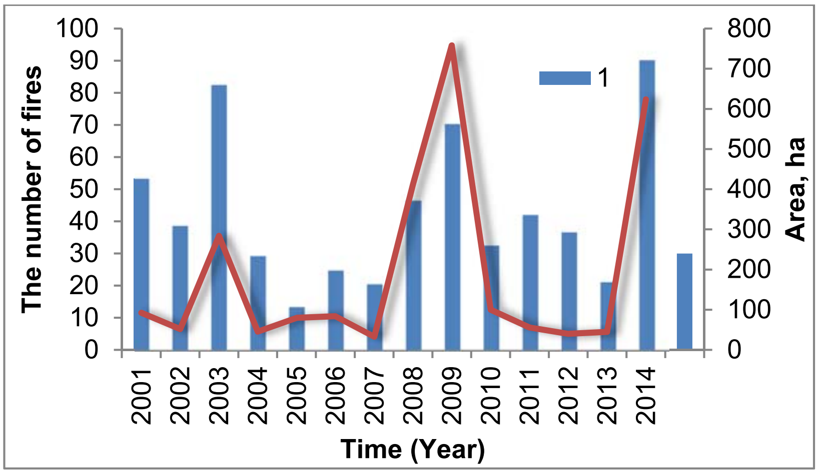

Figure 2.1.2. Dynamics of number (1) and burned area (2) of forest fires in the Primorsky Kray in 2001-2014

2.2. Dry deposition

2.2.1 Gaseous pollutants

Sulphur dioxide (SO_2) predominates among other measured small gaseous admixtures in the atmosphere at all monitoring sites (Table 2.2.1). In East Siberia, inter-annual variations in sulphur dioxide concentrations strongly depend on air temperature in winter months: the colder the winter, the higher the average concentration (Fig. 2.2.1).

More higher concentrations of SO_2 were recorded in East Siberia in 2000-2001, 2005-2006 and 2009-2013 during cold winters. In such periods, the amount of burnt fuel increased, and temperature inversions favoured the accumulation of gaseous byproducts in the atmosphere. The main pollutants emitted into atmosphere due to coal burning are ash, oxides of sulphur, nitrogen, and carbon. As a result, atmospheric aerosol is enriched with compounds of sulphur and nitrogen and alkaline components (Kelly et al., 2012; Behera et al., 2013; Karagulian et al., 2015; Vu et al., 2015). PPs in Irkutsk use coal mined in the Irkutsk region and Krasnoyarsky Krai, which contains up to 1-2 % sulphur.

Table 2.2.1. Average concentrations ($\bar{x}$) and mean-square deviation of concentration (σ) of gaseous impurities at the Russian EANET monitoring sites of atmospheric deposition, μg·m^{-3}

Sites	Gaseous impurities	2000-2004		2005-2009		2010-2014	
		$\bar{x}$	±σ	$\bar{x}$	±σ	$\bar{x}$	±σ
Irkutsk	HNO_3	0.45	0.21	0.57	0.68	0.26	0.13
	NH_3	1.15	0.77	2.23	0.56	1.41	0.44
	SO_2	4.98	4.01	9.44	5.10	12.27	9.29
	HCl					4.14	1.27
Listvyanka	HNO_3	1.28	0.50	0.16	0.07	0.23	0.11
	NH_3	0.91	0.32	1.93	0.39	1.10	0.42
	SO_2	3.23	2.49	8.42	5.09	5.39	5.05
	HCl					4.53	1.33
Mondy	HNO_3	0.19	0.18	0.09	0.10	0.14	0.21
	NH_3	0.44	0.20	0.70	0.31	0.34	0.23
	SO_2	0.40	0.18	1.49	0.46	0.70	0.59
	HCl					1.10	0.45
Primorskaya	HNO_3	0.24	0.10	0.34	0.13	0.48	0.24
	NH_3	4.46	2.08	1.81	0.75	1.50	0.56
	SO_2	2.13	1.62	2.78	1.63	2.52	1.84
	HCl					1.15	0.34

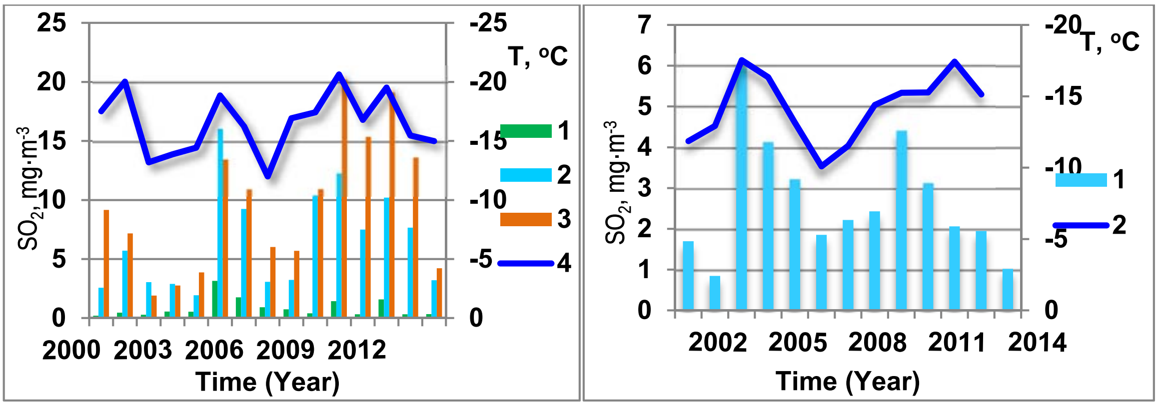

Fig. 2.2.1. Inter-annual dynamics of SO_2 concentrations and mean temperature in winter months (December, January, and February at monitoring sites:

(left) Mondy (1), Listvyanka (2), Irkutsk (3), and air temperature at Irkutsk city (4);
(right) Primorskaya (1), and air temperature at Primorskaya site (2)

At Primorskaya site, in 2010-2014 annual average concentration of sulphur dioxide was lower (2.5 mg m^{-3}) compared to that in East Siberia. Elevated content of SO_2 was recorded in 2004-2005 and 2010 (Fig. 2.2.1). Despite low air temperature in 2012-2014, SO_2 content in atmosphere at Primorskaya site was lower than in the previous years (Fig. 2.2.2a). That was attributed to the transition of TPPs from coal to gas.

The similar seasonal trend was observed in concentrations of NH_3 (Fig. 2.2.2b) and HCl (Fig. 2.2.2c) in Irkutsk and Listvyanka. Interestingly, HCl concentrations increase in warm period at the remote Mondy site in contrast to Listvyanka and Irkutsk. It is likely due to transport of air masses from the arid areas of Mongolia where the intensifications of dust storms has been recorded for the past years. Considerable increase of air temperature for the past decade affected the increase of desertification of several areas of Mongolia, including those with saline lands. In air masses with dust aerosol, relative humidity decreased to 20-40%, which hampered the transformation of acid-forming gases into corresponding to them anions (Zhang et al., 2010; Lee and Sohn, 2011). The content of HNO_3 increased in atmosphere of Irkutsk and Listvyanka in February-March and September-October and decreased in December-January and April-August (Fig. 2.2.2b). Such a seasonal trend of HNO_3 content in atmosphere was also recorded at these sites in the previous years of observations (2000-2004 and 2005-2009).

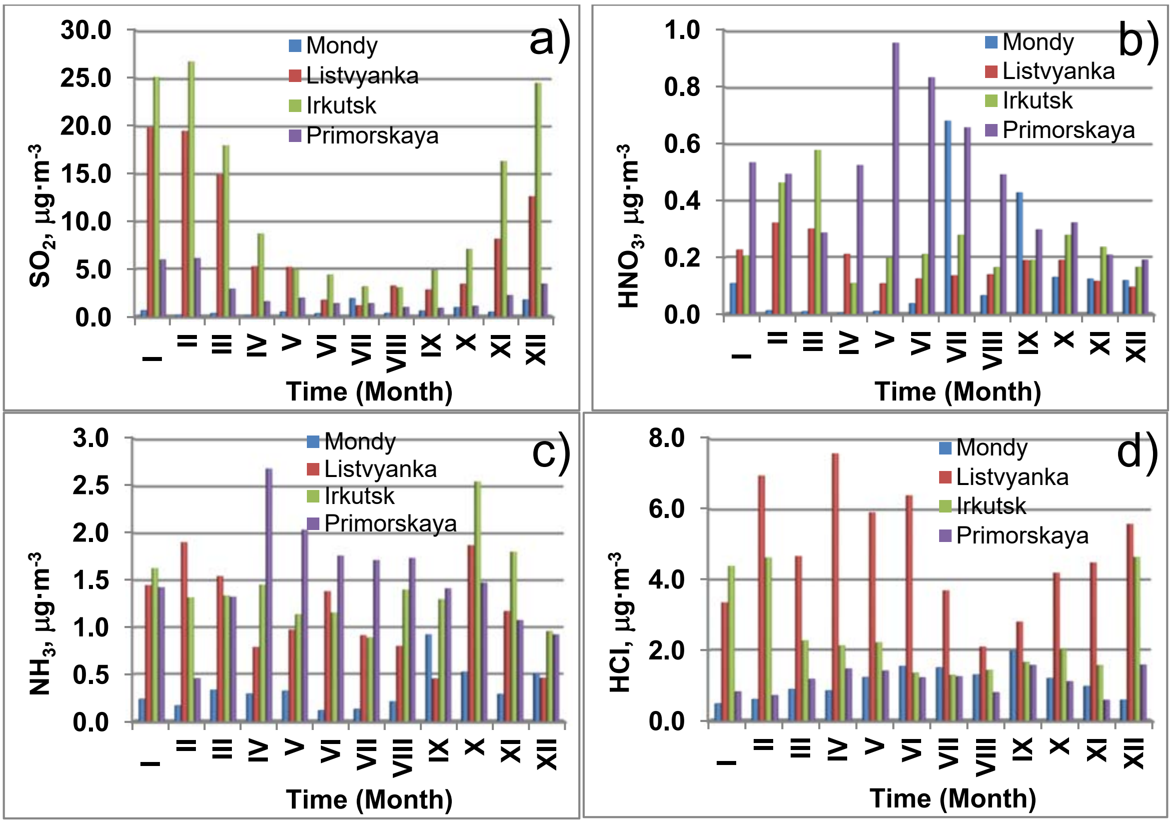

Figure 2.2.2. Seasonal dynamics of gaseous pollutants at the Russian EANET monitoring sites in 2010-2014: a – SO_2; b – HNO_3; c – NH_3; d – HCl

There was no distinct seasonal distribution of HNO_3 at Mondy site, although its elevated content was recorded more often in warm period (Fig. 2.2.3).

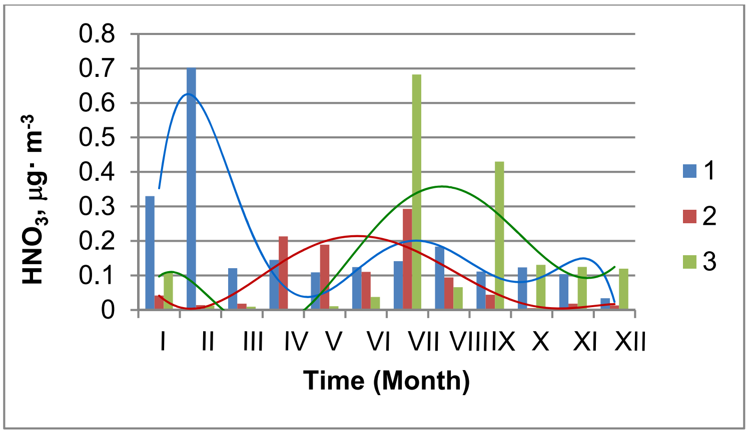

Figure 2.2.3. Seasonal dynamics of HNO_3 at the remote site Mondy: 1 – 2000-2004; 2 – 2005-2009; 3 – 2010-2014, µg m^{-3}

At Primorskaya site, the concentrations of gaseous admixtures (HNO_3, NH_3, and HCl) increased like in the previous years in warm period (Fig. 2.2.4).

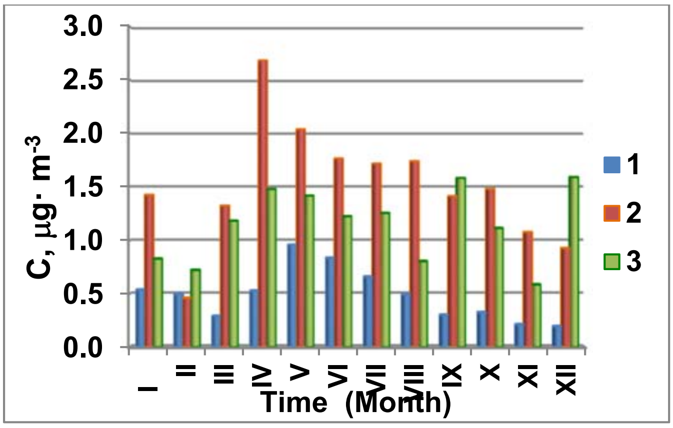

Figure 2.2.4. Seasonal dynamics of gaseous admixtures at Primorskaya site in 2010-2014: 1 – HNO_3; 2 – NH_3; 3 – HCl, µg m^{-3}

NH_3 plays a significant role in regulation of acid deposition. A large source of NH_3 emission is agriculture, including cattle breeding, livestock sector and arable farming. Emissions from industrial enterprises and motor vehicles are also anthropogenic sources. Forest fires and peat fires contribute to emission of ammonia into atmosphere (Behera et al., 2013). Annual average area of a single forest fire on the territory of the Baikal region in East Siberia is show in Figure 2. NH_3 concentrations in atmosphere of Irkutsk and Listvyanka change depending on the area of a single forest fire on this territory. Obviously, the expansion of the area of forest fires affects the emission of NH_3 into atmosphere (Fig. 2.2.5).

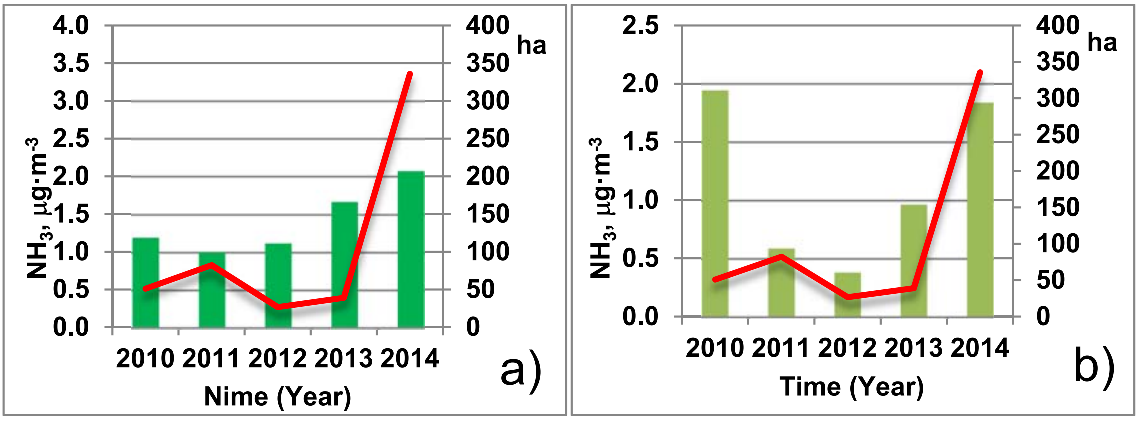

Figure 2.2.5. Annual area of a single forest fire in the Baikal region (red line) and mean inter-annual concentration of NH_3 in atmosphere of Irkutsk site (a) and Listvyanka site (b)

Peat fires also play a significant role in contamination of atmosphere. This problem was the most topical in the Baikal region in the 1980s. The main causes of peat fires are the rise of air temperature, low water level, and sinking of groundwater. Peat is able to ignite spontaneously at the moisture level lower than 35% (Kuksin et al., 2015). Since September 2013, the number of peat fires has increased in the Baikal region (Minprirody of Russia, 2016). As the result, forest and peat fires in 2013-2014 affected atmospheric content of NH_3 in Irkutsk and Listvyanka (Fig. 2.2.6).

The SO_2 content was higher by 60% in Irkutsk atmosphere in 2010-2014 than in 2000-2005. At sites in Listvyanka and Mondy, the SO_2 content increased in 3.7 and 2,6 times in 2005-2009, and decreased in 2.1 and 1.6 times, respectively. It is accepted that the natural reference concentration of SO_2 for ecologically favourable regions of mid-latitudes is 1.28 µg m^{-3} (Stozharov, 2008). The ten-fold rise of the natural reference value of mean SO_2 concentration has been recorded in Irkutsk for the recent years. At Primorskaya site, no significant changes have been observed in mean inter-annual SO_2 concentrations (Table 2.2.1).

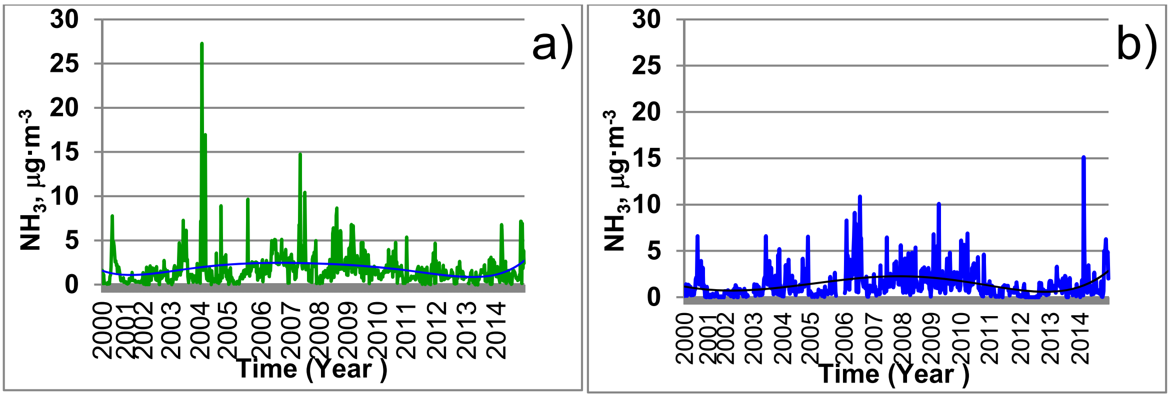

Figure 2.2.6. Dynamics of weekly NH_3concentrations in atmosphere at Irkutsk site (a) and Listvyanka site (b) in 2010-2014, μg m^{-3}

The comparison of mean inter-annual concentrations of NH_3 showed that in the Siberian region the NH_3 concentrations were the highest in 2005-2009. In 2010-2014, mean concentrations of NH_3 decreased by 51% at site Mondy, by 43% at site Listvyanka, and by 37% at site Irkutsk. At site Primorskaya, the decrease of NH_3 concentrations was also recorded, amounting to 66% compared to 2002-2004 (Table 2.2.1).

2.2.2 Ozone

The key function of ozone on the Earth is to absorb ultraviolet solar radiation by a stratospheric ozone layer (approximately 90% of total ozone). For the past decades, the rise of concentrations of tropospheric (surface) ozone has been registered in many areas of the world (Rovinsky and Egorov, 1986; Cynthia Lin et al., 2000; Akimoto, 2003). Elevated concentrations of surface ozone as the strongest oxidizer can negatively affect human health and land vegetation (at concentration higher than 40-60 ppb). Moreover, tropospheric ozone is one of the greenhouse gases, which can contribute to global warming. Most chemical reactions in the atmosphere are governed by tropospheric ozone. One of the main reasons of the rise of tropospheric ozone concentrations is general increase of atmosphere pollution. From the beginning of the industrial revolution till present, average ozone concentrations have increased from 10-20 ppb to 40-60 ppb (Akimoto, 2003). Photochemical reactions with the involvement of anthropogenic oxides of nitrogen and carbon and volatile organic compounds are considered to be a source of additional accumulation of tropospheric ozone (Pochanart et al., 2003; Pochanart et al., 2004; Belan, 2010). However, inverse effect is also possible, as well as ozone depletion under the influence of anthropogenic pollution. Therefore, studies of processes of formation and sink of surface ozone, as well as its seasonal and long-term variability are important for estimation and forecast of possible ecological changes in different natural environments.

Ozone was measured at these three sites of East Siberia using passive and active sampling methods: Mondy – remote in mountains, Listvyanka – rural and Irkutsk– urban conditions. Automatic control of ozone content in atmosphere (active sampling) was performed using an optical ozone meter Dylec Model 1007–AHJ. Instrument error was no higher than 10%. Since 1997, measurements have been conducting permanently with 1 hour time resolution.

Besides instrumental methods of ozone measurement, simpler and universal passive sampling methods were also used. At present, the passive sampling of ozone is used in some countries and by monitoring networks (WMO, EANET) for monitoring air quality in offices, dwelling houses and polluted cities and for determining the dose effect on vegetation (Hirano et al., 2002; EANET, 2013). During passive sampling, pollutants accumulate onto an impregnated filter. A typical scheme of passive sampling was described in (Ohizumi et al., 2013). The filters were exposed for two weeks, so the time resolution of the method was 2 weeks. Since 2010, ozone has been monitored using passive sampling method at all three sites of East Siberia.

Seasonal and diurnal dynamics of surface ozone concentration (SOC) was studied under background conditions of the continental climate. A disadvantage of passive sampling is low time resolution (from a week to two weeks). The comparison of passive and active (automatic) data shows satisfactory coincidence of both methods. The same comparison for site Mondy for 2010-2014 (Fig. 2.2.7) demonstrates good similarity of seasonal and long-term variability of ozone. However, significant discrepancies (over 2 standard deviations) were recorded in separate months. Nevertheless, this method may appear to be a good alternative for more costly automatic methods, especially in remote and hard-to-reach areas.

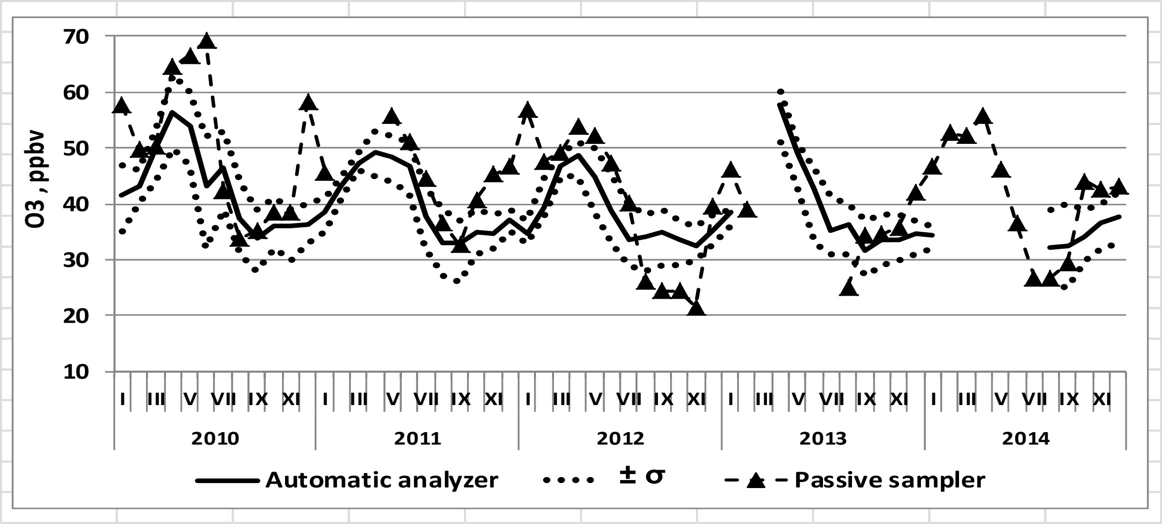

Figure 2.2.7. Comparison of ozone concentrations between passive and active (automatic) methods at Mondy site

According to passive measurements, annual dynamics of ozone concentrations at three sites in 2010-2014 was typical of many areas of the Northern Hemisphere (Rovinsky and Egorov, 1986; Pochanart et al., 2004, Akimoto, 2006;) with its maximum in spring (April-May) and minimum in autumn (September-October) (Fig. 2.2.8).

Given that the annual trend of distribution of surface ozone in the atmosphere is similar at all three Siberian sites, average ozone concentrations appeared to be significantly lower at the urban site (Irkutsk) than those at the remote site (Mondy) and rural site (Listvyanka). The most probable reason was that ozone was consumed in larger quantities for oxidation of other anthropogenic impurities within the large city.

It is known that winter-spring maximum of ozone is caused by its sink from stratosphere into troposphere (Rovinsky and Egorov, 1986; Jacob et al., 1991). The decrease of ozone concentrations in summer (Demin and Beloglazov, 2004, Demin et al., 2004; Latysheva et al., 2005) is attributed to weakening of anticyclone activity in the Siberian region. Insignificant barometric pressure gradients in the warm period cause the decrease of wind velocity. Cyclones and anticyclones are less active, and the exchange of air masses between stratosphere and troposphere slows down. At the same time, ozone depletes more intensely in summer due to ozone consumption for oxidation of organic matters, which form as a result of intense growth of vegetation, as well as due to ozone leaching by summer atmospheric precipitation.

Atmospheric circulation can also affect the variability of surface ozone concentrations. Ozone concentration and atmospheric pressure were synchronously recorded at site Listvyanka in April of 2014 (Fig. 2.2.9).

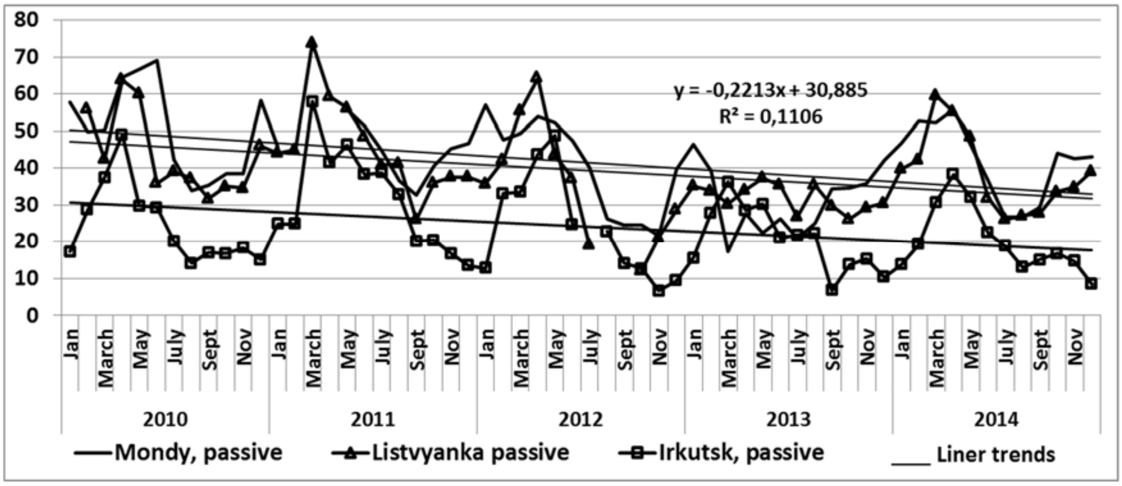

Figure 2.2.8. Seasonal variability of ozone concentrations monitored by passive sampling at three EANET monitoring sites in East Siberia

Besides regular diurnal (photochemical) fluctuations of ozone concentrations, there are "longer" irregular fluctuations, which are in anti-phase with atmospheric pressure: low ozone concentrations correspond to high pressure and, vice versa, ozone content increases at low pressure. The periodicity of fluctuations makes up a few days, testifying to variations of synoptic scale and therefore it is likely connected with the intensity of horizontal and vertical transport of ozone by wind. For example, strong NW winds along the Angara River valley to the south of Lake Baikal are usually caused by elevated atmospheric pressure over the Irkutsk area. This regional air mass transport may bring polluted urban air with lower ozone concentration to the Listvyanka area (Fig. 2.2.8). It is known that emissions from industrial enterprises can be a reason of short-term non-periodic fluctuations of ozone in rural and urban areas (Butukhanov et al., 2002). Numerous observations performed at site Listvyanka showed that anthropogenic emission plumes favoured ozone depletion rather than its formation (at least at night time). As an example, Figure 2.2.10 presents a fragment of automatic registration of concentrations of ozone and sulphur and nitrogen oxides in December of 2013 (with 5 minute time resolution): on December 22, the ozone concentrations were stably high (35-45 ppb) at the wind blowing from Lake Baikal.

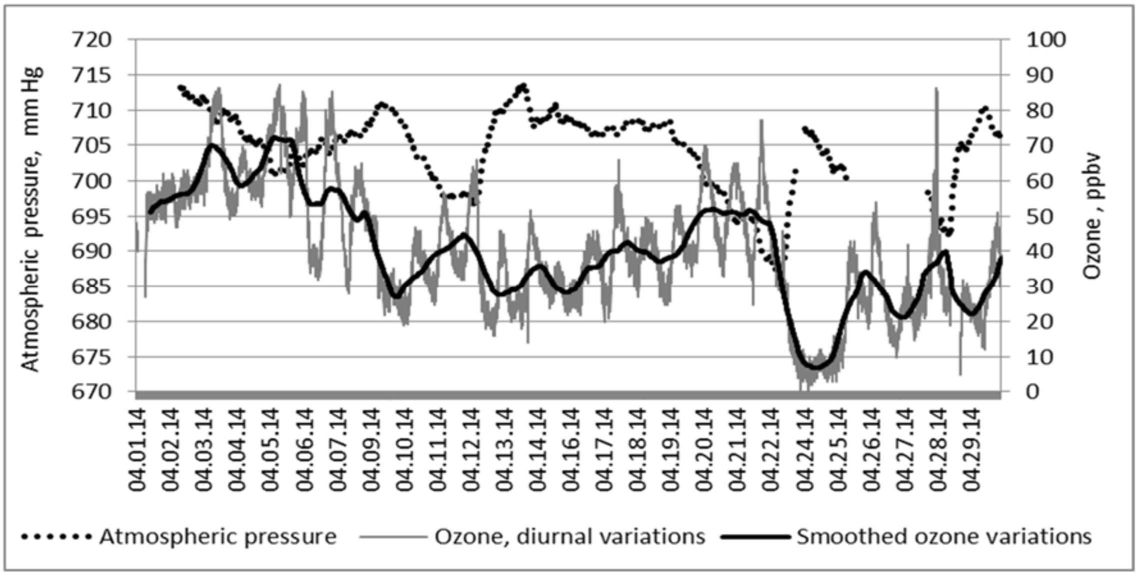

Figure 2.2.9. Dynamics of ozone concentrations and atmospheric pressure in surface atmosphere at Listvyanka site, April of 2014

At midnight on December 23, the wind changed its direction to the north-west, and the atmospheric plume of the power plant was transported from Irkutsk over the area of site Listvyanka. As a result, the ozone content fluctuated up to zero synchronously with the rise of concentrations of sulphur and nitrogen oxides. Ozone within such plumes can completely react with nitrogen oxides.

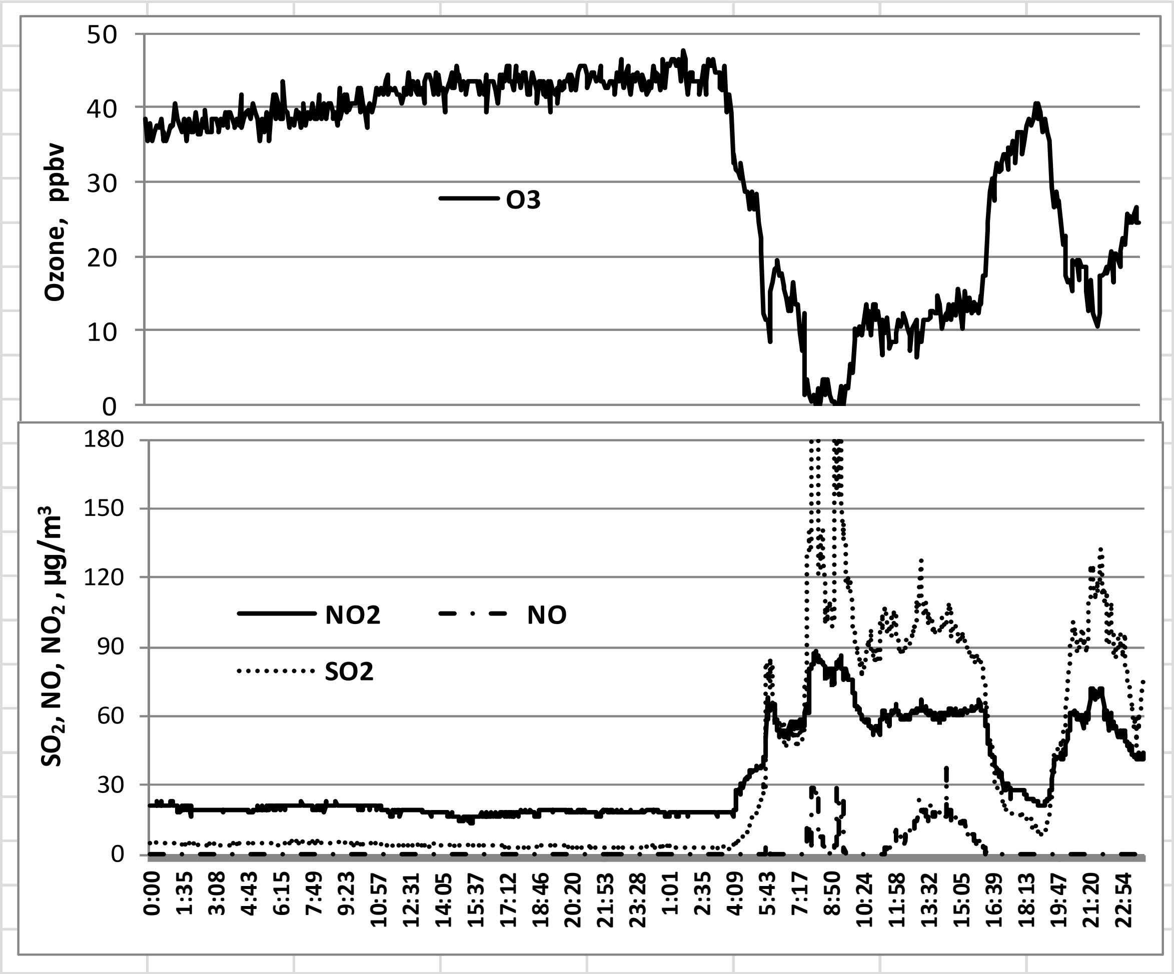

Figure 2.2.10. A fragment of records of ozone and nitrogen oxide concentrations during transport of plume from the coal power-electric plant over Listvyanka site, December of 2013

Therefore, its concentrations within the plume were close to zero. Several cases of this kind were registered for January 2014. Ozone concentration decreased sharply 6 times up to zero. Short-term and abrupt increases in concentrations of sulphur and nitrogen oxides at site Listvyanka were caused by the so-called “low-level atmospheric jets”, which transported weakly scattered plumes emitted from coal heat power-electric plants (Cocks et al., 1983; Obolkin et al., 2014). These fluxes formed more often at night and in the morning in the inversion layers of atmosphere at an altitude of 200-500 m above the ground surface (at the height of emissions from tall chimneys of large heat power electric plants). Site Listvyanka is located on the way of these plume transport as it is situated at the same altitude.

Diurnal fluctuations of ozone concentration were clearly observed during a year, except December and January. These fluctuations depended on diurnal dynamics of solar radiation, which is one of the main factors of photochemical ozone generation. Daily ozone photogeneration (site Listvyanka) increased from winter (January) to spring (April) and summer under the influence of growing solar radiation (Fig. 2.2.11).

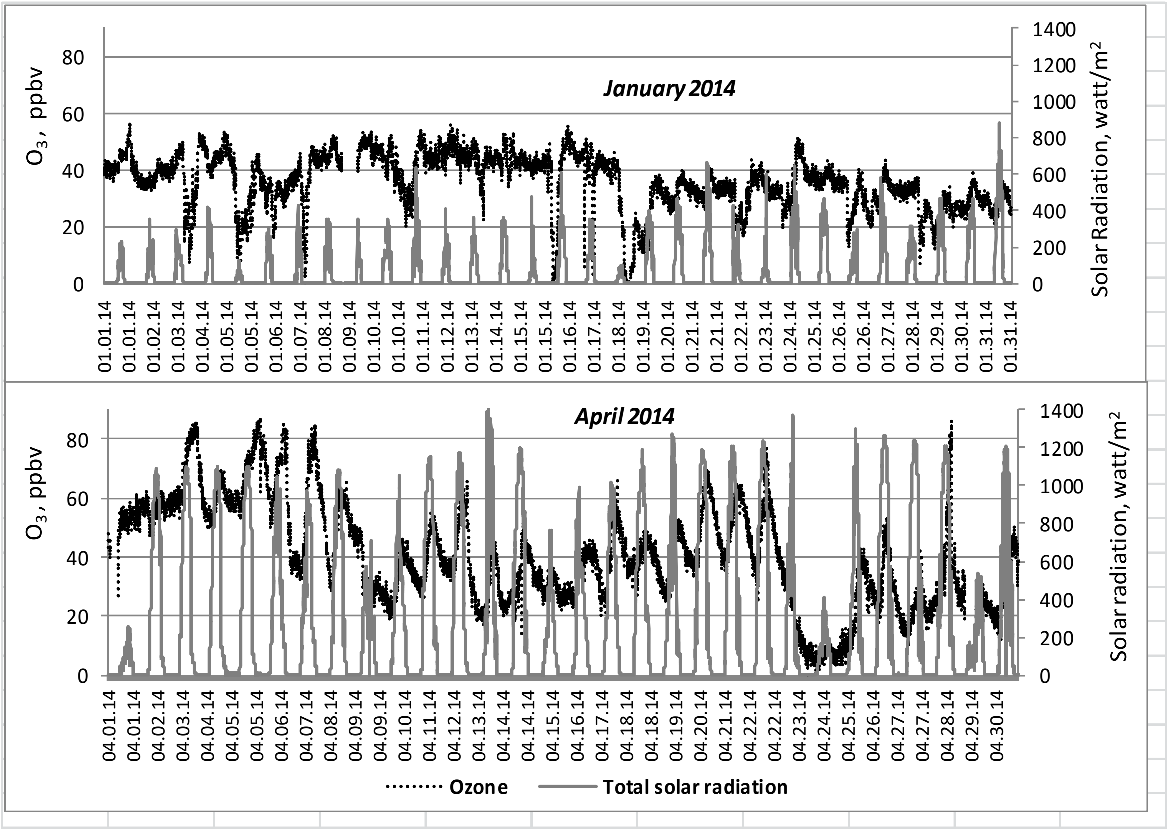

Figure 2.2.11. Diurnal variation of solar radiation and ozone concentration at site Listvyanka, January and April of 2014

Ozone generation started with the sunrise at radiation of approximately more than 200 W/m^2 and ended before the sunset at radiation lower than this value. Therefore, maximal concentrations of ozone were recorded in the evening. The delay of diurnal ozone maximum with respect to the solar radiation maximum depended on the length of daylight amounting to 3-4 hours in February-March and 5-6 hours in June-July. This is clearly seen in the inter-correlation functions of variability of ozone and solar radiation (Fig. 2.2.12), the maximal correlations being in May-June (approximately 0.6) and minimal ones in December-January (0.1). On cloudy days, as a rule, the diurnal amplitude of ozone concentration is expressed weaker than that on sunny days.

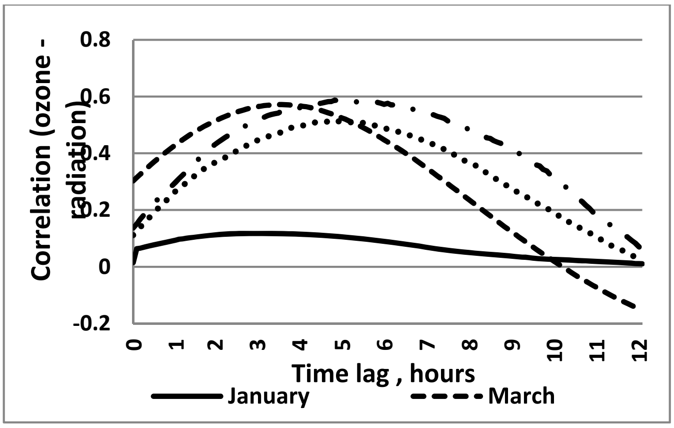

Figure 2.2.12. Correlation of solar radiation and ozone concentrations depending on hour lags for different seasons

At night due to the absence of ozone photogeneration, its concentrations gradually reduced because of its consumption for oxidation processes in atmosphere or absorption by underlying surface (vegetation). Mean night ozone concentrations were 20-40 ppb in spring and practically zero in September-October. In a cold season and early spring, ozone sink was minimal at night probably due to the snow cover, which prevented interaction between ozone and vegetation. In summer and autumn months, the ozone sink intensified, and in September-October, it was not compensated by lower daytime photochemical generation. Total ozone concentrations reached their minimal values.

Despite the minimal solar radiation in winter months (from January to early February), ozone concentrations were relatively high (30-40 ppb). In this season, the major source of ozone can be not only photochemical reactions occurring in the atmosphere but also other processes, e.g., ozone sink from the stratosphere. In March-April, photochemical generation intensified due to the increase of the length of daylight. At the same time, the depletion of ozone at night was minimal because of the snow cover and low air temperature. As a result, its maximal concentrations were recorded in spring in the surface atmosphere of East Siberia. The longest series of automatic ozone observations (18 years) was obtained at site Mondy (Fig. 2.2.13).

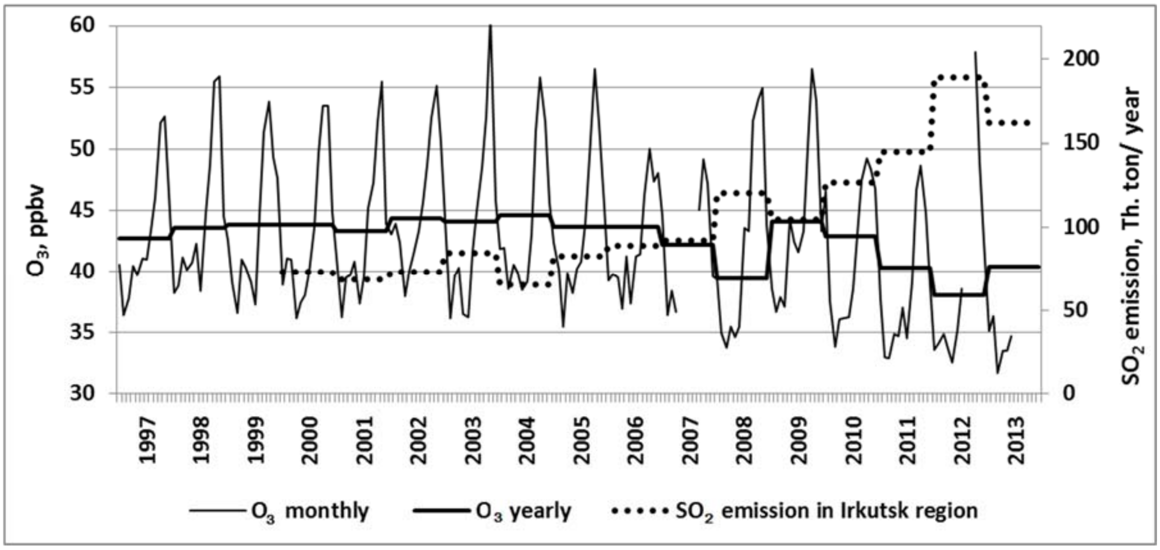

Figure 2.2.13. Long-term trend of ozone concentrations at the remote Mondy site (active sampling)

During this period up to 2002-2004, the tendency to growth of ozone concentrations was registered, but after those years up to recent time the tendency to decrease of average annual ozone concentrations is clearly detected. The same tendency can be also observed analysing passive data obtained at all three sites during shorter periods of observations (2010-2014).

The long-term trends of ozone concentration at those three Siberian sites can be compared with global data from the Tropospheric Ozone Assessment Report (www.ignproject.org/TOAR). According to this Report, seasonal and inter-annual variability of ozone was found to be different for many stations of the world making it difficult to identify a common long-term ozone trend. Prior to the 1900s, almost all records indicated a stable rise, while during the 1900s the picture was very diverse. Some data show stable or decreasing trends in northern mid-latitudes after 1980. At least in most regions, surface and tropospheric ozone concentrations have not risen significantly since 2000 (WMO, 2015). One of the most possible reasons of the decrease of average annual concentrations of ozone at all three sites in Siberia after 2006 may be a significant rise of anthropogenic emission in this area. Since 2007, average annual concentrations of ozone are in anti-correlation with annual emissions of sulphur dioxide in Irkutsk.

2.2.3 Trends of trace gas and aerosol concentration

The trends of gaseous and aerosol compounds at Russian *rural* and *remote* EANET stations were estimated based on accumulated data sets on air concentrations measured by filter pack for a whole period of 2000-2014. The statistical approach of median regression estimation and correspondent software was applied to the long term period of the data series without prior averaging of measurement results (raw data). Trends were estimated for whole time series without attention to possible seasonal variations.

The median regression approach was applied to assess general trends which were accompanied with quantile regression for the trends in upper quantiles (Koenker and Bassett, 1978). This approach is less sensitive to outliers which are randomly appeared in the data sets and usually could have more effect on ordinary least-square trend values. The relevant confident interval was used to decide whether estimated trend is statistically significant or not.

The total results of trend estimations for gases and aerosol compounds of filter pack measurements are presented in Table 2.2.2. The color scheme represents the type of trends: values on red background are correspondent to significant increasing, ones in green cells are of significant decreasing, and those in gray cells are of no significant both decreasing (negative) and increasing (positive) tendencies.

Table 2.2.2. The results of trend estimation for air concentration measurements by filter pack at rural and remote site of EANET for 2000-2014

Measured pollutant		Russian EANET monitoring sites		
		Primorskaya	Mondy	Listvyanka
Gases, ppb/year	SO_2	0.016	0.003	0.032
	HNO_3	0.002	0	-0.004
	HCl	0.015	0.010	0.009
	NH_3	-0.132	-0.002	0.019
Aerosols µg/m³/year	SO_4^{2-}	0.027	-0.013	-0.035
	NO_3^-	0.002	-0.002	-0.008
	Cl^-	-0.003	0	-0.005
	NH_4^+	-0.005	-0.008	-0.019
	Na^+	0.001	0	-0.001
	K^+	0	-0.001	-0.002
	Mg^{2+}	0.001	-0.001	-0.001
	Ca^{2+}	0.006	-0.002	-0.006

The magnitude (absolute or relative) of median trend slopes is varied both for certain species and different stations but the directions of tendencies are similar for the stations except certain pollutants (like reduced nitrogen at Primorskaya). There were general increasing trends of sulfur dioxide concentrations around 3.2-3.8% per year (compared to long-term averages) at the regional stations Listvyanka and Primorskaya with more pronounce in winter and early spring, while the sulfate concentration in the region of Lake Baikal decreased by 3.8-4.7% per year .

We also estimated significant decreasing trends for all major ions measured in aerosol phase at the Listvyanka station; those at background station Mondy were of much weaker decreasing or not significant. Estimates of median trends demonstrated opposite changes of HNO_3 and NH_3 contents for different stations, while gaseous HCl is increased at all three stations by 5 to 16% per year.

2.3. Wet deposition

2.3.1. Seasonal and multiyear results

The results of monitoring of atmospheric precipitation chemical composition in the Eastern Siberia and Primorsky Kray of Russia in 2010-2014 showed that higher level of total precipitation mineralisation (TDS) was recorded at the urban site Irkutsk (Fig. 2.3.1). Mean long-term values of total ions were 20.5 mg·L^{-1}. The lowest values of TDS were recorded at the remote site Mondy: of 5.5 times lower than in Irkutsk. At sites Listvyanka and Primorskaya, mean mineralisation of atmospheric precipitation was 7.8 and 13.2 mg·L^{-1}, respectively. Maximum TDS values were recorded in 2011 at sites Mondy and Primorskaya when precipitation was minimal (Figs. 2.3.1-2.3.2). In Irkutsk and Listvyanka, maximal values were registered in 2010; that was attributed to high level of atmospheric pollution in the industrial centre while minimum of precipitation was recorded in 2013.

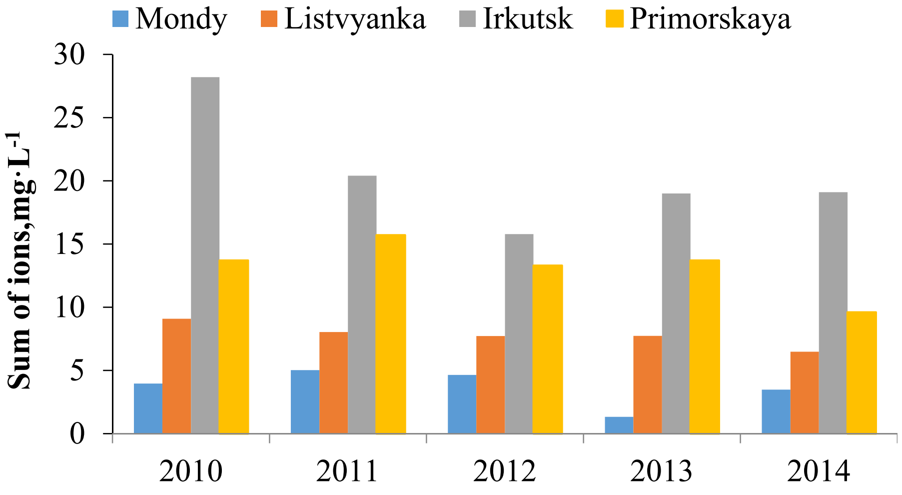

Figure 2.3.1. Inter-annual dynamics of TDS in atmospheric precipitation at monitoring sites

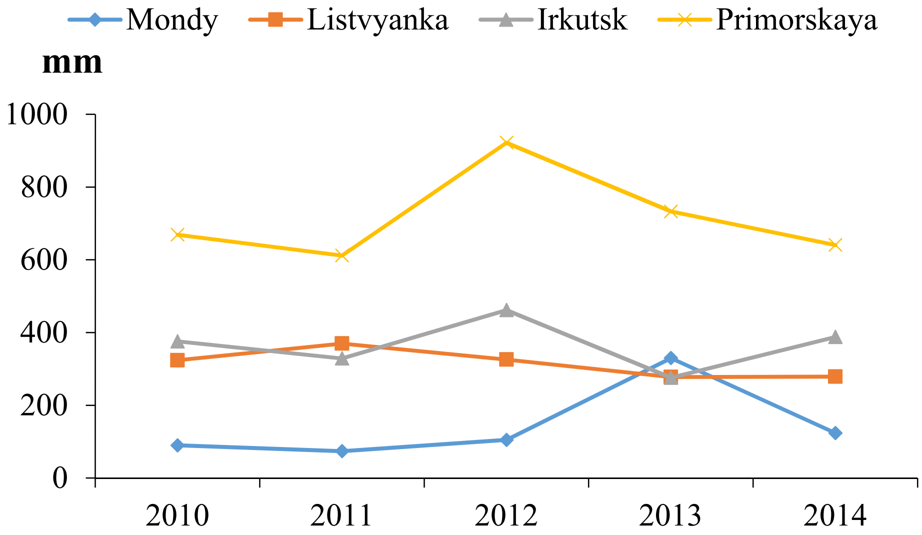

Figure 2.3.2. Inter-annual dynamics of atmospheric precipitation amount at EANET monitoring sites

TDS of precipitation decreases, as a rule, when precipitation is higher. For example, minimal values of mineralisation were at site Irkutsk in 2012 and at site Mondy in 2013: that coincided with the maximum of atmospheric precipitation in these years. In 2014, compared to 2010, precipitation TDS was lower at all sites, up to of 1.5 times Irkutsk site (Figs. 2.3.1-2.3.2).

TDS of wet deposition in warm period (May-October) was 2 times lower on average at all monitoring sites than in cold period. The biggest difference was recorded at site Irkutsk (Fig. 2.3.3). Lower mineralisation of rain was attributed to higher precipitation of rain (in 2-5 times).

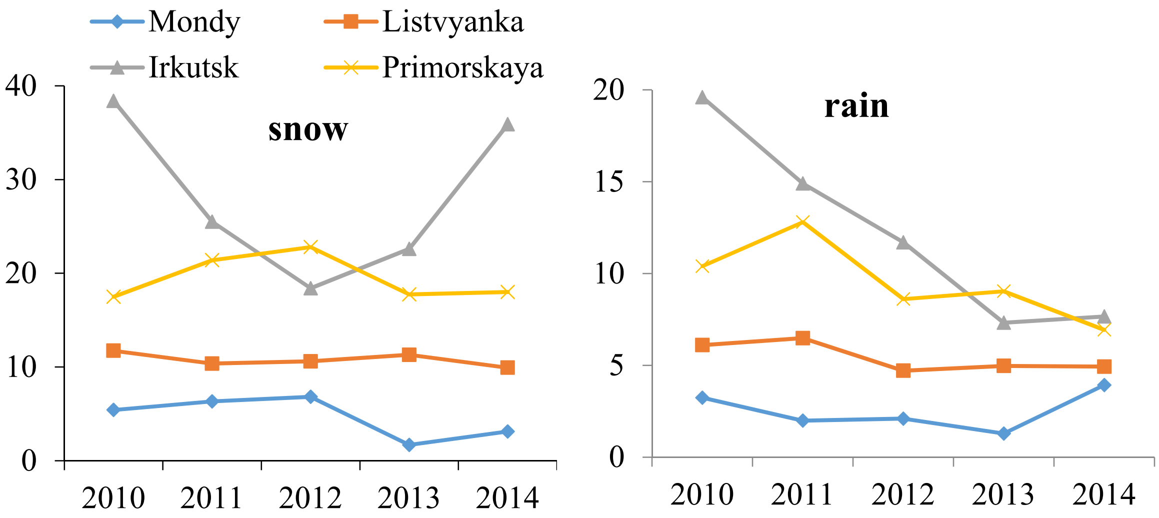

Figure 2.3.3. Inter-annual dynamics of TDS in atmospheric precipitation at the EANET monitoring sites during cold (left) and warm periods, mg·L^{-1}

TDS of snow precipitation at the urban site was 6 times higher than at the remote site Mondy, and rain precipitation was 5 times lower. Mineralisation of atmospheric precipitation was 1.8 times lower in Listvyanka than at site Primorskaya. At all sites, except site Mondy, TDS of rain had decreased during the period of observations: the most expressed decrease was recorded at site Irkutsk (in 2.6 times).

Like in 2005-2009, sulphate and calcium were the major ions in atmospheric precipitation at all sites. In the contrast to 2005-2009, sulphate and ammonia were dominated in atmospheric precipitation in the Primorsky Kray in 2010-2014. Lower concentrations of bicarbonate were recorded at Irkutsk and Mondy, nitrate in Listvyanka and chloride at site Primorskaya. Among cations, calcium ions were registered at site Primorskaya and ions of ammonia were recorded at the rest sites (Table 2.3.1). The contribution of sulphate, nitrate and hydrogen ions was the most significant in Listvyanka, while bicarbonates, calcium and potassium in Mondy, calcium in Irkutsk, and chloride, sodium and ammonia in Primorskaya.

Table 2.3.1. Relative ionic composition of atmospheric precipitation at the EANET monitoring sites, %-eqv. (2010-2014)

Ion	Mondy	Listvyanka	Irkutsk	Primorskaya
HCO_3^-	**14.2**	2.2	9.3	4.6
SO_4^{2-}	**15.9**	**27.4**	**23.8**	**21.0**
NO_3^-	8.8	**14.5**	7.4	9.2
Cl^-	6.5	3.7	7.0	**15.3**
Na^+	4.0	3.6	5.6	**8.6**

Ion	Mondy	Listvyanka	Irkutsk	Primorskaya
K^+	**4.5**	2.1	1.9	2.5
Ca^{2+}	**20.6**	**20.0**	**24.2**	13.6
Mg^{2+}	4.9	4.4	4.7	4.0
NH_4^+	11.1	10.3	11.4	**16.1**
H^+	8.9	**10.3**	3.2	5.1

Analysing specific characteristics of the relative ionic composition of atmospheric precipitation in different periods of the year, we found out that sites Mondy and Primorskaya differed significantly from the others. Bicarbonate ion prevailed in the snow at site Mondy, ammonia ion was the main cation in rain at site Primorskaya. At all sites, except Primorskaya, the percentage of bicarbonate ion was higher in cold season. During the same period, the contribution of nitrate was also high at all sites, except Mondy. High contribution of nitrate in the rain was attributed primarily to its natural origin. The contribution of calcium and sodium was also maximal in snow at all sites. The percentage of ammonia and hydrogen ions was high in rain at all sites, as well as sulphate, except site Primorskaya (Fig. 2.3.4).

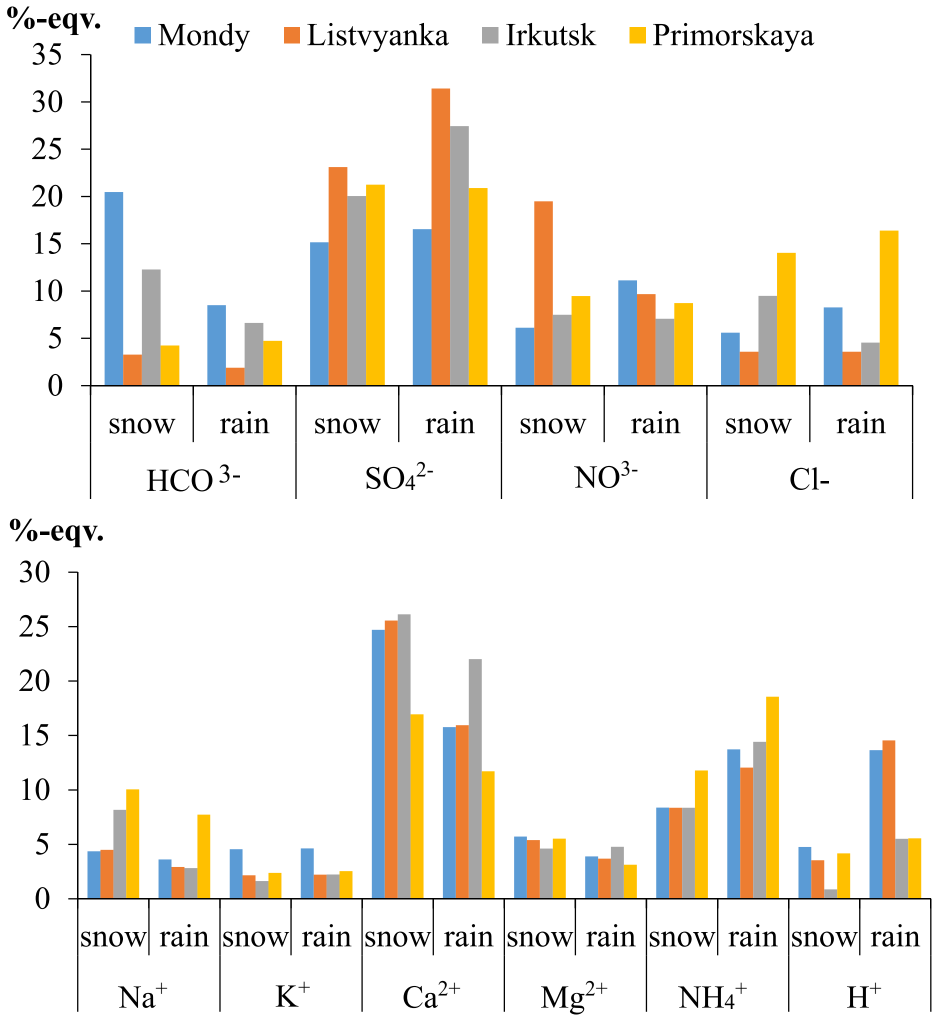

Figure 2.3.4. Average long-term relative ionic composition of atmospheric precipitation during warm and cold periods at the EANET monitoring sites, %-eq. (2010-2014)

Average annual concentrations of prevailing ions decreased from 2010 to 2014 at monitoring sites (Table 2.3.2), except site Mondy, where concentrations of most ions increased in 2014 compared to 2010. Concentrations of chloride, nitrate and ammonia were high in atmospheric precipitation at site Primorskaya and other ions at site Irkutsk. At sites Irkutsk and Listvyanka, despite different level of anthropogenic impact with high content of most ions (2-8 times) in the industrial centre, the concentration of nitrate was almost similar. The ionic content at the remote site Mondy compared to the urban one was 2-11 times lower.

Table 2.3.2. Chemical composition of precipitation at the EANET monitoring sites, mg L^{-1}

Year	HCO_3^-	SO_4^{2-}	NO_3^-	Cl^-	Na^+	K^+	Ca^{2+}	Mg^{2+}	NH_4^+
Irkutsk									
2010	5.27	8.55	2.61	3.30	1.91	0.86	3.93	0.51	1.11
2011	3.80	6.03	2.30	2.25	1.33	0.43	2.90	0.36	0.91
2012	2.64	6.66	2.43	1.55	0.90	0.52	3.08	0.35	0.83
2013	3.34	6.78	2.06	1.67	0.91	0.41	3.17	0.33	0.80
2014	5.56	5.00	1.49	1.59	0.88	0.28	3.08	0.25	0.88
Mean	**4.12**	**6.60**	**2.18**	**2.07**	**1.19**	**0.50**	**3.23**	**0.36**	**0.91**
Listvyanka									
2010	0.93	3.05	2.42	0.36	0.23	0.14	1.26	0.20	0.40
2011	0.6	3.01	2.21	0.29	0.19	0.15	1.12	0.12	0.44
2012	0.24	2.92	2.50	0.19	0.16	0.15	1.01	0.13	0.42
2013	0.16	3.10	2.11	0.34	0.24	0.25	1.01	0.16	0.29
2014	0.62	2.42	1.44	0.20	0.17	0.17	0.86	0,11	0.37
Mean	**0.51**	**2.90**	**2.14**	**0.28**	**0.20**	**0.17**	**1.05**	**0.14**	**0.38**
Mondy									
2010	1.34	0.72	0.60	0.15	0.09	0.13	0.43	0.06	0.34
2011	2.32	0.60	0.43	0.23	0.14	0.30	0.58	0.11	0.29
2012	2.04	0.73	0.55	0.20	0.10	0.33	0.49	0.09	0.40
2013	0.12	0.34	0.31	0.18	0.03	0.08	0.18	0.02	0.05
2014	0.96	0.75	0.32	0.30	0.14	0,28	0.50	0.06	0.14
Mean	**1.36**	**0.63**	**0.44**	**0.21**	**0.10**	**0.22**	**0.44**	**0.07**	**0.24**
Primorskaya									
2010	0.67	5.20	2.29	1.57	0.93	0.41	1.24	0.22	1.16
2011	1.55	2.75	3.81	3.59	0.65	0.59	1.25	0.26	1.41
2012	0.85	3.74	3.31	1.68	0.92	0.41	1.18	0.26	0.97
2013	1.06	4.74	2.49	2.50	1.26	0.39	1.54	0.29	1.05
2014	1.54	4.10	0.72	1.32	0.52	0.31	1.15	0.22	0.81
Mean	**1.13**	**4.11**	**2.52**	**2.13**	**0.86**	**0.42**	**1.27**	**0.25**	**1.08**

Concentrations of sulphate, nitrate and ammonia were maximal during heating season: in January-February of 2013, in March and October of 2010, and in February and November-December of 2014 (Fig. 2.3.5). In Listvyanka, the concentrations of nitrate and sulphate also increased in winter: in January of 2011 and 2013 and in March of 2012. The content of ammonia ions was maximal in warm period: in May of 2012 and September of 2014. At site Primorskaya, sulphate and nitrate increased in cold period (in February of 2012, January of 2013, and April of 2014) and ammonia ions because of forest fires (in May of 2011 and 2012). At site Mondy, concentrations of all ions, especially ammonia, also increased in May of 2010 and 2012, in October of 2011 and in August of 2014.

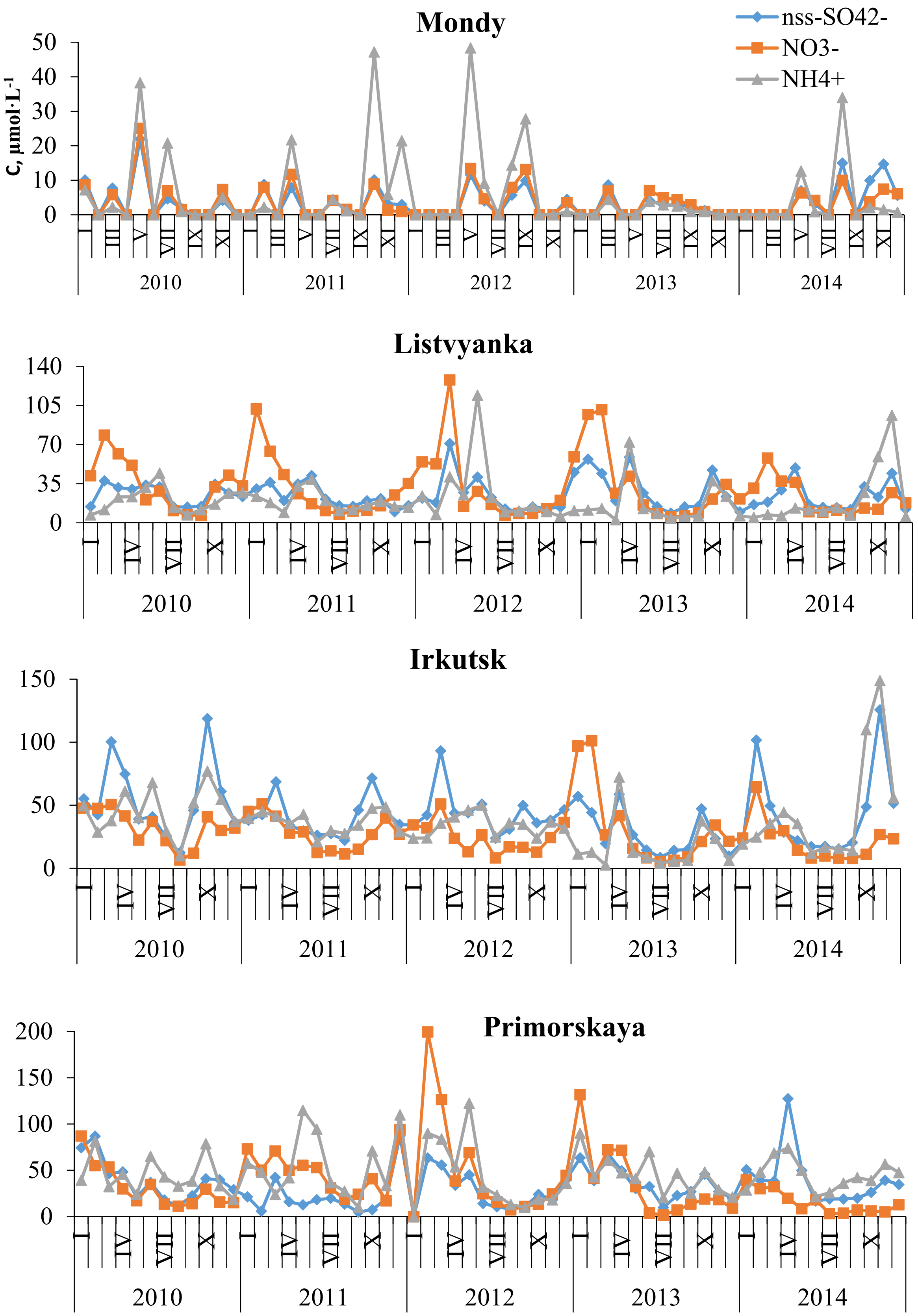

Figure 2.3.5. Inter-annual dynamics of weighted-mean ion concentrations at the EANET monitoring sites, µmol L^{-1}

On average, the highest values of weighted-mean concentrations of sulphate were recorded at rural sites in April, at urban site Irkutsk in March and October, and at remote site Mondy in May (Fig. 2.3.6). Maximal content of nitrate was measured in February in Irkutsk and Listvyanka, in May at site Mondy, and in January at site Primorskaya. The maximal concentrations of ammonia ions were registered in May at all sites, except Irkutsk. At the urban site, the highest values of this component were observed in April and November. The rise of ammonia and sulphate concentrations was attributed, as a rule, to forest fires and combustion of waste.

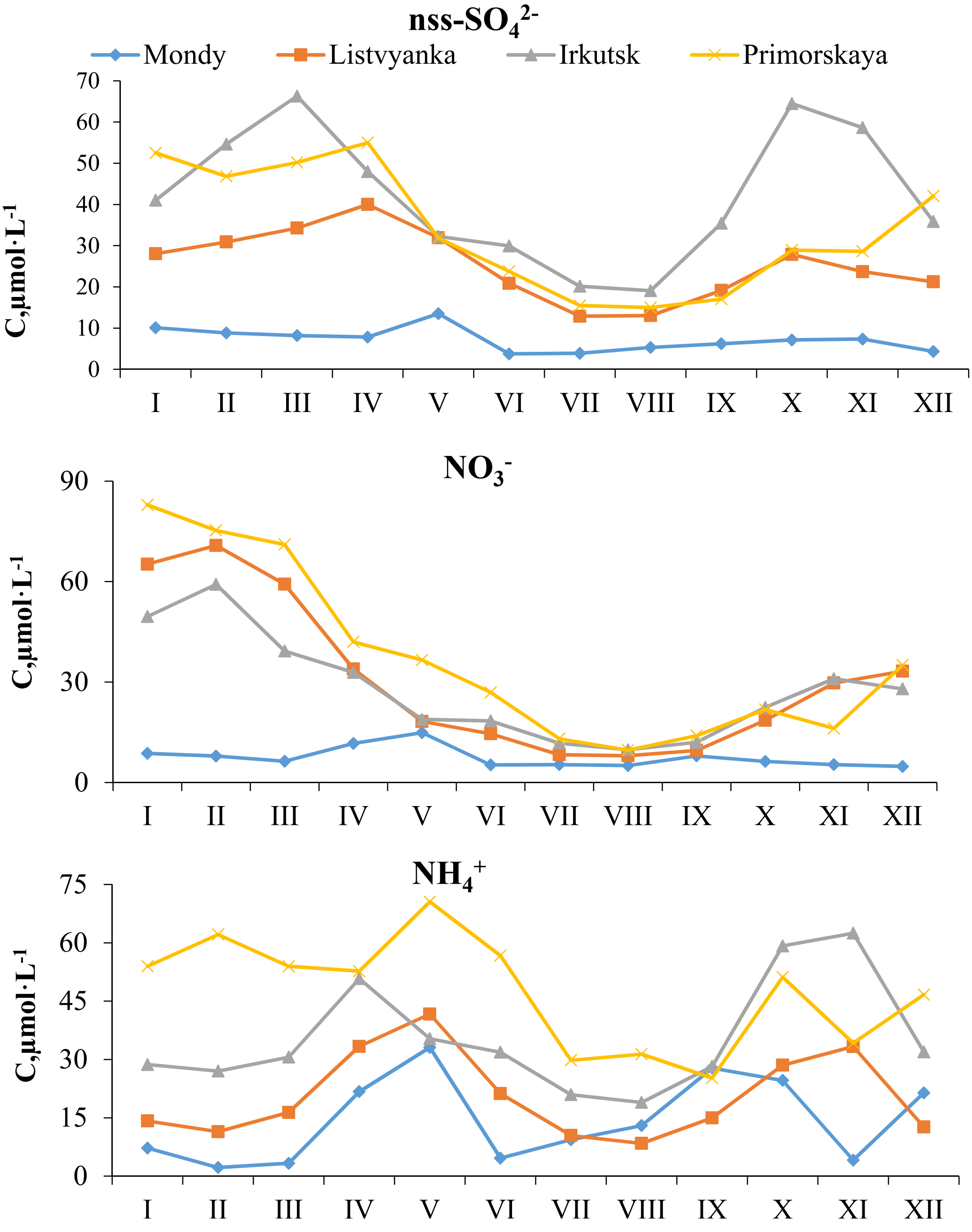

Figure 2.3.6. Inter-annual dynamics of weighted-mean ion concentrations at the EANET monitoring sites, (2010-2014), µmol L^{-1}

Maximal concentrations of sulphate and nitrate in the atmosphere at Irkutsk were caused by high level of atmosphere pollution, i.e., gaseous emissions from heat-and-power engineering enterprises (Fig. 2.3.7), exhaust gases in the period of low amount of precipitation, and meteorological conditions did not favour dispersion of atmospheric pollution. At the rural site Listvyanka, another source of pollution besides motor vehicles, boiler plants and stoves was the transfer of air masses along the valley of the Angara River from Irkutsk, Angarsk and other industrial centres of the Baikal region. Like in Irkutsk, specific meteorological conditions in winter, particularly high recurrence of calm and low velocities of wind were favourable for accumulation of pollutants in the atmosphere of the settlement.

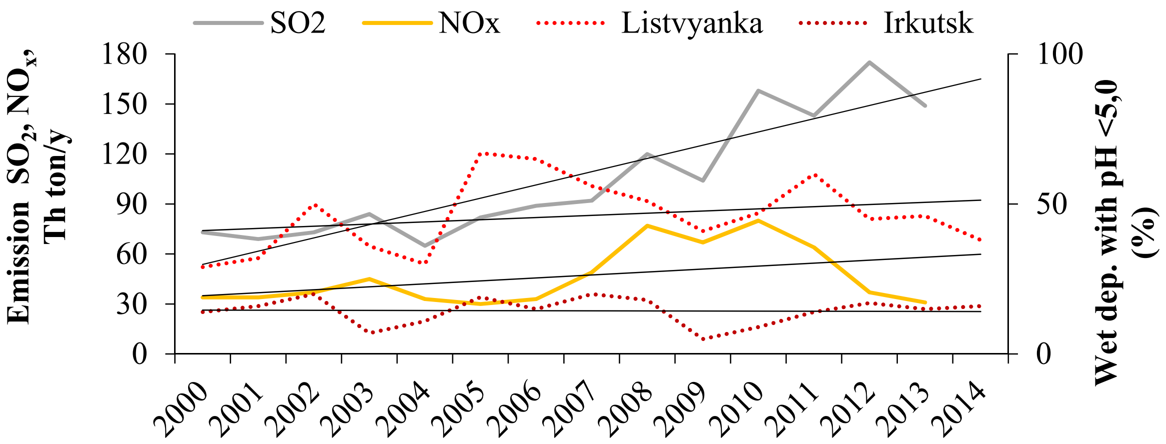

Figure 2.3.7. Inter-annual emission dynamics of total sulphur and nitrogen oxides in Irkutsk and Angarsk (thousand tons per year) and recurrence (%) of atmospheric precipitation with pH < 5.0

At site Primorskaya, one of the factors for formation of chemical composition of atmospheric precipitation, like in Listvyanka, was the transport of pollutants from regional anthropogenic sources because of their location on the way of the main transport of air masses. The site is situated 30 km from the town of Ussuriysk with the pollution level of air considered as the highest level because of a high number of vehicles and large amount of emission from industrial enterprises. Moreover, industrial emissions from such countries as China and North Korea affect the chemical composition of atmospheric precipitation in the Primorsky Kray located on the way of air masses transported from these countries.

2.3.2. Acidity of precipitation

The lowest pH values in atmospheric precipitation were recorded at site Listvyanka (Fig. 2.3.8). The average for 5 years value was 5.15, a little higher than in the previous period of 2005-2009 (5.05). The highest pH values (on average 5.98) were recorded in atmospheric precipitation at the urban site Irkutsk. At the remote site Mondy, the pH value was lower (5.66) than in Irkutsk. The lowest acidity values were in Mondy in 2013. Mean pH value at site Primorskaya was 5.47 coinciding with the similar parameter in the previous period. The minimal value was registered in 2011 like in Listvyanka. At site Primorskaya, the trend of pH rise was recorded from 2010 to 2014.

At the same time, the ratio of mean annual equivalent concentrations NO_{3-}/SO_4^{2-} was an order lower in the Primorsky Kray, whereas the pH value increased. It dropped from 1.4 to 0.1 from 2011 to 2014. The similar tendency was observed in Listvyanka. However, the ratio decreased insignificantly from 0.7 to 0.39. In Irkutsk, the NO_3^-/SO_4^2- ratio varied within 0.25-0.44. Thus, nitrate effect on the acidity of atmospheric precipitation decreased at the rural site.

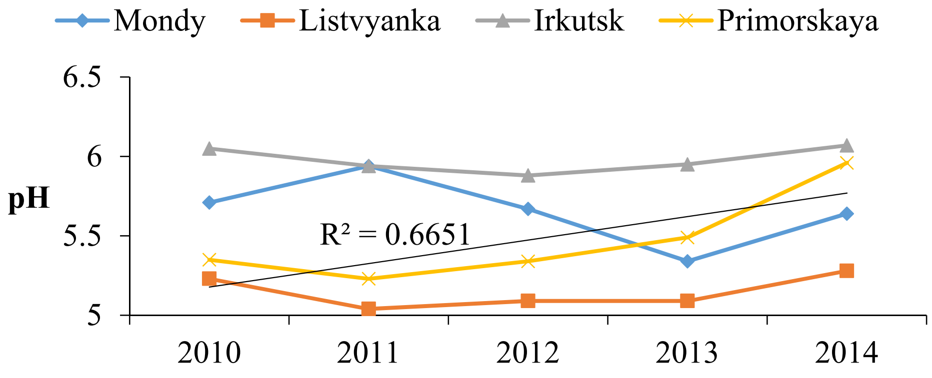

Figure 2.3.8. Inter-annual dynamics of pH values at the EANET monitoring sites

At all sites, acidity values of atmospheric precipitation were higher in cold period (Fig. 2.3.9). In cold and warm seasons of 2010-2014, pH at site Irkutsk was 6.28 and 5.5; at Listvyanka 5.44 and 4.91; at Mondy 5.88 and 5.45, and at Primorskaya 5.6 and 5.38, respectively. The pH values decreased in snow and rain in Irkutsk and Mondy from 2010 to 2013, whereas in Listvyanka and Primorskaya pH values in rain increased, as well as those in snow at site Primorskaya.

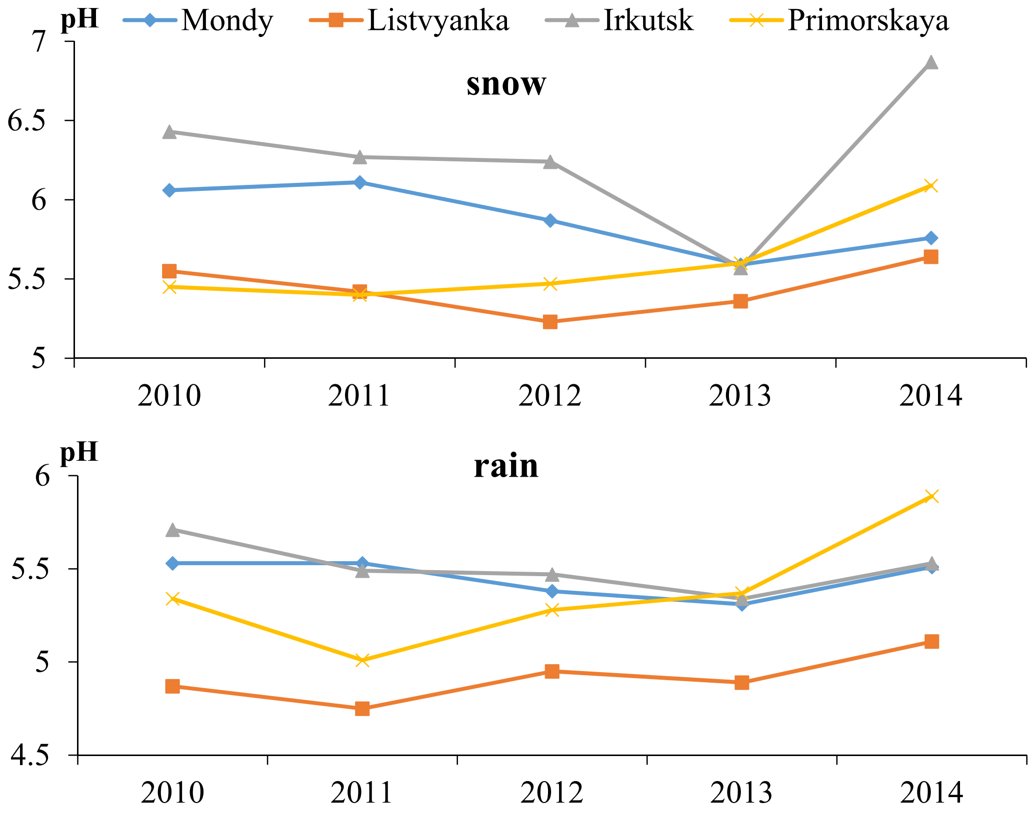

Figure 2.3.9. Inter-annual pH dynamics in atmospheric precipitation in cold and warm periods at the EANET monitoring sites

Minimal acidity of atmospheric precipitation was recorded from November to March and its maximum in summer months (Fig. 2.3.10). The lowest pH values were in Listvyanka in October of 2011 and June of 2012, at site Primorskaya in July of 2011 and April of 2014, and in Irkutsk in September of 2013 (Fig. 2.3.11).

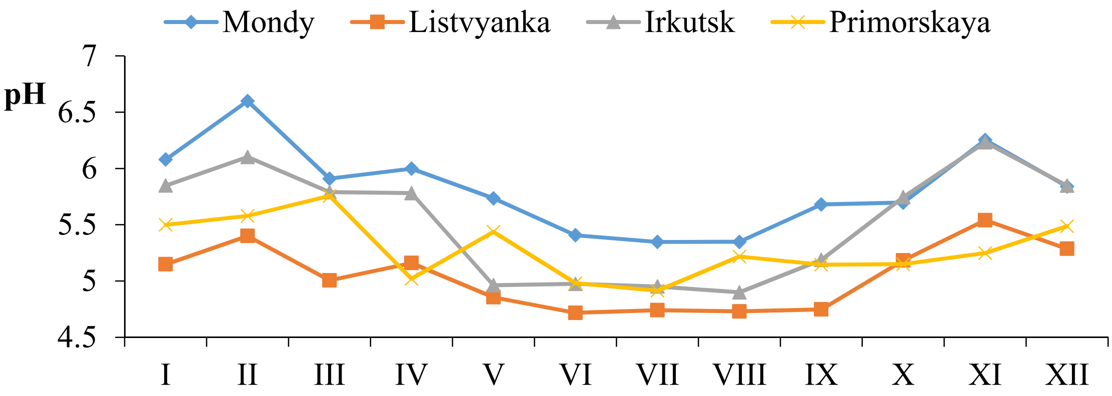

Figure 2.3.10. Inner-annual dynamics of weighted-mean pH values in atmospheric precipitation at the EANET monitoring sites (2010-2014)

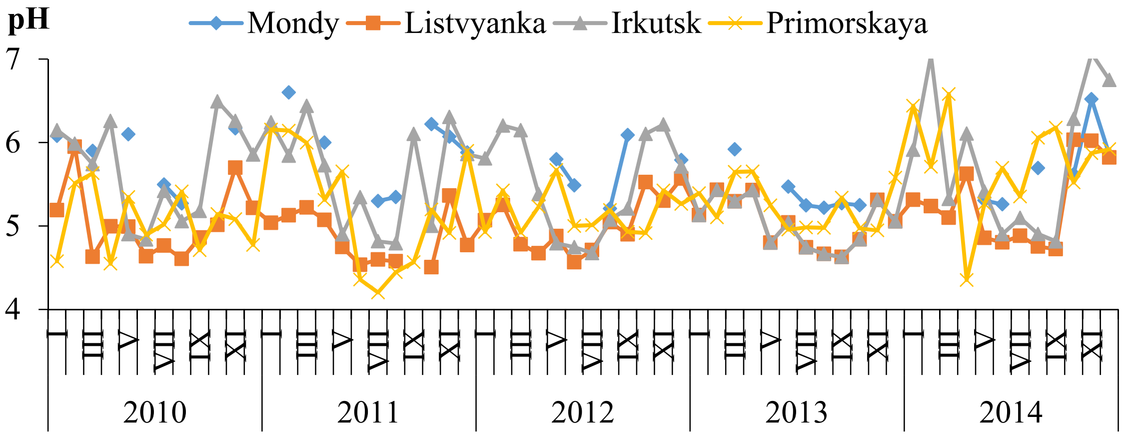

Figure 2.3.11. Inter-annual dynamics of weighted-mean pH values in atmospheric precipitation at the EANET monitoring sites

In 2010-2014, the pH value lower than 5.0 was registered in 47% precipitation in Listvyanka, being 10% lower than the values recorded in 2005-2009. The highest repeatability of such precipitation was in 2011 and the lowest one in 2014 (Fig. 2.3.12). At sites Primorskaya and Irkutsk, acidity of precipitation was 2 and 3 times lower than at site Listvyanka, on average 24 and 14%, respectively. These values were also lower than in 2005-2009. Maximal repeatability of acid precipitation corresponded to that of 2011 and 2012. At sites Listvyanka and Primorskaya, the repeatability of acid precipitation decreased from 2011 to 2014, and at site Irkutsk, the repeatability ranged within 14-17%.

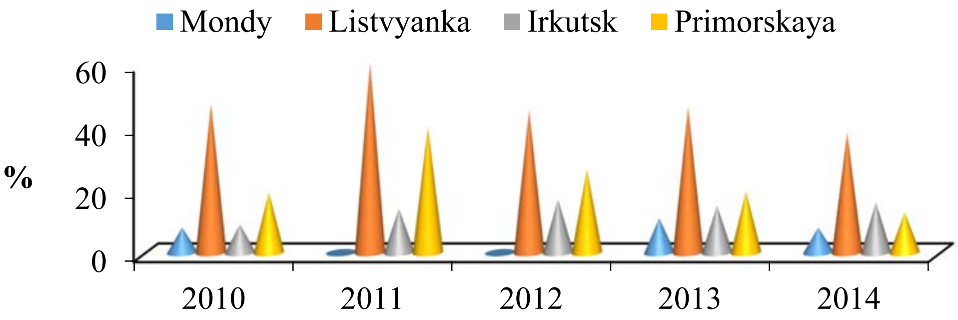

Figure 2.3.12. Inter-annual dynamics of the percentage of precipitation with pH < 5.0 at the EANET monitoring sites

The most common pH values at site Listvyanka were 4.5-5 (on average 35%) with the maximum in 2011. The ranges of pH values of 4-4.5 and 5-5.5 were recorded more often in 2012. At site Primorskaya, in 2010-2014 the most common pH values were 5.5-6 (29%), whereas in 2005-2009 they were 5-5.5 (26%). The pH values of the 5.5-6 range were more often in 2010, and the ranges of 4-4.5 and lower were registered in 2011. Compared to the previous years, in 2014 the pH values increased up to 6-7 (Fig. 2.3.13).

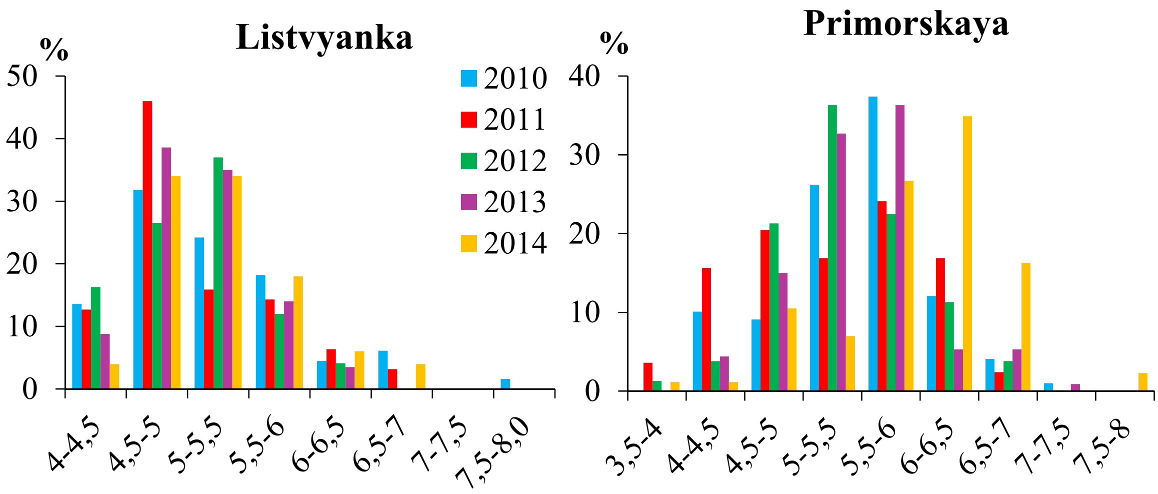

Figure 2.3.13. Repeatability of different pH values in the precipitations at Listvyanka and Primorskaya sites

2.3.2. Wet deposition fluxes

Maximal content of ions, except bicarbonates, deposited with precipitation at site Primorskaya because higher amount of precipitation (Fig. 2.3.2). In comparison with site Irkutsk, wet deposition of ions was approximately 2.2 times higher. Fluxes of all ions, except hydrogen, were from 1.2 (nitrate) to 8.3 (bicarbonate) times higher in the industrial centre than in Listvyanka because of their high concentrations. The lowest content of ions (20 times lower than at site Primorskaya) were at site Mondy, where we recorded low concentrations of ions (Table 2.3.2) and small amount of precipitation (Fig. 2.3.2).

In 2010-2014, the deposition of most ions increased (Table 2.3.3). In the Primorsky Kray, the fluxes of bicarbonate and magnesium increased, in Irkutsk bicarbonate and potassium in Listvyanka. The deposition of other ions decreased in 2014 compared to 2010. Atmospheric precipitation decreased compared to 2010 only at rural sites by 30-50 mm. Therefore, the decrease of wet deposition of ions in Irkutsk was attributed to the decrease of their concentrations (2 times), in Listvyanka due to the decrease of concentrations of most ions (1.5 times) and amount of atmospheric precipitation, and in the Primorsky Kray due to decrease of precipitation and concentrations of some ions by 10-30% (Table 2.3.3).

Table 2.3.3. Wet deposition amounts of ions at the EANET monitoring sites, kg/ha/y

Year	**HCO_3**	**$SO_4^{2-}{}_{nss}$**	**NO_3^-**	**Cl^-**	**Na^+**	**K^+**	**$Ca^{2+}{}_{nss}$**	**Mg^{2+}**	**NH_4^+**	**H^+**	**Sum**
	Irkutsk										
2010	5.9	12.0	5.2	3.2	1.6	0.8	4.9	0.6	2.3	0.03	36.8
2011	5.2	10.8	4.2	2.5	1.3	0.6	4.5	0.6	1.9	0,03	31.8
2012	3.7	16.7	5.2	2.4	1.0	0.9	5,7	0.7	2.8	0.06	39.4

Year	HCO_3	$SO_4^{2-}{}_{nss}$	NO_3^-	Cl^-	Na^+	K^+	$Ca^{2+}{}_{nss}$	Mg^{2+}	NH_4^+	H^+	Sum
2013	4.8	9.6	2.8	1.7	0.8	0.6	3.6	0.4	1.5	0.03	25.9
2014	7.8	8.8	3.0	1.4	0.8	0.5	4.2	0.4	1.7	0.03	28.7
Aver.	**5.5**	**11.6**	**4.1**	**2.3**	**1.1**	**0.7**	**4.6**	**0.5**	**2.1**	**0.04**	**32.5**
	Listvyanka										
2010	0.7	6.4	4.0	0.4	0.3	0.2	1.6	0.2	1.1	0.06	15.0
2011	0.4	7.0	4.1	0.9	0.3	0.2	1.6	0.2	1.1	0.,08	16.0
2012	1.3	7.1	4.2	0.4	0.3	0.3	1.6	0.2	1.7	0.06	17.2
2013	0.2	5.0	2.8	0.6	0.4	0.5	1.3	0.2	0.5	0.04	11.5
2014	0.6	4.6	2.3	0.4	0.3	0.3	1.4	0.2	0.7	0.04	10.9
Aver.	**0.7**	**6.0**	**3.5**	**0.5**	**0.3**	**0.3**	**1.5**	**0.2**	**1.0**	**0.05**	**14.1**
	Mondy										
2010	0.9	0.6	0.4	0.1	0.06	0.09	0.3	0.04	0.3	0.00	2.9
2011	1.0	0.3	0.2	0.1	0.07	0.14	0.3	0.05	0.1	0.00	2.3
2012	2.0	0.7	0.5	0.2	0.10	0.37	0.5	0.10	0.4	0.00	4.9
2013	0.2	1.1	1.0	0.4	0.10	0.30	0.6	0.07	0.2	0.02	4.1
2014	1.4	0.7	0.4	0.2	0.06	0.10	0.4	0.04	0.1	0.01	3.3
Aver.	**1.1**	**0.7**	**0.5**	**0.2**	**0.08**	**0.20**	**0.4**	**0.06**	**0.2**	**0.01**	**3.5**
	Primorskaya										
2010	3.1	20.2	9.2	6.9	3.7	1.5	4.4	0.7	5.1	0.07	55.2
2011	7.2	7.1	14.0	14.6	1.9	1.6	3.3	0.6	5.9	0.15	56.4
2012	2.2	18.0	13.3	9.7	4.9	1.8	4.4	1.0	4.5	0.08	60.0
2013	2.1	19.9	8.3	10.8	4.2	1.6	5.1	0.9	5.1	0.06	58.4
2014	7.3	16.8	2.3	5.1	2.1	1.1	4.3	0.9	4.4	0.02	44.4
Aver.	**4.4**	**16.4**	**9.4**	**9.4**	**3.3**	**1.5**	**4.3**	**0.8**	**5.0**	**0.08**	**54.9**

The comparison of values of wet deposition at two rural monitoring sites showed that at site Primorskaya sulphate and nitrate deposited 2.7 times more, ammonia 5 times and hydrogen ions 1.6 times more than at site Listvyanka, (Fig. 2.3.14).

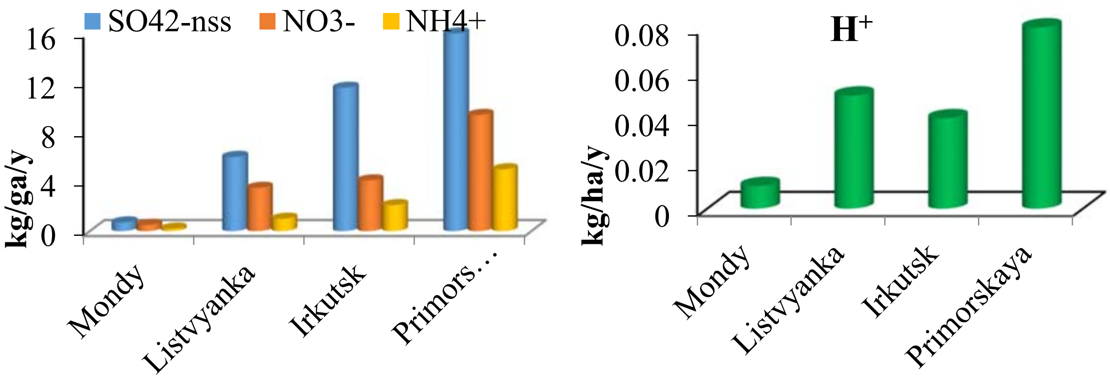

Figure 2.3.14. Wet deposition of ions at the EANET monitoring sites, kg/ha/y (2010-2014)

Maximal deposition of nitrogen compounds and hydrogen ions was recorded at site Primorskaya in 2011, sulphate in 2011 and total ions in 2012. At sites Irkutsk and Listvyanka, maximum of these components were in 2012 (Fig. 2.3.15) because of the extremely large amount of precipitation in that year, almost by 100 mm larger than mean long-term values (Fig. 2.3.2).

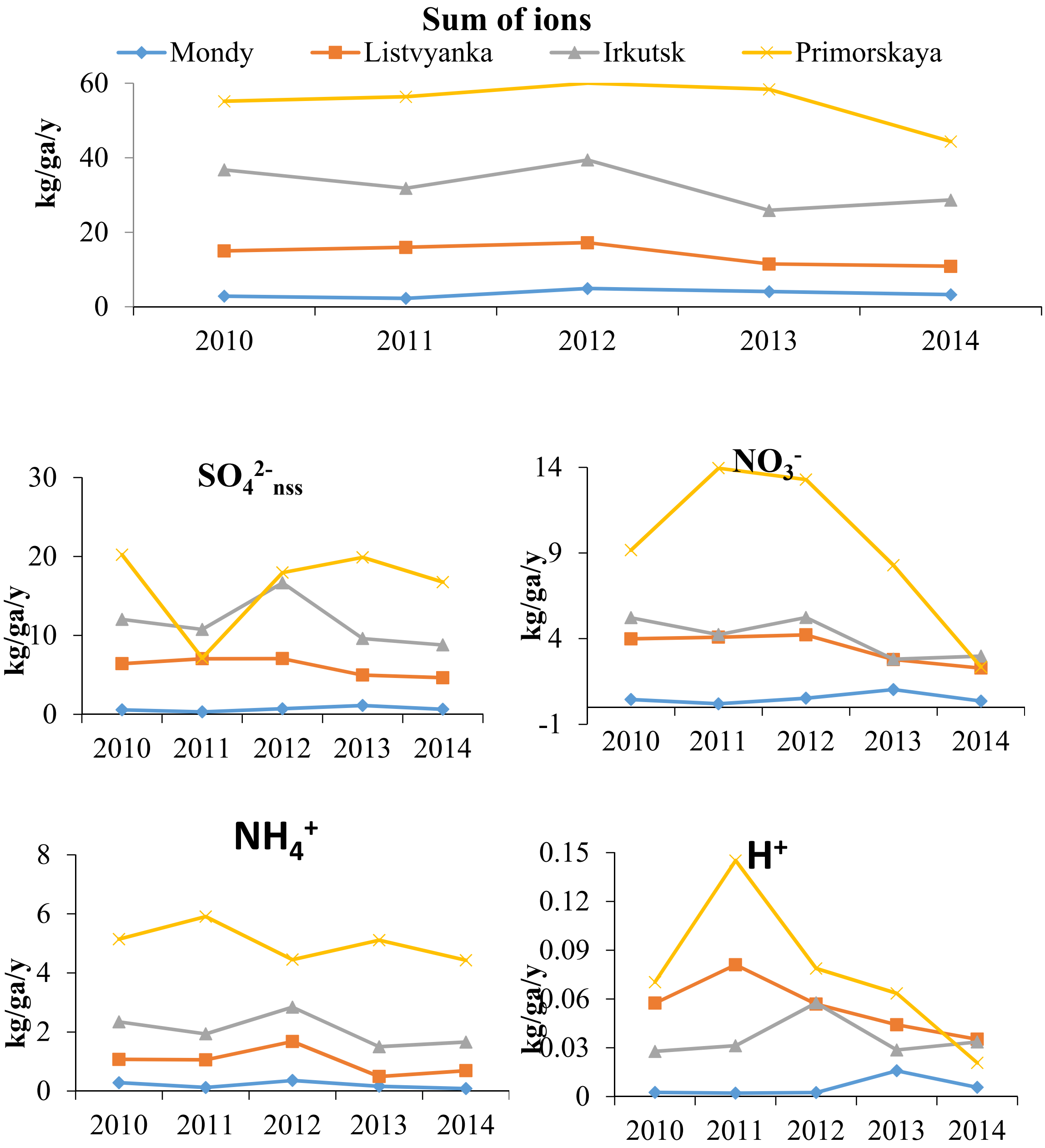

Figure 2.3.15. Inter-annual dynamics of wet deposition of ions (kg/ha/y) and precipitation (mm) at the EANET monitoring sites

3. State of Inland Aquatic environment

3.1. Pereemnaya River

The Pereemnaya River, a tributary of Southern Lake Baikal, was taken as a model object for studying influence of acidified atmospheric precipitations on the chemistry of surface waters. The river originates near Sochor Mount (the northern slope of the Khamar-Daban Ridge) at an altitude of 2,316 m. Its length is 42 km; catchment area is about 360 km^2. The average height of the basin is 1,260 m, slope of the river is 34.9. The Archean rocks represented mainly by gneisses, schists, and pegmatites are developed in the basin. Most of the basin is a part of the taiga soil zone, with the soils characterised mainly by acid pH. The river is fed by atmospheric precipitation. In the area of the Khamar-Daban Ridge and the Pereemnaya River basin, annual amount of precipitation is the highest for the Baikal region: up to 1,060-1,720 mm. The thickness of snow cover may reach 2 m.

Atmospheric monitoring sites and location of aquatic monitoring site (river waters) are presented on Fig. 3.1.1 where the numbers are correspondent to SO_2 emission (in thousand tonnes per year) in the largest cities and towns of the region.

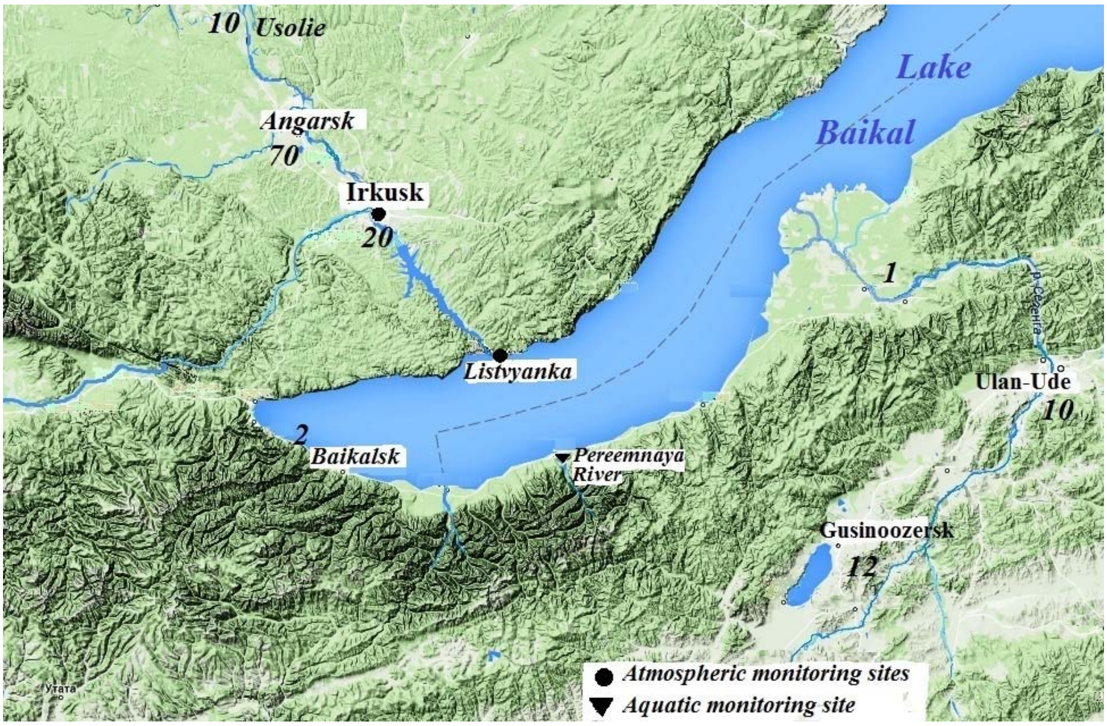

Figure 3.1.1. Scheme of atmospheric monitoring sites: Irkutsk (urban site), Listvyanka (rural site) and Pereemnaya River (aquatic monitoring site)

The main direction of air mass transport in this area is north-western. Therefore, the most complete atmospheric monitoring (including automatic hourly measurements) was performed at site Listvyanka. The main parameters for monitoring are given in Table 8.

We measured equivalent ion ratios (%-eqv) in the snow cover in the Pereemnaya River basin during different years (Table 3.1.1). Nitrate was dominant among anions in the snow water of this area for about 15 years, whilst sulphate dominated in the larger part of the Baikal region. The ratio of equivalent concentrations of nitrate to sulphate also attested to the great contribution of nitrate to the acidification of snow cover in this area (>1). Obviously, H^+ was another major cation in snow waters (Table 3.1.2).

Hence, snow precipitation was dominated by nitrate formed during transport of nitrogen oxides from the regional PPs within the Pereemnaya River basin. Sulphate contributed insignificantly in winter. In summer, however, according to the data obtained from Listvyanka site (Fig. 2.3.14), sulphate deposited was higher than that of nitrate. Based on these results it is possible to conclude that emissions from the Angarsk-Irkutsk industrial complex significantly affected the chemistry of atmospheric precipitation, such as nitrate and sulphate, on the south-eastern coast of Lake Baikal.

Table 3.1.1. Ionic composition of snow water within the Pereemnaya River basin, %-eqv

	HCO_3^-	SO_4^{2-}	NO_3^-	Cl^-	Na^+	K^+	Ca^{2+}	Mg^{2+}	NH_4^+	H^+	NO_3^- $/SO_4^{2-}$
1997	0	20.2	22.6	3.3	5.3	2.0	21.3	6.0	5.1	4.0	1.1
2003	0	22.3	25.5	1.7	3.2	2.2	12.7	2.0	6.4	24.1	1.1
2007	0	20.7	25.7	5.9	4.8	1.5	23.0	3.7	5.4	9.4	1.2
2011	0	15.5	30.7	4.4	6.5	3.2	16.1	3.9	1.7	18.0	2.0
2013	0	18.4	33.4	1.2	2.2	0.7	23.5	4.1	0.9	15.3	1.8
1997-2013	0	20.4	26.8	3.6	5.4	2.4	19.3	4.2	6.9	10.8	1.4

Polluted air masses penetrate to the Pereemnaya River basin along the Angara River valley because of climatic conditions in the region and prevailing north-western transport. The Pereemnaya River is mainly fed by atmospheric precipitation. Therefore, this river has been chosen as a model for investigation of the effect of acid precipitation on chemistry of surface waters (Semenov et al, 2006). Approximately 800 mm precipitation are recorded annually on the lake coast, whereas in the mountains up to 1,500 mm and more. The Pereemnaya River waters possess extremely low buffer capacity Water mineralization varies within a year from 17 mg L^{-1} during flooding to 33 mg L^{-1} during the low-water period. Input and mixing of acid snow waters with mineralized river waters affect the decrease of pH value of the river waters and ionic imbalance especially during snow melting (Sorokovikova et al., 2004). For the past 15 years, the chemistry of the Pereemnaya River waters has changed significantly under the influence of acid precipitation. Sulfate and nitrate concentrations increased in the river water, whilst the content of bicarbonates decreased (Table 3.1.2).

Table 3.1.2. Water chemistry of the Pereemnaya River and Lake Baikal, mg L^{-1}

	HCO_3^-	SO_2^{4-}	NO^{3-}	Cl^-	Na^+	K^+	Ca^{2+}	Mg^{2+}	pH
Baikal (11)									
Year	66.4	5.25±0.45	0.30±0.18	0.44±0.08	3.40±0.30	1.01±0.15	16.6±1,0	3.03±0.18	7.85±0.35
Pereemnaya River (2001)									
Year	8.60±3.72	6.6±3.5	0.94±0.45	0.14±0.13	1.03±0.61	0.72±0.22	2.9±1.0	0.81±0.35	7.05±0.56
Pereemnaya River (2010-2014)									
March	8.48±1.46	13.6±1.6	0.84±0.11	0.19±0.06	1.60±0.34	0.79±0.10	5.5±0.7	0.82±0.17	6.78±0.18
May	7.51±1.10	7.8±1.4	0.77±0.10	0.15±0.08	0.84±0.06	0.55±0.04	4.0±0.1	0.64±0.08	6.71±0.10
July	8.21±0.59	12.3±3.5	0.44±0.13	0.17±0.11	0.99±0.15	0.64±0.14	5.1±1.1	0.90±0.40	6.99±0.23
October	8.88±1.62	12.6±1.7	0.41±0.09	0.19±0.12	1.08±0.08	0.79±0.10	5.4±0.8	0.93±0.18	6.76±0.07
Average	8.27±1.19	11.6±2.1	0.61±0.11	0.17±0.09	1.13±0.16	0.69±0.09	5.0±0.6	0.82±0.21	6.81±0.14

River waters belong to the sulphate class of the calcium group for most of the year. Acid-neutralising capabilities (ANC) estimated in different periods of observations (1950-1960) decreased in the water of the Pereemnaya River from 219 μeqv L^{-1} to 99 μeqv L^{-1} . ANC decreased up to critical values (≥50 μeqv L^{-1}) during snow melting. Changes in chemical composition occurring in the river waters attested to geochemical changes in the catchment basin of this tributary. The situation deteriorated because of widely spread acid soil-forming rocks (gneiss and schist). Acid precipitation was not neutralised under such conditions. This negatively affects the river waters and can cause degradation of forest ecosystems.

At present, concentrations of nitrate and sulphate in the water of the Pereemnaya River are two times higher than those in Lake Baikal. The river has a low water flow and so its waters cannot affect significantly the lake water chemistry. Therefore, acidification of lake waters is not expected in the near future because of its huge buffer capacity. Nevertheless, the increased flux of anthropogenic nitrate can provoke the growth of algae in near-estuary shallow area this lake part.

Eventually, the situation in this region will deteriorate. Emissions will tend to increase (Fig. 3.1.2a), and acidity of atmospheric precipitation will intensify in Southern Baikal (data from Listvyanka site) (Fig. 3.1.2b).

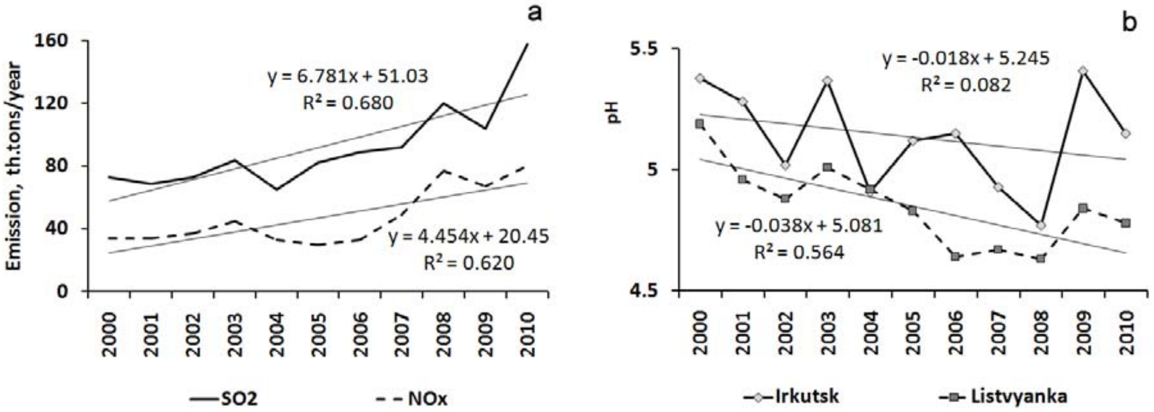

Figure 3.1.2. Long-term trends of total emission of sulphur and nitrogen oxides in the region (a) and pH of precipitation in Irkutsk and Listvyanka (b)

Earlier studies on transport of sulphur and nitrogen oxides in the Baikal region showed that plumes emitted from tall chimneys of large power plants (PPs) could be transported at tens and hundreds of kilometres within the so-called system of "low-level atmospheric jets". Such flows emerged at the upper interface of the boundary atmospheric layer at night and in the morning during inverse thermal stratification. Tall plumes from PPs entering the flows were transported at high speed (approximately 10 m/sec) without scattering because of weak turbulence. Anthropogenic atmospheric emissions from tall sources of Irkutsk and Angarsk were transported by NW winds towards Southern Baikal and deposited there.

Wet depositions of sulphur and nitrogen compounds were registered monthly at monitoring sites Irkutsk and Listvyanka (Fig. 3.1.3). The amount of wet sulphate depositions decreased during their transport from the sources (Irkutsk) to Lake Baikal (Listvyanka) throughout the year (Fig. 3.1.3a). Nitrate behaved in another way: its deposition was, on the contrary, two times higher from December to February in Listvyanka (Lake Baikal) than in Irkutsk.

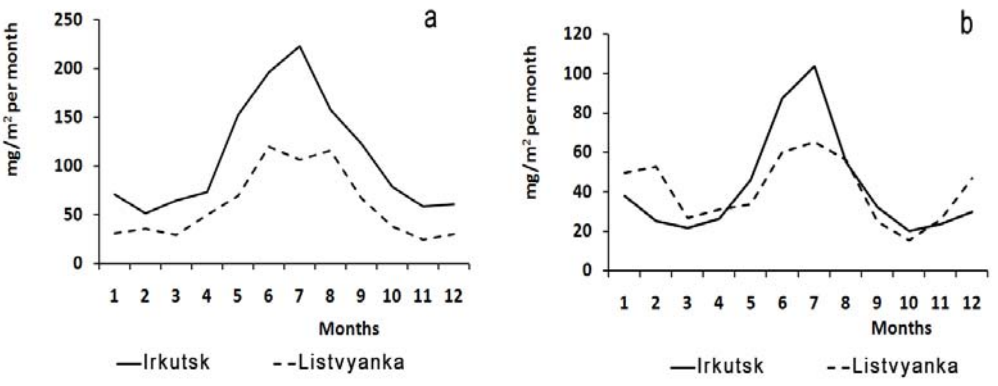

Figure 3.1.3. Wet depositions of sulphate and nitrate at monitoring sites Irkutsk and Listvyanka

According to the data of automatic measurements of NO_x and O_3 concentrations (Fig. 3.1.4), nitrogen oxides after their emissions from the PP chimneys were oxidised by ozone, sometimes causing complete deficit of the latter at site Listvyanka, i.e. in 2-4 hours after emission. The relationship between the content of ozone and nitrogen oxides in the atmospheric air was strong and almost linear (scatter plot in Fig 3.1.4). Thus, transformation of primary gases (NO and NO_2) into nitrate occurred during transport within the PP plumes and caused an increase of nitrate content in the atmosphere and atmospheric precipitation.

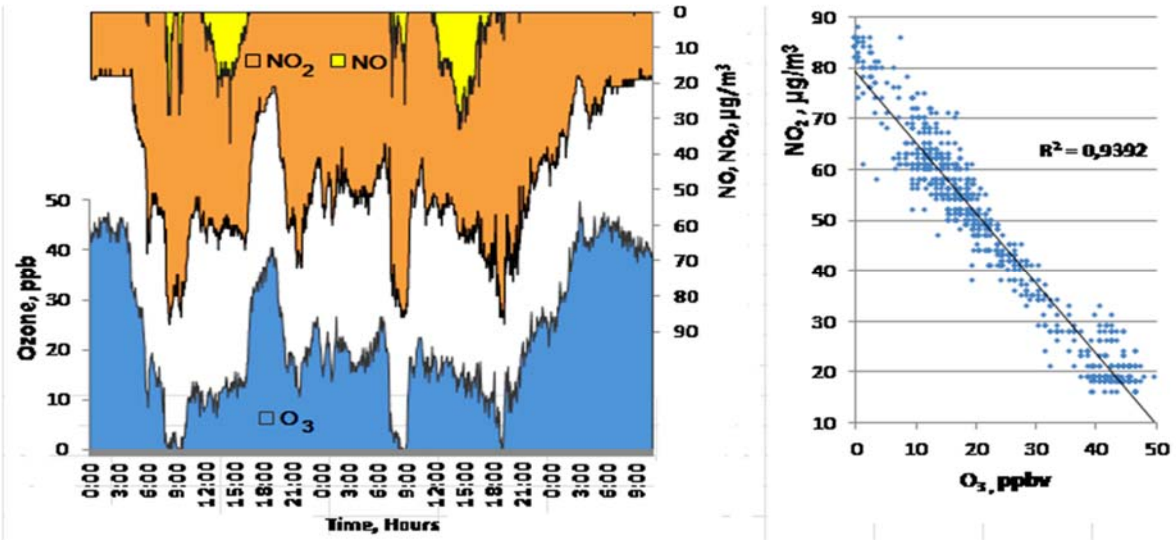

Figure 3.1.4. A fragment of synchronous registration of nitrogen oxides and ozone (left picture) and scatter plot of NO_2/O_3 (right) during plume transport from PPs above Listvyanka site (23-25 December, 2012)

The reaction of ozone with nitrogen oxides is an order of magnitude faster than with sulphur oxides. Therefore, the reaction of ozone with SO_2 was complicated because of a probable ozone deficit. In winter, low temperatures and absence of water drops also slowed down this reaction. Therefore, sulphur dioxide was not transformed into sulphate in winter during its transport towards Lake Baikal, although in summer this transformation was possible in cloud drops and on foggy days. This is more vividly shown in the spatial distribution of ionic composition in snow cover (Fig. 3.1.5).

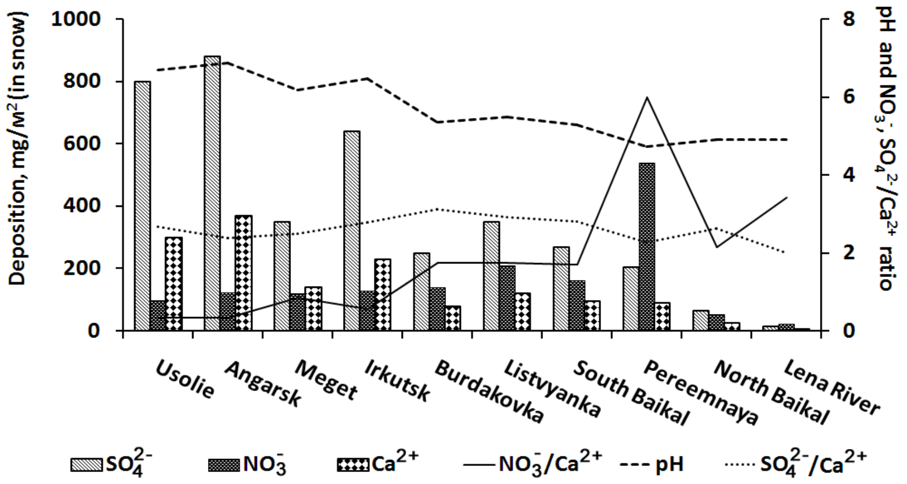

Figure 3.1.5. Accumulation of major ions in snow cover along the transect Angarsk-Irkutsk-Southern Baikal, mg m^{-2}, winter of 2012-2013

Accumulation of sulphate in snow cover was maximal around cities-sources with pH values close to the alkaline ones (>6). The concentrations of sulphate and major cations decreased at a distance from the pollution source towards Lake Baikal , whereas the nitrate content increased, reaching its maximum on the eastern shore of the lake. This was probably due to the additional formation of nitrate from anthropogenic NO_x during its transport from the sources (Angarsk and Irkutsk). Despite the decrease of total contamination of the snow cover, its acidity increased with its maximum (pH=4.7) in the Pereemnaya River basin (south-eastern coast of Lake Baikal). The nitrate/calcium ratio increased manifold (a solid curve in Fig. 3.1.5), whereas the sulphate/calcium ratio remained relatively stable (2.3-2.5, dotted curve), corresponding to $CaSO_4$. No additional sulphates formed from SO_2 during winter transport of pollutants.

Nitrate was likely to be balanced by hydrogen ion (there were no sources of other cations above the lake). Nitric acid caused a gradual rise of acidity in the snow water at a distance from the sources towards Southern Baikal. The analysis of pH spatial distribution in the snow cover in this area (Fig. 3.1.6) showed that maximal acidification of the snow cover (pH <4.7) caused by nitrate deposition was registered in the basin of the Pereemnaya River.

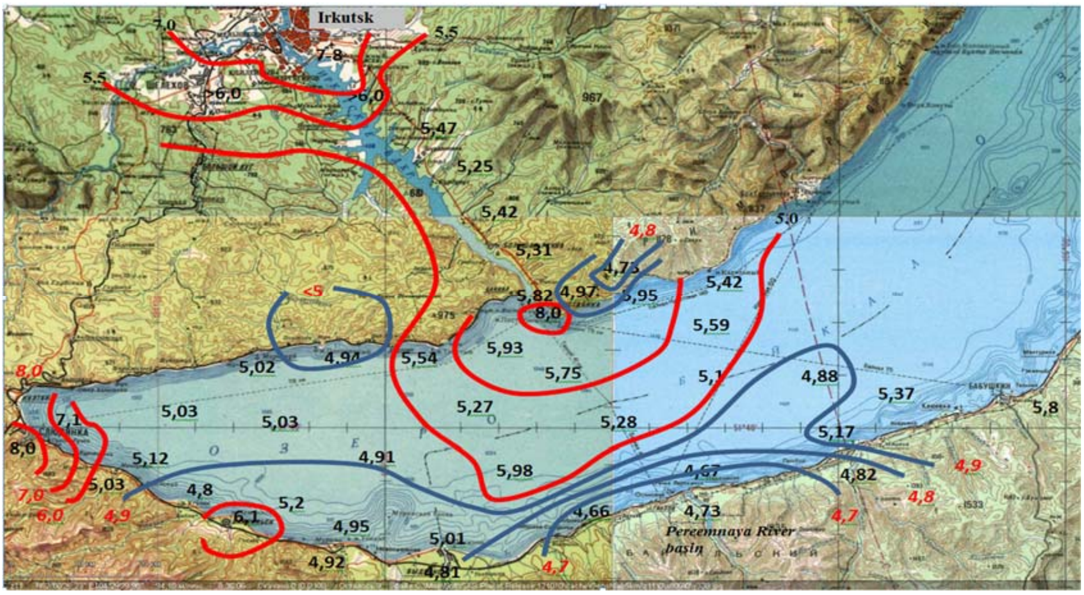

Figure 3.1.6. Spatial distribution of pH in snow cover, Southern Pribaikalye

Unlike the case of nitrate, there was no additional formation of sulphate from SO_2 during atmospheric transport in winter. The maximum level of sulphate was recorded near the sources, whereas at a distance from the pollution sources its content decreased rapidly (Fig 3.1.5). The sulphate/calcium ratio (calcium is the main neutraliser of potential acids) was almost unchangeable, varying from 2.3 to 2.9 and being close to that of gypsum ($CaSO_4$) which precipitated mainly near the sources. Their smallest amount dispersed along the transport transect as gypsum aerosols. They were not involved in acidification of snow cover.

The pH value of the Pereemnaya River water varied between 6.56 and 7.21 from 2010 to 2014 (Fig. 3.1.7). Elevated values were recorded in the summer of 2010 and the lowest values in the summer of 2012. The decrease of pH in summer during maximal algal vegetation and CO_2 consumption attested to floods at that period and input of acid atmospheric precipitation into the river flow. The pH value of the snow waters in the Pereemnaya River basin was 4.6-4.8. The ratio of equivalent concentrations of cations (K= (Ca^{2+} + Mg^{2+} + NH_{4+} + Na^{+})) and anions (A= (SO_4^{2-} + NO_{3-}) decreased in snow waters for the period of observations from 0.9 to 0.7, attesting to their acidification.

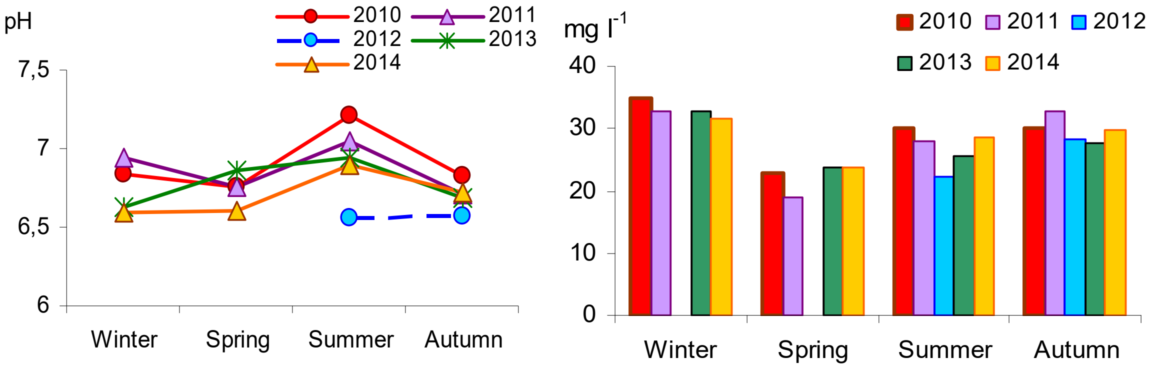

Figure 3.1.7. The Seasonal fluctuations of pH and total ions in water of the Pereemnaya River, 2010-2014

The waters of the Pereemnaya River are well-aerated. The concentrations of dissolved oxygen varied insignificantly (9.1-12.5 mg/l) during the period of observations. Its maximal concentrations were recorded in late autumn due to elevated level of its solubility in water at temperature decrease. Moreover, elevated concentrations were registered in winter because of scours formed in the ice, thus favouring water aeration.

In 2010-2014, total ions changed from 18 to 34 mg/l in the Pereemnaya River water. Elevated concentrations of major ions were recorded in winter (Fig. 3.1.7). The lowest ion concentrations were observed during floods when snow waters of low mineralisation entered the river flow. After spring minimum, concentrations of major ions and their total amount in the river water gradually increased. During long-term investigations, mineralisation level of the water increased. In 2005, maximal value of ions was 25.3 mg L^{-1}, whereas in 2010-2014 maximal values were 31-32 mg L^{-1}. High concentration of ions may be attributed to low water level in this period and to intensification of denudation processes caused by acidification of pore waters.

Inter-annual variability of concentrations of major ions and their total amount is unchangeable and mainly depends on changes of water level. In 2010-2014, sulphate concentrations ranged between 6.4-15.9 mg L^{-1}. Their maximum was recorded in the summer of 2010 (Fig. 3.1.7). In the pre-industrial period, HCO_{3-} and Ca^{2+} were the major components in the Pereemnaya River water (Votintsev et al., 1965; Votintsev and Khodzher, 1998).

However, the input of acid atmospheric precipitation into the river caused the rise of sulphate concentrations (Fig. 3.1.8) and changes of the relative composition of major ions in the river waters.

In recent years, the relative composition of major ions in the river waters corresponds mainly to the sulphate class of the calcium group. Earlier, the transition from the bicarbonate class to the sulphate one was recorded sporadically (Sorokovikova et al., 2004).

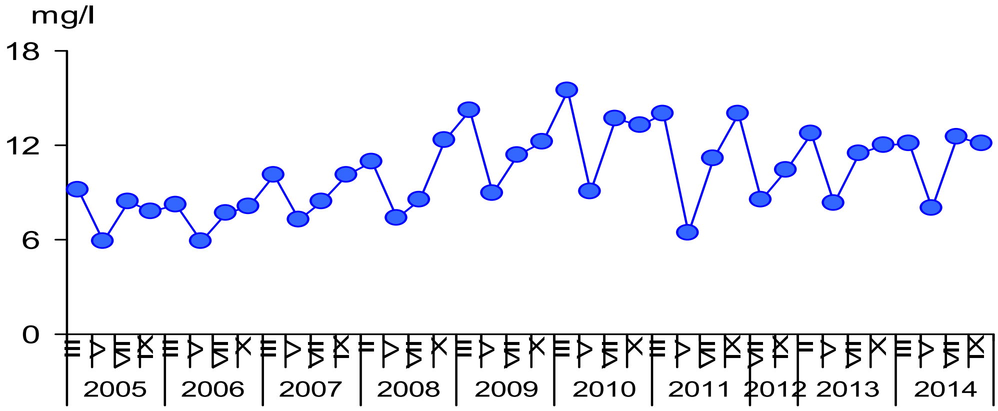

Figure 3.1.8. Changes of sulphate concentrations in the Pereemnaya River water

The index of acid-neutralising capabilities (ANC) of the water calculated during different periods of observations shows that beginning from the 1950-2060s, ANC decreased from 219 µeqv L^{-1} to 99 µeqv L^{-1}, whereas during snow melting the index decreased to critical values (≥ 50 µeqv L^{-1}), demonstrating sharp development of “pH shock”. Changes of chemical composition of river waters attested to changes of the geochemical situation in the Pereemnaya River watershed. The situation deteriorates as acid soil-forming rocks are widely spread in the river basin. Therefore, acid precipitation was not neutralised, thus affecting unfavourably the river waters.

Seasonal dynamics of nutrient concentrations registered in 2010-2014 was similar to that recorded in the previous years. Minimal concentrations of nitrate nitrogen were recorded in summer, which attested to its consumption by plankton. In autumn, NO_3^- concentrations gradually increased in the water (Fig. 3.1.9), reaching its maximum in winter.

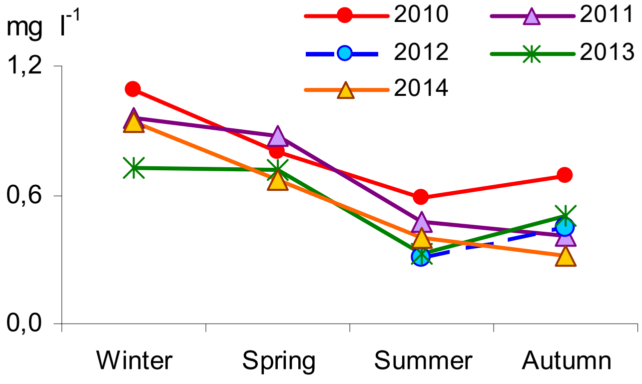

Figure 3.1.9. Seasonal fluctuations of nitrate nitrogen (mg L^{-1}) in water of the Pereemnaya River, 2010-2014

Dynamics of concentrations of both mineral and organic phosphorus varies significantly seasonally and annually. Concentrations of mineral phosphorus were minimal in spring of 2010-2011 (Fig. 3.1.10), whereas they increased to maximum in 2014 while hydrological conditions were the same.

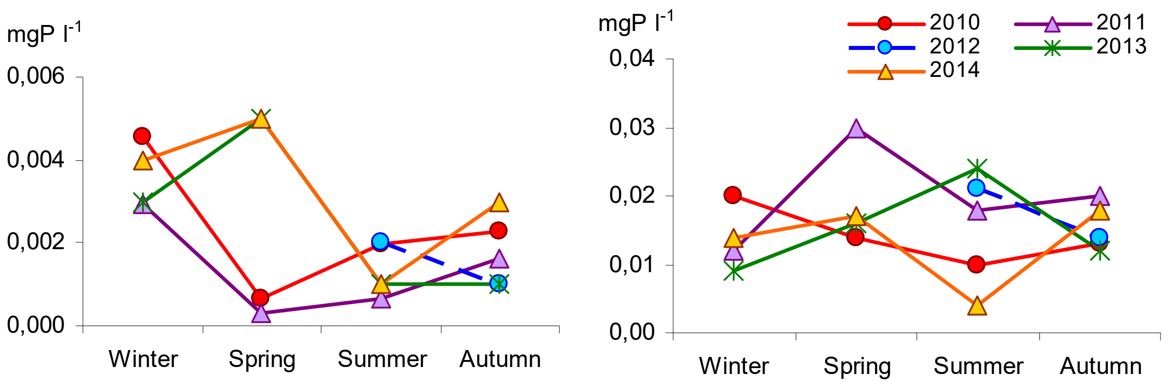

Figure 3.1.10. Seasonal fluctuations of mineral (left) and organic (right) phosphorus in the Pereemnaya River water, 2010-2014

The content of organic carbon varied from 0.42 to 1.80 mg C/l. Their lowest concentrations were recorded in winter (Fig. 3.1.11), when there was no input of organic matter into the watershed.

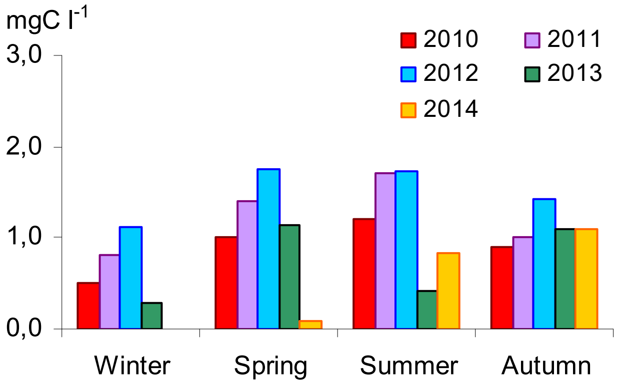

Figure 3.1.11. Seasonal fluctuations of the organic matter in the Pereemnaya River water, 2010-2014

3.2. The Komarovka River

The Komarovka River, a mountain river, was as a model object for studying the influence of atmospheric precipitation on the chemistry of surface waters in the Primorsky region. The river originates in spurs of the Sikhote-Alin Ridge at an altitude of 380 m above sea level. The river, which is a left tributary of the Razdolnaya River, belongs to the Japanese Sea basin. Its length is about 66 km. Mean annual water discharge varies 0.66 m^3/s to 3.79 m^3/s, averaging 1.55 m^3/s. The observation site is located at the hydrological post “Tsentralny” within the area of site Primorskaya, 34 km far from the city of Ussuriysk and 44 km from the river mouth.

There are no stationary pollution sources of the river flow at the observation site. The river is likely polluted by rain flow from the watershed and by snow waters. Hydrochemical observations at the river have been performed since 2005. In 2010-2014, like in previous years, the studies were carried out in February, April, June, September, and November, thus recording changes of chemical composition of the river waters during different hydrological periods and different years.

The water temperature in the river changed from 0.1°C to 18.0°C with its maximum recorded in June. The warmest month was June in 2011 and 2013, whereas in 2012, the temperature was only

13°C. The water in the river is mild and low mineralised. Its mineralisation varied within narrow ranges of 44.1-67.7 mg L^{-1} throughout the year (Fig. 3.2.1). It should be noted that mineralisation was significantly lower in the river in 2005-2009 varying from 34.4 to 46.6 mg L^{-1} depending on the water level.

Elevated values of conductivity and total ions and concentrations of major ions were recorded mainly in winter and autumn at the low water level in the river (Figs. 3.2.1-3.2.2). The rise of water level during flooding in 2010 and the autumn flood in 2012 caused the decrease of ion concentrations and conductivity. The lowest values of these components were registered in 2010 due to the increased water level in the river.

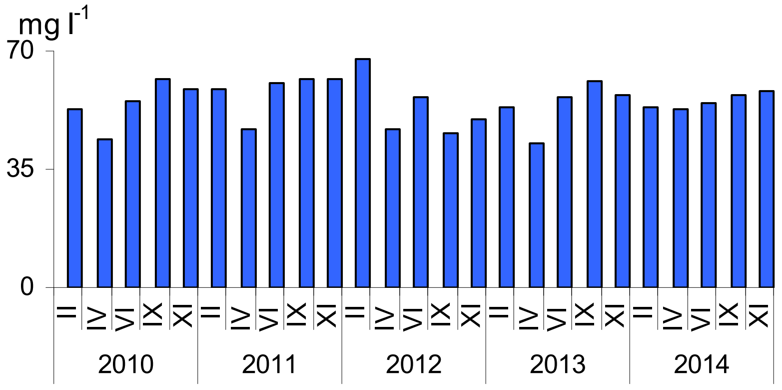

Figure 3.2.1. Seasonal and inter-annual dynamics of total ions in the Komarovka River water, 2010-2014

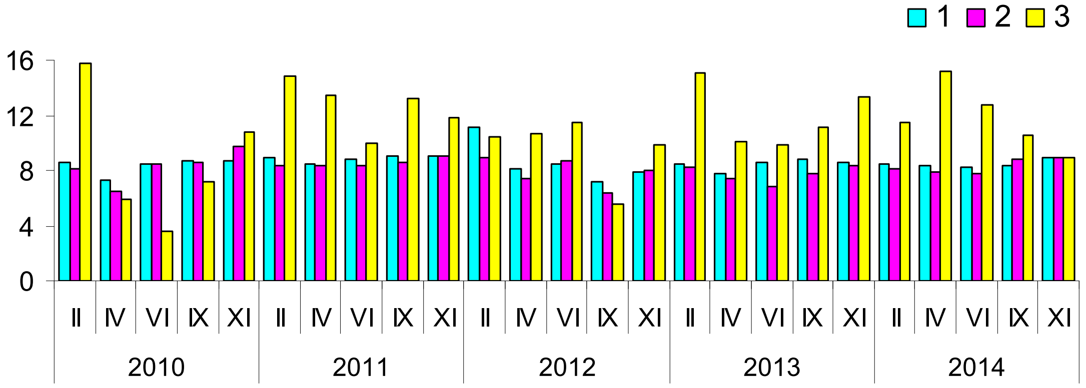

Figure 3.2.2. Variations of conductivity (1, mS/m), content of calcium ions (2, mg L^{-1}), and sulphate (3, mg L^{-1}) in the Komarovka River water

In 2010-2014, chloride concentrations in the water varied from 2.8 to 5.1 mg L^{-1}. The river water level affects their concentration changes insignificantly. The sodium content ranged from 2.1 to 5.3 mg L^{-1}, potassium from 0.3 to 1.1 mg L^{-1}, and magnesium from 1.5 to 3.3 mg L^{-1}. The results obtained showed that throughout the year and within the year the content of chloride, sodium, potassium, and magnesium changed insignificantly. No regular patterns were observed in dynamics of their concentrations.

Concentrations of mineral phosphorus in waters varied from 0.005 to 0.022 mg P/L. The lowest values were recorded in June, which may be caused by phytoplankton consumption. However, there was no expressed seasonal dynamics of mineral phosphorus concentrations. Phosphate concentrations remained stable (0.005 mg P/l) during all seasons of 2013-2014 (Fig. 3.2.3).

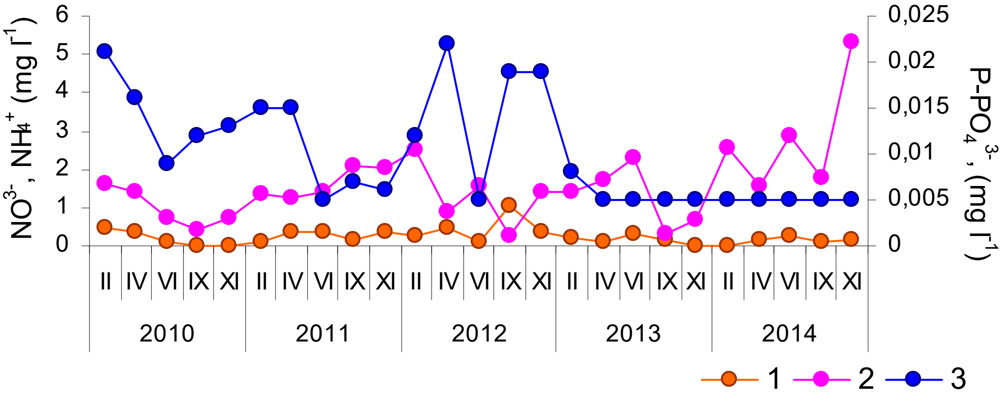

Figure 3.2.3. Variations of ammonia nitrogen (1), nitrate (2) and mineral phosphorus (3) in the Komarovka River water, 2010-2014

The content of nitrate nitrogen in the river water varied from 0.27 to 2.53 mg NO_3^- L^{-1}. Its decrease was recorded in summer-autumn months except November of 2014 (5.31 mg NO_3^- L^{-1}). Elevated concentrations of nitrite nitrogen (0.026-0.059 mg NO_2^- L^{-1}) were recorded throughout the whole year. Concentrations of ammonia nitrogen ranged between 0.02 and 1.04 mg NH_4^+ L^{-1}. There were no regular patterns in seasonal and inter-annual dynamics of its concentrations. The content of silicon amounted to 3.0-8.3 mg L^{-1} without any certain seasonal dynamics of its concentrations. For example, its lowest values (3.0 and 4.4 mg L^{-1}) were registered in November of 2010 and 2013, and 4.0, 3.4 and 5.2 mg L^{-1} in April of 2011, 2012 and 2014, respectively. Inter-annual dynamics of elevated concentrations varied in June of 2010 (5.7 mg L^{-1}), in November of 2011 (5.9 mg L^{-1}), in September of 2012 and 2014 (6.7 and 7.5 mg L^{-1}), and in April of 2013 (8.3 mg L^{-1}).

The pH values in the Komarovka River water ranged from 6.60 to 7.36, the lowest values being in April of 2010 and highest values in April of 2013. The river waters were enriched with dissolved oxygen (8.1-14.5 mg L^{-1}). Its low concentrations were recorded in June and elevated content in February and April.

Permanganate oxidation (PO) varied from 1.8 to 8.7 mg O/l (Fig. 3.2.4). Its lowest values were recorded in autumn-winter periods. The rise of PO was registered during floods or summer-autumn high water, which was associated with the input of organic matter from the watershed.

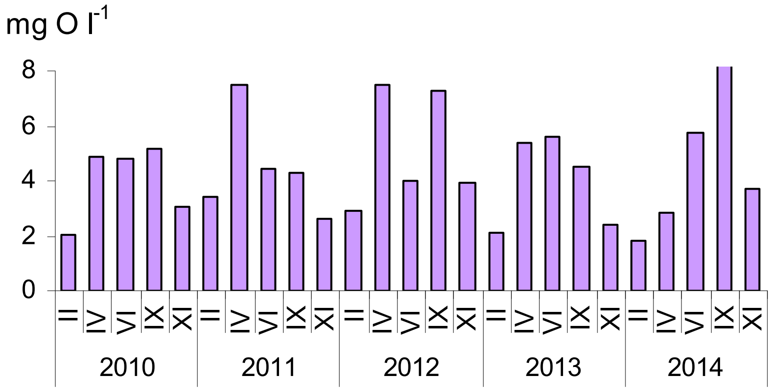

Figure 3.2.4. Chemical oxygen demand for permanganate oxidation in the Komarovka River water, 2010-2014

Thus, the investigations performed showed that seasonal and inter-annual variations of concentrations of major ions and water mineralisation in the Komarovka River water ranged within narrow values in 2010-2014. The content and relative composition of major ions in the water were rather stable. Elevated concentrations of nitrite and nitrate nitrogen were registered in the river waters. The waters were enriched with dissolved oxygen, and its concentrations during the period of observations did not decrease below 8.1 mg L^{-1}.

3.3. Trends in surface water concentrations

Based on the long-term inland aquatic monitoring data at two EANET ecological sites the trends of several measured parameters were evaluated with the use of specific methodology and software developed by EMEP MSC-East (MSC-East, 2015, Hirsch et al., 1982). This methodology was developed for the data with evident periodic (for example, seasonal) variations and selected for application to surface water chemistry data at EANET sites for the period 2007-2014.

The mentioned approaching methodology uses the observing facts that the dynamics of natural surface water concentrations can be decomposed to the three components. Two of them could be described by certain formulas: the general decrease/increase of concentrations during the whole period (main component) is approximated by sum of exponential items, but the second one prescribes the strong periodic seasonal variations by combination of periodic function items with changing amplitudes. The last component is the variability of temporal data set which is not described by the two components above but reproduces a perturbation of these two tendencies by variations of measurements (residues).

For practical application the changes of main component are supposed to be determined as temporal trend and presented by the parameters of its *total reduction* (for whole data set periods)

$$R_{\text{tot}} = (C_{\text{beg}} - C_{\text{end}}) / C_{\text{beg}} = 1 - C_{\text{end}} / C_{\text{beg}}, \qquad (1),$$

and its *maximum* (R_{max}) and *minimum* (R_{min}) values of all annual reductions as well as *average annual reduction* (of geometric mean of them for all years)

$$R_{\text{av}} = 1 - (\Pi_i\, C_i/C_{i-1})^{1/(N-1)} = 1 - (C_{\text{end}} / C_{\text{beg}})^{1/(N-1)} \qquad (2).$$

The amplitude of seasonal component is evaluated as mean normalized value to the main component for respective year to obtain the relative contribution of this component to common trend values. The general characteristics to quantify changes of trend main component through all years due to seasonal variations might be presented by an average of these amplitudes over whole period, and its value of over 0.1 is defined as an essential importance of seasonal component:

$$F_{\text{seas}} = (1/N)\ \Sigma\ ((\max(C_{\text{seas},\,i} / C_{\text{main},\,i}) - \min(C_{\text{seas},\,i} / C_{\text{main},\,i}))/ 2),\ \ i=1\ldots N \qquad (3).$$

The general results of trend estimation for major anions and cations in inland aquatic environment at EANET sites are presented in Table 3.3.1. Note that reduction was calculated in relative unit (decimal part of measured value) with relation to concentration at the beginning of estimated period (see Equation (1)). This means that decreasing trend is demonstrated in Table 3.3.1 by positive value while increasing one is negative.

Acidity of water is the well-known characteristic of inland aquatic environment measured widely (and routine) by all hydrochemical networks, usually as *in-situ* operation. The acidification of environmental systems may be disclosed in the first approach with changes of pH to be driven to more acidic zone (less than 7 for surface fresh waters or lower 5.6 in rain waters).

Table 3.3.1. Trends of major chemical ions in surface stream water at EANET ecological sites

	Reduction for the period 2007-2014				
Measured Ion	Total R_{tot}	Annual average R_{av}	Annual maximum R_{max}	Annual minimum R_{min}	Mean seasonal variations F_{seas}
Komarovka river (Far East region)					
Ca	0.0058	0.0007	0.0007	0.0007	0.074
Mg	-0.109	-0.013	0.047	-0.044	0.118
NH4	-0.735	-0.072	-0.072	-0.072	0.437
NO3	-1.21	-0.105	-0.105	-0.105	0.403
pH	0.032	0.0041	0.0046	0.0036	0.023
SO4	-0.0071	-0.0009	0.011	-0.014	0.139
Pereemnaya river (Baikal Lake area)					
Ca	-0.0204	-0.0026	-0.0026	-0.0026	0.263
Mg	0.309	0.046	0.046	0.046	0.256
NH4	0.900	0.252	0.830	0.051	1.33
NO3	0.629	0.118	0.119	0.117	0.462
pH	-0.0054	-0.0007	-0.0007	-0.0007	0.028
SO4	-0.177	-0.021	-0.021	-0.021	0.236

The multiyear inner-annual fluctuation of water pH of Pereemnaya river is within 6.5-7.2 while one of Komarovka is 6.6-7.6. The results of comparative analysis demonstrate the most evident decreasing trend of pH in the water of Komarovka river (Far East region) for the last 8 years: total decreasing of trend main component was more than 3%, with average annual reduction of 0.4%. The mean seasonal variation is less than 10% of trend main component, hence the estimated value of decreasing pH (or increasing of acidity) with 0.23 pH for whole period is supposed to be reasonable conclusion (Fig. 3.3.1).

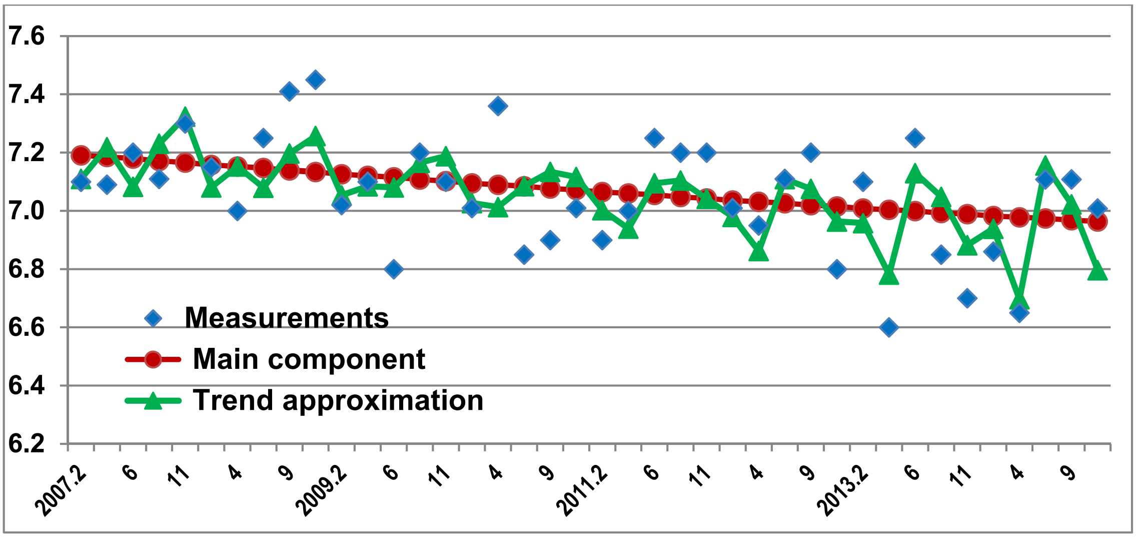

Figure 3.3.1. Estimated trend of pH in surface water at EANET site Komarovka (Far East).

The nitrogen compounds (e.g., nitrate and ammonium) had the increasing trends for the same period at Komarovka river: total growths of their concentrations were estimated of 120% and 73% correspondently, or for 1 mg/l and 0.1 mg/l (Fig. 3.3.2 and 3.3.3). The calculation for other ions provided much weaker tendencies of increasing (sulfate, magnesium) or decreasing (calcium) with no particular significance.

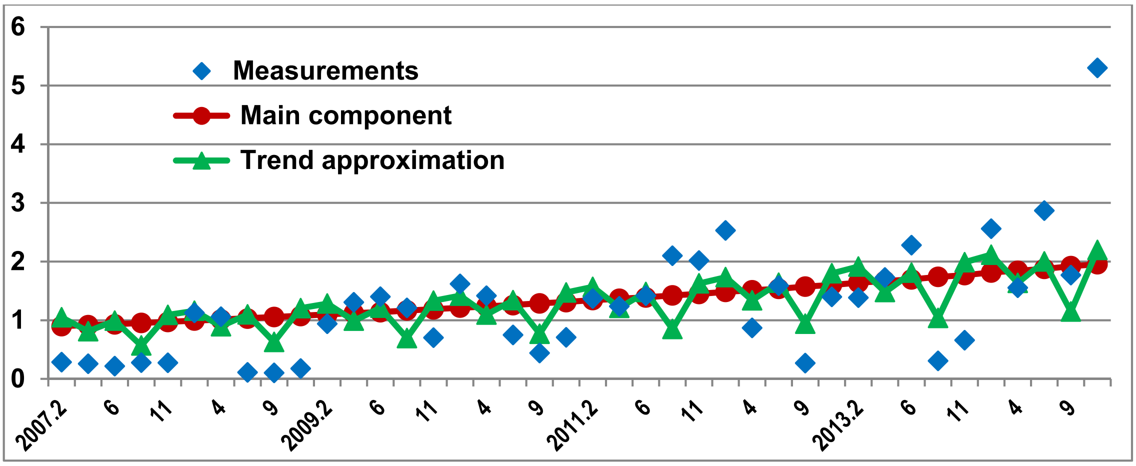

Figure 3.3.2. Estimated trend of nitrate in surface water at EANET site Komarovka (in mg/l)

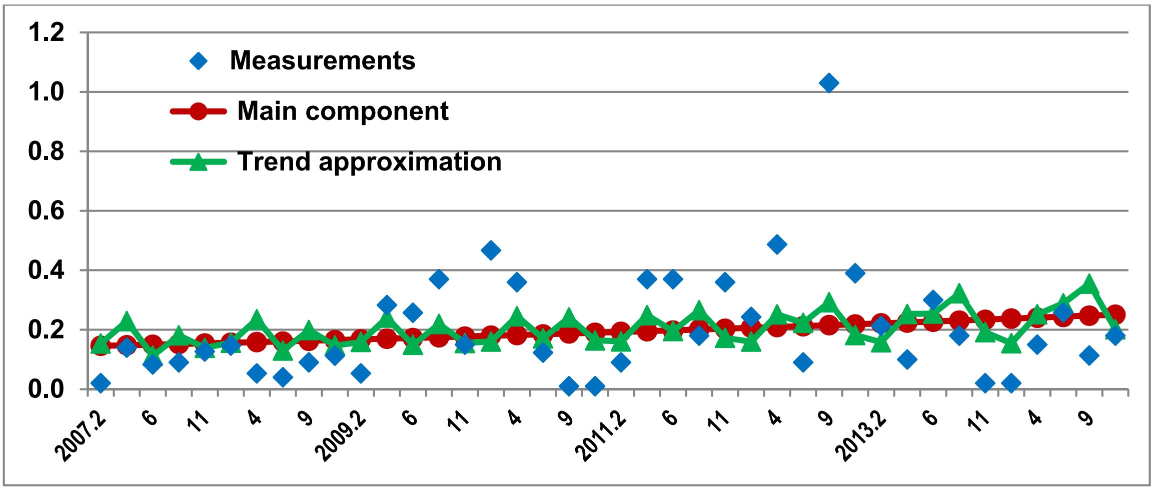

Figure 3.3.3. Estimated trend of ammonium in surface water at EANET site Komarovka (in mg/l)

The stream water of small river Pereemnaya in Baikal Lake area has evident regular trends of major anions (sulfate and nitrate) of different directions. The sulfate content is quite higher than of other compounds being in the range of 6 to 16 mg/l, so its estimated growth of about 2% per year in average seems to affect more efficiently on water chemical state among others (Fig 3.3.4).

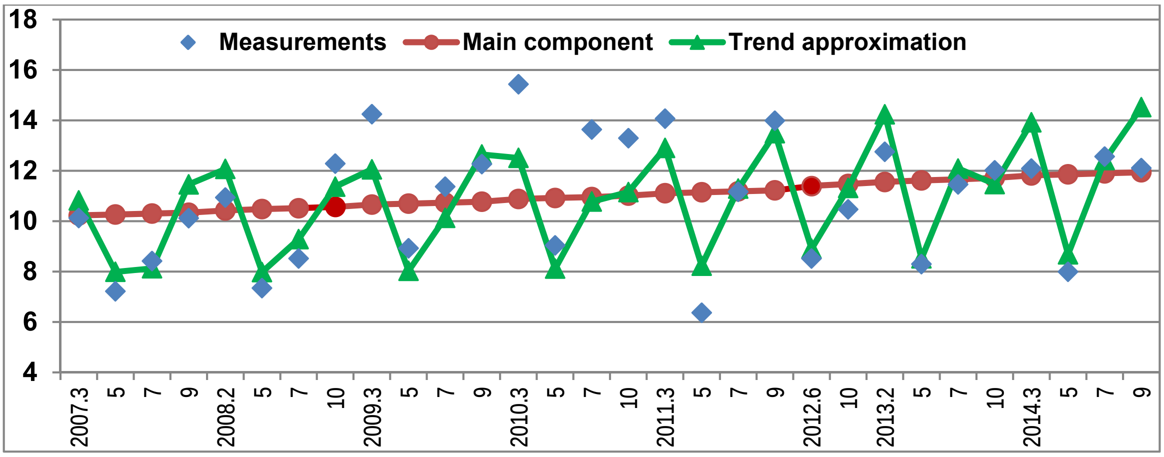

Figure 3.3.4. Estimated trend of sulfate in surface water at EANET site Pereemnaya (in mg/l)

The nitrate ion concentration had decreased in Pereemnaya river waters for 63% for whole period to the lowest values of 0.3 mg/l in summer (Fig. 3.3.5). In spite of decreasing trend of ammonium was calculated even larger than of nitrate, it was caused by the sharp changes during the first year of observations with following sustainable level of low concentrations through other years.

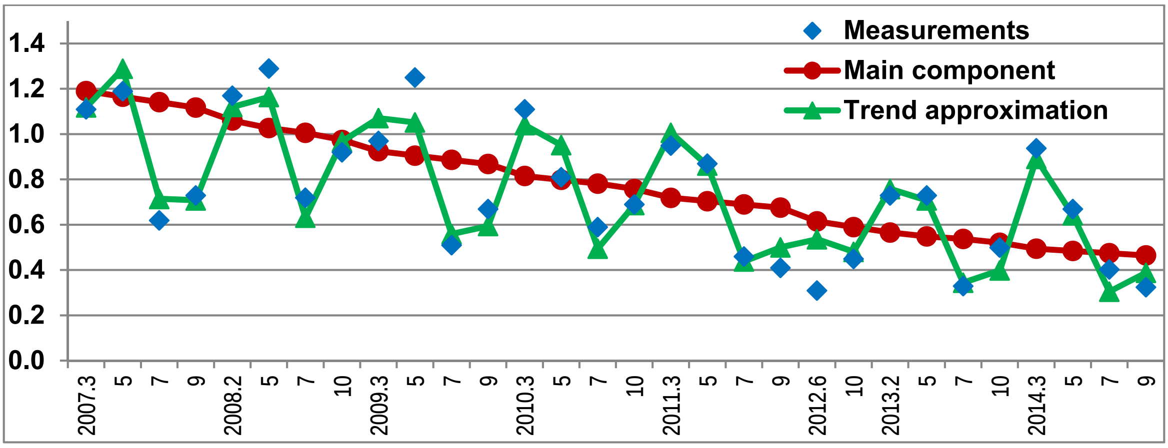

Figure 3.3.5. Estimated trend of nitrate in surface water at EANET site Pereemnaya (in *mg/l*)

The decreasing of Mg in stream water was in steps at the middle of whole period (between 2010 and 2011), and its trend is not monotonous like for nitrate. And because Ca plays the major role in ion balance of Pereemnaya stream water, the pH has to follow its content demonstrating no trend in 2007-2014.

The total estimated changes are also presented in Figure 3.3.6 in per cent being accompanied with estimated average annual reductions (negative values) or growths (positive) for last 8 years.

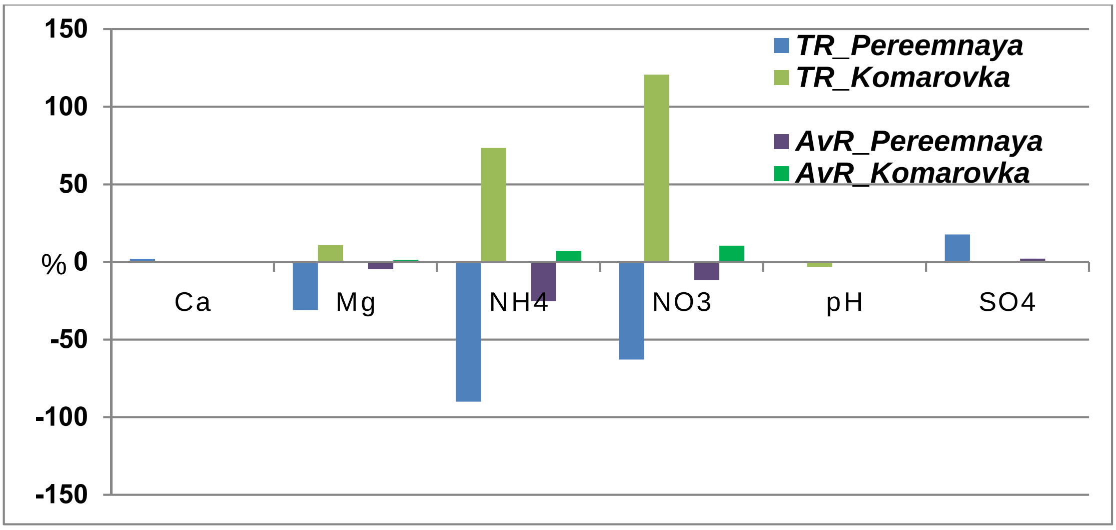

Figure 3.3.6. Changes of major chemical ions in surface stream water at EANET ecological sites (*TR* - "total reduction", *AvR* – "average annual reduction", in % of the value at the beginning of period)

4. Conclusion

In East Siberia 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 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 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. They caused by its photochemical generation at daytime and its partial depletion at night, so ozone quantity in near surface air depends on duration and intensity of solar radiation daytime, whereas its depletion at night controls by the state of underlying surface. No significant tendency of mean annual ozone concentrations had been identified at the remote Mondy site during the past 18 year period of continuous observations.

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. Snow samples collected in the background areas of the Baikal region had also low pH values (4.8-5.0) to be characteristic over the majority of alpine areas that are not affected by regional sources. So far the reasons and scales of lower acidification of atmospheric precipitation have remained unclear. It is likely associated both with natural processes (certain deficit of alkaline components in clean atmosphere to be driven with aerosols) and long-range transport of transforming sulfur and nitrogen oxides with air masses from large industrial sources.

More acidified precipitation over the south area of Lake Baikal is attributed to the transformation of emitted gaseous pollutants to acidic compounds during their transportation from main regional industrial sources (mainly in Irkutsk and Angarsk) of 70-100 km far from the west coast of lake. The ratio of major components in the atmospheric emission, the contents of sulfur and nitrogen oxides among the all chemical substances measured in aerosols, as well as balance estimates (emission/deposition) showed that precipitation acidification in Southern Baikal is caused mainly by the formation and transport of nitric acid, in spite the ratio NO_3^-/SO_4^{2-} had decreased in 2011 at sites Listvyanka (as well as at Primorskaya). Detailed analysis of chemical composition of snow samples across the coast and the ice surface of Lake Baikal collected in 2011-2014 has confirmed this conclusion.

Sulphate and calcium are dominated in precipitation chemical composition at monitoring sites of the East Siberia, whereas sulphate and ammonia are most important at site the Primorsky Kray. Among the sites the concentrations of chloride, nitrate and ammonia were the highest at site Primorskaya and other ions are at site Irkutsk. The lowest concentrations of ions were at Mondy site (20 times lower than at Primorskaya) with lowest deposition due to small amount of precipitation. Wet deposition of all ions, except bicarbonate and calcium, were much higher at site Primorskaya with maximal amount of hydrogen ions and mineral nitrogen in 2011 and sulphate in 2013. The general decrease of the most of ion concentrations and deposition fluxes were recorded for all sites, except Mondy, from 2010 to 2014.

Long-term monitoring of precipitation chemistry and the chemical regime of river waters in Southern Baikal areas shows that regional atmospheric transport of emitted sulphur and nitrogen oxides from large regional coal power plants can significantly affect the state of surface water chemistry in small rivers located at tens to hundreds kilometres far from emission sources.

The main negative effect of long-range transport of atmospheric pollutants onto the river basins are the increase of anthropogenic contribution of sulphate and nitrate ions compared to unexposed natural areas and, as a result, the rise of acidity of river waters. In particular, atmospheric transport of these pollutants from the coal-fired power plants of Irkutsk and Angarsk could potentially affect the mountain river basins of the south-eastern coast of Lake Baikal. In spite of the weathering and depositing calcium still ensures buffering capacity of surface water, further acidification due to changes of atmospheric precipitation can adversely affect the composition of soil, its properties and the state of the forest ecosystems in this area.

Therefore, further monitoring of the natural environment in the southern basin of Lake Baikal is desirable together with the reduction of sulphur and nitrogen 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.

The changes of surface water chemistry (mostly, in acidity and nitrogen contents) at Far East have to be investigated more with the possible recognition of regional effect (including possible increase of transboundary fluxes) from the local impact or modification of land use.

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National Assessment on Acid Deposition in Thailand

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1. Basic Information on National Monitoring Activities

1.1. Outline of the activities on acid deposition and national monitoring plan

Acid deposition monitoring network consists of several activities, including monitoring of both wet and dry depositions and monitoring of ecological impacts on soil, vegetation and inland aquatic environments. Air Quality and Noise Management Bureau, Pollution Control Department, has been appointed by the Royal Thai Government as the National Focal Point and the National Center for the Acid Deposition Monitoring Network in East Asia (EANET). Thailand participated in the preparatory phase of (EANET) during 1998-2000. Since then, EANET activities have been implemented on a regular basis together with the others East Asian countries.

Thailand's acid deposition monitoring network classified into EANET sites and national sites. There are 6 EANET monitoring sites: two urban (Bangkok), three rural (Pathumthani, Chiang Mai and Nakhon Ratchasima) and one remote site (Kanchanaburi). In addition to EANET sites, Thailand attempts to set up the national sites to examine the status of the other regions of the country and some specific areas such as the industrial complexes. These sites were not continuously operated due to limited resources and budget. At present, there are 3 national sites that attain the continuous operation, which include Songkhla, Chonburi and Rayong. All 3 sites are classified as urban sites. Songkhla is located in the South of Thailand. Chonburi and Rayong are the sites located in the Eastern part within the vicinity of the large industrial complexes, including power plants, petrochemical plants, oil refinery and gas separation plants. The monitoring sites are as shown in Figure 1.3.1.

The monitoring activities have started since 2000. Generally, all stations monitor both wet and dry depositions. The wet deposition daily sampling is collected by the automatic wet sampler. The dry deposition is carried out by either automatic ambient air monitoring stations and/or the four-stage filter packs collected every ten days in monthly basis. The status of acid deposition in Thailand presented in this report is based on the 6 EANET sites and 3 national sites.

1.2 Monitoring program from 2010 to 2014

National Monitoring Plan from 2010 to 2014 in Thailand were developed by the Air Quality and Noise Management Bureau, Pollution Control Department, which included the monitoring sites, the activities and monitoring parameters, the responsible agencies and the monitoring schedule. The monitoring program included four major environmental aspects; Wet and Dry Deposition, Soil and Vegetation and Inland Aquatic Environment are carried out in line with EANET monitoring guidelines.

1.3 Monitoring stations

There are 6 designated EANET monitoring sites as summarized in Table 1.3.1.
(1) Khanchanaburi, located at Vachiralongkorn Dam, Khanchanaburi province (Remote Site) : monitoring for wet deposition; dry deposition are monitored by automatic analyzer and filter pack, Inland aquatic environment, soil and vegetation are also included in this site.
(2) Bangkok, located in the area of Pollution Control Department (PCD) and The Government Public Relations Department (PRD), Bangkok (Urban Site): PRD site monitoring is for dry deposition by automatic analyzer and filter pack; PCD site monitoring is for wet deposition. Both sites located in the same area.

(3) Samutprakarn, located at Thai Meteorological Department (TMD), Bangkok (Urban Site) : monitoring for wet deposition and dry deposition by automatic analyzer.
(4) Pathumthani, located at the Environmental Research and Training Center (ERTC), Pathumthani Province (Rural Site) : monitoring for wet deposition.
(5) Chiang Mai, located at Chiang Mai University (CMU), Mae-Hia Campus, Chiang Mai Province (Rural Site) : monitoring for wet deposition and dry deposition by filter pack.
(6) Nakhon Ratchasima, located at Sakaerat Silvicultural Research Station (SKR), Nakhon Ratchasima Province (Rural Site) : monitoring for wet deposition and dry deposition by filter pack.

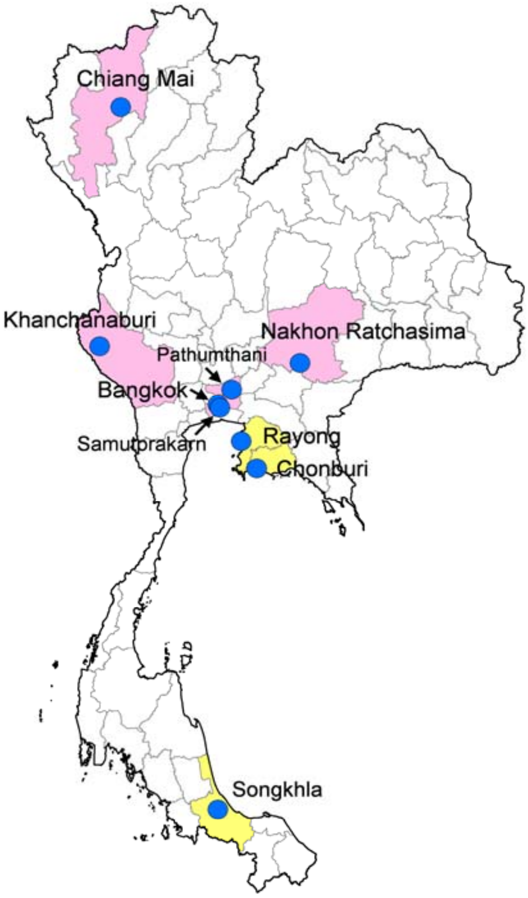


Figure 1.3.1. EANET Monitoring Sites in Thailand

Table 1.3.1. Locations of EANET Monitoring Sites in Thailand

City	Site	Classification	Latitude	Longitude	Altitude (m)
Bangkok	Bangkok	Urban	13°47′04″N	100°32′22″E	5
	Samutprakarn	Urban	13°39′58″N	100°36′21″E	4
Pathumthani	Pathumthani	Rural	14°02′46″N	100°42′43″E	6
Khanchanaburi	Khanchanaburi (Vachiralongkorn Dam)	Remote	14°47′05″N	98°36′05″E	130
Chiang Mai	Chiang Mai (Mae Hia)	Rural	18°45′54″N	98°55′42″E	349
Nakhon Ratchasima	Nakhon Ratchasima	Rural	14°28′04″N	101°54′05″E	409

1.4 Sampling and Measurements

The measurement parameters and monitoring interval are summarized as shown in Table 1.4.1.

(1) Wet Deposition Monitoring

Wet deposition is monitored by "Wet-Only-Sampler" resulted in concentration. Rain gauge is used for precipitation measurement. Twenty-four hours composite samples are collected in polyethylene collecting bottles. Rain samples are weighted and then analyzed for chemical composition (EC, pH and ionic species). If the samples cannot be analyzed within one day or is needed to be transferred from the sampling location to the laboratory, the samples are required to refrigerate at 4 °c or kept in a box with freezer packs and sent to the laboratory on daily basis.

(2) Dry Deposition Monitoring

Atmospheric gases concentrations, i.e. SO_2, NO_x and O_3, are measured on-site by automatic analyzers at Bangkok, Samutprakarn, and Khanchanaburi. At Khanchanaburi site, SO_2, NO_x and O_3 are monitored for 2 weeks, three times per year in March, July and November. At Bangkok and Samutprakarn sites, SO_2, NO_x and O_3 are monitored continuously all year round.

Atmospheric gases and aerosols concentrations are measured by filter pack method at Chiang Mai, Bangkok, Nakhon Ratchasima, Pathumthani and Khanchanaburi. Duration of sampling in all sites except Khanchanaburi is 10 days/sample continuously. For Khanchanaburi, the sampling frequency is three times per year (14 days/sample) at the same monitoring period using an automatic analyzer. That samples are analyzed for SO_4^{2-}, NO_3^-, Cl^-, NH_4^+, Na^+, K^+, Mg^{2+} and Ca^{2+} in particulate (aerosol) and analyzed for SO_2, HNO_3, NH_3 and HCl in gas phase.

(3) Inland Aquatic Environments Monitoring

Inland aquatic environments are monitored at Khanchanaburi. Samples are collected from two locations in Vachiralongkorn Reservoir, namely Ban Pong Chang (BPC) and Ban Pang Pueng (BPP) stations. The sampling frequency for inland aquatic environment monitoring is every 3 months, 4 times per year in March, June, September and December.

Table 1.4.1. Measurement parameters and monitoring interval

Items	Measurement parameters	Monitoring interval
Wet deposition	pH, EC, NH_4^+, Na^+, K^+, Ca^{2+}, Mg^{2+}, SO_4^{2-}, NO_3^-, Cl^-, precipitation amount, CH_3COO^-, $HCOO^-$, PO_4^{3-}	daily
Dry deposition - Automatic analyzer	SO_2, NO_2, NO, O_3, Particulate Matter (PM-10)	- hourly
- Filter pack	HNO_3, SO_2, NH_3, HCl, Aerosol	- 10 days
Soil	pH (H_2O), pH (KCl), exchangeable (Na^+, K^+, Ca^{2+}, Mg^{2+}), Exchangeable acidity, ECEC, Moisture content	every 3-5 years
Vegetation	observation of tree decline, description of trees	every 3 years
Inland aquatic environment	water temperature, pH, EC, alkalinity, NH_4^+, Na^+, K^+, Ca^{2+}, Mg^{2+}, SO_4^{2-}, NO_3^-, Cl^-, transparency	4 times/year

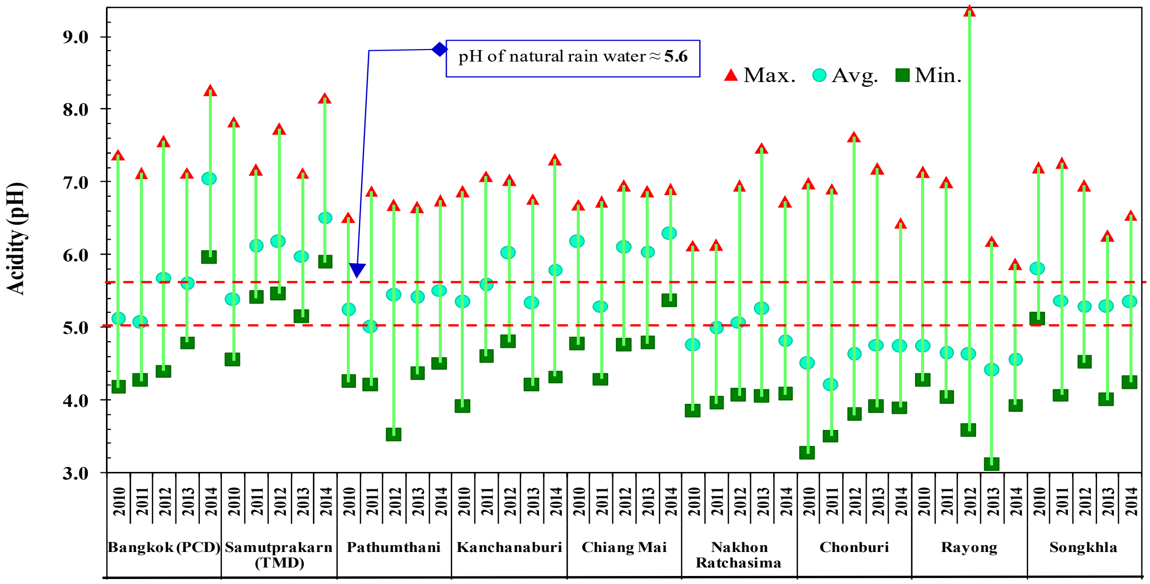
2 State of Acid Deposition in Thailand

2.1 State of wet deposition

The status of wet deposition in Thailand presented in this report was analyzed based on the EANET data of 5-year period from 2010 to 2014. In addition to 6 EANET sites in Thailand, Thailand has been attempted to set up the other national sites. Three national sites have also been used to examine the status of wet deposition in Thailand including Songkhla, Chonburi and Rayong.

The acidity or pH of rainwater depends on the concentration of cationic and anionic species. Acidic pH reveals the presence of strong acids, such as SO_4^{2-} and NO_3^-, while neutral or alkaline pH values indicate neutralization of acids by NH_4^+ and soil dust. The naturally existing CO_2, NO_x and SO_2 will dissolve into the clouds and rain droplets then result in pH values of the rain in the clean atmosphere to be between 5.0 and 5.6

Figure 2.1.1-2.1.3 shows the annual mean pH and percentage of samples which pH lower than 5.6 of all monitoring sites in Thailand from 2010-2014. It was found that the tendency of the annual mean pH has not appeared considerable changed for most of the sites except for Bangkok (PCD) and Samutprakarn (TMD), which were shown slightly increasing trend. Five-years averages annual mean pH were ranged from 4.48-5.81 which the lowest pH was observed at Chonburi and the highest pH was at Samutprakarn (TMD). It was also observed that the monitoring sites located in the vicinity of the industrial areas including Chonburi and Rayong were shown pH lower than 5.6 at most of the samples. In contrary, the other six monitoring sites located in urban, rural and remote areas, were shown that less than 30 percent of samples having pH lower than 5.6.



Note : Rain sample of Bangkok (PCD) for all year round in 2014 carried out on daily basis by bulk method

Figure 2.1.1. Annual mean pH for the monitoring sites in Thailand during 2010-2014

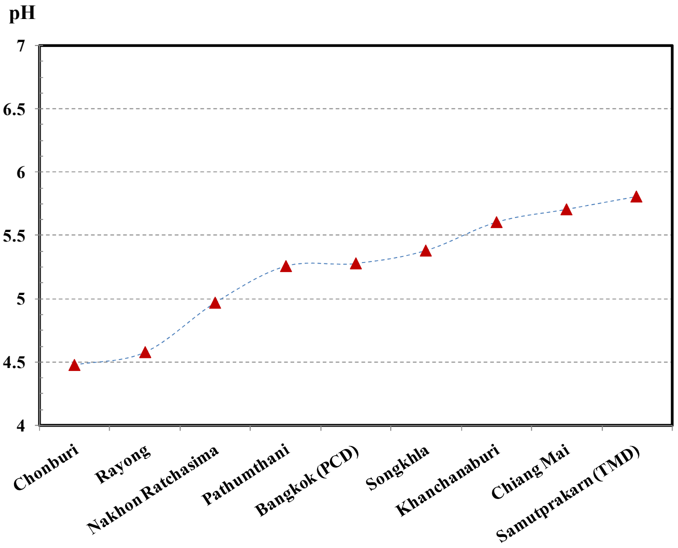


Figure 2.1.2. Annual mean pH for the monitoring sites in Thailand (Five-year averages during 2010-2014)

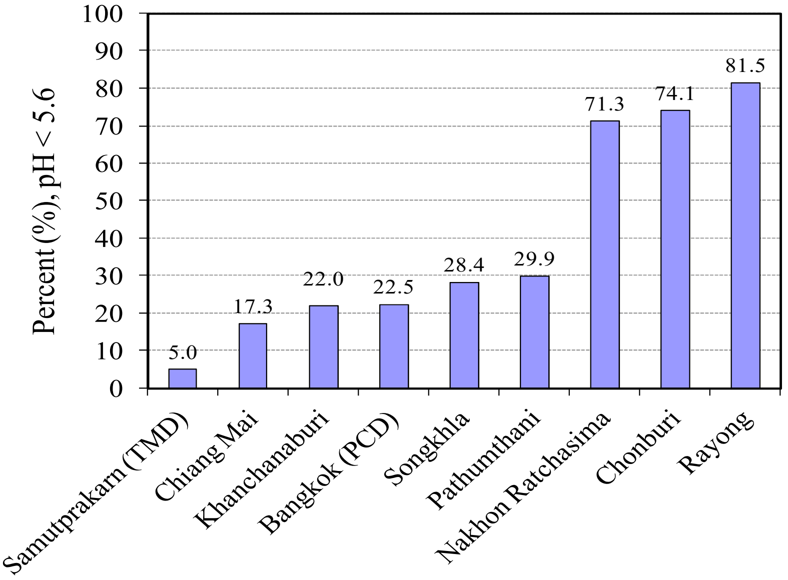


Figure 2.1.3. Percentage of Sample which pH lower than 5.6 during 2010-2014

Frequency distribution of pH during 2010-2014 is shown in Figure 2.1.4. In this study, pH range of urban areas (industrial areas) were mostly found at range lower than 4.5 to 5.0, i.e., Chonburi at pH lower than 4.5 with n = 436 and Rayong at pH range of 4.5-5.0 with n = 352. Urban area (city area), pH level was found normally at pH range of 6.0-6.5, i.e., Bangkok (PCD) at pH range of 6.0-6.5 with n = 325, Samutprakarn (TMD) at pH range of 6.0-6.5 with n = 279 and Songkhla at pH range of 6.0-6.5 with n = 550. For rural areas, pH level were found normally at pH range of 5.0-6.5, i.e., Nakhon Ratchasima at pH range of 5.0-5.5 with n = 446, Pathumthani at pH range of 6.0-6.5 with n = 448 and Chiang Mai at pH range of 6.0-6.5 with n = 486. For remote area at Khanchanaburi the pH level were found normally at pH range of 5.5-6.0 with n = 460.

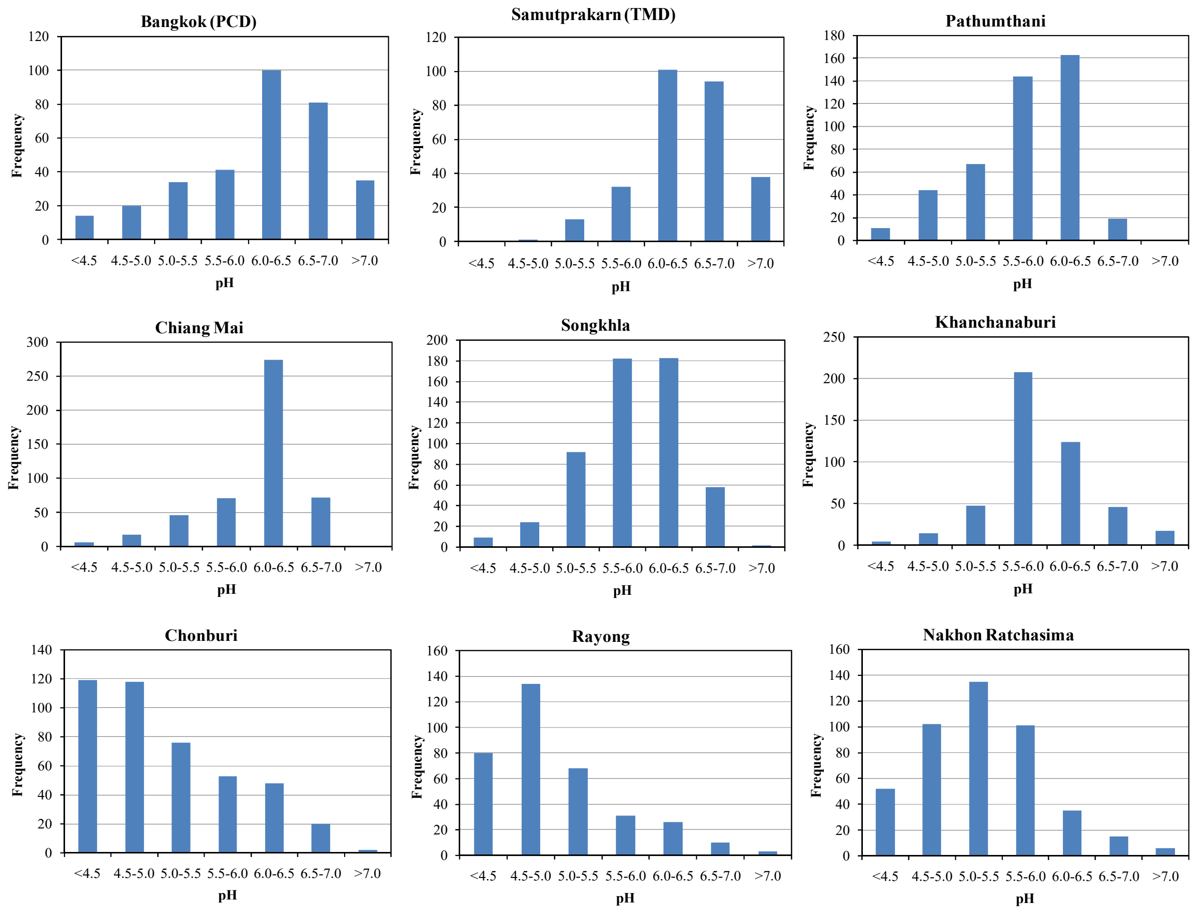


Figure 2.1.4. pH frequency distribution for the monitoring sites in Thailand during 2010-2014

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

$$A_i = [nss\text{-}\ SO_4^{2-}] + [NO_3^-]$$

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

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

The pH and pAi are the indices providing information on acid and base balance in precipitation. During the neutralization process, the pH increased with additional bases while the pAi remain constant throughout the process.

Figure 2.1.5. shows a relation between five-year annual mean pH and pAi for the monitoring sites in Thailand from 2010-2014. It was found that all sites plot are successfully located on or above the diagonal line of the pH-pAi diagram, in which pH is equal to pAi. The pH and pAi respectively ranged from 4.19-4.97 and 4.48-5.81. This overshooting of pH values was caused by the existence of an appreciable amount of bases such as $CaCO_3$ and NH_3.

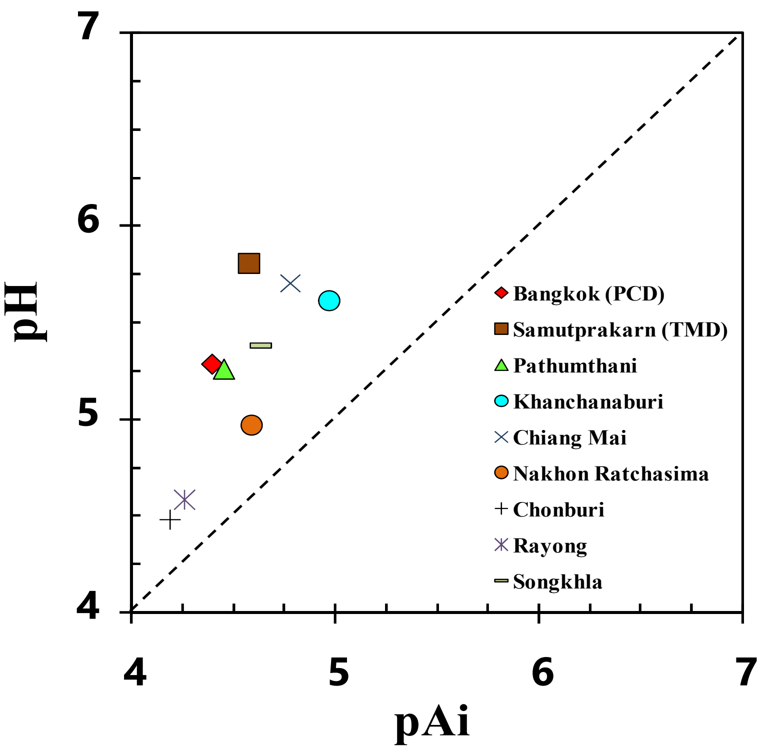


Figure 2.1.5. The pH-pAi diagram for annual mean of monitoring sites in Thailand during 2010-2014

In acid deposition chemistry, Nitric acid and Sulphuric acid are the two important acids. The relative contribution of these two acids is evaluated in the terms of corresponding anions, NO_3^- and nss-SO_4^{2-}. Knowing the ratio of the two acids is useful in identifying major acidifying substances. Nitric and sulphuric acids play an exclusively important role in acidification of the atmosphere and ecology although some significant roles are played by some other acids. The NO_3^- and nss-SO_4^{2-} are so stable that they are free from further acid-base interactions. The relative contribution for the entire concentration range for the two anions can be determined in the form of NO_3^- fraction for the sum of the ion pair, NO_3^- and nss-SO_4^{2-}: $[NO_3^-]/ ([NO_3^-] + [\text{nss-}SO_4^{2-}])$, which is denoted as fraction #1or F1 for simplicity.

$F1 = [NO_3^-]/([\text{nss-}SO_4^{2-}]+[NO_3^-])$

The F1 was calculated for the five-year annual means for all sites in Thailand as shown in Figure 7. The maximum, 0.53, occurred at Pathumthani and Bangkok (PCD), which means HNO_3 was slightly more significant than H_2SO_4 in acidification of rain. This value was followed by 0.51, 0.48, 0.48, 0.43, 0.40, 0.26 and 0.22 for Chiang Mai, Kanchanaburi, Nakhon Ratchasima, Songkhla, Samutprakarn (TMD), Chonburi and Rayong, respectively. The lowest ratio was found at 0.22 for Rayong, where H_2SO_4 was two times or more dominant acid than HNO_3 on an equivalent basis.

Whereas F1 could focus on the two acids, a similar discussion would be applicable to a pair of two basic compounds, NH_3 and $CaCO_3$. In precipitation samples, these compounds would be represented by NH_4^+ and nss-Ca^{2+}, which suggested defining a fraction, F2, to assess the importance of atmospheric NH_3 relative to $CaCO_3$ as:

$F2 = [NH_4^+]/([\text{nss-}Ca^{2+}] + [NH_4^+])$

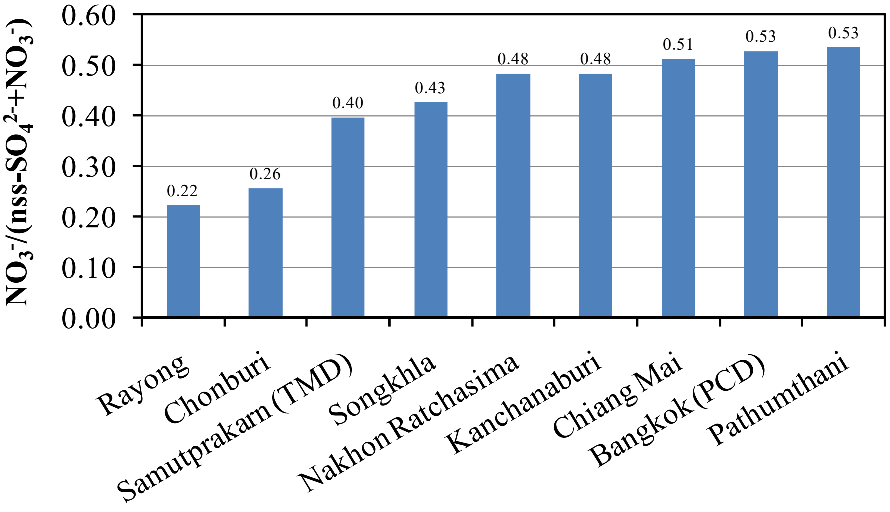


Figure 2.1.6. Equivalent fraction of Nitrate ; $[NO_3^-]/([\text{nss-}SO_4^{2-}]+[NO_3^-])$

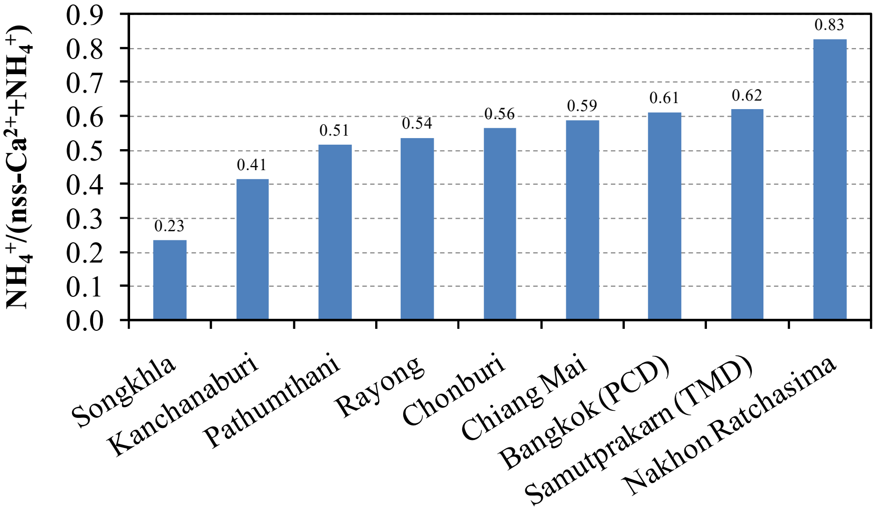


Figure 2.1.7. Equivalent fraction of Ammonium ; $[NH_4^+]/([\text{nss-}Ca^{2+}] + [NH_4^+])$

Figure 2.1.7 displays F2 ratio for the five-year annual means in order of the increasing ratio. The values for F2 are in a wide range from 0.23 to 0.83. Most of the ratios are greater than 0.50 where the two compounds equally work as bases in the interaction. It was found that seven out of 9 sites had shown F2 greater than 0.5, which are Nakhon Ratchasima, 0.83; Samutprakarn (TMD), 0.62; Bangkok (PCD), 0.61; Chiang Mai, 0.59; Chonburi, 0.56; Rayong, 0.54 and Pathumthani, 0.51. For these sites, ammonia is the dominant base in comparison with $CaCO_3$. The other two sites in Songkhla and Kanchanaburi had shown F2 less than 0.5 indicated that $CaCO_3$ is the dominant base.

The five-year average annual deposition of nss-SO_4^{2-} and NO_3^- (2010-2014) in Thailand is illustrated in Figure 2.1.8. The deposition of nss-SO_4^{2-} are in range from 4.3 - 30.4 mmol/m^2/y. The highest amount of nss-SO_4^{2-} was found at Chonburi (urban site, industrial area), with an annual flux about 30.4 mmol/m^2/y and the lowest amount was found at Khanchanaburi (remote site), with an annual flux about 4.3 mmol/m^2/y. The deposition of NO_3^- are in range from 8.1 - 35.5 mmol/m^2/y. The highest amount of NO_3^- was found at Bangkok (urban site, city area), with an annual flux about 35.5 mmol/m^2/y and the lowest amount was found at Khanchanaburi, with an annual flux about 8.1 mmol/m^2/y. It was clearly seen that at monitoring site located in the industrial areas such as Rayong and Chonburi, the annual deposition of nss-SO_4^{2-} were found much more than NO_3^- . The higher sulfate deposition might have been contributed from the of high SO_2 emissions from industrial fossil fuel combustion.

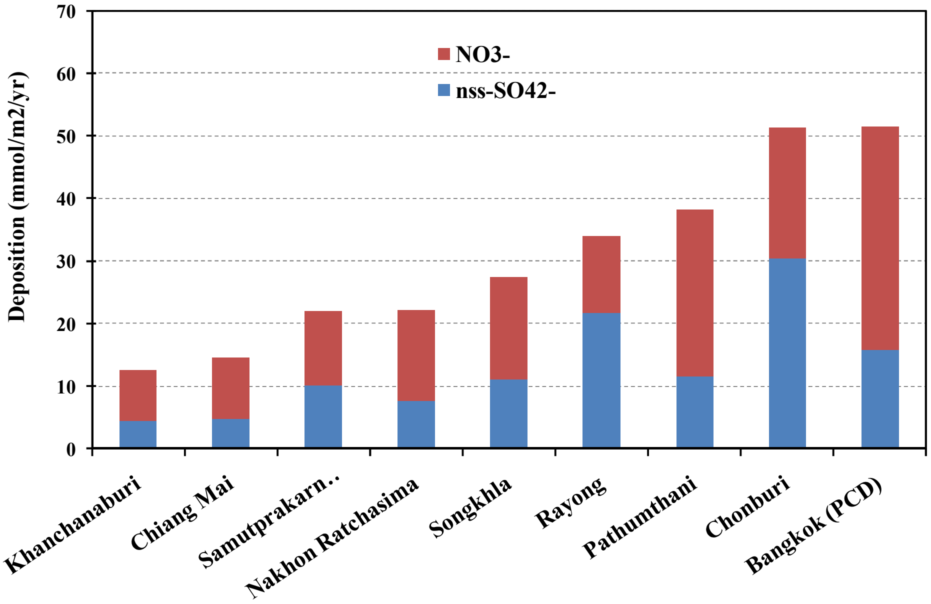


Figure 2.1.8. Five-year average annual deposition of nss-SO_4^{2-} and NO_3^- (2010-2014)

2.2 State of dry deposition

To assess total acid deposition, the dry deposition follows the wet deposition criterion which 5-year data (2010 - 2014) of EANET are assessed and all dry deposition monitoring sites are located within the vicinity of the wet deposition monitoring. The analysis will be presented in terms of monthly concentration variation and topographical differences (urban, rural and remote sites). The principal acid chemicals for analyses consist of the gas components: SO_2, HNO_3,NH_3 and aerosol components: SO_4^{2-}, NO_3^- and NH_4^+. The following analysis is based on filter pack samples.

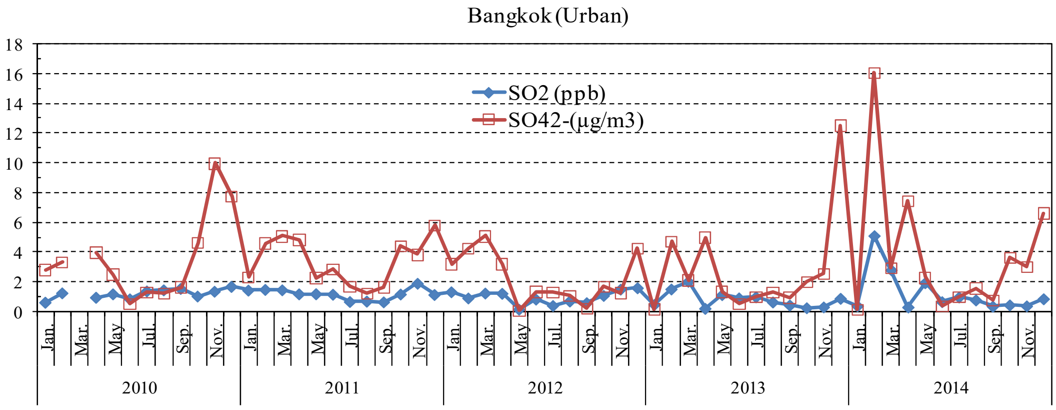
Gas and aerosol concentrations of sulfur

The gaseous SO_2 and aerosol SO_4^{2-} are the principal man-made acid species affecting neutrality of the atmosphere. The status trends of these acid concentrations during 2010 - 2014 in the urban, rural and remote areas are presented in Figure 2.2.1(a). The yearly SO_2 concentrations were found in the ranges of 0.79 - 1.22 ppb at the urban sites in Bangkok. High concentrations were found in the dry season (September - February) and low concentrations were found in the wet season (June – August). The low concentrations are considered to be affected by atmospheric wash-off such as heavy rainfall in the tropical climate. The SO_4^{2-} concentration follows the same decreasing trend as SO_2. The SO_4^{2-} concentrations were observed in high values in the dry season and relatively low in the wet season. The yearly concentrations of SO_4^{2-} in Bangkok were in the range of 2.13 – 3.60 µg/m^3.

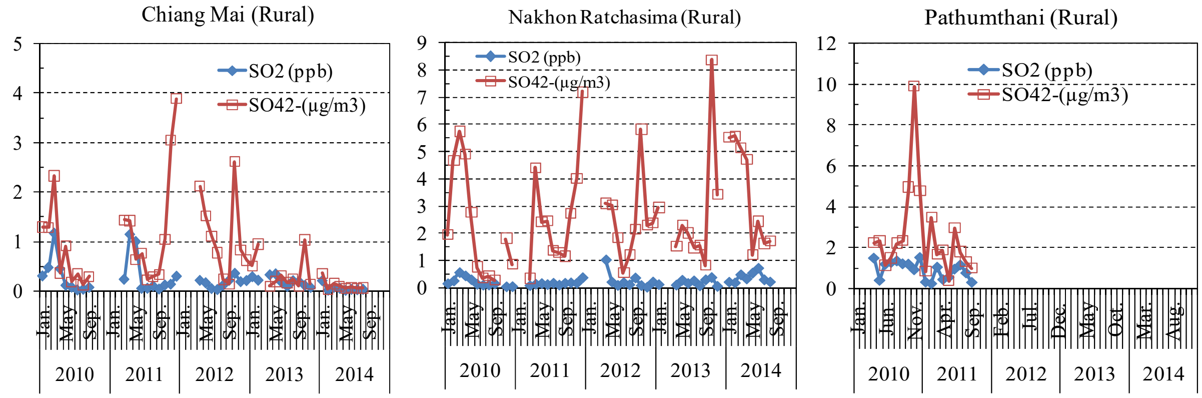
The monthly variation of SO_2 concentrations in the rural sites in Chiang Mai, Nakhon Ratchasima and Pathumthani are shown in Figure 2.2.1(b). The yearly concentrations were observed within the ranges of 0.06 - 0.32 ppb, 0.17 - 0.40 ppb and 0.62 - 1.17 ppb in Chiangmai, Nakhon Ratchasima and Patumthani, respectively. The observed values of SO_4^{2-} concentrations were in the ranges of 0.11 – 1.33 µg/m^3, 0.18 - 0.61 µg/m^3 and 1.51 - 3.63 µg/m^3 in Chiang Mai, Nakhon Ratchasima and Pathumthani, respectively.

The yearly concentration of SO_2 in the remote site, as shown in Figure 2.2.1(c), was observed in the ranges of 0.05 - 0.17 ppb in Khanchanaburi. The SO_4^{2-} concentrations were found in the ranges of 0.03 – 0.12 µg/m^3 in Khanchanaburi.

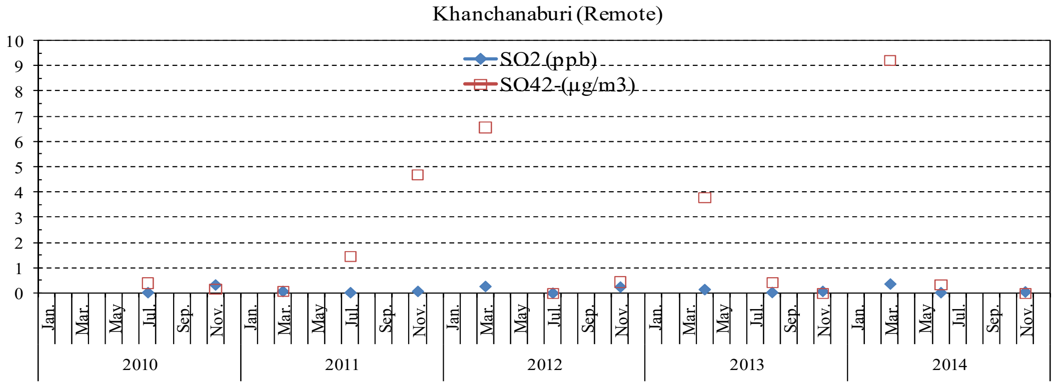
All observed acid gases and aerosol concentrations occupied the same pattern of seasonal variation between the high and the low concentrations during the 5-year monitoring period (2005 – 2009). The urban concentrations of SO_2 were reported to be 5 - 21 times higher than the concentrations in the remote areas.



(a)



(b)



(c)

Figure 2.2.1. The monthly variation in concentrations of gaseous SO_2 and aerosol during 5-year monitoring (2010 - 2014). (a) Bangkok sites (urban), (b) Chiang Mai, Nakhon Ratchasima and Patumthani sites (rural) and (c) Khanchanaburi sites (remote).

Gas and aerosol concentrations of nitrogen

The principal chemical species of nitrogen, due to acidic nature, compose of gases, HNO_3 and NH_3 and aerosols, NO_3^- and NH_4+. The observed values of these chemicals were shown distinguishable trend of high and low concentration in the dry and the wet season. The ratio concentrations between dry/wet seasons were approximately 2 to 10.

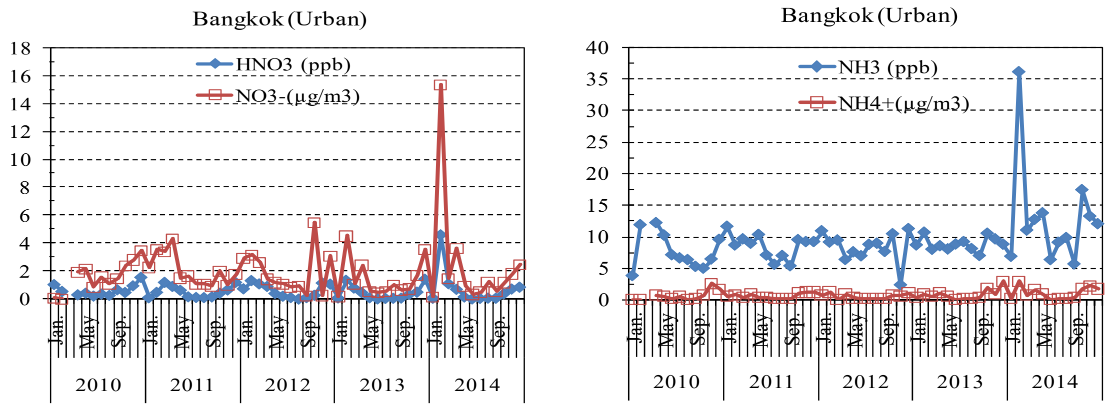
The yearly concentrations of gaseous HNO_3 and NH_3 in the urban city of Bangkok were in the ranges of 0.43 – 0.62 ppb and 7.63 – 10.71 ppb, respectively, as shown in Figure 2.2.2(a). The concentration of NH_3 was significantly 10-20 times higher than HNO_3. The sources of NH_3 emission in the urban area are envisaged to arise from nearby industrial wastewater and sewage treatments and agriculture utilizing fertilizers. The yearly concentrations of aerosol NO_3^- and NH_4^+ in the urban city of Bangkok were observed in the ranges of 1.44 – 2.01 μg/m^3 and 0.50 – 0.84 μg/m^3, respectively. The trend of both gases appeared steady during the past 5 years and the maximum value was observed during the dry season and the minimum value was observed during the wet season. The observed low concentration was supposed to resulted from the atmospheric wash out by heavy rainfall.

In the rural areas of Nakhon Ratchasima, the concentrations of gaseous HNO_3 and NH_3 were found in the ranges of 0.10 – 0.29 ppb and 1.84 – 3.66 ppb, respectively. The concentrations of aerosol NO_3^- and NH_4^+ were in the ranges of 0.18 – 0.61 μg/m^3 and 0.76 – 1.06 μg/m^3, respectively. See Figure 2.2.2(b).

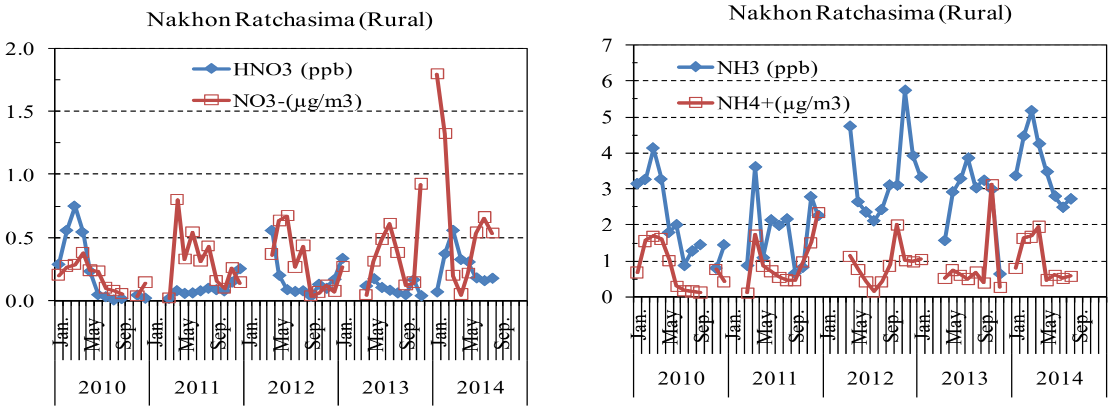
In the rural areas of Chiang Mai and Pathumthani, the concentrations of gaseous HNO_3 were found in the ranges of 0.04 - 1.95 ppb and 0.35 – 0.91 ppb, and the concentrations of NH_3 were found in the ranges of 1.66 – 9.06 ppb and 4.69 – 7.69 ppb respectively. The concentrations of aerosol NO_3^- of Chiang Mai and Pathumthani were found in the range of 0.11 – 9.89 μg/m^3 0.82 – 1.85 μg/m^3, and NH_4^+ was in the ranges of 0.09 – 3.64 μg/m^3 and 0.21 – 0.79 μg/m^3, respectively. These observed data also show significant trend of high NH_3 concentration in the rural areas. See Figure 2.2.2 (c) and (d).

In the remote areas of Khanchanaburi, the concentrations of gaseous HNO_3 and NH_3 were found in the ranges of 0.01 – 0.36 ppb and 1.54 – 3.70 ppb, respectively. The concentrations of aerosol NO_3^-

and NH_4^+ were in the ranges of 0.03 – 0.12 µg/m^3 and 0.07 – 0.53 µg/m^3, respectively. The remote site was also shown high values of NH_3. It should be noted that the existence of high NH_3 in the atmosphere can be a normal occurrence in the agricultural country. See Figure2.2.2 (e).



(a)



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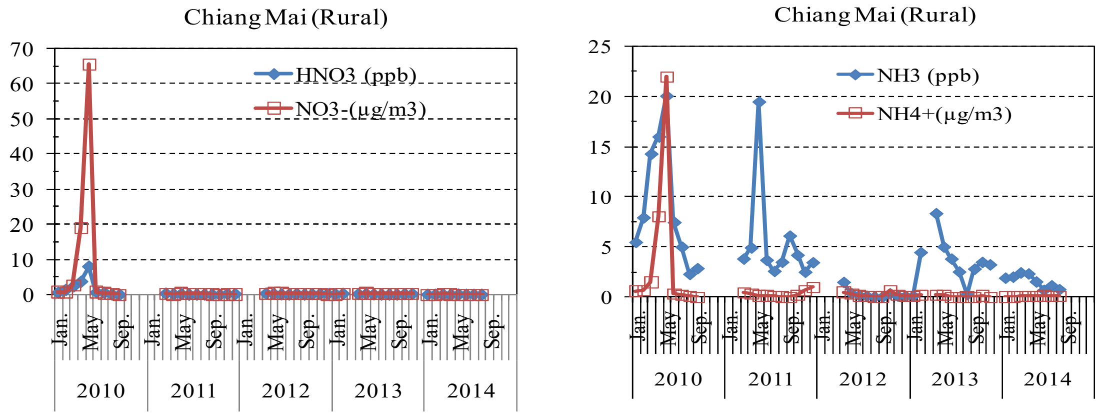

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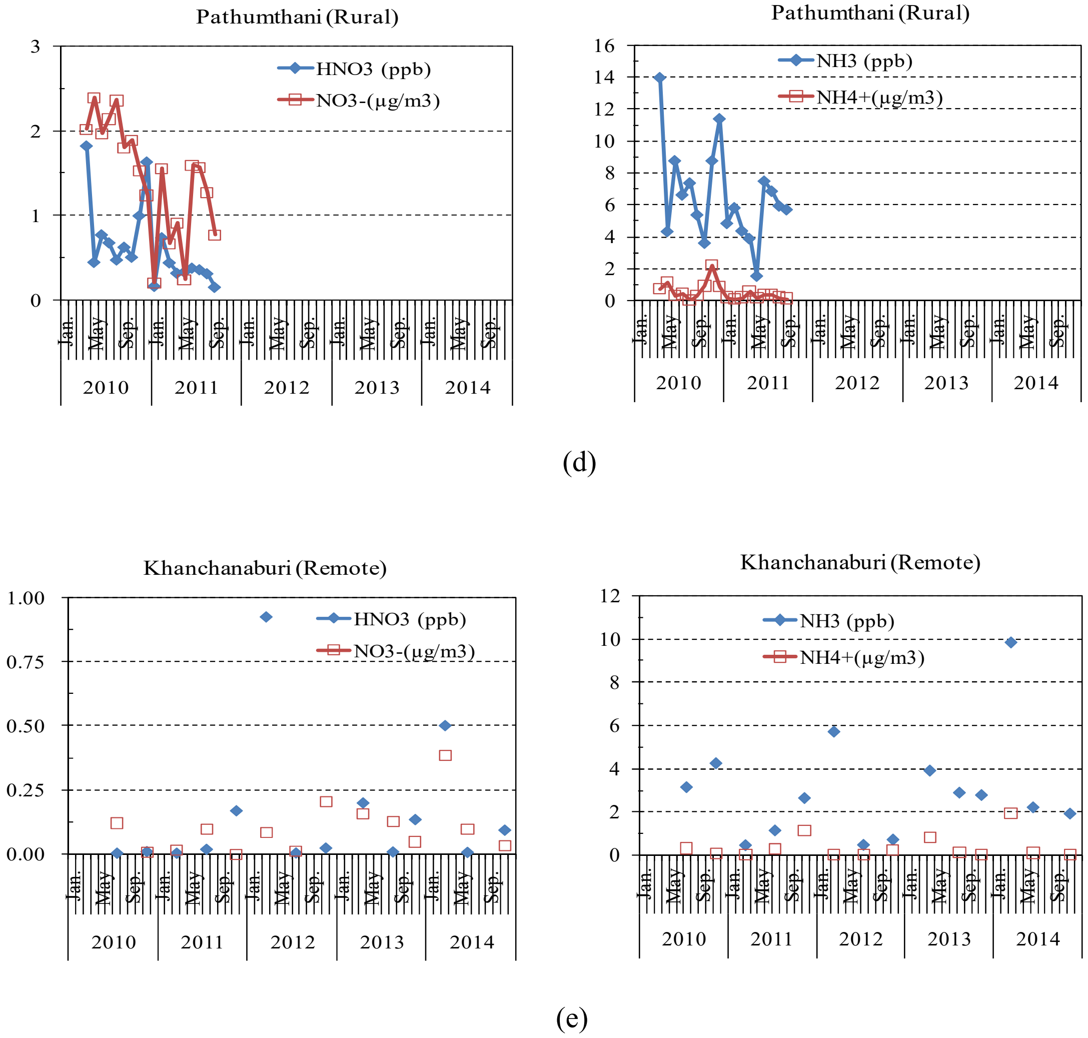


Figure 2.2.2. The monthly variation in concentrations of gaseous HNO_3, NH_3 and aerosol NO_3^- and NH_4^+ during 5-year monitoring (2010 – 2014). (a) Bangkok site (urban), (b) Nakhon Ratchasima site (rural), (c) Chiang Mai site (rural), (d) Patumthani site (rural) and (e) Khanchanaburi site (remote).

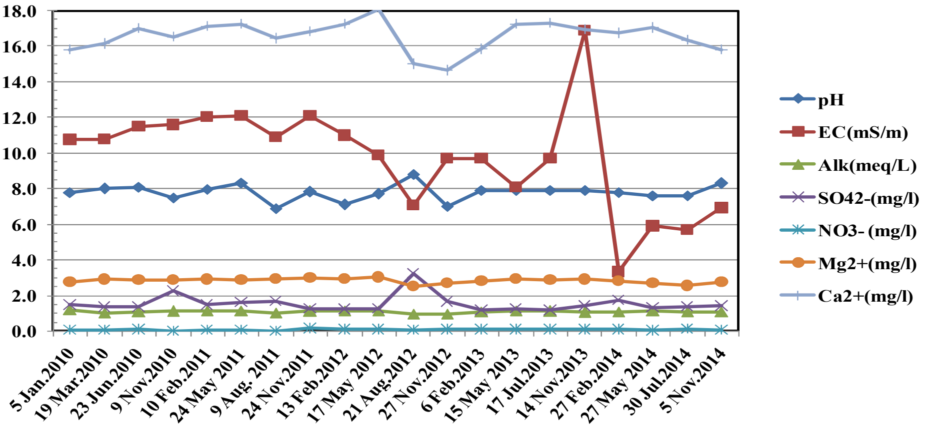
2.3 State of inland aquatic environment

Vachiralongkorn Dam has been selected for the inland aquatic environment monitoring since 2000. Vachiralongkorn Dam is a rock filled dam covering the area of 388 km^2. The watershed area is 3,720 km^2 with an average inflow of 5,500 million m^3. The maximum water storage volume is 8,860 million m^3. The average water depth is 115.0 m with the maximum depth of 153.2 m. The annual water level fluctuated between 0-18 meters (average 9 m.) The residence time of water is 165 days. One river stream flows into the dam. Main bed rock type is lime stone. The drainage area is covered by forest. The dam is highly utilized for electric power generation, irrigation, fish culture and recreation. The inland aquatic environments monitoring during 2010 – 2014 were carried out at two sampling sites, Ban Pang Pueng and Bang Ban Pong Chang , in Vachiralongkorn reservoir, Khanchanaburi province.

At Ban Pang Pueng, the monitoring results of pH , electrical conductivity (EC), alkalinity, SO_4^{2-}, NO_3^-, Ca^{2+} and Mg^{2+} were found in the ranges of 6.9 – 8.8, 3.3 – 16.9 mS/m, 0.9 – 1.2 meq/l, 1.2 – 3.3 mg/l, 0.0 – 0.2 mg/l, 14.7 – 18.1 mg/l and 2.5 – 3.0 mg/l, respectively. See Figure 2.3.1(a).

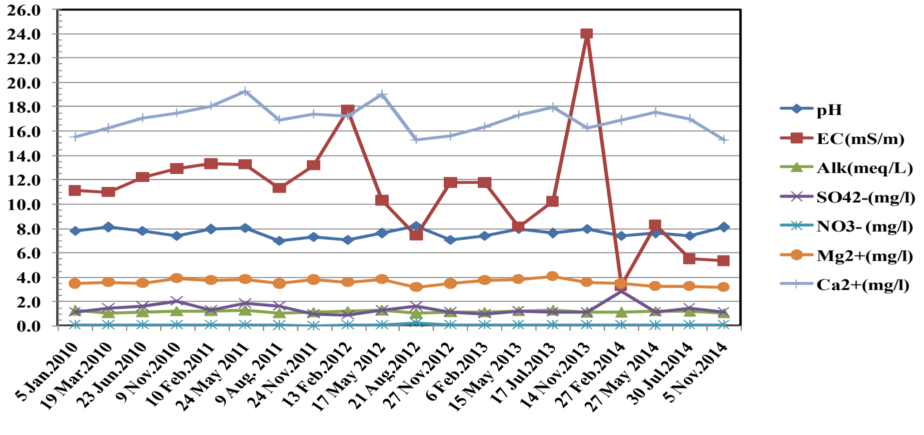
At Ban Pong Chang, the monitoring results of pH , electrical conductivity (EC), alkalinity, SO_4^{2-}, NO_3^-, Ca^{2+} and Mg^{2+} were found in the ranges of 7.0 – 8.2, 3.3 – 24.0 mS/m, 1.0 – 1.3 meq/l, 0.9 – 2.8 mg/l, 0.0 – 0.3 mg/l, 15.3 – 19.3 mg/l and 3.2 – 4.1 mg/l, respectively. See Figure 2.3.1(b).

Based on monitoring data for 2010 – 2014 at Ban Pang Pueng and Ban Pong Chang, there were no clear seasonal and yearly trends for all monitoring parameters except for EC in November 2013 and February 2014 showing high fluctuation; however, the reason was not reported. Meanwhile, the data showed that the high pH and alkalinity values are associated with the lime stone rock type of the reservoir basin.



Ban Pang Pueng (2010-2014)

(a)



Ban Pong Chang (2010-2014)

(b)

Figure 2.3.1. Results of inland aquatic environments monitoring at Vachiralongkorn reservoir during 5-year monitoring (2010 – 2014). (a) Ban Pang Pueng site and (b) Ban Pong Chang

3 Review of National Measures against Acid Deposition

In Thailand, the general policies on air quality management are to maintain the air quality in the attainment area and to reduce the air pollution in the nonattainment area. National Ambient Air Quality Standard is one of the key indicators related to the air quality management system which is usually considered as the air quality goal to evaluate the air quality status.

Air pollution and acid deposition are related issues. The national measures related to the air pollution control strategies have provided the co-benefit to control acid deposition problem as well. Air pollution management in Thailand involves many organizations.

Sources of air pollution can be categorized into various groups. Specific sources include fire in landfills, haze and smog in the northern part of Thailand that resulted from the open burning of agricultural land and forests. These are unique to areas because of their activities or seasonal patterns. In addition to the specific sources, many areas of the country that found the concentrations of particulate matters and ozone exceeded the national standards shared the same air pollution sources. These sources were transportation, domestic and industrial fuel combustion for power generation and industrial sectors. Transportation and domestic sectors had shown increasing trend in energy consumption. Nevertheless, Thailand has consistently implemented energy saving measures. The energy efficiency became slightly better in recent year.

Fuel combustion is the major sources of several air pollutants. Cleaner fuel has been very pro-active in developing cleaner fuel specifications for more than a decade. Improve fuel quality to obtain cleaner fuel is the important measure; for instance, lower the sulfur content in diesel fuel to be 50 ppm in 2010. Other kind of alternative fuels such as gasohol, biodiesel, and CNG, with non-toxic, biodegradable and renewable, have been promoted and used for several years. The change of fuel oil from EURO3 to EURO4 in 2012 contributed to the decrease in particulate matter, which was observed in the big cities especially Bangkok and its vicinity.

Emission standard for new and in-used vehicles are implemented. Emission standards for new vehicles have been adopted since 1995, follow the European emission standard. Stricter emission has been progressively employed. Other measures, namely Inspection and Maintenance Program and Ecology car (Eco car) are also launched along with the Real-Euro for additional NOx reduction measures. However, their additional effects were estimated relatively small. Vehicle emission inspection has been implemented including roadside inspection and emission test before license renewal. The over aged vehicles (over 7 years) are required to pass the emission inspection annually prior to the annual renewal of the license. The Eco car has recently been promoted due to fuel saving policy. Public transit system development and mass transit system improvement are important measures to improve the air quality in big cities especially Bangkok Metropolitan area.

Haze episodes still happen as major air pollution problem in the northern part of Thailand. Open burning is the greatest source of particulate matter. Emission sources include forest fires, municipal waste and agricultural waste burning and typically exposes to the largest population every summer. The situation of transboundary haze pollution in the southern part of Thailand has also been observed almost every year. ASEAN Agreement on Transboundary Haze and National Master Plan on Open Burning Control provided the basis for control activities in Thailand. The National Master Plan tends to focus on forest fires prevention and rehabilitation of traditional crops land preparation rather than on establishment of new stringent regulation. Consequently, the following implementation programs are mainly based on preserve and protect nature. These programs have been made possible through the joint efforts of various ministries, including Ministry of Natural Resources and Environment, Ministry of Agriculture and Cooperatives, Ministry of Interior, Ministry of Public Health, Ministry of Transport, and Ministry of Foreign Affairs. In 2014, the operation to prevent and solve the problem of haze and smoke was also undertaken by provincial administrations, as they have an understanding of the situation of the area and the authority to enforce many measures. Such operations included awareness campaigns for farmers to prepare farming areas by growing alternative crops or weed ploughing instead of fire clearance. The administration also worked to prepare personnel, vehicles and fire extinguishing equipment for local agencies. The Department of Forestry and the Department of National Parks and Plant Conservation were prepared with forest firefighters and have established forest fire and haze solution centers for the northern region, as well as at a community and Subdistrict level. Recently, the cooperation among the relevant agencies, regional administrations and the public has improved.

The above mentioned examples are some of the measures that were implemented in the country.

Several measures on air pollution control resulted in the reduction of sulfur dioxide, oxides of nitrogen and particulate matter as these air pollutants are also involved in the acid deposition mechanism.

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National Assessment on Acid Deposition in Vietnam

Chapter 1. Basic Information on National Monitoring Activities

1.1 Outline of the activities on acid deposition and National Monitoring Plan

There are 2 networks of environmental monitoring stations in operation. Networks of environmental background and impacts stations are all under Ministry of Natural Resources and Environment. Network of environmental background includes 24 rain-water chemistry monitoring stations (10 automatic stations), 1 background air monitoring station, 51 river water quality stations, 10 reservoir monitoring stations, 1 experimental station for reservoir environment, and 6 sea water monitoring stations. These stations take on-site measurements and samples taken are delivered to 5 laboratories in the North, Central and South of Vietnam to analyze.

In this network, 23 rain-water chemistry monitoring stations have been operated since 1987 and located in Thai Nguyen, Viet Tri, Bac Giang, Bai Chay, Phu Lien, Hai Duong, Ha Noi, Ninh Binh, Cuc Phuong in the North of Vietnam; Thanh Hoa, Vinh, Hue, Da Nang, Qui Nhon, Nha Trang, Phan Thiet in the Central part of Vietnam; Pleiku, Buon Me Thuot, Da Lat in the Central High Land of Vietnam; Nha Be, Tan Son Hoa, Tay Ninh, Can Tho, Ca Mau in the South of Vietnam. In these stations, rain water samples are collected semi-automatically, and pH and EC are measured on site. In addition, in 2008 Hanoi has 01 more automatic air monitoring station was brought into operation.

Monitoring parameters and interval are as following:

- Wet deposition: In order to observe wet deposition, samples are taken in every precipitation event. Beside these samples, seven day-mixed samples are also analyzed with parameter of pH, EC, SO_4^{2-}, NO_3^-, NH_4^+, Cl^-, Ca^{2+}, Na^+, Mg^{2+}, $K^+$and HCO_3^-. In these stations, rain water samples are collected semi-automatically, and pH are measured on site.
- River and reservoir quality monitoring stations: Every month, water samples are taken. The monitoring parameters compose of pH, EC, alkalinity, SO_4^{2-}, COD, Cl^-, Ca^{2+}, Na^+, NH_4^+, NO_3^-, Mg^{2+}, and K^+

Since 2002, 6 Automatic Air quality Monitoring stations (KIMOTO Brand from Japan) with acid rain monitor have been set up and operated in Ha Noi (Lang), Phu Lien, Cuc Phuong, Da Nang, Pleiku, Nha Be stations.

Monitoring parameters and interval are as following:

- Meteorology: wind direction, wind velocity, air temperature, air humidity, air pressure, solar radiation, rainfall and ultra-violet;
- Air quality: SO_2, NO, NO_2, NH_3, CO, O_3in surface, CH_4, OBC, TSP, PM10;
- Wet deposition: pH, EC was measured for each mm of rainfall. Rainfall water samples were transferred to the laboratory for analysis. These samples is the combination of 10-day from 2010 to 2012) and 7-day from 2013 to now with measure parameters pH, EC, SO_4^{2-}, NO_3^-, NH_4^+, Cl^-, Ca^{2+}, Na^+, Mg^{2+}, $K^+$and HCO_3^-.

All real-time data of automatic stations are online transferred to a data-sever in Ha Noi Network Center of Hydrometeorology and Environment to analyze.

Up to now, there are 4 automatic stations including: Long Bien station (Ha Noi) and 3 additional stations are Son La station, Vinh station and Can Tho station but these stations do not have equipment to measure parameters such as: O_3, dust and THC.

Vietnam has taken a part in EANET since August 1999 and Institute of Hydrology- Meteorology and Climate Change (IMHEN) belonging to Ministry of Natural Resource and Environment (MONRE) is representative as the National Center for Vietnam.

In 1999, with the support of equipment and machines (two wet only samplers and two filter packs) from Japan Government, 2 monitoring stations based in Lang (Hanoi) and Hoa Binh (Hoa Binh province) have been set up and operated since then. In the end of 2008, with the agreement of Vietnam Government, Ministry of Natural Resource and Environment added 3 sites: Cuc Phuong station (Ninh Binh), Da Nang station (Da Nang city); and In 2014 added 2 sites Ho Chi Minh station (HCM city) and Can Tho station (Can Tho province) to take part in EANET network.

Table 1. EANET acid deposition monitoring sites in Vietnam

Items	Before 2015			From 2015		
	Urban sites	Rural sites	Remote sites	Urban sites	Rural sites	Remote sites
Wet deposition	3 (Ha Noi, Đa Nang, Ho Chi Minh city)	2 (Hoa Binh, Can Tho)	1 (Cuc Phuong)	3 (Ha Noi, Đa Nang, HoChi Minh city)	3 (Hoa Binh, Can Tho)	1 (Cuc Phuong)
Dry deposition	2 (Ha Noi, Ho Chi Minh city)	2 (Hoa Binh, Can Tho)		3 (Hanoi, Ho Chi Minh city, Da Nang)	3 (Hoa Binh, Can Tho)	
Soil & vegetation			1 (Cuc Phuong)			
Inland aquatic environment		1 (Hoa Binh)			1 (Hoa Binh)	

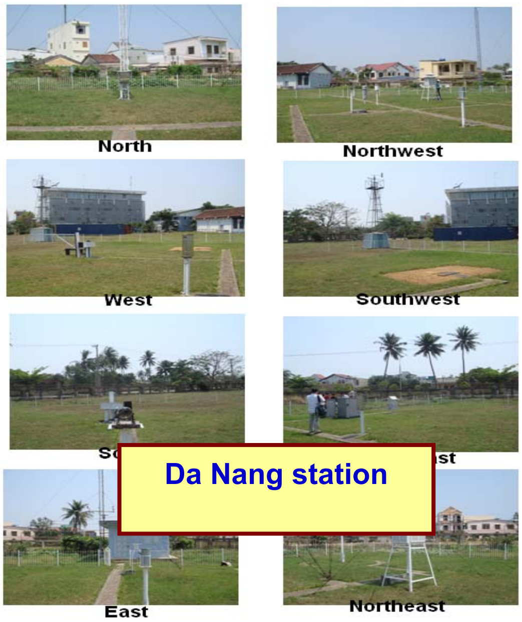
Figure 1.1: Monitoring stations

1.2. Monitoring plan from 2010 to 2014

Items	Sites classify	Place	Sampler	Analytical offices
Wet deposition	Urban sites (3 sites)	Ha Noi	Wet only sampler	Environmental Laboratory - Center for Environmental Research - IMHEN-MONRE
		Da Nang	Wet sampler with pH, EC automatic measurement each mm of rainfall	Environmental analysis laboratory II area- Mid-central regional hydro meteorological center – National Hydro-meteorological Service (NHMS) –MONRE
		Ho Chi Minh city	Wet only sampler	Environmental Laboratory - Sub-Institute of HydroMeteorology and Climate Change (SIHYMECC) – IMHEN- MONRE
	Rural sites (2 sites)	Hoa Binh	Wet only sampler	Environmental Laboratory - Center for Environmental Research - IMHEN-MONRE
		Can Tho*	Wet only sampler	Environmental Laboratory - Sub-Institute of HydroMeteorology and Climate Change (SIHYMECC) – IMHEN- MONRE
	Remote sites (1 site)	Cuc Phuong	Wet sampler with pH, EC automatic measurement each mm of rainfall	Environmental analysis laboratory I area - Center for Hydro-Meteorological and Environmental Networks - National Hydro-meteorological Service (NHMS) – MONRE
Dry deposition	Urban sites (2 sites)	Ha Noi,	Fiter Pack	Environmental Laboratory - Center for Environmental Research - IMHEN-MONRE
		Ho Chi Minh*	Fiter Pack	Environmental Laboratory - Sub-Institute of HydroMeteorology and Climate Change (SIHYMECC) – IMHEN- MONRE
	Rural sites (2 sites)	Hoa Binh	Fiter Pack	Environmental Laboratory - Center for Environmental Research - IMHEN-MONRE
		Can Tho*	Fiter Pack	Environmental Laboratory - Sub-Institute of HydroMeteorology and Climate Change (SIHYMECC) – IMHEN- MONRE
Inland aquatic environment	Rural sites (1 sites)	Hoa Binh		Environmental Laboratory - Center for Environmental Research - IMHEN-MONRE

Note: *Ho Chi Minh and Can Tho sites have just started providing wet and dry monitoring data since 2014.


Cuc Phuong station


Da Nang station


Ha noi station


Hoa Binh station

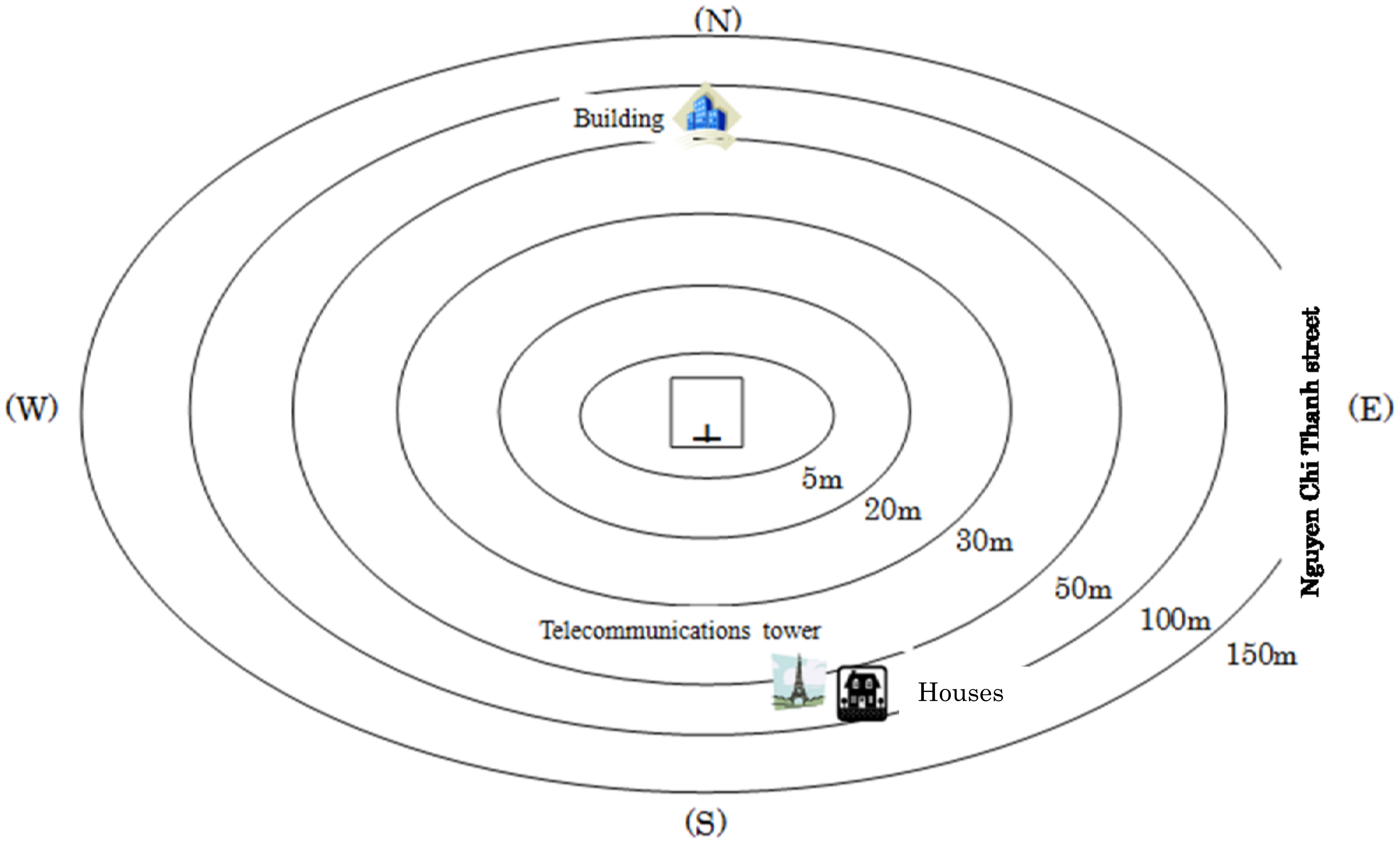

Can Tho station


Ho Chi Minh station

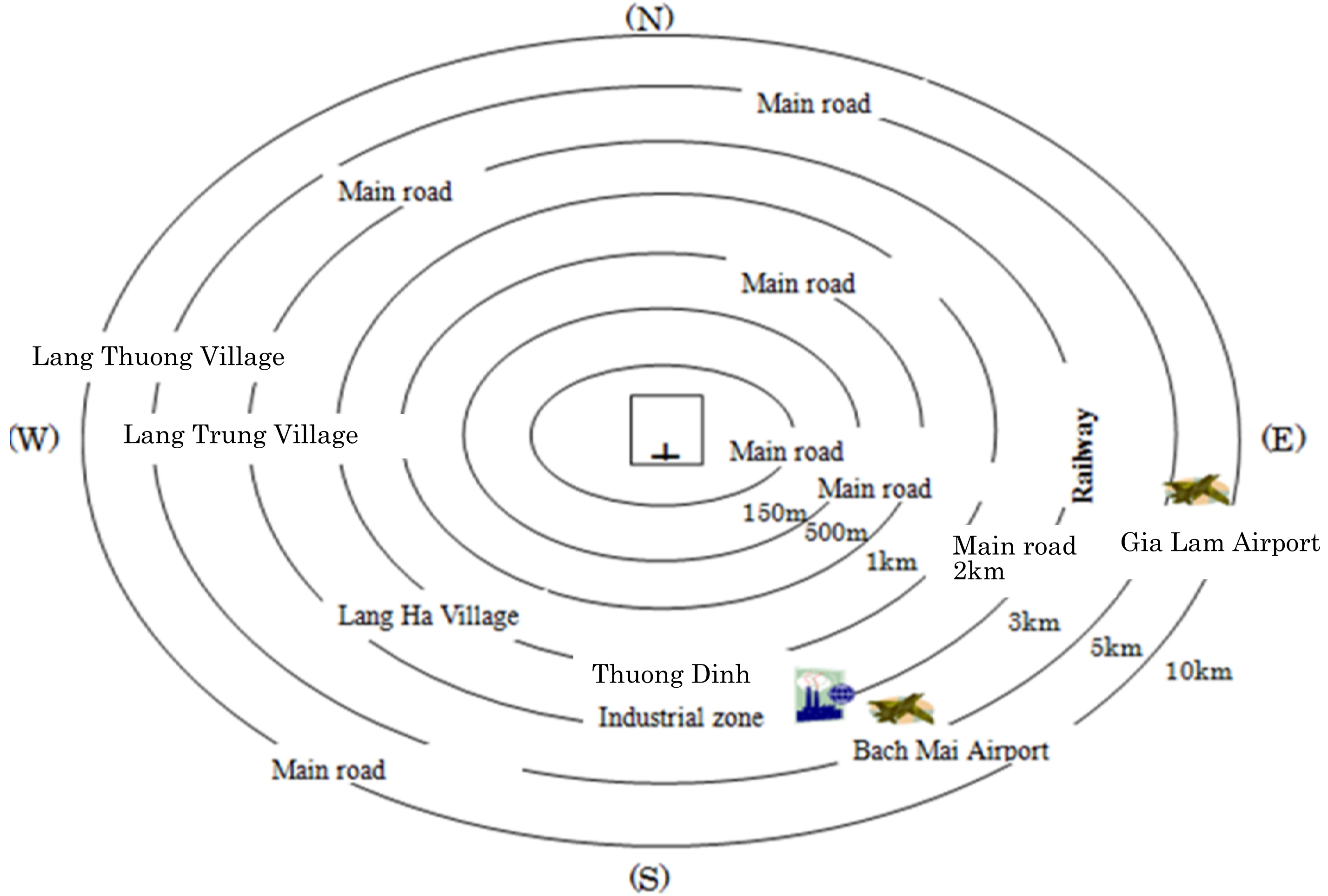
1.3. Location of monitoring sites

a. Ha Noi station

Outline of monitoring site: On-site scale (distance within 150 m)

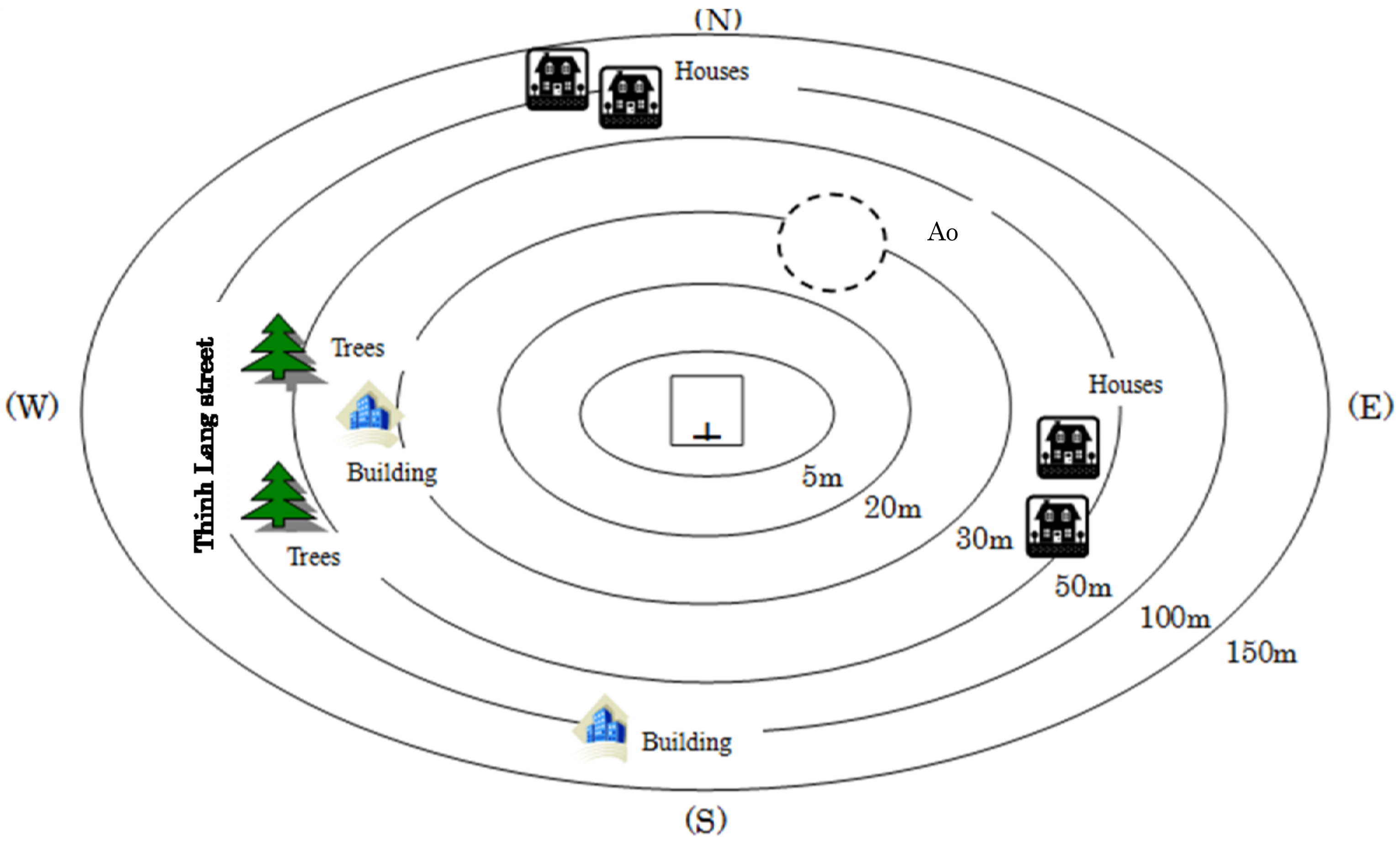


Outline of monitoring site: Local scale (distance 150 m – 10 km)



b. Hoa Binh station

Outline of monitoring site: On-site scale (distance within 150 m)



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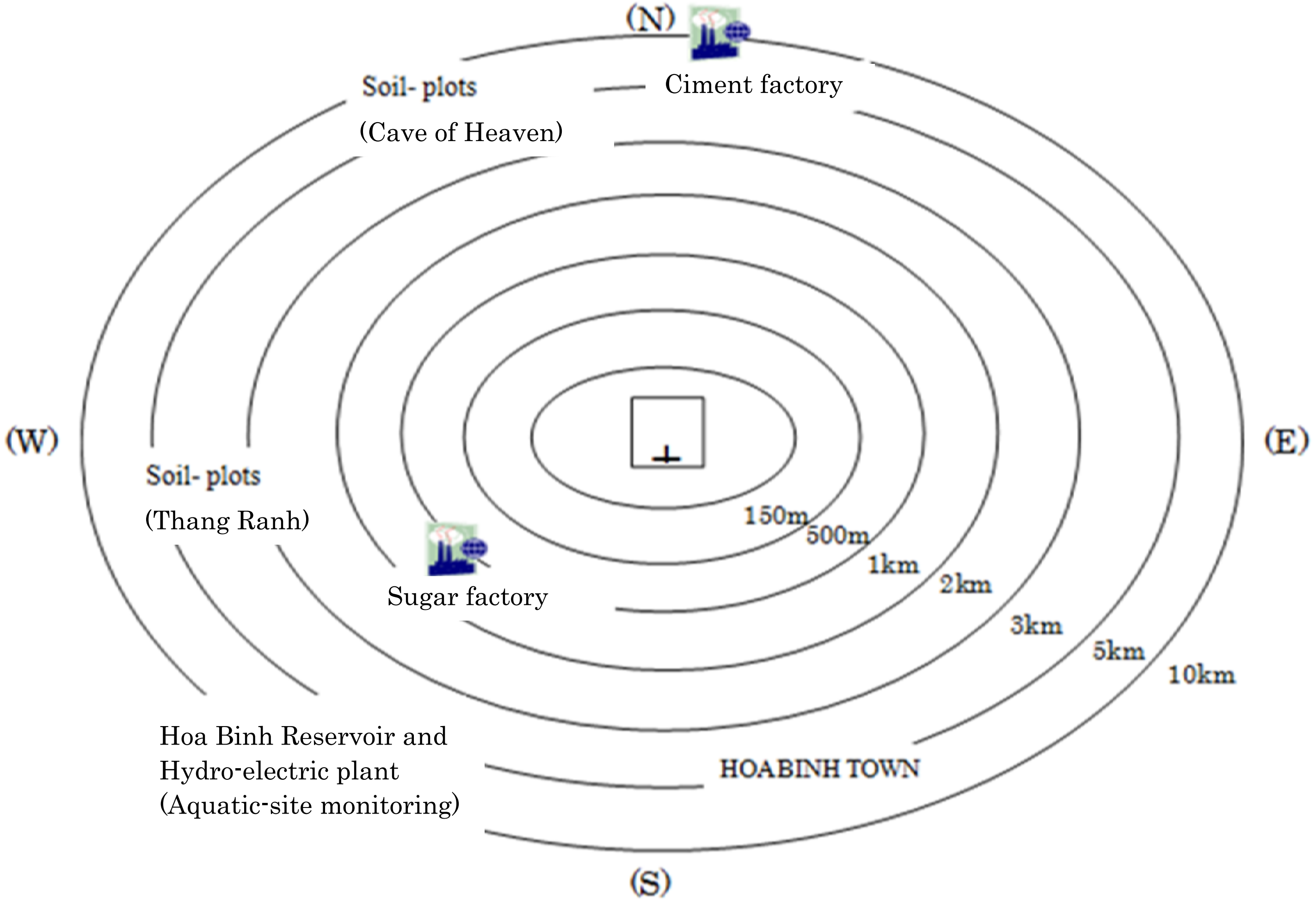
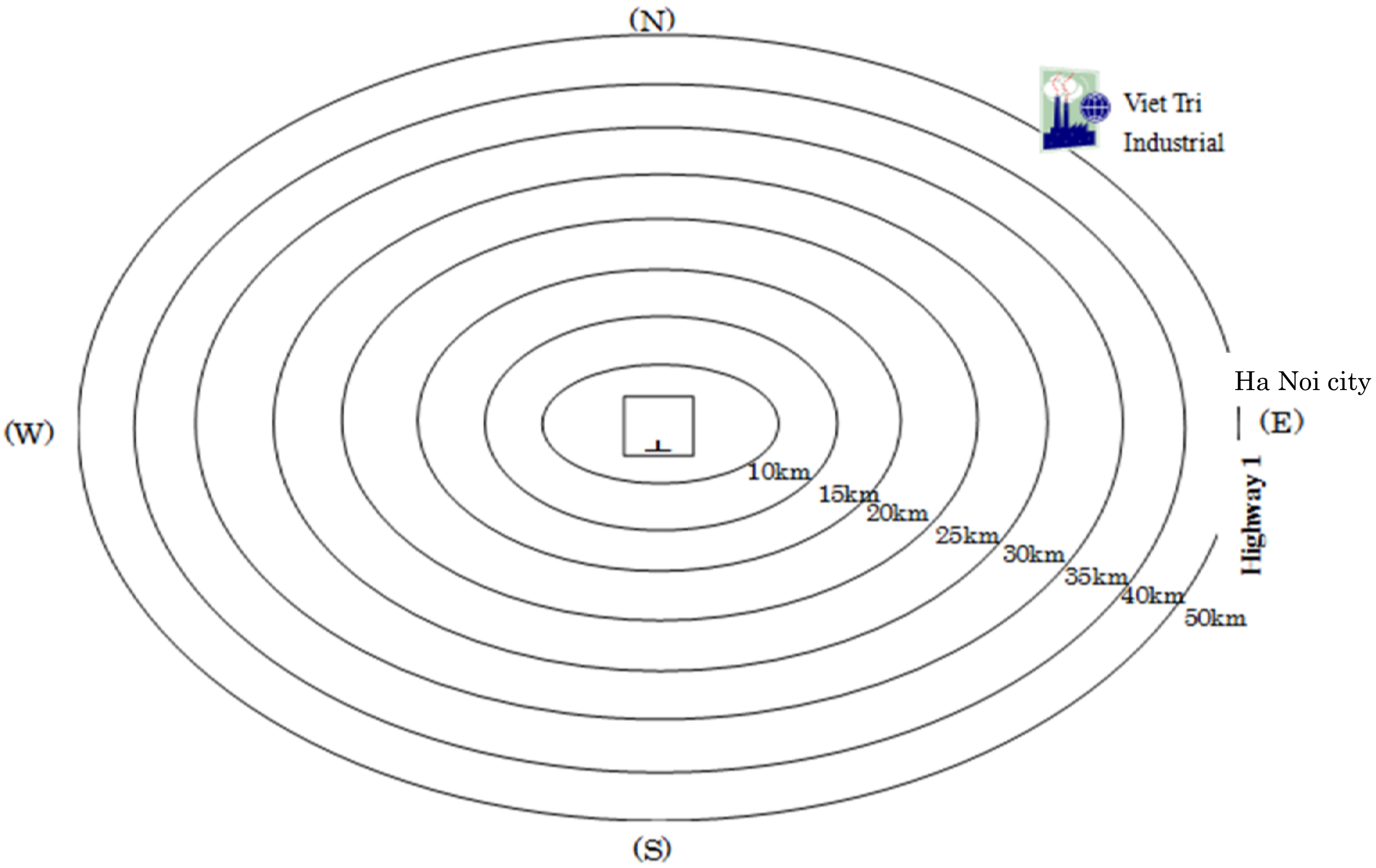
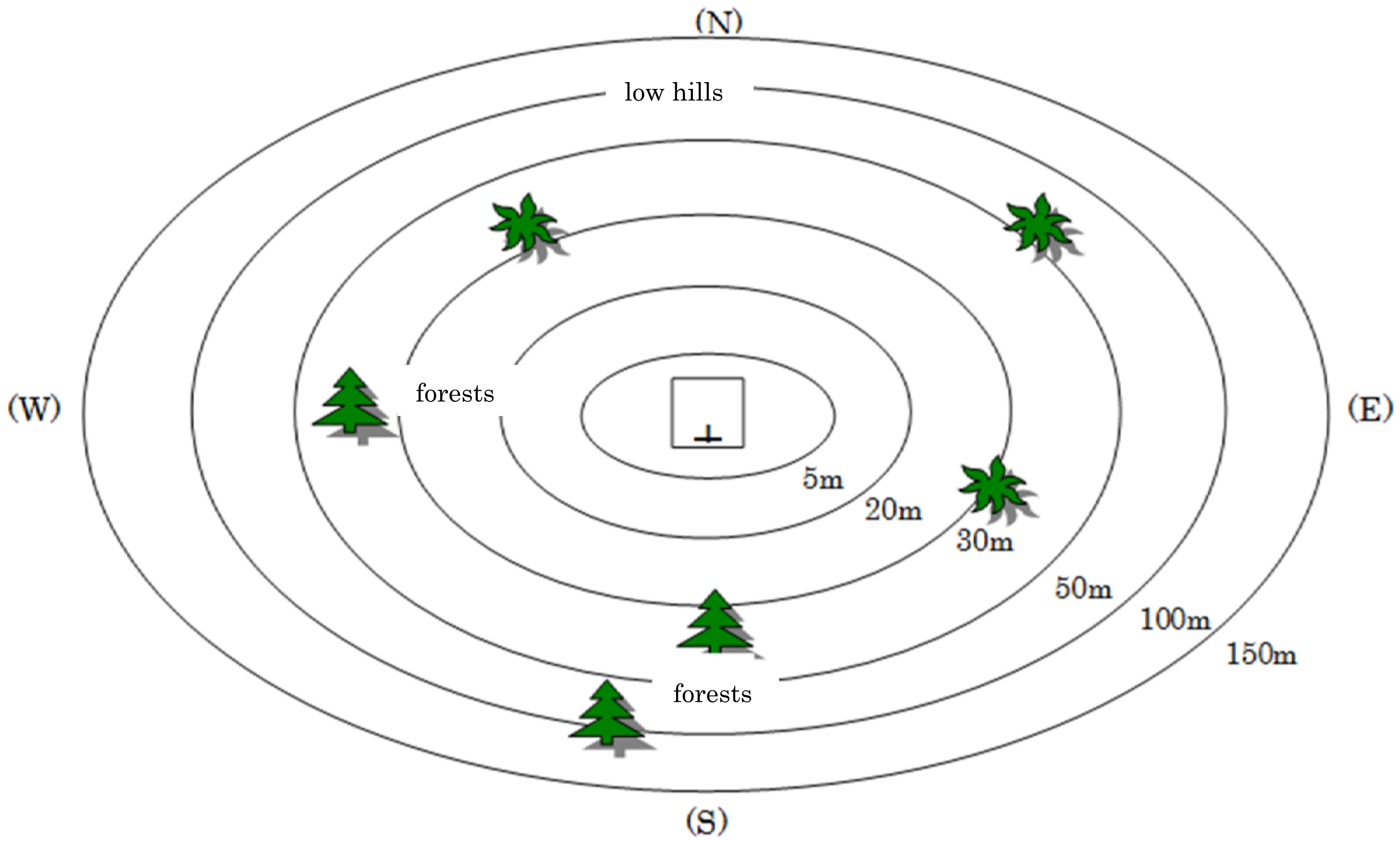


Outline of monitoring site: Regional scale (distance 10 km – 50 km)



c. Cuc Phuong station

Outline of monitoring site: On-site scale (distance within 150 m)



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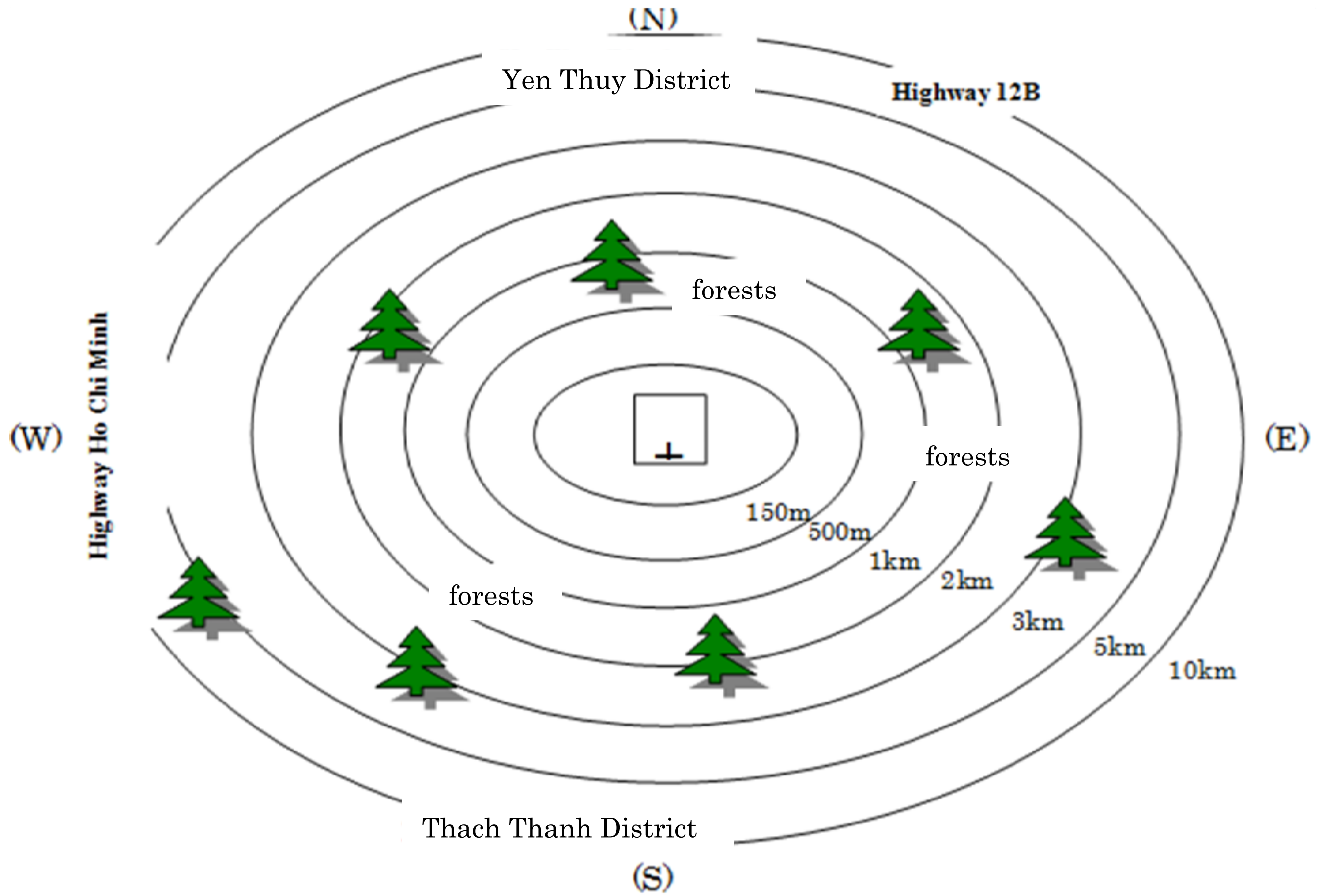
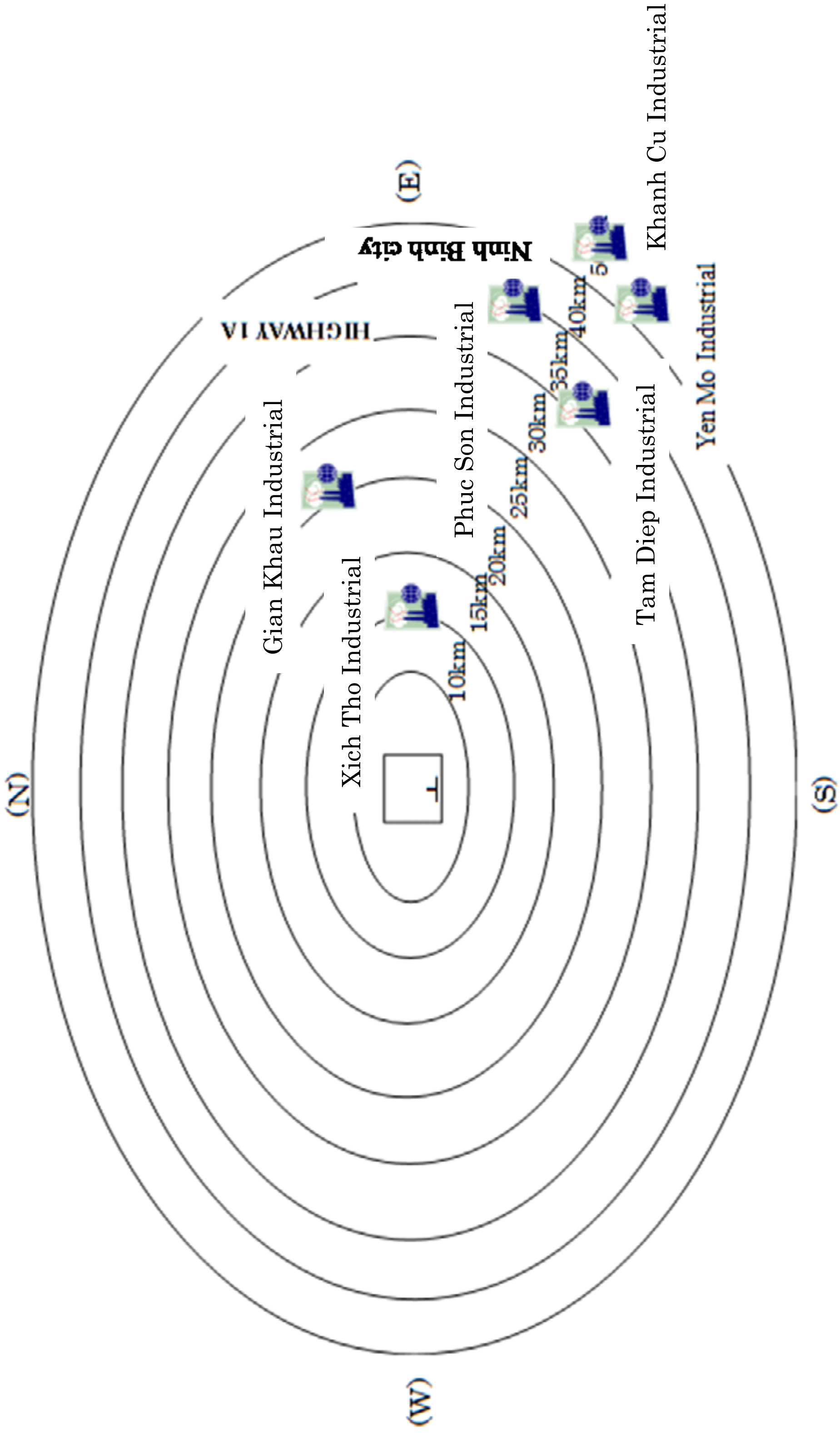
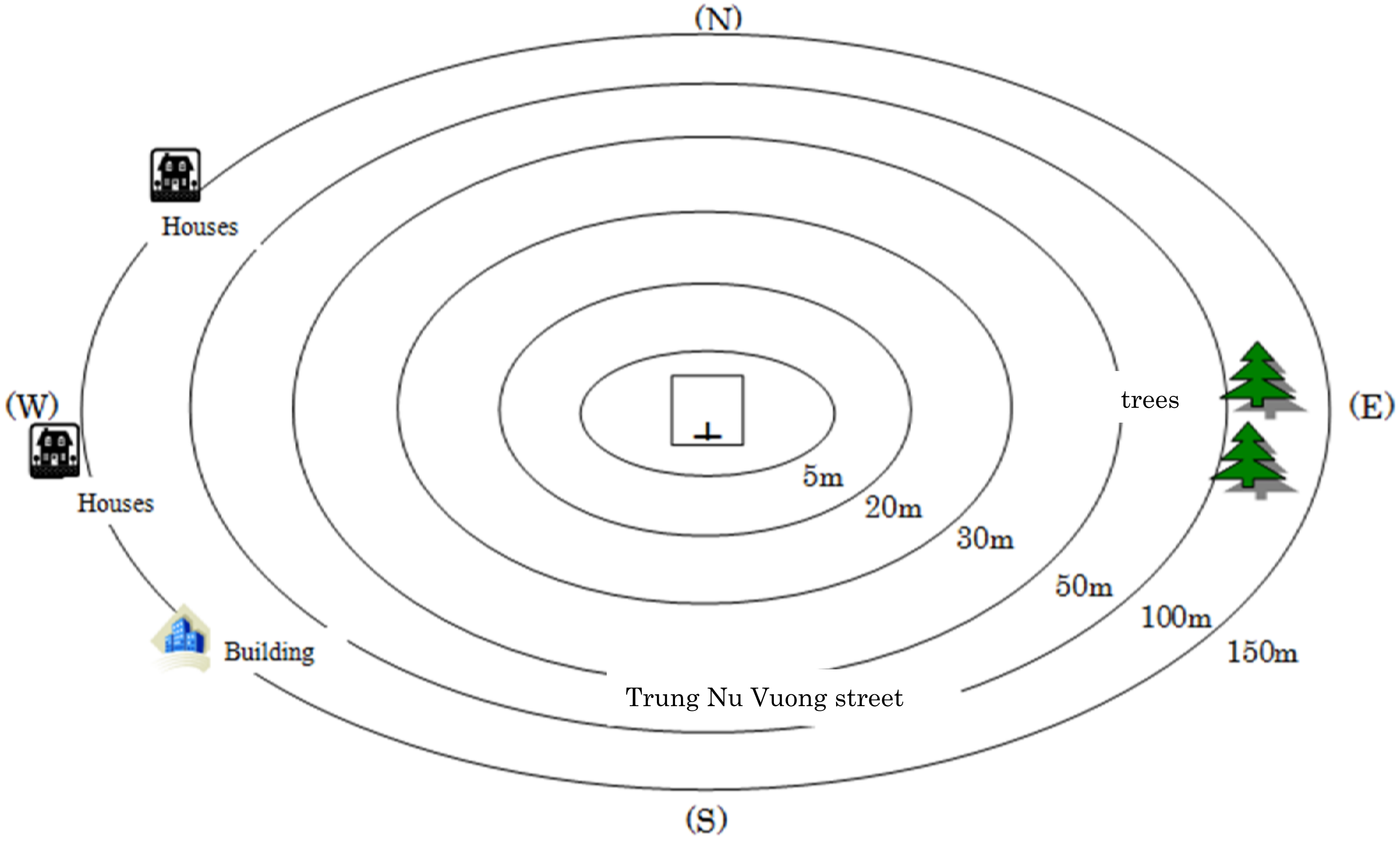


Outline of monitoring site: Regional scale (distance 10 km – 50 km)

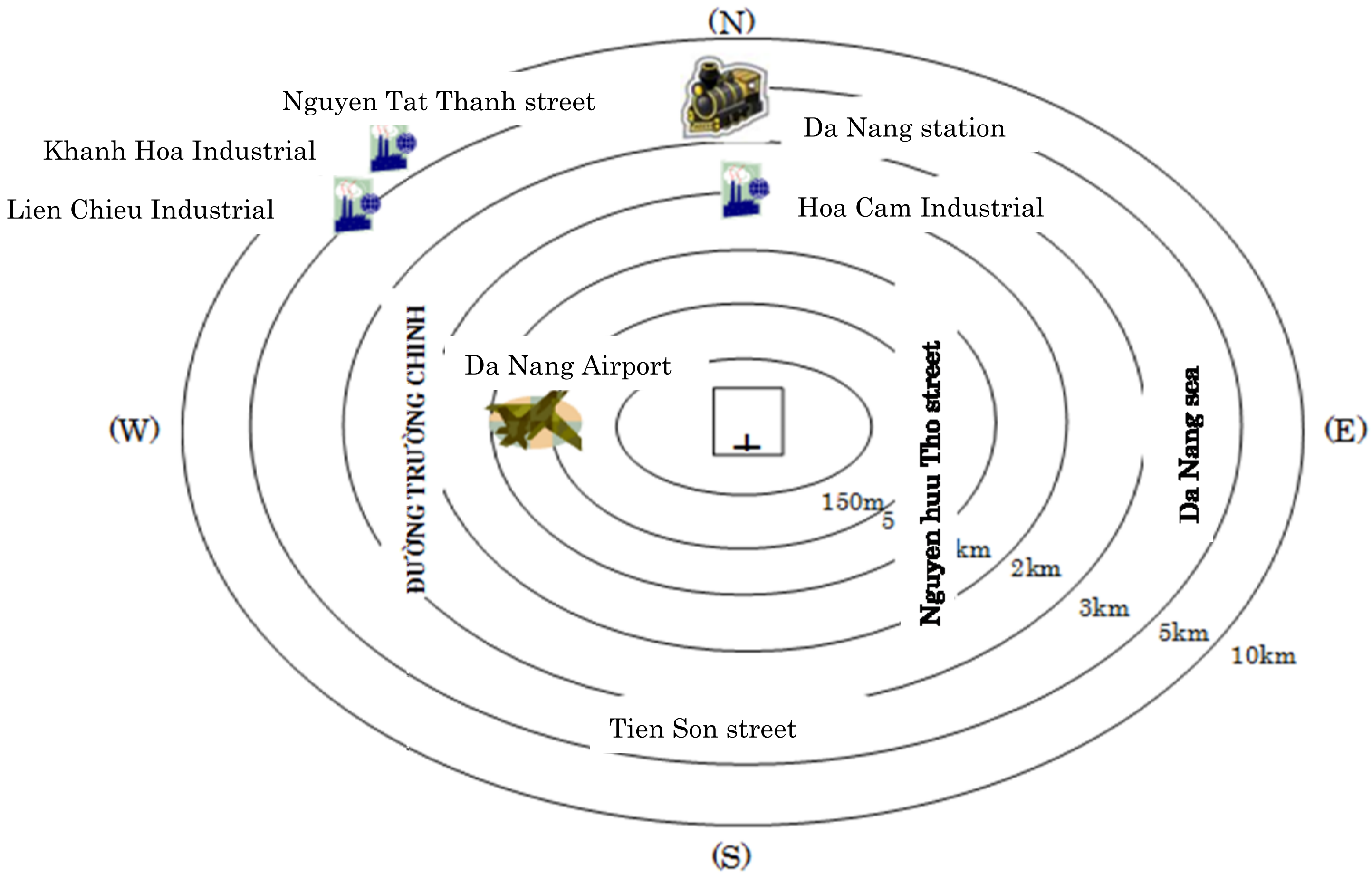


d. Da Nang station

Outline of monitoring site: On-site scale (distance within 150 m)

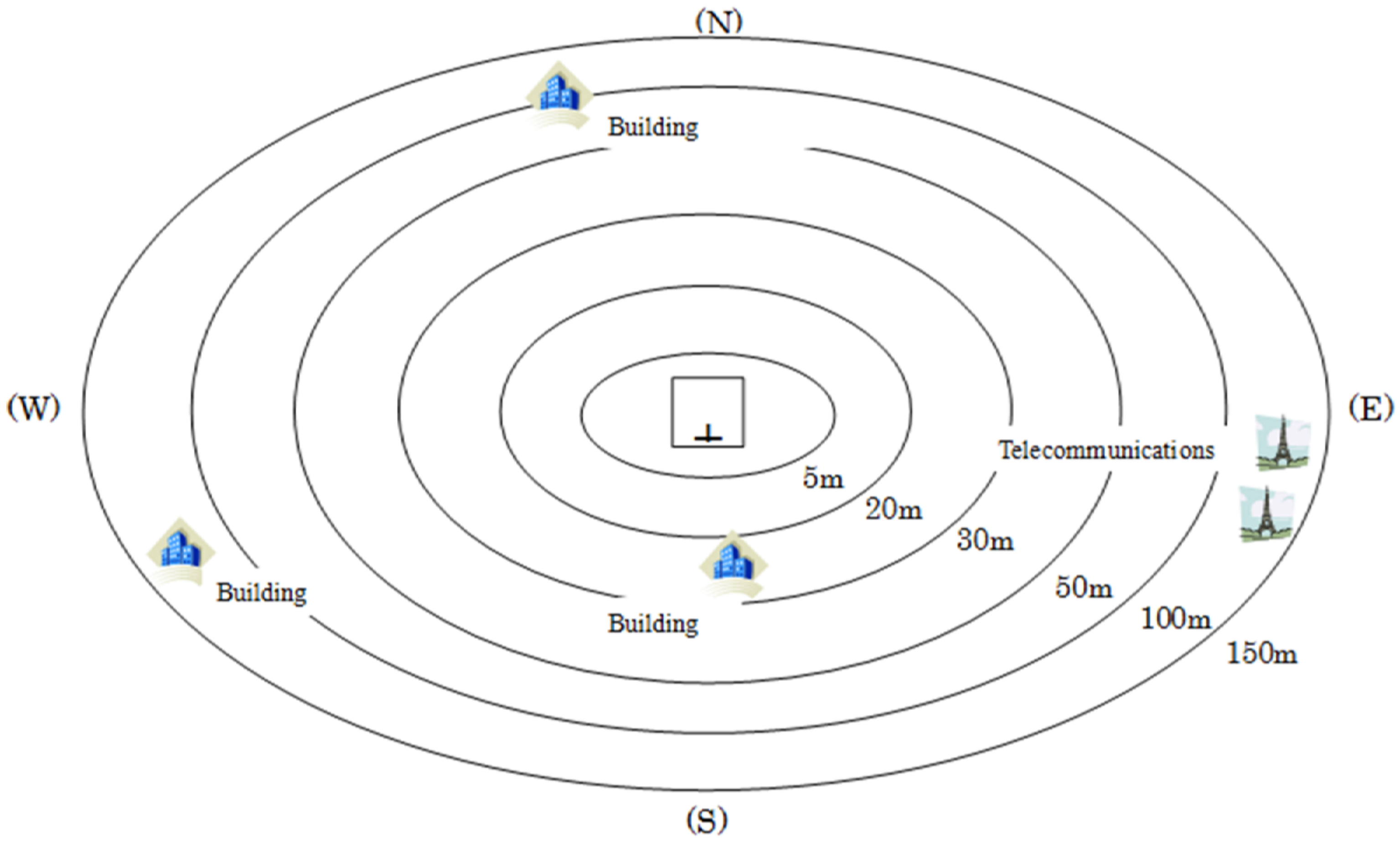


Outline of monitoring site: Local scale (distance 150 m – 10 km)

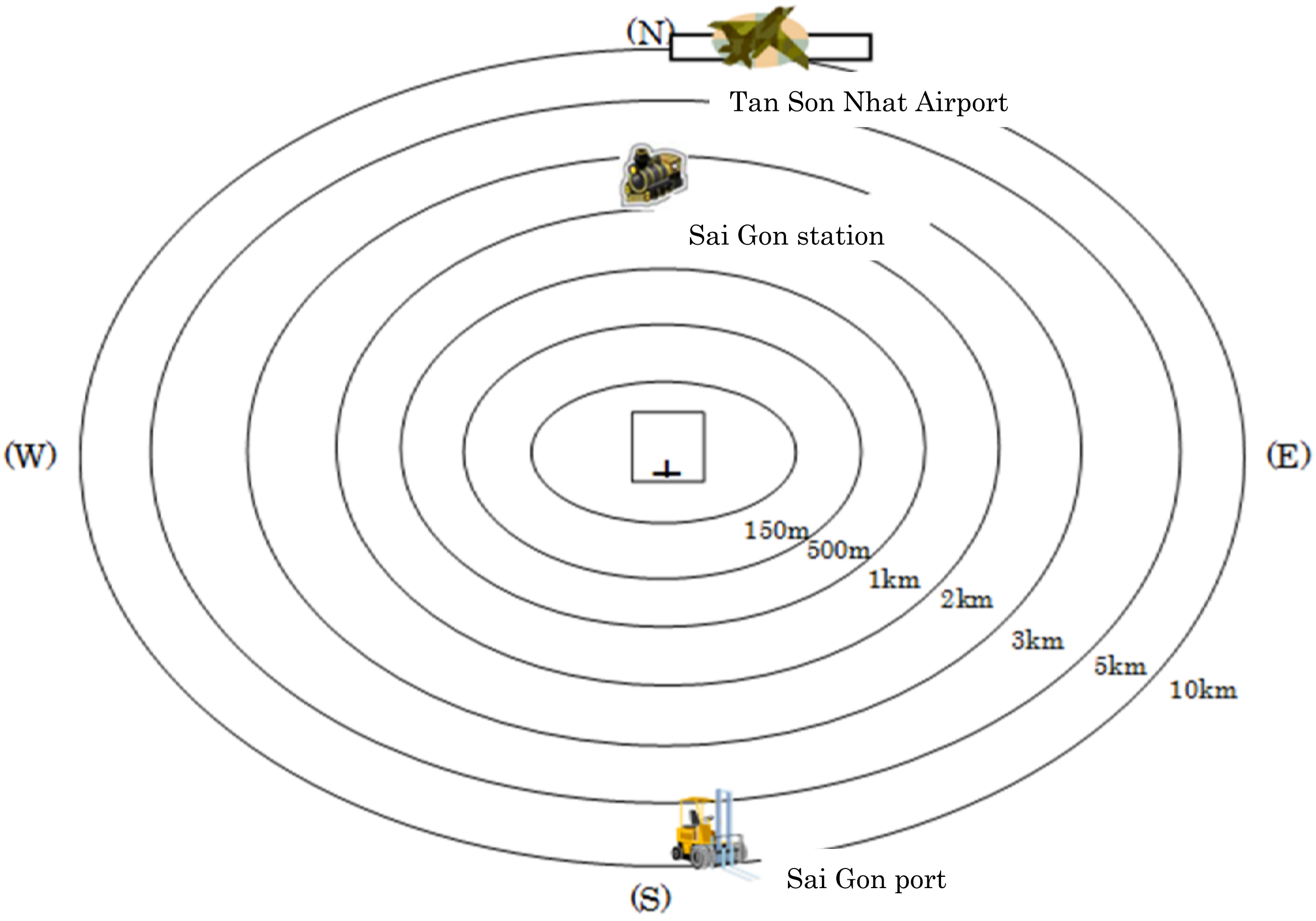


e. Ho Chi Minh city station

Outline of monitoring site: On-site scale (distance within 150 m)

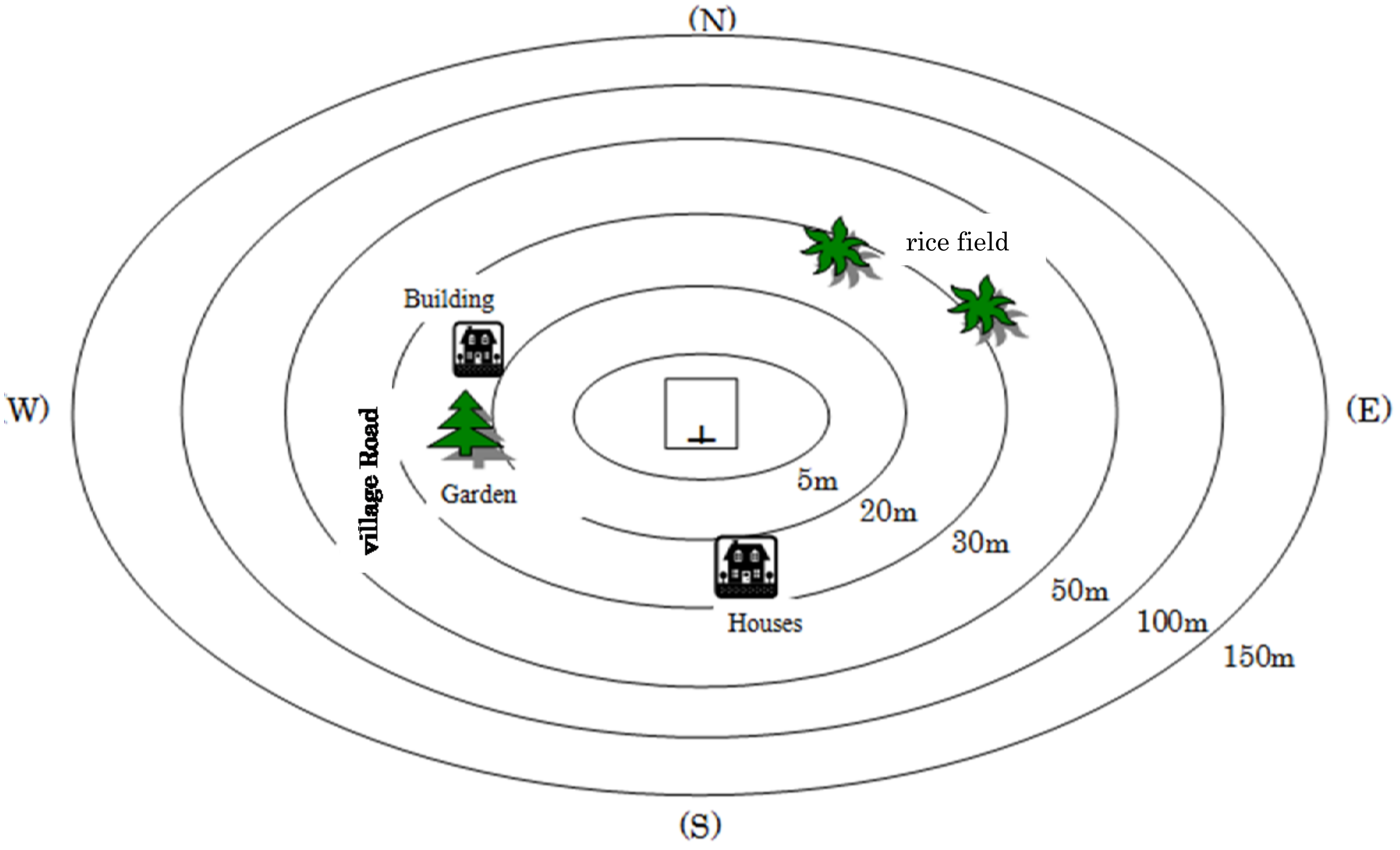


Outline of monitoring site: Local scale (distance 150 m – 10 km)

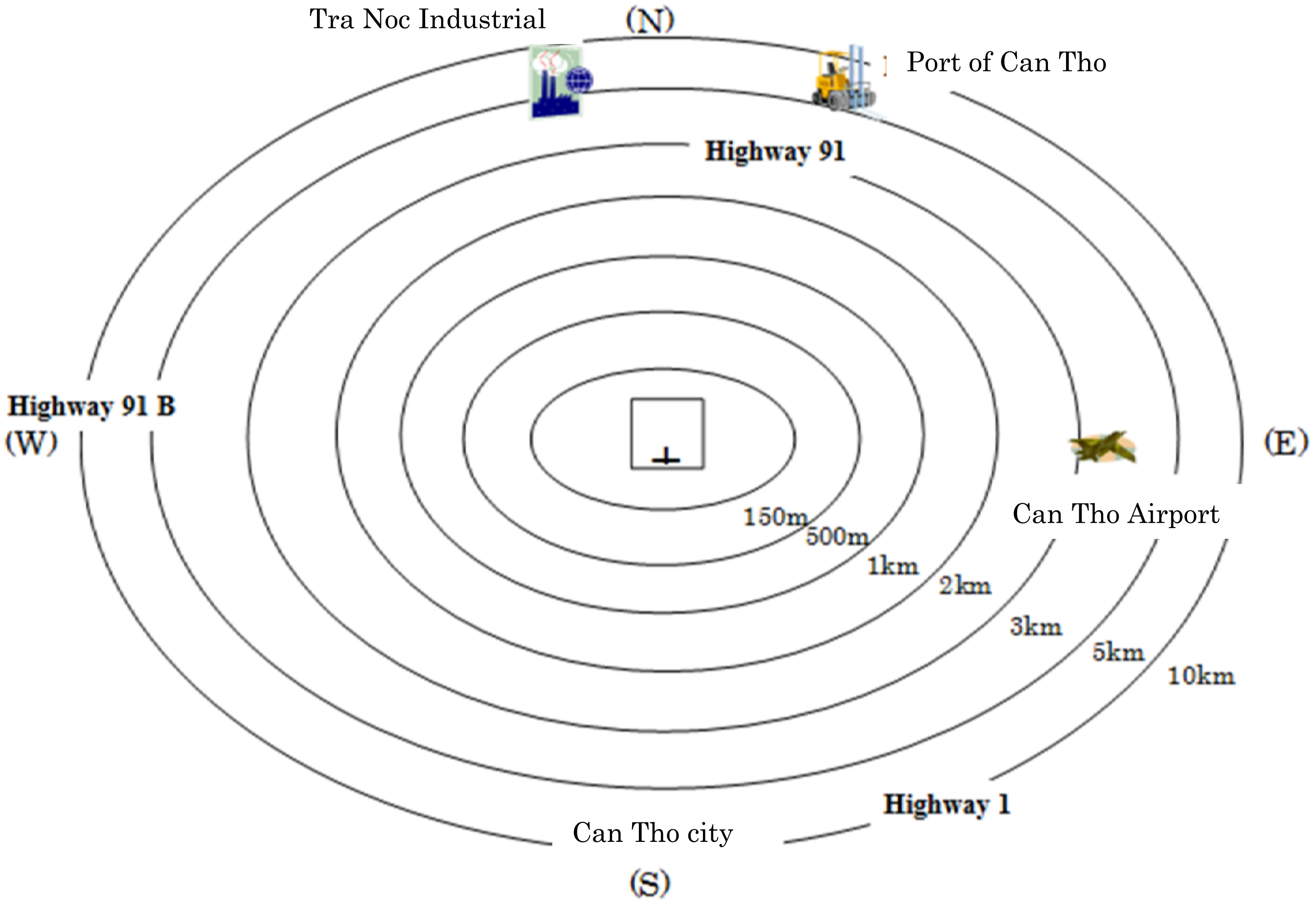


f. Can Tho station

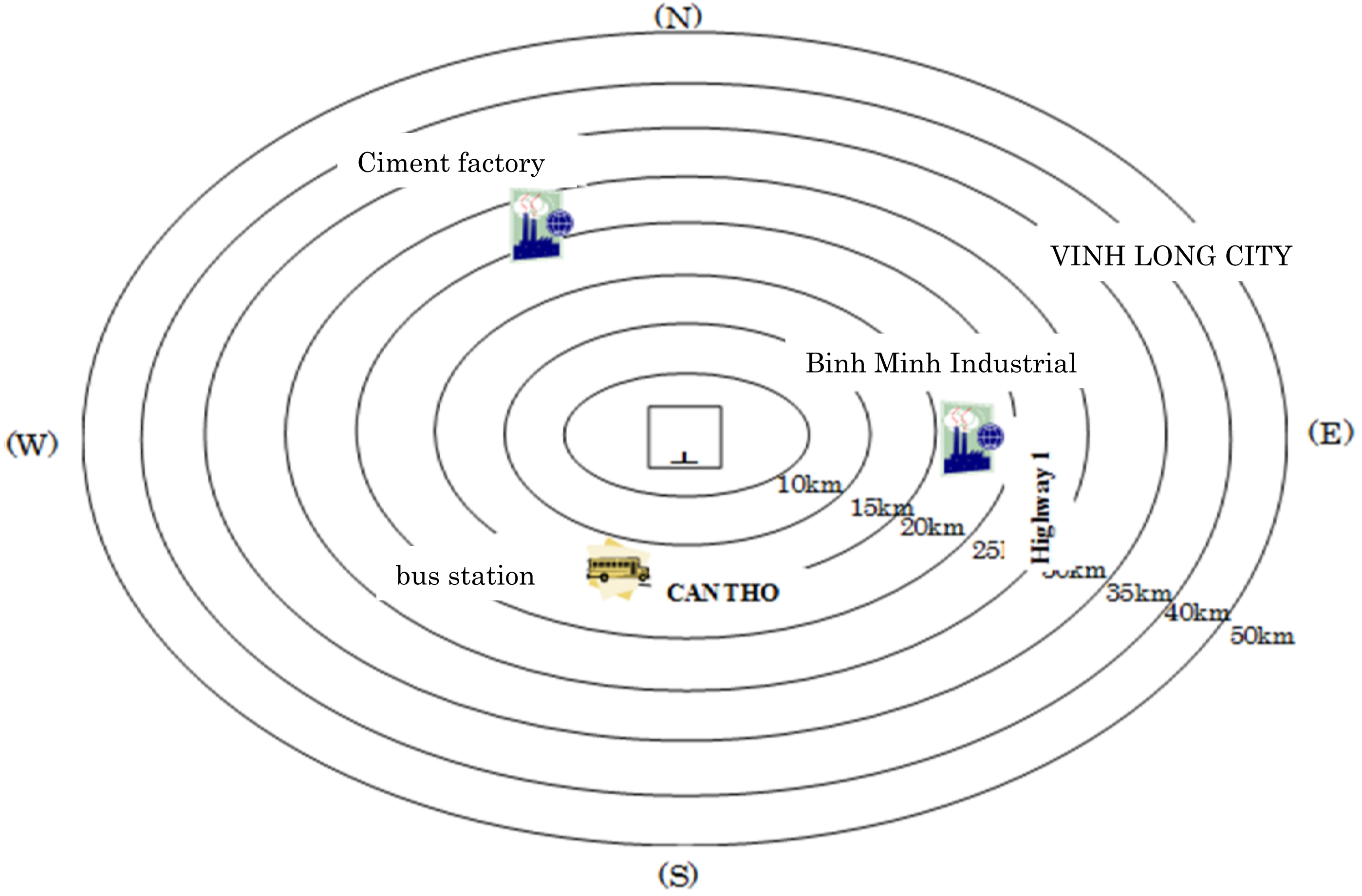
Outline of monitoring site: On-site scale (distance within 150 m)



Outline of monitoring site: Local scale (distance 150 m – 10 km)



Outline of monitoring site: Regional scale (distance 10 km – 50 km)



1.4. Sampling and Measurements

- Wet deposition:
    - Monitoring Interval: 24 hours from 9:00 am to 9:00 am of next day and seven days composite samples can be analyzed in Ha Noi, Hoa Binh, Ho Chi Minh, Can Tho sites. Samples are taken in every precipitation event In Da Nang, Cuc Phuong sites and pH, EC was automatic measured each mm of rainfall; These samples is the combination of 10-day from 2010 to 2012) and 7-day from 2013 to now
    - Monitoring parameters including: pH, EC, F^-, Cl^-, NO_3^-, SO_4^{2-}, Ca^{2+}, Mg^{2+}, K^+, Na^+, NH_4^+; meteorological parameters (temperature, humidity, wind velocity, wind direction, rainfall, ultra-violet).
    - Analytical Method: pH meter, EC meter, IC for anions and NH_4^+, Na^+, AAS for cations
- Dry deposition:
    - Monitoring method: Filter Pack,
    - Monitoring Interval: seven days, from 9:00 am, Monday this week to 9:00 am, Monday next week,
    - Monitoring parameters: Gases: SO_2, HCl, HNO_3, NH_3 and ions Cl^-, NO_3^-, SO_4^{2-}, Ca^{2+}, Mg^{2+}, K^+, Na^+, and NH_4^+ in the aerosol.
    - Analytical Method: pH meter, EC meter, IC for anions and NH_4^+, Na^+, AAS for cations.
- Inland aquatic environment:
    - Monitoring Interval: 4 times/year,
    - Monitoring parameters: pH, EC, Cl^-, NO_3^-, SO_4^{2-}, Ca^{2+}, Mg^{2+}, K^+, Na^+, NH_4^+, alkalinity and COD, NO_2^-, clarity.
    - Analytical Method: pH meter, EC meter, IC for anions and NH_4^+, Na^+, AAS for cations, titration method for alkalinity at pH 4.8 endpoint, $KMnO_4$ method for COD and colorimetry for NO_2^-
- Soil and vegetation environment: Since location of Hoa Binh station does not meet the technical requirements of the station's acid deposition assessment in period 2009-2014, so this station was conducted measurements. Recommend to the support of EANET Network Center to select new monitoring station in Cuc Phuong province.

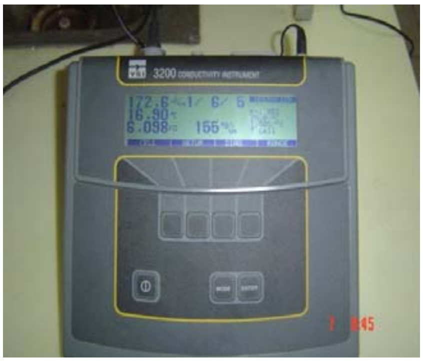
Wet only Sampler (OgasawaraUS330)

Wet Sampler with pH, EC automatic measurement each mm of rainfall (Kimoto MCSAM-6-VB)

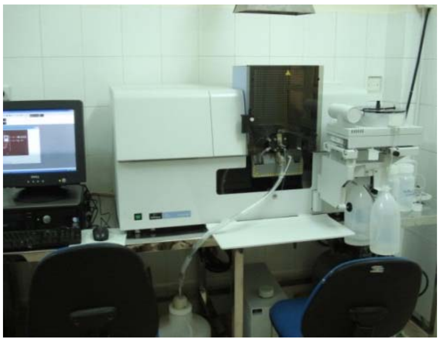
Some equipment for Acid Deposition Monitoring Analysis in Environmental Laboratory - Center for Environmental Research - IMHEN- MONRE

IC Metrohm Mic 3

pH meter – 793 Metrohm



EC meter – YSI 3200



AAS800 of PerkinElmer

UV-Vis system –HP8453

Untrasonic bath

Extra-pure Water system 611 DI Sartorius

Water still Instruction

Chapter 2. State of Acid Deposition in Vietnam

2.1 Outline of the activities on acid deposition and National Monitoring Plan

2.1.1 State of wet deposition

a) pH of rain water

In general, in period of 2005 – 2014, annual average pH values of sites such as Hoa Binh (HB), Cuc Phuong (CP) and Da Nang (DN) are below 5.6, especially, in Danang site the annual average pH values are the lowest, in range of 4.75 – 5.58. Therefore, it means that acid rain has occurred frequently in Hoa Binh, Cuc Phuong and Da Nang. In Hanoi site, the annula average pH values are relatively high, almostly over 5.6 except in 2011 (pH = 5.25). In period of 2010- 2014, pH values of sites Hoa Binh, Cuc Phuong and Da Nang have the increasing trend. Only in Hanoi site, a slightly decreasing trend has been observed. For new sites Can Tho (CT) and Ho Chi Minh (HCM) city (from 2014), pH values fluctuate in range of 5.85 – 6.26, no acid rain has been traced.

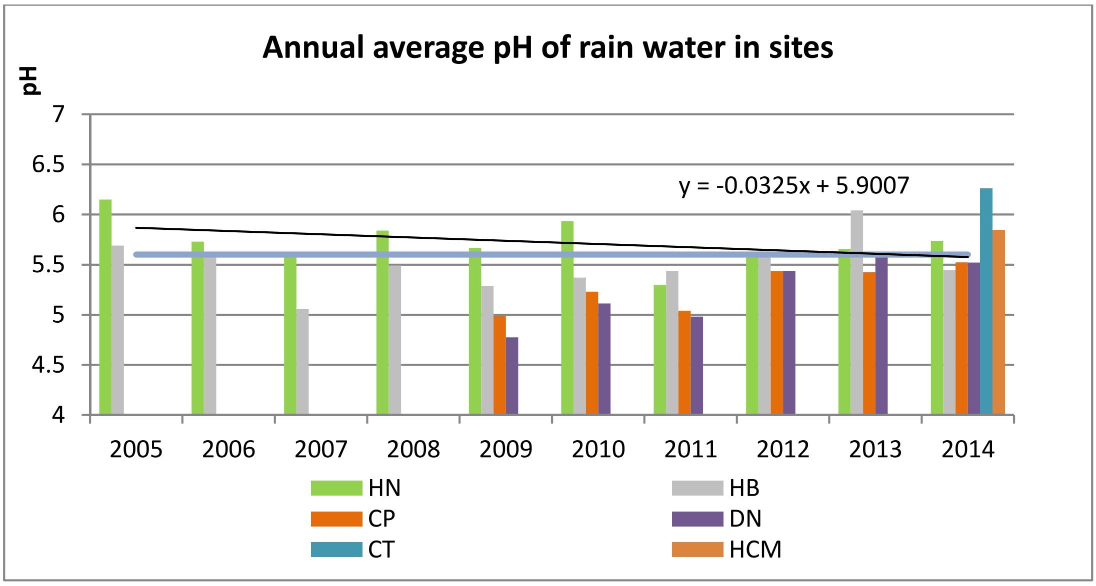


Figure 2.1: Graph of annual average pH of rainwater in sites (2005 – 2014).

In period of 2010 – 2014, annual precipitation amounts in sites like Hanoi, HoaBinh and CucPhuong are similar, in range of 1100mm - 2000mm. Especially, the precipitation at DaNang site has changed dramatically, which gets peak in 2011 (3639mm), at half as much as other years, however, its pH value got the lowest (pH= 5.0)

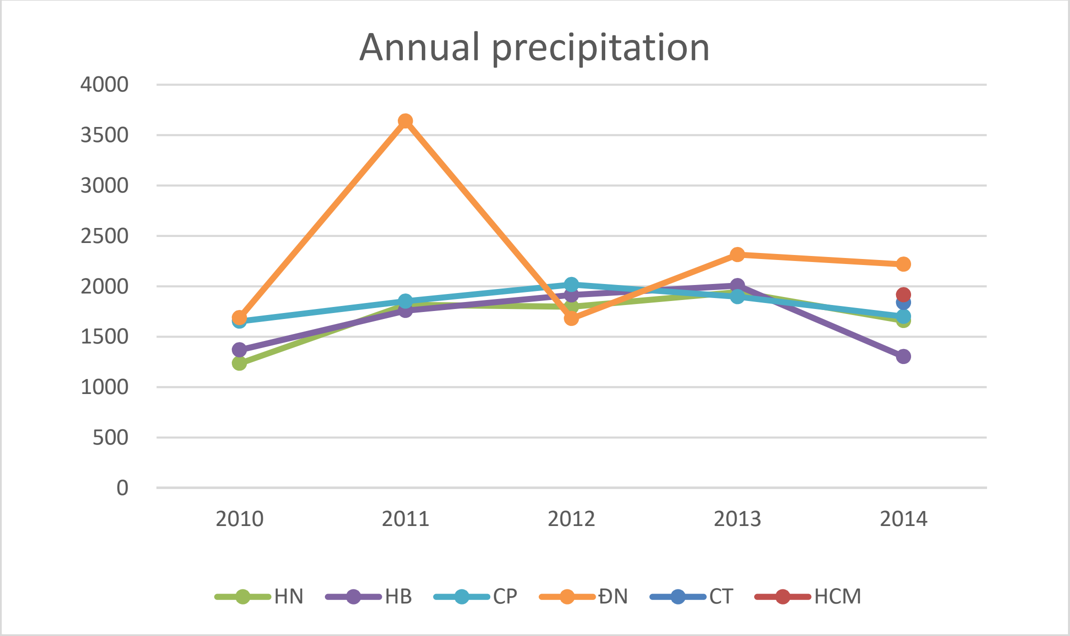
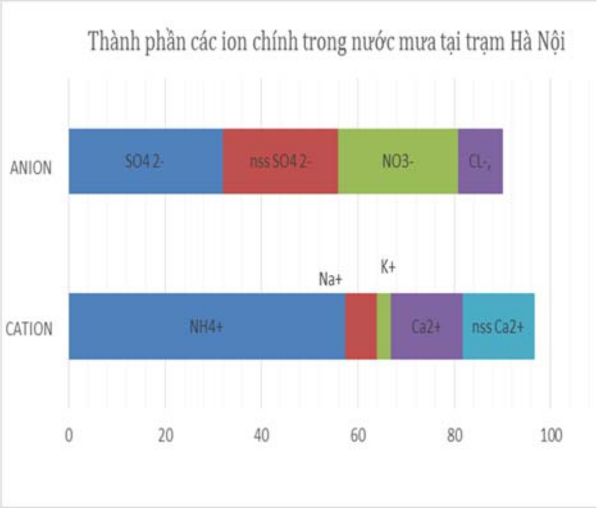
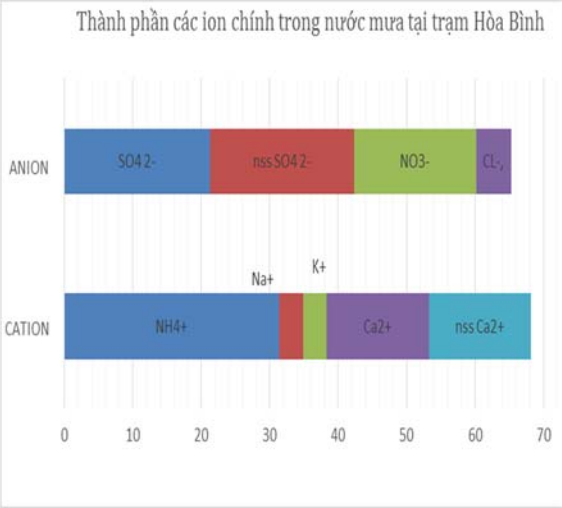


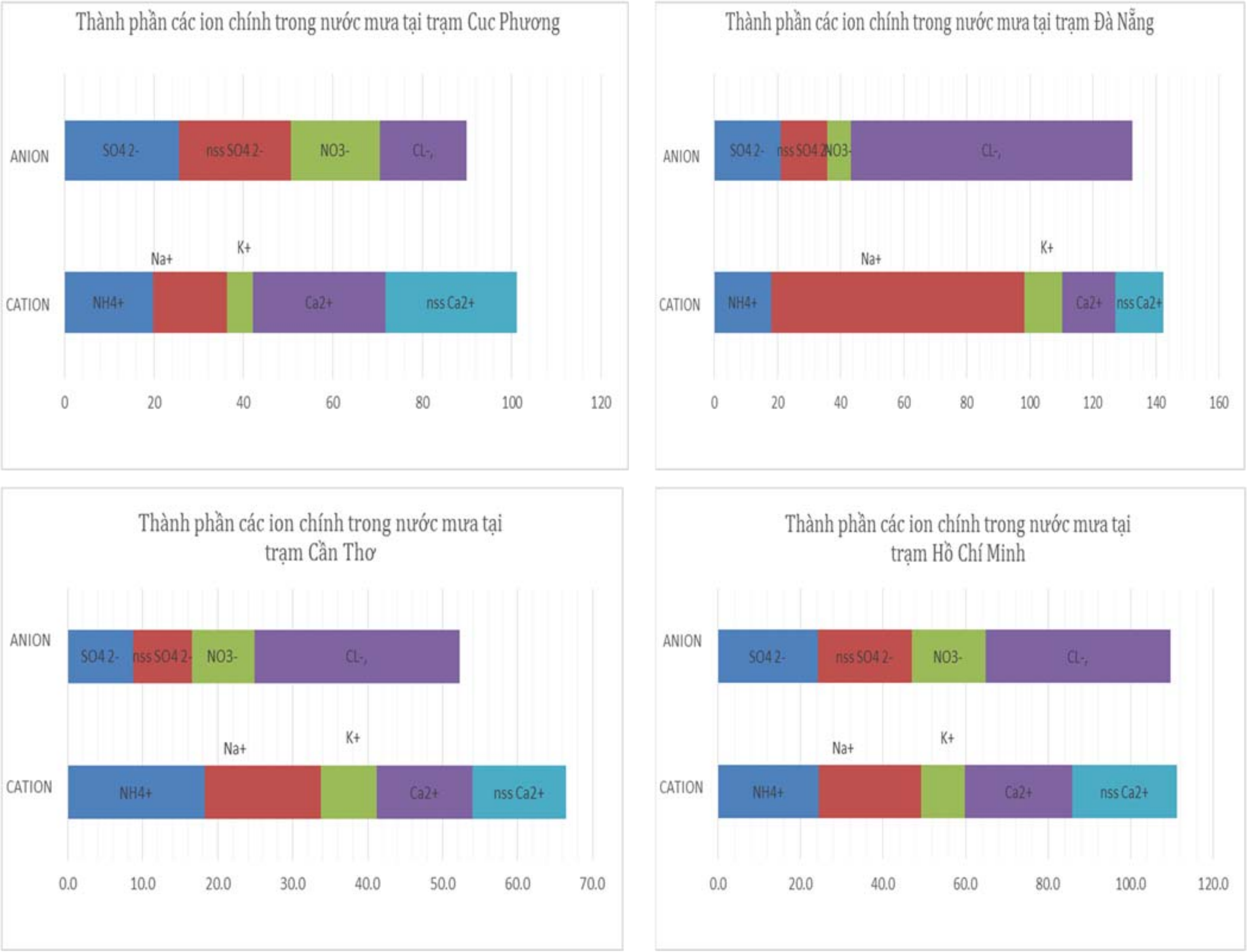
Figure 2.2: Annual precipitation amount in sites (2010 – 2014)

b) Ion composition in rain water:

In sites as Hanoi, Hoa Binh and Cuc Phuong, ions of SO_4^{2-}, NO_3^-, NH_4^+, Ca^{2+} are predominant in ion composition of rainwater. In particular, concentration of NH_4^+ in rainwater of Hanoi site is very high. Ion composition in rainwater of Da Nang, Can Tho and Ho Chi Minh sites have traced seasalt effect leading to high concentration of Cl^- và Na^+ ions, especially at Da Nang site.







Thành phần các ion chính trong nước mưa tại trạm Cuc Phương

Thành phần các ion chính trong nước mưa tại trạm Đà Nẵng

Thành phần các ion chính trong nước mưa tại trạm Cần Thơ

Thành phần các ion chính trong nước mưa tại trạm Hồ Chí Minh

Figure 2.3. Major ions composition in rainwater of sites (2010 – 2015)

c) Trend of annual ion concentration and wet deposition variation

Annual variation of ions nss- SO_4^{2-}, NO_3^-, H^+ concentration and wet deposition in sites (2010 – 2014) are presented in above figures. There is a singnificant variation in DN site in 2011 with peak of precipitation amount and low pH value, resulting to high concentration and wet deposition of ions (nss- SO_4^{2-}, NO_3^-, H^+ are 61 mmol/m^2/y, 57 mmol/m^2/y, 38 mmol/m^2/y, respectively). For Hanoi and Hoa Binh sites, ions concentration and wet deposition are lower than those of Cuc Phuong and Da Nang sites.

There is a similar pattern of annual variation between Hanoi and Hoa Binh sites; nss- SO_4^{2-} and NO_3^- have the increasing trend while H^+ has the decreasing trend in the both sites. Besides, Cuc Phuong and Da Nang sites have the same trend; both of 3 ions have a decreasing trend over time.

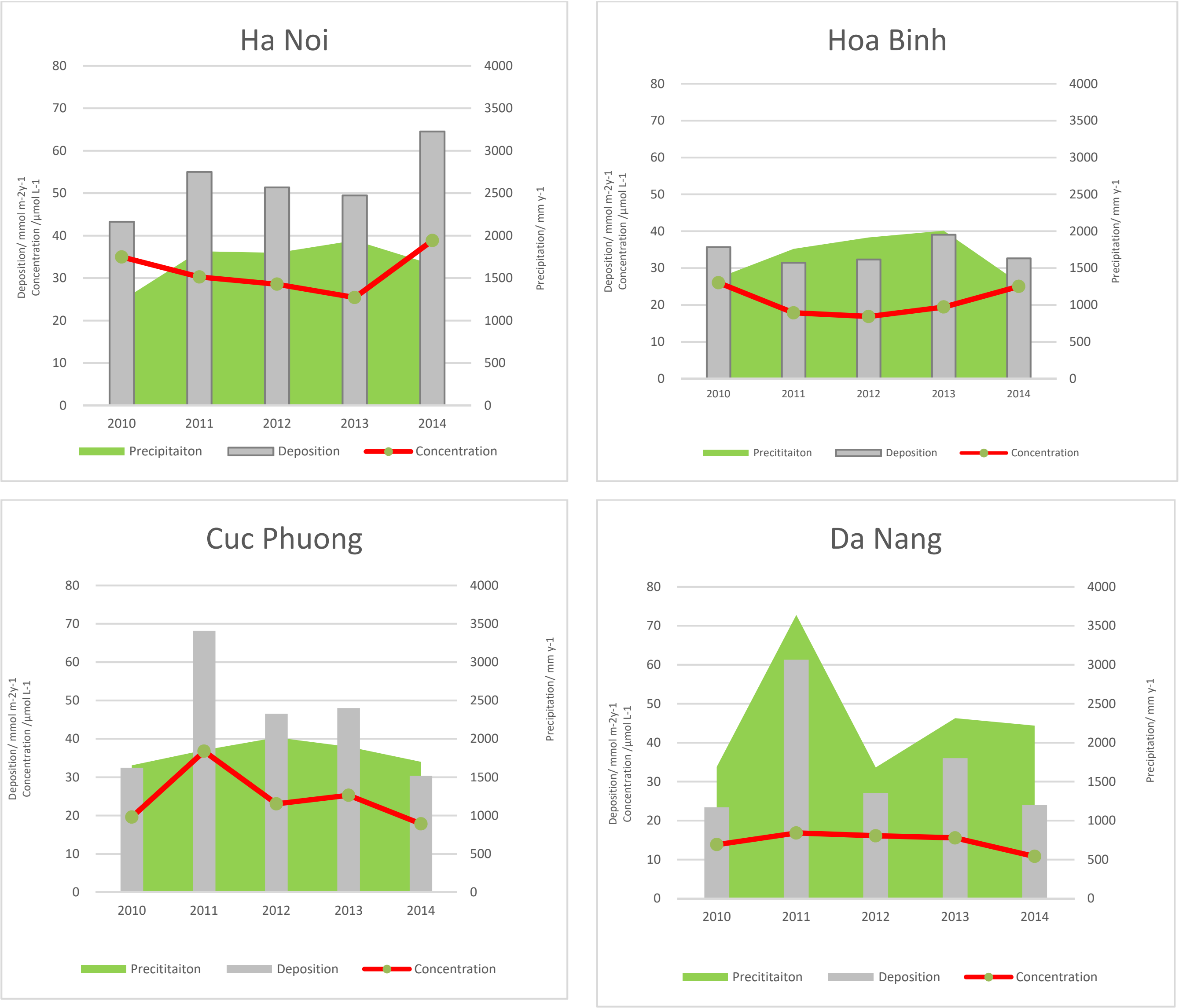


Figure 2.4. Variation of annual nss- SO_4^{2-} concentration and wet deposition in sites (2010 – 2014)

Figure 2.5. Variation of annual NO_3^- concentration and wet deposition in sites (2010 – 2014)

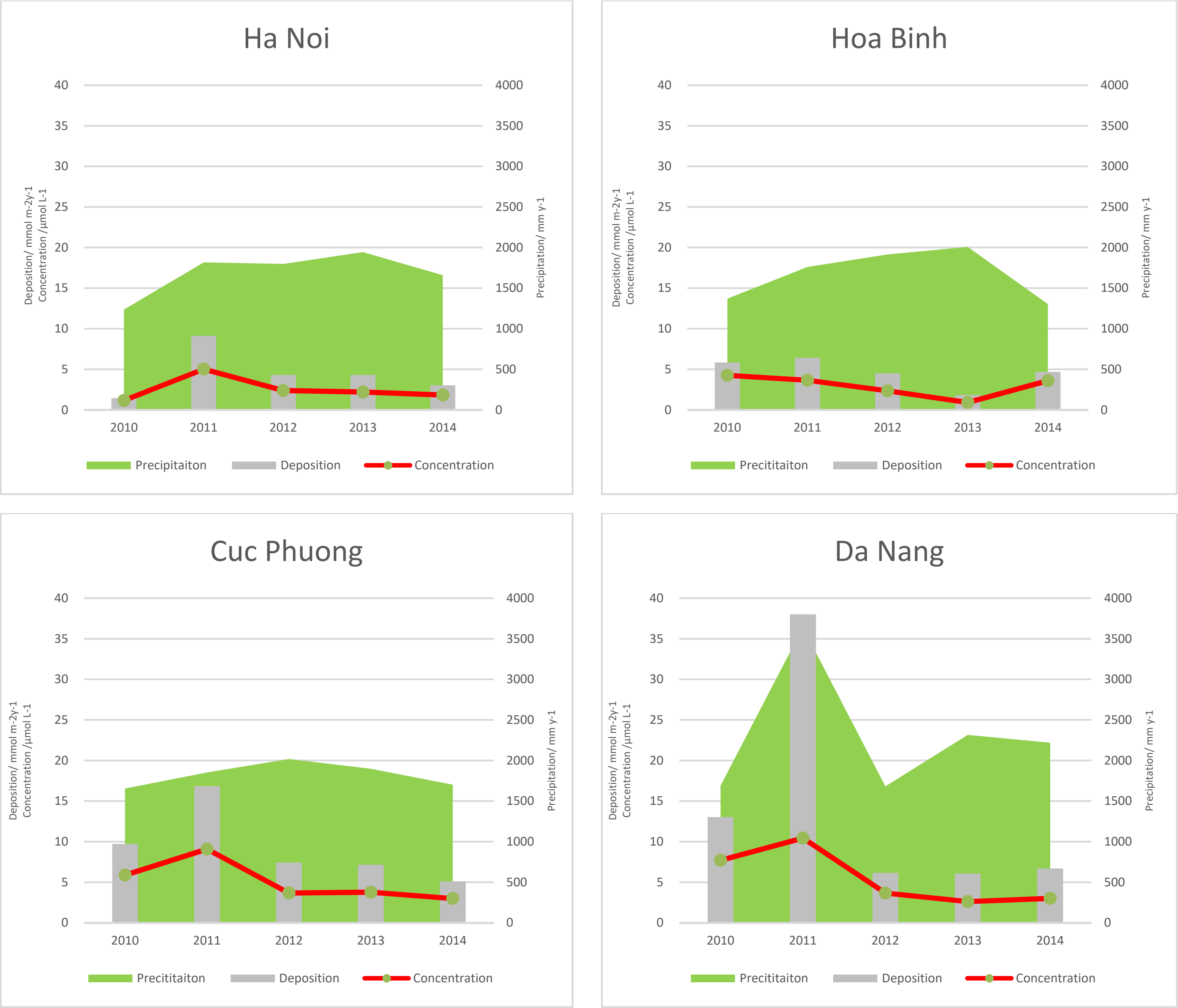


Figure 2.6. Variation of annual H^+ concentration and wet deposition in sites (2010 – 2014)

Seasonal variation of ions wet deposition in sites (2010 – 2014)

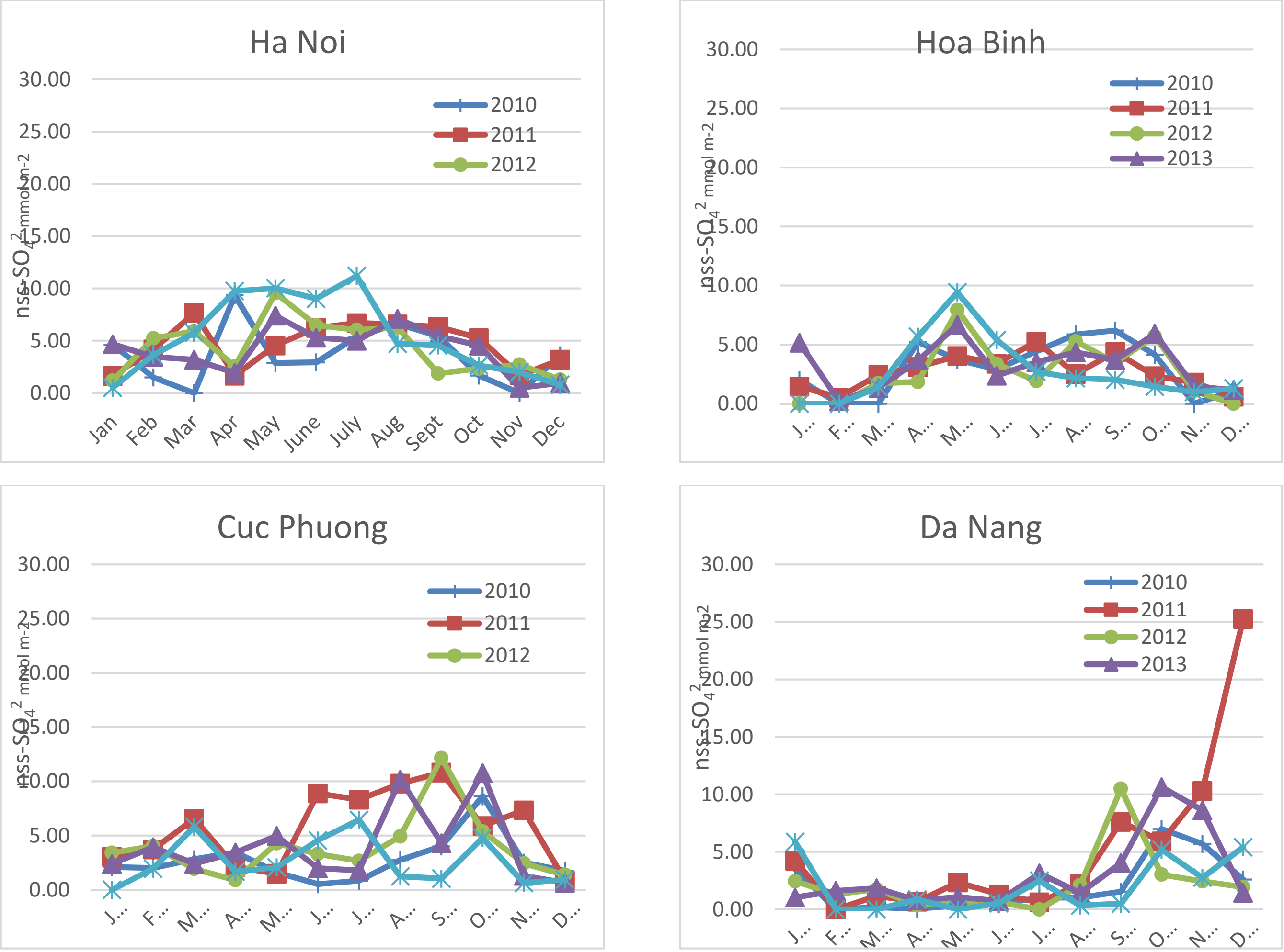
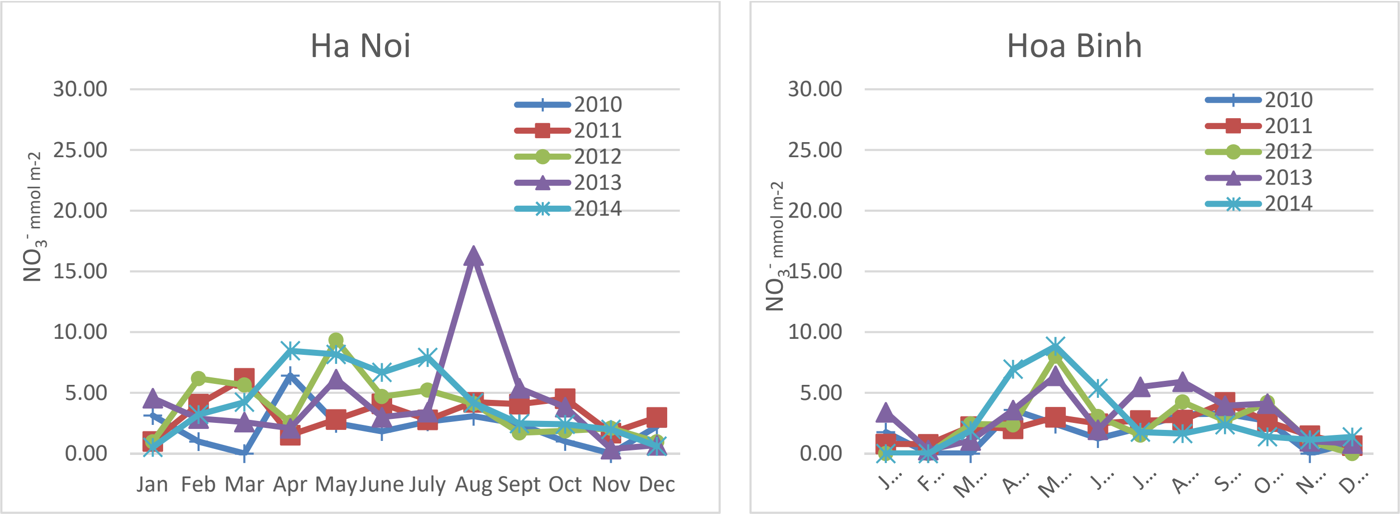


Figure 2.7. Seasonal variation of nss-SO$_4^2$ ion deposition in sites (2010 – 2014)



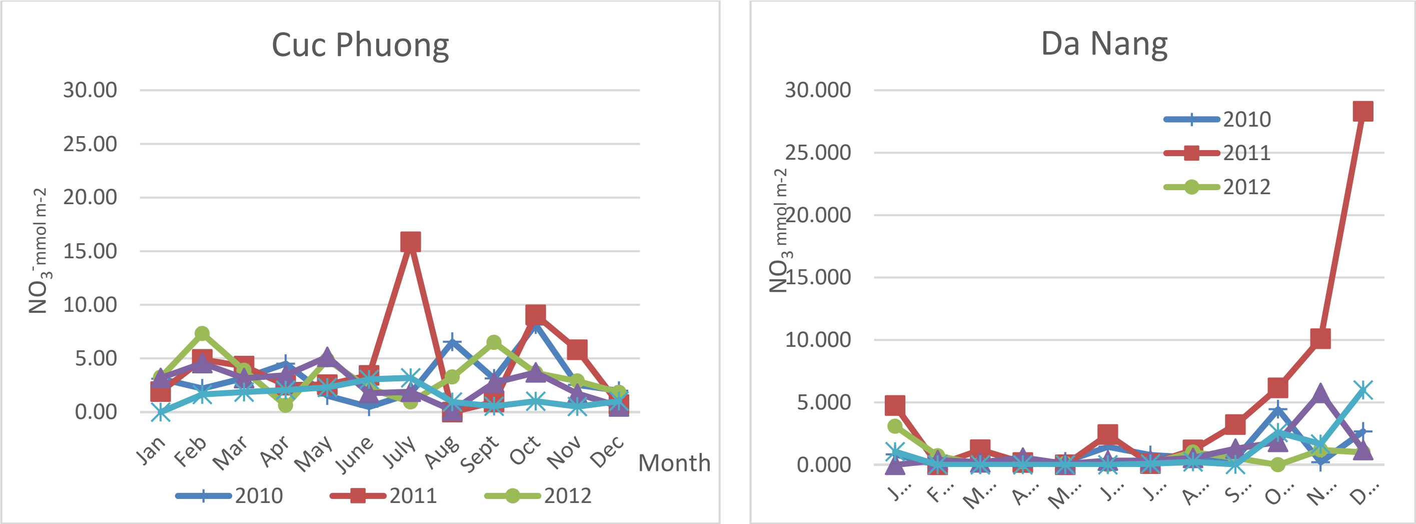


Figure 2.8. Seasonal variation of NO_3^- ion deposition in sites (2010 – 2014)

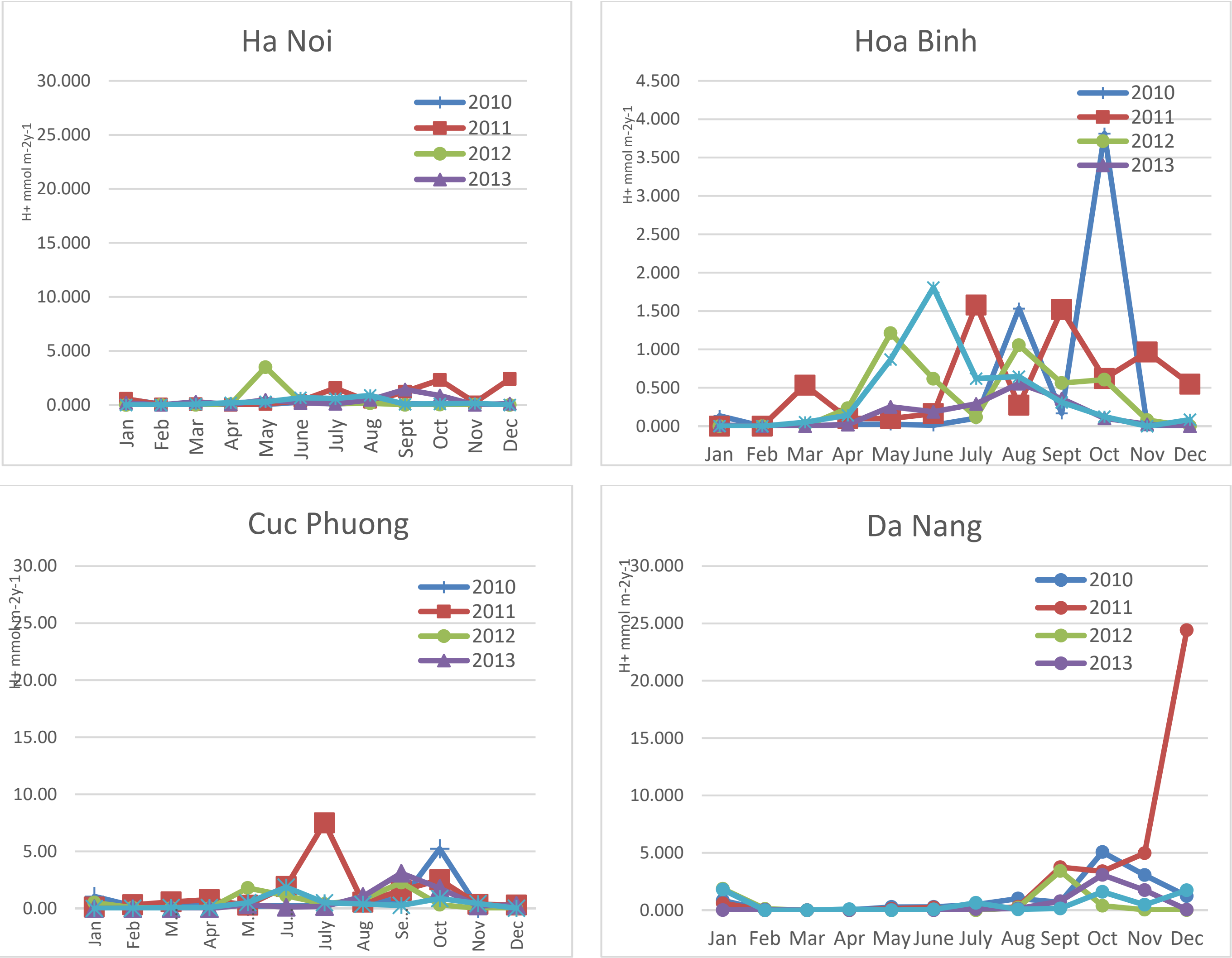
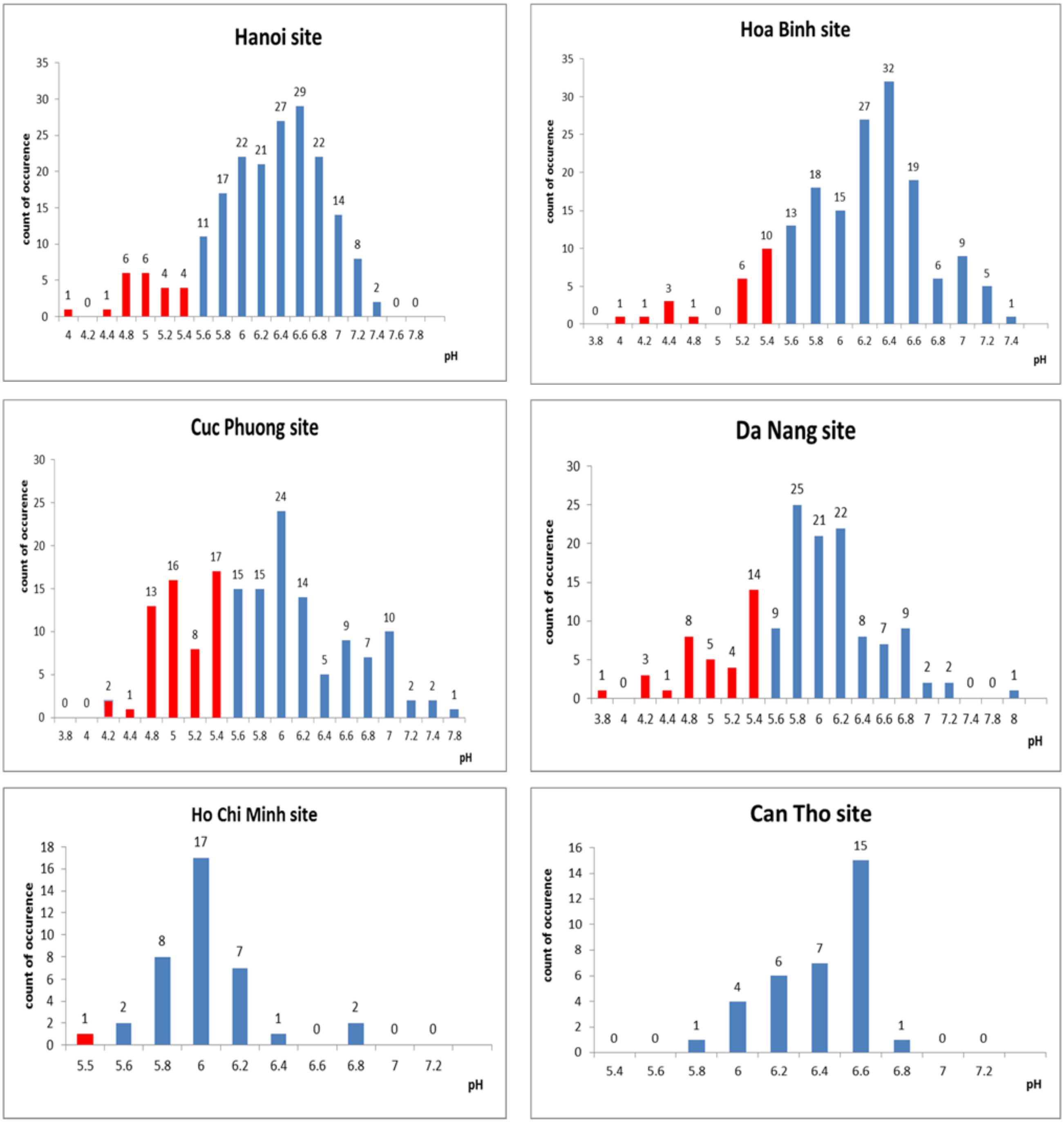


Figure 2.9. Seasonal variation of H^+ ion deposition in sites (2010 – 2014)

Wet deposition amount of ions is largerly dependent on local weather/climate condition, especially rainfall (precipitation amount) and air pollution level. Total wet deposition of nss- SO_4^{2-} in Hanoi, Hoa Binh and Cuc Phuong had a decreasing trend in dry season and a increasing trend in rain season. In DN site, total ion wet deposition has increased in rain season , get a peak in December 2011 (deposition of H+ is 24.4mm/m^2, NO_3^- is 28.32mm/m^2, nss-SO_4^{2-} is 25.25mm/m^2).

d) Current state of acid rain

Result on assessing pH<5.6 frequency in period of 2010- 2014 showed that acid rain frequency is the highest in Cuc Phuong site (35.4%), followed by Da Nang site (25.35%), next to Hanoi (11.22%), and Hoa Binh (3.59%), Ho Chi Minh (2.63%), only Can Tho site not yet been observed acid rain.



Note: For Ho Chi Minh site and Can Tho site, pH data are collected from 2014.

Figure 2.10. Frequency distribution of rainwater pH values in sites (2010 – 2014)

Correlation between pH- pAi of 4 sites (Hanoi, Hoa Binh, Cuc Phuong, Da Nang) presented a bias toward pH, especially in Hanoi site. The reason can be that Ammonia gas and/ or calcium, magnesium in dust can neutralize acids (HSO_4, HNO_3) in rain water. Da Nang site has pH- pAi nearly 1, it means that rainwater is not contaminated by ions NH_4^+ và Ca^{2+}.

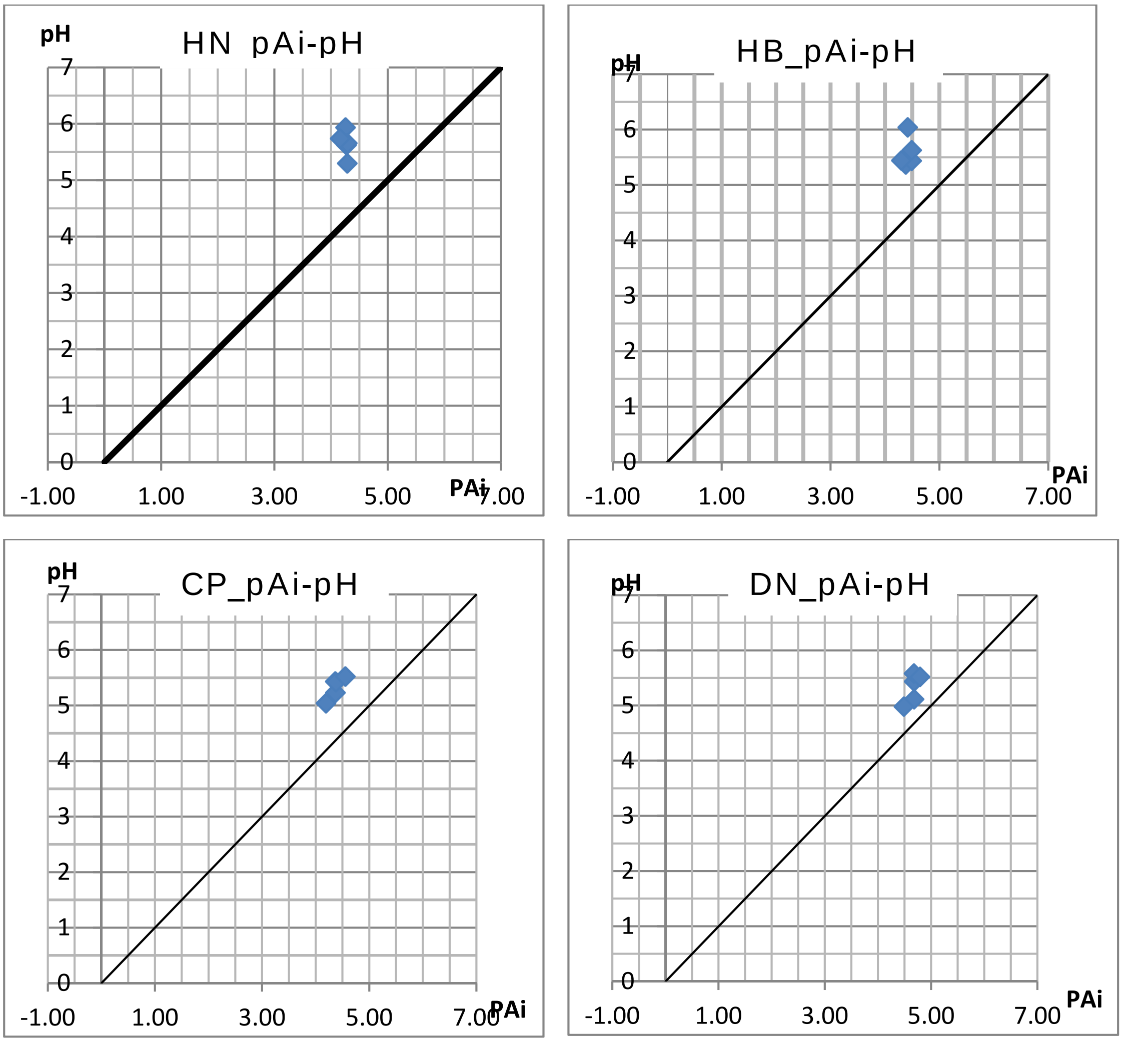


Figure 2.11. Correlation between pH and pA$_i$ of sites

2.1.2 State of dry deposition

Assessing air and aerosol concentration and composition

Both 4 EANET sites in Vietnam are operating air quality monitoring by Filter Pack. Ions of Ca^{2+}, NH_4^+ and SO_4^{2-}, NO_3^- are dominant in aerosol composition for almost sites (62-80% and 79-93%, respectively), except for Can Tho site contribution of K+ and Cl- is much higher than those of 3 others (26% và 21%, respectively).

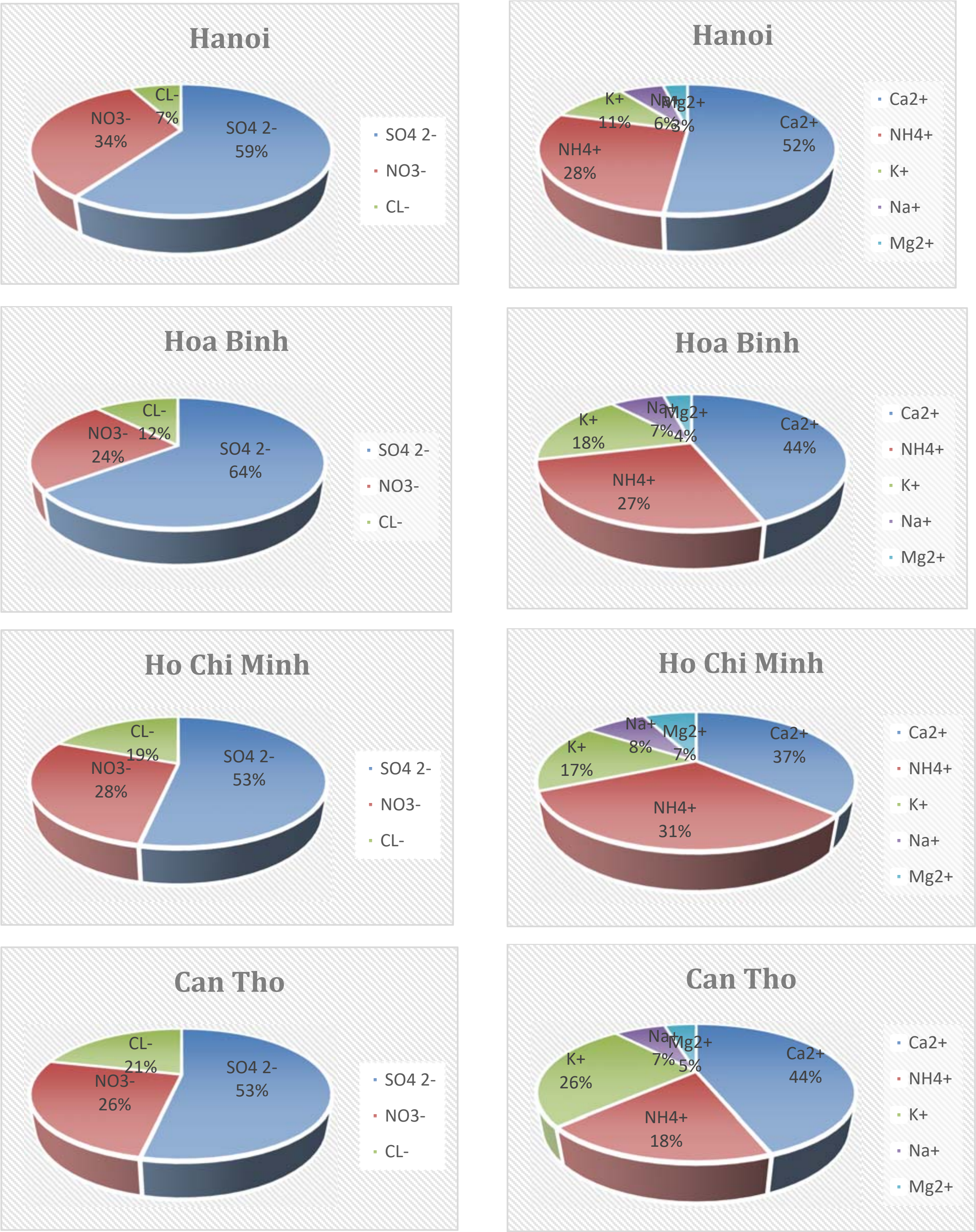


Figure 2.12. Major ion composition of aerosols in sites

Annual SO_2 concentration in Hanoi site is always the highest during 2010- 2014. There is a clear increasing trend of SO_2 concentration in Hanoi and Hoa Binh sites, particularly in 2014. Seasonal trend is dectected for Hanoi and Ho chi Minh sites (increasing in dry season and decreasing in rain season), however, the trend is not clear for Hoa Binh and Can Tho sites.

Monthly average HNO_3 and NH_3 concentration of Hanoi and Ho Chi Minh (2 urban sites) are always higher than those of Can Tho and Hoa Binh (2 rural sites).
There is a dramatically decreasing trend of HNO_3 and NH_3 concentration in Hanoi site, recently.

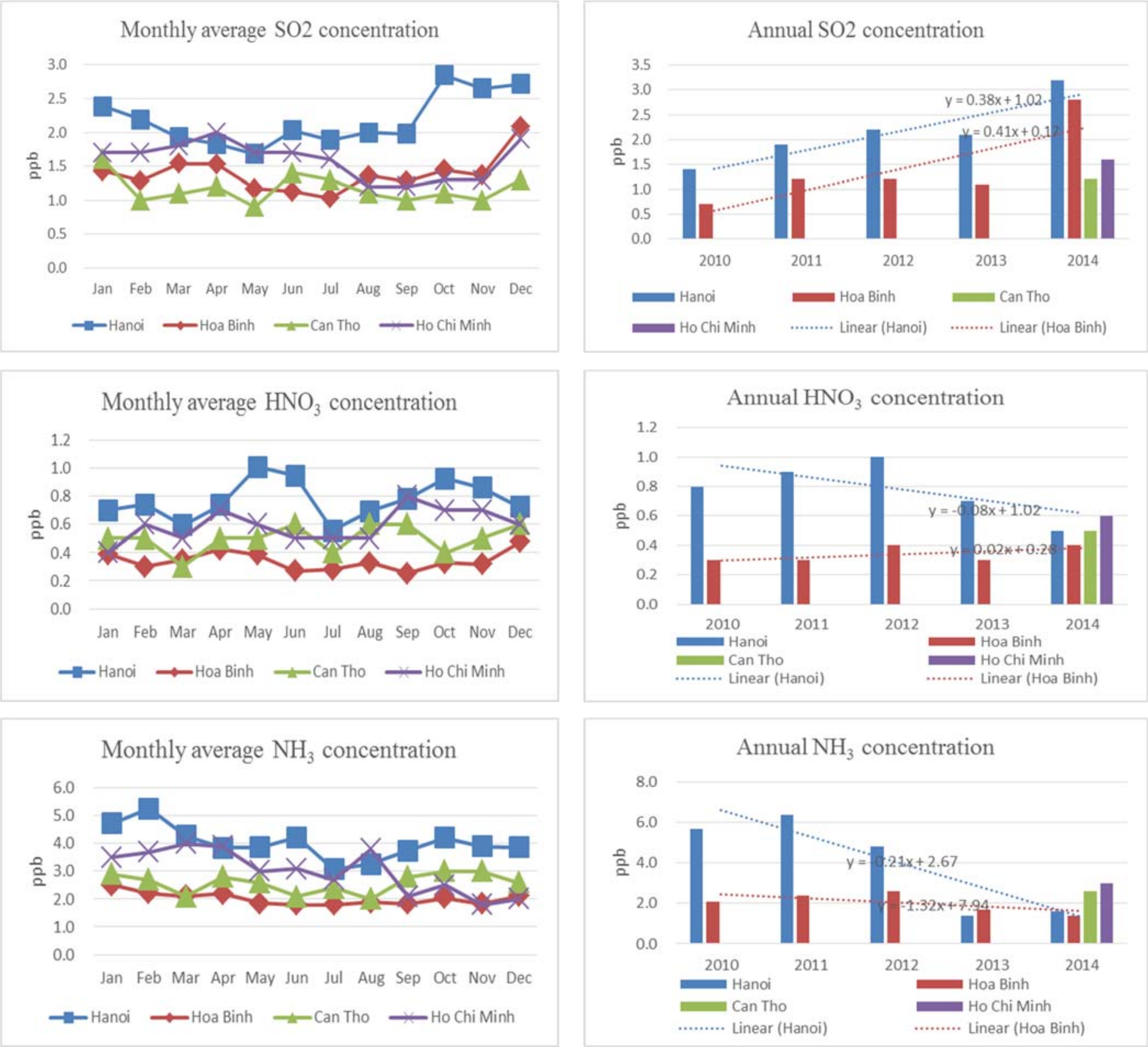


Figure 2.13. Variation of gases concentration in sites (2010-2014)

Estimation of dry deposition flux

Dry deposition flux is estimated according to EANET's guideline for remote (forest) and rural sites.

In case of Vietnam, dry deposition flux is estimated for Hoa Binh (rural sites) which are being monitored by Filter Pack method.

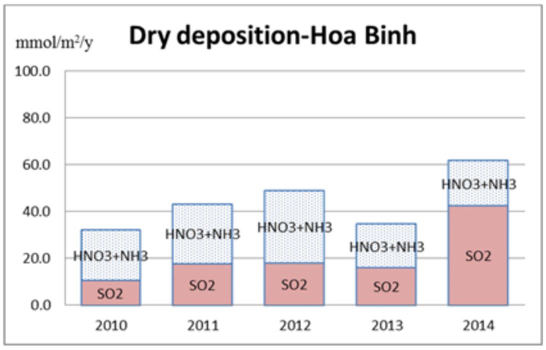


Figure 2.14. Annual dry deposition of Hoa Binh sites

Annual dry deposition amount of sites is in range of 30- 60 mmol/m^2/y. In general, total dry deposition in Hoa Binh is not much changed in period of 2010- 2014.

In 2014, dry deposition of 2 sites (Hoa Binh and Can Tho) are not so different in total deposition amount, around 50 mmol/m^2/y. However, there is a difference in deposition composition between the northern site (Hoa Binh) and the southern site (Can Tho). For Hoa Binh site, deposition of SO_2 is predominant and contribution ratio of SO_2/ (HNO_3+ NH_3) is equivenlant (50%:50%). For Can Tho site, deposition of SO_2 and NH_3 are equal (about 40% of each), and the deposition of HNO_3 only contributes a minority (around 20%).

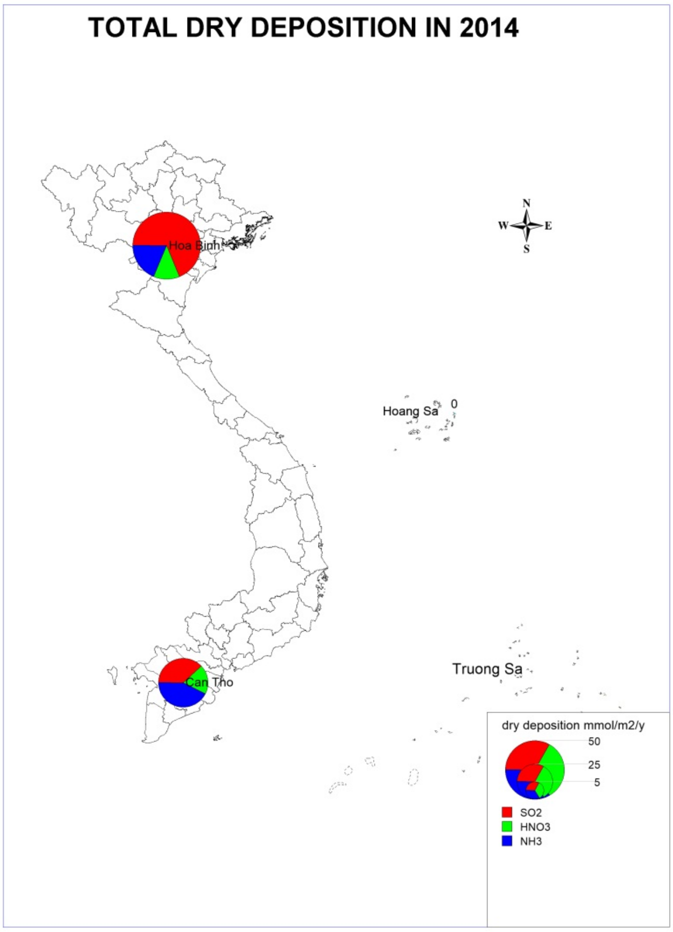


Figure 2.15. Spatial distribution of dry deposition (2014)

2.2 State of inland aquatic environment

Hoa Binh reservoir has been selected to monitor acid deposition for inland aquatic environment in Vietnam since 2001. Inland water samples are taken quarterly/seasonally (in every March/ spring, June/ summer, September/ autumn and December/ winter).

Calculation of ion balance showed that anion HCO_3^- and cation Ca^{2+} are predominant in composition of Hoa Binh reservoir water.

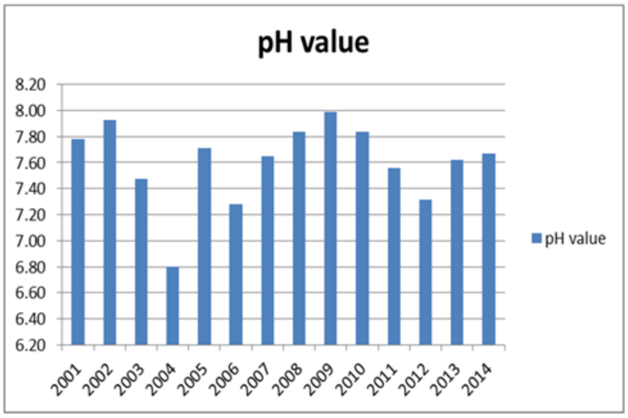


Figure 2.16. Change of annual average pH values

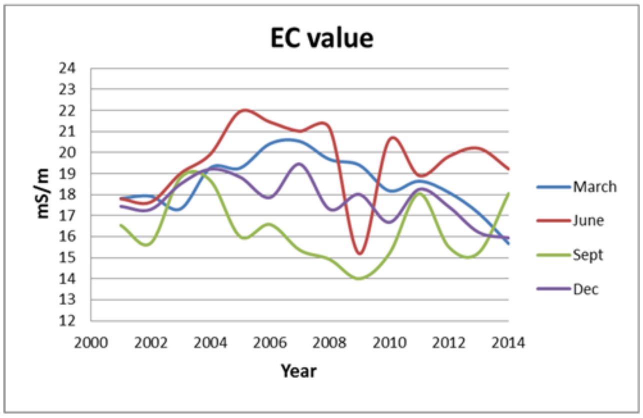


Figure 2.17. Change of seasonal average EC values

EC values fluctuate in range of 14 - 21.95mS/m, and get the highest value in June/summer, next to in March/spring. The summer is rainy season in Vietnam, therefore, the reservoir is disturbed largely due to flood and rainfall.

Annual average pH values are changed from 6.8 to 8.0, almosts are in range of 7<pH<8 (77%). Seasonal variation of pH values is not detected in duration 2001- 2014.

For major ions concentration (SO_4^{2-}, NO_3^- Ca^{2+}, Mg^{2+}), the highest values, generally, are observed in June.

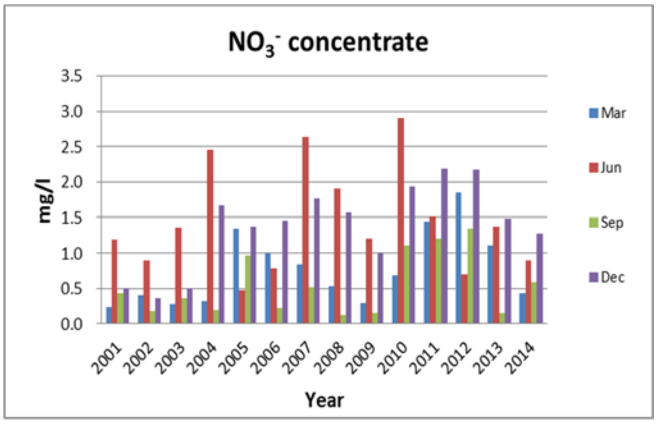


Figure 2.18. Change of SO_4^{2-} concentration in Hoa Binh reservoir water (2001-2014)

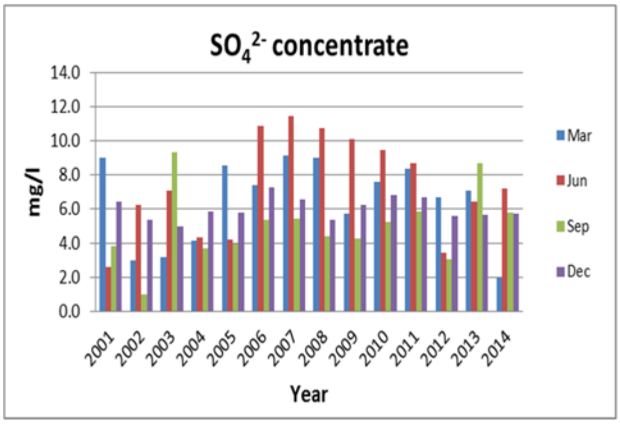


Figure 2.19. Change of NO_3^-concentration in Hoa Binh reservoir water (2001-2014)

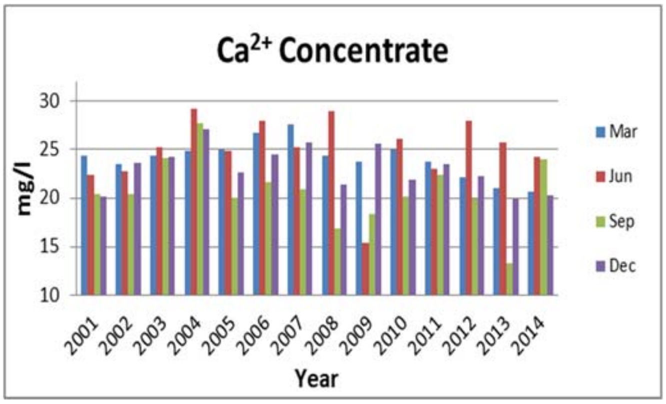


Figure 2.20 Change of Ca^{2+}concentration in Hoa Binh reservoir water (2001-2014)

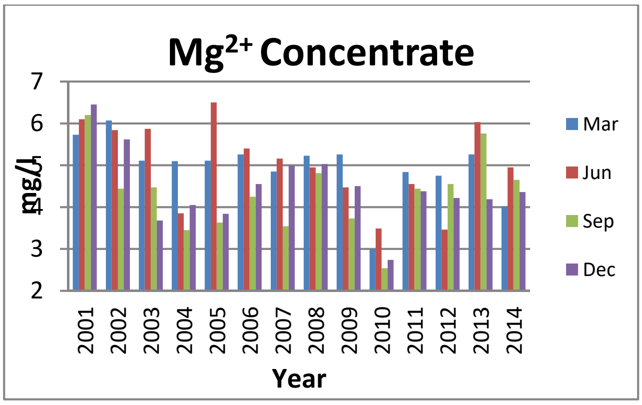


Figure 2.21. Change of Mg^{2+}concentration in Hoa Binh reservoir water (2001-2014)

Water monitoring results indicated that alkanity of Hoa Binh reservoir is very high (1500µeq/L) which exceeds 7-8 times compared to the level recommended by EANET (<200 µeq/L).

Chapter 3. Review of National Air Quality Management including Acid Deposition

3.1. Legal and institutional structure of air quality management system

Legal documents system of air quality management in Vietnam has been set up along with the legal system of environmental protection, integrating management contents into some Laws and Resolutions of the Ministry of Politic; Strategy, Decision of the Prime Minister and the guiding circulars from the relevant ministries.

In general, the ambient air quality management system in Vietnam can be figured out in the below.

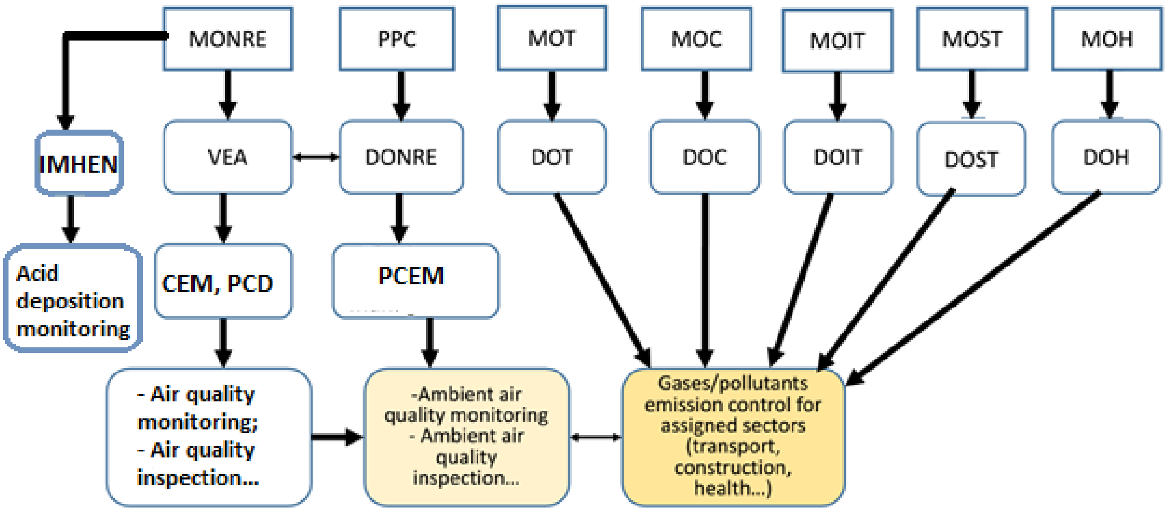


Figure 3.1. Diagram of air quality management and monitoring system in Vietnam

MONRE: Ministry of Natural Resources and Environment
PPC: Provincial People Committee
MOT: Ministry of transportation
MOC: Ministry of construction
MOIT: Ministry of Industry and Trade
MOST: Ministry of Science and technology
MOH: Ministry of Health
IMHEN: Institute of Meteorology, Hydrology and Climate change
VEA: Vietnam Environmental Administration
CEM: Center of Environmental Monitoring
PCD: Pollution controll department
DONRE: Department of Natural Resources and Environment
PCEM: Provincial Center of Environmental Monitoring
DOT: Department of transportation
DOC: Department of construction
DOIT: Department of Industry and Trade
DOST: Department of Science and technology
DOH: Department of Health

Functions, Mandates, and Current Actions on AQM of Concerned Ministries:

The functions, mandates, and current actions on AQM of the six concerned ministries are summarized as the follow:

(a) MONRE

- MONRE is the leading central body governing environmental management. Article 140 of Chapter 14 of LEP 2014 (No: 55/2014/QH13) outlines the responsibilities of MONRE with regard to state administration of environmental protection.
- All ministries, ministry-level agencies, and other government bodies cooperate with MONRE in carrying out environmental protection within their sectors.
- The government spends 1% of the state budget expenditure for environmental protection activities but there is limited data on the compliance with this law and how much is used for air quality management.

- VEA, an agency under MONRE, carries out the functions of advising and assisting the Minister of MONRE in environmental management and legal enforcement on a national scale, and manages and implements environmental public services.
- Key departments and agencies within VEA are as follows:
a) The Department of Policy and Legislation (DPL), which assists MONRE in policy making and developing environmental regulations, strategies, and plans.
b) The Department of Appraisal and Environmental Impact Assessment (DAEIA), which manages the EIA and appraisal system.
c) The Center for Environmental Monitoring (CEM), which implements national environmental monitoring including air quality monitoring. CEM has prepared reports on environmental quality within the framework of VEA's functions and mandates, e.g., State of Environment 2013's topic is "Air Environment", published in 2014.
d) The Department of Pollution Control (PCD), which focuses on control, prevention, and reduction of environmental pollution in soil, water, and air; hazardous chemical management; prevention, response, and mitigation of environmental pollution/contamination caused by natural disasters or environmental accidents.
- The Center for Hydro-Meteorological and Environmental Station Network, under the National Hydro-Meteorological Service of MONRE, is operating nine automatic air quality monitoring stations in the whole Vietnam. According to the survey implemented by the Project, the tasks for operating air monitoring stations are demarcated between the center and the Center for Environmental Monitoring (CEM). In particular, the center is in charge of "background monitoring stations", which exist in places under "no-impact" conditions, and CEM is in charge of "impact monitoring stations", which exist in places along the road and/or near pollution sources.
- IMHEN, under MONRE, is responsible for researching and training graduate students in the field of meteorology, hydrology, climate change and environment. IMHEN is assigned as national focal point of EANET by the Vietnam Government. IMHEN is in charge of managing the EANET monitoring network in Vietnam.

Current activities related to AQM of MONRE:

As the leading agency for helping the government in environmental management of the environment, MONRE has carried out a lot of activities on pollution control, as follows:
- To strengthen the control of air pollution, noise, chemical emission, and transboundary pollution.
- To complete the system of standards and regulations, and to enhance management of environmental monitoringnetwork of the national local level and ministries.
- To carry out research for control of air and chemical emissions, environmental accidents, industrial zones, villages and rural environment, and environmental protection in food safety management.
- To continue to improve the legal framework, and the system of legal documents in the field of environmental pollution control including those on ambient air protection.
- To work closely with the provincial departments of environmental protection in pollution control.
- To carry out research and to advise the leaders of the departments and ministries of assigned functions and tasks of control of environmental pollution in general and air pollution inparticular between ministries and relevant agencies to ensure harmony and unity.

(b) MOT

- To provide technical safety standards,and environmental protection for motor vehicles.
- To evaluate strategic environmental assessment and environmental impact assessment reports for investment construction projects for transport infrastructure and industrial production facilities.
- To coordinate with MONRE and other relevant ministries, ministerial-level agencies, government agencies, and the provincial People's Committee (PC) to direct, guide, and inspect the implementation of the LEP relating to the construction of transport infrastructure and transport operations.
- To provide for the issuance of the certificate of environmental standards for motor vehicles in road, rail transport, inland waterways, maritime and aviation.

The Department of Environment has the following tasks and authority over environmental management sectors:

a) Act as a leader in building the five-year and annual plan and environmental protection programs of the ministry.
b) To develop mechanisms and policies for protecting natural resources, the environment, energy efficiency and conservation, climate change, technology transfer and capacity development for environmental protection.
c) To conduct inspection and certification ofenvironmental standards, technical regulations, and energy labels for motorized transport by road, rail, inland waterway, maritime, and civil aviation.
d) To regulate the operating conditions of the inspection establishment, and environmental protection laboratory for motor vehicles.
e) To implement international cooperation activities related to environmental protection of transportation as assigned by the Minister.

Current activities related to AQM of MOT:

There are 105 car inspection stations established all over the country and the National
- Motor Vehicle Test Center (NETC). In the 2008-2012 period, MOT in collaboration with the authorities at the local level organized annual monitoring and inspection of buses and passenger cars by mobile testing devices in order to test and detect vehicles that do not meet the conditions on emissions.
- In 2012, the Prime Minister issued a roadmap for the application of biofuel and environmentally-friendly fuel. According to this roadmap, from 12/2012 gasoline blended with E5 biofuel was produced, blended, and sold for use of road motor vehicles nationwide
- MOT is studying the development of software for alert systems that automatically update cars having their reached expiry date in order to warn the inspection unit to handle them accordingly.

(c) MOIT

- To perform the functions of state management of industry and trade, including the sectors of engineering, metallurgy, electricity, new energy, renewable energy, oil and gas, chemicals, industrial explosives, mining industry and mineral processing, consumer goods, food processing, commercial and domestic markets, export and import, border trade, etc.
- To provide guidance, supervise and carry out inspection of the implementation of the provisions of the law on industrial safety techniques and environmental protection under the state management of MOIT.
- To provide leadership and coordination with MONRE and other ministries that are involved in directing the development of environmental industries as stipulated by law.
- To provide guidance on the implementation of environmental monitoring, resources and waste statistics, building and managing environmental database system for the ministry’s management.
- To lead and coordinate with relevant agencies to guide and organize the implementation of programs, tasks, and projects related to climate change under the ministry’s management.
- MOIT established the Industrial SafetyTechniques and Environment Agency to perform the functions of state management and law enforcement on technical safety and environmental protection in industry and trade.

Current activities related to AQM of MOIT:

- To promote the inspection and control of environmental pollution due to industries.
- To organize monitoring teams for environmental protection works at production facilities.
- The above works were carried out mainlyat production facilities and state enterprises which might cause serious air pollution (2008: works were implemented in 35 establishments, 2009: 36 establishments, 2010: 40 establishments, 2011: 26 establishments, 2012: 20 establishments).
- Industrial production establishments have indicated concerns in processing technologies for industrial emission treatment, and efficiency of dust filtration equipment in major plants, especially of foreign direct investment (FDI) funded plants, by instruction of MOIT.
- To implement Vietnam's commitment tothe Montreal Convention Protocol implied in January 2010

(d) MOC

- To coordinate with MONRE and MOIT in the appraisal process of issuance of license and reporting of environmental impact assessment (EIA) of development projects under the administration of MOC.
- To direct and guide the integration ofplanning and environmental protection programs into construction activities.
- To direct and guide the implementation of establishment of strategic environmental assessment (SEA) reports and EIA reports, appraisal of reports on EIA under the authority, monitoring impacts to the environment due to construction activities, management and control of waste, noise, vibration, light, radiation, prevention, response to environmental accidents, environmental pollution, environmental rehabilitation in areas under MOC, such as infrastructure development.
- The Department of Science, Technology and Environment acts as the focal unit with regard to pollution problems in MOC. Their functions/mandates are related to scientific research and technological development, application of advanced techniques, technology transfer, standards, metrology and quality goods, industrial property, technical barriers in trade, environmental protection and information on science and technology.

The main functions/mandates on environmental management are as follows:

a) To provide guidance on integration of planning and environmental protection programs in the strategy, planning, program for development and to support the preparation of SEA and EIA reports.

b) To monitor environmental impacts caused by the operation of the construction industry, to provide the situation EIA report of the construction industry, and to carry out management and control of waste, noise, vibration, light, radiation, preventing, response toenvironmental incidents, remedies for environmental pollution, and environmental restoration in areas.

c) To carry out research and propose for new issuance or adjustment of technical regulations, national standards for the environment, and to submit to MOC for issuance within their authority of the technical regulations on environmental quality and waste management in the areas.

Current activities related to AQM of MOC:

- Control of emission sources from construction activities in Vietnam in recent years has made the following progress:
- To reduce dust caused by transportation trucks carrying earth and sand.
- To reduce dust generation from construction activities and from other activities such as mining and selling of construction materials.
- To develop a greenhouse gas mitigation action plan in the cement manufacturing industry.

(e) MOST:

- MOST performs the state management function with regard to science and technology, including scientific and technological activities, development of the scientific and technological potential, intellectual property, quality measurement standards, atomic energy, radiation and nuclear safety, and management of public services.
- Regarding pollution control works, MOST is responsible for issuance of standards, national technical regulations, procedures, and economic technical norms.
- The agencies under MOST have functions and duties such as development and promulgation of Vietnamese National Technical Regulations (QCVN) for air pollution control, management ofsystem for technical standards and regulations of Vietnam, evaluation and publication of national standards, and guidance on development and evaluation of national technical regulations.
- The Vietnam Standards and Quality Institute under the Directorate for Standards, Metrology and Quality assumes the major responsibilities regarding QCVN.
- The organizational charts of MOST and the Vietnam Standards and Quality Institute are both shown in Attachment 20.

Current activities related to AQM of MOST:

- MOST led the drafting of the clean technology use strategy until 2020, with a vision to 2030, which was approved by the government under Decision No. 2612/QD-TTg dated December 30, 2013.

- Specifically, the strategy focuses on the development and application of standards and technical regulations on clean technology in energy-consuming industries which may cause serious pollution to the environment such as textile dyeing, manufacture of fertilizers and pesticides, steel production, mining and mineral processing, thermal power, paper manufacturing, cement production, and sugar production. The specific objectives of the strategy are as follows:
a) By 2020, 100% of new investment projects in the fields above meet the standards and technical regulations on clean technologies, and 60-70% of the production facilities operating in the industries mentioned above complete the development and implementation of technological innovation roadmap towards using clean technology.
b) By 2030, 100% of the production facilities in the industries adopt the standards and technical regulations on clean technology.

(f) MOH:

- To lead and coordinate with MONRE, MOC, and other relevant authorities in issuing regulations, standards, and national technical regulations on environmental protection in health activities.
- To evaluate the SEA report and EIA report for the projects subjected to the approval of the Ministry of Health (MOH).
- To direct and guide the implementation of i) monitoring of environmental impacts from the operation of the health sector, and ii) management and control of pollution and health environmental restoration due to medical waste generation.
- To collect, store, and provide environmental information related to the areas under the jurisdiction of MOH as prescribed by law, such as the National Technical Regulation on Emission of Health Care Solid Waste Incinerators (QCVN02/2013/BTNMT).
- To direct and guide the implementation of measures to protect human health from the impacts of climate change, pollution, and other adverse environmental factors.
- To provide leadership and to guide in the implementation, inspection, and supervision of legal documents, national technical regulations on the management and disposal of medical waste, and environmental protection in health activities.

3.2 Policies and regulations on AQM in Vietnam

(a) Current Standards for Air Pollutants

- QCVN 05 : 2013/BTNMT - National technical regulations on ambient air quality.
- QCVN 06:2009/BTNMT –National technical regulations for hazardous substances in the ambient air.
- QCVN 19:2009/BTNMT – National technical regulations on industrial emissions for dust and inorganic substances.
- QCVN 20:2009/BTNMT – National technical regulations on industrial emissions for some organic matter.
- QCVN 21:2009/BTNMT – National technical regulations on industrial emissions of chemical fertilizer production.
- QCVN 22:2009/BTNMT – National technical regulations on industrial emissions of thermal power.
- QCVN 23:2009/BTNMT – National technical regulations on industrial emissions of cement production.
- QCVN 30:2010/BTNMT – National technical regulations on emission of industrial waste incinerators.
- QCVN 34:2010/BTNMT –National technical regulations on industrial refinery petrochemical emissions for dust and inorganic substances.
- QCVN 51 : 2013/BTNMT - National technical regulations on industrial emissions of steel production

(b) Current Regulations and policies related to air quatily management

- Law on Environmental protection dated June 23rd, 2014;

- Resolution No. 35/NQ-CP of the Government dated 18th March 2013 on urgent issues in the field of environmental protection;
- Decree No.38/2015/NĐ-CP of the Government dated on 24th April 2015 on wastes and scraps management;
- Decision No. 432/QĐ-TTg dated 12th April 2012 of Prime Minister on approving Sustainable Development Strategy for Vietnam during the period of 2011-2020;
- Decision No.166/QĐ-TTg dated 21st January 2014 of Prime Minister on promulgating National environmental protection Strategy until 2020 with vision to 2030;
- Decision No. 177/2007 / QD-TTg of 20th July 2007, focusing on the propagandizing, disseminating knowledge about biofuels and promoting the technical infrastructures using biofuels.
- Decision No 49/2009/QD-TTg dated January 1st, 2011 by Prime Minister defining roadmap for application of emission standards for cars, manufactured, assembled and new-imported motorcycles.
- Decision No. 909/QD-TTg dated 17 June 2010 focuses on supplement of legal documents system in order to create a legal framework for controlling emission from the motor vehicles, motorcycles.
- Decision No. 855/QD-TTg dated 6 June 2011focuses on the application of the further emission standards (Euro 3,4,5) for road motor vehicles.

3.3 National air monitoring system

Ambient air quality monitoring activities in Vietnam has started for implementation since 1995 through monitoring programs at national and local levels. Since 2000 up today, in order to provide continuous monitoring data, 35 automatic atmospheric environmental monitoring stations was built and still has been operated in a number of megacities such as VEA (7 stations), National Meteo and Hydrology center (10 stations), Hanoi (2 stations) Quang Ninh (10 station), Vinh Phuc (2 stations), Da Nang (1 station), Hue (1 station), Khanh Hoa (1 station), Can Tho (1 station), Daklak (1 station), Đồng Nai (2 stations), Quang Nam (1 station). In addition, a number of automatic atmospheric environmental monitoring stations were invested in VEA (1 station), Quang Ninh (1 stations), Daklak (1 station). In addition, in Dong Nai, Quang Ninh, Thai Nguyen provinces, projects on setting automatic atmospheric environmental monitoring stations are implemented at local level. In Ho Chi Minh City, there are used to have 9 atmospheric environmental monitoring stations, but all stations are stopped due to lake of resources.

For semi-automatic monitoring stations,in other locations, due to insufficient expense, still carrying out with interruptive monitoring method with frequency from 4-6 times/year. The air monitoring sites are located primarily at environmental hotspots of mega urban areas or industrial zones.

The environmental monitoring programs in general, and air monitoring programsin particular are just focused on urban areas, areas near the industrial zones ... lack of overall and periodic monitoring programs for rural areas, trading villages. The monitoring issues in order to control air pollution sources across borders still face many difficulties.

As stipulated in the decision approving the EIA report, the production facilities are required to perform periodic environmental monitoring, but most of the production facilities are not implemented properly and adequately monitoring emissions at the smokestacks. The cause is mainly due to the production facilities had no arrangement or improper technical layout of monitoring position, sampling taking in smokestacks. The installation of the automatically, continuous emissions monitoring systems performed only in large plants in the cement industry, thermal power, chemical, oil refining, chemical production plants. Some other plants have installed but for the purpose of monitoring production technologies, thus there are lacks of environmental parameters, especially toxic parameters.

Monitoring activities not follow a uniform procedure, a lot of units participating in observation with various field sampling and analyses, which make difficult for the evaluation of data quality. Vietnam has issued in the Circular No. 28/2011/TT-BTNMT dated August 1, 2011 on providing for the environmental monitoring technical process for ambient air quality and noise, however, currently there is regulation on industrial exhaust emissions monitoring technical process under Circular number 40/2015/TT-BTNMT dated 17 August 2015 of the Ministry of Natural Resource and Environment. The implementation of QA/QC is still weak, causing difficulties to the data quality assessment. The air monitoring equipment in many places are weak and obsolete, it's not automated in the stages of storage, processing and exchange of data.

Data on emissions still unused, quality on ambient air still not synchronized and has not formed as a database system at national level, causing difficulties to information exploitation, use and share.

4. Conclusion

Through 15 years of development, East Asia acid depocition monitoring network has had significant activities in rising public awareness and solving problem of acid deposition among regional countries. Vietnam is an active member in the EANET's activities. Up to now, there are six stations under EANET in Vietnam. Acid deposition monitoring results show that acid rain has occurred at five of six sites in Vietnam (except Can Tho), but their acid deposition are different from site to site. As a result of transboudary pollution, Cuc Phuong has the maximum frequency of acid rain, up to 35.4%, in spite of the ecological station. The monitored concentrations of precursors (SO_2, HNO_3) causing acid deposition also indicated high levels of pollution in urban stations (Hanoi, Ho Chi Minh City). The amount of wet deposition (H^+, nss-SO_4^{2-}, NO_3^-) and dry deposition (SO_2, HNO_3) in Vietnam stations is in range from tens to hundreds mmol/m^2/year.

Facing to the increase of air pollution in recent years, the Vietnamese government has been taking a lot of efforts in institution and policy related to air quality management and air pollution controls. The governmental departments/agencies involving in air quality management have been consolidated and clarified their responsibilities. In addition, many legislation documents have been issued such as Law, Decrees, Circular, plans and national technical standards on air emission control. Moreover, Vietnam needs to develop more monitoring systems of air quality and acid deposition that could contribute to achieve national targets on air quality protection and regional targets, as well.

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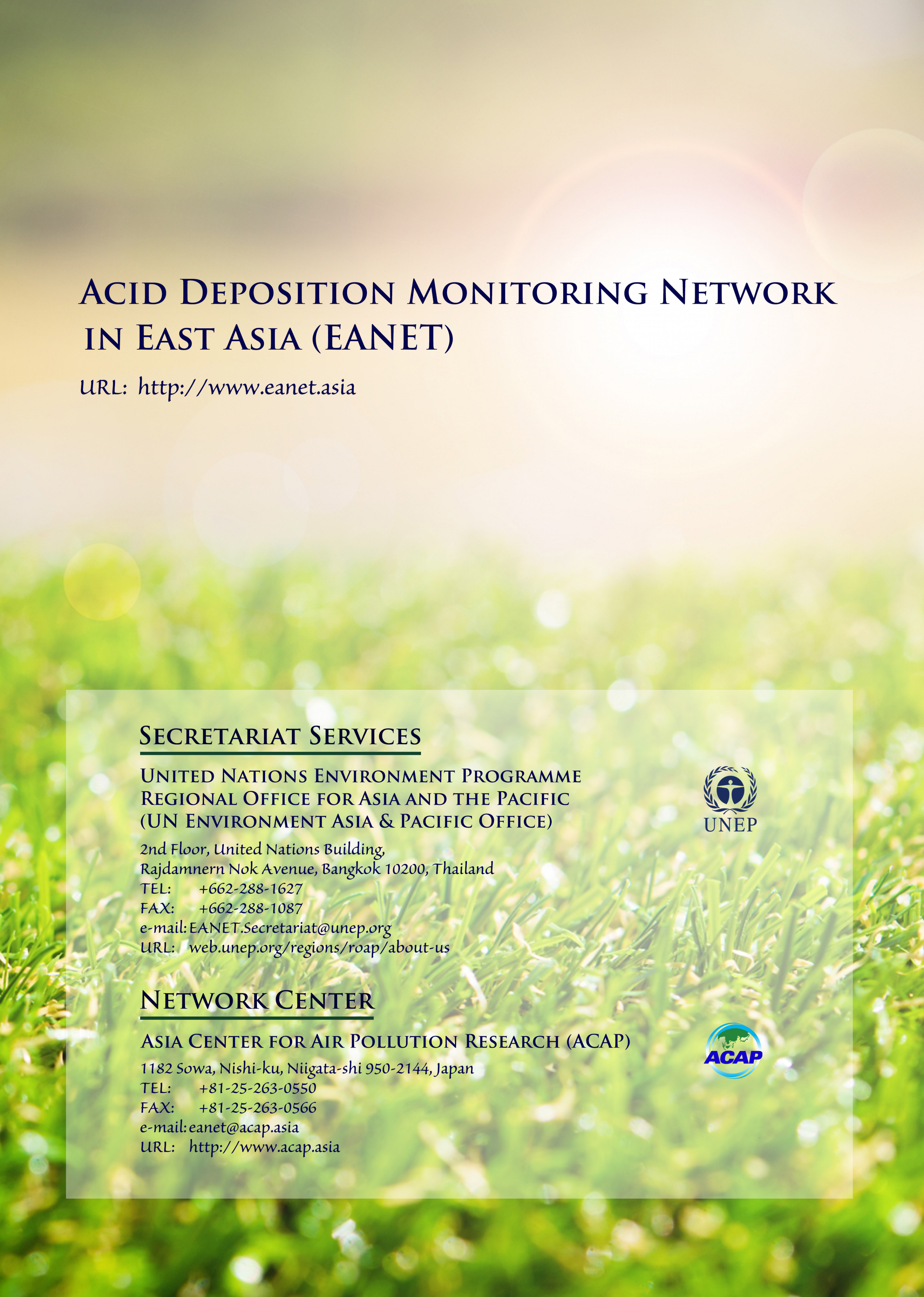

Acid Deposition Monitoring Network in East Asia (EANET)

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