

JAPAN INTERNATIONAL COOPERATION AGENCY (JICA)
POLLUTION CONTROL DEPARTMENT
THE GOVERNMENT OF THE KINGDOM OF THAILAND



FINAL REPORT
VOL.2
MAIN REPORT

FEBRUARY 2003

THE **ACID** DEPOSITION CONTROL STRATEGY
IN THE KINGDOM OF THAILAND

JICA LIBRARY



1172404{4}

SUURI-KEIKAKU CO.,LTD.
PACIFIC CONSULTANTS INTERNATIONAL

SSS

JR

03-55

JAPAN INTERNATIONAL COOPERATION AGENCY (JICA)
POLLUTION CONTROL DEPARTMENT
THE GOVERNMENT OF THE KINGDOM OF THAILAND

FINAL REPORT
VOL.2
MAIN

FEBRUARY 2003

THE **ACID** DEPOSITION CONTROL STRATEGY
IN THE KINGDOM OF THAILAND

SUURI-KEIKAKU CO.,LTD.
PACIFIC CONSULTANTS INTERNATIONAL



1172404[4]

The exchange rates applied in this Study are:

US\$ 1.00 = Japanese Yen 120.00

Baht 1.00 = Japanese Yen 2.85

(as of February 2003)

PREFACE

In response to a request from the Government of the Kingdom of Thailand, the Government of Japan decided to conduct "the Study on the Acid Deposition Control Strategy in the kingdom of Thailand" and entrusted the Study to the Japan International Cooperation Agency.

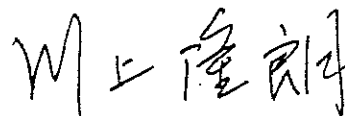
JICA selected and dispatched to the Kingdom of Thailand a study team headed by Mr. Hideshi Kase, Suuri-Keikaku Co., Ltd., and composed of members of Suuri-Keikaku Co., Ltd. and Pacific Consultants International, five times between January 2002 to February 2003.

The team held discussions with the officials concerned of the Government of the Kingdom of Thailand and conducted field surveys at the study area. After the team returned to Japan, the team conducted further studies and prepared this final report.

I hope that this report will contribute to the promotion of the mitigation of acid deposition in Thailand as well as the countries participating in the Acid Deposition Monitoring Network in East Asia and to the enhancement of friendly relationship between our two countries.

Finally I wish to express my sincere appreciation to the officials concerned of the Government of the Kingdom of Thailand for their close cooperation extended to the study.

February 2003



Takao Kawakami

President

Japan International Cooperation Agency

February 2003

Mr. Takao Kawakami
President
Japan International Cooperation Agency
Tokyo, Japan

Letter of Transmittal

Dear Sir,

We are pleased to formally submit herewith the final report of "the Study on the Acid Deposition Control Strategy in the Kingdom of Thailand".

This report compiles the results of the Study which was undertaken in the Kingdom of Thailand from January 2002 through February 2003 by the Study Team, organized jointly by Suuri-Keikaku Co., Ltd. and Pacific Consultants International.

We owed a lot to many people for the accomplishment of the Study. First, we would like to express our sincere gratitude and appreciation to all those extended their kind assistance and cooperation to the Study Team, in particular, relevant officials of Pollution Control Department, the counterpart agency.

We also acknowledge all the officials concerned of your agency, the JICA Advisory Committee, Ministry of Foreign Affairs, Embassy of Japan, and Ministry of Environment.

We wish the report would be able to contribute to appropriate policies and measures for the mitigation of the acid deposition in Thailand as well as the countries participating in the Acid Deposition Monitoring Network in East Asia.

Sincerely Yours,

賀勢秀史

Mr. Hideshi Kase
Team Leader
JICA Study Team

Contents

Description of the Study	i
1. Acid Deposition and Air Quality Data Analysis.....	1-1
1.1 Result of Wet Deposition Monitoring.....	1-1
1.2 Result of Monitoring Results	1-1
2. Socio-economic Issues.....	2-1
2.1 Existing Socio-Economic Conditions	2-1
2.2 Socio-economic Framework for Inventory Development.....	2-18
3. Stationary Source Inventory.....	3-1
3.1 Basic Frame.....	3-1
3.2 Inventory of the Year 2000	3-3
3.3 Inventory of the Year 2011	3-36
4. Mobile Source Inventory	4-1
4.1 Outline	4-1
4.2 Mobile Source Inventory of the Year 2000	4-4
4.3 Mobile Source Inventory of the Year 2011(BAU Case).....	4-66
5. Inventory by Pollutants, SO _x and NO _x	5-1
5.1 Emission Amount of Pollutants.....	5-1
5.2 Summary of Emission Inventory.....	5-
6. Model Simulation	6-1
6.1 ATMOS 2	6-1
6.2 Airviro	6-42
6.3 Technology Transfer on Simulation Models.....	6-110
7. Evaluation of Acid Deposition and Air Quality.....	7-1
7.1 Acid Deposition.....	7-1
7.2 Ambient Air Pollution	7-2
7.3 Prioritization	7-4
8. Countermeasures for SO ₂ in BMR	8-1
8.1 Methodology	8-1
8.2 Summary of SO _x Emission in BMR	8-2
8.3 Current Mitigation Measures.....	8-3
8.4 Countermeasures.....	8-5
8.5 Selection of Countermeasure	8-11
8.6 Conclusion.....	8-17
8.7 Consideration of Action Plan.....	8-19
9. Countermeasures for NO ₂ in BMR.....	9-1
9.1 Methodology	9-1
9.2 NO ₂ Concentration at 2011 (BAU Case)	9-2
9.3 Countermeasures Selection.....	9-4

9.4	Conclusion.....	9-35
9.5	Action Plan.....	9-37
10.	Acid Deposition Control Strategy.....	10-1
10.1	Introduction.....	10-1
10.2	Control Strategy.....	10-2
10.3	Strategy A: Shift to Natural Gas for SO ₂ Mitigation in the BMR.....	10-3
10.4	Strategy B: Enhancement of Real EURO and LEV/OVR for NO ₂ Mitigation in the BMR.....	10-6
10.5	Strategy C: Enhancement of Environmental Management.....	10-10

List of Tables

1. Acid Deposition and Air Quality Data Analysis	
Table 1.1.1.1	Brief Description of Concentration of Acid Deposition..... 1-2
Table 1.1.1.2(1)	Brief Description of Deposition Amount..... 1-3
Table 1.1.1.2(2)	Brief Description of Deposition Amount..... 1-4
Table 1.1.1.3	Brief Description of pH..... 1-7
Table 1.1.3.1	Annual Average of NP/AP..... 1-12
Table 1.1.4.1(1)	Monthly Average/Amount of Wet Deposition Parameters in the year 1999..... 1-13
Table 1.1.4.1(2)	Monthly Average/Amount of Wet Deposition Parameters in the year 1999..... 1-14
Table 1.1.4.1(3)	Monthly Average/Amount of Wet Deposition Parameters in the year 1999(Precipitation Amount)..... 1-14
Table 1.2.1.1(1)	Brief Result of the Air Quality Monitoring (SO ₂)..... 1-21
Table 1.2.1.1(2)	Brief Result of the Air Quality Monitoring (SO ₂)..... 1-22
Table 1.2.1.1(3)	Brief Result of the Air Quality Monitoring (NO ₂)..... 1-23
Table 1.2.1.1(4)	Brief Result of the Air Quality Monitoring (NO ₂)..... 1-24
Table 1.2.2.1	Air Quality Standards of Thailand (1995) & Guidelines for Air Quality of WHO (1999)..... 1-30
Table 1.2.2.2	SO ₂ : Evaluation of Air Quality of the Year 2000..... 1-31
Table 1.2.2.3	NO ₂ : Evaluation of Air Quality of the Year 2000..... 1-31
Table 1.2.2.4	Evaluation of Ambient Air Quality, SO ₂ and NO ₂ , 2000..... 1-32
2. Socio-economic Issues	
Table 2.1.1.1	Area of Regions..... 2-1
Table 2.1.2.1	Trend of Population by Region..... 2-5
Table 2.1.2.2	Urban Population and Population Density at Regional Level..... 2-6
Table 2.1.2.3	Structure of Population (as of 1998)..... 2-8
Table 2.1.2.4	Labour Force by Sectors..... 2-8
Table 2.1.3.1	Averaged monthly Income and Expenditure (as of 1998)..... 2-9
Table 2.1.3.2	Poverty and their ratio of Thailand..... 2-9
Table 2.1.4.1	Population by Region..... 2-11
Table 2.1.4.2	GDP per capita by Region..... 2-12
Table 2.1.4.3	GDP by Region..... 2-12
Table 2.1.4.4	GDP Growth Rate by Region..... 2-12
Table 2.1.4.5	Key Indicators of Economic Trends..... 2-14
Table 2.1.4.6	GDP Growth Rate by Sector 1995-1999 (%)..... 2-15
Table 2.1.4.7	Macroeconomic Target by NESDB..... 2-17
Table 2.2.1.1	Population Projections of the Related Studies and NESDB..... 2-19
Table 2.2.1.2	Population Projections of the Related Studies at Regional Level..... 2-19
Table 2.2.1.3	Population Projections by Region 2002-2021..... 2-20
Table 2.2.1.4	GDP Projections of the Related Studies..... 2-21
Table 2.2.1.5	GDP Projection by Sectors (% per annum)..... 2-21
Table 2.2.1.6	GDP Projections for Regions by LTP-2 (% per annum)..... 2-22
Table 2.2.1.7	GDP Projections of the Related Studies for BMR..... 2-22
Table 2.2.2.1	GDP Projections at National and Regional Level (% per annum)..... 2-24
Table 2.2.2.2	GDP Projections by Sector (% per annum)..... 2-24
3. Stationary Source Inventory	
Table 3.1.1.1	Basic Frame of Stationary Source Inventory of Country..... 3-1
Table 3.1.1.2	Basic Frame of Stationary Source Inventory of BMR..... 3-1
Table 3.1.1.3	Relation between Sector and Source Type..... 3-2
Table 3.1.1.4	Sector and Fuels Used..... 3-3
Table 3.2.1.1	Questionnaire Survey Result..... 3-4
Table 3.2.1.2	Basic Data Collected and Used..... 3-5
Table 3.2.2.1	Fuel Consumption by Sector in Whole Thailand in 2000..... 3-6
Table 3.2.2.2	Fuel Consumption of Power Plants Connected to National Grid (2000)..... 3-7
Table 3.2.2.3	Fuel Consumption of Agriculture Sector in 2000..... 3-7
Table 3.2.2.4	Fuel Consumption of Mining Sector in 2000..... 3-8

Table 3.2.2.5	Total Fuel Sale in Thailand in 2000	3-8
Table 3.2.2.6	Total Fuel Consumption by Manufacturing Sector in Thailand.....	3-9
Table 3.2.2.7	Comparison of DCR Figures and DEDP Figures.....	3-9
Table 3.2.2.8	Consumption of Coal and its Products in Manufacturing Sector in 2000.....	3-10
Table 3.2.2.9	Lignite Consumption by Manufacturing Sector in 2000.....	3-10
Table 3.2.2.10	Fuel Consumption of Manufacturing Sector in 2000.....	3-12
Table 3.2.2.11	Fuel Consumption of Construction Sector in 2000.....	3-13
Table 3.2.2.12	Fuel Consumption of Residential and Commercial Sectors (2000).....	3-14
Table 3.2.3.1	Fuel Composition	3-17
Table 3.2.3.2	SOx Emission Factor for Combustion Facility.....	3-18
Table 3.2.3.3	SOx Emission Factor for Sulfuric Acid Plant and Cement Plant.....	3-18
Table 3.2.4.1	Fuel Consumption by Power Plants in BMR in 2000.....	3-19
Table 3.2.4.2	Fuel Consumption by Agriculture Sector in BMR in 2000	3-19
Table 3.2.4.3	Fuel Consumption by Mining Sector in BMR in 2000.....	3-20
Table 3.2.4.4	Fuel Consumption by Manufacturing Sector in BMR in 2000	3-20
Table 3.2.4.5	Fuel Consumption by Construction Sector in BMR in 2000	3-21
Table 3.2.4.6	Fuel Consumption by Residential and Commercial Sector in BMR in 2000	3-21
Table 3.2.4.7	Petroleum Fuel Sale in BMR in 1997 and 2000	3-24
Table 3.2.4.8	NOx Emission Factor	3-25
Table 3.2.4.9	Net Calorific Value of Fuel.....	3-26
Table 3.2.5.1	Annual SOx Emission by Sector in 2000.....	3-26
Table 3.2.5.2	Annual SOx Emission by Point Sources in 2000.....	3-27
Table 3.2.5.3	The annual SOx Emission from Point and Area Sources in 2000.....	3-28
Table 3.2.5.4(1)	SOx Emission by Province in 2000	3-30
Table 3.2.5.4(2)	SOx Emission by Province in 2000	3-31
Table 3.2.5.5	Provinces Emitting More Than 10,000 tons of SOx in 2000	3-31
Table 3.2.5.6	Regional SOx Emission in 2000.....	3-32
Table 3.2.5.7	Comparison with Other Estimation for 2000	3-33
Table 3.2.6.1	Annual SOx Emission in BMR in 2000.....	3-34
Table 3.2.6.2	Annual NOx Emission in BMR in 2000.....	3-35
Table 3.3.1.1	Data Collected and Used	3-36
Table 3.3.1.2	Collected EIA Reports	3-36
Table 3.3.2.1	Ratio of Regional Final Energy Consumption by Sector between 2011 and 2000	3-38
Table 3.3.2.1	Forecast of Total Power Generation in 2011 (EGAT and IPP) by Fuel....	3-40
Table 3.3.3.1	Fuel Consumption of Power Plants Connected to National Grid (2011) ..	3-43
Table 3.3.3.2	Fuel Consumption of Agriculture Sector in 2011	3-44
Table 3.3.3.3	Fuel Consumption of Mining Sector in 2011	3-44
Table 3.3.3.4	Fuel Consumption of Manufacturing Sector in 2011	3-45
Table 3.3.3.5	Fuel Consumption of The construction sector in 2011	3-45
Table 3.3.3.6	Fuel Consumption of Residential and Commercial Sector in 2011.....	3-46
Table 3.3.4.1	Fuel Consumption by Power Plants in BMR in 2011.....	3-46
Table 3.3.4.2	Fuel Consumption by Agriculture Sector in BMR in 2011.....	3-47
Table 3.3.4.3	Fuel Consumption by Mining Sector in BMR in 2011	3-47
Table 3.3.4.4	Fuel Consumption by The manufacturing sector in BMR in 2011	3-48
Table 3.3.4.5	Fuel Consumption by Construction Sector in BMR in 2011	3-48
Table 3.3.4.6	Fuel Consumption by Residential and Commercial Sector in BMR in 2011.....	3-49
Table 3.3.5.1	Annual SOx Emission by Sector in 2011.....	3-49
Table 3.3.5.2	Annual SOx Emission by Point Sources in 2000.....	3-50
Table 3.3.5.3	Annual SOx Emission from Point and Area Sources in 2011.....	3-51
Table 3.3.5.4(1)	SOx Emission by Province in 2011	3-53
Table 3.3.5.4(2)	SOx Emission by Province in 2011	3-54
Table 3.3.5.5	Provinces Emitting More Than 10,000 tons of SOx in 2011.....	3-54
Table 3.3.5.6	Regional SOx Emission in 2011.....	3-55
Table 3.3.6.1	Comparison of SOx Emission between 2011 and 2000.....	3-56
Table 3.3.6.2	Change of Share of Power Plants to Total SOx Emission.....	3-57
Table 3.3.6.3	Change of Regional SOx Emission between 2000 and 2011	3-58



Table 3.3.7.1	Annual SOx Emission in BMR in 2011	3-59
Table 3.3.7.2	Annual NOx Emission in BMR in 2011	3-60
Table 3.3.7.3	Comparison of SOx Emission between 2011 and 2000.....	3-61
Table 3.3.7.4	Comparison of NOx Emission in BMR between 2011 and 2000.....	3-62

4. Mobile Source Inventory

Table 4.2.1.1	Vehicle Kilometers in Thailand in the Year 2000	4-5
Table 4.2.1.2	Emission Standard Enforcement Year	4-9
Table 4.2.1.3	Vehicle Type Conversion from COPERT 3 to Traffic Data	4-12
Table 4.2.1.4	Mileage Distributions by Vehicle Type	4-15
Table 4.2.1.5	Actual Sulphur Contents and Specific Gravity of Fuel.....	4-17
Table 4.2.1.6	Emission Factors of SOx	4-17
Table 4.2.1.7	Fuel Consumption and SOx Emission of Vehicles in the Year 2000.....	4-18
Table 4.2.1.8	Number of Train Operations in the Year 2000.....	4-20
Table 4.2.1.9	Fuel consumption rate and SOx emission factor	4-20
Table 4.2.1.10	Fuel Consumption and SOx Emission of Railways in the Year 2000.....	4-21
Table 4.2.1.11	Number of Calls of Vessels on Arrival & Departure by Ship Type in the Year 2000	4-23
Table 4.2.1.12	Number of Fishing Boats in the Year 2000	4-24
Table 4.2.1.13	Number of trips of Small Boats in the Chao Phraya River in the Year 2000.....	4-24
Table 4.2.1.14	Rated Power of Main & Sub Diesel Engines.....	4-25
Table 4.2.1.15	Rated Fuel Consumption of Main & Sub Boilers.....	4-26
Table 4.2.1.16	GRT Average by Ship Type.....	4-26
Table 4.2.1.17	Loading Patterns of Engines in Port Area	4-26
Table 4.2.1.18	Mooring Hours by Ship Type in Port Area	4-27
Table 4.2.1.19	Sulfur Contents in Fuel and Specific Gravity.....	4-27
Table 4.2.1.20	Mode, Load Factor of Main Diesel and Vessel Velocity in Cruising	4-27
Table 4.2.1.21	Fuel Consumption of Vessels in the Year 2000	4-30
Table 4.2.1.22	SOx emission of Vessels in the Year 2000	4-30
Table 4.2.1.23	Fuel Consumption and SOx emission of Fishing Boats in the Year 2000.....	4-31
Table 4.2.1.24	Fuel Consumption and SOx emission of Small Boats in the Year 2000 ..	4-31
Table 4.2.1.25	Annual Aircraft Movement in the Year 2000.....	4-33
Table 4.2.1.26	Sulfur Contents and Specific Gravity of Fuel	4-34
Table 4.2.1.27	SOx emission factor by aircraft type	4-34
Table 4.2.1.28	Time-In-Mode.....	4-35
Table 4.2.1.29	Fuel Consumption and SOx Emission of Aircraft in the Year 2000.....	4-36
Table 4.2.1.30	SOx Emission of Mobile Sources of the Year 2000 in the Whole Thailand.....	4-37
Table 4.2.1.31	Fuel Consumption of Mobile Sources for the Year 2000 in the Whole Thailand	4-38
Table 4.2.2.1	Vehicle Kilometers by Vehicle Type in BMR in the Year 2000	4-40
Table 4.2.2.2	Test Data by Chassis Dynamometer.....	4-46
Table 4.2.2.3	Thai Emission Standards of Equivalent EU Emission Standards.....	4-46
Table 4.2.2.4	Reduction rates of NOx Emission Factor in EURO 2 onward from EURO 1.....	4-47
Table 4.2.2.5	Vehicle Type Conversion from MOBILE5 to Traffic Data	4-51
Table 4.2.2.6	Emission Factors and Deterioration Rates by Vehicle Type and Model Year	4-51
Table 4.2.2.7	Test Data by Chassis Dynamometer.....	4-53
Table 4.2.2.8	Thai Motorcycle Emission Standard.....	4-53
Table 4.2.2.9	Shares of 2 or 4 Stroke in MCs.....	4-53
Table 4.2.2.10	NOx Emission Factor of MCs(2, 4 strokes) and Tuk-tuks/Taxis(LPG)	4-55
Table 4.2.2.11	NOx Emission Factors of MCs	4-55
Table 4.2.2.12	NOx Emission Factors of All Vehicle Types and Motorcycles	4-56
Table 4.2.2.13	Estimated NOx and SOx Emission of vehicles in BMR in the Year 2000	4-57
Table 4.2.2.14	NOx emission factor of railways.....	4-59
Table 4.2.2.15	NOx and SOx Emissions of Railways in BMR in the Year 2000	4-59



Table 4.2.2.16	Number of Calls of Vessels on Arrival & Departure in BMR in the Year 2000.....	4-61
Table 4.2.2.17	Number of Fishing Boats in BMR in the Year 2000.....	4-61
Table 4.2.2.18	Number of trips of Small Boats in the Chao Phraya River in the Year 2000	4-62
Table 4.2.2.19	NOx emissions of Vessels in BMR in the Year 2000.....	4-62
Table 4.2.2.20	SOx emissions of Vessels in BMR in the Year 2000.....	4-63
Table 4.2.2.21	Estimated NOx and SOx emissions of Fishing Boats in BMR in the Year 2000	4-63
Table 4.2.2.22	Estimated NOx and SOx emissions of Small Boats in BMR in the Year 2000	4-63
Table 4.2.2.23	Annual Aircraft Movement in the Year 2000	4-64
Table 4.2.2.24	NOx emission factor by aircraft type	4-65
Table 4.2.2.25	Time-In-Mode.....	4-66
Table 4.2.2.26	Estimated NOx and SOx emission of airport in BMR in the Year 2000 ...	4-66
Table 4.2.2.27	Estimated NOx Emission of Mobile Sources in BMR in the Year 2000 ...	4-67
Table 4.2.2.28	Estimated SOx Emission of Mobile Sources in BMR in the Year 2000 ...	4-68
Table 4.3.1.1	Vehicle Kilometers in Thailand in the Year 2011	4-71
Table 4.3.1.2	Growth Rate of Vehicle Kilometers in the areas except BMR in Thailand.....	4-71
Table 4.3.1.3	Regression model for the future numbers of new registered vehicles	4-74
Table 4.3.1.4	Age Distributions for the Year 2011 (BAU Case).....	4-75
Table 4.3.1.5	Future Sulphur Contents and the Specific Gravity of Fuel	4-76
Table 4.3.1.6	Emission Factors of SOx.....	4-76
Table 4.3.1.7	Fuel Consumption and SOx Emission of Vehicles in the Year 2011	4-78
Table 4.3.1.8	Number of Operations of Train in Year 2011	4-80
Table 4.3.1.9	Fuel consumption rate and SOx emission factor	4-80
Table 4.3.1.10	Fuel Consumption and SOx Emission of Railways in the Year 2011	4-81
Table 4.3.1.11	Number of Calls of Vessels on Arrival & Departure by Ship Type in the Year 2011.....	4-84
Table 4.3.1.12	Growth Rate of Freight Demand	4-84
Table 4.3.1.13	Number of Fishing Boats in the Year 2011	4-85
Table 4.3.1.14	Number of trips of Small Boats in the Chao Phraya River in the Year 2011.....	4-85
Table 4.3.1.15	Growth Rate of Tourist Forecast	4-85
Table 4.3.1.16	Sulfur Contents in Fuel and Specific Gravity.....	4-85
Table 4.3.1.17	Fuel Consumption of Vessels in the Year 2011.....	4-86
Table 4.3.1.18	SOx emissions of Vessels in the Year 2011.....	4-86
Table 4.3.1.19	Fuel Consumption and SOx emission of Fishing Boats in the Year 2011.....	4-87
Table 4.3.1.20	Fuel Consumption and SOx emission of Small Boats in the Year 2011...	4-87
Table 4.3.1.21	Annual Aircraft Movement in the Year 2011	4-89
Table 4.3.1.22	Growth Rate of Annual Movement.....	4-90
Table 4.3.1.23	Fuel Consumption and SOx Emission of Aircraft in the Year 2011	4-91
Table 4.3.1.24	SOx Emission of Mobile Sources for the Year 2011 in the Whole Thailand	4-93
Table 4.3.1.25	Fuel Consumption of Mobile Sources for the Year 2011 in the Whole Thailand	4-94
Table 4.3.2.1	Transport Projects considered in BMR for 2011(BAU Case).....	4-97
Table 4.3.2.2	Vehicle Kilometers by Vehicle Type in BMR in the Year 2011	4-98
Table 4.3.2.3	Emission Control considered in the BAU Case.....	4-100
Table 4.3.2.4	Shares of 2 or 4 Strokes in MCs	4-101
Table 4.3.2.5	NOx Emission Factor of MCs.....	4-101
Table 4.3.2.6	NOx Emission Factors of All Vehicle Types and Motorcycles	4-102
Table 4.3.2.7	Estimated NOx and SOx Emissions of vehicles in BMR in the Year 2011.....	4-104
Table 4.3.2.8	NOx and SOx Emission of Railways in BMR in the Year 2011.....	4-106
Table 4.3.2.9	Number of Calls of Vessels on Arrival & Departure in BMR	



	in the Year 2011.....	4-109
Table 4.3.2.10	Number of Fishing Boats in BMR in the Year 2011	4-109
Table 4.3.2.11	Number of trips of Small Boats in the Chao Phraya River in the Year 2011.....	4-109
Table 4.3.2.12	NOx emission of Vessels in BMR in the Year 2011.....	4-110
Table 4.3.2.13	SOx emission of Vessels in BMR in the Year 2011	4-110
Table 4.3.2.14	Estimated NOx and SOx emission of Fishing Boats in BMR in the Year 2011.....	4-110
Table 4.3.2.15	Estimated NOx and SOx emission of Small Boats in BMR in the Year 2011.....	4-111
Table 4.3.2.16	Annual Aircraft Movements in the Year 2011.....	4-113
Table 4.3.2.17	Estimated NOx and SOx emission of airports in BMR in the Year 2011..	4-113
Table 4.3.2.18	Estimated NOx Emission of Mobile Sources in BMR in the Year 2011....	4-114
Table 4.3.2.19	Estimated SOx Emission of Mobile Sources in BMR in the Year 2011....	4-115
5.	Inventory by Pollutants, SOx and NOx	
Table 5.1.1.1	SOx Emission Amounts of the Whole Thailand by Sector	5-2
Table 5.1.1.2	SOx Emission Amounts of the Whole Thailand by Fuel Type	5-3
Table 5.1.2.1	SOx Emission Amounts of BMR by Sector.....	5-4
Table 5.1.2.2	SOx Emission Amounts of BMR by Fuel Type	5-5
Table 5.1.3.1	NOx Emission Amounts of BMR by Sector	5-7
6.	Model Simulation	
Table 6.1.1.1	Data and Pre-Processors.....	6-2
Table 6.1.3.1	Pollutant Emission Source Types.....	6-21
Table 6.1.3.2	Dry Deposition Velocity.....	6-24
Table 6.1.4.1	Comparison of Simulation Results with Measurements.....	6-26
Table 6.2.1.1	Airviro Model Type.....	6-43
Table 6.2.1.2	Type of Indico Package.....	6-43
Table 6.2.3.1	Static Information of Point Source and Area Source	6-46
Table 6.2.3.2	Searchkeys in the BMR.....	6-47
Table 6.2.3.3	General and Static Information of Line Source.....	6-50
Table 6.2.3.4	Emission Factor by Vehicle Type for Airviro for the Year 2000.....	6-53
Table 6.2.3.5	Composition Rates of Vehicle Types based on DOH.....	6-61
Table 6.2.3.6	Composition Rates of Vehicle Types based on the year 1997 Airviro	6-62
Table 6.2.3.7	Composition Rates of Traffic Vehicle for Year 2000.....	6-62
Table 6.2.3.8	Relation between Hourly Patterns and Vehicle Types Composition.....	6-64
Table 6.2.3.9	General and Static Information of Line Source.....	6-71
Table 6.2.3.10	Emission Factor by Vehicle Type of Airviro for the Year 2011	6-72
Table 6.2.3.11	Composition Rates of Vehicle Types for the Year 2011.....	6-74
Table 6.2.3.12	Relation between Hourly Patterns and Vehicle Types Composition.....	6-75
Table 6.2.4.1	Deflection of Free Wind.....	6-85
Table 6.2.6.1	Ambient Air Standards of Thailand & Guidelines for Air Quality of WHO	6-94
Table 6.2.7.1	Types of Monitoring Stations	6-96
Table 6.2.7.2	Criteria and Evaluation Results of the Monitoring Data.....	6-97
Table 6.2.9.1	Comparison Simulation Results with the Ambient Annual Standard	6-103
Table 6.3.1.1	Training Items.....	6-107
7.	Evaluation of Acid Deposition and Air Quality	
Table 7.2.2.1	Evaluation of SO ₂ Concentration, Other than BMR.....	7-3
Table 7.2.2.2	Evaluation of SO ₂ Concentration, the BMR.....	7-3
Table 7.2.3.1	Evaluation of NO ₂ Concentration, the BMR.....	7-4
8.	Countermeasures for SO₂ in BMR	
Table 8.3.1.1	SO ₂ Emission Standard.....	8-3
Table 8.3.1.2	Specifications for Sulfur in Petroleum Products	8-4
Table 8.3.2.1	Current Abatement measures for SOx.....	8-4
Table 8.4.2.1	FGD Plant of Mae Moh Power Station.....	8-7
Table 8.5.2.1	Primary Screening.....	8-12

Table 8.5.3.1	Cost Estimation	8-13
Table 8.5.4.1	Secondary Screening	8-13
Table 8.5.5.1	Exceeding Grid Number	8-14
Table 8.7.1.1	Types of Soft Loans	8-19
Table 8.7.1.2	Implementation Schedule	8-23
Table 8.7.2.1	Brief Frame of "the Society for Atmospheric Environment Conservation"	8-27
Table 8.7.3.1	Action Plan for the Shift to Natural Gas	8-28
9. Countermeasures for NO₂ in BMR		
Table 9.2.1.1	Emission Control and Transport Projects considered in the BAU Case ..	9-2
Table 9.2.1.2	Summary of NO _x / NO ₂ Simulation Result	9-4
Table 9.3.3.1	Past and Future Emission Standards for New Vehicles	9-8
Table 9.3.3.2	Emission Factors Comparison between default of the other sources and Thai	9-11
Table 9.3.3.3	Outline of Tentative Countermeasures	9-14
Table 9.3.3.4	Primary Screening Results of 1st Draft Countermeasures (Financial Acceptability & Technical Possibility)	9-15
Table 9.3.4.1	Emission Factors and Deterioration Rates	9-17
Table 9.3.4.2	Investment and Annualised cost for LDV and HDDV	9-18
Table 9.3.4.3	Emission Factors/Deterioration Rates of Conventional HDDV/Ts and NG Buses	9-19
Table 9.3.4.4	Investment and Annualised Cost	9-20
Table 9.3.4.5	Age Distributions of the BAU Case and OVR Case at 2011	9-21
Table 9.3.4.6	Investment Cost and Annualised Cost	9-22
Table 9.3.4.7	Emission Factors of the BAU Case and the Countermeasure Case	9-23
Table 9.3.4.8	Agencies Concerned in the 2nd Draft Countermeasures	9-25
Table 9.3.4.9	Cost-Effectiveness Evaluation Results of 2nd Draft Countermeasures ...	9-26
Table 9.3.5.1	LEV/OVR Countermeasure Mix Matrix	9-28
Table 9.3.5.2	Evaluation of NO _x Reduction and the Cost on LEV/OVR Countermeasure Mix	9-31
Table 9.3.5.3	Simulation Results of the Recommended Control Cases	9-32
Table 9.5.1.1	Action Plan	9-40
Table 9.5.2.1	Financial Support for BMTA	9-41
Table 9.5.2.2	Financial Support for Private bus operators	9-41
Table 9.5.2.3	Economic Incentives for NGV	9-41
Table 9.5.2.4	Replacement Plan and Required Investment for BMTA and Private Operators	9-42
Table 9.5.2.5	Financial Sources and the Problems	9-45
Table 9.5.2.6	Implementation Schedule	9-46
Table 9.5.3.1	Replacement Plan and Required Investment for Old Aged Buses (VR1 case)	9-47
Table 9.5.3.2	Financial Sources and the Problems	9-49
Table 9.5.3.3	Implementation Schedule	9-50
10. Acid Deposition Control Strategy		
Table 10.3.5.1	Action Plan for the Shift to Natural Gas	10-6
Table 10.5.1.1	Strategy for Environmental Management	10-10

List of Figures

1. Acid Deposition and Air Quality Data Analysis

Figure 1.1.1.1	Rain Amount of Each Monitoring Site	1-4
Figure 1.1.1.2(1)	Monthly Trends of SO ₄ and NH ₄	1-5
Figure 1.1.1.2(2)	Monthly Trend of Cl and Na	1-6
Figure 1.1.1.3	Frequency Distribution of pH	1-7
Figure 1.1.2.1	Anion Composition of Each Monitoring Site	1-9
Figure 1.1.2.2	Cation Composition of Each Monitoring Site	1-10
Figure 1.1.2.3	Ratio of non Sea Salt SO ₄ and Ca	1-11
Figure 1.1.4.1	Rain Amount of Each Country	1-15



Figure 1.1.4.2(1) Monthly Trend of pH, nss-SO ₄ and NO ₃ in Urban Area.....	1-16
Figure 1.1.4.2(2) Monthly Trend of pH, nss-SO ₄ and NO ₃ in Rural Area.....	1-17
Figure 1.1.4.2(3) Monthly Trend of pH, nss-SO ₄ and NO ₃ in Remote Area.....	1-18
Figure 1.2.1.1(1) Hourly and Daily Average of SO ₂ in Ambient Air.....	1-25
Figure 1.2.1.1(2) Hourly and Daily Average of NO ₂ in Ambient Air.....	1-26
Figure 1.2.1.2 Annual and Seasonal Average of Each Monitoring Site.....	1-28
Figure 1.2.1.3 Time Trend of NO ₂ concentration.....	1-29
2. Socio-economic Issues	
Figure 2.1.1.1 Land Use In the Whole Kingdom.....	2-2
Figure 2.1.1.2 Annual Temperature in Bangkok.....	2-3
Figure 2.1.1.3 Annual Rainfall in Bangkok.....	2-3
Figure 2.1.2.1 Trend of Population in the Whole Country.....	2-5
Figure 2.1.2.2 Trends of Population in BMR.....	2-6
Figure 2.1.2.3 Employment Situation in the Whole Kingdom (as of 2000).....	2-7
Figure 2.1.4.1 Economic Structure (as percent of GDP).....	2-11
Figure 2.1.4.2 GDP per capita at 1998 prices and Annual Growth Rate.....	2-14
Figure 2.1.4.3 Changes in Trade Structure.....	2-16
Figure 2.2.1.1 Comparisons of Population Projections of the Related Studies and NESDB.....	2-19
Figure 2.2.1.2 Population Projections for BMR.....	2-20
Figure 2.2.1.3 GDP Projections of the Related Studies.....	2-21
Figure 2.2.1.4 GDP Projections of the Related Studies for BMR.....	2-23
3. Stationary Source Inventory	
Figure 3.2.2.1 Share of Energy Consumption by Sector in Whole Thailand in 2000.....	3-6
Figure 3.2.2.1 Lignite Consumption Area for Tobacco Curing.....	3-11
Figure 3.2.3.1 Flowchart for Development of Stationary Source Inventory for ATMOS2.....	3-15
Figure 3.2.4.1 Flowchart to Develop Inventory of Manufacturing Sector for ATMOS2 and Airviro 2000.....	3-22
Figure 3.2.5.1 Sectoral Share in Total SO _x Emission in Thailand in 2000.....	3-27
Figure 3.2.5.2 Annual SO _x Emission by Point Source in 2000.....	3-28
Figure 3.2.5.3 Distribution of Provincial SO _x Emission in 2000.....	3-29
Figure 3.2.5.4 Provinces emitting more than 10 thousand tons of SO _x in 2000.....	3-32
Figure 3.2.5.5 Regional SO _x Emission in 2000.....	3-33
Figure 3.2.6.1 Provincial SO _x Emission in BMR in 2000.....	3-34
Figure 3.2.6.2 Annual NO _x Emission in BMR in 2000.....	3-35
Figure 3.3.2.1 Regional Final Energy Consumption Growth between 2000 and 2011 ..	3-39
Figure 3.3.2.2 Share of Fuels in Power Generation (EGAT pp and IPP) in 2011.....	3-41
Figure 3.3.2.3 Flowchart for Estimation of Fuel Consumption and SO _x Emission of Power Sector in 2011.....	3-41
Figure 3.3.2.4 Conceptual Diagram of Fuel Consumption of The manufacturing sector in 2011.....	3-43
Figure 3.3.5.1 Total SO _x Emission by Sector in 2011.....	3-50
Figure 3.3.5.2 SO _x Emission by Point Sources in 2011.....	3-51
Figure 3.3.5.3 Distribution of Provincial SO _x Emission in Thailand in 2011.....	3-52
Figure 3.3.5.4 Provinces Emitting More than 10,000 tons of SO _x in 2011.....	3-55
Figure 3.3.5.5 SO _x Emission by Region in 2011.....	3-56
Figure 3.3.6.1 Comparison of SO _x Emission by Sector between 2011 and 2000.....	3-57
Figure 3.3.6.2 Change of Share of Power Plants by Type between 2000 and 2011.....	3-58
Figure 3.3.7.1 Provincial SO _x Emission in BMR in 2011.....	3-60
Figure 3.3.7.2 Provincial NO _x Emission in BMR in 2011.....	3-61
Figure 3.3.7.3 Change of Provincial SO _x Emission in BMR between 2000 and 2011..	3-62
Figure 3.3.7.4 Change of Provincial NO _x Emission in BMR between 2000 and 2011 ..	3-63
4. Mobile Source Inventory	
Figure 4.1.1.1 General Flow of Mobile Source Inventory Development in Year 2000 ...	4-2
Figure 4.2.1.1 Flow of SO _x emission estimation of vehicles of the Year 2000 in whole Thailand.....	4-4



Figure 4.2.1.2	Location of Mobile Source of the Year 2000 in the Whole Thailand.....	4-6
Figure 4.2.1.3	General Workflow of SOx Emission Factor Calculation.....	4-8
Figure 4.2.1.4	Workflow of Age Distribution Calculation.....	4-13
Figure 4.2.1.5	Age Distributions for the Year 2000.....	4-14
Figure 4.2.1.6	Mileage Distributions by Vehicle Type (2000).....	4-15
Figure 4.2.1.7	Fuel Consumption Rate by Vehicle Type.....	4-16
Figure 4.2.1.8	Fuel Consumption of Vehicles in the Whole Thailand in the Year 2000.....	4-18
Figure 4.2.1.9	SOx Emission of Vehicles in the Whole Thailand in the Year 2000.....	4-18
Figure 4.2.1.10	Flow of SOx emission estimation of railways for the Year 2000 in the whole Thailand.....	4-19
Figure 4.2.1.11	Fuel Consumption and SOx Emission of Railways in the Whole Thailand in the Year 2000.....	4-21
Figure 4.2.1.12	Flow of SOx emission estimation of ships for the Year 2000 in the whole Thailand.....	4-22
Figure 4.2.1.13	Share of SOx Emission of Ships in the whole Thailand in the Year 2000.....	4-31
Figure 4.2.1.14	Flow of SOx emission estimation of aircraft for the Year 2000 in the whole Thailand.....	4-32
Figure 4.2.1.15	Fuel Consumption and SOx Emission of Aircraft in the Whole Thailand in the Year 2000.....	4-35
Figure 4.2.1.16	SOx Emission of Mobile Sources for the Year 2000 in the Whole Thailand.....	4-37
Figure 4.2.1.17	Fuel Consumption of Mobile Sources for the Year 2000 in the Whole Thailand.....	4-38
Figure 4.2.2.1	Flow of SOx and NOx emission estimations of vehicles for the Year 2000 in BMR.....	4-39
Figure 4.2.2.2	Location of Mobile Source in BMR in Year 2000.....	4-41
Figure 4.2.2.3	General Workflow of NOx Emission Factor Calculation.....	4-43
Figure 4.2.2.4	Detailed Workflow of NOx Emission Factor Calculation for Vehicles.....	4-45
Figure 4.2.2.5	NOx Emission Factors and Test Data (LDGV).....	4-48
Figure 4.2.2.6	NOx Emission Factors and Test Data (LDDV).....	4-49
Figure 4.2.2.7	NOx Emission Factors and Test Data (LDDT, HDDV/T).....	4-50
Figure 4.2.2.8	Detailed Workflow of NOx Emission Factors calculation for MCs and Tuk-tuks/Taxis(LPG).....	4-52
Figure 4.2.2.9	NOx Emission Factors and Test Data (MCs 2,4 strokes).....	4-54
Figure 4.2.2.10	Estimated NOx Emission of vehicles in BMR in the Year 2000.....	4-57
Figure 4.2.2.11	Estimated SOx Emission of vehicles in BMR in the Year 2000.....	4-57
Figure 4.2.2.12	Flow of SOx and NOx emission estimation of railways for the Year 2000 in BMR.....	4-58
Figure 4.2.2.13	Flow of SOx and NOx emission estimation of ships for the year 2000 in BMR.....	4-60
Figure 4.2.2.14	Flow of SOx and NOx emission estimation of aircraft for the Year 2000 in BMR.....	4-64
Figure 4.2.2.15	Estimated NOx and SOx emission of airport in BMR in the Year 2000.....	4-66
Figure 4.2.2.16	Estimated NOx Emission of Mobile Sources in BMR in the Year 2000.....	4-67
Figure 4.2.2.17	Estimated SOx Emission of Mobile Sources in BMR in the Year 2000..	4-68
Figure 4.3.1.1	Flow of SOx emission estimation of vehicles of the Year 2011 in whole Thailand.....	4-69
Figure 4.3.1.2	Location of Mobile Sources for the Year 2011 in the Whole Thailand....	4-72
Figure 4.3.1.3	Age Distributions for the Year 2011(BAU).....	4-75
Figure 4.3.1.4	Comparisons of SOx Emission Factors for 2000 and 2011(BAU Case)	4-77
Figure 4.3.1.5	Fuel Consumption of Vehicles in the Whole Thailand in the Year 2011.	4-78
Figure 4.3.1.6	SOx Emission of Vehicles in the Whole Thailand in the Year 2011.....	4-78
Figure 4.3.1.7	Flow of SOx emission estimation of railways for the Year 2011 in the whole Thailand.....	4-79
Figure 4.3.1.8	Fuel Consumption and SOx Emission of Railways	



	in the Whole Thailand in the Year 2011	4-81
Figure 4.3.1.9	Flow of SOx emission estimation of ships for the Year 2011 in the whole Thailand	4-82
Figure 4.3.1.10	Share of SOx Emission of Ships in the whole Thailand in the Year 2011	4-87
Figure 4.3.1.11	Flow of SOx emission estimation of aircraft for the Year 2011 in the whole Thailand	4-88
Figure 4.3.1.12	Fuel Consumption and SOx emission of Aircraft in the Whole Thailand in the Year 2011	4-92
Figure 4.3.1.14	SOx Emission of Mobile Sources for the Year 2011 in the Whole Thailand	4-93
Figure 4.3.1.15	Fuel Consumption of Mobile Sources for the Year 2011 in the Whole Thailand	4-94
Figure 4.3.1.16	SOx Emission of Mobile Sources for the Year 2000 and 2011 in the Whole Thailand	4-95
Figure 4.3.1.17	Fuel Consumption of Mobile Sources for the Year 2000 and 2011 in the Whole Thailand	4-95
Figure 4.3.2.1	Flow of SOx and NOx emission estimation of vehicles for the Year 2011 in BMR	4-96
Figure 4.3.2.2	Location of Mobile Source in BMR in Year 2011	4-99
Figure 4.3.2.3	Comparison of NOx Emission Factors for the years 2000 and 2011(BAU Case)	4-103
Figure 4.3.2.4	Estimated NOx Emission of vehicles in BMR in the Year 2011	4-104
Figure 4.3.2.5	Estimated SOx Emission of vehicles in BMR in the Year 2011	4-104
Figure 4.3.2.6	Flow of SOx and NOx emission estimation of railways for the Year 2011 in BMR	4-105
Figure 4.3.2.7	Flow of SOx and NOx emission estimation of ships for the Year 2011 in BMR	4-107
Figure 4.3.2.8	Flow of SOx and NOx emission estimation of aircraft for the Year 2011 in BMR	4-112
Figure 4.3.2.9	Estimated NOx and SOx emission of airport in BMR in the Year 2011 ..	4-113
Figure 4.3.2.10	Estimated NOx Emission of Mobile Sources in BMR in the Year 2011	4-114
Figure 4.3.2.11	Estimated SOx Emission of Mobile Sources in BMR in the Year 2011	4-115
Figure 4.3.2.12	NOx Emission of Mobile Sources of the Year 2000 and 2011 in BMR ..	4-116
Figure 4.3.2.13	SOx Emission of Mobile Sources for the Year 2000 and 2011 in BMR ..	4-117
Figure 4.3.2.14	Fuel Consumption of Mobile Sources for the Year 2000 and 2011 in BMR	4-117
5. Inventory by Pollutants, SOx and NOx		
Figure 5.1.1.1	SOx Emission Amounts for the Whole Thailand by Sector	5-2
Figure 5.1.1.2	SOx Emission Amounts for the Whole Thailand by Fuel Type	5-3
Figure 5.1.2.1	SOx Emission Amounts of BMR by Sector	5-5
Figure 5.1.2.2	SOx Emission Amounts of BMR by Fuel Type	5-6
Figure 5.1.3.1	NOx Emission Amounts of BMR by Sector	5-7
6. Model Simulation		
Figure 6.1.1.1	Monthly Precipitation Amount	6-6
Figure 6.1.1.2	Precipitation Observation Stations	6-8
Figure 6.1.1.3	CDC/NCEP Precipitation Data in East Asia	6-8
Figure 6.1.1.4	CDC/NCEP Precipitation around Thailand	6-9
Figure 6.1.1.5	Combined Precipitation around Thailand	6-9
Figure 6.1.1.6	Simulation Flow Diagram	6-10
Figure 6.1.2.1	SOx Emission in the Whole of Thailand for the Year 2000	6-13
Figure 6.1.2.2	SOx Emission in the Urban Area for the Year 2000	6-13
Figure 6.1.2.3	SOx Emission in the Whole of Thailand for the Year 2011	6-14
Figure 6.1.2.4	SOx Emission in the Urban Area for the Year 2011	6-14
Figure 6.1.2.5	SOx Emission in the Whole of Thailand with the Control	6-15
Figure 6.1.2.6	SOx Emission in the Urban Area with the Control	6-15

Figure 6.1.3.1	Meteorological Data Field.....	6-18
Figure 6.1.3.2	Regional Grid System.....	6-18
Figure 6.1.3.3	Urban Grid System.....	6-19
Figure 6.1.3.4	2-Dimensional Linear Interpolation.....	6-20
Figure 6.1.3.5	Vertical Layers Structures.....	6-21
Figure 6.1.3.6	Modified Euler Algorithm for Trajectory.....	6-22
Figure 6.1.3.7	Branching and Mixing during The Transitions.....	6-23
Figure 6.1.4.1	Improvement of Simulation Model.....	6-26
Figure 6.1.4.2	Wet Deposition in the Whole of Thailand for the Year 2000.....	6-27
Figure 6.1.4.3	Total Deposition in the Whole of Thailand for the Year 2000.....	6-28
Figure 6.1.4.4	Wet Deposition in the Urban Area for the Year 2000.....	6-30
Figure 6.1.4.5	Total Deposition in the Urban Area for the Year 2000.....	6-31
Figure 6.1.4.6	SO ₂ Concentration in the Whole of Thailand for the Year 2000.....	6-32
Figure 6.1.4.7	Trans-Boundary Contributions on the Total Deposition.....	6-33
Figure 6.1.5.1	Total Deposition in the Whole of Thailand for the Year 2011.....	6-35
Figure 6.1.5.2	Total Deposition in the Urban Area for the Year 2011.....	6-36
Figure 6.1.5.3	SO ₂ Concentration in the Whole of Thailand for the Year 2011.....	6-37
Figure 6.1.6.1	Total Deposition in the Whole of Thailand for the Year 2011 with the Control.....	6-39
Figure 6.1.6.2	Total Deposition in the Urban Area for the Year 2011 with the Control...	6-40
Figure 6.1.6.3	SO ₂ Concentration in the Whole of Thailand for the Year 2011 with the Control.....	6-41
Figure 6.2.2.1	Grid Model Proceeding.....	6-44
Figure 6.2.3.1	SO _x Emission for the Year 2000 in the BMR (Point Source).....	6-48
Figure 6.2.3.2	SO _x Emission for the Year 2000 in the BMR (Area Source).....	6-48
Figure 6.2.3.3	NO _x Emission for the Year 2000 in the BMR (Point Source).....	6-49
Figure 6.2.3.4	NO _x Emission for the Year 2000 in the BMR (Area Source).....	6-49
Figure 6.2.3.5	Road Links Map in 1997 (upper) and 2000 (low).....	6-51
Figure 6.2.3.6	Traffic Volumes Measurement Points.....	6-52
Figure 6.2.3.7	Comparison of Measurement with Traffic Forecast.....	6-52
Figure 6.2.3.8	Hourly Pattern and Vehicle Type Composition.....	6-54
Figure 6.2.3.9	Measurement Points of Traffic Volume.....	6-55
Figure 6.2.3.10	Hourly Pattern of Traffic Vehicles.....	6-55
Figure 6.2.3.11	Classified Hourly Patterns in the Year 2000.....	6-56
Figure 6.2.3.12	Classified Hourly Patterns in the Year 1997.....	6-57
Figure 6.2.3.13	Whole Hourly Patterns of Traffic Volumes.....	6-58
Figure 6.2.3.14	Relation between Road links and Hourly Patterns in the BMR.....	6-59
Figure 6.2.3.15	DOH Measurement Points in the BMR.....	6-60
Figure 6.2.3.16	Method for Setting Vehicle Types Composition.....	6-61
Figure 6.2.3.17	Vehicle Types Composition for the Year 2000 in the BMR.....	6-63
Figure 6.2.3.18	SO _x Emission for the Year 2000 in the BMR (Line Source).....	6-65
Figure 6.2.3.19	NO _x Emission for the Year 2000 in the BMR (Line Source).....	6-66
Figure 6.2.3.20	SO _x Emission Map for Year 2011 Bau in the BMR (Point Sources).....	6-68
Figure 6.2.3.21	SO _x Emission Map for the Year 2011 Bau in the BMR (Area Source)...	6-68
Figure 6.2.3.22	NO _x Emission Map for the Year 2011 Bau in the BMR (Point Sources)...	6-69
Figure 6.2.3.23	NO _x Emission Map for the Year 2011 Bau in the BMR (Area Source)...	6-69
Figure 6.2.3.24	Road Links Map for the Year 2011.....	6-70
Figure 6.2.3.25	Hourly Pattern and Vehicle Type Composition.....	6-72
Figure 6.2.3.26	Relation between Road links and Hourly Patterns in the BMR.....	6-73
Figure 6.2.3.27	Vehicle Types Composition in the BMR.....	6-74
Figure 6.2.3.28	SO _x Emission Map for the Year 2011 Bau in the BMR (Line Sources)...	6-76
Figure 6.2.3.29	NO _x Emission Map for the Year 2011 Bau in the BMR (Line Sources)...	6-77
Figure 6.2.4.1	Inflow and Outflow of Pollutants in a Box.....	6-78
Figure 6.2.4.2	Procedure of the Wind Field Calculation.....	6-80
Figure 6.2.4.3	Characterization of the Wind Speed and Wind Direction of the Master Station.....	6-81
Figure 6.2.4.4	Monin-Obukhov length (L) by Stability.....	6-83
Figure 6.2.4.5	Final Plume Height and Stack Height.....	6-89
Figure 6.2.5.1	Result of Statistical Model for Year 2000.....	6-92



Figure 6.2.6.1	Maximum Hourly Value and Annual Mean Value of Monitoring Data	6-94
Figure 6.2.7.1	Location of Monitoring Stations.....	6-95
Figure 6.2.8.1	Comparison of Calculation Values and Monitoring Data	6-100
Figure 6.2.8.2	SO ₂ Concentration Map for the Year 2000 in the BMR.....	6-101
Figure 6.2.8.3	NO ₂ Concentration Map for the Year 2000 in the BMR.....	6-102
Figure 6.2.9.1	SO ₂ Concentration Map for the Year 2011Bau in the BMR.....	6-104
Figure 6.2.9.2	NO ₂ Concentration Map for the Year 2011Bau in the BMR.....	6-105
7.	Evaluation of Acid Deposition and Air Quality	
Figure 7.3.1.1	Target Area : the BMR	7-5
8.	Countermeasures for SO₂ in BMR	
Figure 8.1.1.1	Methodology for Studying Countermeasure	8-1
Figure 8.2.1.1	SO _x Emission by Sector, BMR	8-2
Figure 8.2.1.2	SO _x Emission by Fuel Type, BMR.....	8-2
Figure 8.4.1.1	Cosumption of Fuel Oil in BMR	8-5
Figure 8.4.3.1	Natural Gas Consumption in BMR	8-8
Figure 8.4.5.1	Share of Energy Consumption by Sector	8-10
Figure 8.5.3.1	Cost Effectiveness.....	8-13
Figure 8.5.4.1	Screening of Countermeasure.....	8-14
Figure 8.5.5.1	2011 Control Case : Shift to Natural Gas.....	8-16
Figure 8.7.1.1	Process of the Environmental Fund	8-20
Figure 8.7.1.2	Procedure of JBIC's two step loan	8-21
Figure 8.7.1.3	Procedure of Clean Development Mechanism.....	8-22
9.	Countermeasures for NO₂ in BMR	
Figure 9.1.1.1	Basic Flowchart for Building the Scenario of NO ₂ Countermeasures.....	9-1
Figure 9.2.1.1	NO ₂ Airviro Simulation Result of 2011 (BAU Case).....	9-3
Figure 9.3.1.1	NO _x Emission estimated by Vehicle Type in 2011 (BAU).....	9-4
Figure 9.3.4.1	Schematic Diagram for the Secondary Screening Result	9-27
Figure 9.3.5.1	Schematic Description of LEV/OVR Countermeasure by Target Vehicle Type.....	9-30
Figure 9.3.5.2(1)	Airviro simulation result of the ambient NO ₂ concentration in the BAU/Control Case	9-33
Figure 9.3.5.2(2)	Airviro simulation result of the ambient NO ₂ concentration in the Control Cases.....	9-34
Figure 9.5.2.1	Financial Sources and Arrangement	9-46
Figure 9.5.3.1	Financial Sources and Arrangement	9-49
10.	Acid Deposition Control Strategy	
Figure 10.1.1.1	Acid Deposition Control.....	10-1
Figure 10.1.1.2	Countermeasure and Management.....	10-2
Figure 10.2.1.3	Strategy	10-3

Abbreviation

AAT	Airport Authority Thailand
Airport Study	The Study on Airport Development Master Plan in the Kingdom of Thailand, January 2000
AP	Acidification Potential
AQNMD	Air Quality and Noise Management Division
BHP	Brake Horse Power
BMA	Bangkok Metropolitan Administration
BMR	Bangkok Metropolitan Region
BMTA	Bangkok Metropolitan Transit Authority
CDC/NCEP	Climate Diagnosis Center / National Centers for Environmental Prediction
CDM	Clean Development Mechanism
COPERT3	Computer Program to Calculate Emissions from Road Transport
CVS	Constant Volume Sampler
DCR	Department of Commercial Registrations
DEDP	Department of Energy Development and Promotion
DIW	Department of Industrial Works
DMR	Department of Mineral Resources
DOH	Department of Highways
DWT	Dead Weight Tonnage
ECE	Economic Commission for Europe
EGAT	Electricity Generating Authority of Thailand
EIA	Environmental Impact Assessment
EPPO	Energy Policy and Planning Office
ESCAP	United Nations Economic and Social Commission for Asia and the Pacific
EUDC	Extra Urban Driving Cycle
FAO	Food and Agriculture Organization of the United Nations
GDP	Gross Domestic Product
GRP	Gross Regional Product
GRT	Gross Registered Tonnage
GWh	GigaWatt-Hour (10 ⁹ Watt-Hour)
Harbor Study	The Master Plan Study for the Coastal Channels and Ports Development in the Kingdom of Thailand, March 2002
HDDV	Heavy Duty Diesel Vehicle
HSD	High Speed Diesel
I/M	Inspection and Maintenance
IFCT	Industrial Finance Corporation of Thailand
IPCC	International Panel on Climate Change
IPP	Independent Power Producer
JBIC	Japan Bank for International Cooperation
kg	10 ³ grams
kL	10 ³ litre
kton	10 ³ ton
LDDT	Light Duty Diesel Truck
LDDV	Light Duty Diesel Vehicle

LDGV	Light Duty Gasoline Vehicle
LEV	Low Emission Vehicle
LPG	Liquefied Petroleum Gas
LSD	Low Speed Diesel
LTD	Department of Land Transport
LTO	Landing and Take Off
LTP-2	Consulting Services for the Study on the Strengthening of DOH's Management and Updating of the Long-Term Strategic Investment Plan, December 2001
M m ³	million m ³
MC	Motorcycle
MJ	Million Joules
MMscf	Million Standard Cubic Feet
MOF	Ministry of Finance
MOI	Ministry of Industry
MOSTE	Ministry of Science, Technology and Environment
MOTC	Ministry of Transport and Communications
MRT	Mass Rapid Transit
NBIA	New Bangkok International Co., Ltd
NEPO	National Energy Policy Office
NESDB	National Economic and Social Development Board
NG	Natural Gas
NGV	Natural Gas Vehicle
NP	Neutralization Potential
NSO	National Statistical Office
O & M	Operation and Maintenance
OCMLT	Office of The Commission for the Management of Land Traffic
OEPP	Office of Environmental Policy and Planning
OVR	Overage Vehicle Retirement
PCD	Pollution Control Department
PCU	Passenger Car Unit
PTT	PTT Public Company Limited
PTT	Petroleum Authority of Thailand
RTP	Royal Thai Police
SBIA	Second Bangkok International Airport
scf	Standard Cubic Feet
SMHI	Swedish Meteorological and Hydrological Institute
SPP	Small Power Producer
SRT	State Railway of Thailand
TDRI	Thailand Development Research Institute
TDRI	Thai Development Research Institute
TDSRT	Investment of Capacity Constraints and Determination of the Need for Track Doubling of SRT Network (2002)
TISI	Thai Industrial Standards Institute
TJ	1012 Joules
TMD	Thailand Meteorological Department
toe	Ton of Oil Equivalent

ULG	Unleaded Gasoline
URMAP	Urban Rail Transportation Mater Plan (BMA and Surrounding Areas), November 2001
US EPA	United States Environmental Protection Agency
UTM	Universal Transverse Mercator
VR	Vehicle Retirement
WB	World Bank
WHO	World Health Organization

List of Study Member

JICA Study Team

Mr. Hideshi Kase	Supervisor/Planning of Countermeasure
Mr. Masahiko Fujimoto	Vice-Supervisor/Preparation of Mobile Source Inventory
Mr. Makoto Miyakawa	Preparation of Stationary Source Inventory
Mr. Kenichi Kuramoto	Evaluation of Monitoring Results
Mr. Akeo Fukayama	Simulation by ATMOS2 and Training
Mr. Toru Tabata	Simulation by Airviro and Training
Mr. Kenji Asakawa	Planning of Countermeasure
Dr. Akira Ogihara	Project Evaluation
Mr. Bungo Kinokuni	Coordination and Web Development

Thai Counterpart Team

Dr. Supat Wangwongwatana	Supervisor, Deputy Director General of Pollution Control Department
Ms. Mingquan Wichayarangsaridh	Director of Air Quality and Noise Management Bureau (AQNMB)
Mr. Punsak Theramongkol	Vice-Supervisor, AQNMB
Mr. Prapat Pentamwa	Secretariat, AQNMB
Mr. Panya Warapetcharayut	AQNMB
Mr. Nawarat Mitrijit	AQNMB
Ms. Walailuck Borrell	AQNMB
Ms. Manwipa Kuson	AQNMB
Mr. Aunnop Rungraksathum	AQNMB
Ms. Piraporn Petchthong	AQNMB
Mr. Pichaid Atipakya	AQNMB
Dr. Vanisa Surapipith	AQNMB

Description of the Study

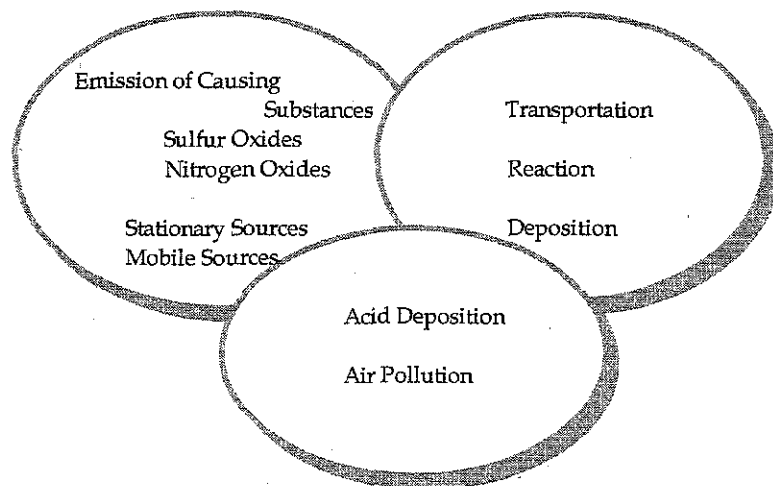
Description of the Study

1. Outline

Acid deposition is trans-boundary pollution in East Asia. Due to long-range transport, it is necessary to tackle the pollution by respective nation and by whole countries of East Asia. In addition, it is necessary that mitigation activities should be arranged not on isolated basis but on systematic approach basis. For this end, the systematic approach for preparation of acid deposition control strategy was applied to Thailand. The approach can be applied to other East Asian countries. In the course of the preparation, necessary technology transfer was carried out in Thailand. And international seminar was held for the dissemination of the outcome of the Study.

Emission of sulfur oxides and nitrogen oxides causes acid deposition, and leads to ambient air pollution. Currently, acid deposition and ambient air pollution are both subjects of public concern in Thailand. The major causing substances of acid deposition and ambient air pollution are sulfur oxides and nitrogen oxides. The Study investigated into acid deposition together with ambient air pollution, caused by the same substances.

The collection and evaluation of monitoring results was one of starting points. The preparation of inventories, i.e. the list of discharging amounts and the location of causing substances, was an indispensable field of the Study. Socio-economic condition was an important factor of the inventory. Based on monitoring results and the inventory, the simulation analysis of sulfur deposition of whole Thailand and SO₂ and NO_x concentrations in the BMR were another point of the study. According to the evaluation of monitoring and simulation results, atmospheric SO₂ and NO₂ concentrations in the BMR were current problems to tackle. Because the reduction of causing substances is a method of mitigation, countermeasures for the reduction of sulfur oxides and nitrogen oxides in the BMR were investigated.



Acid Deposition and Air Pollution



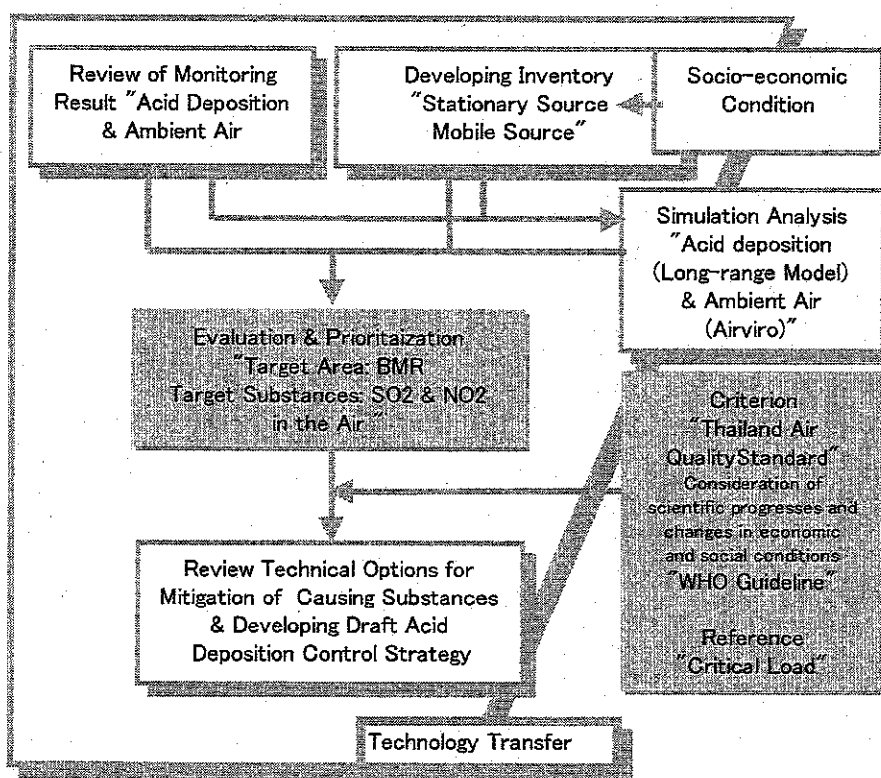
A draft control strategy, including countermeasures for pollutant reduction and enhancement of management, was prepared.

Technology transfer, especially for the preparation of inventories, the simulation by international model and investigation for policy, was implemented in the course of the Study.

2. Objectives

In order to prepare the strategy for mitigation of acid deposition including ambient air pollution, the Study selected the following objectives;

1. to develop/elaborate the emission inventories of substances that cause acid deposition in the whole country;
2. to apply a long-range transport model, based on the latest emission inventories developed in 1. above;
3. to review possible technical options to mitigate substances that cause acid deposition, based on the results of the simulation by the long-range transport model, and develop an acid deposition control strategy for consideration by the Royal Thai Government;
4. to train the technical staff of the relevant government agencies / institutions on the above subjects; and
5. to review the monitoring result of acid deposition and ambient air in the country.



Objectives of the Study

3. Methodology

3.1 Components and Method

Components and methods of the Study are;

1. Investigation of current acid deposition and ambient air concentration of SO₂ and NO₂
 - Collection of existing materials
 - Evaluation of collected data
2. Study for socio-economic conditions
 - Investigation into national and provincial conditions, collection and evaluation of future conditions
 - Analysis of energy growth elasticity to economic growth
3. Preparation of an emission inventory worthy of analysis of the current situation and projection for the future
 - Preparing an inventory of stationary and mobile sources for causing substances, i.e. sulfur oxides for the country, moreover nitrogen oxides for the BMR
 - Revision of the mobile source emission equation of nitrogen oxides
4. Simulation analysis of current and future status, based on current concentration and the prepared inventory
 - Validity check by monitoring results
 - Sulfur simulations for the country
 - Sulfur dioxide and nitrogen oxides simulation for the BMR
5. Evaluation of conditions and prioritization of the problems to be tackled
6. Preparation of countermeasures and a management strategy
 - Technical, political, social and financial feasibility study and preparation of countermeasures
 - consideration for the enhancement of management
7. Technology transfer for the counterparts

3.2 Background

The Study investigates and collects scientific, social, and economic materials. If there is a lack of domestic materials, international data are collected and they support the investigation. For the Study, research of environmental issues is out of scope.

One of important approaches for this field depends on the critical load. The approach has shown successful results in Europe. However, on consideration of the argument over the critical load value and its adequacy in East Asia, the Study regards the critical load approach as reference.



4. Outputs

The systematic approach for preparation of acid deposition control strategy was applied to Thailand. The approach can be applied to other East Asian countries. After evaluation of the condition, the Study revealed that the current issues for mitigation was atmospheric pollution in the BMR. The outputs of the Study were as follows.

For draft acid deposition control strategy;

- Countermeasure for SO₂ is concentrated to the shift from high sulfur fuel to natural gas in the industrial sector in the BMR.

- Countermeasures for NO₂ are the introduction of substantial compliance with the emission standard, low emission vehicle promotion, and over age vehicle retirement in the BMR.

- Enhancement of environmental management for acid deposition and atmospheric pollution.

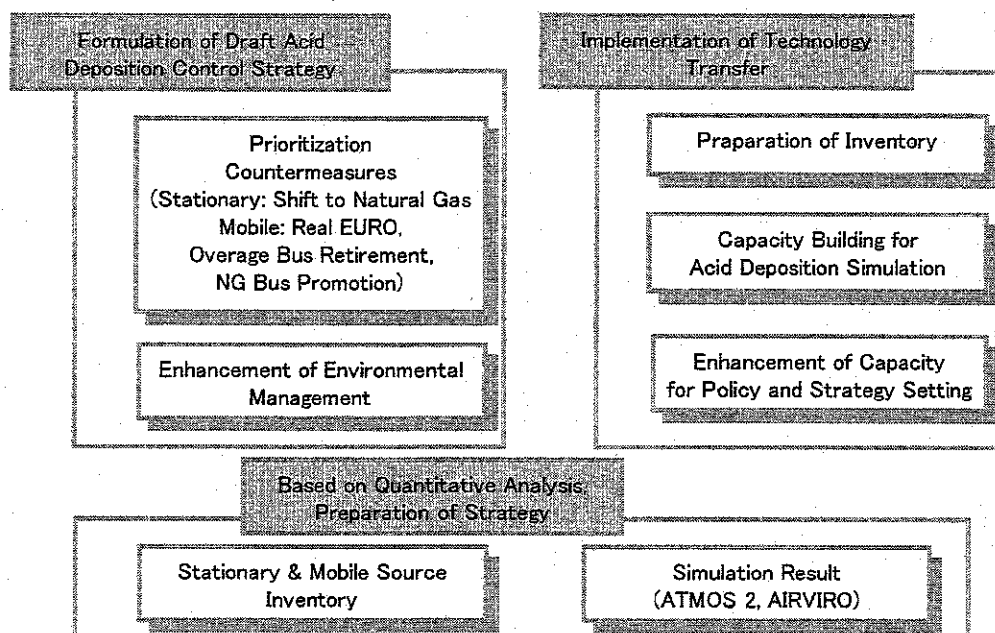
Moreover, one of important factors of the Study was technology transfer.

- Technology transfer activities for inventory, simulation and policy setting were built in to the Study. And it was undertaken on various parts of the Study.

- Through the activity of transfer, series of technology, i.e. from monitoring to simulation and preparation of countermeasures were transferred.

- The technology transfer to East Asian countries was carried out by the international seminar.

During the Study, the inventory for stationary and mobile sources was prepared. And based on the inventory, the simulation analysis was implemented. The inventory and the outcome of the simulation were utilized for the preparation of strategy, and they were regarded as the quantitative basis for countermeasures against acid deposition and air pollution in Thailand.



【 Concept of Outputs 】

Chapter 1

Acid Deposition and Air Quality Data Analysis



1. Acid Deposition and Air Quality Data Analysis

1.1. Result of Wet Deposition Monitoring

Concerning acid deposition monitoring, following activities are being carried out now in Thailand:

- EANET monitoring program;
- Joint Monitoring Program between PCD and Universities, and
- Joint Examination between ERTC and SERI.

Details of monitoring activities are described in Supporting Report, Chapter 1.

PCD carries out data validation following the EANET manual (Supporting Report, Chapter 1). As the data validation doesn't focus on data screening but just indicator for recheck, PCD does not reject monitoring data exceeding allowable range for preparing reports. The Study Team utilizes all data for model simulation, however analysis of acid deposition in this chapter is carried out tentatively by data within allowable range of R1 and R2 validation.

Data calculation was carried out considering the following factors;

- Rainy Season: May to October,
- Dry Season: November to April, and
- Deposition amount of each parameter was calculated by the following equation.

$$EP = MP \times \frac{TR}{AR}$$

EP: Estimated value of respective measuring parameter

MP: Total deposited amount of respective measuring parameter

TR: Measured total rain amount

AR: Total rain amount of accepted sampling period

For the evaluation of wet deposition amount in this chapter, the Study Team used this estimated value.

1.1.1 Brief Description of Wet deposition

The monthly and yearly averages of analyzed concentration of acid deposition parameters in the year 2000 are shown in Table 1.1.1.1, the monthly and yearly deposition amount of each parameters in the year 2000 are shown in Table 1.1.1.2.



Table 1.1.1.1 Brief Description of Concentration of Acid Deposition

	SO ₄ ²⁻ ($\mu\text{mol/L}$)	nss-SO ₄ ²⁻ ($\mu\text{mol/L}$)	NO ₃ ⁻ ($\mu\text{mol/L}$)	Cl ⁻ ($\mu\text{mol/L}$)	NH ₄ ⁺ ($\mu\text{mol/L}$)	Na ⁺ ($\mu\text{mol/L}$)	K ⁺ ($\mu\text{mol/L}$)	Ca ₂ ⁺ ($\mu\text{mol/L}$)	nss-Ca ₂ ⁺ ($\mu\text{mol/L}$)	Mg ₂ ⁺ ($\mu\text{mol/L}$)	H ⁺ ($\mu\text{mol/L}$)	pH	EC (mS/m)
Bangkok (OEPP-Urban Site)													
Yearly Base													
Min	4.9	4.4	0.4	4.1	2.1	1.7	<1	<0.3	<0.3	<0.2	0.1	3.91	0.430
Max	96.0	95.1	212.9	25.6	191.5	24.4	14.2	65.0	64.6	8.2	123.0	6.99	6.83
Average	33.6	33.1	37.7	12.2	52.2	9.0	4.1	15.2	15.0	2.7	23.0	5.08	2.37
Monthly Base Average													
Feb													
Mar	38.3	37.9	40.6	18.4	52.6	6.9	<1	12.5	12.4	2.5	37.2	4.43	3.23
Apr	79.6	78.6	143.3	18.1	168.3	17.6	6.2	37.0	36.6	6.9	32.6	4.51	4.96
May	57.7	57.2	48.2	12.5	104.1	7.1	1.1	19.3	19.1	3.4	32.1	4.57	3.39
Jun	14.0	13.3	20.1	13.0	32.4	11.5	3.5	10.7	10.5	2.6	2.9	5.99	1.24
Jul	21.2	20.6	17.0	10.5	43.3	9.4	3.6	9.3	9.0	2.0	2.3	5.72	1.27
Aug	10.7	10.4	1.7	7.2	17.1	5.0	<1	2.7	2.7	0.0	5.7	5.62	0.760
Sep	48.4	47.8	51.6	14.7	39.5	9.3	8.3	24.7	24.5	3.6	49.0	4.40	3.66
Oct	27.7	27.4	26.7	8.5	31.9	5.1	4.2	10.2	10.1	1.6	32.3	4.59	2.16
Samutprakan (TMD-Urban Site)													
Yearly Base													
Min	9.7	9.1	<0.3	2.0	5.7	1.1	<1	<1	<0.3	<0.2	0.4	4.18	0.630
Max	157.9	155.9	103.6	47.5	229.8	45.5	20.8	94.5	93.5	14.2	66.1	6.42	5.83
Average	36.0	35.2	17.0	15.5	42.9	13.4	4.4	14.5	14.3	3.3	14.6	5.19	1.86
Monthly Base Average													
Feb													
Mar													
Apr	29.3	28.1	19.2	18.2	30.7	18.5	5.1	6.1	5.7	1.5	20.5	4.79	1.94
May	45.9	44.7	38.9	18.9	45.0	19.0	7.7	29.5	29.1	4.8	17.7	4.84	2.50
Jun	29.5	28.6	14.9	14.4	38.9	13.4	3.0	8.2	7.9	2.7	9.8	5.07	1.77
Jul	48.7	47.5	14.3	20.8	62.1	19.8	3.4	20.1	19.7	4.5	8.0	5.56	2.12
Aug	37.7	37.2	5.3	12.8	48.1	9.0	4.9	8.1	7.9	2.7	12.7	5.33	1.65
Sep	29.4	28.7	12.5	16.4	35.8	12.8	4.4	14.9	14.6	3.2	8.3	5.40	1.47
Oct	25.9	25.5	26.2	7.8	26.2	5.6	3.6	11.4	11.2	2.5	33.4	4.69	1.93
Patumthani (ERTC-Rural Site)													
Yearly Base													
Min	8.4	8.0	5.7	2.0	16.1	1.7	0.4	2.0	2.0	<0.2	0.1	4.43	0.630
Max	70.7	69.8	77.3	35.7	101.4	82.9	11.4	58.6	58.3	8.2	37.2	6.95	4.14
Average	23.4	22.3	20.4	14.7	41.3	18.0	2.5	16.2	15.8	2.6	4.5	6.03	1.53
Monthly Base Average													
Feb													
Mar	70.7	69.8	77.3	23.4	101.4	15.2	10.0	58.6	58.3	8.2	7.2	5.14	4.14
Apr	9.0	8.8	11.9	2.0	18.9	1.7	0.5	2.0	2.0	0.0	8.7	5.06	0.850
May	20.1	19.2	17.7	16.1	47.6	15.0	3.7	12.2	11.9	2.4	0.5	6.41	1.37
Jun	24.8	22.8	20.0	16.9	34.6	32.2	1.7	11.6	10.9	2.8	1.4	5.98	1.42
Jul	18.5	17.3	11.2	17.2	34.1	19.4	1.9	22.4	22.0	3.0	0.2	6.72	1.19
Aug	28.1	27.8	31.8	9.2	57.9	5.2	2.2	18.6	18.5	2.5	1.4	5.85	1.95
Sep	26.4	25.4	32.7	12.8	41.0	16.9	1.4	17.7	17.3	2.8	12.0	4.92	1.83
Oct	24.0	23.8	21.1	3.8	33.8	3.2	0.8	4.6	4.5	0.5	31.7	4.51	2.02
Kantchanaburi (Khao Laem-Remote Site)													
Yearly Base													
Min	<0.2	<0.2	<0.3	2.2	<0.5	1.3	<1	<0.3	<0.3	<0.2	0.6	5.10	0.22
Max	8.5	8.3	15.6	26.0	12.7	22.7	15.7	8.7	8.5	2.9	7.9	6.19	0.74
Average	2.7	2.3	6.5	10.8	5.0	8.0	3.7	3.3	3.1	1.0	2.7	5.70	0.44
Monthly Base Average													
Feb													
Mar													
Apr													
May	3.3	2.8	11.8	11.9	6.6	8.6	2.3	3.9	3.8	1.8	3.2	5.59	0.56
Jun	2.2	1.4	10.4	11.9	4.7	12.1	2.9	3.6	3.3	1.6	2.3	5.70	0.51
Jul	3.6	3.0	3.8	12.1	4.2	10.7	<1	4.2	4.0	0.9	1.6	5.85	0.44
Aug	0.9	0.6	2.6	11.8	3.7	5.9	9.2	1.6	1.5	0.5	1.1	5.98	0.29
Sep	8.5	8.3	6.9	6.5	12.7	2.7	4.8	3.2	3.1	0.7	7.8	5.11	0.67
Oct	2.4	2.3	5.5	4.0	4.3	1.8	3.4	3.0	3.0	0.4	5.9	5.24	0.37



Table 1.1.1.2(1) Brief Description of Deposition Amount

	SO ₄ ²⁻ (umol/m ²)	nss-SO ₄ ²⁻ (umol/m ²)	NO ₃ ⁻ (umol/m ²)	Cl ⁻ (umol/m ²)	NH ₄ ⁺ (umol/m ²)	Na ⁺ (umol/m ²)	K ⁺ (umol/m ²)	Ca ₂ ⁺ (umol/m ²)	nss-Ca ₂ ⁺ (umol/m ²)	Mg ₂ ⁺ (umol/m ²)	H ⁺ (umol/m ²)
Bangkok (OEPP-Urban Site)											
Yearly Base											
	13636 (38802)	13455 (38350)	11092 (31874)	4319 (11195)	21768 (61488)	2998 (7497)	1111 (2805)	4698 (13113)	4639 (12967)	855 (2296)	9124 (24995)
Monthly Base											
Feb	-	-	-	-	-	-	-	-	-	-	-
Mar	153 (165)	151 (163)	162 (174)	74 (79)	210 (226)	27 (30)	-	50 (54)	50 (53)	10 (11)	149 (160)
Apr	934 (8789)	927 (8718)	896 (8426)	191 (1799)	1624 (15282)	126 (1189)	7 (70)	366 (3447)	364 (3421)	63 (590)	269 (2529)
May	5091 (11271)	5052 (11184)	3970 (8789)	1068 (2364)	9206 (20382)	651 (1442)	84 (186)	1647 (3646)	1633 (3615)	302 (668)	2511 (5560)
Jun	1437 (2368)	1373 (2263)	1735 (2860)	1067 (1759)	3240 (5339)	1059 (1745)	182 (301)	999 (1646)	976 (1608)	247 (407)	123 (202)
Jul	681 (1938)	665 (1892)	624 (1776)	284 (808)	1507 (4289)	271 (771)	100 (284)	314 (894)	308 (877)	73 (209)	58 (166)
Aug	1153 (3131)	1135 (3083)	42 (113)	464 (1259)	1180 (3205)	297 (807)	-	24 (66)	24 (64)	-	768 (2085)
Sep	2187 (5402)	2171 (5360)	1942 (4795)	588 (1451)	2531 (6249)	280 (691)	377 (932)	906 (2238)	900 (2223)	124 (306)	1903 (4699)
Oct	2000 (5738)	1962 (5689)	1722 (4941)	584 (1675)	2271 (6517)	287 (823)	360 (1033)	391 (1122)	385 (1104)	37 (106)	3343 (9594)
Samutprkan (TMD-Urban Site)											
Yearly Base											
	17848 (24293)	17426 (23745)	9550 (14085)	7869 (10375)	20944 (28373)	7006 (9094)	2208 (3086)	7588 (10394)	7437 (10198)	1767 (2405)	8147 (12536)
Monthly Base											
Feb	-	-	-	-	-	-	-	-	-	-	-
Mar	-	-	-	-	-	-	-	-	-	-	-
Apr	79 (79)	77 (77)	52 (52)	47 (47)	80 (80)	42 (42)	9 (9)	15 (15)	14 (14)	3 (3)	77 (77)
May	2420 (3991)	2361 (3893)	2205 (3636)	1036 (1708)	2838 (4660)	985 (1625)	340 (561)	1265 (2087)	1244 (2052)	271 (447)	898 (1481)
Jun	2785 (2785)	2708 (2708)	1489 (1489)	1349 (1349)	3806 (3806)	1281 (1281)	312 (312)	806 (806)	778 (778)	242 (242)	973 (973)
Jul	3652 (3689)	3555 (3591)	1260 (1273)	1643 (1659)	4261 (4304)	1616 (1632)	278 (281)	1844 (1863)	1810 (1826)	347 (351)	679 (685)
Aug	1879 (3196)	1840 (3130)	288 (491)	869 (1478)	2668 (4537)	643 (1094)	203 (345)	454 (772)	440 (749)	143 (243)	529 (900)
Sep	4950 (5968)	4832 (5829)	2233 (2693)	2316 (2793)	5106 (6157)	1957 (2360)	770 (929)	2209 (2664)	2167 (2613)	558 (672)	2578 (3108)
Oct	2083 (4584)	2054 (4520)	2023 (4452)	609 (1341)	2185 (4808)	481 (1060)	294 (648)	993 (2186)	983 (2163)	203 (447)	2414 (5313)
Patumuthani (ERTC-Rural Site)											
Yearly Base											
	7741 (20698)	7414 (19973)	6600 (20840)	4711 (10328)	15929 (38594)	5428 (12029)	735 (1613)	4519 (12128)	4402 (11868)	762 (1938)	1866 (6802)
Monthly Base											
Feb	-	-	-	-	-	-	-	-	-	-	-
Mar	39 (622)	38 (614)	42 (680)	13 (206)	56 (893)	8 (134)	5 (88)	32 (516)	32 (513)	5 (72)	4 (64)
Apr	123 (742)	121 (733)	163 (988)	27 (183)	258 (1562)	24 (144)	7 (42)	27 (166)	27 (163)	-	119 (722)
May	2391 (2994)	2306 (2887)	1800 (2254)	1838 (2302)	6623 (8292)	1422 (1781)	378 (474)	1238 (1550)	1207 (1511)	219 (275)	66 (83)
Jun	2275 (3846)	2121 (3585)	2168 (3665)	1449 (2449)	3708 (6268)	2568 (4341)	148 (250)	1133 (1915)	1077 (1821)	264 (447)	149 (252)
Jul	1073 (1291)	1014 (1221)	688 (828)	921 (1109)	2347 (2826)	973 (1171)	112 (135)	1377 (1658)	1356 (1632)	176 (212)	15 (18)
Aug	402 (3222)	397 (3186)	454 (3645)	131 (1052)	828 (6644)	74 (593)	31 (250)	266 (2133)	264 (2120)	35 (282)	20 (162)
Sep	380 (5625)	365 (5407)	471 (6970)	184 (2718)	590 (8728)	244 (3611)	20 (303)	254 (3764)	249 (3686)	41 (601)	173 (2563)
Oct	1059 (2356)	1052 (2341)	814 (1811)	148 (330)	1519 (3381)	114 (253)	32 (72)	192 (427)	189 (422)	22 (48)	1320 (2939)

Upper column atates measured value

Lower column (within ()) shows estimated value



Table 1.1.1.2(2) Brief Description of Deposition Amount

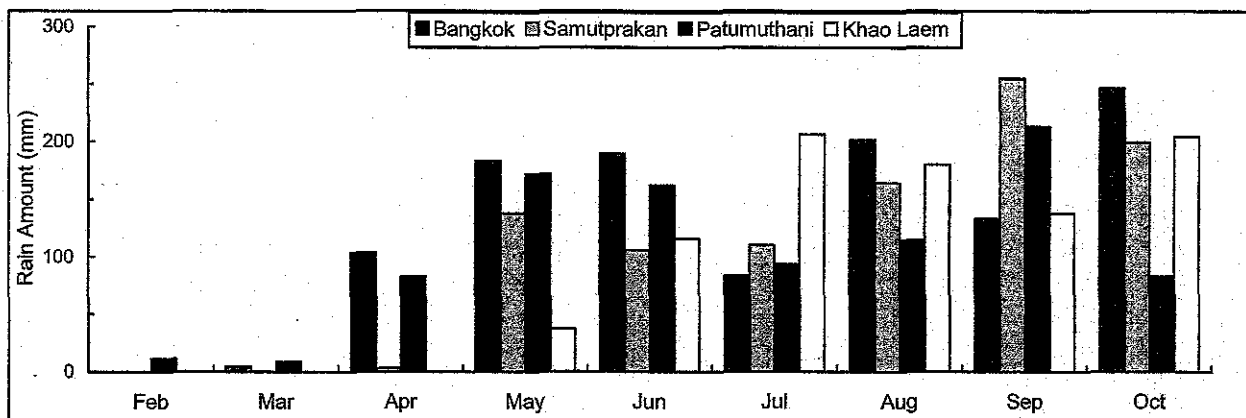
	SO ₄ ²⁻ ($\mu\text{mol}/\text{m}^2$)	nss-SO ₄ ²⁻ ($\mu\text{mol}/\text{m}^2$)	NO ₃ ⁻ ($\mu\text{mol}/\text{m}^2$)	Cl ⁻ ($\mu\text{mol}/\text{m}^2$)	NH ₄ ⁺ ($\mu\text{mol}/\text{m}^2$)	Na ⁺ ($\mu\text{mol}/\text{m}^2$)	K ⁺ ($\mu\text{mol}/\text{m}^2$)	Ca ₂ ⁺ ($\mu\text{mol}/\text{m}^2$)	nss-Ca ₂ ⁺ ($\mu\text{mol}/\text{m}^2$)	Mg ₂ ⁺ ($\mu\text{mol}/\text{m}^2$)	H ⁺ ($\mu\text{mol}/\text{m}^2$)
Kantchanaburi (Khao Laem-Remote Site)											
Yearly Base											
	889 (2761)	756 (2486)	1677 (4481)	2969 (6614)	1558 (4704)	2312 (4838)	958 (3059)	1002 (2531)	960 (2443)	221 (529)	905 (3202)
Monthly Base											
Feb	-	-	-	-	-	-	-	-	-	-	-
Mar	-	-	-	-	-	-	-	-	-	-	-
Apr	-	-	-	-	-	-	-	-	-	-	-
May	119 (122)	100 (102)	429 (439)	416 (425)	221 (226)	324 (331)	73 (75)	176 (180)	169 (173)	64 (66)	96 (98)
Jun	83 (197)	57 (136)	483 (1150)	420 (1000)	277 (658)	429 (1021)	100 (237)	159 (376)	150 (356)	52 (123)	115 (274)
Jul	410 (694)	348 (589)	247 (419)	1194 (2023)	507 (860)	1028 (1742)	0 (0)	379 (643)	360 (610)	54 (92)	225 (381)
Aug	59 (145)	41 (102)	144 (355)	635 (1567)	227 (560)	402 (993)	540 (1332)	76 (187)	72 (178)	15 (37)	81 (200)
Sep	115 (1171)	113 (1149)	93 (951)	88 (896)	172 (1757)	36 (366)	65 (663)	43 (440)	42 (432)	10 (102)	105 (1070)
Oct	104 (432)	98 (408)	280 (1168)	217 (904)	154 (643)	92 (385)	180 (752)	168 (702)	166 (694)	26 (108)	283 (1179)

Upper column states measured value

Lower column (within ()) shows estimated value

Source: PCD, modified by the Study Team

The rain amount of each monitoring site is shown in Figure 1.1.1.1.



Source: PCD, modified by the Study Team

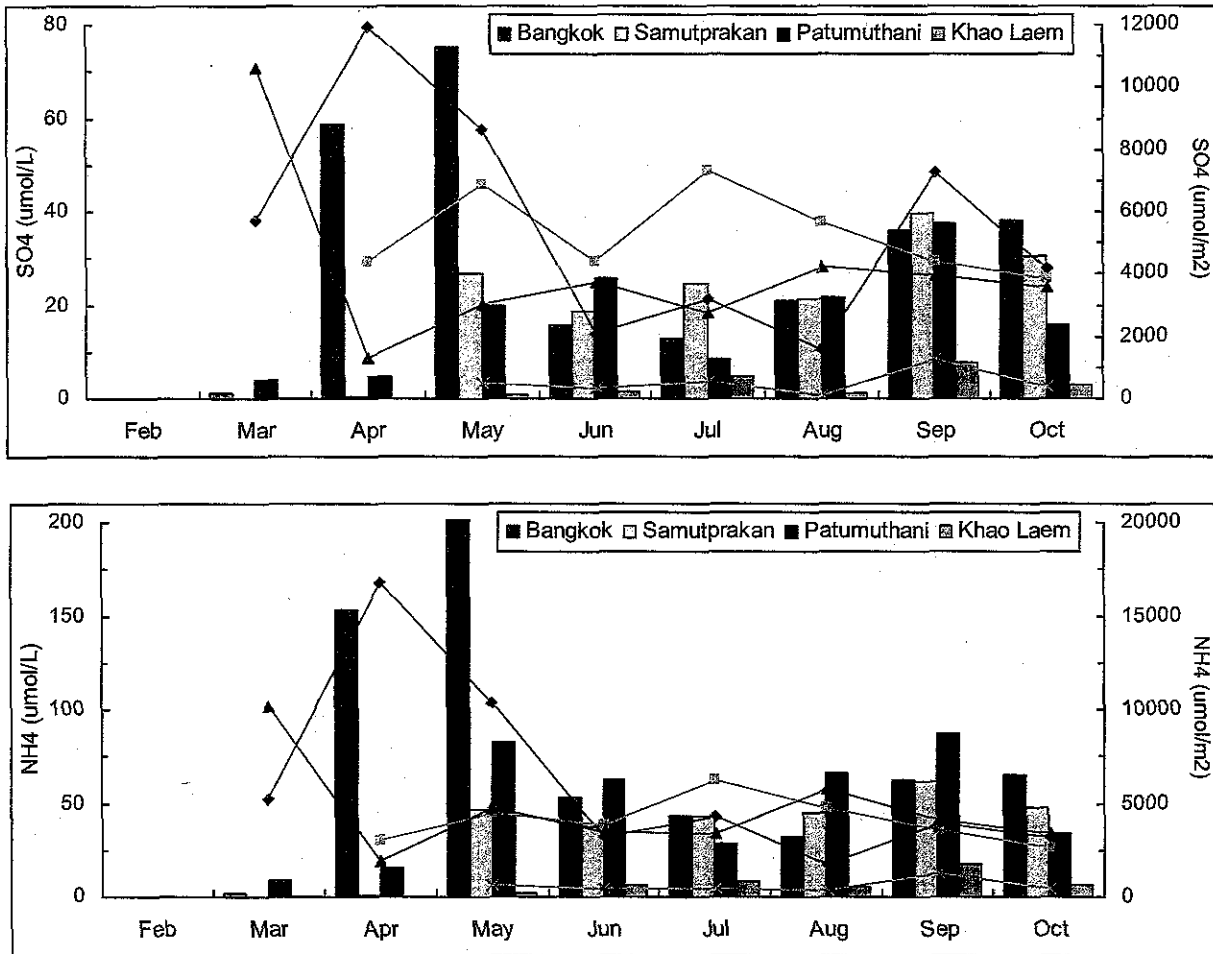
Figure 1.1.1.1 Rain Amount of Each Monitoring Site

The yearly rain amount of OEPP site (located in Bangkok) was approximately 1100 mm, and was the highest of all the monitoring sites. Those of the other sites were approximately 900 mm, therefore there was little difference. The rainy and dry seasons are clearly divided in Thailand, with the period of May to October being defined as the rainy season. On the other hand, there was no rain in the month of January and between November to December in 2000. The rain dose not continue a long time and usually falls intermittently.



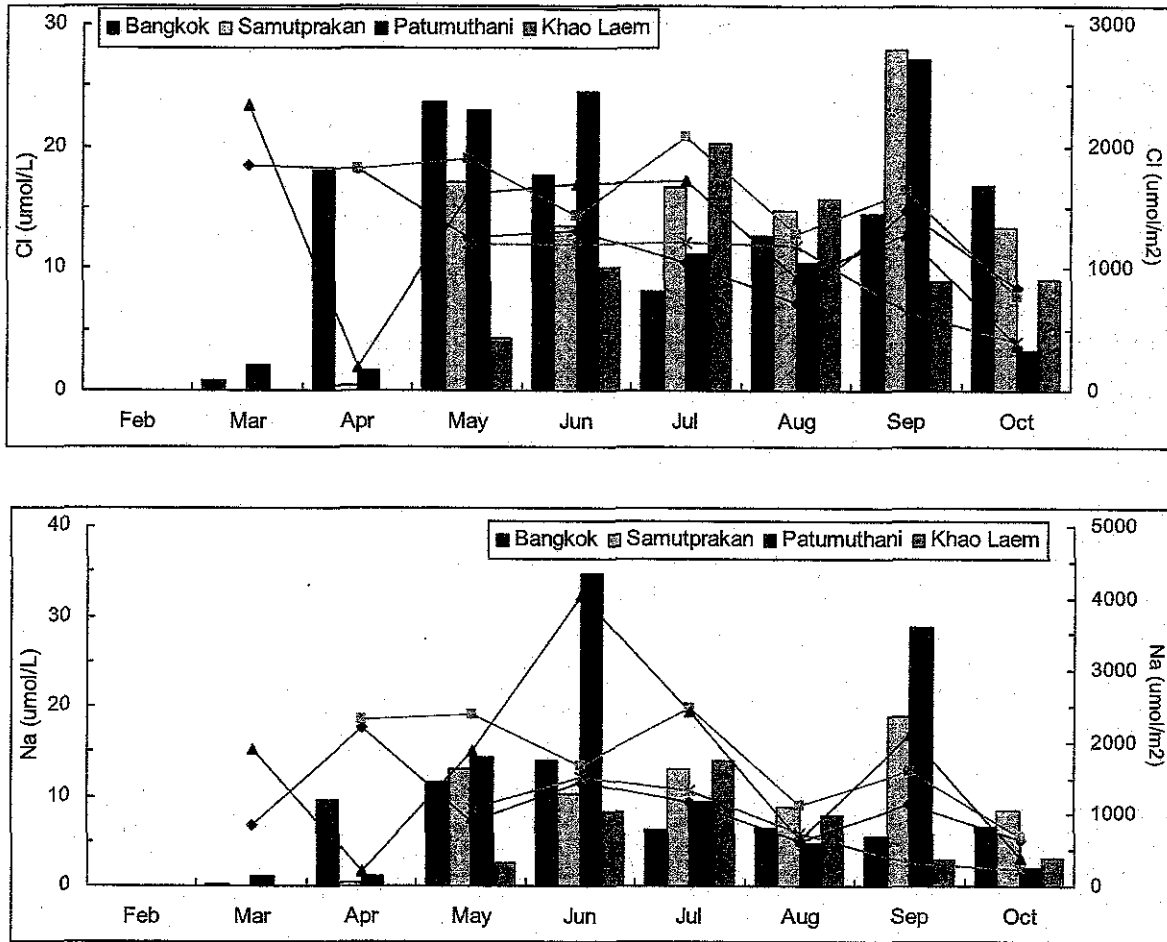
Ion contents in rain indicate its source and condition, etc. Ions in rain can be classified into two types; one is sea salt origin and the other is non-sea salt origin. Generally speaking, Na, Mg and Cl ions are classified as sea salt origin, on the other hand Ca, NH₄, SO₄ and NO₃ ions are classified as non-sea salt origin. Ca will be mainly soil origin, and NH₄ mainly agriculture, stockbreeding and also industry. SO₄ ion may be mainly discharged from industrial zones, or in some areas by volcanic activity. The case of NO₃ ion is similar to SO₄ ion. However emission of NO₃ is concentrated in urban zones, and may be discharged from mobile sources.

The monthly trends of SO₄, NH₄, Cl and Na ions are shown in Figure 1.1.1.2. As mentioned above the SO₄ and NH₄ ions have roots in human activity, and the Cl and Na ions are of sea salt origin.



Notice:
 Line graphs state concentration, bar graphs state total amount.
 Source: PCD, modified by the Study Team

Figure 1.1.1.2(1) Monthly Trends of SO₄ and NH₄



Notice:

Line graphs mean concentration, bar graphs mean total amount.

Source: PCD, modified by the Study Team

Figure 1.1.1.2(2) Monthly Trend of Cl and Na

Concerning the concentration for the yearly averages of SO_4 ion, TMD site (located in an urban area) showed the highest value, 36.0 $\mu\text{mol/L}$, next OEPP site (also located in an urban area) was 33.6 $\mu\text{mol/L}$. On the other hand, Khao Laem site (located in a remote area) was 2.7 $\mu\text{mol/L}$, the value was below 1/10 of the urban area. NH_4 ion had the same trend of SO_4 ion, that is, concentrations in the urban sites were higher than those in the remote site. In particular SO_4 ion concentration of OEPP site between March to May were high values which decreased in June. On the other hand, Cl and Na ion concentrations showed similar trends in all 4 monitoring sites.

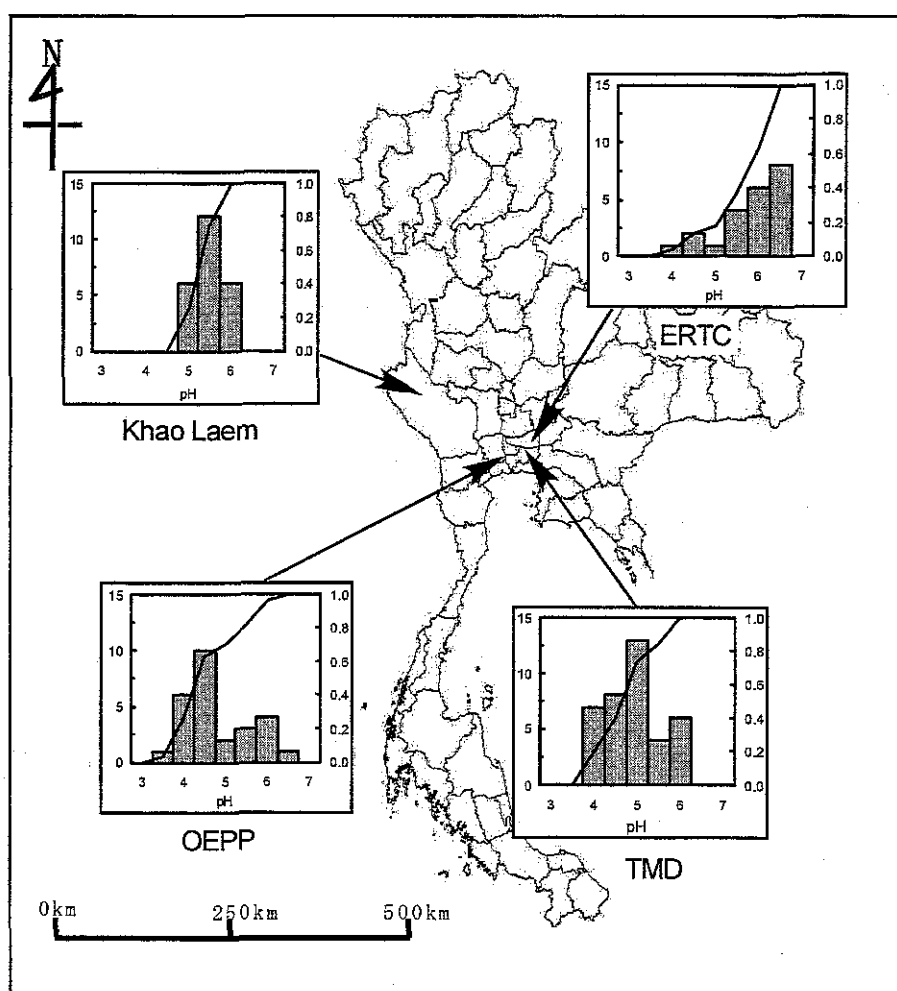
This is the case because human activities do not affect Cl and Na ion concentrations generally. That said, human activity has influences on increasing the sulfur and nitrogen concentrations in rain, and as a result it causes acid deposition.

Let us analyze the most important parameter, the pH. Table 1.1.1.3 shows a brief description of the pH. And Figure 1.1.1.3 shows frequency distribution of pH.

Table 1.1.1.3 Brief Description of pH

Site Name	OEPP	TMD	ERTC	Khao Laem	For 4 sites
Min	3.91	4.18	4.43	5.10	3.91
Max	6.99	6.42	6.95	6.19	6.99
Mean	5.10	5.19	6.07	5.72	5.44
Median	4.89	5.15	6.19	5.77	5.38

Source: PCD, modified by the Study Team



Source: PCD, modified by the Study Team

Figure 1.1.1.3 Frequency Distribution of pH

The pH distribution in Thailand in 2000 was 3.91 to 6.99, its median value was 5.38. The pH in OEPP site (urban site) was lower than the other 3 sites, in particular pH value showed the lowest value, 3.91, on 19th September. Similarly TMD site showed a lower value.



Comparing ERTC site and Khao Laem site, the pH in Khao Laem site was lower than ERTC site.

Frequency distributions could be classified into 3 types. OEPP and TMD sites show similar frequency distribution. Two peaks, a lower pH and a higher pH are observed. At ERTC, the higher pH shows the higher frequency. At Khao Laem, the distribution shape is like the normal distribution.

These results lead us to following findings:

- SO_4 ion concentration of urban sites was higher than rural and remote site;
- NH_4 and NO_3 ions also showed the same characteristics as SO_4 ;
- ERTC site showed an intermediate position between urban and remote site;
- On the other hand, these concentration in Khao Laem site were not high;
- It may be regarded that the main source of SO_4 ion in near urban areas is human activity.

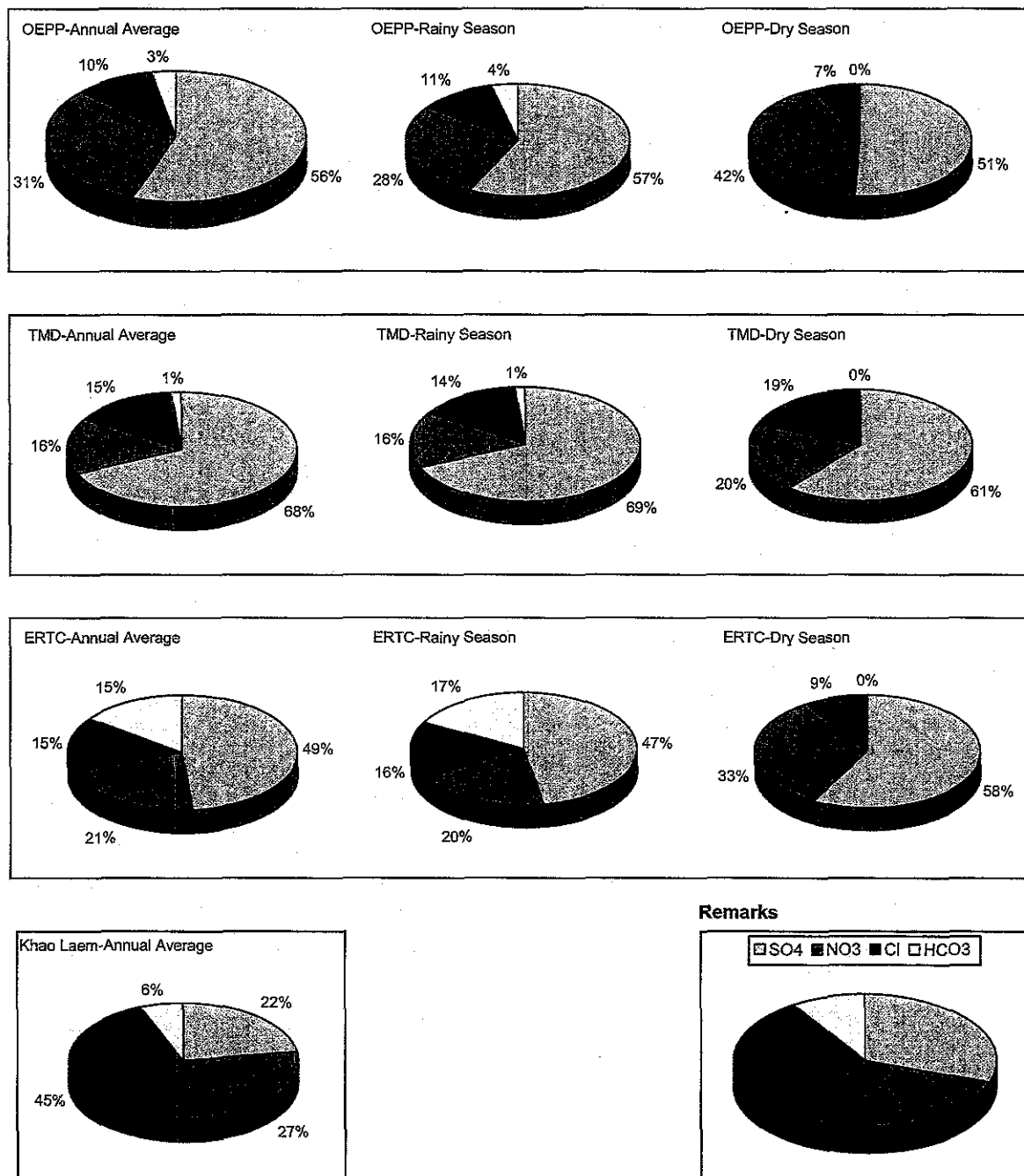
And also it causes increased sulfur and nitrogen deposition;

- Concentrations of Cl ion and cation were almost the same value in all 4 monitoring sites. Generally speaking these ions are not influenced by human activity so much;
- The pH in urban site was lower than in rural and remote sites.
- The pH in Khao Laem site was lower than ERTC. It is necessary to investigate the reason for this, and
- The decrease of pH may be caused by human activities.



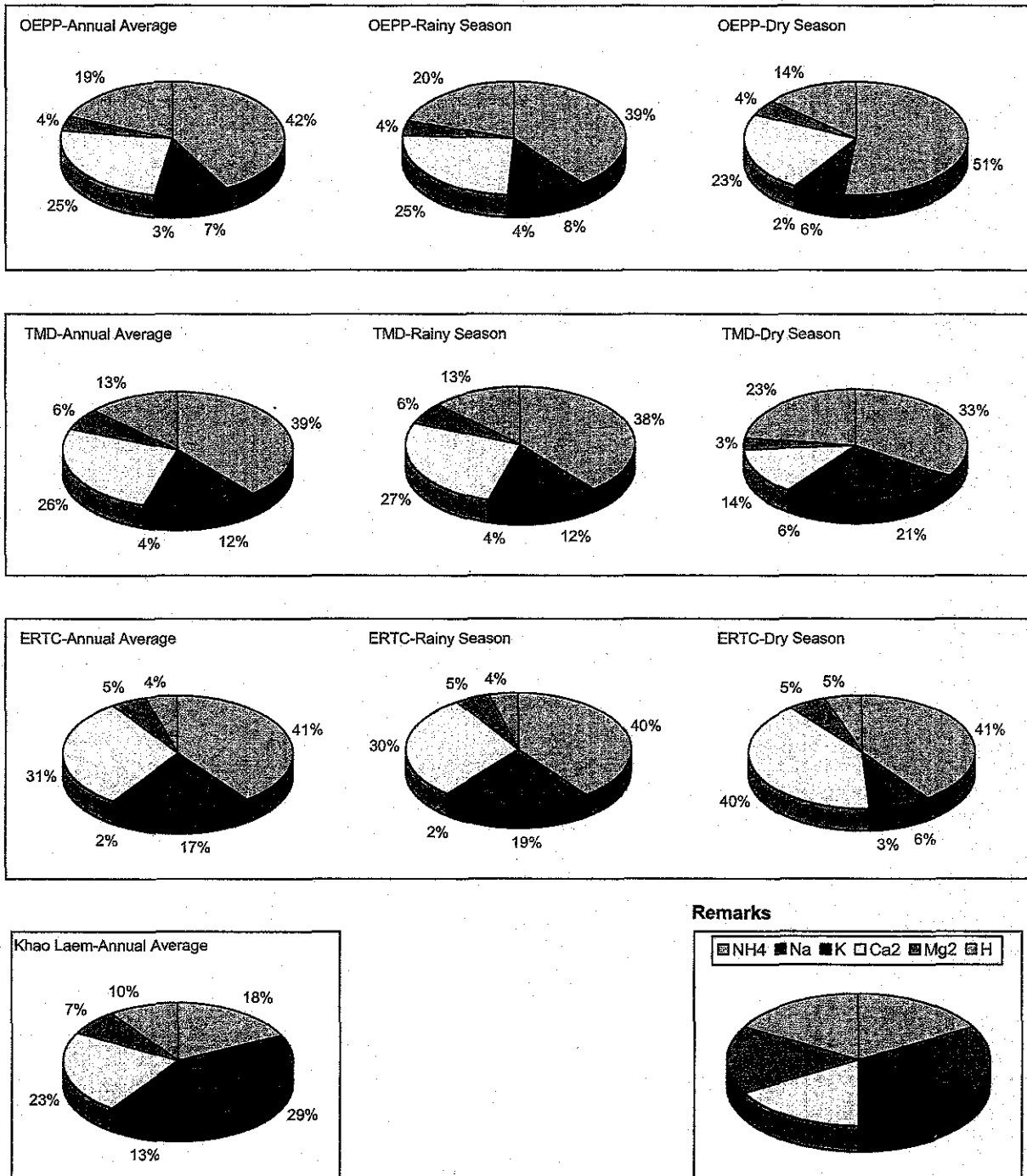
1.1.2 Ion Composition

As mentioned before, ion composition shows the rain condition and ion source. Figure 1.1.2.1 shows the anion composition, and Figure 1.1.2.2 shows the cation composition.



Source: PCD, modified by the Study Team

Figure 1.1.2.1 Anion Composition of Each Monitoring Site



Source: PCD, modified by the Study Team

Figure 1.1.2.2 Cation Composition of Each Monitoring Site

1.1.2.1 Anion

SO₄ ion accounted for over 50 % of anion in OEPP and TMD sites located in urban areas. Next, NO₃ ion accounted for approximately 20 to 50 %. As mentioned previously, SO₄ and NO₃ ions are mainly originated by human activities such as emission gases from mobile and

industrial sources.

Although ERTC site is located in a rural site, it showed similar trends as urban site, that is to say, the ratio of SO₄ ion was higher than any other anion.

On the other hand, the ratio of SO₄ and NO₃ ions in Khao Laem site were not so high, Cl ion accounted for 45 % of anion. Generally speaking, Cl ion does not depend on human activity and is regarded as being of sea salt origin.

1.1.2.2 Cation

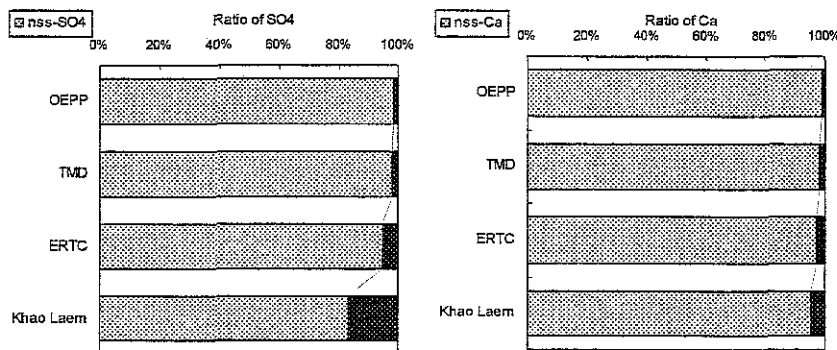
NH₄ ions ratio showed a similar distribution as with SO₄ and NO₃ ions, that is to say, NH₄ ion ratio of OEPP, TMD and ERTC sites were about 40 to 50 % of cation. Ca ion occupied the second highest part of cation apart from with TMD site during the dry season. On the other hand, Khao Laem site showed different distributions. NH₄ ratio was not so high, Na and Ca ion occupied the major parts.

1.1.2.3 Findings

According to the descriptions above, the following findings are derived.

OEPP and TMD sites located in urban areas are influenced by human activity. Such SO₄, NO₃ and NH₄ ions as emitted by human activities has serious effects on the acidity of precipitation. ERTC site, however which is located in rural area, has a similar distribution. On the other hand, Khao Laem site does not show as much influence on SO₄, NO₃ and NH₄ ions because of the low impact from human activity. The relative ratio of Cl, Na and Ca ions were bigger than other 3 sites.

Sea salt impact in Khao Laem site appeared stronger than the other sites, however the degree of impact was not so high as shown in Figure 1.1.2.3. The sea salt impact may be small even if the distance from the sea coast is not so far. It will be important to compare with the data of an inland area such as Chiang Mai site in a further study.



Source: PCD, modified by the Study Team

Figure 1.1.2.3 Ratio of non Sea Salt SO₄ and Ca

1.1.3 Tendency of Acidity

For evaluating the differences of acidity, the following analysis was tried. The analysis was based on the report by Dr. Tsuruta ¹. In the report, some of the ions are classified into two groups. One group has Acidification Potential (AP), which makes acidity of precipitation high. That to say, nss-SO₄ and NO₃ ions have AP. Another group has Neutralization Potential (NP), which makes acidity of precipitation low. Both nss-Ca and NH₄ ions have NP.

Table 1.1.3.1 shows the annual average of NP/AP. NP/AP indicates tendency of the change of acidity. Namely, when NP/AP is high, rain frequently shows lower acidity. On the other hand, if NP/AP is below 1.0, precipitation may easily be of higher acidity.

Table 1.1.3.1 Annual Average of NP/AP

Monitoring Site	NP/AP
OEPP	1.21
TMD	1.17
ERTC	0.92
Khao Laem	0.82

Source: The Study Team

Briefly speaking, NP/AP of OEPP and TMD sites was higher than ERTC and Khao Laem sites. The value of Khao Laem site was the lowest. As mentioned before, the ratio of NH₄ ion concentration at Khao Laem was lower than OEPP and TMD (see Figure 1.1.2.2), and the portion of nss-Ca ion in cation might also be small. As, NP at Khao Laem site was lower than AP, precipitation on Khao Laem area might be influenced by high acidification potential materials, and apt to show lower pH.

¹ TSURUTA H., Acid Deposition in East Asia, Kagaku, 59, 305-315, 1989



1.1.4 Comparison with Wet Deposition of Other Countries

EANET is an international monitoring network system for acid deposition. After steady preparation, it officially started in 2001. At present the following 12 countries participate in EANET.

China, Indonesia, Japan, Lao P.D.R., Malaysia, Mongolia Philippines, Republic of Korea, Russia, Thailand, Vietnam, and Cambodia

The JCA Study Team obtained EANET data for the year 1999. Therefore comparisons with some countries, near to Thailand and Japan, were carried out. Table 1.1.4.1 shows the monthly average/amount of wet deposition parameters in the year 1999. Also Figure 1.1.4.1 indicates the monthly rain amounts for each country.

Table 1.1.4.1(1) Monthly Average/Amount of Wet Deposition Parameters in the year 1999

Parameter	Country	Site Name	Month Classification	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Total Average	
Rain (mm)	Thailand	OEPP	Urban				145.1	329.2	194.7	115.0	154.9	115.7	49.2			1103.8	
		ERTC	Rural			19.4	153.6	254.5	123.7	173.4	102.6	159.2	64.5			1050.9	
		Khao Laem	Remote				13.8	40.9	41.5	84.9	23.9	7.8	255.4	53.0		521.2	
	Vietnam	Hanoi	Urban									97.1	170.9	184.8	81.0	73.5	607.3
		Hoa Binh	Rural									81.1	270.7	202.3	102.8	104.2	781.1
	Malaysia	Petaling Jaya	Urban	143.3	222.2	388.8	174.9	411.1	38.9	203.5	145.3					1728.0	
	China	Tanah Rata	Remote	113.1	128.9	374.4	349.0	83.3	104.9	215.6	396.6	242.6	326.4	114.5	293.5	2742.8	
		Jiancexhan	Urban					120.0	93.5	43.4	185.7	99.6		22.2	12.7	577.1	
	Japan	Xiaoping	Remote				24.0	299.0	165.0	142.1	268.0	169.6				1067.7	
		Ashiruri	Remote	34.0	115.8	225.0	214.9	247.5	264.0	392.0	220.5	405.0				2118.7	
		Lake Ijira	Rural						294.5	353.0	258.0	764.0				1669.5	
		Lake Banryu	Urban					143.0	244.0	371.0	109.5	176.5				1044.0	
pH	Thailand	OEPP	Urban				4.8	5.5	5.5	5.2	5.7	4.8	5.0			5.2	
		ERTC	Rural			4.5	4.5	4.7	5.4	5.2	4.9	4.6	4.8			4.8	
		Khao Laem	Remote				5.7	6.0	5.7	5.9	5.7	5.6	5.5	5.3		5.7	
	Vietnam	Hanoi	Urban								6.3	5.9	5.3	5.2	5.3	5.6	
		Hoa Binh	Rural								5.6	5.5	5.1	5.7	5.2	5.4	
	Malaysia	Petaling Jaya	Urban	4.3	4.2	4.3	4.3	4.4	4.2	4.3	4.3					4.3	
	China	Tanah Rata	Remote	4.9	5.0	5.0	5.0	4.7	4.8	5.0	5.0	4.8	5.0	5.0	4.9	4.9	
		Jiancexhan	Urban					5.3	6.1	6.0	5.3	5.2		6.1	6.7	5.8	
	Japan	Xiaoping	Remote				4.8	4.9	4.8	4.9	5.4	5.0				5.0	
		Ashiruri	Remote	4.1	4.5	4.6	5.1				5.4	5.2	5.0			4.8	
		Lake Ijira	Rural						4.7	4.3	4.6	4.9				4.6	
		Lake Banryu	Urban					4.9	4.9	5.0	4.6	4.9				4.9	
nss-SO ₄ (umol/L)	Thailand	OEPP	Urban				15.2	20.8	17.1	16.9	17.2	16.7	22.5			18.1	
		ERTC	Rural			58.5	17.7	17.2	20.6	18.5	24.9	24.3	21.7			25.4	
		Khao Laem	Remote				10.7	3.5	<1.0	2.3	1.2	4.0	2.0	1.5		3.6	
	Vietnam	Hanoi	Urban								5.3	14.6	31.6	10.5	7.2	13.8	
		Hoa Binh	Rural								5.3	4.4	26.0	26.4	7.5	13.9	
	Malaysia	Petaling Jaya	Urban	18.5	25.2	20.8	16.6	15.7	29.2	23.3	20.0					21.2	
	China	Tanah Rata	Remote	1.5	2.8	2.6	2.4	3.5	6.4	2.9	5.8	4.8	<1.0	1.9	1.2	3.3	
		Jiancexhan	Urban					17.1	21.8	204.0	25.2			101.0	69.1	73.0	
	Japan	Xiaoping	Remote				15.5	18.2	26.0	12.3	14.6	21.7				18.1	
		Ashiruri	Remote	26.5	17.6	16.4	11.4			<1.0	2.3	3.0				12.9	
		Lake Ijira	Rural						8.6	16.3	13.5	8.0				11.6	
		Lake Banryu	Urban					5.1	6.5	4.6	4.8	5.1				5.2	
NO ₃ (umol/L)	Thailand	OEPP	Urban				6.6	9.9	18.3	17.7	16.8	26.0	27.8			17.6	
		ERTC	Rural			49.9	28.5	15.5	14.4	11.6	23.6	19.8	27.6			23.9	
		Khao Laem	Remote				27.8	3.9	1.8	5.1	1.2	4.5	3.1	2.3		6.2	
	Vietnam	Hanoi	Urban								10.1	9.9	11.2	8.2	10.0	9.9	
		Hoa Binh	Rural								10.4	10.2	10.6	11.2	10.9	10.7	
	Malaysia	Petaling Jaya	Urban	13.6	18.3	12.9	8.6	9.5	17.3	18.4	25.8					15.6	
	China	Tanah Rata	Remote	2.1	4.5	3.7	3.3	5.8	8.8	3.9	8.3	5.1	<1.0	1.8	<1.0	4.7	
		Jiancexhan	Urban					17.3	10.8	17.9	30.1	35.0		104.0	65.8	40.1	
	Japan	Xiaoping	Remote				16.2	17.5	17.1	9.9	12.0	13.2				14.3	
		Ashiruri	Remote	59.3	9.8	16.0	13.8				1.9	2.9	3.4			15.3	
		Lake Ijira	Rural						15.0	36.0	24.5	13.2				22.2	
		Lake Banryu	Urban					6.0	8.4	3.6	9.1	6.0				6.6	



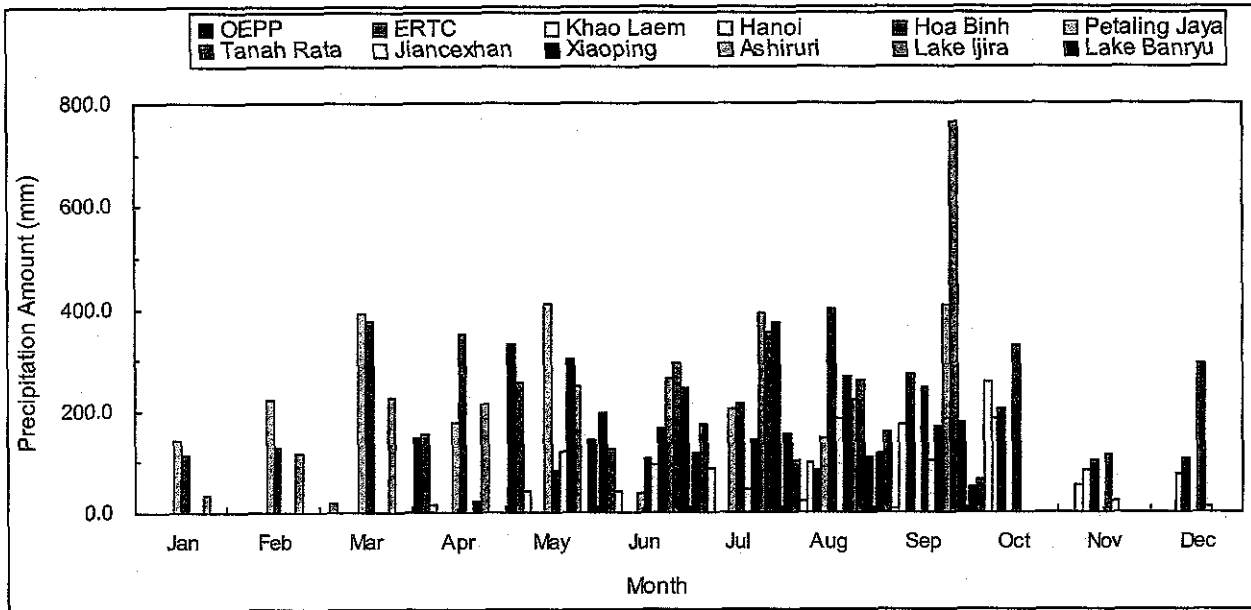
Table 1.1.4.1(2) Monthly Average/Amount of Wet Deposition Parameters in the year 1999

Parameter	Country	Site Name	Month Classification	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Total Average	
NH ₄ (umol/L)	Thailand	OEPP	Urban					34.0	42.2	59.8	49.6	40.5	40.4	34.2		43.0	
		ERTC	Rural			68.1	37.9	17.8	34.6	30.9	38.7	40.5	42.9				38.9
		Khao Laem	Remote				57.0	8.8	9.4	12.9	4.8	9.1	4.3	2.8			13.6
	Vietnam	Hanoi	Urban									9.3	8.6	3.2	1.3	8.1	6.1
		Hoa Binh	Rural									5.5	4.4	2.3	4.0	8.2	4.9
	Malaysia	Petaling Jaya	Urban		4.2	12.3	8.0	2.9	5.0	10.7	14.9	13.6					9.0
		Tanah Rata	Remote		5.2	6.5	8.0	9.8	10.6	19.4	12.9	13.6	4.2	<1.0	<1.0	<1.0	10.0
	China	Jiancexhan	Urban						9.6	3.1	19.5	39.5	13.3		95.6	149.0	47.1
		Xiaoping	Remote					35.9	37.0	49.1	23.2	52.2	15.5				35.5
	Japan	Ashiruri	Remote		29.1	10.2	14.6	12.0			<1.0	2.0	1.3				11.5
		Lake Ijira	Rural							6.1	18.6	17.9	11.1				13.4
		Lake Banryu	Urban						9.1	17.0	14.8	5.3	5.3				10.3
nss-Ca (umol/L)	Thailand	OEPP	Urban					11.6	14.5	15.0	11.1	11.5	10.0	15.8		12.8	
		ERTC	Rural			30.0	7.6	4.8	12.6	13.3	12.1	7.6	11.4			12.4	
		Khao Laem	Remote					7.1	4.7	1.4	1.6	<0.2	0.6	1.2	1.1	2.5	
	Vietnam	Hanoi	Urban									21.1	21.4	33.4	8.6	13.8	19.7
		Hoa Binh	Rural									7.8	13.1	27.3	42.7	14.4	21.1
	Malaysia	Petaling Jaya	Urban		3.0	4.7	3.9	3.8	1.9	5.2	3.0	6.1					4.0
		Tanah Rata	Remote		1.3	1.6	0.8	1.0	1.1	3.5	2.8	2.9	1.3	0.3	1.0	0.4	1.5
	China	Jiancexhan	Urban						42.6	184.0	182.0	27.1	46.9		180.0	102.0	109.2
		Xiaoping	Remote					2.4	10.8	19.9	0.7	0.4	6.1				6.7
	Japan	Ashiruri	Remote		2.2	0.8	5.1	5.8				1.6	1.7	0.2			2.5
		Lake Ijira	Rural							8.0	6.9	6.6	4.7				6.6
		Lake Banryu	Urban						0.6	0.3	<0.2	0.3	0.2				0.4

Table 1.1.4.1(3) Monthly Average/Amount of Wet Deposition Parameters in the year 1999
(Precipitation Amount)

Parameter	Country	Site Name	Month Classification	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Total Average	
nss-SO ₄ (mmol/m ² /month)	Thailand	OEPP	Urban				2.2	6.9	3.3	1.9	2.7	1.9	1.1			20.1	
		ERTC	Rural			1.1	2.7	4.4	2.5	3.2	2.6	3.9	1.4			21.8	
		Khao Laem	Remote				0.2	0.1	0.0	0.2	0.0	0.0	0.5	0.1		1.2	
	Vietnam	Hanoi	Urban									0.5	2.5	5.8	0.9	0.5	10.2
		Hoa Binh	Rural									0.4	1.2	5.3	2.7	0.8	10.4
	Malaysia	Petaling Jaya	Urban		2.6	5.6	8.1	2.9	6.5	1.1	4.7	2.9					34.5
		Tanah Rata	Remote		0.2	0.4	1.0	0.9	0.3	0.7	0.6	2.3	1.2	0.3	0.2	0.3	8.3
	China	Jiancexhan	Urban						2.1	2.0	8.8	4.7			2.2	0.9	20.7
		Xiaoping	Remote					0.4	5.4	4.3	1.7	3.9	3.7				19.4
	Japan	Ashiruri	Remote		0.9	2.0	3.7	2.5				0.3	0.5	1.2			11.1
		Lake Ijira	Rural							2.5	5.8	3.5	6.1				17.9
		Lake Banryu	Urban						0.7	1.6	1.7	0.5	0.9				5.4
nss-Ca (mmol/m ² /month)	Thailand	OEPP	Urban				1.7	4.8	2.9	1.3	1.8	1.2	0.8			14.4	
		ERTC	Rural			0.6	1.2	1.2	1.6	2.3	1.2	1.2	0.7			10.0	
		Khao Laem	Remote				0.1	0.2	0.1	0.1	0.0	0.0	0.3	0.1		0.9	
	Vietnam	Hanoi	Urban									2.1	3.7	6.2	0.7	1.0	13.6
		Hoa Binh	Rural									0.6	3.6	5.5	4.4	1.5	15.6
	Malaysia	Petaling Jaya	Urban		0.4	1.1	1.5	0.7	0.8	0.2	0.6	0.9					6.1
		Tanah Rata	Remote		0.1	0.2	0.3	0.4	0.1	0.4	0.6	1.1	0.3	0.1	0.1	0.1	3.9
	China	Jiancexhan	Urban						5.1	17.2	7.9	5.0	4.7		4.0	1.3	45.2
		Xiaoping	Remote					0.1	3.2	3.3	0.1	0.1	1.0				7.8
	Japan	Ashiruri	Remote		0.1	0.1	1.1	1.3				0.6	0.4	0.1			3.6
		Lake Ijira	Rural							2.4	2.4	1.7	3.6				10.1
		Lake Banryu	Urban						0.1	0.1	0.0	0.0	0.0				0.3

Source: PCD and ADORC, modified by the Study Team



Source: PCD and ADORC, modified by the Study Team

Figure 1.1.4.1 Rain Amount of Each Country

The highest total rain amount in 1999 appeared in Tanah Rata located in Malaysia, and was over 2700 mm. The second one appeared in Ashizuri of Japan. This would be influenced by a typhoon.

Figure 1.1.4.2 shows the monthly trend of pH, nss-SO₄ and NO₃ ions in 1999. These Figures are compared by urban, rural and remote areas.

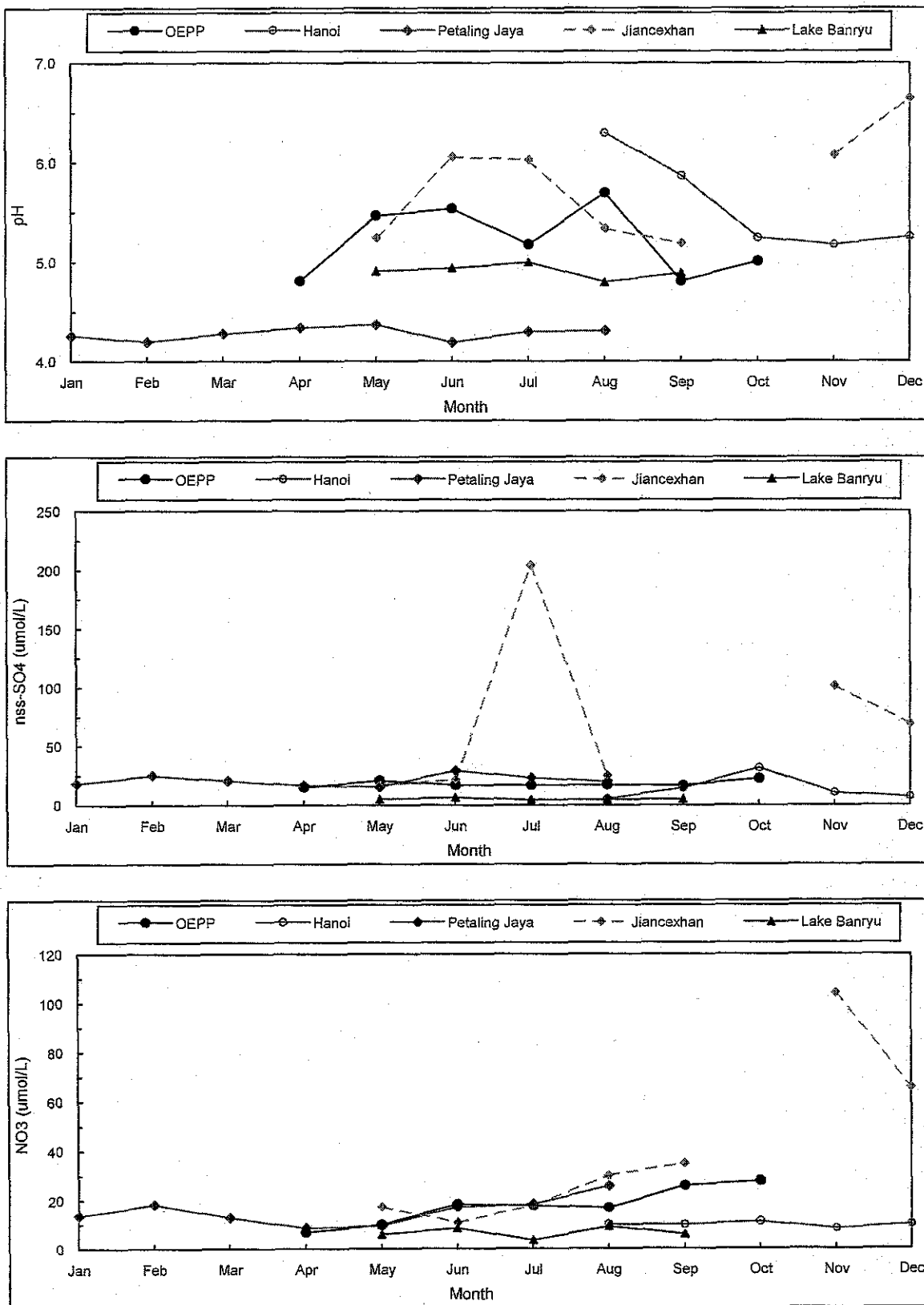


Figure 1.1.4.2(1) Monthly Trend of pH, nss-SO₄ and NO₃ in Urban Area

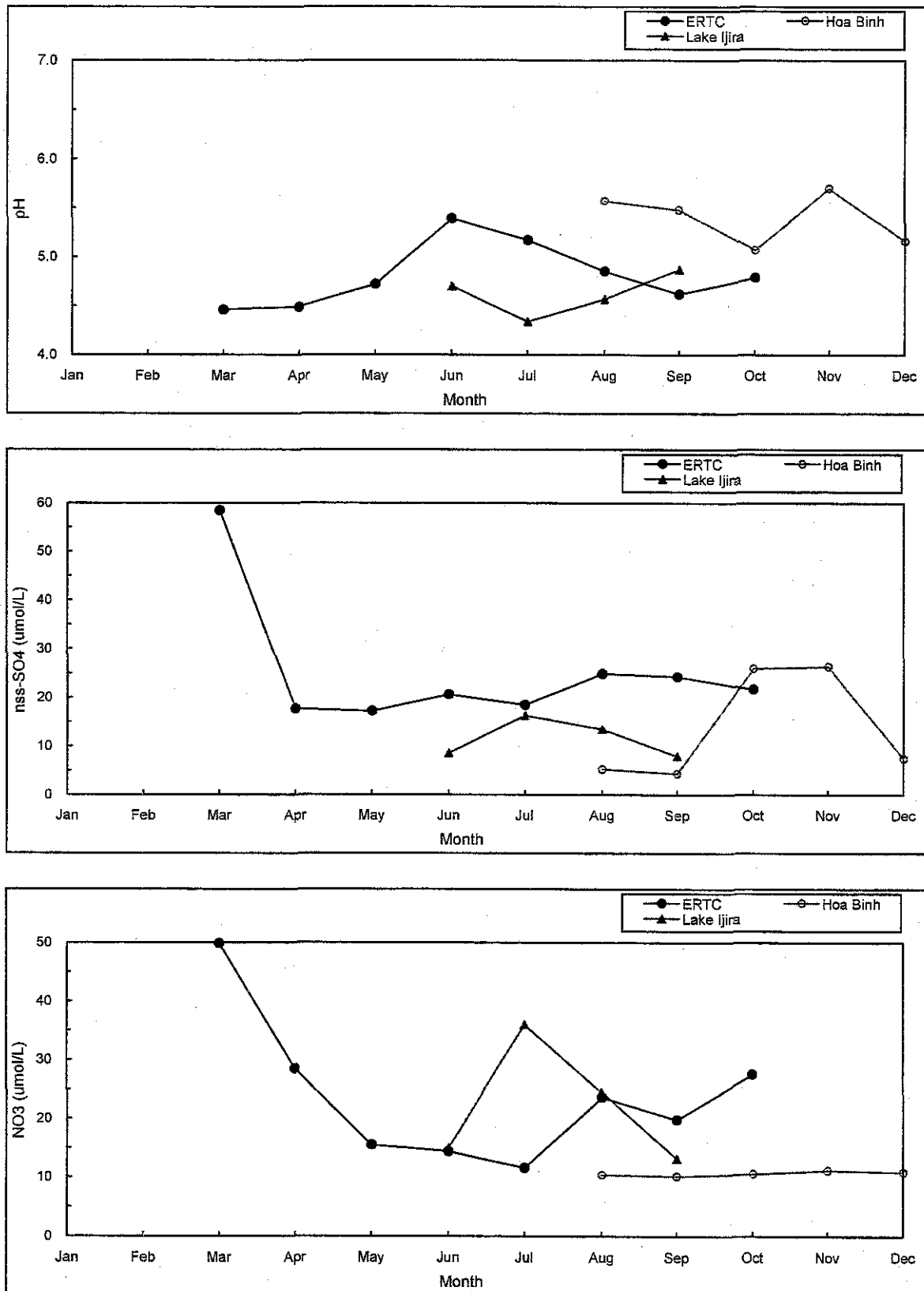
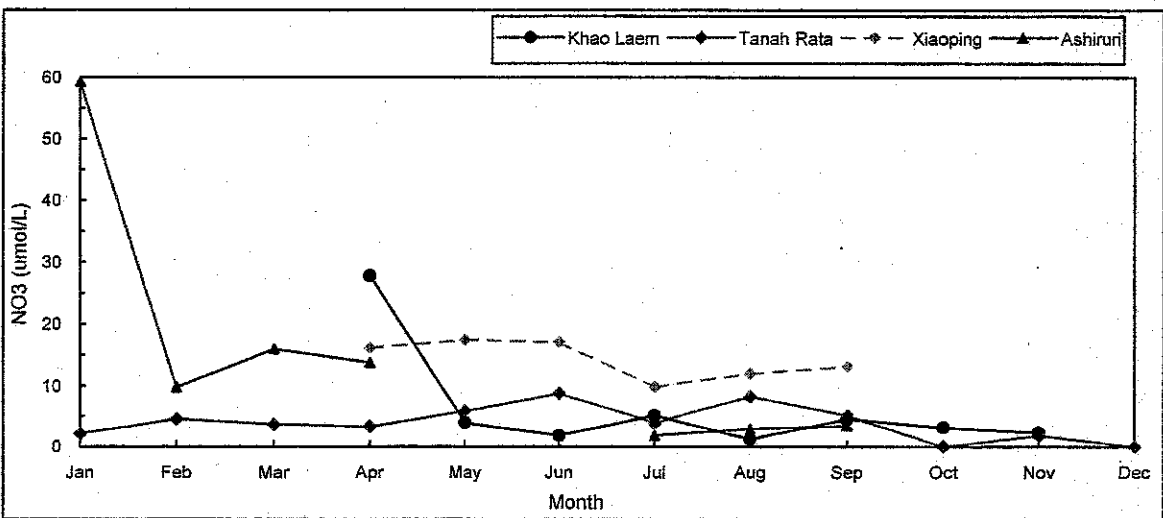
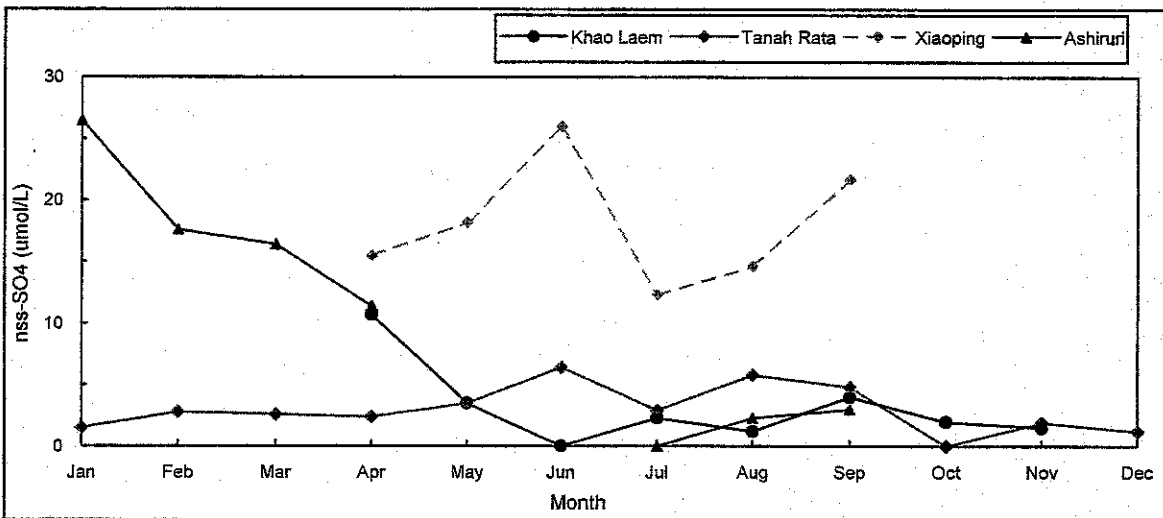
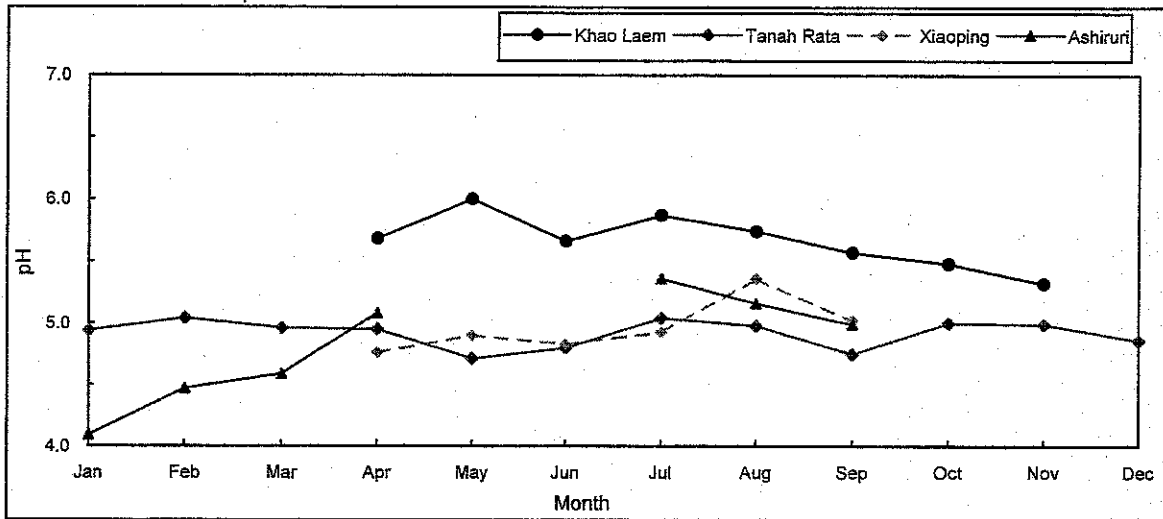


Figure 1.1.4.2(2) Monthly Trend of pH, nss-SO₄ and NO₃ in Rural Area



Source: PCD and ADORC, modified by the Study Team

Figure 1.1.4.2(3) Monthly Trend of pH, nss-SO₄ and NO₃ in Remote Area



1.1.4.1 Urban Area

The lowest pH appeared at Petaling Jaya located in Malaysia, all the monthly averages were below 5.0. The second lowest value was at Lake Banryu in Japan where values were approximately 5.0. pH in Thailand was not as low, these values were almost normal compared to other countries.

The concentrations of Nss-SO_4 and NO_3 ions were of lowest value in Japan. However the differences between other countries was not so large and monthly trends of each country were similar apart from some months in China.

1.1.4.2 Rural Area and Remote Area

The pH trends of rural/remote areas in Thailand did not show much difference from other countries, Khao Laem site was higher than other countries.

Nss-SO_4 and NO_3 ion concentrations at ERTC appeared higher in March and April, in the Dry Season. However the values in the Rainy Season were not so different.



1.2. Result of Air Quality Monitoring

1.2.1 Brief Description of Air Quality

PCD carried out an air quality survey at 44 points in the year 2000. Table 1.2.1.1 shows a brief result of the hourly and daily data of each monitoring point. Processing of daily data was carried out for the valid day, which demanded hourly 20 or more valid data per day.

In Japan, the attainment of some air quality standards is evaluated by 98 percentile value. The reason of adoption of this method is to reject abnormally high values. However, this method is not adopted in Thailand, air quality hourly and daily monitoring data are evaluated by this method tentatively.

Figure 1.2.1.1 shows the average of hourly and daily data, and 98 % percentile value of hourly data.