RAINS-ASIA:
AN ASSESSMENT MODEL FOR AIR POLLUTION IN ASIA

Chapter 1

Introduction

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Report on the World Bank Sponsored Project
"Acid Rain and Emission Reductions in Asia"

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1. INTRODUCTION

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1. INTRODUCTION

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1.1 Acid rain in Asia: the problem

What is acid rain? Acid Rain is a term used to describe the result of atmospheric chemical reactions of pollutants such as SO_x and NO_x with naturally occurring atmospheric water and oxygen. The popular term "Acid Rain" includes both the wet deposition and dry deposition (SO_2 gas) on the environment. Anthropogenic emissions of acid rain precursors occur during the combustion of fossil fuels, especially coal, for energy production in the power, transport, industrial and residential and commercial sectors. The impacts of these emissions are felt at the local, national and regional scales, via air quality deterioration at the local level, and via the impacts of acid rain on ecosystems at the national and regional levels.

Acid rain has been an issue of widespread concern in Europe and North America for more than 15 years. Because of the heavy utilization of fossil fuels in industrial countries in the second half of this century, the acidity of rain has increased markedly, damaging lakes, soils, forests, and materials in many countries. In response, a number of countries have carried out major programs of monitoring, damage assessment, modeling, and analysis of various technical and economic strategies for mitigating the effects of acid deposition.

Although policy-makers in Europe and North America are still attempting to resolve issues related to the choice and implementation of acid rain control strategies, progress has clearly been made in decreasing acid deposition. This progress is based on a number of steps, including energy conservation and efficiency improvements, a shift away from using fossil fuels containing large quantities of acid rain precursors, deployment of emission control technologies, and existing or anticipated national and regional laws and agreements. In the Asia region, emissions of acid rain precursors are currently at high levels and expected to increase further given the rapid growth in energy consumption.

Growth in energy consumption in Asia. Many Asian countries have experienced rapid economic growth during the last two decades and this trend is expected to continue. Accompanying rapid economic growth is a gargantuan appetite for energy. At current growth rates, Asian energy demand is doubling every twelve years -- as compared to the world average of every twenty-eight years. The demand for electricity is growing even faster: two to three times faster than GDP for most of the rapidly industrializing East Asian countries and up to two times faster for most of South Asia. The amount of new investment being planned in the Asian power sector during the 1990s is two-thirds of all the power-related investments being made in the development world during this period. Over 80 percent of all energy is derived from fossil fuels and 95 percent from fossil and biomass fuels. Coal is the dominant energy source (58 percent in East Asia, and 39 percent in South Asia), and is expanding at 6.5 percent per year, a rate which exceeds regional economic growth.

Local impacts of emissions. Local air pollution is becoming a serious problem and high pollutant deposition levels are being measured in an increasing number of locations (Rodhe et al., 1988; Bhatti et al., 1991). Most of the air pollution problems identified in the nations of Asia are confined to localized areas of high emissions, usually associated with the densely populated metropolitan regions such as Bangkok, Beijing, Bombay, Calcutta, Delhi, Hong Kong, Jakarta, Kuala Lumpur, Manila, Shenyang, and Seoul and pollutant concentrations in most of these cities regularly exceed the World Health Organization (WHO) recommended limits for particulate matter and sometime for SO_2. Additional monitoring in these areas may uncover a more widespread pollution problem than is presently observed.

Transboundary impacts of emissions. The projected development of fossil fuel energy systems (mostly involving coal combustion), would entail greatly increased emissions of a wide range of substances of concern including, most prominently, acidifying compounds and greenhouse gases (Foell and Green, 1991). Because these would likely be emitted from large energy facilities with high stacks, they could decrease local effects but increase the long-range transport of these acidifying substances to potentially sensitive geographical areas. Table 1.1 shows the current and projected emissions of sulphur dioxide (SO_2) for Europe, USA, and Asia . The total projected SO_2 emissions for the Asian countries in 2000 and 2010 are 54 and 76 million tons, respectively. These estimates far exceed the estimated emissions of North America and Eastern/Western Europe combined.

Table 1.1 Current and projected SO_2 emissions by region

Region/country	1990	2000	2010
Europe	38	22	14
USA	21	15	14
Asia	34	53	78
China	22	34	48
India	4.5	6.6	10.9
Other	7.5	12.4	19.1

Sources:

Europe: Cofala, J., Schöpp, W., 1995: Assessing Future Acidification in Europe. Note prepared for the 15th Meeting of the UN/ECE Task Force on Integrated Assessment Modelling, May 1995, The Hague. IIASA, Laxenburg, Austria.

USA: Estimates obtained from National Acid Precipitation Assessment Program (NAPAP) Integrated Assesment. Draft Sept. 1990.

Asia: Reference scenario from Chapter 7 of this report.

Acid rain in Asia. Figure 1.1 gives an overview of the acid rain situation in Asia as estimated before the start of this study (Bhatti et al., 1991). Relative sulfur dioxide emissions in 1985 by country or region are indicated by vertical bars. Emissions are significant in China, India, Japan, and the Koreas and are small but growing very rapidly in several other countries of South and Southeast Asia. Deposition patterns of emissions are largely determined by wind flow patterns, shown by arrows in the figure. In winter (January) the flow is generally from the land mass to the ocean, while in summer (July) the reverse occurs. Typical monitored values of pH are shown in the circles. Low pH values, (e.g., 4.5) occur in Japan and Southern China where emissions are large; elsewhere the pH values are 6 to 7. Because of the paucity of monitoring sites, the probability of low pH's at other unsuspected locations is high.

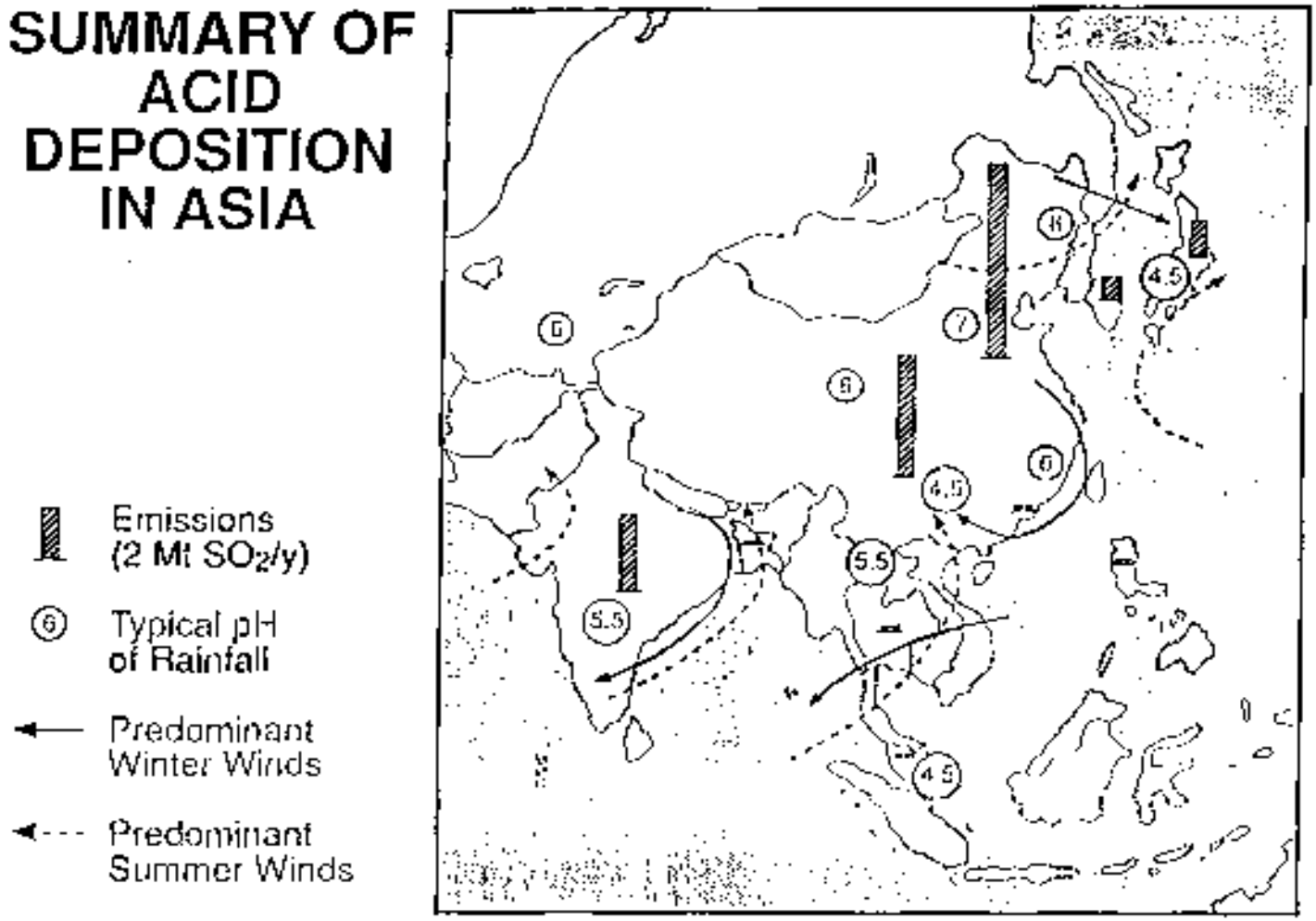

Figure 1.1 Summary of Acid Deposition in Asia (Bhatti et al., 1991)

Status of research. In Asia, where recognition of this phenomenon is just beginning, very little research has been conducted on the levels and impacts of acid deposition. However, available monitoring data show that the acidity of rainfall has been rising dramatically in some areas of the region. The degree to which this increased acidity is affecting Asian ecosystems is unknown at present. However, given the North American and European experience, impacts can be expected to be significant. Some of the ecosystems of the Asia region are similar to those found in areas of North America and Europe where the majority of the research on acid deposition impacts has been conducted. Thus, in some cases it should be possible to extrapolate the potential effects found in these western nations to the corresponding ecosystems of Asia. However, many other environments in Asia are very different from those for which acid deposition impacts have been studied, and research will have to be conducted to analyze and assess the relative vulnerability of these various anthropogenic and natural environments to acidic inputs.

Nevertheless, based on knowledge of the various components (i.e., soils, flora, fauna, climate, etc.) of the ecosystems in question, their relative vulnerability to acidic inputs and their distribution in the Asian region, it is possible to attempt to predict the potential effects of acidic deposition (Bhatti et al., 1991). For a given area to be at high risk from acidification, a number of conditions must be present simultaneously. First, the area must be receiving or at risk of receiving high levels of deposition. Second, the soils of the area must be sensitive to acidification, and the area must have vegetation, fauna, aquatic organisms, man-made materials and/or large human populations vulnerable to increased inputs of acidity. One attempt to assess these risks for the Asian region showed Japan, Korea, Southern China, and the mountainous regions of South-east Asia with the mountain zones of Southwestern India to be at greatest risk (Bhatti et al., 1991) (see Table 1.2).

In most Asian countries there does not seem to be either a strong scientific or a public constituency to address the potentially serious problems in the future for long-range transport and deposition of sulfur and nitrogen species, and for the consequent damage to ecosystems, health, and materials.

In addition to their global implications, the long-term and regional/local implications of these atmospheric emissions touch not only the natural environment, but also have far-reaching implications for important commercial and cultural activities such as forestry, agriculture, and tourism. The political ramifications of transboundary environmental pollution in Asia are also likely to be serious.

Table 1.2 Vulnerability of various Asian regions to acid deposition risk factors

	High emis-sions		High deposition		Sensitive soils	Sensitive vegetation and materials	High risk
Region	Current	Future	Current	Future			
NE China	X	X		X		X	
Japan, Korea			X (winter mostly)	X (winter mostly)	X	X	X
S China		X	X (winter mostly)	X (winter mostly)	X	X	X
SE Asia	X	X	X (local areas, summer mostly)	X (local areas, summer mostly)	X (mountain areas)	X (mountain areas)	X (mountain areas)
SE Asian islands	X	X	X (isolated, local)	X (isolated, local)	X (mountain areas)		
N India	X	X		X (summer)		X (Himalayan foothills)	
SW India			(borderline acidity)	X (winter)	X	X (mountain areas)	(borderline in mountain areas)
NE India		X		X (summer)	X		
Sri Lanka, Mal-dives			(borderline acidity)	X (winter)			
Siberia, N Mon-golia				X (summer)		X	

Why RAINS-ASIA? In light of this outlook, the time has come to develop an integrated program of assessment and policy analysis for the purpose of analyzing long-term strategies for acid rain problems at national and at Asia-wide levels. A key component of such a program entails the application of the analytic and policy development experience gained in the West to this emerging issue in Asia. An analytical tool has been built to help decision-makers project future trends in emissions, estimate the regional consequences for acid deposition levels, evaluate the vulnerability of natural and artificial systems, and estimate the costs and effectiveness of alternative mitigative actions that might be taken. Such a policy analysis exercise can start to raise environmental awareness in the region and begin a dialogue that could help ameliorate (or prevent the worsening of) an environmental problem in the early stages.

The role of the World Bank. World Bank involvement would help the ongoing process of assisting countries in the Asia region incorporate environmental considerations into the developing strategies. The Bank is active at the national levels through assistance to countries to prepare and implement National Environmental Action Plans, and at the global level through partnership in the Global Environmental Facility. Increasingly, the Bank is beginning to assist countries work together to understand the causes and impacts of regional or common environmental problems and explore mitigatory options, as a means to facilitating countries meet their obligations under international or regional treaties. Further, by using RAINS-ASIA, the Bank should be able to minimize the acid rain related environmental consequences of its work in the power and industrial sectors in Asia, and adopt a environmentally pro-active development strategy.

1.2 Project history

This project has its institutional genesis in 1989. At that time there was a small but growing recognition of the potential air pollution problems resulting from the massive growth of fossil fuel use in Asia. In response to the above concern, an effort to explore mechanisms to bring together a group of prominent scientists to assess the magnitude of the problem and to recommend needed actions began. This resulted in the convening of a small group of international specialists on acid rain at Asian Institute of Technology (AIT) in Bangkok, Thailand in November, 1989, with the financial support of the U.S. Department of Energy. The objectives of this small workshop were to assess the status of existing or potential acid rain issues in several Asian countries; to review relevant experiences in Europe and North America; and if appropriate, to begin to plan and design a follow-up research/action program.

First conference in 1989. The AIT workshop brought together a considerable body of international knowledge and experience dealing with acid rain problems. The participants were chosen to represent the entire spectrum of issues and expertise, ranging from energy technologies and pollutant emissions, all the way through the cause-effect chain to the ultimate damage of natural and manmade systems. Participants from Asia included specialists from several of the Asia countries with greatest concerns about acid rain, including China, India, Thailand, Indonesia, and Korea, the United Nations Environmental Program (UNEP), and several energy/environment scientists from AIT.

As a result of its review of the current and future situation in Asia, the workshop concluded that acid deposition had the potential to cause significant damage in Asia. In China there already appeared to be considerable evidence of the effects. The participants were greatly concerned by the implications of the planned initiatives for accelerated development of massive fossil-fuel energy systems in many Asia nations, which could entail greatly increased emission of acid deposition precursors. Because these would likely be emitted from large energy facilities with high stacks they could increase the transport of these acidifying substances to sensitive geographical areas.

Based on the above conclusions, the Workshop participants recommended the development of an intensified monitoring program in Asia and the development of a program for research on pollutant transportation/transformation and on the impact of acid depositions on natural and man-made systems. In addition the participants strongly recommended that an integrative program of assessment and policy analysis be developed for the purpose of analyzing long-term strategies for acid rain problems at national and Asia-wide levels. This initial conference became the first of a series of "Annual Conferences on Acid Rain and Emissions Reduction in Asia".

Second conference on Acid Rain. In November 1990, an expanded group of prominent experts attended a "Second Annual Conference on Acid Rain and Emissions Reduction in Asia" at AIT under the broader sponsorship of the U.S. Department of Energy, the World Bank, UNEP, and ESCAP. It had the objective of reviewing the problem in more depth, and if appropriate, to lay out a detailed program and plan of action. At this conference, several papers were presented and discussed (AIT 1990) which provided a further quantified understanding of the current status and potential of the acid rain problem in Asia. Major results included: (1) a survey paper

(Bhatti, et al. 1991) which gave a broad perspective of the issues; and, (2) the first Asia-wide estimate of acid precursors through the year 2010 (Foell and Green, 1991).

Based on the discussions at this Conference, a phased integrated policy analysis framework was planned. The plan included personnel and resource requirements, schedules, institutional statements of interest and responsibilities from approximately 14 institutions through Asia, Europe, and North America. In the addition, for the first time, the conference produced a Proceedings, containing several papers presented at the conference (Foell and Sharma, 1991). A major outcome and follow-up of this conference was a growing awareness of the potential acidification and air pollution problems in Asia. This included increased interest within national governments and research organizations, as well as in the international community, including UNEP, ESCAP, ADB and the World Bank.

World Bank - Asian Development Bank involvement. In early 1991 the World Bank expressed interest in a project which focussed on the development of a policy-oriented assessment tool to address acid rain related issues. Based on the earlier discussions the possibility of adapting to Asia the RAINS model, developed by IIASA for acid rain assessment in Europe was explored. At the third annual conference, held at AIT in November 1991, with environmental officials of the World Bank and ADB in attendance, detailed project plans and agreements were developed for a so-called RAINS-ASIA project. Using the RAINS model as the analytical framework for the project, the conference produced a specific written proposal to the two multilateral banks as discussed below. In addition a Conference Proceedings was published laying out major technical frameworks for the anticipated research (Foell and Green, 1992).

1.3 Goal of the projects

In recent years, integrated assessment models have been utilized for international negotiations on acid rain. The purpose of these models is to provide negotiators or regulators with a full regional picture of the problems associated with the entire causal process from energy systems and emissions through to the ultimate impact on natural and man-made systems. The model user can analyze the regional and national implications of various scenarios, which include options for energy use, control strategies, and mitigation policies. Such an effort for the acid rain problem in Europe has led to the Regional Acidification INformation and Simulation (RAINS-EUROPE) model.This model has increasingly been used for policy analysis under the Convention on Long-range Transboundary Air Pollution (United Nations, Geneva). Most recently the RAINS-EUROPE model has been used in the negotiations that led to the signing of the Second Sulfur Protocol. This Protocol contains SO_2 emission reduction requirements for the 33 Signatories which have largely been based on calculations with RAINS-EUROPE.

In 1992 the World Bank commissioned several research institutes to develop the first phase of a complete assessment methodology of the acid rain impacts for Asia, as done for Europe. To achieve this goal in phase 1 of the project, the experience collected in the construction and use of the RAINS-EUROPE model was used to create RAINS-ASIA. Additional expertise on the specific Asian situation was added to the research team. RAINS-ASIA was aimed to be an integrated acid rain and emissions policy analysis model for the development of national and regional policy perspectives in Asia. The model design includes the entire causal chain from energy systems and emissions through to the ultimate impact on natural and man-made systems.

Similar to the RAINS model for Europe, RAINS-ASIA consists of three modules, each describing a part of the cause-effect chain. The modular structure of RAINS-ASIA will allow for easy replacement of individual modules when knowledge progresses. The four basic modules of the RAINS model are:

1. Regional Energy Scenario Generation Module (RESGEN)
2. Energy and emissions module (ENEM)
3. Atmospheric module (ATMOS)
4. Impacts module (IMPACT)

The RAINS-ASIA model covers the countries of East, South, and South-East Asia, with particular focus on China, India, Thailand, and North and South Korea (10° South to 55° North in latitude and 60° to 150° East in longitude). The temporal range of all the model is 1990 - 2020 with time resolution of one year. RAINS-ASIA has been implemented on a PC.

In addition, the Regional Energy Scenario Generator (RESGEN) has been developed. RESGEN output is directly linked to RAINS-ASIA.

1.4 Terms of Reference for the Program

The development of the RAINS-ASIA model took place as a collaborative effort involving several international institutions. The RAINS-ASIA program included development of several components:

(a) Energy and Emissions Module and Energy Economic Analysis;
(b) Atmospheric Transport and Deposition Module;
(c) Ecosystem Sensitivity Evaluation and Mapping for Asia;
(d) Critical Load Evaluation and Model Integration Modules; and,
(e) Asian Countries Data Collection and Institutional Development.

Separate consulting contracts were prepared for each of these components. The first four components were funded through the World Bank while a separate contract for the fifth component was prepared by the Asian Development Bank (ADB). This report is for the model development projects financed by the World Bank. The results of ADB Asian Countries data gathering effort project through AIT has been reported in a separate report.

A. ENERGY AND EMISSIONS MODULE

The Energy and Emissions module development for RAINS-ASIA included:

(i) Development of a policy-based energy/emissions module for front-end interfacing with RAINS-ASIA. The model structure shall be based on the definition of the regions of interest and the level of sub-country analysis necessary to produce the required gridded energy and emission data for baseline and scenario emission inventories.

(ii) Construct a detailed protocol to define the methodology for data collection of country and sub-country specific data on Asian energy and economic systems.

(iii) Create a preliminary emissions inventory for the Asian region for a base year on the basis of 1° by 1° grid resolution. This emissions inventory shall differentiate between the location of point and area sources as needed for the atmospheric transport calculations and shall try to incorporate season variations in emission patterns.

(iv) Integrate all appropriate collected and assimilated data into the energy/emissions model.

(v) Develop baseline and future energy/emission scenarios, based on the revised regional sub-country energy/emissions model. This includes initial model runs, model testing, and development of the baseline energy/emissions scenario.

Energy/Economic Analysis

The Energy/Economic Analysis for RAINS-ASIA included the following:

(i) Provide important national information on which to base a thorough analysis of the potential for energy conservation, efficiency and fuel substitution;

(ii) Apply a "top-down" econometric model of energy and emission to a few Asian countries, particularly China, India, S.Korea and Indonesia;

(iii) Identify and evaluate information needed for the development of alternative scenarios and develop insight into the analysis of economic impacts of efficiency improvements and fuel substitutions; and,

(iv) Initiate an analysis at macro scale of the institutional, financial and resource constraints to fuel substitution and energy sector development.

B. ATMOSPHERIC TRANSPORT AND DEPOSITION MODULE

The Atmospheric transport and deposition sub-module development for RAINS-ASIA included:

(i) Develop an acid deposition dispersion model for use in Asia. The Asian domain shall consist of the window bounded by 10° South to 55° North latitude, and 60° to 160° East longitude and should treat emissions from elevated sources.

(ii) Select model parameters (dry deposition velocities, reaction rates, dispersion parameters) which are appropriate for Asian applications. Asia specific parameters must take into account high levels of dust, and tropical conditions. Sensitivity calculations shall be performed to identify key input parameters.

(iii) Select base year for calculation of annual deposition. Special attention to be paid to select representative meteorological conditions.

(iv) Calculate annual sulfur deposition (wet, dry and total) on a grid to grid basis for a complete annual cycle. Sulfur dioxide and sulfate surface concentrations shall also be calculated.

(v) Develop appropriate post processing tools to calculate the transfer matrices needed by the RAINS model, calculate country-to-country matrices, and display the data on regional and sub-regional basis.

(vi) Identify observational data in Asia on sulfur dioxide and sulfate ambient concentrations, and precipitation sulfate, for use in model verification. Preliminary model performance evaluation shall be initiated.

(vii) Obtain data on the base-cation composition of anthropogenic and natural aerosol components in Asian countries. Locate regions of natural emissions and identify seasonal dependence. This information shall be used in future studies estimating base-cation deposition in Asia.

(viii) Establish a network of scientists and principal contacts in Asia to coordinate the development and application of the atmospheric model in Asia.

(ix) Deliver the dispersion model for use as tool to study long range transport of air pollutants in the Asia region. This model shall be used outside of the RAINS-ASIA model.

C. ECOSYSTEM SENSITIVITY EVALUATION AND MAPPING

The development of an Ecosystem Sensitivity Evaluation and Mapping for Asia module for RAINS-ASIA and included:

(i) Enhancement of data collection, digitization, GIS manipulation and production of interim maps for review and assessment. Activities will include: collection of maps and digital data; land use data; soil type, geology, precipitation, evaporation, and GIS manipulation; and methodology refinement.

(ii) Organize a scoping meeting on the final methodology including establishment of sensitivity and critical load relationship criteria.

(iii) Participate in workshops to discuss sensitivity mapping and assignment of critical loads for the region.

(iv) Coordinate with other components including critical load maps preparation.

D. CRITICAL LOAD EVALUATION AND MODEL INTEGRATION MODULES

The work on the Critical Load Evaluation module for RAINS-ASIA included the following:

(i) The sensitivity of Asian ecosystems shall be described by means of preliminary computed critical loads. A review and contacting of the Asian institutes for the exchange of methodologies, maps and data for critical load evaluation shall be initialized during the project;

(ii) Expansion of the application of critical load assessment methodology in Asia in collaboration with Asian scientists working on other components. The methodology for the computation of critical loads in Asia shall be examined using existing data which will be

digitized and made available through other project component, and data from China, Japan, and Korea if available and appropriate. The results of this effort shall be disseminated for review of the methodology including background maps developed under another component of the project;

(iii) Organize a scoping meeting on the final critical load assessment methodology and carry out preliminary evaluation of critical loads and maps for the region;

(iv) Compute critical loads for grid cells in Asia and, if appropriate, use sensitivity classes for the verification and regional extrapolation of the computed critical loads. The result of this activity shall be an applicable map of critical loads which can then be incorporated into RAINS-ASIA;

(v) Disseminate critical loads maps to other consultants and organizations;

(vi) Conduct a workshop to evaluate and review the results of the critical load and background maps; and

(vii) Submit the critical loads map to the Model integration task manager for incorporation into RAINS-ASIA.

Model Integration

The Model Integration module consisted of the following tasks:

(i) The RAINS-ASIA model will consist of several modules. The linkage among all modules shall be established under this component. The RAINS-EUROPE model shall be modified to accommodate the changes necessary to implement RAINS-ASIA. Cooperation and coordination with other consultants will be a key to the success of this component;

(ii) Redefine the region of interest from Europe to Asia by developing a grid matrix and geographic map for the Asian region and integrate this matrix and map into the RAINS format;

(iii) Input Asian technological information on combustion and control technologies and adapt the RAINS-EUROPE cost functions for Asia;

(iv) Adapt base year emissions inventory and baseline scenario to reflect the needs of modeling for Asia;

(v) Change the RAINS-EUROPE user interface to meet the Asian policy requirements;

(vi) The RAINS model is capable of assessing scenarios such as emission level changes through technical measures or alterations in energy consumption patterns. A preliminary energy scenario shall be incorporated from the other components to illustrate the operation of RAINS-ASIA;

(vii) Deposition patterns and first assessments of these patterns by comparison to critical

loads shall be computed and displayed geographically. Emission and energy scenarios shall be displayed graphically; and,

(viii) A manual for RAINS-ASIA shall be developed.

E. ASIAN COUNTRIES DATA COLLECTION AND INSTITUTIONAL DEVELOPMENT

Work under this task included collection of data on socio-economic indicators and energy characteristics (see Chapter 3.3), monitoring sulfur dioxide in East Asia (see Chapter 5.6), and organizing an IMPACT task meeting (see Chapter 6, Annex 5). This work was carried out under a separate contract from the Asian Development Bank.

Workshops planned in Terms of Reference

Three major workshops to coordinate various components were planned during for the project. These activities are described below.

(i) Task Group & Project Coordination/Progress Workshop, Four months after project start To be held in Asia. The first major workshop is planned at the end of the fourth month of the project. This workshop shall serve two specific purposes: working group meetings for the four components and a project coordination meeting. At this meeting, the methodologies of the working groups shall be discussed and finalized, critical data gaps shall be identified, and task-specific activities refined as necessary.

(ii) Model Integration Workshop, Nine months after project start. After nine months, the preliminary individual RAINS-ASIA components shall be delivered to the model integration team. At this workshop, the individual components shall be presented to the group, and these components shall be interfaced within the RAINS-ASIA model. All protocols regarding units, formats, and component details shall be discussed at this time. The plans for testing the assembled RAINS-ASIA model, and finalization of the base case RAINS-ASIA simulation, shall be determined at this meeting.

(iii) Preliminary Results and Program Progress Meeting, twelve months after project start. This project conference, held in the twelfth month of the project, shall be to review the first complete initial results using RAINS-ASIA. This meeting shall contain all key members of the project team. Results from the four major components shall be reported, along with the integrated RAINS-ASIA products. Further developments, refinement in the type and display of model outputs, plans for additional model testing, and final selection of scenarios shall be discussed at this time.

1.5 Major meetings and workshops held during the project

The project has met several times to discuss progress and interact with scientists from Asian countries. A brief overview of the project meetings is listed below. Apart from these meetings, the various tasks leaders met with Asian scientists to improve input and discuss tentative results. These meetings are discussed in the respective chapters in this report.

June 1992: Start of the project (kick-off meeting); timetable; definition of final products (Madison, Wisconsin, USA)

November 1992: 4th Annual Conference on Acid Rain and Emissions in Asia (Bangkok, Thailand)

April 1993: Integration meeting; interim results of sub-modules; first version of the software (Laxenburg, Austria)

September 1993: Presentation of interim report to the World Bank Task Managers (Washington, D.C., USA)

February and July 1994: Integration meeting; second version of software; scenario development (Laxenburg, Austria)

October 1994: Scenario development and final report meeting (Beijing, China)

November 1994: Symposium on Acid Rain and Emissions in Asia (Bangkok, Thailand)

May 1995: Peer Review Meeting (Washington, D.C., USA)

1.6 Team and network in Asia

This project has been carried out by a team of experts from Asia, Europe and the United States. This broad-based effort has been co-coordinated by the Asia Technical Department of the World Bank and the Asian Development Bank. The project has been organized into four major tasks: Energy and Emissions; Transport, Deposition and Monitoring; Ecosystem Sensitivity; and Integration. Each task involved a team of Asian and European/USA scientists. For each task there is an Asian project leader and focal center(s) to support the development of the RAINS-ASIA model and to facilitate networking among scientists and analysts in Asia. A unique team of experts from Europe and the United States, has been assembled for the project. The team members were specifically selected for their extensive experience and dedication to the subject of acid rain in Asia. Participating institutes for the project:

Contract Management:

World Bank	--	Jitendra Shah
Asian Development Bank	--	Ali Azimi

Project Management:

USA/Europe	Leen Hordijk, Wageningen Agricultural University, Netherlands Wesley K. Foell, Resource Management Associates, USA
ASIA	S.C. Bhattacharya and R.M. Shrestha, Asian Institute of Technology, Thailand

Energy and Emissions Module:

USA/Europe	Project Leader:		Wesley K. Foell, Resource Management Associates, USA
	Institutions:		Resource Management Associates, USA Argonne National Laboratory, USA ECON Energy, Norway
Asia	Project Leaders:		S.C. Bhattacharya and R.M. Shrestha, AIT
	Focal Points:		
	Japan	-	University of Tokyo
	India	-	Tata Energy Research Institute
	China	-	Research Center for Eco-Environmental Sciences
	Thailand	-	Dept. of Energy Development and Promotion
	Bangladesh	-	Bangladesh Council of Scientific and Industrial Research
	Indonesia	-	Institute of Technology at Bandung
	Philippines	-	Department of Energy
	Pakistan	-	Pakistan Atomic Energy Commission
	Myanmar	-	Ministry of Energy
	Vietnam	-	Institute of Energy
	South Korea	-	Korean Institute of Energy Economics
	Malaysia	-	University Sains Malaysia, Penang

Atmospheric Transport and Deposition Module:

USA/Europe	Project Leader:		Greg Carmichael, University of Iowa, USA
Asia	Project Leader:		Manju Mohan, Indian Institute of Technology, India
	Institutions:		
	Japan	-	Central Research Institute Electric Power Industry Kyushu University
	Hong Kong	-	Royal Observatory
	South Korea	-	Ajuo University
	South Korea	-	Korean Institute of Science and Technology
	China	-	Research Center for Eco Environmental Sciences
	Monitoring Network Collaborators:		
	India	-	Indian Institute of Technology
	Nepal	-	Nepal Meteorological Services
	South Korea	-	Ajou University
	Thailand	-	Environmental Research and Training Center
	Malaysia	-	Malaysia Meteorological Agency
	Indonesia	-	Institute of Technology at Bandung
	Taiwan	-	Taiwan National University
	Hong Kong	-	Hong Kong Polytechnic

	Vietnam	-	Institute of Chemistry, Hanoi
	Bangladesh	-	Jahangirnagar University
	China	-	Research Center for Eco-Environmental Sciences
	Sweden	-	Swedish Environment Research Institute

Impacts Module:

USA/Europe	Project Leader:	Jean-Paul Hettelingh, RIVM, Netherlands
	Institutions:	
		Stockholm Environment Institute, England University of Lund, Sweden GEODAN, Netherlands
Asia	Project Leader:	Zhao Dianwu, Research Center for Eco-Environmental Sciences, Beijing, China
	Institutions:	

South Korea	-	Kyong-gi University
Bangladesh	-	Jahangirnagar University
Japan	-	National Institute for Environmental Studies
Vietnam	-	Institute of Chemistry, Center for Research of Vietnam
Taiwan	-	Taiwan National University

Integration of RAINS-ASIA

USA/Europe	Project Leader:	Markus Amann, IIASA. Austria

Other Institutions from which individuals have participated in the Project

Thailand	-	King Monkuts Institute of Technology, Thonburi
	-	Electric Generating Authority of Thailand
	-	Thailand Development Research Institute
Australia	-	University of Technology Sydney, CSIRO
USA	-	Oak Ridge National Laboratory; East-West Center
International	-	UNEP
	-	ESCAP

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