RAPIDC

Regional Air Pollution In Developing Countries

Air Pollution in Asia and Africa: Approaches in the RAPIDC Programme

Compiled & edited by
Johan Kuylenstierna & Kevin Hicks

RAPIDC

Regional Air Pollution In Developing Countries

Air Pollution in Asia and Africa: Approaches in the RAPIDC Programme

Compiled & edited by
Johan Kuylenstierna & Kevin Hicks

AIR POLLUTION IN ASIA AND AFRICA: THE APPROACH OF THE RAPIDC PROGRAMME

Proceedings of the First Open Seminar on
Regional Air Pollution in Developing Countries,
held at Stora Hörsalen, Sida (Sveavägen 20, Stockholm)
on June 4, 2002

Compiled and edited by Johan C.I. Kuylenstierna and W. Kevin Hicks

www.rapidc.org

Stockholm Environment Institute
Lilla Nygatan 1
Box 2142
S-103 14 Stockholm
Sweden
Tel: +46 8 412 1400
Fax: +46 8 723 0348
E-mail: postmaster@sei.se
Web: www.sei.se

Communications Director: Arno Rosemarin
Publications Manager: Steve Cinderby
Layout: Lisetta Tripodi
Cover: Erik Willis

ISBN 91 88714 845

Contents

Figures and Tables

List of abbreviations and useful web page addresses

ABC	Atmospheric Brown Cloud	http://www-c4.ucsd.edu/ProjectABC/
ADB	Asian Development Bank	http://www.adb.org/
APINA	Air Pollution Information Network for Africa	http://www.york.ac.uk/inst/sei/rapidc2/apina/apina.html
APMA	Air Pollution in the Megacities of Asia	http://www.asiairnet.org/
ASEAN	Association of Southeast Asian Nations	http://www.aseansec.org
CAAP	Composition and Acidity of Asian Precipitation	http://www.york.ac.uk/inst/sei/rapidc2/cad.html
CAD	Composition of Asian Deposition	http://www.york.ac.uk/inst/sei/rapidc2/cad.html
CAPIA	Cross Border Air Pollution Impact Assessment Project for SADC	http://dbn.csir.co.za/capia/
CNG	Compressed Natural Gas	
CO	Carbon Monoxide	
CO_2	Carbon Dioxide	
CPCB	Central Pollution Control Board (Delhi)	
CSIR	Council for Scientific and Industrial Research-South Africa	http://dbn.csir.co.za/
DACST	Department of Arts, Culture, Science and Technology, South Africa (now the Department of Science and Technology)	
DEBITS	Deposition of Biogeochemically Important Trace Species	http://www.igac.unh.edu/sub_pages/debits.html
EANET	East Asia Acid Deposition Monitoring Network	http://www.adorc.gr.jp/
EAP-AP	Environmental Assessment Programme for Asia and the Pacific (now RRC-AP)	
ELMS	Environment and Land Management Sector	
EMEP	European Monitoring and Evaluation Programme (see LRTAP)	
EU	European Union	http://europa.eu.int/
FP	Framework Programme	
GC	Governing Council	

GNP	Gross National Product	
ICIMOD	International Centre for Integrated Mountain Development, Nepal	http://www.south-asia.com/icimod/welcome.html
ICP	International Co-operative Programme (see LRTAP)	
IES	Institute of Environmental Studies, University of Zimbabwe	http://www.ies.ac.zw/default.htm
IGAC	International Global Atmospheric Chemistry Programme	http://www.igac.unh.edu/
IGBP	International Geosphere Biosphere Programme	http://www.igbp.kva.se/cgi-bin/php/frameset.php
INDOEX	Indian Ocean Experiment	http://www-indoex.ucsd.edu/
INEC	Department of Infrastructure and Economic Co-operation (Sida)	www.sida.se
IUAPPA	The International Union of Air Pollution Prevention and Environmental Protection Associations	http://www.iuappa.fsnet.co.uk/about.htm
IVL	Swedish Environmental Research Institute	http://www.ivl.se/en/
KEI	Korea Environment Institute	http://www.kei.re.kr/eng/
LRTAP	Long-range Transboundary Air Pollution	http://www.unece.org/env/lrtap/
MATCH	Mesoscale Atmospheric Transport Chemistry Model	http://www.york.ac.uk/inst/sei/rapidc2/cad.html
MISU	Department of Meteorology, Stockholm University	http://www.misu.su.se/
MMS	Malaysian Meteorological Service	http://www.kjc.gov.my/
MoC	Monitoring Committee (Malé Declaration)	www.rrcap.unep.org/malereport
NAC	National Advisory Committee	
NFP	National Focal Point (Malé Declaration)	http://www.rrcap.unep.org/issues/air/maledec/
NGO	Non-governmental Organisation	
NH_x	Reduced Nitrogen (NH_3 ammonia; NH_4^+ ammonium)	
NIA	National Implementing Agency (Malé Declaration)	http://www.rrcap.unep.org/issues/air/maledec/
NO_x	Oxidized Nitrogen (NO nitric oxide; NO_2 nitrogen dioxide)	
NV	Swedish Environmental Protection Agency	
O_3	Ozone	
OECD	Organisation for Economic Co-operation and Development	http://www.oecd.org/
PAG	Programme Advisory Group (RAPIDC)	

PAH	Polycyclic Aromatic Hydrocarbon	
PM	Particulate Matter (PM_{10} - diameter less than 10 microns; $PM_{2.5}$ - diameter less than 2.5 microns)	
PSC	Programme Steering Committee (RAPIDC)	
POPS	Persistent Organic Pollutants	
RAINS Asia	Regional Air Pollution Information and Simulation Model	http://www.iiasa.ac.at/Research/TAP/rains_asia/docs/rains.asia.html
RAPIDC	Regional Air Pollution in Developing Countries	http://www.rapidc.org
REAP	Regional Environmental Action Plan, Central Asia	
RRC-AP	Regional Resource Center for Asia and the Pacific	http://www.rrcap.unep.org/issues/air/maledec/
SACEP	South Asia Co-operative Environment Programme	www.sacep.org
SADC	Southern African Development Community	http://www.sadc.int/
SANTREN	Southern African Network for Training on the Environment	http://www.santren.com/live/santren/content/e572/index_eng.html
SAFARI	Southern African Regional Science Initiative	http://safari.gecp.virginia.edu/index.asp
SAREC	South Asia Regional Energy Coalition	http://www.energysouthasia.com/Index.html
SCI	Swedish Corrosion Institute	http://www.corr-institute.se
SEI	Stockholm Environment Institute	http://www.sei.se/
Sida	Swedish International Development Co-operation Agency	http://www.sida.se/
SMHI	Swedish Meteorological and Hydrological Institute	http://www.smhi.se/
SO_2	Sulphur Dioxide	
TSP	Total Suspended Particulates	
UNDP	United Nations Development Programme	http://www.unp.org/
UN DESA	United Nations Department of Economic and Social Affairs	http://www.uncosa.unvienna.org/directory/desa/
UN/ECE	United Nations Economic Commission for Europe	http://www.unece.org/
UNEP	United Nations Environment Programme	http://www.unep.org/
UNESCAP	United Nations Economic and Social Commission for Asia and the Pacific	http://www.unescap.org/
VOC	Volatile Organic Compound	
WHO	World Health Organization	http://www.who.int/home-page/
WMO	World Meteorological Organisation	http://www.wmo.ch/indexflash.html

1 Introduction

Air pollution is one of the major environmental concerns in the World today. It impacts on our quality of life and environment, affecting health, crops and forests, man-made materials and objects of cultural heritage and ecosystems. These impacts have been experienced in Europe for one and a half centuries and although large problems remain, there has been a shift in the will to tackle these problems and improvements have been observed. There is now growing concern about the rising air pollution trends in Asia and Africa. These concerns have led the Stockholm Environment Institute (SEI) to develop, on behalf of the Swedish International Development Cooperation Agency (Sida), a programme on Regional Air Pollution in Developing Countries (known as RAPIDC).

RAPIDC has grown over the last ten years from a modest collection of projects investigating potential acidification problems in developing countries, to a comprehensive programme which is attempting to enhance regional policy processes on air pollution issues, facilitate the development and implementation of strategies at urban scales and address the science required to inform these policy processes. The Programme is responding to needs expressed by collaborators in Asia and Africa. There is broad involvement of Swedish institutions using experience gained from many years of tackling air pollution in Sweden and through active participation in European efforts to reduce emissions, particularly related to the UN/ECE Convention on Long-Range Transboundary Air Pollution (LRTAP). A large number of Asian and African institutions are collaborating in the projects that make up the programme.

As part of the current phase of Sida funding, an open seminar was held in Stockholm in June 2002 to a broad audience of one hundred or so people, outlining the problems being faced and some of the issues being tackled by projects under RAPIDC to address these problems in Asia and southern Africa. The welcome address was given by Sara Stenhammar (Senior Adviser, Environmental Matters, Urban Division, Sida) and this document outlines the presentations given.

2 Air Pollution in the Global Context

Johan Kuylenstierna (Stockholm Environment Institute, Stockholm, Sweden, and York, UK)

2.1 Trends in emissions

There is a need for a Programme on Regional Air Pollution in Developing Countries as the impacts that have been common in Europe and North America are becoming more apparent in Asia and parts of Africa. Whilst emissions of sulphur have been rising in Asia (50% higher in 1997 compared to 1985) and in Africa from the 1980s, emissions in Europe have been declining from a peak in the late 1970s (see Figures 2.1 (a) and (b)). This has resulted from the policies and changes that have taken place in Europe, partly as a result of the international negotiations that have been taking place since the mid 1970s (discussed by Lars Lindau in Chapter 3 of these proceedings). Emissions of nitrogen oxides (NO_x) have doubled in Asia between 1985 and 1997 whereas they have been stable in Europe (see Figures 2.2 (a) and (b)). The UN/ECE Convention on LRTAP has helped reduce NO_x emissions in Europe and North America but reductions have not been as great as for sulphur. Unlike sulphur, nitrogen oxides originate largely from the transport sector and large increases have been seen in vehicle numbers in recent decades which have offset improvements in efficiency of petrol use. The value for the emission goal in 2010 is in line with the UN/ECE LRTAP Protocol to Abate Acidification, Eutrophication and Ground-level Ozone which was signed in Göteborg in 1999, also known as the multi-effect, multi-pollutant protocol.

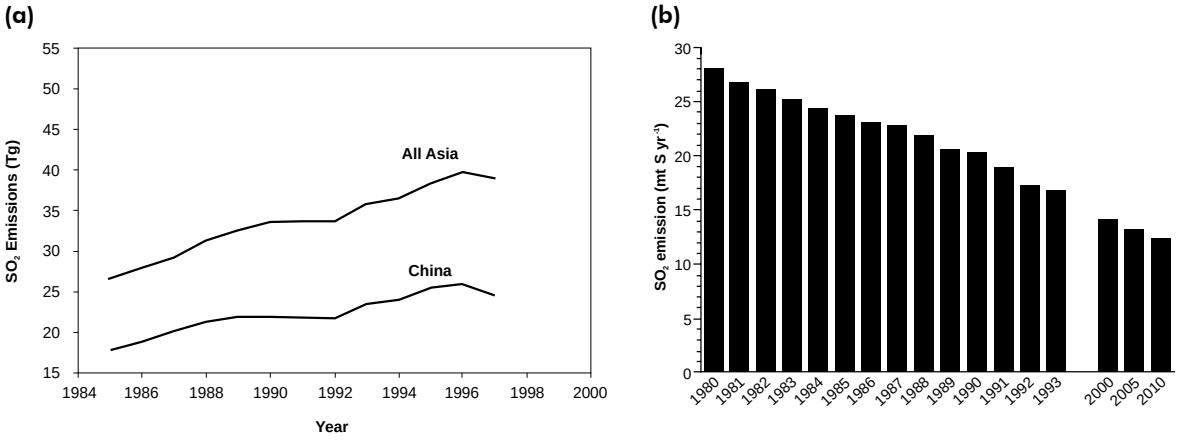


Figure 2.1 (a) Progression of sulphur dioxide emissions in Asia and China 1984–1997 (Streets *et al.*, 2001) and (b) Progression of sulphur emissions in Europe 1980–1993, and emissions for 2000, 2005 and 2010 expected after the implementation of LRTAP Protocols (Berge *et al.,* 1995).

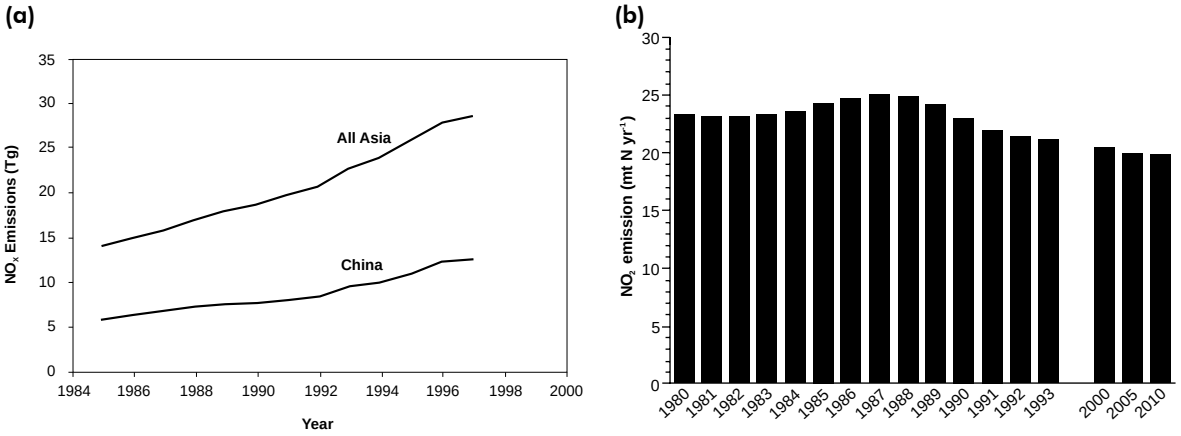


Figure 2.2 (a) Progression of nitrogen oxide emissions in Asia and China 1984–1997 (Streets *et al.,* 2001) and (b) Progression of nitrogen oxide emissions in Europe 1980–1993, and emissions for 2000, 2005 and 2010 expected after the implementation of the LRTAP Protocols (Berge *et al.,* 1995).

Scenarios for sulphur and oxidized nitrogen project that present emissions could double in Africa and Asia for both pollutants if current development pathways are maintained (see Figures 2.3 (a) and (b)). The increases in air pollution emissions have led to impacts at different scales and it is these impacts that can drive policy development and give rise to emission prevention or control.

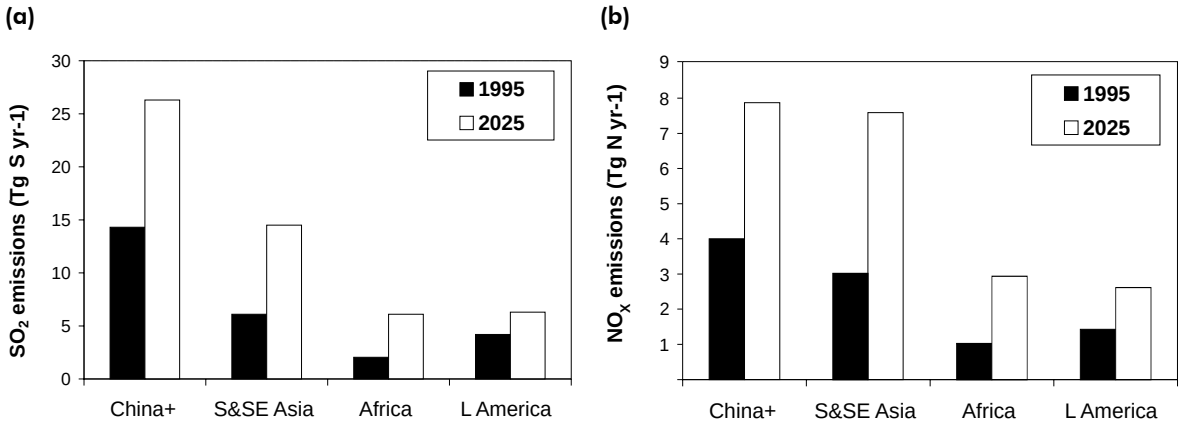


Figure 2.3 (a) Sulphur dioxide and (b) nitrogen oxide emission increase scenarios project that present emissions could double in Africa and Asia for both pollutants if current development pathways are maintained (Vallack *et al.,* 2001) Note differences in scales.

In recent decades Europe and North America have realised that ammonia emissions from agriculture are also an important component of nitrogen emissions and deposition, and the multi-effect, multi-pollutant protocol, mentioned above, was the first UN/ECE LRTAP protocol to include the agricultural sector. Ammonia emissions have decreased slightly in Europe since the late 1980s while there seems to have been a slight increase in the USA. In other areas there is little information. In some developing countries there may be large increases in the future due to increased fertiliser use. Galloway (2001), states that, based on atmospheric emissions alone, food production emissions of NH_3 have twice the acidification potential as energy production related emissions of NO_x. In many areas of Asia the ratio of acidifying N- to S-deposition is likely to increase in the future (Streets *et al*. 2001). As a result there is an increasing realisation of the importance of acidification resulting from excess N deposition.

2.2 Impacts at different scales

The different scales at which impacts of air pollution may occur are: indoor air pollution impacts on health (a common problem in rural Africa and Asia), health and corrosion impacts at urban scales, impacts on agriculture around cities and other point sources, and impacts far from sources of pollution through transboundary transport of air pollution. In Asia and Africa most of the focus has been on impacts at urban scales, and to some extent on peri-urban problems, such as the pollution damage to the Taj Mahal deriving from Agra. Now, however, regional air pollution has become a focus. In 1997, forest fires burning out of control in Indonesia caused smogs that covered much of SE Asia and also affected the South Asian islands of the Maldives. More than 8000 people were admitted to hospital in Malaysia due to these forest fires burning in another country. Recently, focus has been attached to the Atmospheric Brown Cloud (ABC) phenomenon which was first detected during the Indian Ocean Experiment, known as the INDOEX experiment. Pollution from the region is forming a thick layer of aerosols high up in the atmosphere and this covers a large area of Asia (discussed by Surendra Shrestha in Chapter 4 of these proceedings). The interest in air pollution impacts is therefore increasing in Asia at urban, peri-urban and regional scales. This is also the case in southern Africa (see Chapter 5).

2.3 Health

One of the most significant impacts of air pollution in terms of affecting policy is on human health. The links between pollutant gases such as sulphur dioxide, nitrogen oxides and ozone, as well as small particulate matter (PM), and health effects are now very clear. Globally, it is estimated that 1200 million people are exposed to excessive outdoor SO_2 concentrations and more than 1400 million to excessive particulate concentrations (Murray *et al*., 2001). The effect of cleaning up air pollution on improvements to children's health was very clearly illustrated in Hong Kong (Figure 2.4). In 1990, in one polluted district, new fuel regulations were introduced reducing the sulphur content drastically and the ambient SO_2 concentrations reduced by 75%. At the same time the respiratory health of children was monitored and the prevalence of the respiratory problems decreased by 50-66%.

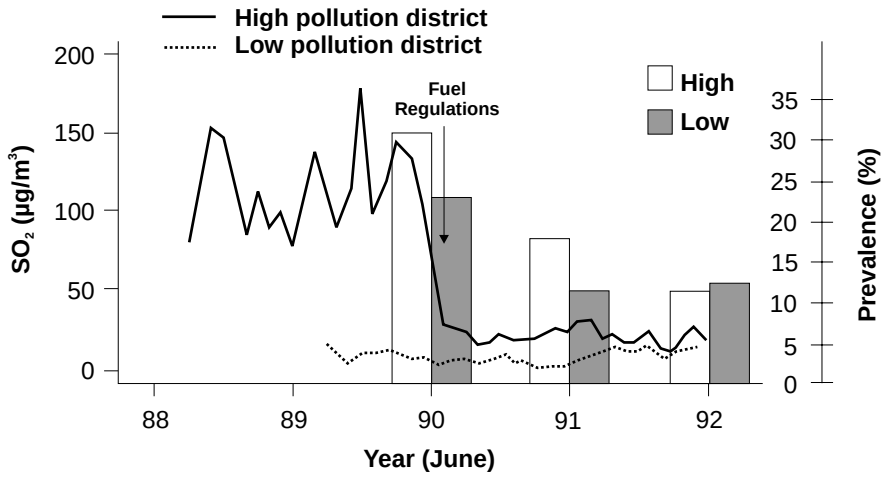


Figure 2.4 SO_2 concentrations in one of the most polluted districts in Hong Kong, before and after fuel regulations were introduced and the response of the prevalence of bronchial hyper-responsiveness in children over the same period in low versus high pollution districts (Figure derived from Wong *et al.* (1998) and Environmental Protection Department (1993)).

Many people in Asia are being exposed to ever increasing concentrations of air pollution and one problem that differs from Europe is indoor air pollution. Indoor air pollution is of particular concern when smoky fuels are used for cooking and/or heating in poorly ventilated conditions and many premature deaths have been attributed to the phenomenon (see Murray *et al*., 2001).

2.4 Corrosion

The impacts of corrosion are felt mainly at urban scales and are particularly related to the concentrations of pollutants such as sulphur dioxide. These impacts have occurred widely in Europe and this has been particularly clear on cultural monuments where many have been destroyed over the last one hundred years, even if they survived the previous three hundred. Pollution damage to cultural monuments is of concern in developing countries where impacts are now being felt. There is also evidence that corrosion at a given level of pollution proceeds more rapidly under warm humid conditions. This would mean that corrosion damage in sub-tropical and tropical regions could be exacerbated by the climatic conditions. In Europe high costs of corrosion have been calculated for maintenance of deteriorating buildings and cars in urban environments. These data need to be made available to policy makers in developing countries to show the extent of the problem and this aspect is discussed by Vladimir Kucera in Section 7.1 of these proceedings.

2.5 Crops

Moving to a broader scale gaseous pollutants such as ozone and sulphur dioxide have impacts on the yield, pest infestations, nutritional quality and disease of different crops and on forests around cities and point sources. Ozone is also a regional pollutant which can be dispersed over wider areas. These impacts have been documented widely in Europe and North America but there is more limited work in Asia and Africa. However, the work that has been carried out has shown the potential for large impacts. In Lahore, Pakistan, 50% yield reductions have been observed in rice and wheat. Other studies in China have developed dose-response relationships for a number of crops related to SO_2 impacts (Figure 2.5). More research is required to determine the extent of the crop yield reductions and a project of RAPIDC is tackling this.

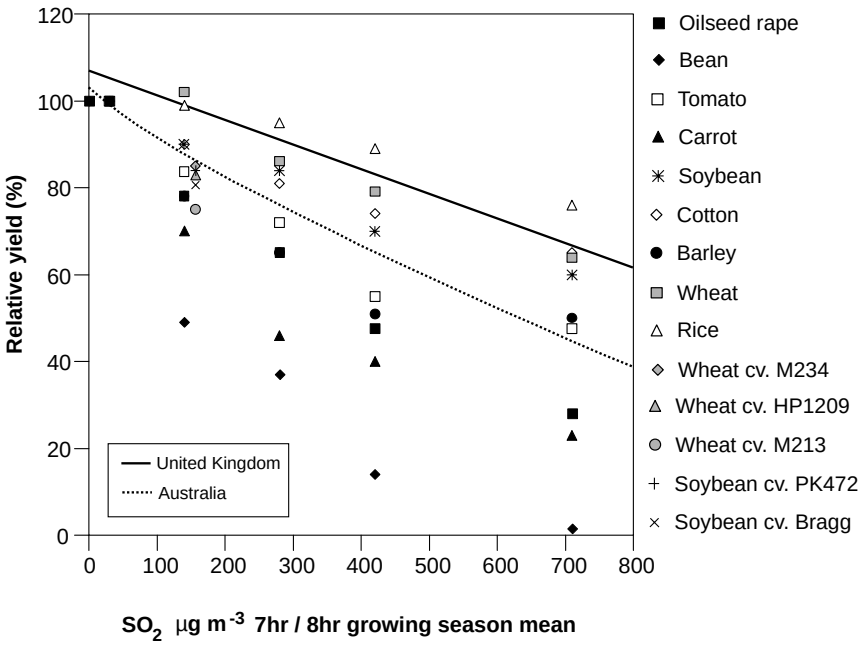


Figure 2.5 SO_2 dose-response relationships pooling data from China, India, Australia and the UK for different species and cultivars (Emberson *et al.,* 2001)

2.6 Regional impacts: acidification and eutrophication

When air pollution is transported in the atmosphere by winds, it undergoes chemical transformations and is deposited in rainfall or as gases or aerosols, it can give rise to impacts far from the sources of

pollution. In some cases the emissions in one country can give rise to impacts in another. Apart from the ozone impacts mentioned above, the major transboundary impacts are acidification and eutrophication. Acidification by sulphate, nitrate and ammonium deposition and their chemical transformations in ecosystems leads to reduced pH of the soil, reduced availability of nutrient cations and also the release of toxic cations such as aluminium. Acidification of soils has already been shown over time in China. These impacts have the potential to affect the growth of forests and vegetation, although we do not know how Asian ecosystems will respond to these changes. Also, the runoff from acidifying soils can cause acidification of small streams and also of lakes. This acidification leads to the loss of fish stocks and other changes in the aquatic ecosystem. Again, although there is ample evidence from Europe, little evidence for such changes has been shown for Asia, as yet. However, certain areas are potentially at risk (see Kuylenstierna *et al.,* 2001). Eutrophication is mainly linked with the deposition of nitrogen (nitrate and ammonium) and, as the growth in many ecosystems is limited by nitrogen availability, the addition of nitrogen has the potential to alter the ecosystem structure and function. Again, changes such as species diversity and species composition shifts and nitrate leaching from catchments have been linked with nitrogen deposition in Europe, but little research into this has occurred in Asia or Africa. Issues of emissions, atmospheric transfer and deposition, as well as acidification, are tackled by projects in RAPIDC as explained by Henning Rodhe in Chapter 6.

2.7 Knowledge required for decision makers

It is clear that policy makers need information to be able to take actions on air pollution. The impacts are often not at all clear or may occur gradually over long periods of time. When the damage is observed, it is often too late, or at least very expensive to reverse the trends. The knowledge required for informed decision making includes quantification of the emissions, concentrations and depositions of the pollutants, the impacts that these cause and the available mitigation options. The policy makers can then decide on the priority for action and can investigate the efficacy of different policies and approaches to reduce emissions.

2.8 RAPIDC approach

The Programme on Regional Air Pollution in Developing Countries, funded by Sida, exists to promote science to policy activities and facilitate the development of the international policy networks that can work together to solve the common air pollution problems. The information required by the policy makers is fed to them through policy dialogues involving the decision makers and the scientists who know about the air pollution problems, as well as other influential stakeholders such as NGOs or industry (see Figure 2.6). From the European experience, regional agreements have been seen to be a catalyst for the promotion of actions to reduce air pollution. Therefore the regional approach has been important in the development of RAPIDC. It is assumed that, through regional agreements involving the different stakeholders and informed by knowledge of the main issues around air pollution, actions will eventually be taken to limit emissions at various scales.

2.9 RAPIDC aims and structure

The programme purpose is to facilitate the development of agreements and/or protocols to implement measures which prevent and control air pollution through promoting international cooperation and developing scientific information for the policy process. The international policy process is being promoted through the development of the Malé Declaration in South Asia, by APINA, the Air Pollution Information Network for Africa in southern Africa, and by the establishment of a network of cities in Asia dealing with reducing air pollution problems – APMA, or Air Pollution in Megacities of Asia

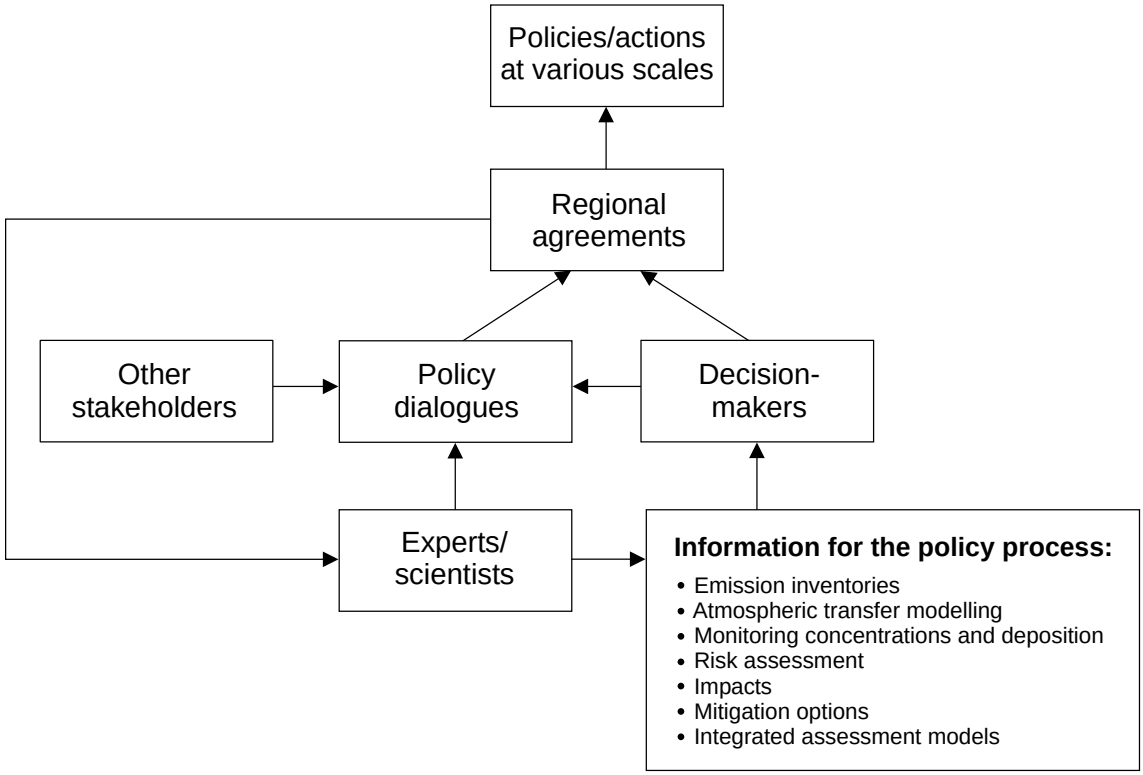


Figure 2.6 Flowchart showing RAPIDC's approach to developing regional co-operation on air pollution control in the South Asia region (Hicks *et al.,* 2001).

project. The information required for the development of policy is divided into studies on impacts of air pollution, modelling and monitoring activities. The activities include modelling the atmospheric transfer of pollutants, networks for the monitoring of deposition, estimation of emissions at national scales and also rapid urban assessments of air pollution. There is also a project on the integrated modelling of air pollution problems for South Asia. The impacts being studied are corrosion, acidification, health and impacts on crops and forests. The RAPIDC structure and activities are shown in Figure 2.7.

2.10 Conclusion

Air pollution is a problem that is getting progressively worse in many parts of Asia and Africa and some impacts are already being experienced, especially in cities. As some of the air pollution effects occur over long periods of time and with recovery taking even longer, there is an opportunity to avoid many major impacts if actions are taken now. The policy process needs to be informed of the impacts and risks to human health, materials and the wider environment. For this process scientific knowledge needs to be developed which is specific to these regions to underpin the policy process. There also needs to be a concerted effort to make sure that science is effectively transferred to the policy process.

2.11 References

Berge E, Bartnicki J, Olendrzynski K, Tsyro SG (1999). Long-term trends in emissions and transboundary transport of acidifying air pollution in Europe. *Journal of Environmental Management*, 57 (1): 31-50.

Emberson LD, Ashmore MR, Murray F, Kuylenstierna JCI, Percy KE, Izuta T, Zheng Y, Shimizu H, Sheu BH, Liu CP, Agrawal M, Wahid A, Abdel-Latif NM, van Tienhoven M, de Bauer LI, Domingos M (2001). Impacts of air pollutants on vegetation in developing countries. *Water Air and Soil Pollution* 130 (1-4): 107-118.

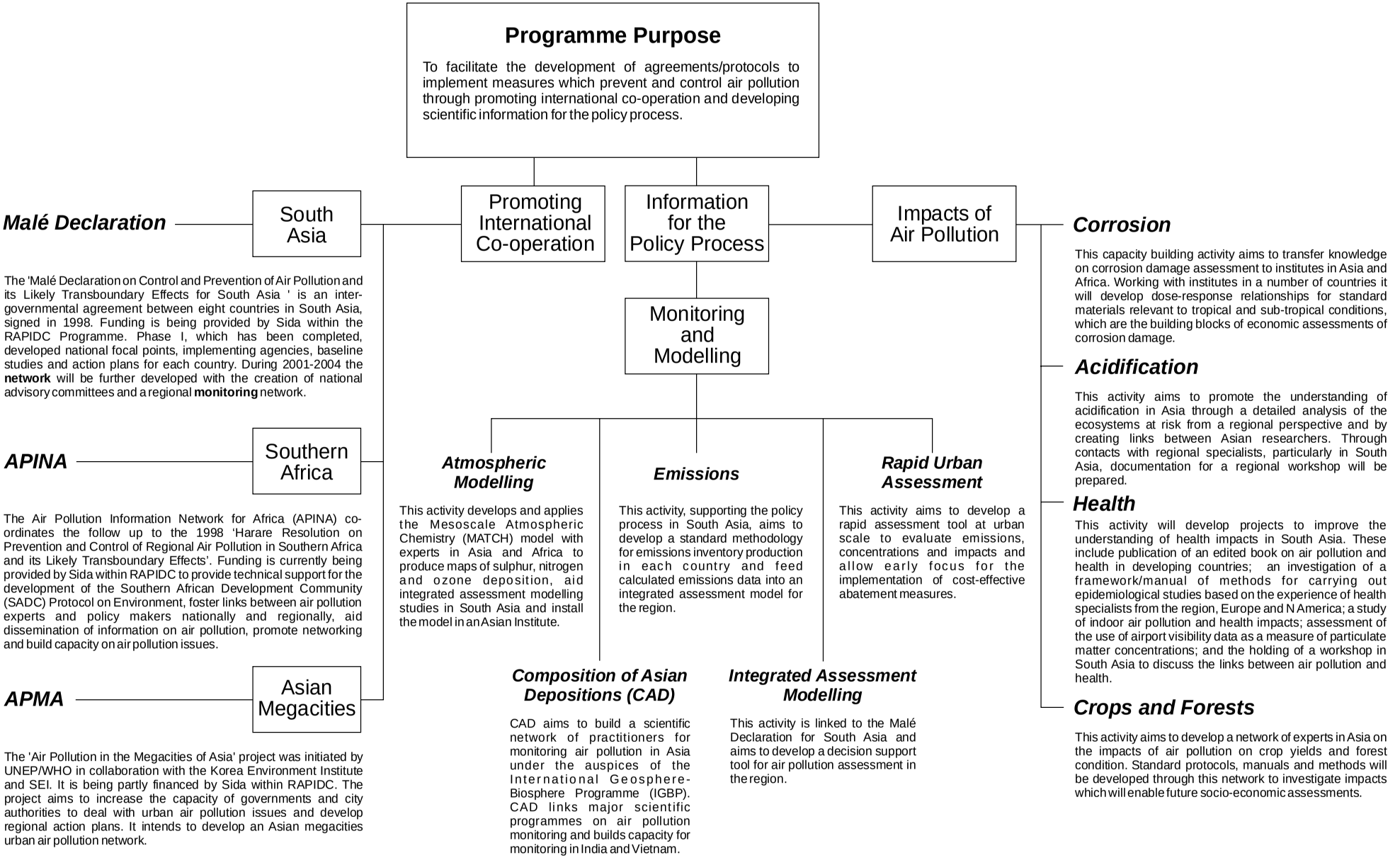


Figure 2.7 RAPIDC Programme structure and activities

Environmental Protection Department (1993). *Environment Hong Kong 1993.* A Review of 1992. Hong Kong: Government Printer.

Galloway JN (2001). Acidification of the world – Natural and anthropogenic. *Water Air and Soil Pollution,*130 (1-4): 17-24.

Hicks WK, Kuylenstierna JCI, Mathur V, Mazzucchelli S, Burijson V, Shrestha S, Iyngararasan M, Simukanga S, Van Tienhoven AM (2001). Development of the regional policy process for air pollution in South Asia, southern Africa and Latin America. *Water Air and Soil Pollution* 130 (1-4): 211-216.

Kuylenstierna JCI, Hicks WK, Cinderby S, Vallack HW, Engardt M (2001). Variability in mapping acidification risk scenarios for terrestrial ecosystems in Asian countries. *Water Air and Soil Pollution* 130 (1-4): 1175-1180 Part 3.

Murray F, McGranahan G, Kuylenstierna JCI (2001). Assessing health effects of air pollution in developing countries**.** *Water Air and Soil Pollution* 130 (1-4): 1799-1804.

Streets D, Tsai NY, Akimoto H, Oka K (2001). Trends in Emissions of Acidifying species in Asia, 1985-1997. W*ater, Air and Soil Pollution,* 130: 187-192.

Vallack HW, Cinderby S, Kuylenstierna JCI, Heaps C (2001). Emission inventories for SO_2 and NO_x in developing country regions in 1995 with projected emissions for 2025 according to two scenarios. *Water Air and Soil Pollution* 130 (1-4): 217-222.

Wong CM, Lam TH, Peters J, Hedley AJ, Ong SG, Tam AYC, Lui J and Spiegelhalter DJ (1998). Comparison between two districts of the effects of an air pollution intervention on bronchial responsiveness in primary school children in Hong Kong. *Journal of Epidemiology and Community Health* 52: 571-578.

3 How Europe Tackled Air Pollution Problems 1960–2002

Lars Lindau (Swedish Environmental Protection Agency, NV, Stockholm, Sweden)

3.1 Air pollution problems in Europe 1960-2002

During the 1950s and 1960s the main air pollution problems experienced in Europe related to health impacts in urban areas. A number of smog incidents led to large numbers of excess deaths and the resulting public response caused national and urban governments to develop policies to clean the air in cities. This was achieved through policies such as smokeless zones and relocation of industry. This has led to improvements in urban air quality across Europe that have continued to this day. The classic pollutants of the 1950s and 60s were a combination of SO_2 and particulate matter that proved very damaging to health. Recent attention has been placed on pollution from transport, which includes pollutants such as CO, NO_2, PAH and benzene.

During the 1960s it became increasingly clear in Scandinavian countries that lakes were becoming acidified and that this was mainly due to acidic deposition deriving from emissions outside Sweden and Norway. During the 1970s and particularly during the 1980s there was an increased focus on the long-range transport of sulphur and nitrogen pollutants causing acidification. During more recent years the focus has shifted to include the regional distribution of photochemical oxidants, particularly ozone. Ozone has been shown to affect crop yields across large areas of Europe. Recently, transboundary transfer of particulates has been included and the importance of reduced nitrogen emissions from agriculture acknowledged. Other air pollution problems are heavy metals, such as lead (Pb), mercury (Hg) and cadmium (Cd), and persistent organic pollutants (POPs) such as dioxins and brominated flame retardants.

3.2 European discussions on air pollution

The acidification problems of Scandinavia formed the initial focus for the development of inter-governmental agreements on air pollution, particularly in the period between 1968-1972. Initial work was developed through the Organisation for Economic Co-operation and Development (OECD) between 1972 and 1979, but the main development was the formation of the Convention on Long-Range Transboundary Air Pollution (LRTAP) in 1979 under the auspices of the United Nations Economic Commission for Europe (UN/ECE), which initiated its work in 1976. One of the major decisions taken was the setting up of EMEP (European Monitoring and Evaluation Programme) and

also the core financing of this body dedicated to modelling and monitoring through the EMEP Protocol (1979/80). In the 1980s widespread forest decline in Central Europe added impetus to the negotiations. For many air pollution issues Integrated Cooperative Programmes were established. These covered issues such as corrosion, forest health and crops. One of the key ingredients in developing the policy responses was the development of the RAINS (Regional Air Pollution Information and Simulation Model) integrated assessment model which helped to combine the different aspects of air pollution and investigate policy options for the reduction in emissions.

The UN/ECE LRTAP Convention has developed a series of Protocols on different pollutants. The first was the Sulphur Protocol of 1983, the so-called '30 per cent club' and this was followed by the NO_x Protocol, second Sulphur Protocol, Heavy Metal and POPs Protocols. The latest is the Göteborg Protocol, the so-called 'multi-effect, multi-pollutant' protocol developed in 1999.

The European community also started to develop agreements and Directives from the 1980s. The first were related to sources, where the Large-Plant Directive was one of the most well known. From 1996 Air Quality Directives were developed. In 2001 the 'Ceilings Directive' was developed referring to SO_x, NO_x, NH_x and VOCs.

3.3 Conclusions

European cities were the first to take action on air pollution. Scandinavian scientists realised the importance of long-range transport of air pollutants for acidification and this concern led to the development of international agreements. Since these international agreements have been in existence sulphur emissions have decreased significantly. Other emissions show lesser decreases, but at least emissions have stabilised and show downward trends in many cases. In the future more stringent targets will be set.

4 Tackling Transboundary Air Pollution in Asia with an Emphasis on the Malé Declaration

Surendra Shrestha (UNEP Regional Resource Center for Asia and the Pacific – RRC-AP, Bangkok, Thailand) and Mahboob Elahi (South Asia Cooperative Environment Programme – SACEP, Colombo, Sri Lanka)

4.1 Surendra Shrestha (UNEP/RRC-AP)

4.1.1 Introduction

The aim of this chapter is to discuss air pollution issues in Asia and focus on the sub-regional policy initiatives that are attempting to deal with the air pollution problems being faced. These are the Malé Declaration for South Asia, the EANET initiative for NE and SE Asia, the ASEAN Haze Action Plan and the Regional Environmental Action Plan (REAP) initiative for Central Asia.The important Atmospheric Brown Cloud issue that has emerged in recent years will also be described.

In each region the institutional arrangements are different. UNEP/RRC-AP, based at the Asian Institute of Technology, in Bangkok, links with a number of different inter-governmental bodies covering different parts of Asia. The Malé Declaration is linked to SACEP, the South Asia Cooperative Environmental Programme, covering the South Asian countries of Iran, Pakistan, India, Nepal, Bhutan, Bangladesh, Sri Lanka and the Maldives. The haze action plan has been developed under the auspices of ASEAN, the Association of South-east Asian Nations, covering the countries of Brunei, Indonesia, Malaysia, the Philippines, Singapore, Thailand and Vietnam. A number of international agencies are key to these activities, including the Asian Development Bank (ADB) and UNDP as well as bilateral donors.

It is worth noting that whilst Asian GNP is lower than that of the EU or USA (which are similar in size), it is rapidly increasing and in 1999 was about 80% that of the EU or USA. One thing that should be remembered is that the countries of China and India have enormous populations of over one billion people and that there is a wide spread in purchasing power parity within these countries. The middle classes of these countries are large and growing. The potential for further increases in air pollution are therefore great. The production of electricity has been increasing over the 1990s and the rate is increasing during the first decade of the 21st century. To fuel this growth in demand coal consumption is set to double from 1993 levels by 2010. This has obvious impacts on pollutant emissions and Asian sulphur dioxide emissions are set to double in 2010 compared to 1990 (business as usual scenario), whereas European and USA emissions are set to decrease over the same period.

4.1.2 South Asia and the Malé Declaration

Countries in Asia realise the importance of the environmental impacts and therefore have been developing inter-governmental agreements which aim to limit emissions. The Malé Declaration has been developed for South Asia. The main aims are to create a broader dialogue about the air pollution issues in Asia and promote the policy cycle in South Asia by reaffirming that transboundary air pollution is a priority issue for South Asia. Another important aim is to agree upon a draft action plan for the inter-governmental activities. The process is currently being funded by Sida and coordinated by UNEP/RRC-AP and SACEP with technical input from SEI. At the Governing Council of SACEP held on 22 April 1998 in Malé, the Maldives, the Malé Declaration was adopted by all the South Asian countries. The meeting was inaugurated by his Excellency Mr. Maumoon Abdul Gayoom, President of the Maldives, and was attended by ministers and high-level policy makers from South Asian Environment Ministries. The implementation of the Malé Declaration has been developed in Phases. Phase I focused on raising awareness and preparing the baseline information. Phase II, currently being undertaken is developing local capacity for monitoring and analysis. Phase III will provide scientific information and assist in activities to reduce pollution. National Implementation Agencies (NIAs) have been set up by the governments of each of the South Asian countries to implement the Malé Declaration activities (Table 4.1). These are based in environment ministries, agencies or authorities or in research organisations with strong links to government departments. These developed the baseline studies and action plans in Phase I and are now implementing the development of monitoring stations across South Asia. In addition, network meetings and national stakeholder meetings are held which aim to increase stakeholder participation in the Malé Declaration in South Asia.

Table 4.1 Collaborating Institutions for the Malé Declaration Implementation

Country	National Focal Point (NFP)	National Implementation Agency (NIA)
Bangladesh	Ministry of Environment and Forest	Department of Environment
Bhutan	National Environment Commission	National Environment Commission
India	Ministry of Environment and Forests	Central Pollution Control Board (CPCB)
Iran	Department of the Environment,	Department of the Environment
Maldives	Ministry of Home Affairs, Housing and Environment	Minister of Home Affairs, Housing and Environment
Nepal	Ministry of Population and Environment	International Centre for Integrated Mountain Development (ICIMOD)
Pakistan	Ministry of Environment Local Government and Rural Development	Pakistan Environment Protection Agency
Sri Lanka	Ministry of Forestry and Environment	Central Environmental Authority

4.1.3 East Asia and EANET

EANET, the East Asia Network for monitoring, has the objective of creating a common understanding of the state of acidic deposition problems in East Asia and providing useful inputs for decision making at local, national and regional levels aimed at preventing or reducing adverse impacts on human health and the environment due to acidic deposition. Eleven countries in the East Asian region are participating. The first expert meeting was held in 1993 and there have subsequently been three more meetings. The first inter-governmental meeting was held in 1998. Currently, the network has about 40 monitoring stations in urban, rural and remote sites across NE and SE Asia with strong quality control procedures that produce data valid for large areas. Data will be produced which will enhance knowledge about the distribution of pollutants in these regions.

4.1.4 South East Asia and the Haze Action Plan

In ASEAN countries, there is currently a great deal of concern over the haze that has mainly been caused by forest fires burning out of control in Indonesia. These have caused health impacts to people in many countries in SE Asia and this is a truly international problem. Therefore, ASEAN has agreed that air pollution is a priority issue for the SE Asian region and has formulated a cooperation plan on transboundary pollution. This is a legally binding instrument which was signed on June 10, 2002. UNEP is supporting the ASEAN Secretariat in formulating a legal framework to address transboundary air pollution and, in particular, haze pollution.

4.1.5 Central Asia and the Regional Environmental Action Plan

Air pollution is a considerable problem in many central Asian countries including Kazakhstan, Turkmenistan, Uzbekistan, Kyrgyzstan and Tajikistan. These five central Asian countries completed the first Regional Environment Action Plan in September 2001 where air pollution is one of the key priority issues and the action plan requests the co-operation of all five countries in dealing with this issue.

4.1.6 Atmospheric Brown Cloud (ABC)

During the INDOEX experiment (Indian Ocean Experiment), when various observations of the atmosphere over South Asia were made from aircraft, ships and using monitoring stations, a layer of haze in the atmosphere was discovered which was up to 3 km high covering the Indian Ocean, South-east Asia and China, an area the size of continental USA. There are a number of hypotheses concerning potential impacts of this layer of haze. These include the cooling of land surfaces and the warming of the atmosphere. The reduction in temperature leads to reduced evaporation and it has been suggested that rainfall patterns may be disrupted. In recent years there has been 20% more rainfall within the haze area and drier climates outside the area. Drought is an important issue in Asia. For example, in Rajasthan, in India, a drought in 2001 affected over 30,000 villages and a population of 33 million. In this region the monsoon rainfall was 28% below normal levels and water storage is only at 17 % of full levels in three major reservoirs. 2001 was the third year of drought. In another part of the region, in China, summer crop yields have decreased over two successive years, by 9.4 % in 2000 (in comparison to 1999) and by a further 4.6% in 2001. There are several potential reasons for this decrease, and it is suggested that the haze might be one of them. Through concern over this regional haze phenomenon UNEP initiated discussion with INDOEX scientists in 2001. Since then a scientific impact assessment report has been produced and there has been a launch of the UNEP ABC initiative in London during August 2002. A plan is being developed to monitor and assess the extent and impacts of the Atmospheric Brown Cloud over the next 5-10 years.

4.1.7 Recommended steps to address transboundary air pollution

The following are recommended as priorities to tackle long-range transboundary air pollution in Asia:

- Raise awareness and agree that the transboundary air pollution is a priority issue
- Build capacity for scientific base to address the transboundary air pollution
- Address issue through economic, technical and/or legal instruments

4.2 Mahboob Elahi (SACEP), Colombo, Sri Lanka

4.2.1 Introduction

South Asian countries are characterised by diverse conditions. The populations vary from 300,000 in the Maldives to 1,000 million in India. The degree of urbanisation varies from 7% in Bhutan to 37% in Pakistan. The total population is 1,400 million (30% urban) and the population density varies from 25 (Bhutan) to 800 (Maldives) persons per square kilometre. India dominates in fossil fuel production and consumption, particularly of coal which is used for electricity production. The use of coal and other fuels is responsible for a large part of the air pollution in the region. South Asian countries are aware of their air pollution problems and nationally have taken steps to curb emissions. The following summarises what two countries, Bangladesh and India, have been doing in recent years.

4.2.2 Example 1: Bangladesh's actions to mitigate air pollution

The following acts and laws have been introduced:

- The Brick Burning (Control) Amendment Act, 1992
- Bangladesh Environmental Control Act, 1995
- Environmental Control Laws, 2000

These include the control of brick kilns with the necessity to acquire a license and the restriction of the use of fuel wood for brick manufacture. Ecologically critical areas have been designated, air quality standards have been established for different areas and regulations for vehicle pollutant emissions have been put into place. Industrial emissions have also been tackled with the imposition of emission standards. In order to monitor and tackle air pollution, air quality in cities is now monitored, minimum standards have been introduced (e.g. on lubricating oil for 2-stroke engines), new cars should be equipped with catalytic converters (leaded petrol is being phased out) and taxi-cabs are being converted to CNG.

4.2.3 Example 2: India's actions to mitigate air pollution

The Air (Prevention and Control of Pollution) Act, 1981 and the Environment Protection Act of 1986 are the most relevant in India. Ambient air quality monitoring is carried out in many cities allowing the evaluation of status and trends and determination of environmental exposures to pollutants which may be used for correlations of air quality and health (they also allow the planning and assessment of air quality management). Pollutants sampled include Polycyclic Aromatic Hydrocarbons (PAHs) and Benzene as well as the more traditional pollutants. Air pollution problems are being tackled on a number of fronts. These include the on-going phase-out of lead in fuel and public interest litigation for the introduction of CNG in Delhi, for buses and other vehicles. Land use planning is used for pollution mitigation, industries are controlled, economic incentives and penalties and measures to reduce transport emissions by traffic management are being implemented.

In many South Asian countries, air pollution is viewed as a local urban air quality problem compounded by urbanisation, industrialisation and vehicle use. Impacts of long-range transport are not obvious at the national or regional level as yet and therefore are not prominent in the region. Policy makers tend to be reactive to existing problems rather than taking preventive action to address uncertain or poorly researched problems. The main problem is how to insert the concerns of long-range transport into the policy process and develop wider support for the Malé Declaration. This needs to be tackled through measurement of the problem, standardisation and harmonisation of approaches and exchange of information about impacts and mitigation opportunities. The policy process needs to assess common legal frameworks and the association of industry as a partner in long-range

transport issues. The impacts at the different scales need to be integrated such that the impacts and activities at local scale can be reconciled with the long-range transport of air pollution and its impacts. The future development of the regional approach requires credible research which can be validated at the national level and for this there needs to be adequate financing and technical backup. Integrated approaches at local, national, regional and global scales are needed, duly supported by international agencies and donors as well as through national means.

Delegates at an NIA meeting in Kathmandu, 2001

5 Activities in Southern Africa to Tackle Air Pollution

Stephen Simukanga (APINA Co-ordinator, University of Zambia, Lusaka, Zambia)

5.1 Development of APINA for the Harare Resolution follow-up

APINA, the Air Pollution Information Network for Africa, was formed to address issues related to Air Pollution in Africa, with an initial focus on southern Africa. APINA is a network of scientists, policy-makers, industry, and NGOs and has similar aspirations to South Asia where the Malé Declaration is being implemented. It forms another part of the RAPIDC Programme, co-ordinated by SEI on behalf of Sida, and APINA is administered by the Institute of Environmental Studies (IES) of the University of Zimbabwe.

APINA co-ordinates the follow-up to the 1998 'Harare Resolution on Prevention and Control of Regional Air Pollution in Southern Africa and its Likely Transboundary Effects'. The Harare Resolution was the result of a RAPIDC multi-stakeholder dialogue held under the auspices of Southern African Development Community – Environment and Land Management Sector (SADC-ELMS) in Harare 1998. The Harare Resolution recognized air pollution impacts on human health, managed ecosystems (agriculture, forestry, fisheries and wildlife), man-made materials and cultural heritage, climate change and biodiversity, forests, woodlands and savannah. It also recognized the following constraints to progress on the air pollution issue in SADC: limited capacity in terms of funding, equipment and human resources, inadequate information which is often inaccessible and diffuse, limited public awareness, inadequate legislation and enforcement of regulations, and the potential conflict between economic development and environmental protection. In addition it recognized the following opportunities for progress on air pollution issues in SADC:

- the intent of SADC countries to develop in a sustainable manner;
- increased public, media and business awareness will help the development of solutions;
- early awareness may lead to informed decisions on clean development technologies;
- existing co-operation in SADC countries provides an opportunity for harmonizing legislation and other policy instruments.

APINA has resolved to request the SADC Council of Ministers, through SADC-ELMS, to develop a Protocol on Regional Air Quality and Atmospheric Emissions. Within such a Protocol APINA would form a strong link between the air pollution scientific community and policy makers at national and regional levels, including other stakeholders. It will also act to transfer knowledge and data derived in scientific programmes to influence policy decisions on matters of air pollution.

5.2 Project organisation for APINA Programme under RAPIDC

The organisation of APINA is shown in Figure 5.1. The overall project forms part of the RAPIDC Programme, which has its own internal structure. APINA itself is coordinated by Stephen Simukanga, of the Zambia School of Mines, University of Zambia, under the auspices of IES, and he is supported by a core group of APINA members comprising individuals from Zimbabwe, South Africa and Zambia. In all, seven SADC countries are actively involved in APINA (Botswana, Malawi, Mozambique, South Africa, Tanzania, Zambia and Zimbabwe) and each country has a country representative. Beyond this there is a wider APINA membership comprising stakeholders from academia, industry and policy makers.

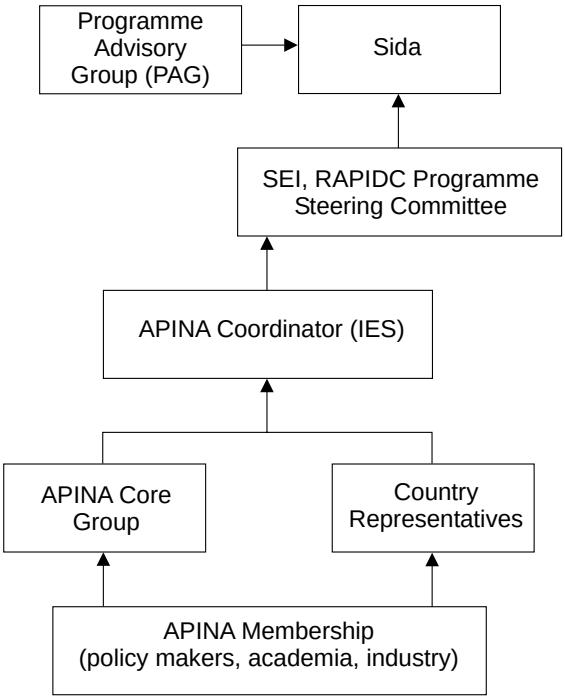


Figure 5.1 Structure and organisation of APINA

5.3 Progress of APINA since 1998

Work carried out on air pollution issues in southern Africa has been compiled and a reference database and library have been initiated. A database of experts involved in issues of air pollution in southern Africa has also been compiled. APINA has also been successful at networking by forging links with other international activities such as with SAFARI 2000, the Southern African Regional Science Initiative, which is investigating atmospheric transport of air pollution around the Southern African region and another initiative, SANTREN, the Southern African Network for Training and Research on Environment.

Strong links with APINA members in the region enabled the Council for Scientific and Industrial Research (CSIR), in South Africa, to submit a proposal on transboundary air pollution to the South African Department of Arts, Culture, Science and Technology (DACST) for funding. The proposal was entitled: '*Cross border transport of air pollutants in the SADC region and the associated agricultural and economic impacts'*. Funding was secured for this research in April 2001 and has become known by its acronym: CAPIA (Cross-border Air Pollution Impact Assessment). CAPIA aims to quantify cross-border air pollution and the impacts of ozone on agriculture in the SADC countries. To date Botswana, Mozambique, South Africa, Zambia and Zimbabwe are involved in the project. Interested participants are being sought from the other SADC countries not yet involved with the initiative.

APINA is actively involved in facilitating regional policy development. APINA has signed a Memorandum of Understanding with SADC-ELMS in which APINA has been tasked to contribute to the development of the SADC Protocol on Environment for transboundary air pollution issues. As a contribution to the developing policy process country status reports on air pollution issues have been completed for six SADC countries: Botswana, Malawi, Mozambique, South Africa, Zambia and Zimbabwe which were presented at an APINA workshop in Lusaka, Zambia (27-28 May 2002) (subsequently a seventh country report for Tanzania has been completed). During the workshop the following issues were discussed from a regional perspective:

Emission sources: The main sources of emissions in the region are industry (e.g. thermal power stations, smelters, cement factories), forest/ savannah fires, biomass burning (e.g. use of firewood, charcoal), waste burning, motor vehicles (e.g. doubling of fleets in Botswana between 1985-1998 and Zimbabwe between 1995-2001).

Impacts of emissions: Impacts reported included human health e.g. respiratory diseases (although not quantified), heavy metal poisoning, ecosystems (e.g. impacts on water bodies, soils and vegetation), agriculture (e.g. reduced crop production), corrosion (of man-made structures), although a general scarcity of information on these impacts was noted.

Legislation on air pollution: Legislation exists in the countries covered, except Mozambique, but enforcement and/or compliance is inadequate.

Gaps in knowledge: Inadequate emission inventories, limited case studies/research, inadequate legislation and enforcement, monitoring is inadequate due to lack of capacity in human resources and funding, access to information on air pollution is difficult, local background levels and standards at national and regional levels are not available.

Dissemination of information: Information dissemination is ineffective.

5.4 APINA way forward

An emission inventory (linking with CAPIA for transboundary ozone) will be produced for the countries of the region. A link with SAFARI 2000 will be enhanced to confirm APINA's role as the means of transferring results to the policy process. APINA country representatives will continue to update country status reports. Corrosion monitoring experiments will begin in South Africa, Zambia (and possibly Zimbabwe) and health monitoring activities will begin in Zambia near a smelter. The support to SADC-ELMS will continue and APINA will contribute to the SADC Protocol on Environment on issues of air pollution.

5.5 APINA information dissemination

An updated RAPIDC website will be produced and a regionally-based APINA website will be developed. Country factsheets will be produced outlining the main points and information from the country reports. An APINA newsletter will be produced annually and a policy dialogue is planned for September 2003 in Mozambique. Media opportunities will be taken as they arise.

5.6 Conclusions

APINA is expanding and starting to establish an information base. This will allow it to carry out its role of transferring information on air pollution to governments, other decision makers, SADC-ELMS, industry and other international programmes such as SAFARI 2000. APINA will naturally become

consolidated in its position to drive forward the air pollution issue in southern Africa once information starts to flow, and for APINA to be successful, people have to be made aware of the impacts of air pollution in their everyday lives. To avoid the serious impacts experienced in Europe and North America, and increasingly in Asia, it is important that air pollution issues find their place on the political agenda in southern Africa so that air pollution can be controlled.

Delegates at an APINA workshop in Zambia, 2002

6 Long-Range Transport of Air Pollution in Asia

Henning Rodhe (MISU, Department of Meteorology, Stockholm University, Stockholm, Sweden)

6.1 Introduction

Regional pollutants are defined here as those that are transported at distances up to 5000 km from the emission sources. The acidifying pollutant emissions are as sulphur dioxide (SO_2), nitrogen oxides (NO_x) and ammonia (NH_3) (although NH_3 is an alkaline gas it can potentially acidify ecosystems, see below). These pollutants, when cemically transformed in the atmosphere, give rise to small aerosol particles of sulphate (SO_4^{2-}), nitrate (NO_3^-) and ammonium (NH_4^+) ions which can travel long distances. NO_x and NH_3 emissions can also give rise to ecosystem eutrophication, acting as fertilising agents. There are some pollutants that give rise to corrosion and these are SO_x, NO_x and ozone (O_3). Aerosols (generally small particles in the atmosphere) and gaseous SO_2, NO_2 and O_3 can be toxic to human health and aerosols also affect the climate .

In Europe, the understanding of long-range transport of air pollutants used several methods. There were trajectory analyses which were used to understand where deposited pollutants came from and these helped to point towards the long-range transport of air pollutants. There were also a number of different experiments showing the transport of air pollution in the atmosphere. The development of air pollution models in combination with monitoring in Europe was an important step in the policy process and these approaches have been used to underpin negotiations over the last 20 years.

6.2 Monitoring of air pollution in Asia

Over the last two decades there has been a development of measurements of wet deposition (rainfall) in remote sites that are typical of a wide area. In comparison to the deposition in Central Europe, one of the more polluted areas of Europe, the deposition in NE India shows lower sulphate, nitrate and ammonium concentrations (Table 6.1).

Table 6.1 Typical ionic composition and pH of precipitation in an acidified region of Central Europe compared to a dusty urban site in NE India.

		Central Europe	NE India
		µeq/l	µeq/l
Anions	SO_4^{2-}	70	20
	NO_3^-	30	10
	Cl^-	15	15
	HCO_3^-		15
Cations	NH_4^+	30	20
	Ca^{2+}	12	20
	Mg^{2+}	5	5
	K^+	3	2
	Na^+	15	13
	H^+	50	0
pH		4.3	6.2

The main difference is the SO_4^{2-} which is more than three times higher in Central Europe. Of the nitrogen species, the NH_4^+ is quite high in India, being two thirds that of the central European value. At the same time the deposition of calcium is higher than in central Europe. The result is that rainfall pH is low in Central Europe and quite high in India. However, the acidification potential is not reflected in the rainfall pH. This is because the NH_3, whilst neutralising the acidity in the rain, can cause acidification in the terrestrial ecosystems through deposition of NH_4^+, chemical transformation in soils to NO_3^- and subsequent leaching of that NO_3^-.

6.3 Modelling air pollution at global and regional scales

Monitoring cannot be carried out at a high enough density to cover a whole region. In addition, it cannot be used to develop deposition scenarios. Therefore, the development of atmospheric transfer models has been an important step forward. Several models have been developed and applied globally (e.g. MOGUNTIA) and regionally in Asia (e.g. MATCH). These have estimated deposition of sulphur nitrogen and calcium. The results can be used to estimate rainfall acidity, total acidic deposition and also to develop budgets for the transport of pollutants from one country or region to another. It is important that monitoring is used to validate these models.

A global model of rainfall acidity has been developed and this shows areas of low rainfall acidity across Europe, Eastern North America and China. High rainfall pH is found in areas which have high emission and deposition of calcium carbonate rich dust. This includes the area of northern India where the sampling station in Table 6.1 is found. The correspondence with modelled rainfall pH and monitored rainfall around the world is reasonable. Therefore, it is considered that the global deposition of acidity and alkalinity may be reasonably modelled. However, in terms of acidifying potential, if all the nitrogen deposition is assumed to acidify soils, then areas such as northern India are shown to have a significant potential acidifying deposition. This is because NH_3 deposition in Asia shows a different pattern and in northern India there is a very high emission from animal excretion and fertilizer use. There is a potential soil acidification effect if NH_4^+ is transformed to NO_3^- in the soil and is leached from the terrestrial ecosystem. More research is required to determine how much of the nitrogen incident on these potentially vulnerable ecosystems contributes to acidification.

The prospects for the future are that SO_2, NO_x and NH_3 emissions are likely to increase significantly, particularly in Asian countries such as China and India, whereas they are likely to decrease in Europe and the US. Sulphur is not a pollutant that travels world-wide. However, China does produce a large plume of sulphur that covers a large part of the NE Asian region and acidification from sulphur deposition is a real threat there. As sulphur emissions increase in India, rain will acidify despite the

large deposition of alkaline dust in the region. Moreover, in Asia in general, as particulate matter emission is reduced, alkaline calcium deposition is also likely to decrease. Therefore, it is likely that acidification of soils is likely to spread in many regions during the coming decades. It will be particularly important to focus on areas with high nitrogen emissions.

6.4 Monitoring networks in Asia

There is a clear need for good quality air pollution deposition monitoring networks in Asia to develop the measurements required to inform policy of the likely impacts of current pollution levels. A number of networks have been set up to promote high quality monitoring of pollutants. One such network which has been operating for over ten years is CAD the Composition of Asian Deposition (until 2000 CAD used to be known as CAAP, the Composition and Acidity of Asian Precipitation, but this was changed so that dry deposition could be included). The objectives of CAD are to determine the atmospheric removal, by dry and wet deposition, of biogeochemically important trace species in S and SE Asia. It also aims to establish atmospheric budgets of such species at regional scales and obtain data for testing regional transport models. Capacity building is an important focus for the CAD network.

CAD is continuing measurements of deposition in India and has started measurements in Vietnam. This involves intensive capacity building and quality control to build up the competence of the practitioners in these countries to the highest international levels. There is a need for high quality data to inform the policy process on air pollution issues in Asia.

6.5 Investigating the impacts of long-range transported air pollutants

Acidification: Sulphur and nitrogen pollution can acidify soils, although base cation deposition resists acidification. The global sensitivity assessment to acidification indicates soils which may become acidified if deposition reaches high enough levels. This can be investigated through the exceedance of critical loads, which are thresholds based on soil weathering rates. A simple comparison indicates that acidification mainly affects SW China although long-range transport of acidifying pollutants to Korea, Japan and Vietnam may give rise to problems. Until now much of northern India has been protected by alkaline dust. As pollutant levels increase sensitive South Asian ecosystems are likely to become at risk.

Eutrophication: Nitrogen deposition can give rise to changes in ecosystem structure (changes in diversity) or function (growth rates, leaching etc.) at high enough levels. These represent risks for the maintenance of biodiversity and biological conservation, as well as the risks associated with the changes to bio-geochemical cycling. The extent of these risks in Asia is poorly understood, but the levels are as high as those that have damaged ecosystems in Europe.

Regional Ozone Pollution: There is a potential for widespread effects of ozone as NO_x emissions increase and because fires put large amounts of organic chemicals in the atmosphere. NO_x and Volatile Organic Compounds (VOCs) react in the presence of sunlight to form ozone. Ozone affects vegetation and human health. It is particularly associated with crop yield decreases.

Aerosols: Large parts of Asia are heavily polluted by soil dust and smoke from household, agricultural fires, traffic and industry. Substantial effects on climate and health are likely. Aerosols in South Asia form a haze across Northern India, SE and NE Asia. This has been called the ‘Atmospheric Brown Cloud’. It was first identified during INDOEX the Indian Ocean Experiment in 1999.

6.6 Conclusions

We know air pollutants are transported over large distances in Europe and in Asia. To determine how much is being transported we need high quality measurements and we need to develop modelling capacity. The main problems of acidification can be illuminated using the models, monitoring and understanding of impacts, but to truly understand the risks and scale of the problem high quality science and awareness among scientists in Asia is required in the region. Improved models can be used to predict future developments which can be used in the emerging international processes. For this to occur efficient and improved connections between scientists and policy makers are required.

7 Urban Air Pollution in Asia and Africa

7.1 Atmospheric corrosion

Vladimir Kucera (Swedish Corrosion Institute, Stockholm, Sweden)

Atmospheric corrosion is an important impact of air pollution damaging cultural heritage and other man-made materials and resulting in large economic losses. The corrosion is due to a combination of the action of a number of pollutants interacting with meteorological parameters. The damage can be caused by wet deposition of acidic rain, dry deposition of gases such as sulphur dioxide (SO_2) and particulate deposition. The damage in Europe precipitated international cooperation on the corrosion of materials through the UN/ECE Convention on LRTAP. Under the Convention, a body known as 'the International Cooperative Programme on Effects of Materials, including Historic and Cultural Monuments' was set up as one of several ICPs under the Working Group on Effects. Through the ICP on Materials 39 test sites were set up. These were mostly in Europe but three of the sites were located in Canada and the United States. At these sites, a set of standard materials were exposed at the same time as pollutants were monitored and from the results dose-response functions for the different pollutants have been developed. These functions generally refer to dry and wet deposition components whose effects are modified by temperature, relative humidity and rainfall pH. Sulphur dioxide is the most widely studied and important pollutant regarding corrosion. It forms part of the dose-response curves for almost all materials. However, nitrogen oxides and particulates are also important. Nitric acid is corrosive and has a high deposition rate, even at low relative humidities and has been found to induce corrosion in warm climates, such as in Athens in Greece. Particulates, as well as soiling buildings, can give rise to corrosion if the aerosols are acidic or, in the case of carbonaceous particles, can catalyse the formation of sulphuric and nitric acids which then corrode materials. It is clear that basic particulates can buffer against acid attack of materials.

Due to the decreasing pollution levels in Europe SO_2 has decreased at all test sites between 1987 and 1998 and the corrosion rates in 1998 of carbon steel, paint on steel, limestone and bronze have decreased to about 60% of the 1987 value (Figure 7.1). The resulting new so-called multi-pollutant situation is currently examined in MULTI-ASSESS, an EU 5FP project aimed at improving the dose-response functions by inclusion of HNO_3, particles and soiling. This is done by complementing and extending the UN/ECE ICP Materials Programme. The dose-response curves can be used together with a stock at risk inventory to assess the cost of damage in entire cities or regions. This can then be linked to economic analyses related to maintenance and replacement costs. Using these techniques it has been estimated that the reduction in corrosion damage after the execution of the 2nd Sulphur Protocol of the UN/ECE will save 10 billion US$ per annum across Europe in rural and urban areas.

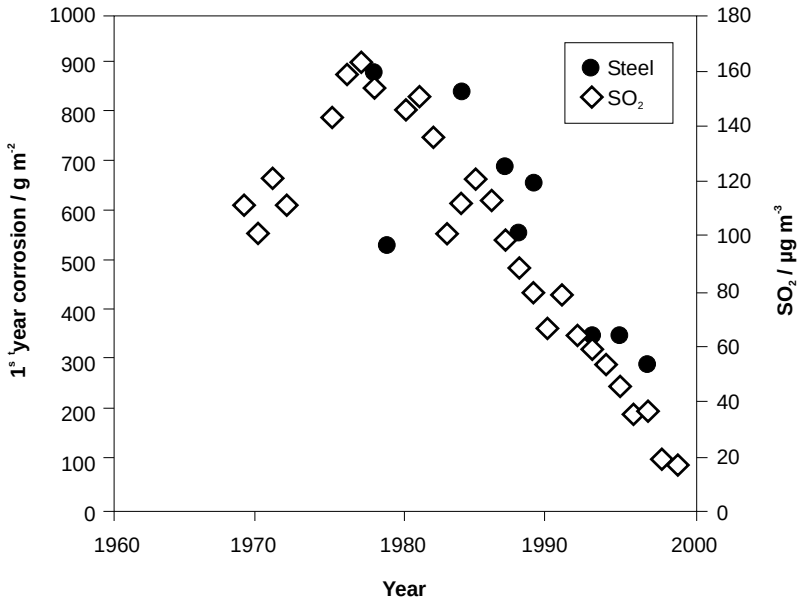


Figure 7.1 Decreasing steel corrosion over time for Kopisty, Czech Republic (courtesy of the Swedish Corrosion Institute)

Corrosion in tropical and sub-tropical regions is less well researched than in Europe and North America, but some data do exist. A compilation of available data shows that the normal range of corrosion in sub-tropical sites is higher than temperate sites and that tropical sites potentially have much higher corrosion rates than any of the other climates. This is backed up by the extremely high corrosion rates in Southern China compared with either Northern China or Europe. This partly due to the very high SO_2 concentrations in cities such as Chongqing or Guiyang, and partly due to the climatic variables.

The lack of dose-response data for the tropical and sub-tropical regions hampers the type of economic assessment that has been carried out in Europe. Therefore, as part of the RAPIDC Programme exposure-response experiments are being set up in 16 locations in 7 countries located in Asia and southern Africa. At these sites, standard samples are being exposed at the same time as pollutant concentrations and climatic variables are monitored in a similar way as is done in the European MULTI-ASSESS project.

7.2 Urban air quality in Asia and Africa

Åke Iverfeldt (Swedish Environmental Research Institute, IVL, Stockholm, Sweden)

7.2.1 Status and assessment of urban air quality in developing countries

The impact of air pollution on urban air quality and its effects on human health has been one of the most important air pollution issues in Europe and North America for the last 50 years. In recent decades the problem has also grown in built up areas in Asia, Africa and Latin America. For example, WHO estimates that 2712 deaths would be avoided in Delhi, India, if Total Suspended Particulates (TSP) were reduced below the WHO air quality guideline. Research into air quality and health effects in Asia and Africa is less comprehensive than in Europe and there is a real need for region-specific information to influence policy makers. In particular studies on dose-response relationships, indoor air pollution, particulate concentrations (especially of PM_{10} and $PM_{2.5}$ concentrations) and practical examples of emission control are required. Table 7.1 shows some of the health impacts of air pollutants.

Table 7.1 Health impacts of air pollutants

Air Pollutant	Documented Impact
Sulphur oxides (SO_x)	Chronic respiratory illness
Lead (Pb)	Affects development of nervous system
Ozone (O_3)	Chronic lung disease
Nitrogen oxides (NO_x)	Lung damage, bronchitis
Carbon monoxide (CO)	Less oxygen in blood, impairs activity
Hydrocarbons (e.g. Benzene)	Adult Leukaemia
Particulate Matter (PM)	Penetrates respiratory tract causing lung damage, cardio-vascular illness/ death

The magnitude of these health effects can be large, for example, PM_{10} (i.e. particles with a diameter of less than 10 micrometers) cause 700,000 premature deaths each year in developing countries, 500,000 new cases of chronic bronchitis globally each year and many more lesser health effects. Health effects of air pollutants therefore represent a significant public policy issue.

An essential component of any assessment is high quality modelling and monitoring data. IVL has carried out several surveys of air quality using passive sampler technology in Europe and in developing countries. Measurements can be made for pollutant gases such as sulphur dioxide (SO_2), nitrogen dioxide (NO_2) and ozone (O_3) and particulate matter (most commonly PM_{10}, although $PM_{2.5}$ measurements are becoming more common). The advantages of passive (or diffusive) samplers is their ease of use and the fact that enough samplers can be deployed to enable maps of pollutant concentrations to be drawn up. A mapping study using passive samplers in Johannesburg, South Africa, showed that the township of Soweto has the highest sulphur dioxide concentrations in the air of the city (values of 40-45 µg SO_2 m^{-3} were recorded). These concentrations were not associated with a point source of pollution, such as a power station, but with the burning of coal for domestic use. Mapping was also carried for NO_2 and these concentrations showed a different distribution to SO_2 which was associated with traffic densities. The Johannesburg mapping exercise showed that indoor air pollution concentrations can be very high, especially in Soweto (from coal burning). Indoor exposure measurements for nitrogen dioxide were also made in Soweto and ranged from 35-300 µg m^{-3}. As a comparison, IVL measurements in Sweden show that indoor and outdoor air pollution concentration for NO_2 are very similar, whereas in developing countries indoor air pollution concentrations can be much higher because of the types of fuels burnt and the ventilation conditions.

In Europe in 1995 more than 45% of the urban population were exposed to concentrations of PM_{10}, NO_2, benzene and O_3 exceeding EU guideline values. The most serious exceedance was for PM_{10} with 90% of the urban population exposed. Exceedance for SO_2, lead and carbon monoxide (CO) were between 10 and 20%. Projections based on commitments to EU policies and the LRTAP protocols show that it is expected that exceedances for NO_2, benzene, O_3, SO_2, lead and CO will all be below 20% for the urban population by the year 2010. However, in the case of PM_{10} exceedance will still be greater than 70% in 2010.

In an effort to improve the understanding of air quality issues in Asia the RAPIDC Programme is conducting various activities. These include the development of an Asia-specific dose-response handbook, Asian case studies of pollution control measures, an indoor air pollution study in India, comparison of $PM_{2.5}$ and visibility measurements at airports to attempt a cheap and convenient assessment procedure for particulate matter concentrations, a rapid assessment emission inventory compilation technique for Hyderabad, in India, and an Asian workshop on air quality issues.

The rapid assessment exercise will explore the use of satellite images for land-cover classification and the identification of different types of roads and buildings for the production of an emission database for the city of Hyderabad. This work is using Indian technology and satellite data where possible and will apply dispersion modelling to the emission database to produce a map of air quality of the city. The rapid assessment map will be compared to another map produced by a parallel process using modelling and monitoring via passive samplers. The two maps will be compared and a final map including an uncertainty estimation will be produced.

The application of these maps of air quality distribution is that they can be overlaid with population figures, rates of mortality or morbidity (from dose-response relationships) and economic values, such as percent GDP, and the cost of abatement measures estimated to give meaningful mitigation options to decision makers. This process was the basis for mitigation measures introduced in Europe for the LRTAP process and local government.

7.2.2 Conclusions

Primary research, using epidemiological studies, is what is required to obtain the extent of air pollution related health effects in developing countries. Dose-response functions may be transferred from Europe and North America but with caution and clearly stated limitations. New studies should be undertaken in developing countries if the contexts are non-comparable. To estimate the cost of health effects to governments in developing countries economic values may be transferred from Europe for broad estimates but studies must consider differences in income and personal preference between the EU and developing countries.

8 Panel Discussion

Facilitated by Pelle Persson (Head of Urban Development Division, Sida, Stockholm, Sweden)

Comment – Power station improvement is very expensive and can be as much as the cost to rebuild stations. In India power stations are a big source of emissions and to improve the situation it would seem then that new power stations are the solution.

Comment – Diesel fuel is also a large source of pollution in India, and indeed diesel is subsidised as a fuel and to solve the overall air pollution problem viable solutions for the different sources, fuels and sectors are required.

Q. In Europe the driving forces for change were acidification, forest die back, health issues and climate change, what are the drivers in Africa and Asia?

A. Health is the main policy driver, for example around smelters. In Africa there is a need to balance impacts of pollution and industrial development.

A. Increased awareness of impacts in Asian society is vital. Some efforts are being made. For example, civil society groups in the Philippines used sheets showing pictures of impacts and also explained the solution and discussed the benefits in terms of lives and the cost to society.

Comment: Health impacts are very important but evidence of impacts on cultural heritage can be a strong driver as well.

Q. Do experiments and dose-response relationships need to be replicated in every country?

A. We do need some regional values at least to give authenticity to claims of impacts in order to persuade politicians in the different countries and to adequately account for the differences in different regions which could affect the dose-response relationships.

Q. Is there a danger of just focussing on health impacts? We have heard about the importance of civil society and NGOs – is Sida supporting NGOs? If not, who is? There is a need to enable NGOs to effectively engage with policy development.

A. There is indeed a need to work on all fronts and Sida does work through SAREC and different programmes on different issues which affect air pollution. With regard to civil society Sida does support NGO activities and for example is supporting an institute in Delhi, the Centre for Science and Environment which does focus on health and air pollution issues.

Q. Why does RAPIDC not cover Latin America too?

A. Sida decided to focus on South Asia and southern Africa rather than spread limited resources over three continents.

Q. Is a change necessary in lifestyles and aspirations in Asia?

A. Yes indeed, the environment will be degraded by unsustainable behaviour patterns at political and lay person level. We need to think about the future, we cannot all live like the Americans.

Comment: Nordic support is appreciated in Asia as it is more effective than other funding.

9 Concluding Remarks

Lars Nordberg (Adviser on International Legislation on Air Pollution, Stockholm, Sweden)

I am heartened that the policy process has been rolling for 25 years in Europe and now is increasing in momentum in developing countries. I would like to refer to a couple of quotations. The first comes from The Economist from the issue of 11 May 2002 (Urban Air Pollution: A Great Leap Forward), page 83:

> *'Until recently, conventional thinking has held that poor cities such as Taiyuan cannot afford rich-world environmental standards: greenery according to this theory, is a luxury good that comes only with wealth. Over the past few years, though, economists have realised that, besides being bad for individuals, pollution is bad for the economy. In a report that proved influential in converting China's leaders to the virtues of pollution control, the World Bank has estimated that in the late 1990s China lost between 3.5% and 7.7% of its potential economic output as a result of the health effects of pollution on the country's workforce. Similarly, Louisa and Mario Molina, who work at the Massachusetts Institute of Technology, argue that Mexico City could see benefits of perhaps $2 billion a year, if officials reduced the concentrations of particulate matter in the air by just 10%.'*

Another relevant quote is from the stated purpose of the RAPIDC Programme:

> *'To facilitate the development of agreements/protocols to implement measures which prevent and control air pollution through promoting international co-operation and developing scientific information for the policy process.'*

This is a very good way of describing the work required to help solve the air pollution problems in the countries of Asia and Africa where the air pollution problems are already very bad in some places and are increasing generally. The objectives of RAPIDC and the projects described in this forum are on track to make a difference in these regions.

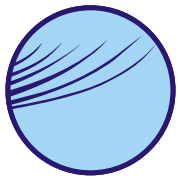
Various scenarios for emissions in China show that there may well be an increase of SO_x and NO_x. There have been recent successes in China in reducing the overall emission of sulphur. However, the rapid economic development is a pressure that may well lead to further increases in emissions unless measures are taken. In South and Southeast Asia the rapid economic development indicates increases in emissions. In Africa and in Latin America emissions are projected to increase until 2025. Impacts of air pollution will increase with these higher emissions and impacts drive policy. This includes effects on environment, health, materials and crop yields. The influence of these impacts is particularly great when the value of avoiding damage is demonstrated (particularly if the monetary costs are given).

As emissions increase, transboundary issues become increasingly important. In Asia, the large countries of China and India may also experience issues related to trans-province and trans-state boundary pollution. At all stages, and on all elements relating to the transboundary pollution, inter-governmental cooperation is required. For example, this can be at the technical level harmonising emission inventories and monitoring networks, to minimising fluxes and developing coordinated mitigation policies for the region.

Varying sensitivity and vulnerability in various parts of the world can lead to differentiated approaches and reduction commitments among countries. In other words, obligations for mitigation can be differentiated relative to damage, as has occurred in the protocols of the UN/ECE Convention on LRTAP.

Coordinated policy between regions is also required as regulatory action in one country or region can be offset by increases elsewhere. The goal is to limit impacts globally and allow a high quality of life and high environmental quality for all and not to shift the problems from one region to another. The RAPIDC Programme, coordinated by SEI provides significant support for developing the science-policy interface in the targeted regions. The need for RAPIDC-type initiatives also exists in regions other than South Asia and southern Africa and Sida/SEI's programme can offer an example for these regions. Much of the RAPIDC Programme has by necessity a long-term component, it is a lengthy process and there are few short-cuts. The benefits of emission reductions are evident to many but they must be better highlighted, as shown in the article in The Economist referred to above.

RAPIDC is a package of 13 projects aiming to move science to policy. The first year of the contract has paved the way and it will be interesting to follow progress and I am confident that the programme can make a difference to the air pollution situation in Asia and Africa.



Atmospheric Environment Programme

The Atmospheric Environment Programme of SEI aims to inform, facilitate and interact with policy processes that limit pollutant emissions to the atmosphere. It carries out research to quantify and model emissions and impacts and assess mitigation options. This information is transferred to policy- and decision-making processes at different scales through networking and multi-stakeholder dialogues. Further activities enhance the capacity to implement international agreements, particularly in developing countries. The Programme concentrates on local and regional air pollution problems in Europe, Asia and Africa. It also builds capacity in developing countries and countries in transition to phase out ozone-depleting substances.

www.sei.se

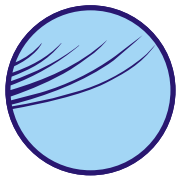
Regional Air Pollution In Developing Countries

RAPIDC is a Programme funded by the Department of Infrastructure and Economic Cooperation (INEC) of Sida, the Swedish International Development Cooperation Agency. It is co-ordinated by SEI and carried out in collaboration with Swedish universities and research organisations together with inter-governmental agencies and research organisations in Asia and Africa. The aim of RAPIDC is to facilitate the development of agreements/ protocols to implement measures which prevent and control air pollution. Projects are carried out that facilitate international co-operation on air pollution issues and develop relevant knowledge to support decision making. Activities are carried out in Asia (mainly South Asia) and in Southern Africa.

www.sida.se

www.rapidc.org

ISBN 91 88714 845



Atmospheric Environment Programme

The Atmospheric Environment Programme of SEI aims to inform, facilitate and interact with policy processes that limit pollutant emissions to the atmosphere. It carries out research to quantify and model emissions and impacts and assess mitigation options. This information is transferred to policy- and decision-making processes at different scales through networking and multi-stakeholder dialogues. Further activities enhance the capacity to implement international agreements, particularly in developing countries. The Programme concentrates on local and regional air pollution problems in Europe, Asia and Africa. It also builds capacity in developing countries and countries in transition to phase out ozone-depleting substances.

www.sei.se

Regional Air Pollution In Developing Countries

RAPIDC is a Programme funded by the Department of Infrastructure and Economic Cooperation (INEC) of Sida, the Swedish International Development Cooperation Agency. It is co-ordinated by SEI and carried out in collaboration with Swedish universities and research organisations together with inter-governmental agencies and research organisations in Asia and Africa. The aim of RAPIDC is to facilitate the development of agreements/ protocols to implement measures which prevent and control air pollution. Projects are carried out that facilitate international co-operation on air pollution issues and develop relevant knowledge to support decision making. Activities are carried out in Asia (mainly South Asia) and in Southern Africa.

www.sida.se

www.rapidc.org

ISBN 91 88714 845