WORKSHOP ON ACID RAIN MONITORING AND ATMOSPHERIC MODELLING

20-23 April, 1998

Kandy, Sri Lanka

PROCEEDINGS

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The Commonwealth Science Council (CSC)

Postgraduate Institute of Science (PGIS),
University of Peradeniya, Peradeniya, Sri Lanka

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Proceedings of the

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Edited by
O.A. Ileperuma

ORGANISING COMMITEE

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PREFACE

Following the Langkawi Declaration on Environment at the meeting of Commonwealth Heads of Government in 1989, the Commonwealth Council (CSC) launched a knowledge-based programme on chemical Research and Environmental Needs(CREN) in the Asia Pacific region

A number of important activities have been developed since CREN was launched including training workshops ,symposiums, publication of states reports, formation of net works on environmental monitoring and modelling programmes.

This is accomplished through collaborating ,exchanging information and sharing experiences, standardisation of analytical method , encouraging information exchanges through modern system e.g.(E-.mail) and developing scientific network to link scientists to undertake joint programmes within and outside the commonwealth, in effective ways , using the limited resources available.

The Science and Technology Division (STD) of the commonwealth Secretariat has provided training to a large number of Sri Lankans. Sri Lanka is an active member of this project in four major areas of the project.

With financial support from Commonwealth Fund for technical Co-operation (CFTC) and with local hospitality provided by Postgraduate Institute of Science ,Peradeniya ,Sri Lanka (PGIS)and Natural Resources and Energy Authority of Sri Lanka (NARESA) holding this workshop under the component Gaseous Emissions and Atmospheric impact of the CREN project.

Rapid industrialisation and economic growth taking place in south and south east Asia leading to increased energy use and the use of coal in thermonuclear power plants will result in increased atmospheric acidification. If the present trends continue, sulphur dioxide emissions alone will exceed the emission for North America and Europe combine by the year 2010.

Although most countries in the region have their individual acid rain monitoring programmes, there is the possibility that acidic emissions from one country could get carried to other neighbouring countries . The long term effect of acid rain on arias such as forestry and agriculture may have far –reaching environmental implications for predominantly agricultural societies of the countries in the region.

It is imperative to share the knowledge on acid rain and develop approaches to formulate national and regional policies to address the problem of regional acid rain monitoring. It is also important that dialogue at the political level to include government and also other donor agencies be initiated and the recommendations based on scientific findings made to initiate appropriate action to deal with the problem.

The main objective of this training is to familiarise participants with issues related to atmospheric acidification and to initiate regional action to correct it's adverse impact on the environment.

This objective will be pursued through consideration of the following issues:

a. Sources of atmospheric acidification
b. Environmental implications of acid rain
c. Methods of acid precipitation monitoring
d. development of a regional model applicable to participating countries

e. Remedial measures to be recommended to governments

We thank all our sponsors for facilitating the participation of a large number of local scientists. We specially thank the Faculty of Science, University of Peradeniya and the Postgraduate Institute of Science for providing all facilities at our disposal for making this workshop a success. Finally we like to extend our special thanks to Dr CTK Thillekeratne, Mr. R.M.Premakeerthi, Miss D. Damunupola and Ms. M.E.Balasooriya who worked hard in the organisation of this workshop.

Organising Committee
20 April 1998

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DOES AIR QUALITY HAVE A FUTURE?

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Modern Cities and GDP

Cities may well be the engines of modern economies, central to the delivery of services that permit ongoing increases in gross domestic product (GDP). But with these increases generally there is found also to be a strong correlation with that other meaning of GDP — garbage, dust and pollution.

Air pollution knows no boundaries. Local activities can not only lead to local problems, but can also lead to national and international consequences lasting from hours to decades:

Industry, transport and other modern urban systems require energy. Consequent emissions of carbon monoxide, carbon dioxide and nitrogen oxides from fossil fuel combustion blanket the earth, trapping excess heat and leading to global warming and ultimately climate change, rising sea-levels, changes in vegetation and increase in severe weather events.

Use of oil and coal fuels for this energy generation additionally leads to the emission of sulfur dioxide. Combined with copious emissions of fine particles, the resulting deadly miasmas in London in the 1950s shocked England into action to control air pollution. The same lessons had to be re-learnt in Japan in the 1970s and again in Korea in the 1980s. They have yet to be heeded in South Asia and China.

But these atmospheric emissions of oxides of sulfur and nitrogen emitted to the atmosphere have had a far wider and more insidious effect: acid rain. Acting over decades, it has killed forest and lake ecosystems in north America and northern Europe hundreds and thousands of kilometres from the major emission centres in eastern USA and in Central Europe. Energy development plans in southern China in particular, have yet to come to grips with the expected deleterious consequences of acid deposition.

Before returning to the surface as acid rain, the sulfur emissions can be transformed into fine sulfate particles that scatter and reflect light very effectively. It is believed that these particles are a major cause of reducing global warming in the northern hemisphere.

Although their consumption is now essentially banned worldwide (in developing countries by 2005), chlorofluorocarbons have been the mainstay of foam blowing, refrigeration and fire fighting systems. The release of these chemicals over past decades continues to cause destruction of the ozone layer each Spring far above the surface. Parts of the earth are consequently unprotected from strong ultra-violet radiation for several months each year until mixing restores the ozone distribution.

In 1997–98 the weather event El Niño brought drought, famine, and heavy pollution from fires in Indonesia throughout the countries of south-east Asia. Levels of fine particles in the air in cities such as Kuala Lumpur and Singapore on occasion reached frightening levels: ten or more times as high as dangerous levels defined by World Health Organization.

Sources of Air Pollutants

Table 1 shows that in Sydney a high percentage of emissions for most pollutants is due to motor vehicles. This found to be the case for all major developed cities of the world. Most of the emissions of nitrogen oxides (NOx) and of volatile organic compounds (VOCs) arise from motor vehicle sources. These two pollutants generate secondary pollutants such as ozone and other smog products.

Table 1: Percentage of air pollutant emissions due to different sources in Sydney. SOE (1996)

Pollutant	**Vehicle**	**Industry**	**Domestic, Commercial**
NOx	82	13	5
VOCs	49	10	41
Particles	31	36	33
CO	91	2	7
SO_2	14	64	22

Although about one-third of all particle emissions in Sydney are reported to be due to vehicles, the influence of road traffic is far more marked for the fine particles fraction. In 1990 in Greater London, for example, it is estimated that 86% of emissions of particles less than 10 μm in diameter (important for human health effects) arose from this source (QUARG, 1993).

In some countries the issue of trans-boundary influx of polluted air is frequently a major confounding issue: in Germany, for instance, it is estimated that approximately 50% of the air pollution burden is due to cross-border influx (BMU, 1996a). Acid rain and bushfire smoke has reached out from Indonesia to countries far away in southeast Asia.

There can be large differences in relative importance of emissions sources between cities of developed and developing countries, depending on the level of motorisation and the level, density and type of industry present:

Motor vehicles continue to be the most significant contributor to air pollution in most newly industrialising countries. The contribution is growing rapidly, with fleet sizes doubling every seven years. In South Korea, vehicle numbers have grown from 3.4 million to over 10 million since 1987, with half of all vehicles in the Seoul area (Manins, 1992b). There most vehicles are relatively young and hence 'clean' compared to a country such as Australia where the average vehicle age is over 12 years.

Cities in Latin America tend to have higher vehicle densities than those in other developing regions. However, in cities in Africa and in cities located in cooler regions, emissions from vehicles are relatively less important. There is a greater dependence on coal or biomass fuels for space heating and other domestic purposes.

Highly polluting diesel vehicles and two-stroke motorcycles are common in many of the less developed countries (45% of vehicles are diesel in South Korea compared with 7.4% in Australia; two-stroke motorcycles are rampant in Taiwan, as are auto-rickshaws in India —they are both rare in Australia).

Sulfur dioxide pollution resulting from the use of poor quality coals and cheap oils has been a feature of pollution emissions due to energy production in cities such as Manila. Only in the more affluent newly industrialising countries has there been a shift to use of cleaner natural gas.

Cities such as Jakarta and Calcutta have very large emissions of smoke from indiscriminate burning and poorly controlled vehicles, but the authorities seem to be in denial, not even acknowledging that there is pollution and that it is due to urban and industrial activity.

Air Pollution

Emissions of air pollutants lead to the production of smogs that destroy sensitive tissues (in people, animals and plants), the formation of inhalable carcinogenic particles, reduced lung function, and are ultimately responsible for many untimely deaths each year. Pollution degrades building materials such as rubbers and stonework, and reduces the visual amenity of scenic vistas. Air quality comparisons for selected global cities are shown in Figure 1. Although annual average total suspended particulate matter (TSP) is only a crude indicator of air quality, it is notable that over the past decade the Figure shows that there has been some improvement in Sydney. Overall, the risk of detriment from air pollution in Australia's largest cities is probably similar to that in New York or Tokyo (Manins, 1992a).

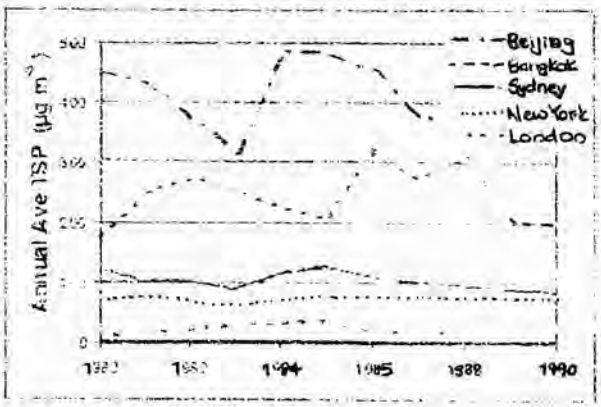

Figure 1: Annual average TSP concentrations in selected international cities. (SOE 1996)

A finer measure of air quality for cities is the number of days on which ozone levels exceed recommended levels. In 1991, residents of Mexico City were exposed to 1,400 hours of high ozone, compared with the World Health Organization guideline of 1 hour. In Sydney there were four such occasions that year. Some American cities experienced: 5 days, Atlanta; 16 days, Chicago; 135 days, Los Angeles; 29 days, New York; 2 days, San Francisco (Ahmet and van Dijk, 1995 XE "Ahmet and van Dijk, 1995").

Figure 2 shows the dramatic success achieved in London since the 1960s in reducing fine particles and sulfur dioxide in the air. Similar successes have been achieved in other cities such as Los Angeles, Tokyo and to a lesser extent, Moscow (UNEP/WHO, 1992 XE "UNEP/WHO, 1992").

The contrast with the worsening situation in many Asian cities except in Japan and South Korea (where there have since been major improvements) is all too stark. A measure of the problem is the number of times each year that World Health Organization air pollution guidelines are exceeded. Table 2 (from ADB 1991□ XE "ADB (1991" □) summarises past annual air quality in some Asian cities using data from the UNEP/WHO Global Environmental Management Systems project.

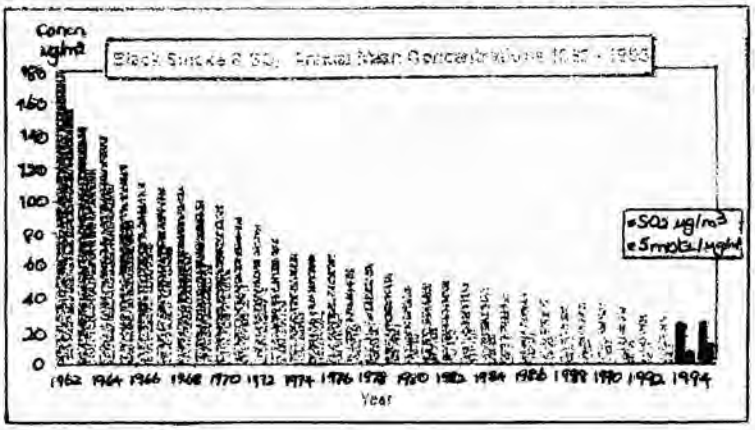

Figure 2: Measured mean black smoke and sulfur dioxide levels in London air (AEA, 1996 XE "AEA, 1996")

Table 2: Exceedances per year (to 1990) of WHO guideline values for sulfur dioxide and airborne particle concentration in selected Asian cities

Cities	SO_2-Days above recommended level		TSP-Days above recommended level	
	Avg.	Max.	Avg.	Max.
Shanhai	16	32	133	277
Shenyang	146	236	219	347
Hongkong	15	74	-	-
Culcutta	25	85	268	330
Manila	24	60	14	225
Bangkok	0	0	97	209
Seoul	87	121	-	-

Business as Usual

A striking difference in urban environmental quality between developed and less developed countries is seen in the trend in premature urban deaths due to atmospheric concentrations of fine (PM10) particles. An interpretation of what continues to be a controversial relationship, is shown in Figure 3, from a presentation by staff of World Bank (1996, "World Bank).

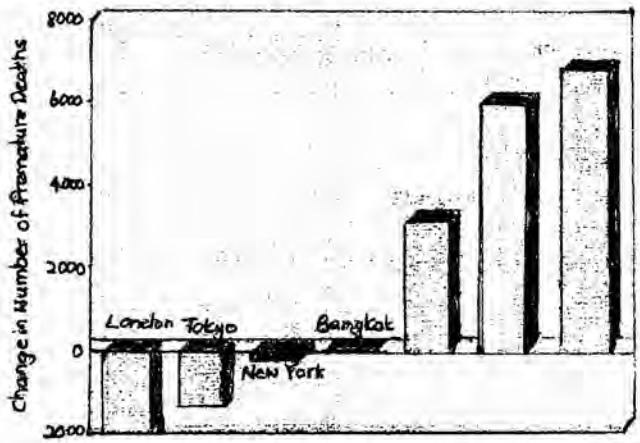

Figure 3: Change in number of premature deaths caused by change in concentration of PM10 (1980-1990).

Recently the Asian Development Bank released an assessment of the state of the environment in Asia (ADB, 1997 ADB, 1997). It points to dismal progress over the last ten years and increasing threats to human health in Asia's cities.

> "Asia's environment has become so polluted and degraded that it poses a threat not just to the quality of life of its people, but also to its economic prospects. Of the world's 15 most polluted cities, 13 are in Asia, as are the most populous countries.
>
> Despite rapid and steady growth in income, at least one in three Asians still has no access to safe drinking water, and at least one in two has no access to sanitation. The costs of this neglect of the environment are massive. Children that ingest lead lose precious IQ points. They and their parents also suffer from chronic respiratory conditions and other ailments. Unsanitary living conditions and polluted water cause a variety of other gruesome conditions."

The report further states that Asia's environmental crisis is in large part the result of failed policies and neglect. Those countries where incomes have lagged have environmental records that are just as bad as those where incomes have grown quickly. As in eastern Europe, rising incomes seem eventually to herald an improvement as growing popular demand for a better environment forces a favourable policy shift. South Korea is a notable example of this. It is entirely possible that other parts of Asia may become even dirtier, less forested, and less ecologically diverse in the future. The prospect of continued urbanisation poses yet further problems. The share of Asia's population living in urban areas will rise from 35 percent in 1995 (see Figure 4) to around 55 percent in 2025. While urban life will offer people greater opportunities and will probably mean less pervasive poverty than in rural areas, Asia's particular style of urbanisation—toward megacities rather than mid-sized cities (13 of the world's 20 biggest cities are in Asia) is likely to further exacerbate environmental and social stresses.

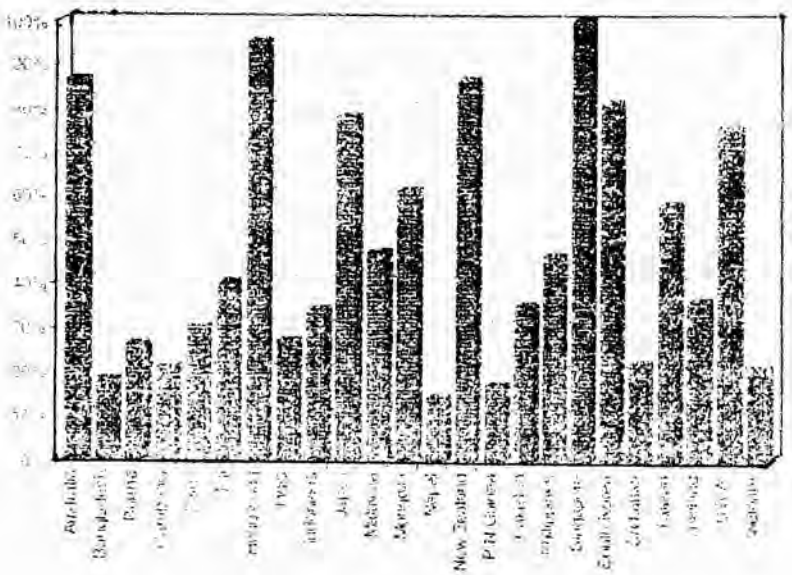

Figure 4: Percentage of populations in urban areas of selected countries. (AsiaWeek, 1997 "AsiaWeek, 1994")

The ADB characterised much of the current environmental policy as "misguided and badly implemented" and "overly ambitious and inflexible". Even before the economic collapse in several Asian countries in late 1997, it predicted dire consequences with global implications (e.g. air emissions from Asia will grow by up to ten times by 2030) if better environmental management is not employed.

A Better Future

Does the ADB assessment have to be the common experience? No.

Some governments have shown enlightened development policies, recognising the interconnectedness with interlinking environmental problems. For example, western Germany has broken the nexus between growth in GDP and the other GDP, as shown in Figure 5. But given the huge effort that Germany has made (much of which has had to be repeated in eastern Germany), Figure 5 also illustrates the difficulty that modern governments face. It is hard to reduce energy consumption (as measured by CO2 and NOx emissions) as is necessary for mitigation of the enhanced greenhouse induced climate change.

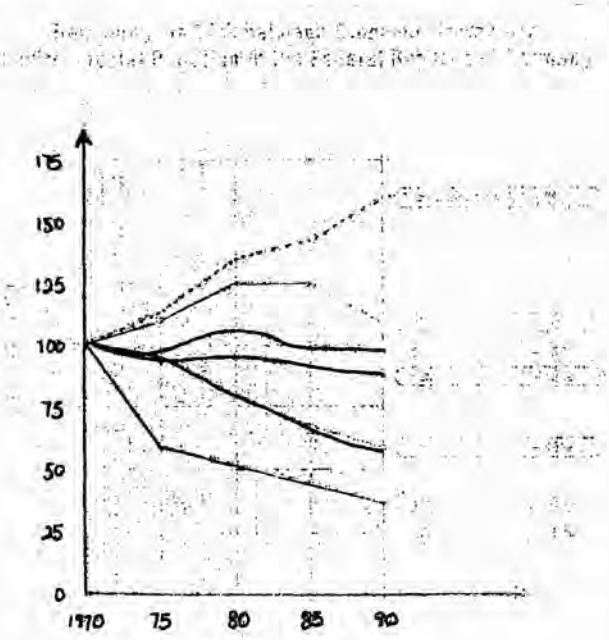

Figure 5: Decoupling increasing GDP and air pollution in Germany. (from BMU, 1996b XE "BMU, 1996b")

Some developed mature cities also have had some successes. In recent years some urban pollution levels (particularly of airborne lead, sulfur dioxide, and particles—see e.g., Figure 2) have decreased in many cities, probably due to better emissions management.

However, increases in vehicle ownership, distance travelled each year, and the increased proportion of diesel from other fuel-type vehicles, leads to the expectation that gross urban pollution emissions and air quality levels may soon rise in developed countries unless further interventions occur. Major innovation and restructuring of transport, service delivery, and commercial activities will be required.

Do we just accept that the growth in pollution and energy consumption is inevitable and inexorable in the long term in our region? Or do we recognise that there are alternatives? Alternatives such as cleaner production processes for industry, radically cleaner vehicles (see e.g. Manins, 1997 XE "Manins, 1997"), or change in the structure of our cities so the need for transport is reduced in the first place (Newton, 1997).

How are these alternatives instituted? Environmental regulations and plans are necessary but are of little use unless they are implemented and enforced. This requires public support. Information, community education, and public participation in the debate on our future leads to action. There are no quick solutions. The present workshop makes an attempt at filling some of the gaps. Things that will be discussed over the next few days include:

- air pollutant emissions databases to identify potential problems and likely trends over time, contributing to assessments of acid deposition and air pollution modelling investigations;
- air quality monitoring to give defensible data on the actual state of the air and how it is changing with time and location in the region;
- meteorological monitoring to identify how pollutants are transported and mixed in the locale;
- acid rain monitoring and soil sensitivity studies to identify the long-term ability of the region to support its present ecosystem and agriculture;
- passive gas monitoring for low-cost preliminary mapping of air quality and assessments of regions; and
- low-cost Airwatch monitoring of fine particles for use by schools and community groups.

Conclusion

There are two possible futures: that of the ADB (1997) assessment, or a cleaner, healthier environment. We have no choice — we must breathe.

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Southeast Asia can expect to pay for Indonesia's inertia for years to come -- in damage to its citizens' health, its economies and the environment. The World Health Organization warns of a dramatic rise in the number of haze-related deaths, particularly among the ill, the elderly and the very young.
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COUNTRY REPORT ON ACID RAIN MONITORING IN AUSTRALIA

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INTRODUCTION

This report briefly summarises results of the major recent acid deposition studies in Australia. The material encompasses measurements of the major components that contribute to the overall level of acidic deposition in the form of gas and rainwater. The focus of the report is primarily on wet and dry deposition of nitrogen and sulfur species to the ground rather than pH and rainwater composition. In some cases research was sponsored by major public utilities and since the results are confidential detailed results cannot be presented.

Australia is a large country with a land area of about 7.7 million square kilometres but with a relatively small population of about 18 million people. Consequently there are large areas of the country that are unpopulated and which are unaffected by industry or urban environments. There are however a number of large cities, such as Sydney and Melbourne, situated near the coast, which have populations of about 3 million people. In these environments acid deposition is increased substantially compared with the areas of low population where industry is almost non existant. In addition there are areas of industrial activity, such as mining and power generation, away from the major population centres where acidic deposition is increased due to fossil fuel burning and smelting of ores.

This work reports on acidic deposition in these three major environments within Australia; remote areas, industrial areas and urban areas. In some cases concentrations of gases and rainwater composition as well as total depositions of sulfur and nitrogen can be given. In other cases only concentrations of nitrogen and sulfur in rainwater can be reported since no gas concentrations were available.

RESULTS

1. Remote Areas
(i) Acid Gases

Acid gases are the precursors of acids found in rainwater. Such gases include sulfur dioxide, nitrogen dioxide, nitric acid, formic acid and acetic acid. Sulfur dioxide and nitrogen dioxide form the mineral acids, sulfuric acid and nitric acid respectively. Sulfur dioxide is emitted mainly from coal burning power stations and from smelting operations in the mining industry and nitrogen dioxide from oxidation of nitrogen gas in internal combustion engines. Other gases such as formic acid, acetic acid and other organic acids occur naturally and are produced via photochemical reactions involving major precursors, such as isoprene, (Brewer et.al., 1984; Grosjean, 1992; Seinfeld and Pandis, 1998) which are emitted from forests.

Organic acids can also be produced from other hydrocarbons and concentrations of these measured in tropical Australia are shown in Table 1. Some hydrocarbons are produced from bushfires during the dry season in northern Australia and these can be identified in fresh bushfire emissions by enhanced carbon monoxide concentrations. Table 1 shows that concentrations of ethylene, acetylene, propane, propylene and butane appear to be enhanced during bushfires and that although

isoprene has concentrations higher than other hydrocarbons it is not emitted by bushfires (Ayers and Gillett, 1988).

Table 1. Mean hydrocarbon mixing ratios (pptv) standard deviations and ranges for samples collected below 500 m.

Hydrocarbon	Mean	St. Dev.	Range	High CO
Ethane	337	35	260 - 410	333
Ethylene	106	23	60 - 320	270
Acetylene	177	60	140 - 400	354
Isoprene	1640	460	800 - 2300	1700
Propane	43	20		145
Propylene	<100			157
Butane	38	20		166
Isobutane	<100			87
Butene	<100			91

The concentrations of formic and acetic acid produced from oxidation of isoprene as well as sulfur dioxide and nitric acid have also been measured in the remote north of Australia. During 1984/85 samples were collected on denuder tubes over 24 hour periods by Gillett and Ayers, (1988) and the results are given in Table 2. Concentrations ranged from 2.4 ppbv to 1.1 ppbv for formic acid and 0.2 to 0.5 ppbv for SO_2.

Table 2. Mean formic acid, acetic acid nitric acid and sulfur dioxide mixing ratios (ppbv) measured at Jabiru, during 1984/85.

Gas	Mean	minimum.	Maximum
formic acid	1.1	0.3	2.4
acetic acid	0.5	<0.1	2.4
nitric acid	0.3	<0.1	1.5
sulfur dioxide	0.2	<0.1	0.5

Concentrations of sulfur dioxide, nitric acid and nitrogen dioxide have also been measured at Charles Point, a sampling station on the coast west of Darwin in the Northern Territory since June 1993. Concentrations of SO_2, NO_2 and HNO_3 averaged 0.75 ppbv 0.91 ppbv, 0.43 ppbv respectively as Table 3 shows. These are low concentrations when compared to those in urban areas. Sulfur dioxide has also been measured at the Cape Grim Baseline Air Pollution Station (CGBAPS) in Tasmania during periods when air masses originate between west and south, from September 1992 until March 1993 (Ayers et.al., 1997) and as Table 3 shows the average is about 6 pptv. Nitrogen dioxide concentrations have also been measured at Cape Grim for short periods of time (Galbally et. al., 1996) and the average concentration of about 4 pptv is very low. Table 3 also has calculated annual deposition of each gas to the ground assuming a deposition velocity of 0.0028 m/sec for SO_2 0.0021m/sec for NO_2 and 0.009 m/sec for HNO_3 as found by Manins et. al., (1996).

Table 3. Average, maximum and minimum concentrations of acidic gases at CGBAPS and Charles Point from July 1993 until December 1997 and annual deposition. Concentrations are in ppbv at Charles Point and pptv at Cape Grim.

Gas	Mean	maximum	minimum	deposition meq/m^2/yr
NO_2 (Charles Point)	0.75	2.69	0.22	2.0
SO_2 (Charles Point)	0.91	2.07	0.26	6.5
HNO_3(Charles Point)	0.34	1.25	0.10	3.9
NO_2 (Cape Grim)	4	6	3	0.01
SO_2 (Cape Grim)	6	20	1	0.05

(ii) Rainwater and Cloud water

Cloud water has been collected in two remote areas of Australia. In both field campaign samples were collected from a CSIRO F27 research aircraft using a purpose designed cloudwater collector (Ayers and Gillett, 1988). In the first study 31 samples were collected from convective clouds during November 1985 near Katherine and Jabiru in the tropical north of Australia (Ayers and Gillett, 1988b). Results of this study showed that samples were uniformly acidic with an arithmetic mean pH of 3.79 and a range of 5.22 to 3.48. Formic acid was found to be the largest single contributor to the free acidity although other acids such as nitric, sulfuric and acetic acids also contributed significantly. This accords well with other studies of rainwater in a similar area when Galloway et. al., (1982) found that rainwater at Katherine, Northern Territory had a volume weighted mean pH of 4.78 and that the free acidity was on average 41% from organic acid, mainly formic acid. The remaining free acidity was composed of H_2SO_4 (33%) and HNO_3 (26%).

Cloudwater has also been collected during two field campaigns, in 1981 and 1983, around the island of Tasmania (Gillett and Ayers, 1989). A total of 55 samples were collected near the western, northern and south western coasts. In contrast to those collected in tropical northern areas cloudwater was not generally acidic with exceptions occurring when cloudwater was influenced by air masses which had passed over the Australian continent. Results of pH measurements showed that the arithmetic mean pH for all samples was 5.16. For samples collected during the two days when air was influenced by the Australian continent the arithmetic mean pH was 4.78 in contrast to about 5.68 when there was no continental influence.

Rainwater has been collected at several places in remote areas of Australia amongst these are Darwin airport, Wagga Wagga, Jabiru, Katherine and Coffs Harbour; the measurements of NO_3^- and SO_4^{2-} concentrations and depositions are compiled in Table 3. Rainwater samples have been collected at Darwin airport since November 1991 (Ayers et. at., 1993) and the data presented here are for the 1994/95 monsoon. During this season 1688 mm of rain fell and the volume weighted mean pH was 4.95. Gillett et. al., 1990 and Noller et. al., (1990) provide data on the concentrations of nitrate and sulfate and vwm pH of rainwater collected at Jabiru. Gillett et. al., (1990) collected rainwater on an event basis from October 1983 till March 1984 with sample classified as transitional (inter-monsoonal) or monsoonal. The vwm pH was 4.62 in the transition, 5.02 during the monsoon and for all samples 4.89. They found that for all samples formic acid contributed about 48% of the free acidity in this region, and that the remainder was H_2SO4 and HNO_3 and with smaller amounts of HCl and CH_3COOH. Noller et. al., (1990) collected rainwater on a daily basis from November 1982 until May 1983 at 3 sites. The vwm pH values at the three sites were 4.49, 4.57 and 4.26 and the lowest pH recorded was 3.6. Table 3 shows the average

volume weighted mean concentrations and deposition of nss-SO_4^{2-} and NO_3^- at these sites. The data from Katherine is from Galloway et. al, (1982) and has been converted to deposition by applying the long term mean rainfall amount.

Table 4. Volume weighted mean concentrations and annual deposition of nitrate and non seasalt sulfate in rainwater at several remote sites in Australia.

Site	NO_3^- (μeq/l)	nss-SO_4^{2-} (μeq/l)	NO_3^- meq/m^2/year	nss-SO_4^{2-} meq/m^2/year	pH
Darwin	2.7	2.2	4.5	3.8	4.95
Wagga	10.0	5.3	3.1	1.6	4.95
Coffs Harbour	3.1	5.6	6.5	11.5	5.43
Jabiru 1983/84	3.2	5.2	4.8	7.7	4.89
Katherine	4.3	6.4	4.2	6.2	4.78
Jabiru 1982/83	4.8	3.8	4.6	3.7	4.26

Typical deposition rates for S+N in remote areas of Australia can be assumed by adding deposition rates of wet and dry deposition. In this case the wet deposition rates measured at Darwin,Wagga Wagga, Coffs Harbour, Katherine and Jabiru and were averaged to give an overall estimate of the wet deposition in remote areas. Dry deposition rates measured at Charles Point (Table 3) have been used to estimate dry deposition rates of S and N in remote areas in Australia. Table 4 has the results of the wet plus dry deposition rates of N+S in remote regions of Australia.

Table 5. Total estimated nitrogen plus sulfur deposition rates in remote areas in Australia.

Wet deposition		dry deposition				
NO_3^- meq/m^2/yr	SO_4^{2-} meq/m^2/yr	HNO_3 meq/m^2/yr	SO_2 meq/m^2/yr	NO_2 meq/m^2/yr	Total meq/m^2/yr	Fraction dry %
4.6	5.8	3.9	6.5	2.0	22.8	54

2. Urban Areas

(i) Rainwater and Gas

A study was conducted from February 1990 until February 1992 to measure rainwater composition at 4 sites in the Latrobe Valley, a rural area east of Melbourne (Ayers et. al., 1995b). The area is mostly rural and has a number of towns and small cities and a total population of about 100,000 people. It also has four brown coal fired thermal power stations and a gas-turbine power station for a total installed capacity of about 5500 MW. Although 3 sites were situated at distances up to 40 downwind of the power stations no real difference in acidity could be measured between them and the site (Warragul) situated upwind of the power stations. Table 4 gives the volume weighted mean pH and concentrations and deposition rates of NO_3^- and SO_4^{2-} measured at each site.

Table 6. Volume weighted mean pH and concentration and deposition of nitrate and sulfate in rainwater at four sites in the Latrobe Valley.

Site	pH (vwm)	NO_3^- μeq/l	nss-SO_4^{2-} μeq/l	NO_3^- meq/m^2/yr	nss-SO_4^{2-} meq/m^2/yr
Warragul	5.17	4.8	9.4	4.7	9.4
LV Airport	5.08	5.0	18.2	5.1	14.5
Rosedale	5.05	5.2	11.8	4.2	7.0
Wilung	5.03	5.1	13.4	6.3	9.0

During the period of September 1986 until August 1987 SO_2 and NO_2 were measured at 13 sites in the Latrobe Valley. The annual average concentrations were calculated to be 1 ppbv and 3.8 ppbv respectively for SO_2 and NO_2. These were converted to molar units at a temperature of 293°K and a pressure of 1013hPa and combined with dry deposition velocities of 0.0028 m/sec for both SO_2 and 0.0021 m/sec for NO_2 to give dry deposition rates (Manins et. al., 1996). Wet deposition of NO_3^- and SO_4^{2-} were estimated from the means of the four sites and the results, along with dry deposition are presented in Table 7.

Table 7. Wet, dry and total deposition rates of nitrogen and sulfur in the Latrobe Valley, Victoria.

dry deposition meq/m^2/yr		wet deposition meq/m^2/yr		Total deposition meq/m^2/yr	Fraction dry %
SO_2	NO_2	nss-SO_4^{2-}	NO_3^-	N+S	
7.3	11	10	3.8	32	57

During the summer of 1980/81 Ayers and Gillett, (1984), collected rainwater at 12 sites across the Sydney metropolitan area. In this study rainwater was rainwater samples were analysed for conductivity, pH, NH_4^+, Cl^- and NO_3^-. Since nss-SO_4^{2-} was not determined in the first study a second study at 3 of the four sampling sites Ayers et. al., (1987) collected rainwater samples during November to March 1982. Since samples were only collected during the summer months, they probably represent an upper bound to the acidity found in a major Australian city. This is because acidity is expected to be at a maximum in the summer period when oxidation of SO_2 and NO_2 is at a maximum and because Sydney is the largest city in Australia. These samples were analysed for pH, NH_4^+, Ca^{2+}, nss-SO_4^{2-} and NO_3^-. Table 6 shows that the vwm pH varied from 4.34 to 5.08 and the vwm NO_3^- from 7.8 to 79.2 μeq/l across the 12 sites and that vwm nss-SO_4^{2-} was 48.4 μeq/l.

Table 8. Volume weighted mean pH and vwm concentrations of nitrate and sulfate across the Sydney metropolitan area.

Site	pH	pH max	min	NO_3^- μeq/l	NO_3^- max μeq/l	min	nss-SO_4^{2-} μeq/l
All sites (vwm)	4.44	5.08	4.25	13.6	79.2	7.8	48.4

Ayers and Gillett, (1984) also provide average gas concentrations over the Sydney area and these can be used to calculate the dry depositions assuming the dry deposition velocities to be 0.0028

m/sec for SO_2 and 0.0021m/sec NO_2 and. Concentrations of SO_2 and NO_2 during the sampling period were 1.7 ppbv and 12.0 ppbv respectively and these were converted to molar concentrations assuming 1013hPa and 298°K. Table 7 shows dry deposition rate of N and S and wet deposition rates of N and S calculated from the rainwater concentration and the long term mean rainwater amount of 1220.4 mm in Sydney.

Table 9. Average wet and dry and total deposition rates of nitrogen and sulfur in the Sydney metropolitan area

dry deposition meq/m^2/yr		wet deposition meq/m^2/yr		Total deposition meq/m^2/yr	Fraction dry %
SO_2	NO_2	nss-SO_4^{2-}	NO_3^-	N+S	
12.3	32.4	59.1	16.6	120.4	37

In an early study of rainwater acidity in Australia, Avery, (1984) collected rainwater at 7 sites in and around Newcastle N.S.W. about 100km north of Sydney. Samples were collected over a 14 month period during the period January 1981 and March 1982 and were analysed for pH, SO_4^{2-}, NO_3^-, NH_4^+ and Na^+ with pH taken to be the prime indicator of acidity. The study found that there was a significant relationship between H^+ and NO_3^- at all sites whereas a relationship between H^+ and SO_4^{2-} was found only at an inland site. The other sites, nearer the coast, probably had a high proportion of sea salt sulfate and so showed no relationship with H^+. Had nss-sulfate been considered a relationship may have been evident at the other six sites. It is difficult to estimate wet deposition rates of N and S at all sites in this study because nss-sulfate was not calculated. However at the inland site where a relationship between H^+ and SO_4^{2-} was evident it is assumed SO_4^{2-} is only produced from SO_2 oxidation and wet deposition of N and S can be estimated using the long term mean rainfall amount of 1138.5 mm. The results of the estimation show that deposition of N and S was 25 and 32 meq/m^2/yr respectively.

3. Industrial Areas

In Australia several studies have been carried out in areas where electricity is produced in coal fired power stations. One such area is the Hunter Valley situated 150 km north of Sydney, NSW, where two major power stations with an installed generating capacity of 4640 MW are located. The Valley area is about 7500 km^2 and in addition to power generation includes areas of grazing, farming, forestry, national parks and coal mining (Robinson et. al., 1995). A study of acid deposition began in the Central Coast and Hunter Valley area (CCHV study) during December 1992 at 6 six sites, increasing to 9 sites in September 1994. Sampling continued at nine sites until January 1997 and is presently progressing at 3 of the nine sites. For this report three sites have been chosen two, Singleton and Muswellbrook, in the central valley region, close to the power stations and one at Murrurundi about 60 km away.

In an area about 100 km WNW of Sydney, near Lithgow, NSW, there is another area of intensive power generation. At this location electricity is generated in two coal fired thermal power stations with a total installed generating of 2320 MW (Ayers et. al., 1995). The population of the area is about 21,000 divided between a few small town and cities and the area is essentially rural with little heavy industry apart from power generation. A 2 year study (COMRAIN) to measure rainwater composition and concentrations of SO_2, NO_2 and HNO_3 commenced in May 1992. The study consisted of 4 four sites, one in the town of Lithgow and the other three scattered about 20 km from the power stations

(i) Acid Gases.

In the Hunter Valley concentrations of the gaseous species SO_2, NO_2 and HNO_3 were measured over periods of a month using passive samplers (Ferm 1991) so that results were the average gas concentration for the monthly period. Depositions were estimated at each site by combining gas concentrations with the appropriate dry deposition velocity. In this case mixing ratios were converted to molar units and dry deposition velocities provided by Manins et. al., (1996) used here are 0.0021 m/sec for NO_2, 0.0028 m/sec for SO_2 and 0.0090 m/sec for HNO_3. Table 10 has concentrations of HNO_3, NO_2 and SO_2 and dry deposition at the three Hunter valley sampling sites.

Table 10. Annual mean Concentration of sulfur dioxide and nitrogen dioxide at three sites in the Hunter Valley.

Site	HNO_3 (ppbv)	NO_2 (ppbv)	SO_2 (ppbv)	HNO_3 meq/m^2/yr	NO_2 meq/m^2/yr	SO_2 meq/m^2/yr
Murrurundi	0.45	2.0	0.4	5.2	5.4	2.9
Singleton	0.90	6.1	2.1	10.4	16.4	16.1
Muswellbrook	0.96	5.8	4.9	11.1	15.9	36.4

Concentrations of SO_2, NO_2 and HNO_3 were measured using passive samplers over four week periods during the COMRAIN study. Concentrations were converted from mixing units to deposition rates using a pressure of 1013 hPa, 298°K and deposition velocities of 0.0030 m/sec for NO_2 and SO_2 and 0.01 m/sec for HNO_3 (Ayers et. al., 1995). Concentrations have been averaged over the two years for each site and those as well as dry deposition at the four sites are presented in Table 11.

Table 11. Annual mean Concentration of sulfur dioxide and nitrogen dioxide at four sites in the COMRAIN Study.

Site	HNO_3 (ppbv)	NO_2 (ppbv)	SO_2 (ppbv)	HNO_3 meq/m^2/yr	NO_2 meq/m^2/yr	SO_2 Meq/m^2/yr
site 1	1.5	6.2	2.2	28.5	23.2	21.2
site 2	0.49	1.0	0.87	8.5	3.5	6.5
site 3	0.42	1.3	0.63	6.4	4.9	5.6
site 4	0.46	1.2	1.2	8.8	5.3	9.8

(ii) Rainwater

During both the CCHV and COMRAIN studies rainwater samples were collected with an automatic rainwater sampler connected to a tipping bucket raingauge which acts as a sensor for the sampler and also records the total rainfall. After one tip of the raingauge the lid opens and the rain falls into a polythene bottle which contains thymol. Thymol has been used in this and other Australian studies to prevent degradation of ions such as $HCOO^-$, CH_3COO^-, NH_4^+ and PO_4^{3-} by bacterial action (Gillett and Ayers, 1991). Samples were collected on a daily basis from 09:00 to 09:00 each day and sent back to the laboratory where they were analysed for the following parameters :

Conductivity, pH, Na^+, NH_4^+, K^+, Mg^{2+}, Ca^{2+}, Cl^-, NO_3^-, SO_4^{2-}, $HCOO^-$, CH_3COO^-, PO_4^{3-}, $CH_3SO_3^-$, F^- and $(C_2O_4)^{2-}$. Analysis of the ions was by ion chromatography and pH and conductivity were measured by standard methods for rainwater.

Anion and cation sums, with concentrations in μmol/l, are defined as :

$CS = [H^+]+[Na^+]+[K^+]+2[Mg^{2+}]+2[Ca^{2+}]+[NH_4^+]$

$AS = [Cl^-]+[NO_3^-]+2[SO_4^{2-}]+[CH_3SO_3^-]+[HCOO^-]+[CH_3COO^-]+2[C_2O_4^{2-}]$

Since formic and acetic acids are weak acids which may not be fully ionised over the range of pH observed in rainwater the last two terms in the anion sum are evaluated as:

[acid anion] = K*X/([H$^+$]+K)
where :
K = ionisation constant of the acid
X = rainwater content of the dissociated and undissociated acid (eg. [HCOOH]+[HCOO$^-$]

Table 12 shows total deposition of sulfur and nitrogen species at the three sites in the CCHV study and four sites in the COMRAIN study.

Table 12. Volume weighted mean concentrations and pH and depositions of nitrogen and sulfur species in rainwater at three CCHV sites and four COMRAIN sites.

Site	nitrate μeq/l	nss-sulfate μeq/l	nitrate meq/m^2/yr	sulfate meq/m^2/yr	pH (vwm)
COMRAIN sites					
site 1	7.9	15.7	7.3	13.2	4.75
site 2	6.0	6.1	6.0	7.0	4.95
site 3	7.5	7.0	7.1	7.2	4.84
site 4	7.9	10.5	5.6	7.8	4.75
CCHV sites					
Murrurundi	6.6	5.4	5.1	4.1	4.88
Singleton	9.5	19.4	5.3	10.7	4.62
Muswellbrook	8.5	26.6	4.7	14.7	4.50

(iii) Total Deposition

Table 13 shows the deposition rates of N and S, the total deposition of N+S and the fraction of dry deposition at the three CCHV sites and the four COMRAIN sites. The COMRAIN study shows that site I has the higher deposition rate for N + S than the other three sites. Site 1 is located in the town of Lithgow and the higher deposition is probably the results of surface gas emissions from the small city of Lithgow rather than from the power stations (Ayers et al., 1995).

Table 13. Total deposition of nitrogen and sulfur species from gas and rainwater deposition at three sites in the CCHV study and four sites in the COMRAIN Study.

Site	N meq/m^2/yr	S meq/m^2/yr	Total N+S meq/m^2/yr	Percent Dry deposition
COMRAIN sites				
site 1	59.0	34.4	93.4	78
site 2	18.0	13.5	31.5	59
site 3	18.4	12.8	31.2	54
site 4	17.3	17.6	34.9	68
CCHV sites				
Murrurundi	15.7	7.0	22.7	59
Singleton	32.1	26.8	58.9	73
Muswellbrook	31.7	51.1	82.8	77

DISCUSSION

The results show that in remote areas of Australia deposition of nitrogen plus sulfate averages about 23 meq/m^2/yr (Table 5). Studies in remote areas have reported gas concentrations varying from <10pptv for SO_2 and NO_2 at CGBAPS to 0.9 ppbv, 0.8 ppbv and 0.3 ppbv for SO_2, NO_2 and HNO_3 respectively at Charles Point. This results in dry deposition rates for N+S of about <0.1 meq/m^2/yr at CGBAPS and <13 meq/m^2/yr at Charles Point. Combining these dry deposition rates with wet deposition rates of N+S (Table 3) shows that a range of <5 meq/m^2/yr to 37 meq/m^2/yr is possible in remote areas of Australia.

The total deposition of N+S in urban areas studied varied from about 32 meq/m^2/yr in the Latrobe Valley to about 120 meq/m^2/yr in the Sydney metropolitan area. This is a large range of depositions but is expected for two reasons. Since sampling in Sydney was only carried out in the summer periods the measured depositions will be the maximum expected because oxidation of SO_2 and NO_2 is more efficient in the summer period. The other reason for the large range is simply the population of Australian cities which can range from <100,000 to about 3 million..

The four COMRAIN sites and the Murrurundi site in the CCHV study could also be considered to be urban sites. With this assumption urban sites in Australia appear to range from about 30 meq/m^2/yr to about 90 meq/m^2/yr and up to about 120 meq/m^2/yr in larger cities.
In Australia acid deposition has been studied in two areas of major power generation, in the Hunter Valley, NSW (CCHV) and the Lithgow area of N.S.W (COMRAIN). Two of the sites close to power stations in the Hunter Valley have total N+S depositions of about 60-83 meq/m^2/yr compared to about 23 meq/m^2/yr at a site further away from the major sources of SO_2 and NO_2. The COMRAIN study results show that Site 1 had N+S depositions of about 93 meq/m^2/yr and since it was located in the city of Lithgow emissions from motor vehicles and burning of coal for domestic heating is probably responsible for the elevated acid deposition at the site. Sites 2-4 were quite uniform and much lower at <35 meq/m^2/yr indicating that no acidic influence from the power stations could be discerned. The data show that these sites have higher depositions than remote areas but that they fall into the same range as predicted for urban sites as discussed above. There have been few studies of acid deposition carried out near industrial areas in Australia so it is difficult to estimate what range of depositions may be expected.

At the present a large acid deposition study is being carried out around the Mount Isa Mines (MIM) copper/lead/zinc smelter in Mount Isa, Queensland. MIM is a major emitter of SO_2 in Australia. This study comprises 40 sites where SO_2 and NO_2 concentrations are measured on a monthly basis, three automatic rainwater sampling sites to collect daily rainwater samples and four sites to collect aerosol samples on a monthly basis. The study design allows for the determination of deposition velocity both by direct measurement in wet and dry seasons and with an appropriate model. Critical loads will also be determined from soil properties on soil samples collected at the sampling sites. Surface water samples at 25 sites will also be collected twice during the study, at the start and end of the wet season. These samples will be analysed for a full range of ions, and with the aim to see how ions deposited during the dry season are distributed during the wet season. This is the most important acid deposition study undertaken in Australia and will provide important information on deposition and critical loads in industrial areas.

The concept of critical loads developed around the middle of the 1980's. It has been employed to quantify the acidity an ecosystem can tolerate without adverse effects. The idea has been defined in various ways but some early examples are : "the highest load that will not cause chemical changes leading to long-term harmful effects on the most sensitive ecological systems" (Nilsson, 1986). A later definition was expressed by Nilsson and Grennfelt, (1988) and then later endorsed by Hettelingh et. al., (1991) as : a quantitative estimate of an exposure to one or more pollutant below which significant harmful effects on specified sensitive elements of the environment do nor occur according to present knowledge". Critical loads can be used to compare with the measured acid deposition of H^+ or total of N+S to determine if any acidic impact is likely in an ecosystem.

Critical loads have not been determined for many Australian regions. Critical loads have been determined for other areas such as European ecosystems and these can be used as a guide for Australia where no other data exists. Table 14 has critical loads for five sensitivity classes determined for European ecosystems and it shows that the most sensitive areas can tolerate only about 20 meq/m^2/yr of N+S and the most insensitive about 200 meq/m^2/yr. The Table actually has two estimates one from the Stockholm Environment Institute (SEI) and the European Co-ordinating Centre for Effects (CCE), (Chadwick, 1990; Hettelingh et al., 1991).

Table 14. Critical loads for European ecosystems according to SEI, with values according to CCE in parenthesis.

Relative sensitivity class	critical loads (as meq/m^2/yr of H^+)
1	>160 (>200)
2	160 (200)
3	80 (100)
4	40 (50)
5	20 (20)

The discussion above indicates that N+S deposition in remote areas averages about 23 meq/m^2/yr, possibly ranging up to 37 meq/m^2/yr. Although there is little information on critical loads for such areas in Australia examination of Table 14 shows that soils would probably have to be in the most sensitive range to be impacted significantly by acid deposition.

Urban areas in Australia appear to be in the range of 30-90 meq/m^2/yr and possibly up to 120 meq/m^2/yr. Table 14 shows that such depositions would have an effect on soils if they were in

classes 3, 4 or 5 and possibly 2. Again critical loads for such areas in Australia have not been determined so it is difficult to speculate on the area that could be impacted by acid deposition.

Industrial areas, represented essentially by the CCHV, study show that deposition of N+S can be at least in the range of 60–80 meq/m^2/yr at some sites close to the source of gas emissions. The higher deposition sites tend to have the highest proportion of dry deposition for example Singleton and Muswellbrook are 70-80% dry deposition compared with <60% at low deposition sites of COMRAIN site 2 and 3 and Murrurundi in the CCHV study. This probably indicates that the high deposition sites are close to the source of gas and that SO_2 and NO_2 have less time for oxidation to the respective acids. Some estimates of critical loads for the Hunter Valley, in terms of H^+, have been made by Robinson et. al., (1995). They found that critical loads for soil classes I, II, III and IV were 177, 60, 27 and 214 meq H^+/m^2/yr respectively. They also estimated that the area of highest deposition (>50 meq H^+/m^2/yr) only covered an area of about 100 km^2.

CONCLUSIONS

This study shows results of acid deposition in three major ecosystems where studies have taken place in Australia; remote areas, urban areas and industrial areas. Studies have involved measurement of total acidic deposition by measurement of SO_2, HNO_3 and NO_2 concentrations as dry deposition and SO_4^{2-} and NO_3^- in wet deposition. In Australia remote areas have an average deposition of N+S of about of about 23 meq/m^2/yr with a range of <5 meq/m^2/yr to 37 meq/m^2/yr. Urban areas in typified by Sydney metropolitan area have N+S depositions of up to 147 meq/m^2/yr. Other urban areas indicated depositions of N+S were in the range of 30-90 meq/m^2/yr. Industrial areas typified by sites in the CCHV study in the Hunter Valley have a range of N+S depositions in the range of 60-83 meq/m^2/yr. Sites in the Hunter Valley but away from the main source of gas emission are much lower than this at about 25 meq/m^2/yr.

Critical loads have not been determined for many areas in Australia apart from the Hunter Valley. Based on the European experience N+S deposition in most remote areas of the country would be close to the critical load for most sensitive soil type and certainly be below the critical load of the other four soil types.

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ACID RAIN IN INDIA - A STATUS REPORT

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INTRODUCTION

India is one of the oldest civilizations with a kaleidoscopic variety and rich cultural heritage. It has achieved multifaceted socio-economic progress during the last 50 years of its independence. India has become self sufficient in agricultural production and is now the tenth industrialized country in the world. It covers an area of 32,87,263 sq. km. Extending from the snow covered Himalayan heights to tropical rain forests of the south. India is well- marked off from the rest of Asia by mountains and the sea which give the country a distinct geographical entity. Bounded by the Great Himalayas in the north it stretches southwards and at the Tropic of cancer tapers off into the Indian ocean between the Bay of Bengal in the east and Arabian sea on the west. Lying entirely in the northern hemisphere, the main land extends between latitudes 8° 4' and 37°6' north, longitudes 88°4' and 97°25' east and measures about 3214 km from north to south between the extreme latitudes and about 2033 km from east to west between the extreme longitudes. It has a land frontier of about 15,200 km. The total length of the coast line of the main land, Lakshadweep islands and Andaman and Nicobar islands is 7516.6 km[1].

Environmental protection is crucial for sustainable economic development. Conservation, protection and preservation of the environment have been the cornerstone of Indian ethos, culture and traditions and it has been enshrined in the constitution. The salient features of India & the geographic location and demography are presented in Table 1[2].

The locational and physiographic factors have greatly influenced the climatic characteristics of the country and a considerable portion belongs to the sub-tropical zone and as a whole it shares the characteristics of tropical monsoon climate , mainly because of the Himalaya functioning as an effective meteorological barrier.
The four main seasons in the country are as under;

- Winter (December to February)
- Summer (March to May)
- Monsoon (June to September)
- Postmonsoon (October and November)

The annual rainfall towards coastal cities varies from 2000-3000 mm and temperature ranges from 10° C in winter and 42° C in summer. Inland annual rainfall varies from 500-1500 mm and temperature varies from 3° C in winter up to 47° C in summer[3].

The combustion of fossil fuels for domestic requirements, for power generation, in motor vehicles and in industrial processes constitute the principal sources of air pollutant emissions in India. The commonest air pollutants include sulphur dioxide(SO_2), the nitrogen oxides (NO and NO_2, collectively termed NO_x), carbon monoxide (CO), ozone(O_3), suspended particulate matter(SPM) and lead (Pb). Combustion of fossil fuels in stationary sources leads to the production of SO_2,, NO_x and particulates. Both primary particulates in the form of fly ash and secondary particulates such as sulphate and nitrate aerosols are formed in the atmosphere following gas to particle conversion. Domestic solid fuel use, mainly coal and wood are the significant sources of these pollutants in some cities. Petrol fuelled motor vehicles are the principal sources of NO_x, CO and Pb whereas diesel fuelled engines emit significant quantities of particulates and SO_2 in addition to NO_x.

Ozone, a photochemical oxidant and the main constituent of photochemical smog, is not emitted directly from combustion sources, but is formed in the lower atmosphere in the presence of sunlight from NO_x, and volatile organic compounds (VOC's).

The sulphur and nitrogen oxides are the principal precursors of acidic deposition; long range transport of SO_2, NO_x and their corresponding acidic transformation products has been linked to soil and fresh water acidification with consequent adverse impacts on aquatic and terrestrial ecosystems. SO_2, NO_x, O_3 are phytotoxic. O_3 in particular has been implicated in crop losses and forest damage. Impaired visibility and damage to materials(eg. Nylon and rubber), buildings and works of art are also attributed to SO_2 (and acid sulphate aerosols) and O_3[4].

Air quality status in India

As a part of global environmental monitoring systems(GEMS) of WHO and UNEP, monitoring of SO_2, NO_2, SPM and RSPM are carried out on regular basis at three stations in each city with a frequency of 10-12 times in a month round the clock for 24 hours. The gaseous samples are collected four hourly while particulates on eight hourly basis. The figs. 1 through 3 show annual mean concentration trends of SO_2,NO_2 and SPM in major urban centres of India from 1978-1997.

The trend analysis has shown that the suspended particulate matter (SPM) exceeds the CPCB standards in all the cities most of the time throughout the year. The concentration ratio of RSPM fraction (human inhalable particles; RSPM) to the total SPM shows remarkably higher percentage. The concentration of RSPM is invariably higher at the industrial sites signifying the anthropogenic origin of these particles. Polycyclic aromatic hydrocarbons (PAH's) associated with respirable particles at various sites have shown high concentrations. These potentially carcinogenic compounds concentrations exceeded the CPCB standard at Ahmedabad, Calcutta, Delhi, Mumbai, and Nagpur during winter months.

The lead concentrations exceeded the WHO guidelines of 0.5 ug/m^3 in most of the cities except in Chennai, Nagpur and Jaipur. The ambient lead concentrations at Mumbai, Calcutta, Delhi and Kanpur cities show that its maximum concentration levels are two orders of magnitude higher than the WHO guidelines.

Atmospheric Acidification

The natural and antropogsnic emissions of sulphur and nitrogen oxides have a profound influence on the atmospheric acidification. Studies related to air pollution and acid rain constitute an important element of studies on global change.

In the atmosphere, the sulphur and nitrogen oxides undergo complex chemical processes that transform them into their respective acids (H_2SO_4 and HNO_3). The amount of acid produced depends on the atmospheric conditions and the height at which they are emitted, and is termed as wet deposition. The scavenging process (Fig. 4) can be viewed as consisting of following steps.

- Mixing of pollutant and condensed atmospheric water (rain, cloud, snow) within the same air space.
- Attachment of pollutant to atmospheric water
- Physical and /or chemical reaction in aqueous phase
- Delivery of pollutant laden atmospheric water to the earth surface

Acid rain problem is a serious threat to environment in many industrialized countries of the world. The detrimental effects of acid rain include acidification of surface and ground waters

with associated biological consequences, acidification of soils, increased rate of corrosion of building materials and monuments and formation of secondary pollutants, such as ozone that are toxic to human and plants. These effects are to be taken more seriously in India where high economic and population growth rates are being witnessed[5].

Atmospheric Acidification

There are two phases involved in the formation of acids namely gas and liquid phase reactions. In both, SO_2 and oxides of nitrogen are converted to sulphate and nitrate. At present most of the investigators are of the opinion that liquid phase reactions are of considerable importance to gas phase reactions and not much is known about the liquid phase chemical transformation.

The gas phase reactions predominates in the vicinity of emission sources. Oxides can be converted into acid in several ways, usually with the help of a catalyst such as photochemically generated free radicals. Because these radicals are formed under the influence of sunlight sunny weather enhances the rate of conversion to acid and the rate of conversion falls rapidly after sunset. The possible chain of gas phase reactions are listed in Table 2.

The liquid phase reactions predominates at a great distance from the emission source, however, there is divergent views concerning the actual mechanisms involved I the reactions. For SO2 oxidation it is considered essential that reactants are highly soluble, and that trace metal catalysts or strong oxidising agents are present. To date the most accepted chain reaction in liquid phase are shown in Table 2 where it is shown that various oxidation products are ultimately hydrolysed to H_2SO_4.

The pH of rain water is controlled by the carbonate buffer CO_2/H_2CO_3 and normally has a value around 5.6. The natural atmospheric cycle of sulfur, nitrogen and carbon introduce strong acids (H_2SO_4, HNO_3) and weak acids (HCOOH, CH_3COOH) which are sufficient to lower pH of rain water. The low concentration of H^+ ions in the rain water may be due to the neutralization of strong acids (H_2CO_3 and HNO_3) in precipitation by the basic atmospheric particulates which contain alkali and alkaline earth metals as well as gaseous ammonia. This would complement the apparent washout behaviour observed in these events. The marked decrease in SO42 and NO3 is accompanied by similar changes in the Na^+, K^+ Ca^{2+} and Mg^{2+} ions. If these cations were initially present in conjunction with some basic anions, a decrease in their concentration would be followed by an increase in the acidity of the rain. Sequeria in 1982 observed significant association of SO_4^{2-} with Na^+, K^+ and Ca^{2+} and pointed out that the SO2 may be adsorbed on to the particulate matter and react with these to form sulfate salts7. Since large soiled derived particles are more rapidly removed by precipitation, the observed rapid decrease of SO_4^{2-}, NO_3^-, Na^+, K^+, Ca^{2+} and Mg^{2+} may be due to washout. The data collected in this study appears to offer unique information about the relationship between H^+, SO_4^{2-}, NO_3^-, Na^+, K^+, Ca^{2+}, $NH_4^+$and Mg^{2+}. In precipitation the converse relationship between H^+, SO_4^{2-} and NO_3^- concentrations during the initial event and the effect of atmospheric cation particulates in neutralizing the acidity of rain water was observed.

Status of Studies on Acid Rain Assessment

In view of the importance of acid rain assessment several research institutions in India initiated studies and the following are the salient amongst these.

Indian Institute of Tropical Meteorology (IITM), Pune

Meteorology Department of Govt. of India has set-up ten stations spread throughout India as a part of global monitoring network of World Meterological Organization (WMO) to generate

baseline data on rain water covering the following quality parameters pH conductivity, sulphates, nitrates chloride, ammonium, sodium, potassium, calcium, magnesium etc. One of its constituent institutes namely Indian Institute of Tropical Meteorology located in Pune has initiated measurements on atmospheric aerosots in diverse geo- climatic regions during past two decades. IITM scientists have also been active in measurements of average concentrations of major ionic components along with pH in rain water at several locations in the country. These studies have concluded that the precipitation in India is by and large alkaline and the total mineralisation varies from 4 to 40 mg/l. Further, besides sea salt, calcium and sulphate are found to be dominants ions.

Bhabha Atomic Research Center (BARC), Mumbai

BARC is also actively pursuing studies on long term trends of rain water characteristics through monitoring of the ionic composition, pH and conductivity through a monitoring network located at four locations in Mumbai. The studies also encompass halogen geochemical cycles and sea salt deposition in aerosols. The annual average data on precipitation has been used for evaluation of geochemical cycles of the halogens. It has been concluded that halogen concentration in rain water over large areas on the Indian West Coast with high rainfall amounts differed considerably from predicted values.

National Physical Laboratory (NPL), New Delhi

Studies on rainwater chemistry is being undertaken through a Indo-Swedish bilateral collaborative project. Chemical Research & Environmental Needs (CREN) in this joint study by Department of Meteorology and Stockholm University, two wet collectors have been installed at two sites viz. Pune and Mumbai, and is being extended to include 3 additional sites at Agra & Tirupati in India and Kathmandu in Nepal.

The collection of samples began since Sept. 1993 and so far about 150 wet samples and 200 samples of dry deposition have been collected and analysed simultaneously at Pune and Stockholm for pH. Conductivity an conventional anions and cations. The meaningful conclusions could not be drawn yet, as the data for minimum period of three years would be required to analyse and extrapolate the trends.

Other Scientific Groups in India

Other groups in various institutions which are actively engaged in the allied areas in India are as under[8].

Institutions	Research Interest
1. Dayal bag College, Agra	Role of organic acids in acidity of rain water
2. Jaipur University, Jaipur	Chemistry and reaction kinetics of aerosols
3. Jawaharlal Nehru University New Delhi	Role of ozone and other trace gases in aerosols

Status of Acid Rain in India

NEERI is assessing the rain water status in the country since 1987 (Annexure I) The purpose of the study is to know the chemical composition of rain water especially the anionic species as they are the precursors of the various acidic pollutants in the atmosphere.

Sample Collection

The rain water is collected by using glass funnel and polyethylene bottles previously rinsed with double distilled water and collected in the monsoon season. Due precautions are taken to avoid excessive dry. The samples are collected from each dity from 3 to 4 areas to represent the city as a whole. The samples collected are filtered through Whatman filter and the filtrate is preserved at 4C and the clank samples of distilled water is also processed in the same way and preserved at 4C. The major cities selected for the purpose are Ahmedabad, Calcutta, Chennai, Delhi, Hyderabad, Jaipur, Ksnpur, Kochi, Mumbai and Nagpur. The rain water analysis is carried out for physical parameters such as pH, conductivity while chemical parameters included anions viz. Fluoride, Chloride, phosphate, nitrate, sulphate and cations viz sodium, potassium, calcium, magnesium and ammonium.

Parameters

The physical parameters such as pri and conductivity is measured within 24 hrs. The anions are measures by using ion chromatograph (Dionex DX-100). Typical chromatograph showing separate anions in samples and standards are shown in Fig. 5. Sodium and potassium are determined by flame photometer. The calcium, magnesium and ammonium are measured by colorimetry.

Findings

The lowest pH values recorded for the individual cities for 1991 to 1996 have been presented in Table 3. The minimum rain water pH recorded at Kochi and Delhi were 4.8 during 1991 and 1994 respectively. Further, it could be seen that at Kocki the acid rain phenomenon occurred during 1991 and in other places the pH was above 5.6. During 1994 the acid rain phenomenon occurred at Delhi, Kochi , Calcutta and Ahmadabad, as the pH was less than 5.6. Perusal of Table 3 showed minimum pH of 4.8 at Delhi while Ahmadabad showed a pH of 5.0 and at Calcutta and Kochi the pH was marginally less (pH 5.5). These results definitely indicate that the occurrence of acid rain phenomena has increased from one city to four cities during 1994 indicating that the pollution control of acidic gases must be undertaken. During 1996 in general the pH was never less than 5.6 but cities like Delhi, Hydrabad showed pH 5.7 and 5.6 respectively, thereby demanding that pollution control steps must be undertaken so as to avoid future acid rain phenomenon.

Fig. 6 map showing the lowest pH recorded during 1991-1996 in selected cities in India.

The average conductivity ranged from 19 to 104 uS/cm for the year 1991 to 1996 (Table 4 through 6) with a single minimum value of 3 uS/cm at Jaipur and single maximum value of 415 uS/cm was observed at Kochi.

The average concentration of sulphates was observed to be (3.4-21 mg/l) for the 3 years (1991, 1994 and 1996). The sulphate concentration as high as 125 mg/l was recorded during 1991 at Kochi though the average value was only 15 mg/l. No definite trends can be seen however the results indicate in general the sulphate concentration is decreasing from 1991 onwards.

Tables 4 through 6 project the average nitrate concentration in rain water for the years 1991, 1994 and 1996 range from 0.4 – 5.5 mg/l. The contribution of nitrates for cities like Mumbai, Calcutta and Delhi could be grouped in the range of 3.3 – 5.5 mg/l while Ahmedabad, Hyderabad, Jaipur, Kanpur and Kochi could be grouped in second category while Nagpur showed minimum nitrate concentration less than 1 mg/l.

The annual deposition rates were calculated for the different cities in India (Table 7). The perusal of table shows that the annual deposition of sulphate was minimum at Jaipur (1.6 g/m^2) while cities like Calcutta, Kochi and Mumbai showed deposition of above (10 g/m^2), Mumbai being the maximum (28.7 g/m^2).The deposition rate for nitrate was maximum at Mumbai (9.7 g/m^2) while other cities showed less than 5 g/m^2 minimum being 0.34 at Jaipur.

In general no significant variation in the concentration of chlorides was observed. Even in the case of coastal cities like Mumbai and Kochi, marginally higher chlorides were observed but these levels did not indicate significant variation.

All the major anions and cations such as SO_4^{2-}, NO_3^-, Cl^-, Na^+, K^+, Ca^{2+}, Mg^{2+} and NH_4^+ have also been studied. The data were evaluated for anions and cations balance which indicates that the charge balance is not neutral in most of the events.

Conclusions

The average rain water pH is in the range of 6.0 to 7.9 at all major ten cities viz. Ahmedabad, Calcutta, Chennai, Delhi, Hyderabad, Jaipur, Kanpur, Kochi, Mumbai and Nagpur. Initial rain having a pH of 4.8n was recorded at Kochi and Delhi during 1991 and 1994 indicating that acid rain phenomenon has occurred at Kochi and Delhi. Further during 1994 Ahmedabad and Calcutta also showed pH marginally less than 5.6.

The situation is likely to worsen in near future with the increased emphasis on thermal power generation including plans for several super thermal power stations resulting in an increase in sulphur and nitrogen oxide levels in the atmosphere and consequently dry and/or wet deposition of these acidic substances. Emissions of NO_2 is also likely to rise with the growth in road traffic and the operations of fertilizer plants, refineries, petro-chemical and other industries. It has been estimated that the total load of acidic pollutants mainly SO_2 and NO_2 would be 245,000 tonnes per annum (TPA) and 227,000 TPA respectively for 3 megacities in India viz., Calcutta, Delhi and Mumbai by 2000.

The alkaline properties of high level soil particulates in the air, particularly in central, north and north-west India have a neutralizing effect on the acidic components moderating the acidity in rain water[10]. Although there apparently is no major threat of acid rain in India, yet its occurrence in future due to increasing inventories of sulphur and nitrogen in the atmosphere cannot be ruled out.

The concentration of anionic species has showed increasing trend in almost all major urban industrial cities of India. The concentration of acidic precursor should therefore be controlled to prevent its occurrence in future. The lowering of pH of rain water below 5.6 is not the only indicator of pollution of acidic gases. The interrelationship of cationic and anionic species and presence of high concentration of SPM, RSPM specially in tropical region needs further investigation.
There is need to continue acid rain studies by strengthening a network of institutions particularly in Asian Region to extend the studies to include bio-geothermal cycles of sulphur, nitrogen, hydrogens, organic acids and other trace gases that critically affect acid rain phenomenon.

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Annexure 1

The National Environmental Engineering Research Institute (NEERI) is a premier R&D organisation in the domain of Environmental Science and Technology in India with its headquarters at Nagpur, a city in the centre of India. It is one of the National Laboratories within the Council of Scientific and Industrial Research, Government of India.

The institute has nine Zonal laboratories across the country through which it participates in the resolution of regional environmental problems. Around 600 scientific and technical staff with rich blend of multidisciplinary expertise viz., physical, chemical, biological sciences and engineering are working in the Institute and provide consultations to international organisations as member of expert committees.

Besides conducting frontline research in the domain of environmental science and technology, the institute disseminates its research through consulting services thereby providing optimal solutions to environmental problems faced by the industries, municipalities, urban and rural development authorities and pollution control organisations in the country. It also renders human resource development services to its clients and actively participates in social missions. The major capabilities of the institute are as under:

- Environmental Monitoring
- Environmental Biotechnology
- Hazardous Waste Management
- Environmental Systems Design, Modelling and Optimization
- Environmental Impact and Risk Assessment
- Environmental Policy Analysis

The data and analysis reported hereunder is drawn from various studies conducted by this institute.

Table 2. The Possible Gas and Liquid Phase Reactions

Gas Phase Reactions

$OH^- + SO_2$	----------> HSO_3^-	..... (1)
$HSO_3^- + O_2$	----------> HSO_5^-	..... (2)
$HSO_5^- + NO$	----------> $[HSO_4^- + NO_2]$	..... (3)
NO_2	---hv-------> $NO + O^·$	..... (4)
$O^· + O_2$	----------> O_3	..... (5)
$NO + O_3$	----------> $NO_2 + O_2$	..... (6)
O_3	----------> $O^· + O_2$	..... (7)
$O^· + H_2O$	----------> $2OH^-$	..... (8)
$OH^- + CO$	----------> $CO_2 + H^·$	..... (9)
$H^· + O_2$	----------> HO_2	..... (10)
$HO_2 + NO$	----------> $NO_2 + OH^-$	..... (11)

Liquid Phase Reactions

$SO_3^- + M^+$	----------> $SO_3 + M^·$	..... (12)
M = Metal		
$SO_3^- + O_2$	----------> SO_5^-	..... (13)
$SO^·_6 + SO_3$	----------> $SO_5 + SO_3$	..... (14)
$SO_3^- + HSO_6^-$	----------> $HSO_4^- + SO_4^-$	..... (15)
$SO_3^- + SO_5^-$	----------> $S_2O_6^- + O_2$	..... (16)

Table 3. Lowest pH Recorded in Rain Water for Different Cities of India

Sl.No.	City/Year	pH 1991	1992	1993	1994	1995	1996
1.	Ahamedabad	6.1	5.7	5.7	5.0	6.3	7.0
2.	Calcutta	6.1	6.5	6.1	5.5	6.1	6.1
3.	Chennai	6.1	5.9	6.2	6.2	-	-
4.	Delhi	6.1	5.6	5.4	4.8	5.2	5.7
5.	Hyderabad	7.1	6.2	5.5	5.8	6.0	5.6
6.	Jaipur	6.4	5.8	5.5	5.8	6.0	5.6
7.	Kanpur	7.1	6.0	5.7	6.8	6.1	7.6
8.	Kochi	4.8	5.6	5.7	5.5	6.4	5.9
9.	Mumbai	6.4	5.9	6.9	5.6	6.8	6.7
10.	Nagpur	6.1	6.1	6.1	6.1	6.1	6.2

Table 4. Chemical Characteristics : Rain Water Monsoon 1991

City	pH	Conductivity µS/cm	Sulphates	Chlorides mg/l	Nitrates
Ahamedabad	6.3 (6.1-6.6)	100 (27-154)	21 (4-34)	14 (3-21)	1 (0.7-1.7)
Calcutta	6.4 (6.1-6.8)	45 (23-83)	6 (2-14)	7 (2-11)	4 (2-8)
Chennai	6.2 (6.1-6.7)	33 (7-101)	8 (08-30)	12 (5-15)	0.8 (0.2-3.4)
Delhi	6.4 (6.1-6.8)	19 (5-40)	5.5 (2.6-12)	4 (2-6.8)	3 (2-6)

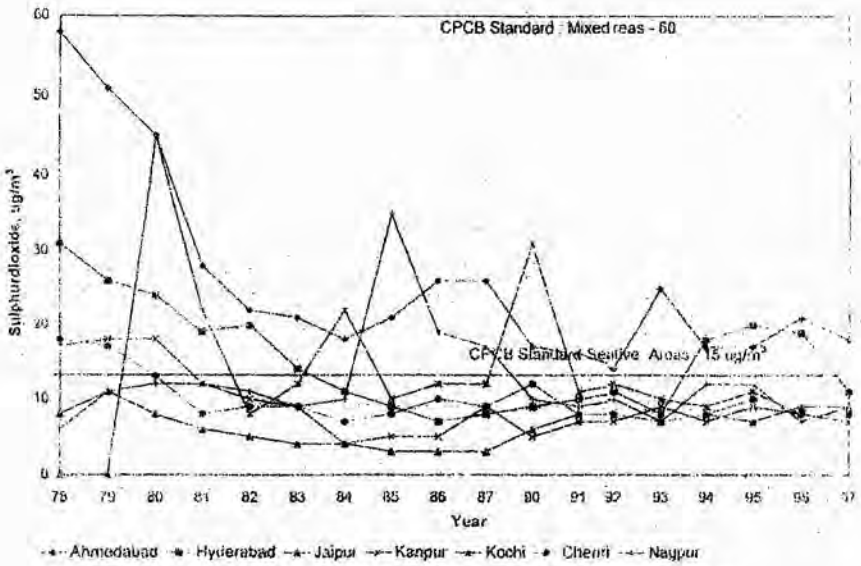


Fig.1: Annual Mean Concentration Trends of SO_2 in MajoUrban Centres

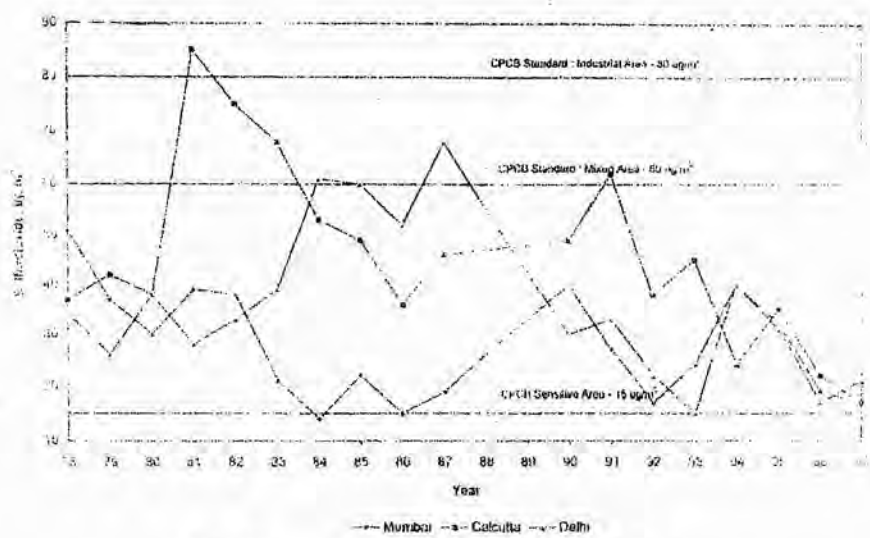


Fig. 1-1: Annual Mean Concentration of SO_2 in Megacities

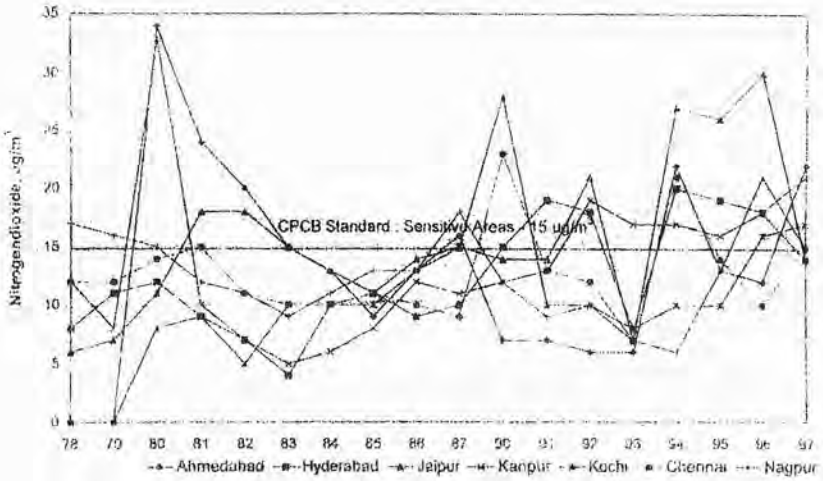


Fig 2:Annual Mean Concentration Trends of NO_2 in Major Urban Centres

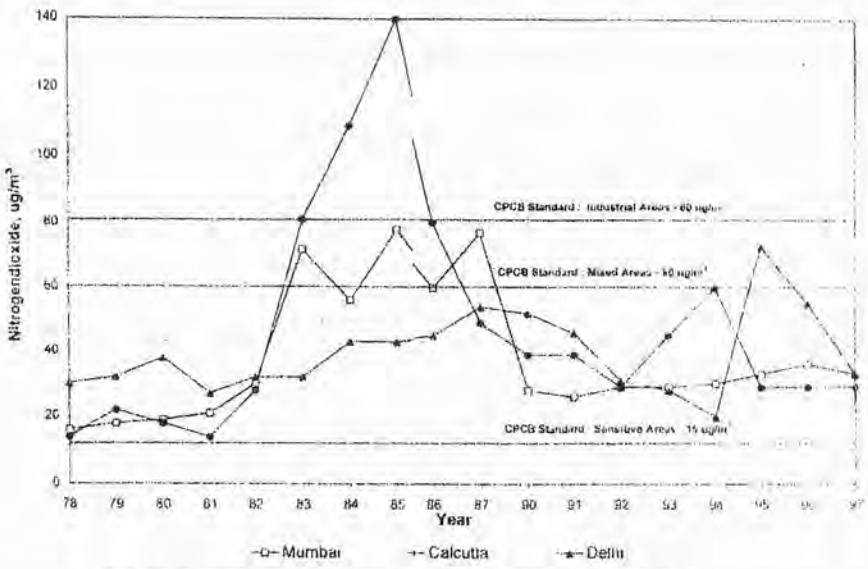


Fig 3 : Annual Mean Concentratin Trends of NO_2 in Megacities

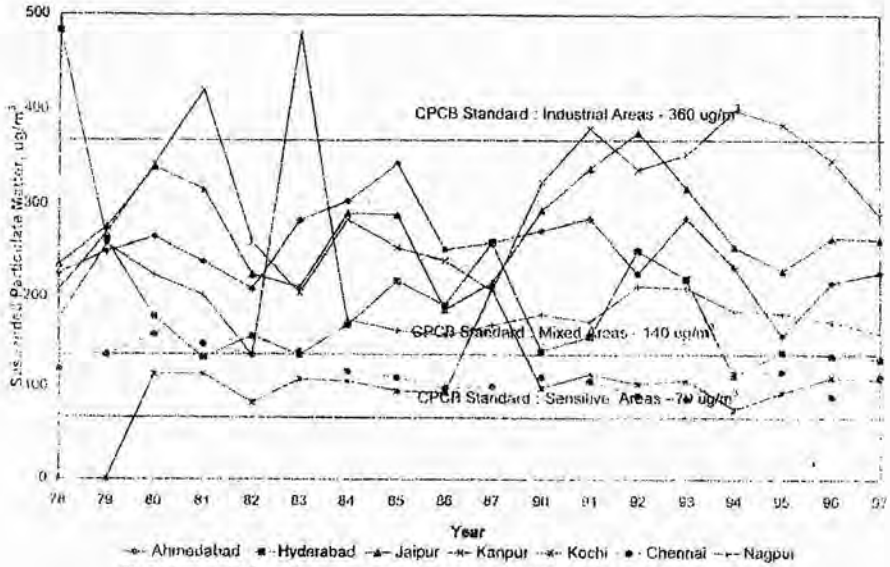


Fig.3: Annual Mean Concentration Trends of SPM in Major Urban Centres

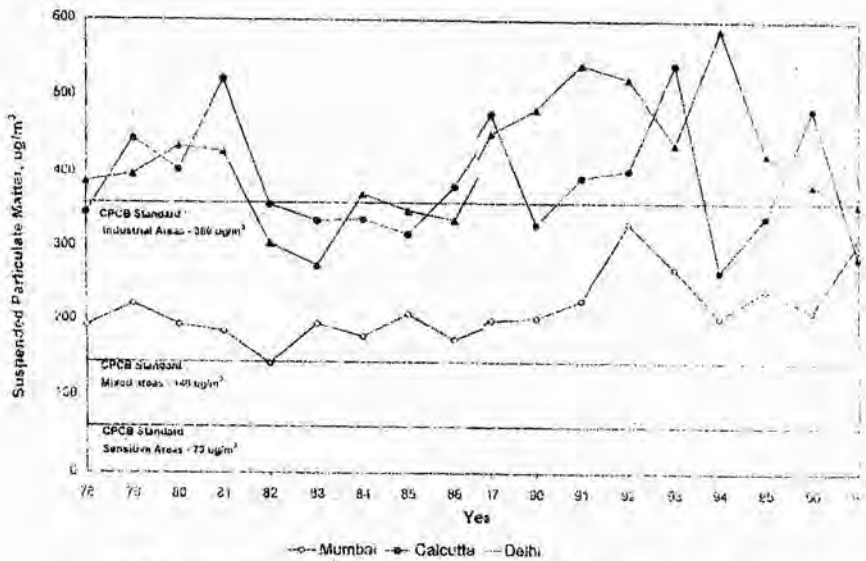


Fig.3.1 : Annual Mean Concentration Trend of SPM in Megacities

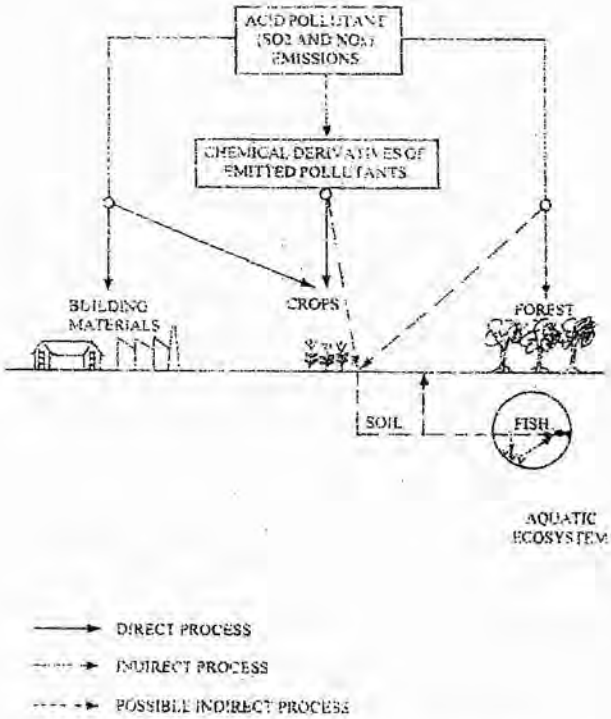
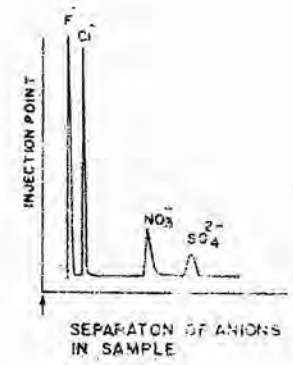


FIG. 4 ATMOSPHERIC SCAVENGING PROCESS



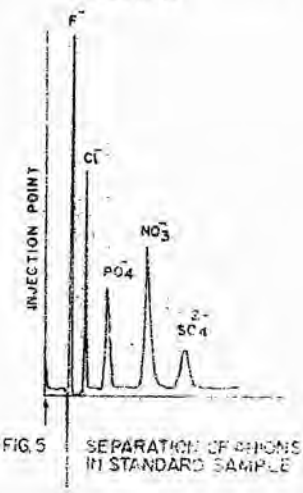


FIG. 5 SEPARATION OF ANIONS IN STANDARD SAMPLE

Fig. 6 Lowest pH Recorded During 1991 - 1996 in Selected Cities of India

COUNTRY REPORT ON ACID RAIN MONITORING AND AIR QUALITY MONITORING IN PAKISTAN

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The word acidification in connection with long range atmospheric deposition of acid substances was probably not familiar till early 1960s, however, the term was coined by Robert Angus Smith of U.K in 1872 when he discovered a link between blackened skies over industrial Manchester and highly acidic rainfall.

Later the detrimental effects of acid depositions on buildings, human health and vegetation could be observed in large areas of Europe and Eastern regions of North America. Other most common examples are, eating away of the beautiful monument of Taj Mahal in Agra (India) and a German Monument found at the Hester Castle is more or less deem eaten away by the acid rain The atmospheric CO_2 reacts with water to produce carbonic acid.

The acidity, though mild is still sufficient to dissolve minerals in the earth's crust and make them available to plant life. The volcanic eruption , forest fires and other similar natural phenomena also contribute to the natural sources of acidity. But it is the contribution of SO_2, NO_2 etc. from anthropogenic activities that disturbs the acid balance and converts natural and mildly acidic rain into precipitation with far reaching environmental consequences. The emission of sulfur and nitrogen oxides into the atmosphere are eventually converted into H_2SO_4 and HNO_3 droplet due to a series of Photochemical reactions.

The droplets are partly neutralized with bases (Lime and NH_3). These salts, H_2SO_4 and HNO_3 along with HCl released into the atmosphere by different sources and the natural HCl emission give rise to acidic precipitation, which is popularly known as ACID RAIN. The acid rain represents one of the major consequences of air pollution because of large SO_2 and NO_2 emission from big industrial areas into the atmosphere. The longer these oxides remain in the atmosphere the greater are chances of their oxidation to H_2SO_4 and HNO_3 by various photochemical and catalytic chemical reactions acid rain may cause extensive damage to various ecosystems and materials such as water, stone, steel, paints, corrosion to metals and above all mortality from respiratory diseases.

Environmental pollution has not been considered as an important issue in Pakistan as it should be during last 20 years. Although the problem is in consideration over the entire globe, has not attained remarkable attention in the country. Industrialization, trend towards science and technology, increase in population at a rapid rate, urbanization and upgrading of living standard together contribute to the environmental pollution.

Geographically Pakistan lies on 24N and 37N latitude and between 61E and 75.5E longitude. The Chinese territory is situated in the North. On the west low dry hills separate Pakistan from Afghanistan. In the south-west, Pakistan has a common frontier with Iran. On the east it is bounded by the Indian State and Arabian sea lies in the south of our country which is part of the Indian Ocean. Pakistan is located in semiarid zone. However, diversity in climatic condition is observed all over the country. About 59% of total area consist of mountains and plateau regions and desert. Only 5% area is occupied by forest while 3.8% of area comprises of pastures and grasslands. Pakistan basically is an agricultural country but the trend towards industrialization is increasing day by day. The increasing population, urbanization etc are creating social problems in addition to deterioration of environment due to human activities. It can also be stated that like other countries of third world the environment of Pakistan is also being polluted at a rapid rate due to growing

population, lack of resources and poor economic conditions. The uplanned industries are being developed in Pakistan over a large scale and at a quite higher speed without sufficient number of treatment plants therefore, the gaseous, liquid and solid wastes are not being disposed off properly. The use of fertilizers, pesticides, etc is inevitable in Pakistan, being as an agricultural country. But lack of knowledge and education has resulted in the adverse effects. The main causes of air pollution are industries, vehicles, smoke, power-plants, agriculture and domestic wastes. Estimated air pollutants from various economic sectors in last thirty years can be seen in Table No.1

TABLE 1. ESTIMATED AIR POLLUTANTS FROM VARIOUS ECONOMIC SECTORS

Sector	1977/78			1987/88			1997/98		
	CO_2	SO_2	NO_x	CO_2	SO_2	NO_x	CO_2	SO_2	NO_x
Industry	12,308	19	n/a	26,680	423	n/a	53,429	928	n/a
Transport	7,068	52	n/a	10,254	57	n/a	18,987	105	n/a
Power	3,640	4	3	11,216	95	n/a	53,062	996	76
Domestic	16,601	n/a		24,054	16	n/a	3,398	40	n/a
Agriculture	845	5	n/a	4,490	13	n/a	6,368	40	n/a
Commercial	1,726	11	n/a	2,587	13	n/a	4,261	25	n/a

Source: NCS Sector Paper on Energy
n/a: not applicable

The important industries of Pakistan include textile, sugar, fertilizers, leather, paper, pharmaceuticals, Chemicals, oil refinery, power plants, etc. All these industries add thousands of tons of smoke and smog into the atmosphere. An example of annual emissions of air pollutants in one of the big cities has been given in Table No.2.

TABLE 2. ANNUAL EMISSIONS OF AIR POLLUTANTS (in tonnes) IN LAHORE 1985

SOURCE	Particulates	SO_2	CO	Hydrocarbons	NO_2	Aldehydes
Motor vehicles	2,014	1,377	123,054	29,536	14,565	209
Railway	171	756	657	447	1,878	26
Natural gas	54	5	193	51	1,553	-
Wood,Coal, Solid Wastes	1,119	302	4,622	1,569	3,424	-
Industrial unit	4,406	358	285	1,010	162	-
TotalEmission	7,764	2,798	128,811	32,613	21,582	235

Source: NCS Sector Paper on Municipal Discharges by Dr. Nawaz Tariq & Waris Ali

The city is particularly important, as in the near vicinities one of the most important crop- rice is cultivated. It can be easily understood how much the environment around the factories has got polluted.

In Multan, the fertilizer industries are the major sources of air pollution. A thick yellow to brown smoke is produced which mainly consists of NO_2 in addition to ammonia and hydrofluoric acid, while the textile and paper industries of Faisalabad and Peshawar contribute in the pollution by adding SO_2, Methane, CO fluorine and cotton lint. In another recent study conducted by Asrar (1996) on pollutants of Quetta valley, though does not come under the heading of acid rain directly,

yet it gives a lot of information about the vehicular traffic which is one of the causes of acidification of the environment and its effects on vegetation and human health.

After the industrial revolution the atmosphere has been destroyed in several ways and to a large extent, for example, after the revolution CO_2 concentration has increased to 348 ppm from 275 ppm i.e. an amount of 50,000/- tons is added to the atmosphere every day which is partly absorbed by the sea and vegetation, while rest is responsible for the green house effect, similarly the oxides of sulfur and nitrogen are responsible for the acid rain, however, no threatening sign of acidity of rain water is observed in Pakistan , which might be due to very intense rainfall in a short period of time in most parts of the country. The high intensity of rain probably lowers down the concentration of impurities of the environment and no remarkable effects due to acidification are observed.

Each habitat or ecosystem has its own threshold for acid deposition, beyond which damage occurs. Areas are affected according to their ability to neutralize increased acidic input. Certain ecosystems cannot tolerate any amount of increased acidity. They are generally away from the equator others may be relatively tolerant. The natural acidity of rainfall is a source of valuable nutrients for plant growth. However, any drastic change in pH is detected by the plants and animals and is indicated by their elimination. Plants and Animals can, therefore, be referred to as Biological Indicators. Pine trees for example, do not flourish in SO_2 polluted areas. The zoo-plankton and the phyto-plankton are also indicator of acidity (Most of the organisms survive at a pH 7.5 to 6.5. Any decrease in pH is indicated by the death of organism. As for example at pH 6 sensitive insects, plants, snails, mollusks die. At pH 5-4.5 white fish, perch, eel etc. die. While still at a lower pH some insensitive, insects certain plants and mosses may survive). In addition to biological indicators, the analysis of water i.e. pH and electrical conductivity determination give a direct measure of rain water acidity. For very precise and quick results, Ambient air monitoring devices are used and air samples are collected at various heights. But these practices are not common in our country as no significant amount of rain acidification have been detected till now. The problem is not taken into consideration seriously because there is no serious threat of acid rain in the near future. Following are the few and major problems encountered:

1. Lack of education and trained staff to conduct world class research is one of the major constraints in this field in Pakistan.
2. Acute lack of funding and resources.
3. Lack of technical and job facilities.
4. Lack of commitment on the part of those who have jobs.
5. Lack of direction.
6. Lack of co-operation between industrialists and Govt. organizations.
7. Lack of co-operation between research organizations and user groups.
8. Non-involvement of private sectors in national research initiatives.
9. Proper rules and regulations declared and implemented for waste disposal. Lack of respect for the law and lack of political commitment to enact and enforce it.
10. Lack of awareness in masses about proper handling of vehicles and other machines and equipment that are a basic source of environmental pollution.
11. Administrative agencies and the judiciary lack awareness of environmental hazards and risk.
12. Non scientific and bureaucratic leadership.

As already mentioned there is little or no threat of acid rain in near future, however, long term effects can be expected. Therefore, a few recommendations are given in this account to avoid any such forthcoming situation.

1. Reduce the use of fuel and energy to the maximum possible extent. Minimize the use of coal and petroleum as fuel and encourage the use of solar energy and biogas.

2. Electrostatic precipitators and scrubbers should be used in most of the industries that can capture particulate matter before it is discharged.
3. The mobile sources of emission i.e. the vehicles should be well tuned and maintained.
4. Use of coal to produce electricity should be reduced or at least use of sub standard coal containing sulfur and other impurities would be discouraged.Instead hydal and solar energies should be encouraged.
5. The residential sectors should be separated from the industrial areas.
6. Proper sites for the factories and power stations according to speed and direction of wind should be selected so that the discharges are not blown towards the residential areas.
7. Laws should be enforced to recycle the gaseous discharges so that minimum wastes are added to the atmosphere.
8. Like all other developed and developing countries limits for the emission of pollutants should be demarcated and any violation should be strictly checked otherwise penalized. It is necessary to shift industries towards producing more with fewer inputs towards clean technology and towards pollution abatement. It will add about 4% to the cost of industrialization but will save a thousand times for the coming generations by avoiding degradation of ecosystems.

To avoid acid rain in Pakistan some measures should be taken necessarily. The areas that need attention include the development of treatment plants and strict implementation of rules. Treatment plants should be maintained along with the factories so that the pollutants are transformed into non-injurious forms before they are emitted.
Moreover, afforestation is an applicable and important step that can help to avoid any danger of rain acidification, if present.

Present Status: The physical framework of Pakistan is composed of two major physiographic regions:

1. The western highlands that extend from the Makran Coast in the south to Pamir Plateau in the north covering most of Baluchistan, NWFP, the Northern areas and a part of the Punjab.
2. The Indus plains that have been formed by the alluvium laid down by the Indus and its tributaries. It is obvious from the brief account of PakistanÆs geography that distribution of population is not even throughout the country. The Indus plain including most of the Punjab and Sindh province is most densely populated area.

However, the mountains are scarcely populated. The cities that are thickly populated are facing sever problems such as shortage of residential areas, traffic difficulties and lack of facilities like education, employment, medicinal facilities and above all day by day increasing pollution. Hence, pollution being a local problem of the major cities of Pakistan does not extend all over the country.

Table No.3 indicates the trend of urbanization in Pakistan during the last 30 years. The figures are according to the census of 1971-72 and that of 1981-82.
Now-a-days census is in progress in Pakistan therefore, the latest figures are not yet available.

TABLE 3. POPULATION OF SOME BIG CITIES.

Name of City	Census 1972(000)	Census 1981(000)	% increase 72-81
Karachi	3515	5208	45.18
Lahore	2170	2953	34.65
Faisalabad	823	1104	32.69
Rawalpindi	615	795	31.06
Hyderabad	629	752	28.39
Multan	539	732	35.44
Gujranwala	324	659	84.26
Peshawar	273	566	103.30
Sialkot	204	302	45.12
Sargodha	200	291	47.00
Quetta	158	286	80.38
Islamabad	77	204	161.00

Source: Population Census of Pakistan ,1961, 1972, 1981.

The study of above mentioned figures of some cities in Pakistan from 1972-81 has gone considerably higher. e.g. the pop. of Islamabad in 1972 was 77,000, but in 1981 it has increased more than 200,000 and this increases is 161.04% more than the population figures of 1972. It can therefore, be concluded that the conditions would have been further aggravated instead of being improved. Urbanization in Pakistan has progressed appreciably. Still Pakistan is for behind and the gap between Pakistan's urban population and that of world has increased rather than decreased and is 16% less than that of world average. A table indicating the total urban and rural population and the % ages in Pakistan are given below in the table.

TABLE 4. PAKISTAN-TOTAL RURAL AND URBAN POPULATION (in thousands) AND RURAL AND URBAN POPULATION AS PERCENTAGE OF TOTAL POPULATION 1901-81

Census Year	Total	Rural	Urban	% Total Population	
				Rural	Urban
1901	16576	14957	1619	90.2	9.8
1911	19382	17693	1689	91.3	8.7
1921	21109	19051	2058	90.2	9.8
1931	23542	20773	2769	88.2	11.8
1941	28282	25267	4015	85.8	14.2
1951	33740	27721	6019	82.2	17.8
1961	42880	33226	9654	77.5	22.5
1972	65309	47976	17333	73.5	26.5
1981	84254	60412	23842	71.7	28.3

Source: Anwar, 1993.

It is, therefore, important that the problems of increasing air pollution should be settled locally and should be emphasized at this stage before it extends from the smaller scale to a larger scale and deteriorates the environment of the entire state.

Inter country co-operation.

It is well known that acid rain-fall may occur at a place far away may be even 500 km û 1000 km from the sources of pollutants. Some events of acid rainfall in Sweden and Canada have been

UK and USA. Also certain events were reported in Pakistan at Quetta, Karachi and Islamabad. Which were thought to be the result of Iraq-Kuwait crisis in 1992. The major part of Pakistan is dominated by dry climate. The rainfall in Pakistan is controlled by three major factors.

1. The Monsoon winds which enter in Pakistan after crossing India, they usually reach Pakistan in July and continue to blow up to September. Most of the rainfall that takes place in Pakistan from July to September is from the Monsoons. Since these winds come into Pakistan from the east, they slow a possibility of carrying pollutants while crossing the industrial zone of India. These winds travel at a height of 1000 to 1500 m and no remarkable effect has been observed seen up until now, however, this possibility cannot be completely ignored.

2. The Western Depression enters Pakistan from the West after passing through Iran and Afghanistan. They bring a small amount of rainfall to Pakistan as most of their moisture is robbed on their long land Journey. The onslaught of the Westerlies begins in December and continues in full strength up to March. Therefore, the polluting agents from the neighbouring countries can be a cause of any environmental disturbance.

1. Rainfall from thunderstorms:
There are two periods of thunderstorms in Pakistan April-June and October-November. During these periods thunderstorms caused by convection bring sporadic and localised rainfall. Most of the rainfall is confined to the Northern mountains while over major part of Sindh and Balochistan October and November are the driest months. All the climatic conditions should be kept in mind at the time of development of industries for example the development of industrial zones along the Motor Way recently build in the country. These industrial zones should be planned in the way not to disturb the environment to the least possible extent.

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MONITORING OF ACID RAIN/FOG IN A CLOUD FOREST AT HORTON PLAINS IN SRI LANKA

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INTRODUCTION

Water is essential for animal as well as plant life. Considering its importance, much of the attention has been given in the past to study the water quantity issues and not the quality. However, studies of water quality aspects have also became important at present as a result of negative impacts of industrialization and the intensification of agriculture. This trend is also present in Sri Lanka, where number of industrial zones have been established recently. In addition, the rapid increase of vehicles in the country during last two decades could add considerable amount of undesirable gases to the environment. All this activities may lead to the loading of atmosphere with undesirable gases, such as carbon dioxide, carbon monoxide, sulfur dioxide, nitrogen dioxide, etc. thiough, comparatively, the industrialized countries may emit substantial quantities of such gases. However, atmospheric pollution in other countries in the region may also can have some influence on Sri Lanka since there are no boundaries as far as environment is concerned.

One of the important indicators of the environmental is the quality of rainfall. Rain is naturally acidic with pH of 5.6 to 6.0. If the pH values is lower than the natural condition, it is known as wet acidic precipitation.. The acid rain condition occur mainly due to various types of gases and particles emitted to the environment. Many adverse environment effects have been attribute to acid rain, including damage to lakes, streams, ground water, forests, agriculture, human health etc.

Horton plain is one of the most important watershed in Sri Lanka, from which the tributaries of three major rivers originates, namely, Mahaweli, Kelani and Walawe. Water quality changes in this area will have serious implications for the water resources of the country. Death of natural forests in the Horton Plains has also been a concern among the scientists in recent times (Balasubramanium et al, 1990). Atmospheric pollution is one of the causes which could cause this problem, and hence is important to assess the quality of the rain water. It has also been shown that the pollutants in fog is substantially higher than rain water (Fowler et al, 1989). Since the Horton Plains is a cloud forests, the monitoring of fog water quality may also provide information on the pollution status of the atmosphere.

Since there has been hardly any work carried out in Sri Lanka with regard to the atmospheric water quality, specially in the upper catchments areas, this study was conducted with the objective of determining the quality of rain water, cloud water, throughfall and stream water in the cloud forest of Horton Plains.

MATERIALS AND METHODS

Study site

This study was carried out at Horton Plains which is located in the Eastern edge of the wet zone and experience an annual average of 2150 mm of rainfall (Gunawardena et al.,1997). At 2100m amsl, the site forms part of an extensive, undulating plateau which supports 8% (3160 ha) of Sri

Lanka's remaining natural montane forest and the grassland. Weather condition in this area is dominated by continuous and, at times gale-strength winds, with persistent cloud cover. The major tributaries of Sri Lanka 's most important rivers such as the Mahaweli, Kelani and Walawe originates from this uplands.

Collection of water samples

Rainfall, throughfall, and stream water samples were collected from Horton plains at weekly intervals from November 1995 to October 1996. Plastic buckets were kept on the weather tower at 20 m above the ground level and under trees to collect rainfall and throughfall respectively. Grab sampling was done to collect stream water. A fog water collector was designed and constructed to collect cloud water, which was made using only plastic and glass materials to prevent metallic contamination. When horizontally fog goes through the nylon threads of the fog collector bigger water droplets are formed and falls in to a glass funnel which is connected to a polythene sampling bag via a plastic tube. The fog water collector arrangement was installed 20 m above the ground level on the Weather tower at the Horton plains. The monitoring of fog was commenced in February 1996 and continued till October 1996. All these water samples were transferred to polythene bags and brought to Peradeniya for chemical analysis. Samples were kept in a deep freezer until the analysis were carried out.
Wind direction data from beginning of November 1993 to end of October 1996 were obtained from the meteorological station located in Horton Plains.

Analysis of water samples

Analysis were carried out to quantify , Nitrate Nitrogen (NO_3-N), Ammonium Nitrogen (NH_4-N) by using colorimetric method whilst turbidimetric method was used to determine Sulfate Sulfur (SO_4-S) quantity in the sample. pH and EC of the water samples were measured using standard pH and conductivity meters.

RESULTS AND DISCUSSION

Quality of rain water

The values of water quality parameters for rain collected at the Horton Plains for the period from November 1995 to October 1996 are shown in Figure 1-a, 1-b and 1-c . The values of pH varied between 5.37 to 7.47. The sulfate concentration of rain water varied from 0 to 3.39mg/l. The NO_3-N concentration had a range from 0 to 3.54 mg/l. High concentration of sulfate and NO_3-N indicated the contamination of rain with sulfur and nitrate. The total dissolved solids in the rain water samples are very low as shown by very low electrical conductivity values.

Quality of fog

Figures 2-a, 2-b and 2-c show the pH, EC, NO_3-N, NH_4-N and SO_4-S of the fog samples collected from mid February to October 1996. pH ranged from 6.52 to 3.88. The highest values observed for NO_3-N, NH_4-N and SO_4-S were 10.23, 5.09 and 9.4 mg/l respectively. Concentrations of all three chemical parameters, acidity and EC of fog were considerably higher than rain. This indicates that the risk of acid precipitation is more due to fog compared to rainfall. This high levels of acidic conditions can cause adverse impacts on trees.

The high concentration of chemicals in fog with compared to rain is due to the high specific area of the fog drip (Calder, 1993). Rain drop has an average diameter of 0.5 mm, whereas the average

diameter of fog is less than 0.05mm. More chemicals can adhere to the outer surface of fog compared to rainfall of same volume.

The lowest value of pH, ie. 3.88, was recorded between 23rd April to 2nd May 1996. In the previous week, pH value was 3.89. This indicate that the average acidity remains as 3.89 for a period of two weeks as shown in Figure 2-a. Events with very high acidity is more important compared to the average acidity over a long period of time with regard to the severity of adverse impacts on trees. Since this average value of 3.89 of pH was obtained from a cumulative sample, it is safe to assume that there were fog incidences with pH of less than 3.89. This could have serious implication on montane forest. In Horton Plains, 0.8% of the total land has been destroyed in the past due to die back. Reasons are not yet been found. This die back condition due to high concentrations of acids in fog can not be ruled out according to the results obtained from this study. Perhaps, high acidity with some other complementary factors, such as water stress, may be responsible for the die back. Therefore, it is difficult to draw firm conclusions that high acidity alone is responsible for die back without carrying out detailed studies at more intensive scale.

The results also showed that this high acidity of fog is mainly due to SO_4-S. The highest concentrations of 7.32 and 9.04 mg/l of SO_4-S were recorded during these two periods, ie. 20/4/96-24/04/96 and 25/04/96 to 02/04/96, respectively.

Table 1. Percentage of the Time that Wind was Blowing from Each Direction at Horton Plains (Oct.1993-Nov 1996).

	N	NE	E	SE	S	SW	W	NW
Jan	15	52	8	3	2	0	4	10
Feb	15	51	12	2	3	1	2	8
Mar	8	49	17	5	1	1	2	6
Apr	13	47	22	7	2	1	2	8
May	7	13	3	3	3	4	27	40
Jun	4	5	0	1	4	2	30	52
Jul	8	5	0	0	0	0	21	62
Aug	7	5	1	0	1	2	25	59
Sep	7	9	2	2	3	3	21	51
Oct	7	15	7	5	6	4	18	35
Nov	8	36	7	4	5	4	15	18
Dec	22	45	9	3	3	1	4	8

As shown in Table 1, wind was coming mainly from Northern, North-Eastern and Eastern direction during April according to wind direction data obtained from the Automatic Weather Station at the Horton Plains. One of the possible hypothesis is that wind coming from India might bring high concentration of SO_4-S from its large numbers of coal power plants located in the eastern coast since emissions from a power station could be deposited over an area extending 1500 km from the facility.

Quality of throughfall

Figures 3-a, 3-b and 3-c show the variation of different water quality parameters of throughfall with time. pH of the throughfall varied from 5.8 to 7.57. The average values of NH_4-N, SO4-S and NO_3-N concentrations of throughfall were higher than rainfall. For example, concentrations of

SO4-S, NH_4-N and NO_3-N of throughfall were about 4, 2 and 1.5 times higher than rain respectively.

Dry deposition of gases or particulate matter on the vegetation may be one of the reasons for this higher level of chemicals in the throughfall. Hairy and granular plants surfaces, specially lichens which attached to the tree stems and branches, could physically trap suspended matter in the form of dry or wet aerosols. Rainfall washes these contaminants from the vegetation. Therefore, throughfall may have higher chemical concentration than rain. Another possibility is the emition of excess nutrients from the plant through stomata.

As in the cases of rainfall and fog, throughfall also showed high concentration of chemicals at the end of March and beginning of April. For example, concentration of SO4-S has increased to 22mg/l and 26mg/l during these two periods respectively.

Quality of stream water at Horton plains

Changes of water quality parameters in the stream at Horton Plains are shown in Figure 4-a, 4-b and 4-c. The range of the EC of the water in the stream varied from 0.0 to 0.1 mmhos/cm, indicating that total dissolved solids in the stream is the lowest compared to rain, fog and throughfall. The observed values of SO_4-S, NH_4-N and NO_3-N were also the lowest compared to the same in rain, cloud and through fall as clearly indicate by Table 2. The buffering action of soils with high Cation Exchange Capacity is one of the main reasons for the presence of lower concentration of ions in stream water (*Kalpage and Thenabadu, 1969*).

Table 1. Range of Values of Water Quality Parameters at Horton Plains (Nov.95-Oct.96)

	pH	EC mmhos/cm	NO_3-N mg/l	NH_4-N mg/l	SO_4-S mg/l
Stream water	5.81-7.45	0.0-0.01	0.0-2.34	0.0-0.64	0.0-3.80
Rain water	5.37-7.47	0.0-0.08	0.0-3.54	0.17-2.38	0.0-3.39
Through fall	5.80-7.57	0.0-0.18	0.0-5.2	0.05-11.44	0.52-26.6
Cloud water*	3.88-6.52	0.0-0.20	1.13-10.23	0.05-5.09	1.05- 9.40

* Values are only for the period from February to October 1996

CONCLUSIONS

The results indicated that the Horton Plains is unlikely to experience acid rain as at present. However, horizontally driven fog with very high acidity is a potential hazard to the natural montane forest in the upper catchment. It is important to monitor rain and fog at Horton Plains since this location experiences two predominant wind patters, one from Indian continent and other from the western part of the country where industries are located, so that any trend in the atmospheric pollution can be recognized in advance. The amplification effect of fog due to its high specific area is an added advantage in recognizing the pollution levels compared to rain. The buffering action of soils is responsible for the good quality stream water from the Horton Plains irrespective of pollutant loading from rain and fog.

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COUNTRY REPORT ON ACID RAIN MONITORING AND AIR QUALITY MONITORING IN BANGLADESH

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INTRODUCTION

Bangladesh occupies an area of 147570 square kilometers between latitudes 20°34' and 26° 38 ' N and longitudes 88° 1' and 92° 4' E. The country is bounded to the west, north and east by India and to the extreme south-east by Myanmar. The Bay of bengal lies to the south.

Almost the entire country of Bangladesh lies in the still active delta formed by three of the world's major rivers, namely, the Ganges, the Brahmaputra and the Mengna, which flow into Bangladesh from the west, north and north-east. Bangladesh is a relatively flat country with its highest peak at only 1200m. In fact, 90 per cent of the land is fertile alluvial plain. On the basis of formation, three principal physiographic units are recognized, namely, the tertiary hills (part of Chittagong Hill Tracts, Chittagong, and Sylhet districts), the Pleistocene terrace (Medhupur Tract, Vhawal Tract and lalmai in the middle and Brained Tract on the north of the country) and the recent alluvial plain (rest of the country).

The Tropic of Cancer passes through the middle of Bangladesh So, the country falls in the tropical region. But due to monsoon and proximity to the Bay of Bengal, temperature is moderate. There are three distinct Climatic condition in Bangladesh. The monsoon from July to October experiences more than 80 percent of the total annual rainfall. It is characterized by high temperature, high humidity and low solar radiation. The dry, winter season from November to February receives negligible rainfall and is characterized by low temperature, low humidity and high solar radiation. The pre-monsoon Summer from March to June receives some rainfall in occasional heavy thundershowers and hailstorms and is characterized by highest temperature and evaporation rates. Cyclones coming from the Bay of Bengal followed by tidal waves occasionally affect the coastal areas during the pre-and post-monsoon transition seasons.

Temperature in Bangladesh ranges between 10°C and 40°C. It peaks during April and reaches the lowest level in January. Winter temperature average maximum 29°C and minimum 11°C. Summer temperature average maximum 34°C and minimum 21°C. Rainfall distribution patterns are uneven and erratic. Average annual rainfall varies from a maximum of about 5800 mm in the north-east comer of the country to a minimum of about 1200 mm in the extreme West.

The greater part of the landscape of Bangladesh is dominated by the combined networks of three major rivers, the Ganges, the Brahmaputra and the Megna. These three great rivers and their tributaries have their headwaters outside the country in Nepal, China, Bhutan and India and about 90 per cent of their flow originates outside Bangladesh. Of the 256 rivers in Bangladesh, 54 are inter-country rivers . In fact, the inter-country rivers are the main sources of freshwater flow in Bangladesh. So, the country has almost no control over it's river water flow. Deforestation, construction of barrages, withdrawal of river water by the upstream country , excessive rainfall and flooding in the upstream countries are adversely affecting the environment of Bangladesh for last few decades.

Bangladesh is one of the most densely populated countries of the world. The total population is estimated to have been 12.4 million in January, 1997 and growing at a rate of 1.75 per cent. Average population density is about 750 per square kilometer. Bangladesh is a developing country. Where the per capita income is only about US$ 250. The population is overwhelmingly rural (80

per cent), and engaged in various agricultural activities. About 63.2 per cent of total labour force is involved in agricultural activities. Health and education levels are very low, with a life expectancy of 95.5 years. Illiteracy rate among adults (over 15 years) is estimated at 57.5 per cent and among women, it is higher (Bangladesh Economic Review, 1997).

The large size of population and the high rate of its growth, poverty and other related social problems gives a tremendous strain on the country's natural resources and on the socio-economic fabric of the society, with much of the pressure on land, forest and fisheries. The situation is compounded by inequalities in wealth distribution and access to productive resources. Furthermore, the youthfulness of the country's population with increasing numbers entering labour force places a tremendous burden on the government to try and create employment opportunities.

There are three major natural hazards impacting Bangladesh and of those, two could be aggravated by man-made degradation of environment both regionally and world-wide. The cyclone occurred in 1991 in Bangladesh caused the death of about 140000 people. The Floods which occurred in 1987 and 1988 were extremely severe, flooded about 57000 and 82000 square-kilometers area respectively of the country (ADV,1991). Some of this severity is said to have arisen out of a reduction of forested land in the watershed, increased drainage congestion and flood plain area reduction and in the delta Cyclones and floods have become regular phenomena in Bangladesh resulting in the damage of crops, houses, roads, embankments, educational institutions etc. The increase in the sea-level, which still in the process of being detected, could have a potentially very severe impact on the deltaic country like Bangladesh.

Rainfall :

There are three main sources of rainfall in Bangladesh.

i) the western depressions of winter.
ii) the Early summer thunderstorms known as the nor-westerns (North-Westerlies), and
iii) the summer rains from the S.W Trades known as the Monsoons.

The main raining period begins with the coming of the moisture-laden south-west-trade popularly known as the monsoons, Which are drown to the India Sub-Continent by the intense heat, and consequent low pressure over the Punjab and Upper Ganges valley.

Annual rainfall data of over 29 stations in Bangladesh are available for the period between 1948 and 1990. Their analysis indicates that there is at most a small increasing tendency (0.1 percent per year) . Evidence shows that rainfall increasing over Bangladesh during the summer months (April-September,Table -1).

A. TABLE : 1 Monthly Average Rainfall (in mm)

	Khulna			Dhaka	
	1981	**1994**	**1995**	**1985**	**1995**
January	22	01	08	08	08
February	42	15	112	01	31
March	220	08	32	195	00
April	286	105	18	176	88
May	233	115	182	300	237
June	255	142	306	399	237
July	376	219	356	262	355
August	268	217	504	317	361
September	186	168	272	306	361
October	26	64	86	79	205
November	00	05	162	00	91
December	65	00	00	03	61

B. TABLE: 1

Annual rainfall of last 15 years (1981-95)

Year	Dhaka	Chittagong	Khulna	Barisal
1981	2169	2790	1981	2322
1982	1809	2686	1608	1863
1983	2365	3728	1835	2186
1984	3021	2529	2107	2858
1985	2053	3170	1340	1458
1986	2479	2810	2416	2111
1987	2186	2598	1922	1640
1988	2486	2852	1552	2386
1989	1627	2694	1418	1996
1990	2103	2274	1931	1996
1991	2850	2360	1754	2378
1992	1169	3360	1224	2486
1993	1540	2445	1954	2586
1994	1752	X	1145	2586
1995	00	X	2040	1777

Effect : Surface runoff from rainfall makes the main contribution to flash flood in the major rivers basins Bangladesh A 10% increase in rainfall will increase runoff by 18-22% depending on the region.

Air Pollution:

Air Pollution now is a headache to the people of the world. It is a major concern to the people of Dhaka ,Chittagong, Khulna City now-a-days.

Air Pollution is mainly caused by emission due to rapid industrialisation and urbanisation. In Bangladesh Air pollution is mainly caused by industries and automobiles emissions.

The main pollutants of air is the following gases and particulate.

i) Suspended particulate matters.
ii) SO_2
iii) NO_2
iv) CO
V) HC
VI) H_2S etc

Sources of Air Pollution in Bangladesh:

Industrial Sector

There are about 30000 industrial units in Bangladesh, out of which only 6000 are large industries and the rests are cottage industries. Most of the mills and factories of Bangladesh are located along the river bank of Dhaka, Narayangong, Tongi, Chittagong and Khulna city.

The major industries in Bangladesh are tanneries, textiles, Cement, Jute, Chemicals & Pesticides, food & sugar, rubber & Plastics, pulp & paper, Pharmaceuticals, engineering, distilleries and fertilizer. Recently, Department of Environment identified 1190 polluting industries in Bangladesh(Table-2)

Table-2 : Sector wise Distribution of Major Pollution Industries in Bangladesh (from DOE, 1997).

Industry	Number
1. Textiles	365
2. Tanneries	198
3. Pharmaceuticals	149
4. Engineering	129
5. Chemicals & Pesticides	118
6. Jute	92
7. Rubber & Plastic	63
8. Food & Sugar	38
9. Sulfuric Acid plant	05
10. Pulp & paper	10
11. Power	09
12. cement	05
13. Fertilizer	05
14. Distilleries	04
Total	1190

About 1000 ships and tankers travel among the port of cities Chittagong and Khulna annually (Khan and Keong, 1992).

Major Environmental Issues:

1. Almost all the industries have little or no regard for pollution control and occupational health.
2. Nearly all agro-chemical and large industries dump the solid and liquid effluents into rivers and canals without any treatment which causes severe pollution of the rivers near industrial areas resulting in the loss of aquatic biodiversity and serious health hazards.
3. Oil spills, ballast water discharge and other pollutant discharge from the large number of ships that travel through the ports of Bangladesh presents a high potential for degrading the marine and coastal environment.
4. Industries pollute air by emitting different kinds of gasses as the enforcement of existing legislation has not been enforced yet. Only the new industries are abiding by the laws to some extent.

Wind direction in Bangladesh:

Dispersion and Transboundary movement of air pollution depends on the wind direction and speed. In Bangladesh during the period from April to June wind blows from West to East. During the period from June to October wind blows from South to North and during the period from November to March wind blows from North to South.

Air Pollution from Automobiles:

At present Black smoke emission from automobile has become the main pollution problem in Bangladesh particularly in major cities. There are around 4,08,000 motor vehicle in Bangladesh out of which 1.42,000 ply in Dhaka city. Most of these vehicles are reconditioned and old vehicles.

Vehicles older then 20 years or more are still plying in Dhaka city. They are polluting the air of urban areas.

Worst polluter is the two stroke three wheelers. These three wheelers use gasoline along with lubricants.The fuel do not burn properly as result they emit unburnt exhaust. These exhaust contain CO, SO_2, NO_2, NO, HC, SPM, Lead etc. which is very harmful for the human health and Public property. But still the number of baby taxi is increasing rapidly. Due to its affordable fare. Other then these traffic jam, road cutting, slow pace of road repairs, occupation of road by hawkers, dumping of construction materials over footpaths & occupation of road by slow moving rickshaw are also contributing to air pollution . Due to these effect the air pollution by vehicles and increase of SPM by construction materials is a common scenery in Bangladesh.

Ambient Air Quality:
Air quality analysis by the Department of Environment shows. the quality of air in Dhaka city as follows:

Location: Farmgate (Commercial Area)

Month	**Air Pollution(g/m^3)**		
	SPM	**SO_2**	**NO_2**
December,96	1797.80	71.53	24.90
January,97	1849.36	73.24	25.30
March,97	1773.70	73.10	30.00
April,97	887.60	65.13	27.00
May,97	508.40	60.09	32.31
June,97	665.00	51.22	25.50

Location : (Industrial Area)

Month	**Level of Air Pollution(g/m^3)**		
	SPM	**SO_2**	**NO_2**
December,96	602.02	128.76	45.50
January,97	435.60	125.12	42.80
March,97	498.96	103.72	47.03
April,97	314.80	71.92	30.07
May,97	330.70	72.23	36.02
June,97	387.90	64.17	29.78

Location : Agargaon (Residential Area)

Month	**Level of Air Pollution(g/m^3)**		
	SPM	**SO_2**	**NO_2**
July,97	209.00	ND	10.54
August,97	56.69	ND	9.55
September,97	245.00	ND	8.35

Air Quality Standards:

Note : 1) Hospital, health Centre, Archaeological site, educational Institution are sensitive area.

Sl.No.	Type of Area	SPM(g/m^3)	SO_2(g/m^3)	CO(g/m^3)	NO_2(g/m^3)
A	Industrial & mixed	500	120	5000	100
B	Commercial & mixed	400	100	5000	100
C	Residential & Rural	200	80	2000	80
D	Sensitive	100	30	1000	30

Note : 1) Hospital, health Centre, Archaeological site, educational Institution are sensitive area.

Acid Rain :

Rain is the only source of fresh water. But in the last few decades, in some countries rain water has become acidic. It is the result of air pollution -the price of industrialization.

The term acid rain is used to describe all precipitation- rain, snow, and dew-which has pH<6.5 Acid rain destroys living organism in lakes, rivers and forest. It also corrodes building, monuments, statues, and metals. It poses a serious threat to human health by contaminating drinking water.

Except some urban Centres the Air pollution status as a whole is not very bad in Bangladesh. The level of industrialization and number of vehicle is less in comparison to developed countries, But due to lack of control over industrial pollution the level of air pollution is increasing.

Analysis shows that rainwater in Khulna, Bangladesh is not acidic in general over the years. (Table-3).

TABLE: 3 .Laboratory Analysis of Rain Water of Khulna City.

Date	Temperature	pH	Electrical Conductivity	Chloride mg/l
14.08.92(010.40hrs)	27	7.30	250	55
25.08.93(1300hrs)	24	7.10	200	28
02.09.93(1500hrs)	24	7.20	200	28
07.09.93(12.30hrs)	23	7.10	200	12
15.09.93(1500hrs)	25	6.8	180	22
02.02.94(11.30hrs)	16	6.5	60	20
18.06.95(12.00hrs)	30	7.4	170	30
10.07.96(1500hrs)	30	7.1	110	30
06.08.96(10.30hrs)	29	7.1	80	40

But in general it is predicted that the level of acidity will increasing over the Urban areas of Bangladesh by the beginning of the year 2001.

Conclusion :

Bangladesh is a small country having a low level of industrialization. But uncontrolled industrialization is posing serious problem to the environment of the country. Department of Environment is striving hard to control the pollution level within habitable limit. If the pollution can be controlled and rainfall pattern does not change acid rain may not pose a threat for Bangladesh.

ACID RAIN IN NEW ZEALAND- A BRIEF OVERVIEW

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Abstract

New Zealand has rapidly moved to become a manufacturing country during the past thirty years. Nevertheless, much of its manufacturing industry is based on its traditional agricultural and food industries. Over the same period of time, both thermal generation of electrical power and the manufacturing industry have moved from high sulphur fuels to natural gas. The combined effect has been to keep New Zealand remarkably free of problems associated with acid rain. Indeed there is evidence that most sulphur now entering the New Zealand atmosphere comes from active volcanoes and other geothermal activity.

Introduction

New Zealand consists of two large islands and many smaller islands lying in the south-west Pacific Ocean mainly between latitudes 35° S and 47° S. It has an area of about 270,000 km² and a population of 3.5 million people. About 75% of the land area lies above 200 metres with a mountain ridge down the western side of the South Island rising to 3764 metres (Mt. Cook) and up the middle of the North Island rising to 2764 metres at Ruapehu which is an active volcano. There are several other active volcanoes in the North Island and considerable geothermal activity which produces sulphur dioxide, carbon dioxide and hydrogen sulphide. A small proportion of this geothermal energy is used to generate electricity and to meet the power demands of a large pulp and paper industry. However about 87% of the electricity used in New Zealand is generated using its rivers and streams which distribute the high rainfall over short distances to the sea. Electricity is also generated thermally using natural gas although both local coal and imported oil have been used in the recent past.

Figure 1 — Monitored sites in New Zealand

Lying across the "roaring forties" - at a latitude where westerly winds prevail, the strong north-south distribution of the land coupled with the mountainous and hilly terrain produces a very turbulent air stream in which still days are rare and frosts are of short duration. As a consequence, dispersion of pollutants into the air is generally good. The use of high- sulphur coal as

a domestic fuel in Christchurch (latitude 44° S), the major city in the South Island (1 million people), caused problems of London-type "smogs" during winter mornings but this has largely been eliminated due to changes in fuels and fuel-burning appliances (see Table 1 for sulphur content of New Zealand coals and 1990 production rates). Similarly Auckland (latitude 37° S), the major city in North Island (1 million people) has observed the precursors of Los Angeles-type photo-chemical smogs.

As well as growing nutritious grass-lands for its sheep and cows, the high and generally reliable all-year rainfall (50 - 200 mm/year) produces excellent exotic forests of *Pinus radiata* which provide sawn logs, timber, pulp and paper to south-east Asia and north America. Since 1955 there has been a trend towards processing indigenous agricultural resources before their export and in 1997, manufactured goods made up about 30% of New Zealand's export earnings. During this forty year period, several pulp and paper mills have been built, two steel mills and one aluminium smelter have come on-line, and, with the discovery of natural gas off the south-west coast of the North Island, the three largest methanol plant in the southern hemisphere have been constructed. All of these industries have made significant contributions to New Zealand's export earnings. (One of these methanol plants also produces about 30% of the country's petroleum fuel requirements as a strategic resource).

NORTH ISLAND	Production in kilo tonnes/yr	% S	SO_2 tonnes/yr
Crooks Farm	70	0.26	364
Huntly East #1	254	0.19	965
Huntly West #1	33	0.21	139
Kopuku	72	0.13	187
Maramarua	157	0.15	471
O'Reilly's	8	0.28	45
Pirongia	91	2.78	5060
Rotowaro	320	0.23	1472
Smith/Ruston	104	0.25	520
Weavers	239	0.20	956
SOUTH ISLAND	**Production in kilotonnes/yr**	**% S**	**SO_2 tonnes/yr**
Cascade	12	0.44	106
Heaphy	21	1.86	781
McLaughlin	0.2	4.26	17
New Creek	2	4.47	179
Stockton #2	197	0.62	2443
Stockton/Webb	460	1.42	13,064
Sullivan	22	0.70	308
TOTALS	2072 kilo tonnes		27 kilo tonnes

Table 1 — Sulphur content of NZ coals

There are a few small oil-fields around the same Taranaki coast but these, like the synthetic petroleum plant, are uneconomic with the current low cost of crude oil on the world market (25 March 1998). Before the discovery of the gas and oil field, New Zealand imported all its liquid fuel

requirements as crude oil and refined it to finished products at Marsden Point in the north of the North Island. Not all crudes could be processed at the Marsden Point oil refinery so it was extensively modernised about twelve years ago. Part of the modernisation required by the installation of catalytic platformers included a de-sulphurising unit. Until that time, high sulphur residual fuel oils had been extensively used as a low cost fuel by New Zealand industry. Such industries traditionally included many small dairy factories and sulphuric acid plant which serviced the production of super-phosphate fertilizer at several small units throughout the country.

In 1972, the New Zealand Clean Air Act was introduced which required that all such industries should be licensed and that they should employ the "Best Practicable Means" approach to limit their air pollution. As a result, improved electrostatic precipitators were fitted to all new sulphuric acid plant and, along with the dairy industry, a few large well-run companies replaced the many small and sometimes inefficient units. The availability of natural gas which was reticulated throughout the North Island effectively eliminated the cost advantage of high sulphur fuels as modernisation at the refinery reduced their availability: Even the few thermal power stations were modified to use low-sulphur methane.

Sulphur oxides

In 1991, the Resource Management Act replaced the Clean Air Act of 1972 and New Zealand moved towards a comprehensive air quality management approach. However several agencies had been collecting information on sulphur emissions and acid rain formation as part of monitoring programmes set up under the earlier legislation. The current air quality guidelines recommended by the New Zealand Ministry of the Environment are set at 500 g/m^3 of SO_2 as a 10 minute average, 350 g/m^3 as a 1 hour average and 125 g/m^3 as a 24 hour average[1]. (Using AS3580.4.1-1990).

WHO guideline levels (1979) were given as 100-200 g/m^3 averaged over a year[2]. Phytotoxic effects on susceptible species has caused the International Union of Forest Research Organisations (IUFRO) has recommended that annual means of 50 g/m^3 in most sites and 50 g/m^3 in sensitive areas. The presence of other phytotoxins such as ozone are known to have a synergistic effect. Background levels in New Zealand are generally below 5 g/m^3 although volcanic activity may produce concentrations well in excess of 3000 g/m^3.

Location	Maximum 10 minute average	Maximum 1 hour average	Maximum 24 hour average
St. Albans	122 µg/m3	106 µg/m3	48 µg/m3
Hornby	349	252	100
Opawa	377	149	42

Table 2 — Maximum SO_2 values measured by Canterbury Regional Council

The **Canterbury Regional Council** which manages the environmental resources around Christchurch has been monitoring sulphur dioxide emissions at several

locations within its region since 1988. The maximum values measured between the 1st September 1996 and 30th September 1997 are presented in Table 2. This table shows that all sites had satisfactory levels of sulphur dioxide emissions[3].

Annual average levels are of the order of 15 to 30 g/m^3. This represents a reduction of approximately 50% over ten years.

These three sites are indicative of the results obtained at over 40 sites in New Zealand during the last twenty years.

The results for the sites shown in Figure 1 can be summarised as follows:

1987/88 monitoring as part of the **Marsden Point** Oil Refinery expansion showed ambient values of 10 to 15 g/m^3 with a maximum recorded 24 hour value of 50 g/m^3;

1980-1990 monitoring at **Auckland** sites show that sulphur dioxide levels have declined significantly. Before 1980, sulphur dioxide levels averaged between 15 and 20 g/m^3 with daily maxima reaching 75 g/m3. By 1991, due to a general move to natural gas as a fuel, average values had dropped to 5 g/m3 (or less) and daily maxima had fallen to 20 to 30 g/m^3.

Huntly Power Station (latitude 37.5 S originally burned local coal). Ten years ago, routine monitoring showed levels of 10 to 15 g/m^3 with daily maxima as high as 75 g/m^3. By 1991, average levels had fallen to 5 to 10 g/m^3 and daily maxima to 15 to 21 g/m^3.

Dunedin (latitude 46°S) is a city some 320 km south of Christchurch and has also experienced a reduction in sulphur dioxide concentrations over the same decade with annual average values in the late 1980's of 10 to 20 g/m^3 and daily values of 35 to 70 g/m^3.

In the mid 1980's, **Invercargill** (latitude 47°S), a town close to a major aluminium smelter had annual averages of 5 to 15 g/m^3 with daily maxima of no more than 25 g/m^3.

The reason that current data are not available is that most regional authorities have concluded that levels are now so low that continued monitoring is an unnecessary expense. Consequently country-wide monitoring has been discontinued.

Nitrogen oxides

Nitrous oxide is not particularly soluble and is not considered to contribute to acid rain. Nitric oxide and nitrogen dioxide are produced by bacterial action in the soil, volcanic activity and electrical storms. These natural levels usually lie between 0.4 and 9.4 g/m^3. Anthropogenic sources include combustion processes. In New Zealand, the highest values measured correlate with peak traffic hours with great variation withe the season of the year and meteorological factors[4]. Phytotoxic effects at concentrations down to 120 g/m^3 have been noted but synergism with sulphur oxides and ozone are also known to exist[5].

The Ministry of the Environment has proposed ambient guidelines as 100 g/m^3 as a 24 hour average (measures as nitrogen dioxide equivalent by AS2447-1981). The WHO recommended levels are 150 g/m^3 for 24 hour average, 400 g/m^3 for an hourly average and 30 g/m^3 as the

annual average of 24 hour means.

For **Auckland**, annual means of 40 to 60 g/m^3 are routinely measured with maximum daily averages in the range of 100 to 300 g/m^3.

Christchurch has recorded annual means in the range of 50 to 100 g/m^3 at most of their sites but maximum daily values of 200 to 500 g/m^3 have occasionally been measured.

Dunedin shows an annual mean between 50 and 60 g/m^3 with maximum daily values 150 to 300 g/m^3.

It can be seen from this data that the three major cities routinely exceed the guideline. There is also no evidence that levels have changed much over the last 20 years. Because NO changes to NO_2 in the atmosphere, the $[NO]/[NO_2]$ ratio indicates the proximity of the source. The above data show values for this ratio between 1:1 and 3:1 (or higher) indicating a local source. Motor vehicles, gas turbines and thermal power stations are considered to be the major local sources[1].

Acid rain

The accepted mechanism for the formation of acid rain is by the solution of sulphur oxides and nitrogen oxides to form sulphurous, sulphuric, nitrous and nitric acids which all have greater ionisation in solution than carbonic acid from carbon dioxide.

Thus acid rain is considered to be any rain water which has a pH below about 5.0 because there is a natural equilibrium set up with the carbon dioxide in the atmosphere to form the bicarbonate ion:

$$CO_{2(g)} + H_2O_{(l)} + H_2CO_{3(aq)} = H^+_{(aq)} + HCO^-_{3(aq)}$$

$$\text{and } 5.6 = pH = -\log_{10}(H^+)$$

The pH of rain water has been measured at several sites over a period of 15 years by various agencies including the National Institute of Water & Atmospheric Research (NIWA)[6]. The pH has consistently shown values between 4.8 and 6.1 with an overall average is 5.3. Monitoring has recently been discontinued because it is not cost effective to monitor problems which do not exist.

It has been concluded that because of New Zealand's geography, acid rain does not appear to be a problem[7].

Discussion

As stated earlier, New Zealand has a reliable rainfall which occurs in both summer and winter. With so little sulphur and nitrogen oxides in the environment and with so much rain (over 2000 mm in the south west), it is unlikely that anthropogenic acid rain would be a serious problem. The occasional value of a pH of 6 measured in New Zealand rainwater has been attributed to the presence of ammonia from vegetation and livestock. It should also be noted that sea spray is a common constituent of New Zealand rainwater due to the extended coast-line.

The noted improvements in ambient sulphur dioxide levels over ten years is attributed to the change of fuels that has taken place: In the North Island this is predominantly change to natural gas whereas in the South Island the change is to low sulphur coals and to hydroelectricity. This is because the availability of natural gas is effectively limited to the North Island where reticulation by pipe-line is extensive.

Geographic factors

With current fuel usage patterns, it is generally considered that background levels of sulphur oxides are more likely to be affected by sporadic increases in volcanic activity than they are by industrial activity. Australia lies generally upwind of New Zealand some 1600 km to the west across a particularly turbulent Tasman Sea. It is therefore probable that emissions from Australian industrial activity are diluted, dispersed or washed into the sea before they reach New Zealand. While it is known that particulates from large forest fires in eastern Australia can colour New Zealand sunsets, no sulphur oxides or acid rain of indisputable Australian origin have been measured in New Zealand.

Figure 2 — Aerial view of White Island

As stated in the introduction, New Zealand has several active volcanoes, frequent earth tremors and some of the most spectacular geothermal scenery in the world. Currently White Island in the Bay of Plenty is the most active volcano producing several thousand tonnes of volcanic gases from its many craters and fumaroles each day. These gases are mainly steam, carbon dioxide, and sulphur dioxide (1 to 12%) with small quantities of fluorine and chlorine. Several attempts have been made to mine the sulphur deposits on the island but in each case the venture has failed due to instability of the crater walls (Eleven miners were killed in 1914) and the acidic, stinging nature of the gases which are discharged at temperatures between 100°C and 800°C.

Conclusions

The fuels currently in use in New Zealand put less sulphur into the atmosphere than those of the past. This beneficial effect is offset to some extent by the overall increase in fuel usage caused by the growth of the New Zealand manufacturing industries.

No comparable decrease in nitrogen oxides has noted. It is hoped that this will eventually happen as the motor vehicle fleet is modernised. It should perhaps be pointed out that the population New Zealand is too small to support an indigenous motor vehicle industry and even the three car assembly plant in New Zealand are being phased out and closed as tariffs and trade barriers are removed. The consequence is that New Zealand must accept the technology required in the country of origin of its vehicles. The reduction in motor vehicle costs in New Zealand over the last ten years has made them more affordable so that the historical image of New Zealand using ancient vehicles is fading fast. Many of the imported cars are fitted with catalytic afterburners and other emission controls. The less favourable aspect of this cost reduction is that there are now more vehicles using the road system.

Until such time as the natural gas resource in New Zealand becomes depleted, it is concluded that acid rain will require no remedial action. However the heavy reliance on grass and trees for New Zealand export earnings means that any deterioration caused by acid rain can be expected to produce a speedy legislative response. Accordingly, most New Zealand monitoring agencies have scaled down their investigative programme into acid rain formation while maintaining their ability to respond should circumstances change. During times of moderate volcanic activity, more sulphur dioxide is produced naturally in New Zealand than is produced by human activity.

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ACID RAIN MONITORING AND ATMOSPHERIC MODELLING: THE CASE OF PAKISTAN

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INTRODUCTION

Integrated activities of modern-day man, though giving him comforts of life, have resulted in many detrimental impacts upon the environment. Whereas the developed countries have realized and maintained a balance between the benefits and the negative effects, developing countries are still far behind. Many reasons can be attributed to this lagging but the focal point remains in the poor economics. It is this pursuit of attaining rapid economic growth that has led to rapid industrialisation and urbanisation in Asian countries including Pakistan. Because of these factors, demand for energy is on the rise. Coal and oil are widely used energy production sources in Pakistan. Increased use of coal and high sulphur content fuel will promote global and regional environmental impacts including the acid rain. It is, therefore, logical and appropriate to address this issue and to estimate the probability of acid deposition in Pakistan. Although poor air quality monitoring system, lack of skill and resources, low priority attached to risk of acid rain, lack of ambient air quality standards, and lack of quantitative evidence of acid rain may be the reasons underlying the poor risk assessment of acid rain in Pakistan, it is not unworthy to make endeavours in establishing the trends of acid rain in Pakistan and to anticipate the control measures. This country report is aimed at providing an overview of current status of acid rain monitoring, on-going activities in this field and the problems being faced in this regard in Pakistan. This country report is a prelude to participation in a workshop on "acid rain monitoring and atmospheric modelling and mini symposium on algae toxins" being held in Peradeniya, Sri Lanka from 20-26 April 1998.

Pakistan and Energy use

Pakistan is an energy-poor country. An average Pakistani consumes less than one-seventh of the energy (13GJ in 1996) used by a person globally and Pakistan's contribution to SO_2 is only 0.4% of the global total (1). Annual deforestation is about 7000-9000 hectares which is 0.1% of total deforestation in world. This rate of deforestation is quite low although the Pakistan has only 5% of forest land. Agriculture is the backbone of Pakistan's economy and it has 23% of its land under cultivation which is twice the global average.

Commercial energy requirements in Pakistan are met from imported and domestic oil, natural gas, coal, hydro and nuclear sources. The shares of these sources are given in Table-1.

This table shows that share of coal in total commercial energy sources in Pakistan is only 9.6% which is far less than that for other Asian countries, where coal accounts for about 40% of energy produced(2). Oil and coal together contribute about 50% of the energy produced in Pakistan in comparison to about 80% in other Asian countries. This indicates that the potential risk of acid deposition in Pakistan is less than other Asian countries. However, the use of coal is expected to rise in Pakistan for the purpose of low-cost energy generation and, indeed, intensive exploration of coal resources is being done. As a result, coal reserves have been demonstrated to increase from 200 million tonnes in 1987 to 500 million tonnes in 1990.

Table 1. Share of commercial energy sources in Pakistan (1992-93)

Energy Source		Share (%)
Oil	imported	29.6
	indigenous	10.1
Natural gas		40.6
Coal		9.5
Hydro		9.9
Nuclear		0.2

The industrial sector accounts for the largest portion of commercial energy consumption followed by transportation. Within the industrial sector, brick-making kilns use 97% of the current coal supply. 90% of the energy used for domestic purposes is non-commercial energy (firewood, animal dung, etc).

ACID RAIN MONITORING

As the main air pollutants responsible for acid deposition are SO_2 and NO_x (and NH_3), the discussion will be limited to SO_2 and NO_x with the exclusion of NH_3. To the information of the author, no systematic study based on field data has been carried out that could identify the extent and trends of acid deposition in Pakistan. Most of the estimates for SO_2 and NO_x have been deduced from energy data. However, some sporadic data on ambient air concentrations of SO_2 and NO_x has been reported by some agencies. This data seems to be insufficient for gaining an overall insight into acid deposition in Pakistan. Table-2 provides estimated amounts of air pollutants from various sources in Pakistan (2).

Table 2. Estimated air pollutants from various sources.

	1987-98		1997-98	
Source	**SO_2**	**NO_x**	**SO_2**	**NO_x**
	(Thousand tonnes)		(Thousand tonnes)	
Industry	423	-	982	-
Power	95	-	996	76
Transport	57	-	105	-
Domestic	16	-	40	-
Agriculture	28	-	40	-
Commercial	13	-	25	-

This table shows that primary sources of SO_2 pollution are industry and power followed by transport. This data does not indicate the areas or pockets of severe SO_2 and NO_x prevalence.

The Environmental Protection Department (EPD) of Punjab has carried out ambient air surveillance in some big cities of Punjab and this data is reproduced in Table 3. It may be noted that Punjab is the most densely populated province of Pakistan and is a centre of many industrial activities. The three other provinces of Pakistan are :Sind (main cities = Karachi, Hyderabad) , NWFP(main cities =Peshawar, Kohat) and Baluchistan
(main city = Quetta)
The data of Table 3 indicates that the ambient air concentrations of SO_2 and NO_x are within the permissible limits of WHO. Although this data may not be sufficient to predict the SO_2 and NO_x concentrations of ambient air all over the year, yet it does give some insight into the situation. A

Table 3. Ambient 24-hr average SO_2 and NO_x concentrations in big cities of Punjab*.

City	Site	Period of Monitoring	SO_2(ppb)	NO(ppb)	NO_x(ppb)
Lahore	Road side	6/96	4.2	13.5	43.5
	Residential		2.3	7.4	21.3
	Industrial		3.1	11.4	34.5
	Sub Urban/rural		1.6	5.2	8.9
Gujrawala	Road side	6/96 & 7/96	3.8	10.1	37.6
	Residential		2.0	6.5	20.1
	Industrial		2.8	14.1	32.3
	Sub Urban/rural		1.8	4.5	7.5
Sialkot	Road side	7/96 & 8/96	3.1	6.2	15.6
	Residential		1.8	4.1	10.3
	Industrial		2.1	5.2	13.2
	Sub Urban/rural		1.0	3.2	6.16
Multan	Road side	10/96 &11/96	3.0	7.6	28.6
	Residential		2.2	6.5	20.2
	Industrial		3.3	6.1	23.7
	Sub Urban/rural		1.6	4.6	8.4
D.G. Khan	Road side	12/96	2.6	5.7	14.5
	Residential		2.1	4.5	12.6
	Industrial		-	-	-
	Sub Urban/rural		1.2	3.6	7.1

* These measurements were taken at a height of 13-16 ft above ground level.

WHO guidelines : SO_2 = 35-52 ppb

NO_2 = 73 ppb

similar survey was carried out by the mobile air pollution laboratory of EPD in remote and uninhabited areas of Punjab. These areas are the expected sites of power plants to be built in future and the basic purpose of the survey was to establish background or pre power plant ambient air quality. The results are reported in Table-4.

Table 4. 2-day SO_2 and NO_x concentrations of ambient air at proposed power plant sites in Punjab.

Site	Date of Monitoring	SO_2	NO_x
Alipur Chatta (Hafizabad)	14-16 June 1995	2.7-7.5 (avg 3.9)	5.1-9.1(avg 7.5)
Katha Sagral (Kushab)	19-21 June 1995	2.1-5.2 (avg 3.6)	6.2-10.4 (avg8.2)
Bahmniwala (Faisalabad)	23-25 June 1995	3.7-10.4(avg 7.9)	8.4-12.9 (avg.11.5)

SO_2 and NO_x concentration reported in Table-4 for remote areas of Punjab show that these values are much less than the WHO guidelines. This data is consistent with the data of Table-3. Apart from Punjab, SO_2 and NO_x data for some other big cities of Pakistan is reported in Table-5.

Table 5. SO_2 and NO_x concentration of some big cities of Pakistan **.

City	SO_2		NO		NO_x	
	Avg.	Max.	Avg.	Max.	Avg.	Max.
Karachi(4)(ppb)	1.6	5.82	2.1	8	8.39	14.49
Peshawar(5)(g/m^3)	1.0	72	19	235	80	401
Kohat(5)(g/m^3)	3.0	48	10	153	167	684

** Data of Karachi is for 1995 while that for Peshawar and Kohat is for 1993.

Like the cities of Punjab, these cities also manifest low average concentration of SO_2 and NO_x. Thus it can be concluded that in the present situation, risk from acid deposition in Pakistan is low.

PROJECTED RISK OF ACID RAIN IN PAKISTAN

Applied System Analysis Group of the Pakistan Atomic Energy Commission has recently carried out a study on the risk of acid rain in Pakistan due to energy production and use(3). This group has used RAINS-ASIA model to predict the acid rain risk. They divided Pakistan into 5 regions and specified 33 large point sources (LPS) locations with each LPS corresponding to a power plant capacity greater than 500 MWe. In this study three energy and emission cases A, B and C were formulated for the analysis varying in terms of fuel mix and use of emission control strategies for SO2. The level of acid deposition estimated by RAINS-ASIA model for 1990 was less than 400 mg/m2-year with higher values (441- 681 mg/m2-year) for Karachi and some other areas of Punjab. The projected deposition level for case A in year 2020 rose to about 9000mg/m2-year in Karachi and to 4400mg/m2-year for some areas in Punjab. These projected estimates shows about 10-15 times increase in 30 years.

Although this study has indicated positive future risks of acid deposition in Pakistan, however, this is a purely theoretical study and is not validated by the field evidence of 1990 or after. Nevertheless, this study provides a direction and concern to the acid deposition risk in Pakistan.

PROBLEMS ENCOUNTERED AND THEIR SOLUTIONS

As mentioned earlier, there is lack of systematic data monitoring system in Pakistan. One reason may be the lack of skill and the resources available. Moreover, there seems to be no integrated network of data collection and its exchange. Most of the studies are done in isolation and as a result of instantaneous requirement or need. Public awareness is also low as far as risk of acid deposition is concerned which has resulted in attaching low priority to this issue in particular.

Following areas need to be strengthened to minimise the potential effects of acid deposition :
Training of manpower and transfer of technology.
Establishing an integrated network of data collection and exchange.
Enhancing the analytical capabilities of various public organisations responsible for air monitoring especially the Provincial Environmental Protection Departments/Agencies.
Dissemination of the information on impacts of acid rain at various levels.
Formulation and promulgation of ambient air quality standards.
Formulation of a focal organisation dedicated to acid rain studies and assessment.

AREAS FOR INTER-COUNTRY COOPERATION

Flow of technology calls for inter-country co-operation between developed and developing countries and among the developing countries themselves to share the experiences. Some suggested areas of co-operation are:

Transfer of know-how through training workshops and seminars focusing on air pollutant transportation and transformation phenomenon data exchange and mutual policy analysis, exchange of engineers and scientists Formulation of an integrated policy and program at macro-regional level rather than individual country level through MoUs or protocols
Software and hard-ware (analytical resources) support to the deficient countries
Provision of free consulting services by the World Bank, UNEP, Asian Development Bank, etc. to developing countries

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AIR QUALITY MANAGEMENT IN SRI LANKA- POLICY, IMPLEMENTATION AND MONITORING ISSUES

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1.0 INTRODUCTION

Unlike many of its Asian neighbours, Sri Lanka, is very fortunate that it does not yet have acute air quality problems in its cities as a result of industrial expansion and increases in vehicular traffic. In Sri Lanka, the region which is most vulnerable is the Western Province namely the Colombo Metropolitan Area (CMA) which encompasses the country's administrative capital, Kotte and its financial capital, Colombo. Found within the borders of the CMA is 70% of the country's industrialisation and over 50% of all vehicles plying Sri Lankan roads. While air pollution in Colombo city appears presently to be at manageable levels, projected rates of economic and vehicular growth could result in air quality becoming adverse all too soon. Of the four sectors contributing emissions from petroleum combustion sources (Transport, Industry, Power & Commercial and Household) approximately 75% of the pollutants released to the air (SPM, SO_2, NO_X, HC, CO) originate from the transport sector with emissions from other sectors, with one exception, being fairly low. That exception is sulphur dioxide where the industrial sector accounts for nearly 93% of the total emissions.

2.0 POLICY - CLEAN AIR 2000 & ACTION PLAN

2.1 Legislation:

While Sri Lanka does not possess a statute concerned exclusively with air pollution there is sufficient reference to the subject in many existing legislation ranging from Municipal and Urban Council Ordinances to Pradeshiya and Provincial Councils Acts to a miscellany of Acts, Laws and Ordinances which cover vehicular and rail traffic and transport, petroleum and its products, and airports among others. Presently, provisions relating to the prevention of air pollution stems from the National Environmental Act (NEA) of 1980 as amended in 1988 Part IV B - Environmental Quality Sections 23J, K and L which prohibits emission of pollutants into the atmosphere and operation of machinery without pollution control devices. Also ambient air quality standards have been formulated and gazetted in 1994 under the NEA.

2.2 Pioneering Efforts

Sri Lanka has limited experience in air quality monitoring and management. Indeed, the first formal monitoring of air quality in Sri Lanka commenced with the 1983 study carried out by the Chemistry Department of the University of Colombo. The growing problem of vehicular air pollution was first recognised in 1987 when an inter-agency committee of experts made some twenty recommendations covering seven major issues.

2.3 Metropolitan Environmental Improvement Programme (MEIP)

One of the urban environmental initiatives of the World Bank in Asia was the establishment, in 1989, of the Metropolitan Environmental Improvement Programme (MEIP). The objective of this regional, city based programme was to assist governments, industries and community organisations in reversing the process of environmental degradation in and around major cities in Asia. Funded for its first five years

by the United Nations Development Programme (UNDP), this programme commenced initially with the endorsement of the national governments of five Asian cities. MEIP-Colombo was initiated at the invitation of the Government of Sri Lanka (GOSL) in 1990. The other cities were Beijing, Bombay, Jakarta and Metro Manila (by mid 1993 Kathmandu was included) making up a total of 6 cities.

2.4 Air Quality Monitoring

By 1992 three short term studies, carried out by three separate research organisations contributed to the better understanding of the air quality situation in Colombo. The most comprehensive of these was the National Building Research Organisation (NBRO) study which commenced in 1990. The NBRO study showed that of the 49 locations monitored for sulphation rate and dust fall, 8 were found to be critical, 24 had moderate air quality and 17 showed excellent air quality. The critical locations were near traffic intersections or industrial areas. The second study, undertaken by the Central Environmental Authority (CEA) during 1991-92, analysed the air quality at 6 roadside locations in Colombo and revealed a direct relationship between the volume of traffic and pollutant levels. A third study, carried out by the Ceylon Institute for Scientific and Industrial Research (CISIR) during 1991, sampled air at 7 locations in Colombo experiencing traffic congestion. The data obtained in this study when compared with existing data for other developing countries in the ASEAN region (such as Indonesia, Malaysia, Philippines, Singapore and Thailand) indicated that Sri Lanka had higher total suspended particulate and fine dust contributing to air pollution.

2.5 Towards Air Quality Management

The situation was not much better with regard to air quality management. Cognisant of this deficiency MEIP-Colombo took a lead role in addressing this gap and air pollution management was identified early as a priority sector for intervention.

In August 1991, MEIP-Colombo organised an in-country workshop titled "*Air Quality Management in Sri Lanka*". The workshop revealed that Sri Lanka lacked sufficient and reliable air quality data to formulate strategies or find technical solutions.

MEIP-Colombo therefore planned and held a "*Short Course on Air Quality Management*" during July 1992 which brought together the experiences of two MEIP cities, Bombay and Beijing, along with regional and international presentations from Thailand, Japan, the United States and the World Bank. Financial support for the workshop was provided by the World Bank/UNDP, NORAD, US AID, JICA, the Government of the People's Republic of China and GOSL.

2.6 Formulation of the Clean Air 2000 - Action Plan

Besides the foreign participants and resource persons, at the workshop, there were over sixty Sri Lankans from a number of government, private and NGO organisations. One of the outcomes of this short course was the preparation of an action plan to mitigate the deteriorating air quality of the CMA by several Sri Lankan participants who formed a task force for this purpose. The plan was given the name - **Clean Air 2000 Action Plan (CA2AP)**. The objective of the action plan involved the reduction of all air pollutants of concern to the Colombo Metropolis by the year 2000. Hence, based on a review of the available air quality data and of the available practical control options, the Action Plan concluded that the following reductions from 1990 ambient levels to be targeted for the year 2000 should be effected:

particulates (SPM)	**40%**
carbon monoxide	**40%**
oxides of nitrogen	**30 %**
lead	**30%**
oxides of sulphur	**75%**
hydrocarbons	**20%**

2.7 Elements of the action plan

The Action Plan was the main outcome of the MEIP conducted international short-course on Air Quality Management in July 1992. To reach these targets specific actions were recommended under seven areas which included vehicle inspection and maintenance (I/M); fuel formulation, pricing and fleet mix; emission inventory and monitoring; standard setting; institutional framework and regulatory compliance; economic instruments and transportation planning and traffic management.. The CA2AP combined policy and strategic measures that needed to be introduced into the overall policy making framework. The sequential steps in the control strategy and key assumptions are given in **Annex 1**.

2.8 Institutionalisation

The task force subsequently expanded on this initial draft by developing detailed actions necessary to achieve the conceptual goals agreed upon during the short course. The task force agreed upon a final draft of the Clean Air 2000 - Action Plan (CA2AP) which was to be submitted by the Nation Programme Co-ordinator of the MEIP - Colombo to the National Environmental Steering Committee (NESC) for observation and comments. Following endorsement of the CA2AP by the NESC in October 1992, the then Ministry of Policy Planning and Implementation sought formal approval from Cabinet.

An important milestone for MEIP has been the publication of "**Clean Air 2000 - An Action Plan for Air Quality Management in the Colombo Metropolitan Area**" as Government policy. This Action plan (CA2AP) was approved by the Cabinet of Ministers on February 19, 1993 upon the recommendation of the then President of Sri Lanka, in his capacity as the Minister of Policy Planning and Implementation

3.0 IMPLEMENTATION

A Clean Air 2000 Action Plan Implementation Committee, which is still functional, was appointed to monitor the implementation of the Action Plan, under the Chairmanship of the Secretary to the then Ministry of Environment and Parliamentary Affairs. Its first meeting was in March 1993 and comprised members from all agencies involved in the implementation of the plan. The findings of the Action Plan were also included in the Environmental Management Strategy (EMS), developed by the Urban Development Authority (UDA) and MEIP.

3.1 Clean Air 2000 Action Plan (Major Issues)

There were 49 recommended actions identifying institutional responsibilities, these were classified under the following seven major issues

1. VEHICLE INSPECTION AND MAINTENANCE (6 actions)

2. FUEL REFORMULATION, PRICING AND FLEET MIX (10 actions)

3. EMISSION INVENTORY AND MONITORING (5 actions)

4. STANDARD SETTING (9 actions)

5. INSTITUTIONAL FRAMEWORK AND REGULATORY COMPLIANCE (11 actions)

6. ECONOMIC INSTRUMENTS (5 actions)

7. TRANSPORTATION PLANNING AND TRAFFIC MANAGEMENT (3 actions)

By 1997 although the committee had met some 30 times and while this is very important in keeping the process alive, rather than discussing issues and taking hard decisions the committee was mostly considering matters left over from previous meetings minutes and had lost sight of the spirit and intent of the original document. By that time only 17 of the 49 actions had been implemented to varying extents, 19 had been addressed and some work was in progress while 13 had not even been considered as shown in the table below.

Issue	Number of Actions	Actions Completed	Actions in Progress	Actions Not Initiated
1. Vehicle Inspection And Maintenance	6	1	4	1
2. Fuel Reformulation, Pricing And Fleet Mix	10	4	3	3
3. Emission Inventory And Monitoring	5	3	2	0
4. Standard Setting	9	2	3	4
5. Institutional Framework and Regulatory Compliance	11	4	5	2
6. Economic Interments	5	3	0	2
7. Transportation Planning And Traffic Management	3	0	2	1
Total	49	17	19	13

Problems ranging from lack of funds to carry out studies and for implementation, enforcement problems, lack of capacity (capability), infrastructure as well as instrumentation were hampering implementation of many of the actions.

There is wide consensus that the CA2AP document is a worthwhile document whose implementation is both practical and of decided value. With a view to re-focus the implementation of the action plan it was decided to re-examine and prioritise the actions in the CA2AP. This would allow the committee to address those issues which could be implemented with reasonable chance of success while dropping some and postponing others that couldn't be implemented for a variety of reasons. This has been taking place since August 1996 and the following activities (of the CA2AP with some new additions) are now being considered at the implementation committee meetings.

No attempt will be made to discuss all the prioritised actions in detail but what will be attempted is to generally cover the issues, highlighting the actions that have been completed

1. VEHICLE INSPECTION AND MAINTENANCE

Some 65 exhaust emission analysers imported from Sweden at considerable cost have been found to be totally unsuitable as they are not portable and many machines need repairs and they are difficult to operate. Lack of funds to maintain, repair and operate is also a constraint. There are suggestions that information on portable exhaust analysers being used in the region be obtained to buy suitable instruments. The minister in charge of environment has appointed a three member committee to study the situation and prepare a report on vehicular emissions and recommend future short term and long term actions. Also being considered are continuing dialogue with the private sector to maintain the country of origin's vehicle emission standards for new cars being imported.

2. FUEL REFORMULATION, PRICING AND FLEET MIX

The Ceylon Petroleum Corporation (CPC) has finally introduced unleaded gasoline to Sri Lanka, initially at 10 stations in Colombo. Pricing is still a problem and does not provide sufficient incentive for leaded petrol users to switch even if able. Moves to reduce diesel proportion of vehicle mix has started with TSPC having analysed the diesel fleet make up annually over the past few years. A draft national policy paper on vehicular emission reduction through fuel reformulation and pricing is presently being recast taking into account wider issues pertaining to this matter.

3. EMISSION INVENTORY AND MONITORING

Ambient air quality monitoring being done by the NBRO using 2 fixed and 1 mobile station for the CEA. The CA2AP Implementation Committee set up a sub committee on Air Quality Monitoring chaired by the Director General of NBRO to oversee this aspect.

Other items have been dropped by the committee temporarily. Although a ToR was prepared to monitor stationary source emissions funds were not available for the budget submitted by CISIR.

4. STANDARD SETTING

Ambient air quality standards were gazetted in 1994 as mentioned earlier. The use of alternate fuels is being addressed by the draft national policy paper on vehicular emission reduction through fuel reformulation and pricing under item (2). Guidelines to control Noise and Air Pollution by diesel power generators installed in buildings though not in the original CA2AP is presently under review. A ToR for a study on "Economic, Social and Environmental Costs of Achieving Pollution reduction of 30% by 1998 and 70% by 2000 in existing Industrial Power Plants" is under discussion. Also emission standards for new industrial facilities and proposed power plants are being finalised with assistance from USEPA through WHO and require inclusion of standards for lower capacity power plants before it can be gazetted. Japan has also reacted favourably to fund CEA's request for emission monitoring equipment.

5. INSTITUTIONAL FRAMEWORK AND REGULATORY COMPLIANCE

New amendments to Motor Traffic Act concerning vehicular emissions is being finalised. A joint cabinet paper to upgrade CISIR and NBRO to undertake ambient air and source emission monitoring has been prepared however the Department of National Planning has some issues it wants cleared up prior to submitting to cabinet.

6. ECONOMIC INSTRUMENTS

In 1994, an annual road tax of Rs 10,000.00 for diesel powered non-commercial vehicles had been imposed with annual renewal of the licences. However, in the last budget this tax was reduced to Rs 5000.00. Despite this tax the number of diesel vehicles on the road, and being imported, especially vans and dual purpose vehicles, are on the increase. The price disparity between petrol and diesel fuel is such (Rs 15.00 vs. Rs 50.00 per litre) that despite the annual road tax and higher repair costs, diesel vehicles are still more economical than petrol vehicles.

7. TRANSPORTATION PLANNING AND TRAFFIC MANAGEMENT

Existing UDA and TSPC plans, developed separately, to be harmonised. A draft National Policy on Air Quality Management has been prepared and has been sent to the CA2AP implementation Committee for comment prior to submission for cabinet approval.

4.0 AIR QUALITY MONITORING

Through a assistance of the World Bank under the Colombo Urban Transport Project (CUTP), MEIP Colombo was instrumental in procuring 3 automatic monitoring stations for the CEA. The NBRO is the implementation agency for the monitoring programme. A sub-committee under the CA2AP Implementation committee comprising of NBRO, CEA, CISIR, Transport Study and Planning Centre (TSPC), Meteorological Department and MEIP provide guidance to the air quality monitoring programme. The sub-committee is headed by the Director General of NBRO. All data collected from the monitoring stations are analysed and presented to this sub-committee. The CEA is responsible for dissemination of the information to the public. However, a publication that reports of the status of the air quality based on the present monitoring programme is being presently pursed by the sub-committee.

Presently, two fixed stations - one near the fort railway station and other in the premises of the Meteorological Station - automatically measures (every 5 minutes) atmospheric pollutants - Oxides of Nitrogen (NOx), Sulphur Dioxide (SO_2), Carbon Monoxide (CO) and Ozone. Particulate Matter (PM 10)less than 10 micron are measured over a 24 hour period on a programme basis. The local meteorological parameters such as wind speed, wind direction, ambient temperature, precipitation, solar radiation are also measured every 5 minutes. The mobile station is presently used for monitoring on consultancy basic for both private and public sector projects. A programme has been developed to monitor 5 locations around the island.

A consultancy assignment is planned through the World Bank to improve the present monitoring programme to develop a air quality model for Colombo. The prime purpose of the model will be for surveillance and also for formulation of national policies on air quality management.

5.0 CONCLUSIONS

It has been 5 years since the formulation of CA2AP. Despite some setbacks and shortcomings implementation of the Action Plan has been considerable. While it is unlikely that the targets for the year 2000 will be achieved much progress towards it has taken place. The very fact that the CA2AP

existed and that it had clearance from the highest authority encouraged interagency co-ordination which enabled concrete actions to be taken very often utilising internal funds. Had there been no co-ordinated effort each agency working in isolation would have expended far more resources and been much less effective towards successful implementation.

The adverse health effects of common air pollutants in excessive concentrations are only too well known but bear repeating here. Sulphur dioxide aggravates respiratory diseases and is an eye and respiratory tract irritant. Oxides of nitrogen aggravate respiratory illnesses. Carbon monoxide is responsible for reduced tolerance for exercise, impairment of mental functions and foetal development and can cause death at high concentrations. Lead accumulates in body organs causing anaemia and damage to the kidney and central nervous system, especially in children.

The introduction of unleaded gasoline is a definite step in the right direction. It was initially supposed to take place in 1995 (not for health reasons but for use by high performance vehicles coming into the country) but this was scuttled by the 1995 Kollonnawa depot fire and consequent reduction in storage capacity. It was however introduced in 1997. CPC had originally estimated bulk imports by 1998 and local production by 1999. This is so far on schedule and from an initial dozen or so stations which dispensed unleaded gasoline of 93 octane CPC has now completely done away with producing its three star leaded gasoline and replace it with unleaded fuel of 93 octane. Consequently all stations which had pumps dispensing three star leaded fuel now dispense unleaded gasoline (93 octane). The only leaded gasoline is the two star gasoline (90 octane). This coupled with the move towards importing used cars which can use unleaded gasoline and the cabinet decision to have only unleaded gasoline after the year 2010 and that all new cars imported after year 2000 be able to use only unleaded petrol exclusively (if this is not abused) is very heartening. In health benefits alone this will be a significant step forward.

One significant problem is the increased sales of diesel fuel which is still sold at a subsidised price. Previously the sale of petrol augmented the loss sustained by subsidising diesel sales. The rationale for this was that it was felt that as the distribution of produce and public transport was heavily dependent on diesel powered commercial vehicles raising the price of diesel would cripple the distribution system of produce such as vegetables and essential food stuffs and financially burden both the travelling public and the poor consumer. However the disparity between the price of petrol and diesel (Rs 50/- vs Rs 15/-) has made it lucrative to run diesel powered commercial vehicles for non commercial use and even import and run non-commercial diesel powered vehicles such as luxury cars despite the road tax of Rs. 10,000/= per year. Consequently, in the last few years CPC has reported that the sale of diesel has risen sharply, an increase not reflected concomitantly in increased petrol sales. The situation has now reached the stage where petrol sales can no longer subsidise the cost of the increased diesel imports necessary. In addition to this large amounts of diesel are wasted due to poorly tuned engines and the most common form of visible air pollution is the black smoke spewing out of all too many diesel vehicles, both commercial and non-commercial. This whole arena, which primarily involves the politically sensitive issue of diesel pricing, is then is an area that has to be addressed aggressively in the very near future.

The area of industrial air pollution is potentially less intractable with upcoming regulations that need monitoring facilities to enforce. In this connection the establishment of the fixed and mobile ambient air quality stations is a hopeful beginning. As the Sri Lankan public and its technologists become more familiar with ambient air quality monitoring, branching out into potentially related fields of stack emission monitoring, air quality modelling will in time become accepted practices. Hopefully in the not too distant future we will have air quality being reported daily along with rainfall data in the news media. The Sri Lankan public will then be able to demand of their country's administrators that they take suitable steps to ensure their constitutional right to the safety of the air they breathe.

Annex 1

SEQUENTIAL STEPS IN CONTROL STRATEGY

		SULPHUR	LEAD	PARTICULATE	CO	HC	NO_x
Base 1990	Tons/Yr.	455	79	3,450	188,736	38,364	5,928
	%	100	100	100	100	100	100
Projected 2000 (No controls)	Tons/Yr.	452	126	4,418	340,001	78,207	16,940
	%	99	159	128	170	204	286
I/M	Tons/Yr.	429	120	4,197	260,095	58,876	16,940
	%	94	151	122	130	153	286
0.15 Pb/.3S	Tons/Yr.	163	40	4,197	260,095	58,876	16,940
	%	36	50	122	130	153	286
Diesel Shift	Tons/Yr.	147	46	3,779	299,704	63,885	17,204
	%	32	58	110	150	167	290
Motorcycle Standards	Tons/Yr.	147	47	2,942	298,974	61,109	17,760
	%	32	60	85	150	159	300
Car/Truck Standards	Tons/Yr.	147	47	2,617	116,351	28,710	3,607
	%	32	60	76	58	75	61
Railway Shift	Tons/Yr.	123	47	2,326	110,656	27,948	3,485
	%	27	60	67	55	73	59

Key assumptions made in these projections include:

- no emission control exists in base year 1990;
- 20 percent of all vehicles registered in Sri Lanka are off the road, and that 50 percent of the remaining vehicles are operating in the CMA;
- the average km per year per vehicle is calculated based on engine efficiencies and fuel consumption amounts by class of vehicle;
- auto diesel and petrol contain 0.8 percent sulphur and 0.45 grams/litre lead respectively;
- annual growth rates for motor cars will be 7 percent by the year 2000 as compared to the present level of 5.9 percent;
- annual growth rate for buses will be 3.5 percent by the year 2000 as compared to the present level of 3.1 percent;
- annual growth rates for motor cycles will decrease from 15 percent to 5 percent by the year 2000;
- annual growth rates for light and heavy trucks will remain the same;
- the vehicle population would have doubled by the year 2000; and
- there will be no major changes in fuel prices.

NA-234-77

SOME ASPECTS OF AMBIENT AIR POLLUTION IN COLOMBO

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1. INTRODUCTION

The transportation could be considered as the major source of air pollution in the city of Colombo today, as the vehicular emissions are substantial and ever increasing. It is very undesirable to curb the growth in road transportation. However, there are possible actions and counter measures to control auto emissions such as improving energy efficiency, introduction of environmentally clean vehicles, clean fuels, traffic management and policy framework. In addition to the emissions due to the transport sector, the emissions from power generation, domestic and industrial sources also contribute significantly. It is a fact that the air pollution starts locally and spreads globally. Therefore, it is possible that Colombo air pollution can affect the rest of the island depending on the climatic conditions.

Air pollutants are classified into two categories; primary, when the pollutants are directly emitted into the atmosphere by a source; and secondary, when the pollutants are formed in the atmosphere as a result of physical and chemical processes such as hydrolysis, oxidation and photochemical reactions. Primary air pollutants include carbon dioxide (CO_2), carbon monoxide (CO), sulfur dioxide (SO_2), oxides of nitrogen (NOx), hydrocarbons (HC) including Volatile Organic Compounds (VOCs) and Poly-Aromatic Hydrocarbons (PAHs), Particulate Matter, lead and other metallic compounds. Among secondary air pollutants are Nitrogen dioxide (NO_2), the entire class of photochemicals such as ozone (O_3), peroxy compounds etc. Acidic depositions could also be considered as a secondary pollutant. However, such acidic depositions could act as an effective scrubber to the atmosphere.

2. The scale of the problem in the city of Colombo

Since the transport sector is the main contributor to the Colombo air pollution, there is a direct relationship between the status of the air pollution and the transport sector.

The growth pattern of the total operational fleet in the past 8 years (1991-1997) (Table 1) shows that the average growth in the number of diesel driven vehicles has increased at an average of 6% per annum whereas that of petrol driven vehicles is 4% per annum, which includes motor bicycles and three wheelers. The average growth in motor cycles and three wheelers has been 3.5% and 8.7% per annum respectively.

Out of total fleet composition of 1200375 vehicles in year 1995, about 51% were motorcycles. The balance 49%, had more than 60% diesel driven vehicles. Of these vehicles, over 50% were registered in the Colombo Metropolitan Area and more than 10% were regular commuters to Colombo from neighboring areas. Therefore, it can be assumed that more than 60% of the vehicle fleet is operated in the Colombo Metropolitan area. The 10% regular commuters were further supported when traffic growth on the main corridors of the city of Colombo is considered which was 2.87% per annum during the period, 1962 to 1980 which increased to 5% per annum during the period, 1981 to 1996 [1].

According to the data available at Ceylon Petroleum Corporation (Table 2), the annual average growth of diesel and petrol consumption was 10% and 3.5 % respectively during the period, 1991 to 1995. The import of diesel has increased from 16% to 25% during the period and there had been a marked increase of 57% of diesel imports from 1995 to 1996 due to the high demand for diesel for power generation. It was substantiated by islandwide power-cuts due to the severe drought prevailed in the country during 1996. Apart from the use of diesel for power generation, it was reported that the ratio of annual consumption of diesel to petrol had increased from 3.5 to 4.5 during the period of 1991 to 1995, attributed to the distorted price structure of diesel and petrol. (During this period the price of petrol was about four-fold compared to that of diesel).

However, when the estimated load of air pollutants in the year 2010 is considered based on the vehicular emission rates and the total kilometre run by each category of vehicles, assuming the present conditions with respect to the quality of the fuel, vehicles and the persistent trend in increasing vehicular population until the year 2010, the total load of pollutants emitted to the atmosphere in the year 2010 would be four-fold when compared with that for year 1991 (Tables 1 & 3). That is, load of air pollutants increases at the rate of 10 % per annum. Since 60 % of the total vehicular population is concentrated in the Colombo district at present, no government can just ignore the pollution of ambient air due to the transport.

3. Factors affecting on ambient concentrations of air pollutants

In the atmosphere, the emitted pollutants get dispersed, diluted or transformed. Therefore, the concentrations of atmospheric air pollutants depend on a number of factors such as meteorological conditions, topography and physical and chemical mixing in the atmosphere.

3.1. Meteorological Factors

Meteorological parameters such as wind direction, wind speed, vertical wind speed, solar radiation, barometric pressure, humidity, rainfall and ambient temperature play an important role in dispersion, dilution and transformation of air pollutants in the ambient air.

Since Sri Lanka is situated closer to the equator within an altitude of 6^0 to 10^0 N, it experiences a typical tropical climate which is somewhat modified by the seasonal wind reversal of the Asiatic monsoons. South-West monsoon (May-September), Inter monsoon followed by the South-West monsoon (October-November), North-East monsoon (December-February) and Inter monsoon followed by North-East monsoon (March-April) could be considered as the major climatic monsoons. This classification is mainly based on the direction of the prevailing wind during the season.

During Inter monsoons, where a relatively low wind speed is experienced, the sea breeze during the daytime and the land breeze during the night time may be present and it is independent of the prevailing wind direction. The maximum wind speeds reported during the South-West monsoon in the city of Colombo are shown in Fig.1. It shows that the wind changes in all directions and throughout the year. When the year as a whole is considered, winds towards the inland are regular and as a result the remote parts of the country could also be affected due to the air pollution load in Colombo.

A stable atmosphere tends to increase pollutant concentrations while an unstable atmosphere tends to minimize the pollutant concentrations. In rare occasions where the wind drops to calm, and vertical

dispersion processes fail due to temperature inversion. (i.e. the temperature of the air high above the ground is greater than that of just above the ground level) and if that condition persists for a day or two, the concentration of pollutants may increase 10 to 20 times of average level.

Average and extreme rainfall data for Colombo collected over the last 30 years (Table 4) show that the rainfall well has been distributed throughout the year. However, relatively high rainfall figures have been reported during the periods of April to June and October to November due to seasonal changes in the atmosphere. These rains act as an effective cleansing agent, flushing particulate and other water-soluble gases out of the atmosphere. Rain water and moisture can react with some pollutants such as NOx, SOx, to yield acids or acid droplets. However, this could be a secondary pollutant to the environment.

Solar radiation plays an important role in the formation of secondary pollutants such as ozone, peroxy compounds etc. Colombo Air Quality Monitoring data (Table 5) show that the high concentrations with respect to ground level ozone. This may be due to high concentration of hydrocarbons and high intensity of solar radiation in the ground level of atmosphere.

4. Measurement and Assessment of Ambient Air Quality in Colombo

The first step in determining the magnitude of the air pollution is measuring and monitoring of air quality continuously within the city of Colombo. Subsequently, it could be extrapolated to the other parts of the country.

In Colombo, there have been short term and long term studies carried out on the monitoring of ambient air quality by several state agencies such as the National Building Research Organisation (NBRO), Central Environmental Authority (CEA), Ceylon Institute of Scientific & Industrial Research (CISIR), University of Colombo, University of Kelaniya and Atomic Energy Authority of Sri Lanka. On methodological grounds, these studies could be classified into two broad categories; (a) Studies based on sample observations (chemical/physical) and (b) Studies based on statistical estimates.

Continuous Air Quality Monitoring Programme (CAMP-Phase I) in Colombo, which commenced in 1989 was the first programme initiated by the NBRO and appears to be the most comprehensive effort until the commissioning of present Air Quality Monitoring Stations at the end of the year 1996. This study involved the preliminary assessment of air quality in order to determine the Sulphation Rate (SR) and Dust Fall (DF) at 49 locations within the city of Colombo. Locations were selected in such a way as to cover an average of 70ha land extent covering average of 13000 population per each sampling unit. The highest average value of 0.45 mg(SO_2) /100cm^2/day was obtained at the Slave Island junction where five main roads intersect. The results are summarized in Table 6 and it could be established that the particulate problems are widespread. To a lesser extent, sulphation was also found to be problematic in the areas experiencing heavy vehicular traffic. The findings of this study were further supported by a study carried out by the CISIR [2]. The air quality of the critical locations identified by the CAMP Phase 1 of NBRO Study were subsequently monitored by the NBRO under CAMP Phase II. However, the NBRO could not publish the data of phase II due to some constraints.

It is difficult to compare the previous results, which were carried out by different organisations, because of the disparity of methods used and the differences in averaging hours and the period of monitoring. In the absence of any other information, one could attempt to get a first order picture. In

general, all those studies support the inference of "high concentration of ambient air pollutants is due to vehicular emissions".

The second category of air pollution studies based on statistical estimates were attempted by institutions such as MEIP, CUTP and NBRO to estimate the current pollution load coming to the atmosphere and also to predict the future levels. (Table 3 and Table 7). All these estimates confirm the relative significance of vehicular emissions as a main source of air pollution.

4.1. Current status of ambient air quality monitoring in Colombo

As a present strategy, to measure and establish the extent of the problem, the "Clean Air 2000 Action Plan" programme, launched a continuous Air Quality Monitoring and a Management Program with the assistance of the World Bank and the Government of Sri Lanka. The Air Quality Monitoring Programme is executed by the Environmental Division of the National Building Research Organisation. Under this programme, two continuous Air Quality Monitoring Units have been set up within the Colombo Municipal Council Area. These equipment could continuously monitor ambient SO_2, NOx, CO, O_3 PM-10 levels and meteorological parameters such as wind speed, vertical wind speed, wind direction, solar radiation, ambient temperature and rainfall, and the data are stored in every five minute average intervals.

One of the fixed stations is located in front of the Fort Railway Station and this location could be considered as a peak station with respect to vehicular air pollution. The other fixed station is located at the premises of Meteorological Dept. at Bauddhaloka Mawatha, Colombo-7, to monitor the background air quality within the city of Colombo.

These stations have been operated since December 1996 and the data acquired are compiled in the Table 5. A similar type of Mobile Air Quality Monitoring Unit will be utilised to monitor in 5 other selected locations in future, in order to cover the rest of the island. Subsequently, these data acquired will be utilised to introduce an air quality model for air quality surveillance studies.

In addition to the above programme, the Atomic Energy Authority of Sri Lanka in association with the Radio Isotope Centre, University of Colombo and supported by RCA/UNDP/IAEA has started a programme for the monitoring of elements present in the ambient particulate less than 10 μm in size(PM 10). This programme was initiated in 1995 for the monitoring of PM 10 at a selected location, and continued initially for one year. At present, the programme is concerned with quantifying the elements present in the atmosphere using Nuclear Analytical Techniques as the 2nd phase of the study.

5. Ambient Air Quality Standards

Ambient Air Quality standards can be considered as a guideline, which assist in the assessment of the air quality. These air quality standards are intended to prevent concentration of air pollutants to reach harmful levels. However, these standards are set for individual pollutants; exposure to a mixture of pollutants may have detrimental effects.

In Sri Lanka, ambient Air Quality Standards have been stipulated in December 1994, under the National Environmental Act. (Table 8). When compared with some other countries, these stipulated

standards appear to be more stringent. However, most of the countries, have secondary standards also for the ambient air quality to accommodate different environmental conditions and land use.

Therefore considering the above, it would be more appropriate to introduce secondary ambient air quality standards at least for the City of Colombo and the other industrial/commercial areas in parallel to the other mitigatory measures to curb the growth of air pollution in Colombo.

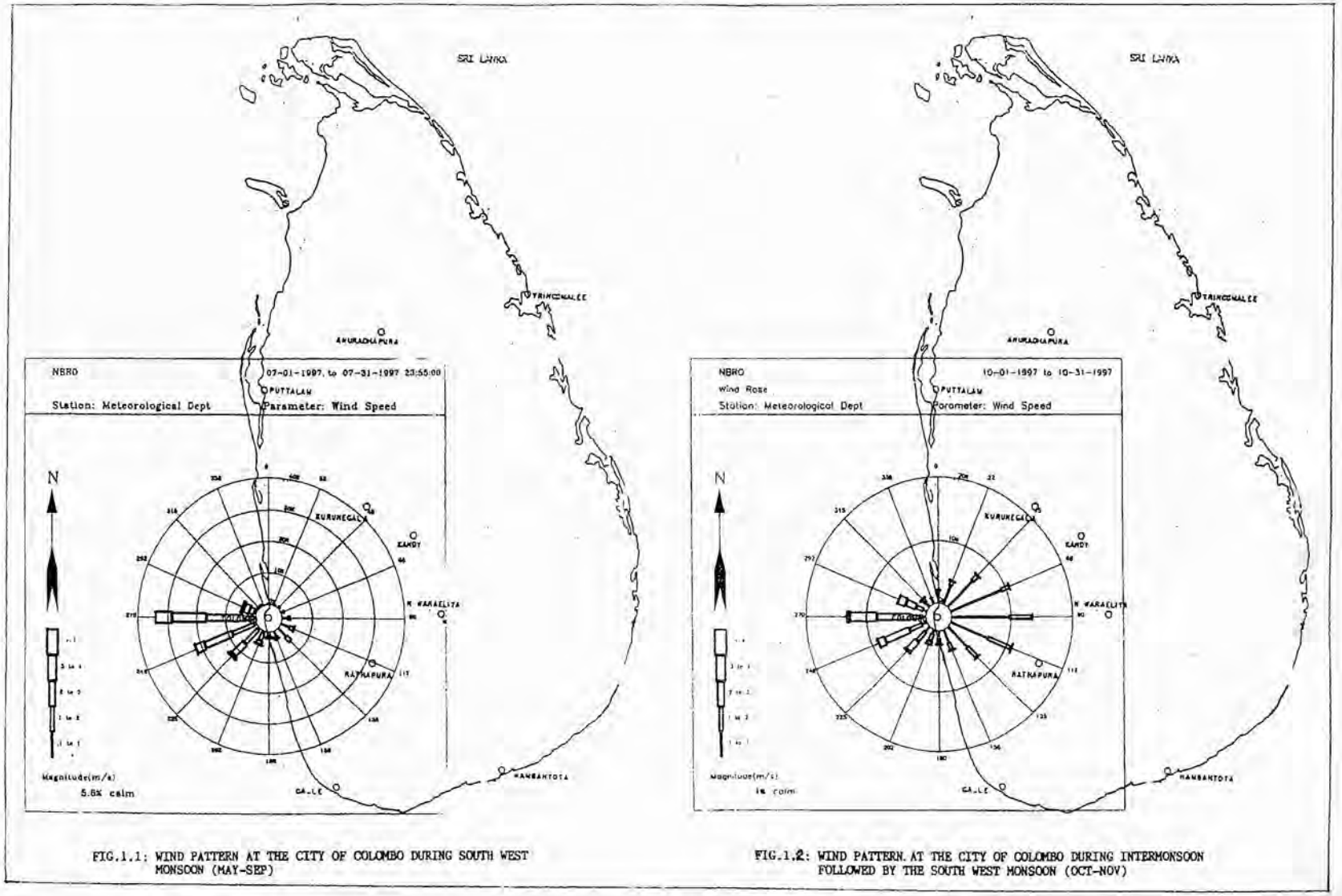

FIG.1.1: WIND PATTERN AT THE CITY OF COLOMBO DURING SOUTH WEST MONSOON (MAY-SEP)

FIG.1.2: WIND PATTERN AT THE CITY OF COLOMBO DURING INTERMONSOON FOLLOWED BY THE SOUTH WEST MONSOON (OCT-NOV)

FIG. 1 : METEOROLOGICAL IMPACTS (CONSIST OF FIG 1.1; 1.2; 1.3; 1.4)

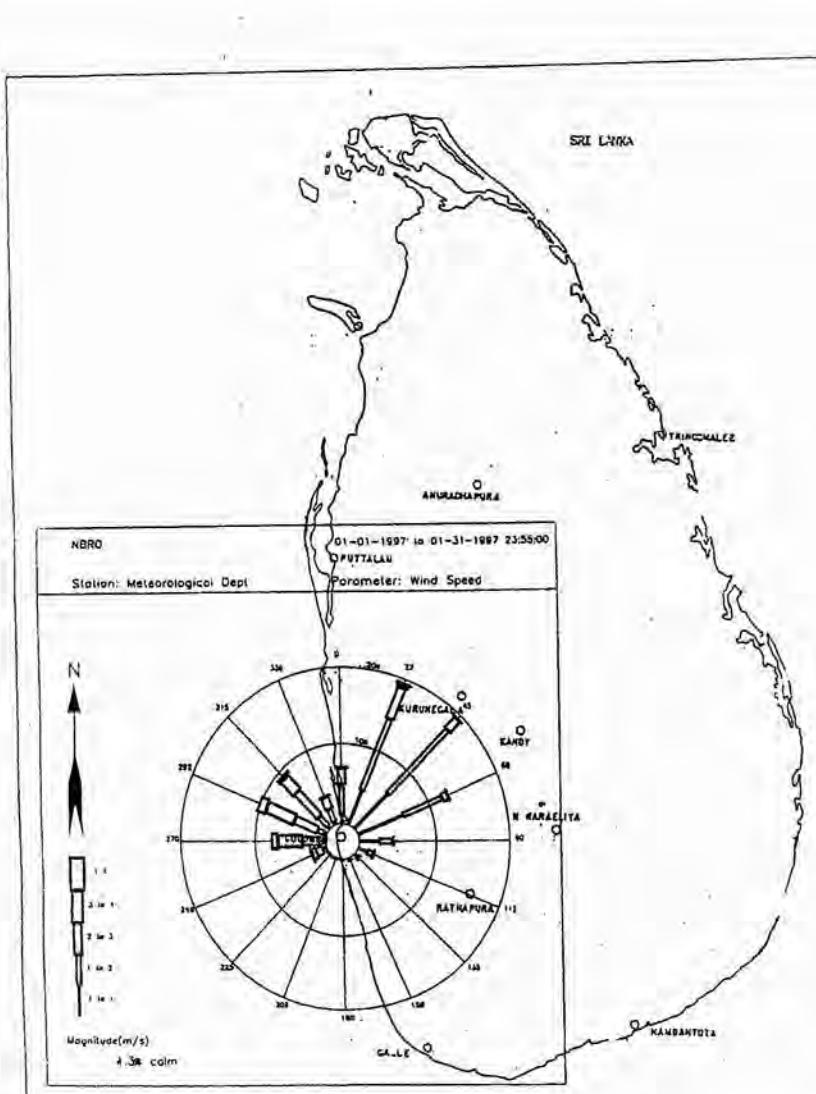

FIG.1.3: WIND PATTERN AT THE CITY OF COLOMBO DURING NORTH EAST MONSOON (DEC-JAN)

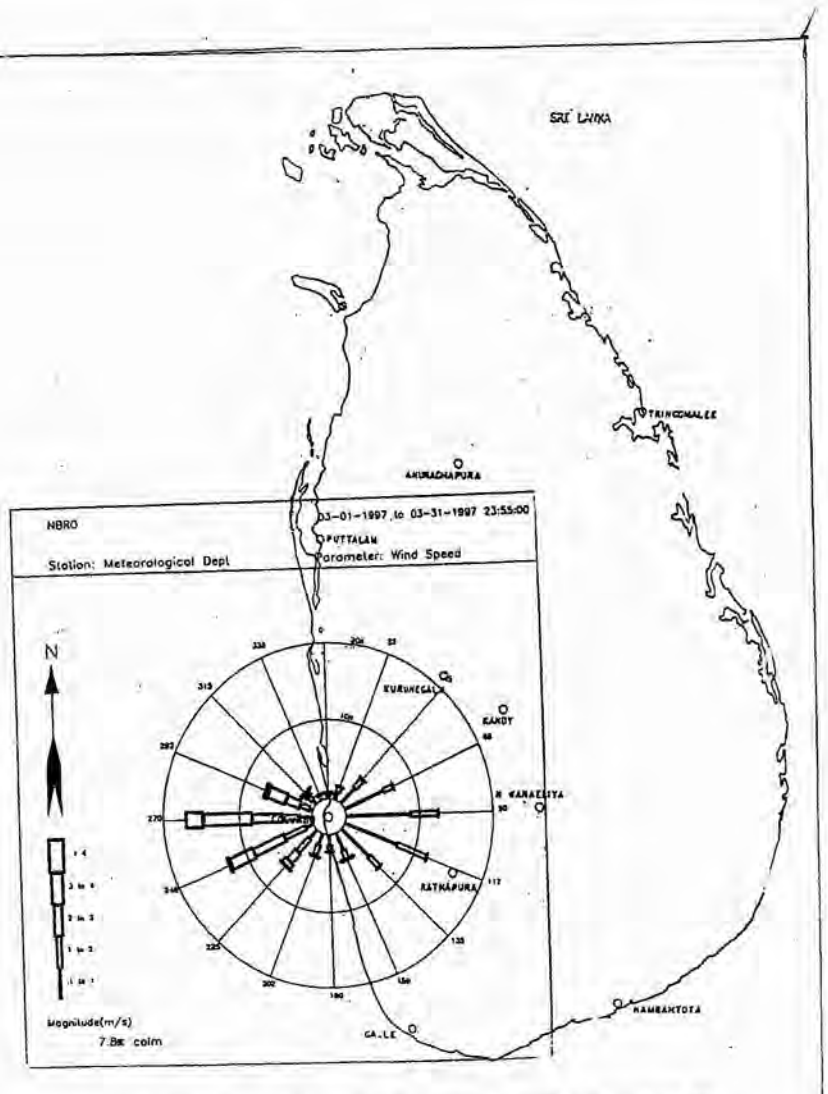

FIG.1.4: WIND PATTERN AT THE CITY OF COLOMBO INTERMONSOON FOLLOWED BY THE NORTH EAST MONSOON (MAR-APR)

FIG.1: METEOROLOGICAL IMPACTS (CONSIST OF FIG 1.1; 1.2; 1.3; 1.4;)

Table 1: **Total operation fleet by class of vehicles**

	1991	1992	1993	1994	1995	1996	1997	2000	2005	2010
Motor Cycles	379,494	426,358	462,484	480,775	501,984	523,899	550,178	635,018	768,345	901,673
Three Wheelers	10,679	11,008	12,882	17,336	29,031	40,632	49,014	65,169	99,170	133,170
Cars(Petrol)	88,817	92,480	94,236	98,065	131,292	134,279	137,772	168,317	216,088	263,860
Cars(Diesel)	4,872	8,097	10,552	13,359	15,040	15,819	16,341	23,656	33,359	43,062
Van-Dual purpose(Petrol)	17,083	16,706	15,863	14,921	13,630	12,118	10,910	8,048	2,704	Negligible
Van-Dual purpose(Diesel)	52,893	63,271	79,267	88,890	99,533	113,339	128,932	164,129	226,365	288,600
Bus/Lorry(Diesel)	45,666	49,299	57,374	65,668	73,548	79,459	85,397	107,135	142,079	177,023

Source :
- Department of Registration of Motor Vehicles
- Sri Lanka Government Railway
- "Ststistical Abstract" – 1996 Dept. of Census & Statistics Ministry of Finance & Planing

Predicted figures upto 2010

Table 2 : **Consumption of Fuel Oil in Metric Tons**

In Sri Lanka	1991	1992	1993	1994	1995	1996
Auto Diesel	588107	627505	688007	750217	816394	951675
Gasoline	159336	164579	172720	183720	191691	198289
In Colombo District						
Auto Diesel	182166	208547	206473	212496	222169	--
Gasoline	64820	65913	67262	71067	73061	--

Source : Ceylon Petroleum Corporation

Table 3 : **Load of Pollutants due to Transport Sector (metric tons)**

	1991	***1992***	***1993***	***1994***	***1995***	***1996***	***1997***	***2000***	***2005***	***2010***
NOx	15,937.68	17,732.07	20,794.10	23,467.22	26,627.04	29,124.45	31,729.03	39,914.17	53,484.13	67,087.09
HC	21,368.38	23,476.58	26,278.01	28,773.23	33,249.58	36,236.47	39,149.89	48,183.70	63,511.53	78,918.57
CO	122,048.95	133,466.78	143,575.29	152,201.74	175,960.22	189,076.78	201,434.83	241,486.92	309,658.81	378,424.73
CO2	2,282,985.19	2,536,681.04	2,965,074.55	3,340,805.22	3,792,381.46	4,148,857.11	4,517,827.98	5,674,127.66	7,594,875.41	9,519,385.36
SO2	8,436.05	9,430.70	11,239.15	12,813.52	14,351.77	15,742.70	17,207.62	21,756.93	29,266.10	36,775.26
SPM	4,012.11	4,479.97	5,293.43	5,998.08	6,769.88	7,459.32	8,168.76	10,291.31	13,845.79	17,401.58
Lead	76.23	81.34	85.31	89.83	110.07	117.19	123.66	148.82	191.46	234.88

Sources :
- **Annual kilometer run by class of vehicles :** estimated based on CUTP & NBRO studies
- **Emission factors :** estimated based on the values presented in Clean Air 2000 Action Plan; CUTP studies; "Vehicular Emission Control in Metro Manila" Final report, 1993; "Diesel Vehicle Emissions and Urban Air Quality", Joint publication by the University of Birmingham and Institute of Public & Environmental Health, Birmingham; and **experimental data from the Environmental division of NBRO**
- **Operation fleet :** Dept. of Registration of Motor Vehicles; Sri Lanka Government Railway

Table 4 : **Average and Extreme Rainfall Data of Colombo, Sri Lanka**

Monthly Averaging Period	Average Rainfall (mm)	Maximum 24 Hour (mm)	Maximum Monthly (mm)	Minimum Monthly (mm)
January	87.9	124.7	310.4	0
February	96.0	132.6	269.2	0
March	117.6	126.5	286.8	4.3
April	259.8	210.1	657.1	4.3
May	352.6	289.6	858.8	20.1
June	211.6	154.7	482.8	38.1
July	139.7	191.3	528.8	7.1
August	123.7	126.0	435.1	3.3
September	153.4	153.4	551.2	17.8
October	354.1	215.9	847.9	82.6
November	324.4	210.3	640.3	56.1
December	174.8	117.9	547.1	6..9
Annual	2395.6	289.6	3933.7	1360.4
Period of Data(Years)	30	35	68	68

Source : Meteorological Dept., Colombo.

Table 5 . **Ambient Air Quality in Colombo**

Month	Station	Max. SO_2 (ppm)		Max. NO_2 (ppm)		Max. NO (ppm)		Max. O_3 (ppm)		Max. CO (ppm)	
		1hr	24hr	1hr	24hr	1hr	24hr	1hr	24hr	1hr	24hr
Dec-96	Peak	0.115	0.056	0.061	0.038	0.117	0.052	0.178	0.026	-	-
	Background	0.037	0.009	0.042	0.02	0.121	0.013	0.094	0.045	3.670	1.187
Jan-97	Peak	0.075	0.025	0.051	0.026	0.145	0.039	0.069	0.028	-	-
	Background	0.061	0.008	0.037	0.014	0.045	0.007	0.092	0.043	2.474	0.959
Feb-97	Peak	0.077	0.024	0.067	0.029	0.136	0.038	0.391	0.054	-	-
	Background	0.031	0.008	0.031	0.018	0.178	0.020	0.123	0.044	2.795	1.337
Mar-97	Peak	0.067	0.023	0.058	0.031	0.126	0.051	0.678	0.037	-	-
	Background	0.040	0.012	0.035	0.022	0.073	0.016	0.150	0.048	3.039	0.048
Apr-97	Peak	0.080	0.032	0.055	0.029	0.132	0.040	-	-	1.691	1.000
	Background	0.031	0.009	0.038	0.018	0.059	0.013	0.239	0.061	2.44	0.858
May-97	Peak	0.081	0.037	0.049	0.028	0.097	0.046	0.049	0.035	2.224	1.058
	Background	0.030	0.007	0.033	0.016	0.061	0.014	0.317	0.843	2.194	0.843
Jun-97	Peak	0.048	0.020	0.029	0.016	0.085	0.035	-	-	-	-
	Background	0.010	0.003	0.023	0.015	0.048	0.015	0.288	0.170	2.119	0.883
Jul-97	Peak	0.011	0.004	0.025	0.014	0.103	0.029	-	-	-	-
	Background	0.038	0.009	0.023	0.012	0.043	0.011	-	-	2.277	0.911
Aug-97	Peak	0.010	0.003	0.029	0.016	0.099	0.042	-	-	-	-
	Background	0.017	0.005	0.019	0.007	0.027	0.006	0.275	0.194	1.504	0.581
Sep-97	Peak	-	-	-	-	-	-	-	-	-	-
	Background	0.019	0.005	0.014	0.005	0.036	0.004	0.349	0.188	1.609	0.527
Oct-97	Peak	0.126	0.007	0.083	0.027	0.131	0.056	-	-	9.141	2.062
	Background	0.147	0.020	0.030	0.150	0.053	0.012	0.678	0.159	13.58	10.373
Nov-97	Peak										
	Background	0.032	0.010	0.035	0.012	0.062	0.021	0.175	0.073	5.318	1.464
Dec-97	Peak	0.037	0.012	0.088	0.061	0.153	0.099	0.070	0.006	11.878	3.213
	Background	0.031	0.009	0.031	0.014	0.102	0.018	0.364	0.104	8.035	1.215

Exceed the Sri Lankan standards for ambient air quality

Source : Environmental Division. National Building Research Organisation. Sri Lanka

Table 6: **Summary of findings of CAMP Phase 1 of NBRO Study**

Parameter	Range mg/100cm2/day	No. of locations	Reference Value* mg/100cm^2/day
Sulphation Rate (SR)	<0.1 0.1-0.2	14 28	0.5
	>0.2	07	
Dust Fall (DF)	<0.2 0.2-0.3 >0.3	15 12 22	0.33

Source : Environmental Division, National Building Research Organisation, Sri Lanka, 1989 – 1991.

* The reference values were obtained by a Study carried out by the National Environmental Engineering Research Institute (NEERI), India

Table 7 : **Estimated Emissions from Petroleum Combustion Sources**

Sources	**Unit**	**SPM**	**SO_2**	**NOx**	**HC**	**CO**
Transport	Tons/Year	3453	455	5928	38364	199736
Industry	Tons/Year	358.42	9791.15	1243.56	68.59	97.98
Power and Commercial	Tons/Year	1.603	107.38	20.358	0.19	1.018
Houshold	Tons/Year	100.5	113.39	76.7	13.34	8.337
Total	Tons/Year	3913	10467	7268	38446	199843

Source : Metropolitan Environmental Improvement Programme (MEIP), Sri Lanka, 1992.

Table 8 : **Ambient Air Quality Standards of Sri Lanka.**
(Gazette Extraordinary No.850/4 of December, 1994)

Pollutant	Averaging time (hrs)	Unit	Standard
SO_2	1	$\mu g/m^3$ (ppm)	200(0.08)
	8		120(0.05)
	24		80(0.03)
NO_2	1	$\mu g/m^3$ (ppm)	250(0.13)
	8		150(0.08)
	24		100(0.05)
O_3	1	$\mu g/m^3$(ppm)	200(0.01)
CO	1	mg/m^3(ppm)	30(26.1)
	8		10(8.7)
	Any time		58(50)
Lead	24	$\mu g/m^3$	2.0
	Annual		0.5
Suspended Particulate Matter	1	$\mu g/m^3$	500
	3		450
	8		350
	24		300
	Annual		100

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1. Jayaweera, D.S. "Is there significant traffic congestion in Colombo", Transport Studies and Planing Centre, Sri Lanka, 1997.

2. Mathes, J.A.P. and Karunasinghe, A.W. J. "Studies of air pollution caused by vehicle emissions in Colombo city", Ceylon Institute of Scientific Industrial Research (CISIR), Sri Lanka, 1992.

NA-234-85

ACID RAIN MONITORING IN SRI LANKA

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INTRODUCTION

Sri Lanka is an island situated in the Indian ocean has a land area of 65600 km^2. The climate is moderate and uniform where the temperature ranges from 16^0 C 35^0 C . Sri Lanka has two major monsoonal periods where it gets rain mainly from South West and North East directions. The annual rainfall ranges from 2500-5000 mm in the south-west and around 1250 mm in the north-west and south-east regions. It is predominantly an agricultural country but is rapidly becoming industrialized.

In 1960 about 90% of the people in Sri Lanka lived in villages and their life centered on agricultural activities. Power requirements were obtained through hydroelectricity and the generation of acid rain precursors to the atmosphere were minimal. However, after the liberalization of the economy1978, the Sri Lankan government implemented plane a rapid industrialization phase which necessitated the installation of alternate power plants such as thermal power generation and the proposed coal powered power stations. The current hydroelectric power production which has reached a saturation point is around 4000 GWh annually. While over 95% of our energy requirements in 1995 were obtained from hydroelectricity, the scenario has rapidly changed during the last two years where the thermal power plants have taken over the generation of around 30% of the national requirement. Already several diesel fired power plants are in operation with an installed capacity of 405 MW. The power requirements are expected to double over the next decade and to meet the increased energy demand the preferred option of the government appears to be the installation of coal fired power plants. Thus a 150 MW coal power plants is proposed to be commissioned around 2002. More coal power plants will come into operation in the future and the projected installed capacity of thermal power plants by the year 2010 will reach 2200 MW. These proposals and the use of high sulphur coal will certainly affect the overall pattern of acidic precipitation in the country.

The number of motor vehicles have been increasing at around 6% annually during the last two decades. Over 60% of all motor vehicles are registered in the Colombo metropolitan area and this will present a major environmental problem as regards air quality. Of particular concern is the increase in diesel powered vehicles. The import of diesel fuel increased by about 25% over the period 1991-1995 while from 1995 to 1996 the increase has been a phenomenal 60%. This is particularly due to the operation of new diesel fired power plants. Air pollution loads will thus increase by about 10% annually and this will result in significant increases in acidic precipitation.

Because of the small size of the country and prevailing winds there is the distinct possibility of acidic precursors getting transported away from their points of generation. Thus, although most of the acid gases are generated in Colombo they could easily get carried out specially to the hill country areas. There is also the possibility of acid fumes from coal power plants of India falling as acid rain in Sri Lanka. The dieback of the montane forests in Horton Plains (elevation 5000-6000 ft) has been attributed to dry acid precipitation. The effects of increased soil acidity arising from acid precipitation should be a matter of concern for both short term crops and plantation crops.

Monitoring rainfall acidity is important for a country like Sri Lanka since it gives a direct indicator about the extent of air pollution. Baseline data on current rainfall acidity is important specially in view of rapid industrialization of the country and the proposal for the installation of coal fired power plants

in the future. Rain fall acidity could have adverse implications in agriculture, forest ecosystems and may have affect the water quality of potable water supplies. It can have effects on fish population of inland reservoirs since fish larvae are particularly sensitive to pH changes of their habitats.

Their is no national acid rain monitoring program in Sri Lanka although there have been some sporadic reports of monitoring acidity of rain at a few isolated locations. There is a tendency to believe that acid rain is not a problem affecting Sri Lanka. However from our studies starting in 1995 it is abundantly clear that acid rain indeed occurs in Sri Lanka at certain locations. From 1995 onwards we have systematically analyzed acid rain collected from 18 weather stations around the country and the results are presented in this report.

EXPERIMENTAL

The locations of collecting points of rain water samples is shown in Fig 1. These are the meteorological stations distributed throughout the country and the Peradeniya university constituted an additional sampling point. Sample preservation on site was done by the addition of the bactericide, thymol and the samples are brought over to the University laboratories for subsequent analysis. The parameters measured were pH, conductivity, and the following ions; nitrate, sulphate, chloride, ammonium, sodium, potassium, calcium and magnesium. The pH of the samples were measured using an ORION SA 720 model pH meter and the conductivity was determined with a Ag/ AgCl electrode using a WPA model CM 35 conductivity meter. An Alltech ion chromatograph was used for the rapid and accurate determination of these ions. Ion balance calculations were carried out and the samples were reanalysed until the percentage ion balance reaches a satisfactory value.

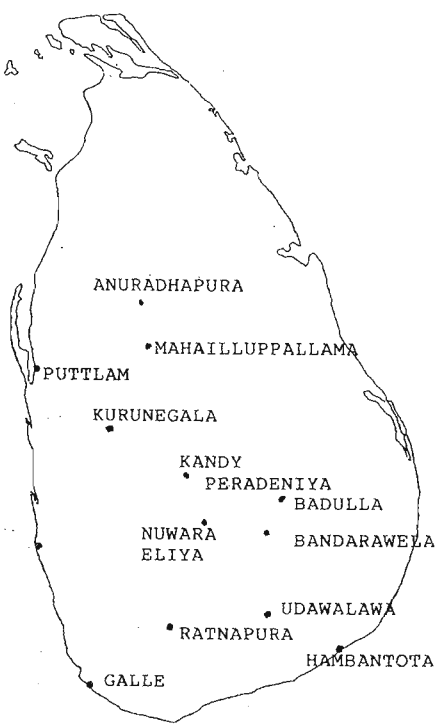

Fig.1. Location of rain water collection points

RESULTS AND DISCUSSION

Acid rain is still not a major problem in Sri Lanka compared to other more industrialised countries in the region such as Singapore, Thailand, Indonesia and Malaysia. However, there are a number of locations where acid rain (rain water having a pH<5.6) is indeed present which should be of concern to the country. This is most prevalent in the hill country and the north central province. The analysis of nitrate and sulphate gives an indication as to the sources of pollution. Pollution arising from vehicular exhausts results in higher nitrate levels and this is specially true of water collected from the western province. As expected, acidic rain is particularly prevalent after extended periods of drought. Surprisingly , Colombo with the highest levels of pollution of its atmosphere did not record major instances of acid rain falling in its environs and it is conceivable that the acidic fumes are transported elsewhere depending on the movement of wind direction and other climatic factors.

Station	pH			Concentration of Cl^- (ppm)			Concentration of NO_3^- (ppm)			Concentration of SO_4^{2-} (ppm)		
	Min	Max	Avg	Min	Max	Avg	Min	Max	Avg	Min	Max	Avg
AP	4.89	6.97	6.00	0.310	3.733	1.625	0.000	1.990	0.742	0.000	0.380	0.052
BD	6.11	7.11	6.64	0.283	3.500	1.921	0.000	2.555	1.421	0.000	2.510	0.741
BW	5.78	6.72	6.24	0.433	4.000	1.666	0.000	0.712	0.296	0.000	3.000	0.755
CB	5.32	6.68	5.89	1.150	5.400	2.217	0.000	1.996	0.566	0.000	8.307	2.948
GL	5.35	7.90	6.45	5.400	32.120	18.058	0.000	2.660	0.896	0.000	8.600	2.438
HT	5.79	5.99	5.89	5.660	14.330	9.995	1.470	2.310	1.890	0.000	0.000	0.000
KG	4.92	6.76	6.28	1.083	7.750	4.276	0.000	1.750	0.876	0.000	1.663	5.550
MI	5.09	6.54	6.07	0.400	2.200	1.369	0.000	1.283	0.517	0.000	1.210	0.486
NE	4.36	6.96	6.18	0.000	2.510	1.216	0.000	0.933	0.281	0.000	2.816	0.402
PT	6.21	7.31	7.00	0.670	8.833	2.556	0.000	0.861	0.433	0.000	7.280	2.473
RP	5.88	6.49	6.25	0.400	1.000	0.787	0.360	0.590	0.483	0.330	0.900	0.537
UNI	4.68	7.27	6.26	0.000	20.200	2.772	0.000	0.790	0.188	0.000	5.500	0.757

Figure 2. Analytical data of rain water samples collected from different stations

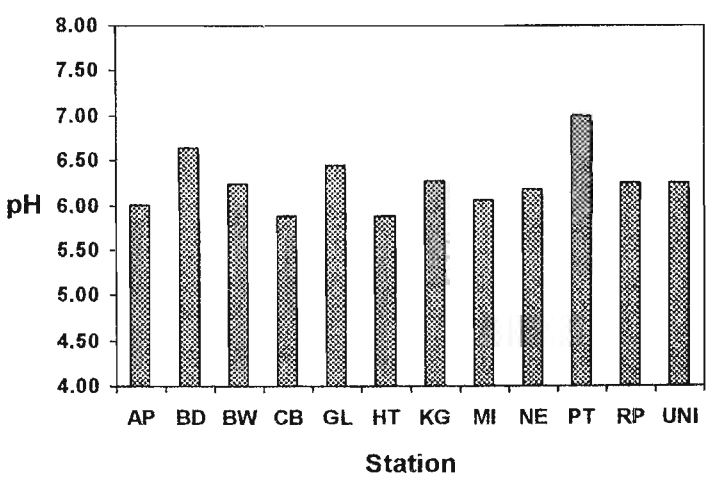

Figure 3 . Mean pH values for rain water from different stations

Key to abbreviations of wether stations:
AP: Anuradapura, BD: Badulla, BW: Bandarawela GL: Galle, HT: Hambantota,
MI: Mahailluppallama ,NE: Nuwara-Eliya, RP: Rathnapura, UNI: Peradeniya University

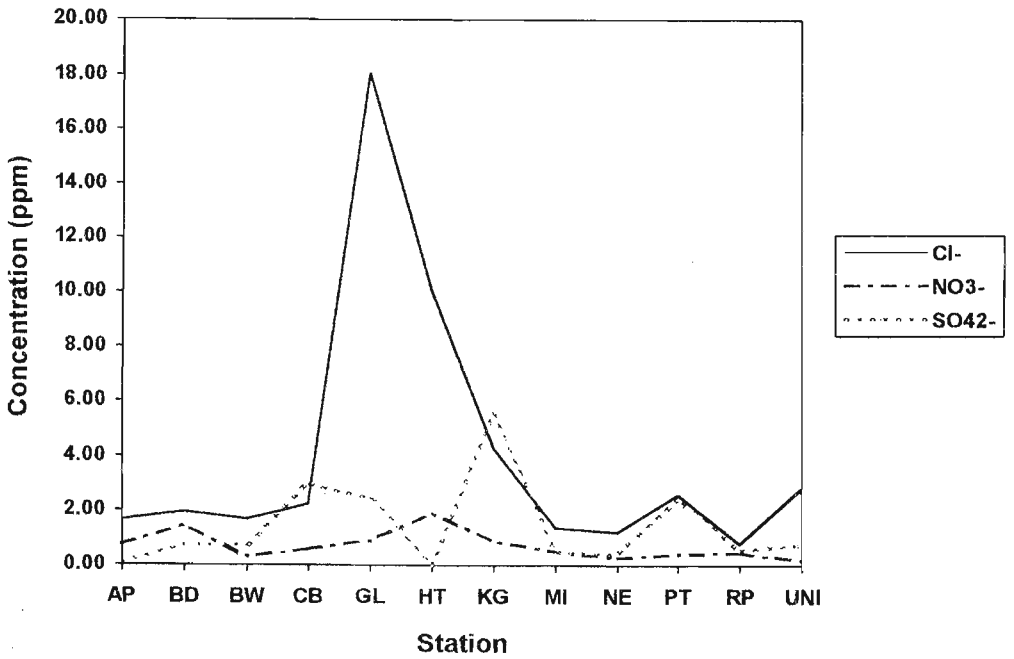

Figure 4. Mean concentrations of nitrate, sulphate and chloride in rain water from different stations

The existence of significant precipitation of acid rain in the north central province should be a matter of concern to Agriculturists since this is a region having high agricultural productivity. The origin of acidic fumes over the atmosphere in this area can be attributed to three factors, (i) exhaust fumes from the Western province carried by wind movements to the north central province (ii) fumes originating from Tamil Nadu power stations finding its way into this region and (iii) increased burning of diesel fuel for rice mills which earlier ran on rice hull as fuel.

Table 1 gives the mean values for the analytical parameters obtained with respect of the different locations from where rain water was collected and figure 1 gives the mean pH values. However the data have still not been statistically analysed and very low pH values for rain water have been found at random, from some stations which still show a mean value for pH higher than 5.6. Figure 2 gives the variation of the mean concentrations of NO_3^- , SO_4^{2-} and Cl^- in rain water from different localities. It is clear that the wide variation recorded from the coastal stations of Galle and Hambantota are due to sea water spray and allowances should be made to take this factor into account when the contributions of the above ions to acidity of rain are evaluated.
Chemical analysis of rain water samples give further insights into the sources of pollution. The chief contributors to atmospheric acidity are nitrate and sulphate. These are sometimes buffered due to the action of ions like calcium and magnesium. Thus the total chemical analysis of water is important before making any assessments of its contributory features. In our context, nitrate levels are fairly high

and this certainly arises from the automobile exhaust fumes. The variations of nitrate and sulphate between urban and suburban areas are not very different due to the fact that wind disperses pollutants in a small island such as Sri Lanka.

Sulphate in rain water arises mainly from two factors; exhaust fumes from mobile sources and industrial stacks and from sea water spray, specially in coastal areas. The total sulphate can be resolved into these two categories by analysing chemical analysis data and these are referred to as sea salt sulphate and non-sea salt sulphate. The non-sea salt concentrations of sulphate originate from the fuel burning process of mobile sources as well as the stationary sources including industrial stacks, thermal power plants etc. These concentrations are relatively low since we do not have any coal fired power plants up to the present time. However, once the projected thermal power plant at Kalpitiya come into operation this scenario may change and hence the importance of collecting baseline data on the chemical analysis of rain water at the present time. The government hopes to build more and more coal power plants in the future to satisfy increasing demand for energy in the future. The importance of searching for alternate energy sources such as solar, wind, biogas etc. is hence important to avoid atmospheric acidification detrimental to our agriculture.

ACKNOWLEDGEMENT

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NA -234-91

MONITORING AIR QUALITY USING DIFFUSIVE SAMPLER

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The theory and functioning of the cost effective, noiseless and lightweight diffusive samplers was investigated in depth and the feasibility of using them for ambient air quality measurements was explored. The performance of these samplers was compared against that of active samplers and the degree of agreement was seen to improve over longer sampling periods. As they obtain time-averaged concentrations, diffusive samplers are well suited for estimating the dry deposition of acid rain precursors and acid vapour, amongst other applications.

INTRODUCTION

The importance of ambient air quality monitoring programs is an issue that has been extensively dealt with and will not be justified here. Often long-term measurements need to be performed over wide geographical areas. Obtaining representative samples under such circumstances can prove to be a very burdensome task. In such cases, the following criteria ought to be given due consideration, prior to choosing a viable sampling protocol:

Availability of electricity: Ideally a sampler which does not utilise electricity for it's performance would prove to be the easiest to handle in remote locations where electricity sources can be difficult to reach.

Simplicity: A small piece of merchandise that requires no specialised attention would be more easily manageable for the presumably non-technical personnel manning the sampling sites. Having to undergo formal training to operate complex instruments would clearly be disadvantageous.

Maintenance and field calibration: These can be burdensome tasks when the apparatus is stationed at distant locations. It is best to opt for maintenance and calibration free apparatus.

Size and weight: The adoption small, lightweight, sampling devices would indeed minimize the woes encountered during transportation of samplers on a regular basis, to remote locations.

Cost and facilities available: When long term investigations are undertaken, employment of cost effective techniques is mandatory.

Accuracy: The accuracy is a measure of the degree of agreement between the obtained result and the true value. A grossly inaccurate sampling method is unworthy of further consideration.

During the recent past scientists have developed a simple but efficient sampler known as the diffusive sampler, in which the above criteria are fulfilled to a satisfactory extent.

Theory and functioning of diffusive samplers

In short, the functioning of the diffusive samplers is based on a chemical and a physical process (i.e. a chemical reaction and laminar diffusion respectively). The rates at which gaseous pollutants in ambient air diffuse into the sampler are controlled by the diffusion coefficients of the respective gases. At the end of the sampler, the gases meet a paper disk that has been impregnated with a chemical capable of reacting very specifically with and almost quantitatively trapping the pollutant of interest. The chemical reactions which are responsible for the sorption process, have been optimised after extensive testing.[1]

A Teflon filter is used to ensure that no aerosols enter the interior of the sampler. A Whatman paper filter is used as the paper disk that is impregnated with the absorbing solution. The amount of product formed during the chemical reaction is then determined according to standard analytical methods in the laboratory.

No field calibration is necessary and the concentration of the pollutant of interest is integrated over the time of exposure (sampling period) typically ranging from one week to one month. Since the sampling process commences the instant the samplers are exposed to air, they are stored in sealed, airtight plastic vials, which are in turn stored in sealed plastic bags.

Depending on the prevailing ambient wind speeds, a static air layer may form at the entrance to the sampler, in which laminar diffusion rather than turbulent transport of molecules may predominate. This phenomenon in effect contributes to the lengthening of the diffusion path. For non-indoor sampling locations the thickness of the static air layer has been found to be 1.5 mm on an average.[1]

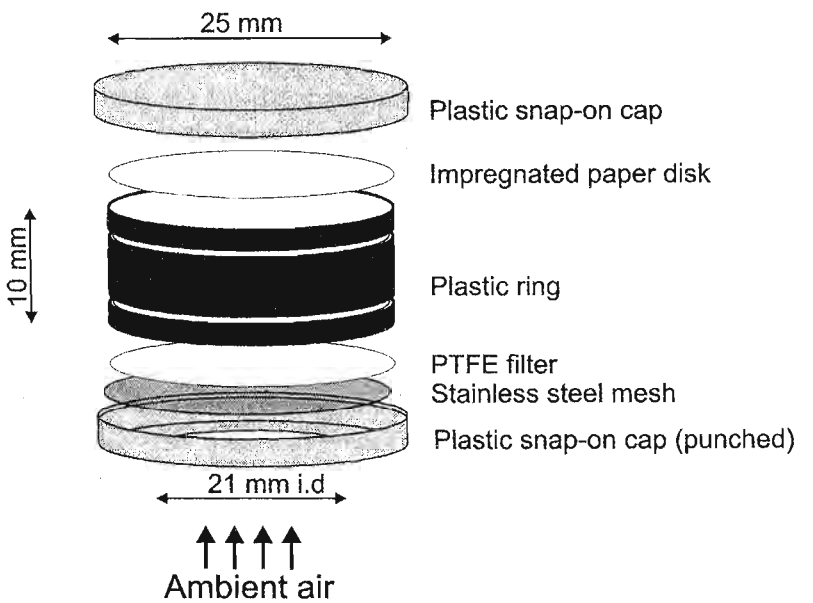

Figure 1: Schematic representation of a diffusive sampler

The ambient air concentrations are evaluated with the use of a formula derived as follows:

Fick's first law of diffusion governs the sampling rate:

- $\emptyset = -D.dC/dL$ where (1)

  $\emptyset$ = Flux of gas in direction of concentration gradient (μg m^{-2} s^{-1}); D = Diffusion coefficient of gas (m^2 s^{-1}); C = Concentration of pollutant (μg m^{-3}); L = Diffusion path length corrected for the Teflon filter, steel mesh and static air layer (m); $-dC/dL$ = Instantaneous concentration gradient of pollutant in direction of air flow

- Since $dX/dt = \emptyset.A$ where (2)

  X = Amount of pollutant trapped on paper disk corrected for the blank (μg); A = Cross sectional area of diffusion path (m^2); t = Sampling time (s)

- Combining (1) with (2) to eliminate Ø gives : $dX/dt = -A.D.dC/dL$ (3)

- Integrating and rearranging (3) yields : $C_{Avg} = [X/(t.D)].(L/A)$ (4)

Based on the configuration of the sampler and it's dimensions specified in Figure 1, the term *L/A* was determined to be 35.0 m^{-1}. Expression of the results as mixing ratios[2] or ppb units i.e. mm^3 (commonly known as μL) of pollutant per m^3 of moist air under sampling conditions, is preferred since the dependence on atmospheric pressure is then eliminated. Under these circumstances the concentration is inversely proportional to the square root of the absolute temperature and will fluctuate by slightly less than 0.2% per °C at ambient temperatures.

The reactions that take place at the surface of the paper disk can be summarised as follows:

SO_2 Sampler: $2SO_2(g) + 4OH^- + O_2 \longrightarrow 2H_2O + 2SO_4^{2-}$

The SO_4^{2-} formed is analysed by Ion Chromatography.[1] The measuring range of this method is 0.1-80 ppb over an exposure period of one month. As an added bonus, the SO_2 sampler is able to simultaneously trap any acid vapours in the atmosphere with the use of the OH^- absorbing solution.

NO_2 Sampler: $2NO_2(g) + 3I^- \longrightarrow 2NO_2^- + I_3^-$

The NO_2^- formed is analysed spectrophotometrically after adding a diazotizing agent.[1] The measuring range of this method is 0.3-40 ppb over an exposure period of one month. In both cases, other reagents are added for chemically stabilizing the reaction products.[3]

Inter-comparison and validation studies

For inter-comparison purposes, experiments were undertaken at a monitoring site where seven 4000 MW power stations are situated within a 50 km radius. In total, the results of 22 diffusive samplers assembled and analysed by three different parties (the CSIRO in Australia, the Swedish Institute for Environmental Research - IVL, and us) were compared against those of a calibrated commercial UV Fluorescence SO_2 monitor, and a Chemiluminescence NO_2 monitor operated at the site. The results are given in Table 1 overleaf.

Although there are discrepancies, the reproducibility and comparability of the results are within acceptable ranges when the detection limits of the methods are taken into account. It must be noted that the systematic errors can be larger than the detection limits but a realistic computation of the errors is not possible with the few data points available. The detection limits are defined as the concentration corresponding to three times the standard deviation of the laboratory blanks used for each pollutant, corrected for the corresponding sampling period.

Table 1: Results of the inter-comparison experiment, expressed in ppb

Gas	Sampling time/h	Sample	Duplic.	Detect. limit	CSIRO	IVL	Active Sampler	Avg.
NO_2	47	6.2	6.8	3.8	-	5.3	9.6	7.0
	168	5.6	5.8	1.1	4.5	3.3	5.4	4.9
	356.5	5.2	6.3	0.5	4.0	3.6	3.8	4.6
SO_2	47	5.2	5.8	2.0	-	4.9	8.5	5.3
	168	3.9	4.3	0.5	2.7	3.8	5.9	4.1
	356.5	7.2	8.4	0.3	7.3	5.9	8.8	7.5

The active samplers obtain readings every 15 seconds and the average of 240 data points is logged every hour. Despite the difference in approaches the two sampling methods are quite comparable, as illustrated in Figure 3:

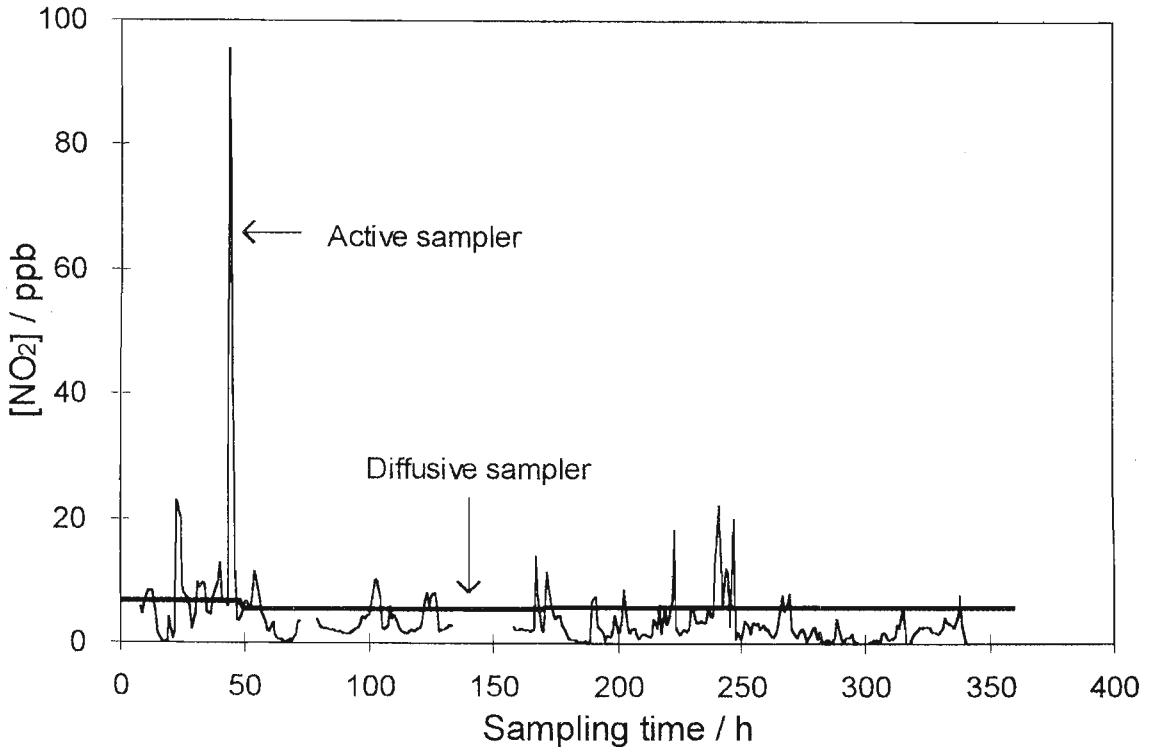

Figure 3: Active versus diffusive NO_2 samplers

The sampling periods of the diffusive samplers have been adjusted to facilitate more reasonable comparisons. Hours 47-168 and 168-356.5 instead of the actual 0-168 and 0-356.5 hours have been treated as separate sampling periods by subtracting the results of the samplers operated from 0-47 and 0-168 hours respectively. Although the systematic errors (considered in this case to be the same as the detection limits) are additive under these circumstances, comparison against active samplers shows a more acceptable degree of agreement.

Figure 4 illustrates how the sampling rate of the diffusive sampler is determined by ambient pollutant concentrations.

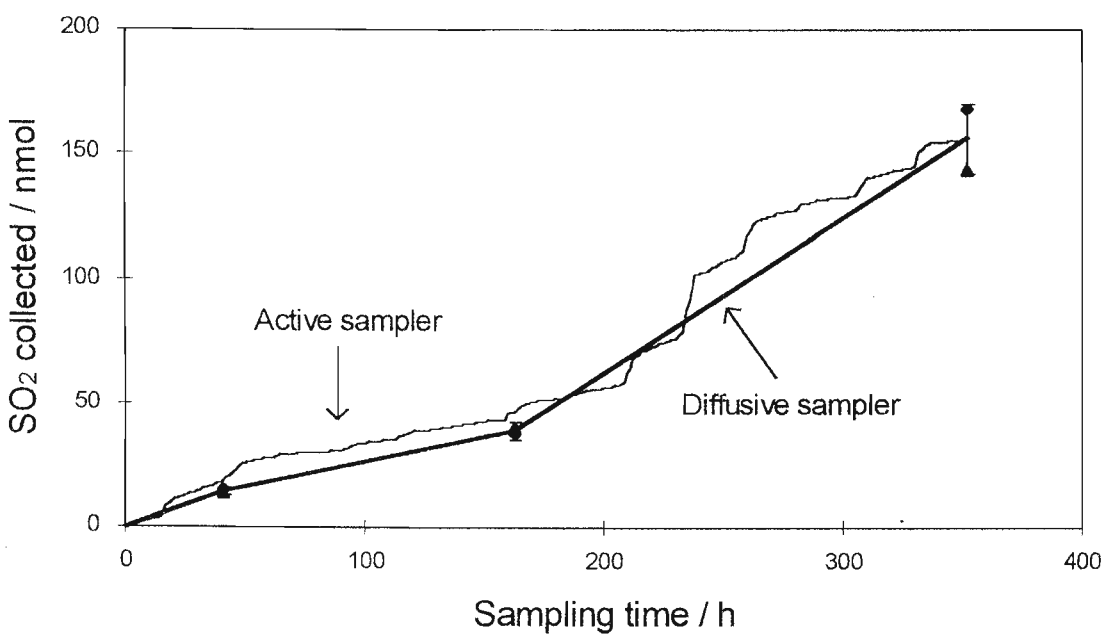

Fig.4. Pollutant collection by SO_2 sorbent

Although the active and passive SO_2 samplers have comparable pollutant collection rates for the duration of the experiment, the data in Table 1 indicates that the 2 sets of results do not match very well over the shorter sampling periods. This can be explained by the fact that the diffusive sampler's pollutant collection rate is slow ($\approx$ 2 pg s^{-1} SO_2 at typical ambient SO_2 levels) and therefore shorter sampling periods result in larger errors, since low amounts of pollutant are accumulated by the sorbent. For example if a SO_2 concentration of 100 ppb is present over a period of one hour, it results in a total of 5.7 nmol of pollutant being accumulated by the sorbent. Due to it's close proximity to the detection limits such a spike will not significantly shift the time averaged result.

Since the samplers were stored for 10 days after the experiment and analysed together, the comparable results of diffusive and active samplers indicate that the sorbed species remains stable over a minimum of 25 days.

It can therefore be concluded from this inter comparison experiment that diffusive samplers are viable alternatives to active samplers, when overall time averaged scenarios rather than instantaneous readings are required.

Cost comparison and potential applications

Consider a case where a study undertaken to map out the pollution concentrations in the vicinity of chemical plants or industries, for public health considerations; this exercise involves the installation of monitoring sites in several urban areas around the vicinity. The usage of active samplers within this context will prove to be relatively expensive. (Around 1 million South African Rand for the monitoring of 4 pollutants at 5 sites simultaneously, according to 1996 estimates) What is sufficient under these circumstances is a time averaged result, which is provided by the diffusive sampler at a comparatively low cost of around R 4000 (equipment costs only for the simultaneous monitoring of 4 pollutants at 5 sites) including the analysis costs, assuming the analytical laboratory is already equipped with an Ion Chromatograph and a UV-Visible Spectrophotometer.

Ayers *et al.* (1995)[4] reported using diffusive samplers to monitor the dry deposition of acidic sulfur and nitrogen species over a two year period, in a study where the wet and dry acidic deposition in the vicinity of isolated point sources was measured. Ground level NO_2 concentrations were measured over a one-year period using an array of 21 sites in rural New Zealand[5] with the use of a triethanolamine (TEA) coated tube type diffusive sampler. The Harvard Ozone Passive Sampler[6] has been used for evaluating the behaviour of Ozone around the human body when indoors.[7]

The concentrations of vapours of inorganic and organic acids which are trapped by the sorbent of the SO_2 sampler, together with the ambient concentrations of SO_2 and NO_2, are mandatory input for research pertaining to acid rain precursors and dry deposition.

The diffusive sampler is ideally suited for observing seasonal trends rather than diurnal variations. However, these lightweight, noiseless, miniature devices are commonly used in indoor pollution monitoring, personal monitoring, Epidemiological[8] and Occupational Hygiene-related studies. In such cases the detection limits, sampling times, time resolution of the result and ventilation rates need to be optimised.

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A PRELIMINARY ESTIMATE OF SULPHUR DIOXIDE AND GREENHOUSE GAS EMISSIONS FROM TRANSPORT SECTOR WITHIN MUNICIPAL LIMITS OF KANDY

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1. INTRODUCTION

Kandy is the hill capital of Sri Lanka situated in the central hills of Sri Lanka. The country itself is a small island having a land area of 65610 sq km and the maximum length of the island from Point Pedro in the north to Dondra head in the south is 435 km (250 mile) and the maximum width from Colombo on the west coast to point Sangamakande on the East coast is 225 km (150 mile). Population and economic centers and plantations of tea, rubber, coconut and coffee which are the primary export agricultural commodities of Sri Lanka are therefore separated by only short distances and Kandy city is situated centrally to all these activities. Kandy has also become a major tourist center, a rich field for international investment in joint projects and free trade zones at Pallekelle.

2. TRANSPORT STRUCTURE

The structure of the transport sector of Kandy reflects the domestic transport sector of Sri Lanka.The transport structure of Kandy can be illustrated as shown in figure 1 below.

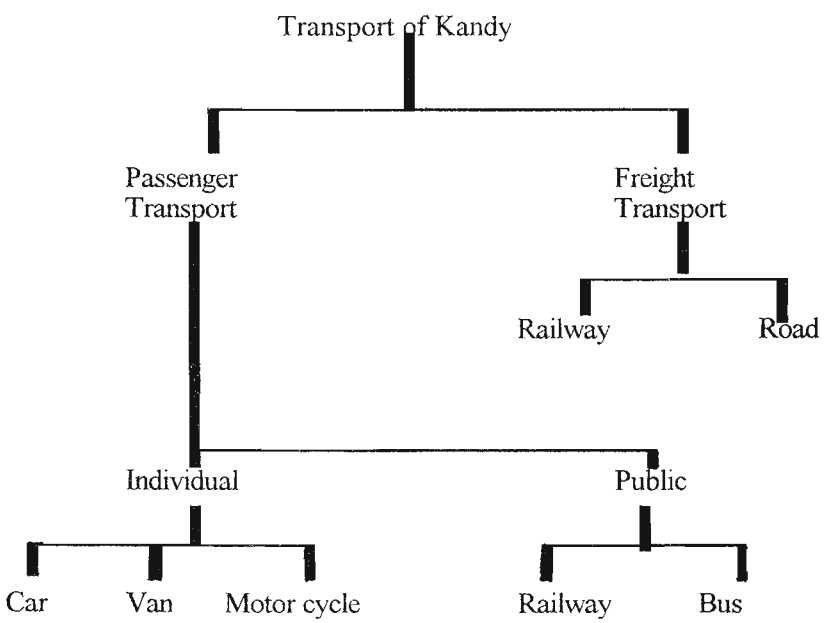

Figure 1. Transport Structure of Kandy

Transport sector in Kandy is mainly dependant on fossil fuel similar to the national transport system of Sri Lanka.

The national domestic transport system includes road and rail networks that penetrates almost every part of the Island having passenger and freight transport. The domestic passenger transport consists of individual and public transport. Individuals use cars , vans, light duty vehicles and motorcycles. Majority of the public makes use of buses and railways for their daily transport activities. The domestic freight is mainly handled by road and rail. Almost 30% gross domestic product of Sri Lanka is generated in the agricultural sector and nearly to 20% in the manufacturing sector. As a result of the above, much of the inland freight transport included transport of agricultural commodities such as food grain and tree crops ,tea, rubber and coconut as well as other bulk goods such as cement , building materials and oil products.The road freight transport is carried out by trucks. In general , the active road vehicle fleet consists of 25 % brand new vehicles and 75 % reconditioned vehicles. All vehicles are imported. Petrol and auto diesel are the main fuels for road transport in Sri Lanka. Buses and trucks are the diesel consumers. Petrol is mainly consumed by cars and vans.

Sri Lanka railway has 1450 km of track. The track is now mostly limited to a single line except for 102 km of double track that extends from Colombo upto Polgahawela on the main line and to Wadduwa on the coastal line. Diesel is the main fuel used in railway transport and small amounts of coal for steam railways. The track length falling within the Kandy Municipal Area is 16.2 km stretching between Peradeniya to Katugastota.

The Central Government of Sri Lanka has a major role in the transport sector in Sri Lanka. Public enterprises are responsible for direct provision of road, railway and port. In the case of transport services, bus service provision is shared between quasi- public and private companies. The quasi - public companies are called Peoplized Companies. Road freight is almost entirely in the hands of the private sector. On the infrastructure side construction and maintenance of roads are controlled by the Road Construction and Development Company (RCDC), which is a fully owned subsidiary of Road Development Authority of Sri Lanka(RDA). The RDA organizes construction and maintenance for the Ministry of Health, Highways and Social Affairs which is responsible for preparing plans , bidding documents contract awarding and works supervision of main roads.

Transport sector accounted for 53.4 % of petroleum product consumption in Sri Lanka in 1990. This percentage could be regarded as significant compared with other Asian countries. In 1989 the transportation sector in Thailand consumed 56% of the total national energy demand while it was about 15% in Korea, 16% in Taiwan, 36% in Malaysia and 30% in Indonesia.

Table 1 given below represents the energy consumption data in transport sector in Sri Lanka for the year 1990.(1)

In terms of road transport energy consumption in Sri Lanka gasoline (petrol) is responsible for 26.5% and diesel is 73.5%. Cars and motorcycles account for nearly 83% of gasoline use. Trucks , buses and dual purpose vehicles consume almost all of the diesel.

TABLE 1 : ENERGY CONSUMPTION DATA IN THE DOMESTIC TRANSPORT SECTOR IN SRI LANKA FOR THE YEAR 1990 (1)

FUEL CONSUMPTION (kt)			
TRANSPORT MODE	PETROL	DIESEL	COAL
ROAD TRANSPORT			
1. Car 2. Pickup 3. Mini Bus 4. Motorcycle 5. Motortricycle	86.4011 20.035 0.9419 47.083 5.9361	9.824	
SUB TOTAL	160.379		
6. Medium Bus 7. Dual purpose 8. Jeep & Other 9. Heavy Bus 10. Truck		81.9399 122.9526 7.2988 46.3147 176.3266	
SUB TOTAL		444.6566	
RAILWAY TRANSPORT		25.8	1.299

3. ROAD TRANSPORT IN SRI LANKA

3.1 Motor Vehicles

Tables 2 and 3 show the active vehicle populations in Sri Lanka for years 1985-1995 based on petrol and diesel respectively.

TABLE 2 : ACTIVE PETROL VEHICLE POPULATION IN SRI LANKA 1990 - 1995(1)

YEAR	CAR	PICKUP	MINI BUS	MOTOR CYCLE	MOTOR TRICYCLE
1990	87962	15056	1918	320452	9365
1991	93689	15241	2412	325099	10679
1992	88817	17083	2269	403197	12882
1993	86521	16576	2140	445035	13532
1994	89192	15275	2012	468475	14522
1995	98334	14089	1893	488630	16074

TABLE 3 : ACTIVE DIESEL VEHICLE POPULATION IN SRI LANKA 1990-1995(1)

YEAR	CAR	MEDIUM BUS	DUAL PURPOSE	JEEP & OTHER	HEAVY BUS	TRUCK
1990	9608	9772	25358	40254	5210	40210
1991	10522	10855	45906	46209	5039	39740
1992	12853	13262	47661	47281	4787	39308
1993	13952	14750	54215	46729	5013	40974
1994	15456	10377	60894	46651	4762	42667
1995	15716	10037	68363	47250	4524	46233

In 1995, 118438000 litres of petrol and 18656000 litres of diesel have been used for private travel in cars, at an average of 1275 million of vehicle km . This represents 11179 km per year (931 km per month) by each of 98334 and 15716 active petrol and diesel cars respectively (1). Data For 1990 - 1995 data are shown in Table 4.

TABLE 4 : DATA ON ROAD TRANSPORT BY CAR IN SRI LANKA
(ACTIVE VEHICLE, ANNUAL VEHICLE km, TOTAL FUEL CONSUMPTION)

	VEHICLE NUMBER		ANNUAL VEHICLE km		1000 LITRE	
	PETROL	DIESEL	PETROL	DIESEL	PETROL	DIESEL
1990	87962	9608	103.5	131.7	113531	11612
1991	93689	10522	1105.7	139.1	113761	12266
1992	88817	12853	1303.0	146.0	118600	11500
1993	86521	13952	958.0	147.4	105434	13829
1994	89192	15456	1042.1	183.8	114692	17241
1995	98334	15716	1076.2	198.8	118438	18656

3.2 Motor Cycles and Motor Tricycles

Out of a total number of 811143 vehicle fleet in Sri Lanka in 1995, there have been about 488630 motorcycles and 16074 motortricycles. The number of motorcycles and tricycles has been rapidly increasing since 1980. Between 1990 - 1995 on an average 77 new motorcycles are added to the roads daily. The marked increase in number of motorcycles in Sri Lanka may be due to their prices being comparatively low and affordable for many of Sri Lankans who generally have low incomes and secondly due to the fact that motorcycles can move faster than other means of transportation in the common traffic jams in cities as they can be ridden zig - zag between cars and buses.

3.3 Public Transport

Bus services have been mainly operated in the past by the state owned enterprise named Sri Lanka Central Transport Board (SLCTB). The SLCTB plays a major role in supervising, monitoring and guiding activities of the peoplised transport services in all areas. Bus services in Sri Lanka which is now shared by the private sector and joint public - private companies are known as Peoplised Transport Services. Today Sri Lanka has over 10000 small private operators and 93 peoplised companies competing with each other.

Bus services in Sri Lanka faces number of problems. Such as declining in number of buses resulting in break downs due to severe overloading and inadequate services, high operating costs due to inefficiencies. Those combined with low fares result in failure to support fleet renewal, poor manage and inefficient peoplized companies.
Table 5 presents the overall consumption of petroleum products by inland transport activities

TABLE 5 : PETROLEUM PRODUCTS CONSUMED BY THE INLAND TRANSPORT(1)

	CONSUMPTION (kt)	
YEAR	DIESEL	PETROL
1990	511.1	181.1
1991	538.0	159.3
1992	627.5	164.6
1993	688.0	172.8
1994	750.2	183.7
1995	816.4	189.7

4 RAILWAY TRANSPORT IN SRI LANKA

After Ceylon became a British crown colony in 1815, the land in Kandy district was planted with coffee, which had a ready market in Europe, products had to be transported through a distance of 120 km to the Port of Colombo. In those days transport had to be carried out using bullock carts , while mail and passengers were moved by horse drawn coaches.

Subsequently there was an increase of traffic and the need for an improved transport system was felt. Accordingly in 1858, the construction of the Colombo - Kandy railway line was launched. The line was opened for traffic from Colombo to Ambepussa in 1864, while it was opened for traffic up to Kandy in 1868. Then the railway began to expand with the development of tea plantations. The line was extended to Gampola and then to Nawalapitiya in 1874. By 1884 it has been extended up to Hatton and Talawakelle and in 1885 to Nanuoya. Haputale was reached in 1893, Bandarawela in 1894, Demodara in 1921 and Badulla in 1924. The line from Kandy to Matale was completed in 1880.

South of Colombo the railway extended upto the well populated coast to the historic harbour and port of Galle. The line proceeded to Matara a distance of nearly 160 km from Colombo, reaching the terminus .

An extension of the line was taken to the North beyond Polgawela reaching Kurunegala in 1894 and Anuradhapura in 1904. Then onwards the line went to Kankesanthurai and Talaimannar via Madawachchi junction reaching the Jaffna in 1905 and Talaimannar in 1914. The Puttalam line

beyond Ragama was completed in stages commencing in 1908 and reaching Puttalam in 1926.

About the same time dual line for the main track was also opened for Polgahawela and the coastal line duplication up to Panadura in 1933. The line to Trincomalee was opened for traffic in 1927 while that to Batticaloa was opened in 1928.

This was the general pattern of development of the railway system in Sri Lanka with a total route of 1453 km . Sri Lanka, Government railway operates 400 trains per day, which cover daily about 33136 train km, 73% of the trains are passenger, 14% goods and 13% mixed(6)

The railways in Sri Lanka are run by a government department known as the Sri Lanka Railway (SLR). It is responsible for a dense network of 1453 km of track, which spans the island from North to South and East to West linking Colombo with all major centers of economic activity.
The Sri Lanka Railway as a government department has had a long record of service supporting the economy of the country. Increasing road vehicle imports plus the inability of the railway to adapt itself to emerging commercial and economic changes and lack of a business approach has resulted the SLR having only 12% of passenger and 6% of the freight compliments.

Table 6 shows the fuel consumption data in railway transport.

TABLE 6 : FUEL CONSUMPTION FOR RAILWAY TRANSPORT(2)

	FUEL CONSUMPTION kt	
YEAR	DIESEL	COAL
1990	25.8	1.299
1991	20.6	0.894
1992	20.7	1.029
1993	21.8	0.61

The drop in fuel consumption after 1984 has been due to continued civil disturbances in the northern and eastern provinces, the railway service on the Thalaimannar line was suspended and Northern and Baticaloa lines were curtailed. The reduction of supply of trains is also a reason for dropping of fuel consumption.

5. AIR POLLUTION DUE TO TRANSPORT SECTOR

Main pollutant gases from the vehicular transport and railways are:
SO_2 : Leading to the formation of acid rain, Leaf damage, reduced growth in plants, Aggravation of respiratory diseases including asthma, Chronic bronchitis.

NO_x : Resulting fading of paints, dyes. Reduced growth and premature leaf drops in plants and aggravation of respiratory illnesses in human beings.
CO :Carbon monoxide is a colourless, odorless gas, highly toxic and is one of the most important pollutants from the petrol powered engine. Carboxyhaemoglobin is formed by the combination of hemoglobin and CO.Carboxyhaemoglobin is useless for respiratory purposes. CO is an insidious poison as there may be no warning until a sudden weakness overcomes the victim.
Particulate pollutants : Suspended particulate matter (SPM) covers a wide range of finely divided solids or liquids that may be dispersed in the air from combustion processes, industrial activities or natural sources. the burning of fuel, emissions from exhaust of vehicles and dust from the road due to the vehicular traffic have been the main causes of SPM.
and
Other greenhouse gases such as CO_2,CH_4,NO_x

6. EMISSIONS FROM TRANSPORT IN KANDY

The transport structure in Kandy has already been illustrated earlier. To summarise transport in Kandy comprises of Road Transport and Railways. Fuel Consumption in these sectors are anlysed in the following sections.

6.1 Emissions from Road Transport:

Fuel for the resident vehicles and incoming traffic is transported from Colombo by means of Rail and road bowsers and distributed to outlets within the municipal limits. There are about 18 distribution outlets within the Municipality for Petrol , Diesel and Kerosene . Use of Kerosene for vehicles has been reported to be negligible within Kandy Municipal Limits. There is one LPG gas filling station established recently for LPG based vehicles. The amounts of LPG dispensed have been found very insignificant compared with Petrol and Diesel usage at present.

Figure 2 below shows a block diagram of the inflow and outflow of a particular fuel such as petrol or diesel to Kandy.

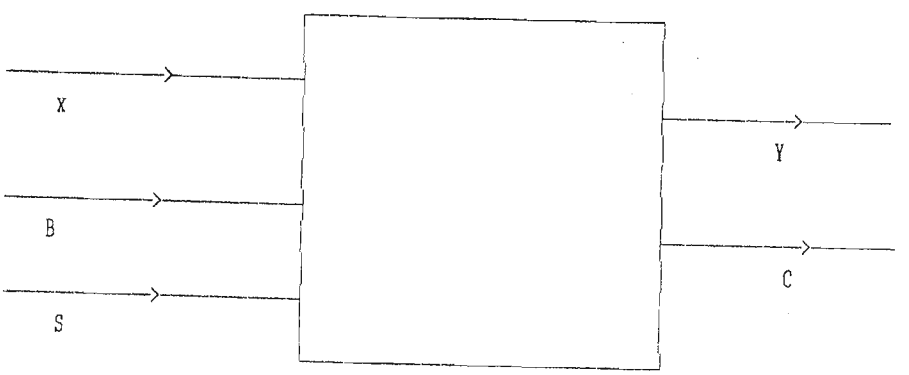

FIGURE 2 BLOCK DIAGRAM OF FUEL FLOW

Here

X - Amount of the fuel brought in by vehicles entering the Municipal Limits/year.
Y - Amount of the fuel taken away in vehicles leaving the Municipal Limits/year.
C . Amount of the fuel consumed within Kandy Municipal Limits/year.
B - Amount of the fuel supplied from Colombo to the filling stations within Kandy Municipal Limits/year
S - Change of Stock position of fuel within Kandy at the beginning and end of the year under consideration (increase taken as positive) .

A Fuel Balance within Kandy Municipal Limits indicates:

$$X + B + S = Y + C$$
$$B - C = Y - X - S$$

Fuel Stock position is Kandy is reported to be small compared with the annual sales. The maximum stock at a given time is about a weeks consumption. The change in stock position is therefore very much less than a weeks consumption in Kandy and this amounts to less than 1/52 fraction of sales. i.e. less than approximately 2% of sales and becomes an insignificant factor in the above equation. The factor S can therefore be neglected with an insignificant error. hence the equation can be expressed as:

$$B - C = Y - X$$

Several cases could now be considered:

Case 1. B <C
This indicates that the amount of fuel supplied by the Corporation is less than the actual amount consumed within the Municipal Limits. An indirect implication to this is that incoming vehicles reaching Kandy brings in fuel for use within the Kandy limits.
This case is far from reality as it is well known that such a situation does not exist within Kandy.

Case 2. B >C
In this case fuel supplied by the Corporation to depots in Kandy is higher than the actual consumption within Kandy. Possibilities in this case are either that the fuel stocks in Kandy are getting increased daily or fuel is loaded into vehicles leaving Kandy because of a shortage of supply of fuel in outskirts or outside cities of Kandy.

This situation cannot arise as there are sufficient fuel depots and filling stations within outskirts and in the neighboring cities.

Hence the only deduction that could be arrive at is the Case 3, where the Corporation supplies sufficient stocks to meet the average fuel demand for consumption within the Kandy limits.

Quantities of fuel issued to the filling stations and bus depots within Kandy town limit for the year 1997 were obtained from the Ceylon Petroleum Corporation. It was observed that fuel demand has not been the same all over the year. It has been changing from month to month during an year .

The fuel consumed was then apportioned between vehicle categories based on the national fuel consumption ratios of different vehicle categories, as shown in Tables 8 and 9.

Table 7 : Fractions of total amount of petrol consumed by all type of vehicles in 1995 in Sri Lanka (1)

Vehicle Type	Average fraction
Car	0.5428
Pick up	0.1240
Mini Bus	0.0055
Motor cycle	0.29210
Motor Tricycle	0.0355

Table 8: Fractions of total amount of Diesel consumed by all type of vehicle in 1995 in Sri Lanka (1)

Vehicle Type	Average Fraction
Car	0.0217
Medium Bus	0.1899
Dual purpose van	0.2755
Jeep	0.0163
Heavy bus	0.1041
Truck	0.3925

These fractions were assumed to remain approximately in the same proportions in 1997 too. The data were then used together with the Calorific values of Petrol and Diesel (44.8 TJ/kt and 43.33 TJ/kt respectively) in order to estimate the energy consumed by the vehicle categories. The results are shown in Tables 9 and 10 respectively.

Table 9 Breakdown of the amount of energy used by petrol vehicles in 1997

Vehicle type	Energy used (PJ) $*10^{-3}$
Car	133.200
Pick up	30.4300
Mini Bus	1.3498
Motor cycle	71.6855
Motor cycle	8.7122

Table 10 : Breakdown of the amount of energy used by Diesel vehicles in 1997

Vehicle type	Emitted energy (PJ)
Car	25.555
Medium Bus	223.637
Dual Purpose	324.445
Jeep	19.195
Heavy Bus	122.594
Truck	462.232

The combustion and emission factors proposed by the guidelines provided by the Intergovernmental panel of Climate Change of the Environmental Protection Agency of US (4) were used together with the above data in order to estimate the emissions of greenhouse gases from the road traffic in Kandy. The SO_2 emissions were estimated by making use of the emission factors for SO_2 (5). Table 11 presents the emission factors used for SO_2 .

Table 11. Emission Factors for SO_2

Fuel type	Emission Factor (kg SO_2 / kg fuel
Gasoline	0.5
Petrol	0.54

Table 12 presents the emissions estimated.

Table 12 Total amount of pollutant gases emitted by Road vehicles from Kandy in 1997 (kt)

Pollutant	Petrol Vehicles	Diesel Vehicles	Total
CO_2	16.996	168.954	185.950
CH_4	0.013	0.005	0.019
N_2O	0.001	0.003	0.004
NO_x	0.101	0.942	1.043
CO	3.035	0.827	3.862
SO_2	0.0027	0.01455	0.01725
NMVOC	0.833	0.193	1.026

6.2 Emissions from Railway Transport:

Emissions from railway transport within the Kandy Municipality seemed to be very insignificant due to the limited track length within the area concerned. However, in order to make this preliminary study complete it was felt that an estimate based on emissions from the National Railway network of Sri Lanka be used to scale down the emissions to Region in Kandy proportionate to the track length. Because of intense activities of Railways within and around Colombo, the estimate herein could be regarded as an upper limit of emissions from Railways from the Municipal Region of Kandy.

Table 13 shows the emissions from the Railway sector of Sri Lanka for the years 1991 and 1992 and the estimated figure for 1995

Table 13. Emissions From Railway Sector of Sri Lanka 1991, 1992 and 1995(kt)

Year	CO2	CH4	N2O	CO	NOx	SO2	NMVOC
1991	67.562	.004	.001	.537	1.614	0.00626	.116
1992	68.178	.004	.002	.540	1.623	0.00633	.116
1997	71.258	.004	.007	0.555	1.668	0.00661	.116

The estimated emissions from the Kandy Municipal Region is shown in Table 14 below.

Table 14 : Estimated Emissions from Railways within Kandy Municipal Region in 1997.

Year	CO2	CH4	N2O	CO	NOx	SO2	NMVOC
1997	0.794	0.000	0.000	0.0062	0.0186	7.37×10^{-5}	0.00125

7. SUMMARY

From the above study, it could be observed that the emissions from the Railway sector within the Kandy Municipality is not significant. Major emissions are from the road transport and here too the emissions from Diesel vehicles have been dominant.

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MONITORING OF ATMOSPHERIC ENVIRONMENT QUALITY IN COLOMBO AND SUBURBS USING BIOINDICATORS

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INTRODUCTION

The problem of air pollution in cities in Sri Lanka, especially Colombo, has become very serious due to recent rapid urbanization and industrial development. Available data on air quality measurements in Colombo City indicate that a large proportion of the population is exposed to various air pollutants. Usually air quality measurements are done using gas analyzers. But if we want to evaluate the impacts of these pollutants on living organisms, it would be better if we use bio-meters along with the gas analyzers. In this study efforts were made to find out whether lichens could be used in the measurement of air pollutants.

This paper describes methods used and results obtained in field experiments carried out to estimate the effect of certain air pollutants in Colombo and suburbs with the following objectives.

1. To study the lichen distribution at certain places in the city of Colombo and suburbs and to provide a data base for future work.

2. To measure SO_2 content of air at those places and to find out a correlation between lichen distribution and air quality.

EXPERIMENTAL

The following sites were selected for this study

1. Garden of the University of Sri Jayewardenepura (site 1)
2. Vihara Maha Devi Park (site 2)
3. Sugathadasa Stadium (site 3)
4. Borella cemetery (site 4)
5. Ranala site (site 5)
6. Sapugaskanda site (site 6)

Selection of trees :-

Seven species of trees which are common in Colombo and suburbs were selected for this study. Trees of more or less similar age were selected according to their diameter at breast height.

1. *Cocos nucifera*
2. *Polyalthia longifolia*
3. *Delonix regia*
4. *Alstonia macrophylla*
5. *Terminalia catappa*
6. *Artocarpus heterophyllus*
7. *Roystonia regia*

Registration of lichens:

The tree trunk from 0.5 m to 1.5 m in height was selected as, sample area for each tree. The lichens in the sample area were recorded using five randomly selected 20cm X 20cm quadrates marked on the tree trunk. In each quadrate the lichen species and coverage of each of those was recorded. At one site three trees of the same species were used in sampling. Tukey's test was employed separately for analyses of data,

Analysis of air quality:-

To estimate the sulphur compounds like $S0_2$, $S0_3$,H_2S in air sulphation rate was measured. A lead peroxide candle was exposed to air for thirty days at different sites under study. The lead sulphate formed was measured turbidimetrically using barium chloride and expressed as μg of $S0_3$ /100 cm^{-2} / day.

RESULTS

Percentage lichen cover and number of different lichen species at different sites, on all tree species under study were compared. Results revealed that site 1 had significantly high values for both these parameters. Further the lichen in site 1 showed copious growth healthy look and numerous reproductive structures.

Percentage lichen cover values obtained for both *Polyalthia longifolia and Terminalia catappa* in site 1 were significantly different from site

2. However, *Roystonia regia* had similar values for lichen cover at both sites. In site *1, Roystonia regia* had mostly foliose and crustose lichens one of which was identified as a species of well-known pollutant tolerant genus *Leconara.*

Lowest percentage of lichen cover and lowest number of lichens were recorded in the site 3. The few lichen present in this site were pale in colour with out much reproductive structures. Lichen cover on *Polyalthia longifolia, Terminalia catappa,* and *Delonix regia* in site 1 were 96.23%, 93.59% and 32.25% respectively while in site 3, same trees had very low lichen over 12.00%,5.87% and 0.53% respectively.

Site 4 had moderate values for percentage lichen cover and for number of lichen species on all trees but were significantly different when compared to site 1 except *on Delonix regia.*
Low values for percentage lichen cover and number of species were obtained in site 5 and site 6. In addition, these sites had only crustose type with pale colour, unhealthy look and reproductive structures.

When percentage lichen cover values obtained on *Polyalthia longifolia, Terminalia catappa and Cocos nucifera* were correlated with sulphation rate at different places, it was found that site 1 which had lowest sulphation rate (50 μg of $S0_3$ /100 sq.cm /day) had highest percentage lichen cover. Where as, site 3 which had highest sulphation rate (270 μg $S0_3$ / 100 sq. cm/day) had lowest percentage of lichen cover. Similarly, *Artocarpus heterophyllus and Alstonia macropylla* had highest percentage lichen cover at site 1 when compared to sites 5 and 6 that had high sulphation rates(110 and 130 μg of $S0_3$/100 sq. cm./day.)

The number of different lichens, recorded at different study sites too coincided with

the sulphation rate. Thus, greater numbers of lichens were recorded on trees in the site 1 while lesser numbers of lichens were recorded from site 3. Moderate numbers were recorded at other sites.

CONCLUSIONS

The results indicate that there is a significant difference in percentage lichen cover in Colombo metropolitan area and suburbs. Even they are on the same species of tree, at different places the percentage lichen cover and number of different lichens were significantly different and this coincided well with the sulphation rate that gave an indication about the quality of air at those places. As lichens are well known for their sensitivity towards air pollutants, they could be used in monitoring air quality over long periods of time, especially when it is necessary to evaluate the effect of air pollutants on the biosphere.

NA 234-113

ACID DEPOSITION MONITORING AND MONITORING AND NETWORKING IN EAST ASIA

Soon Ting Kueh

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1. Introduction

Acid deposition is widely recognised as one of the most serious atmospheric environmental issue which is of global concern . International actions to tackle the problems have been taken in Europe and North America. East Asian countries are also facing acid deposition problems and are now starting to monitor this situation of atmospheric acidification. Cooperative actions in the region are essential to address this issue of acid deposition. Agenda 21 adopted at the United Nations Conference on Environment and Development (UNCED) in June 1992 stated that, on the issue of atmospheric acidification, "The programmes in Europe and North America need to be continued and enhanced, and their experience need to be shared with other regions of the world.

This paper discusses the issues of acid deposition monitoring and networking in East Asia.

At the Environment Congress for Asia and the Pacific (ECO-ASIA) held in Saitama, Japan in June 1994, participating Environment Ministers agreed on the need for establishing a new mechanism to facilitate regional cooperation to address environmental problems common to the region.

The First Expert Meeting on Acid Precipitation Monitoring Network was held in October 1993 in Toyama, Japan. More than 40 experts from 10 countries and 3 international organisations took part in this meeting.

2. Acid Rain Network in South, East and Southeast Asia (ARNSESEA)

The Malaysian Scientific Association together with the Malaysian Meteorological Service and the Department of Environment Malaysia, and with the support of the Commonwealth Science Council and the Ministry of Science, Technology and Environment Malaysia, organised a Workshop on Acid Rain Monitoring Network in South, East and Southeast Asia (ARNSESEA) from 17-19 May 1994 in Kuala Lumpur, Malaysia.

The main aim of the Workshop is to investigate the feasibility setting up an acid deposition network in South, East and Southeast Asia. A total of 65 delegates from 18 countries took part in the Workshop. Organisations which took part in the Workshop included SEI, Sweden, CSIRO, Australia and COSTED. Other programmes which also participated at the Workshop were EMEP, RAINS ASIA, IGAC/APARE (IGBP), CREN and the East Asia Acid Precipitation Monitoring Network.

The Workshop proposed the establishment of the network, ARNSESEA with the following objectives.

- to assess the current levels of atmospheric acidic pollutants in the region;
- to monitor the changes in related air quality over time;
- to identify emission sources which contribute to acid deposition in the region;
- to assess the regional direct and long-term impacts of acid deposition on the environment;

- to make recommendations to governments to mitigate the detrimental effects of acidic deposition;
- to collaborate with other acid deposition monitoring networks to contribute to a global prospective of air quality;
- to strengthen the technical capabilities and quality assurance of participating institutions through technology transfer and training; and
- to promote international harmonisation and standardisation of environmental measurements.

2.1 ARNSESEA Coordinating Group

The Workshop set up an ARNSESEA coordinating group to further develop the technical aspects of the ARNSESEA. Members of the Coordinating Group are:

Dr.SoonTing Kueh (malaysianScientificAssociation) - Chairman
Dr. Greg Ayers (CSIRO)
Professor Zhao Dianwn (china)
Professor Toschiichi Okita (Japan)
Professor Greg Carmichael (RAINS ASIA)
Dr. Frank Murray (Australia)
Professor Hajime Akimoto (IGAC/APARE)
Dr. Barry Noller (FACS)
Dr. T. Ramasami (India/ CREN)
Ms. Leong Chow Peng (Malaysia)

2.2 ARNSESEA Centres

As a meeting of the ARNSESEA Coordinating Group in Darwin, Australia from 14-15 July 1995, it was proposed hat a number of centres with the following functions be established under a number of organisations:

Coordination, communications and promotion
(Malaysian Scientific Association)
Technical support including provision of sampling equipment, analytical service and quality assurance
(SCIRO, JEA & SEI)
Education and training
(JEA, CSIRO & SEI)
Emission inventory
(National Organisations)
Data management and dissemination
(MMS & CSIRO)
Integrated scientific assessment and reporting
(SCIRO & EMEP)
Atmospheric Modelling
(IGAC, CSIRO, JEA, RAINS ASIA, EMEP & WMO)

The Meeting also proposed to set up an ARNSESEA Secretariat at the Malaysian Scientific Association with the following functions:

- to act as a coordinating centre for acid deposition monitoring activities;
- to promote public understanding of acid deposition;
- to develop proposals for training and technical support; and

- to establish contacts with other monitoring networks

3. Expert Meetings on Acid Deposition Monitoring Network in East Asia

The Japan Environment Agency (JEA) organised 3 expert meetings on acid deposition monitoring network with the last being held in Nigata, Japan from 14-16 November 1995. The expert meetings agreed to the establishment of an acid deposition network which is dedicated to creating a common understanding of the status of the acid deposition among countries in the region. The Network proposes to compile acid monitoring data and results gathered by each participating country and publishes reports on the status of acid deposition in the East Asian region. the Network will also facilitate the exchange of technical expertise in the region and promote international collaborations in acid deposition research.

3.1 Structure

The Network will comprise the following elements:

- Implementation of acid deposition monitoring by each country
- Quality assurance/ quality control (QAQC) for monitoring systems
- Data reporting and information exchange systems
- Central compilation and analysis of monitoring data
- promotion of technical cooperation

3.2 Governing Council

A Governing Council comprising representatives from the participating countries will be established to govern the network.

4. Current status of Acid Deposition in South, East and Southeast Asia

The ARNSESEA Workshop also reviewed the current status of acid deposition in the region as summarised below in Table 1:

Table 1: Current Status of Acid Deposition Monitoring in South, East and Southeast Asia

Country	Number of Monitoring Sites	Sampler Type	Sampling Frequency	Analysis Method
Japan	44	wet & dry	Daily	Ion Chromatography
Malaysia	23	wet & dry	Weekly	Ion Chromatography
Indonesia	21	wet & dry	Weekly	Spectrophotometric
Philippines	2	wet	Weekly	Spectrophotometric
Singapore	4	wet	Daily	pH
		dry	Monthly	pH
Thailand	1	wet & dry	Weekly	pH
Bangladesh	1	wet	Daily/Weekly	pH Spectrophotometric
China	ca.30(Research)	wet	Event	Ion Chromatography
India	ca.100(NEPA)	wet	Event	Spectrophotometric
Pakistan	5	wet	Event	pH
Papua New Guinea	1	wet		Spectrophotometric
Sri Lanka	3	wet	Event	pH

5. Other Parameters

The ARNSESEA Workshop also discussed the following parameters:

- Siting Criteria
- Chemical Parameters
- Sampling and Analytical Techniques
- Quality Control and Quality Assurance
- Networking

6. Recommendations from the Expert Meetings

The Expert Meetings recommended the following course of actions towards realising the establishment of the Network.

- Development and enhancement national monitoring network
- Preparation of technical manuals and guidelines
- Promotion of international cooperation
- Formal agreement to establish the Network

Each participating country is to establish national monitoring centres or stations according to criteria stated in the guidelines.

Sampling methods, frequency of sampling, analytical techniques and other technical procedures are to be adhered in accordance with specifications provided in the technical manuals prepared for the Network.

The Network also proposed establishing a Network Centre for the following purposes:

- Compiling, analysing and storing of data submitted by the participating countries
- Publishing periodic reports of the Network
- Providing technical assistance to those participating countries which require assistance
- Developing and implementing education and training programmes for monitoring personnel
- Implementing quality assurance and quality control (QA/QC) procedures
- Providing fora for the exchange of information, experience, etc., within the region, as well as with other fora outside the region.

The Japan Environment Agency (JEA) has taken the responsibility of preparing the technical manuals with experts from Japan, the other countries in the region and international organisations.

Japan has also offered to establish the Network Centre in Japan.

7. Collaboration between ARNSESEA and the East Asian Network

It was agreed that ARNSESEA and East Asian Network are similar acid deposition monitoring networks with the same objectives and modus operandi. The region to be covered by both networks differs in that ARNSESEA proposes to include South Asian countries such as India, Sri Lanka, Pakistan and Sri Lanka, and also countries in the South Pacific such as Australia, New Zealand, Papua New Guinea and Fiji.

The tow networks agreed to work closely with each other and reduce overlaps in work and programmes.

The first area of cooperation is in the development of technical manuals for both networks. The East Asian Network is preparing the technical manuals with assistance from ARNSESEA. It is hoped that with the same technical procedure, data exchange and integration between the two networks can be easily carried out in the future.

It is also possible that the tow networks may be combined into one with increased coverage of participation countries and scope of the programmes.

8. Future Developments

With the establishment of the networks, a number of extended programmes could also be possible. This includes the following:

- Development of Emission Inventories
- Study on Transboundary Movement of Acidic Pollutants
- Numerical Modelling of Acid Deposition
- Effects on Ecosystems, Plant, Livestock and Population
- Collaborative Research on Atmospheric Pollution

9. Conclusion

In conclusion, it is believed that the acid deposition networks will play important roles in monitoring acidic pollutants in the region and provide a solution OT this issue of atmospheric pollution. It will also provide governments with the relevant information to ensure sustainable development in the future.

PROBLEMS ENCOUNTERED IN MODELLING REGIONAL AIR POLLUTION- HOW DO WE PROVE OWNERSHIP OF INDUSTRIAL EMISSIONS

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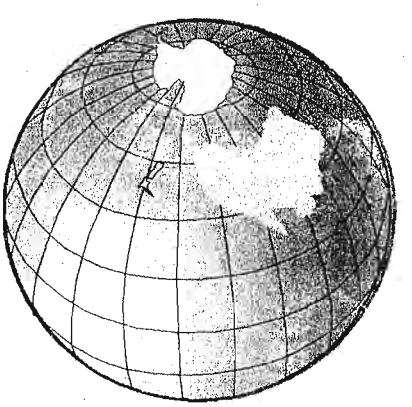
Abstract

In general, the turbulence of the lower levels of the planetary atmosphere ensures excellent dispersion of all airborne pollutants. In regions of heavy rain, many pollutants are quickly captured and utilised by the biosphere before they reach the upper atmosphere. But once in the upper atmosphere, pollutants can travel great distances without being captured. Weather systems are quite constrained in their vertical movement so that some pseudo two- dimensional dispersion and puff models are now emerging which enable the probabilistic determination of the links between emitters of air pollution and the resultant damage caused by it. This paper describes the development of a simple model for the movement of regional air pollution. The region of South India and Sri Lanka is used to illustrate the strengths and limitations of this (and similar) models.

Introduction

The major part of this planet's weather occurs in the lower troposphere. Because our eyes have difficulty focussing on the diffuse blue sky we tend to presume that the atmosphere is limitless: In fact, it is only about 10 km in depth. We can easily walk this distance on the planet's land mass or sail it on the seas and in each case the oxygen content and the air temperature would vary only a little. But 10 km up, the atmosphere is much less forgiving with temperatures down to -50 C and an oxygen content (25% of sea-level) that would leave us gasping for air. In this thin layer, weather systems which extend 1000 km or more bring winds, and rain, storms and snow to the surface. The air flow appears to be turbulent but, only in two dimensions is it unconstrained.



In observing plumes from chimneys, it is apparent that horizontal dispersion is, in most cases, greater than vertical dispersion. For this reason, pollution may spread horizontally downwind many hundreds of kilometres before it enters the upper atmosphere. But once there, the lack of moisture may allow it to travel right around the planet before it is captured and returned to the biosphere. (The presence of high-velocity jet-streams in the upper troposphere also assist the dispersion of pollutants). To a considerable extent, the Coriolis effect ensures that such high level dispersion is constrained to the N-S hemisphere of origin. Some pollutants may react further in the rarified upper atmosphere and are known to cause problems of ozone depletion: Others, such as nitrogen oxides may be decomposed into their constituent elements. Sulphur oxides are very soluble in water so that they can only reach the upper atmosphere if there is considerable vertical turbulence and an general absence of rain. Usually they are captured

within 1000 km of the source and returned to the surface of the planet where they may be usefully utilised by animals and plants. But excess acidity caused by such rain can have harmful effects on the biosphere too. Some species are particularly susceptible to phytotoxins, to acid rain and to sulphates[1].

Sources of acid rain

Natural sources include hydrogen sulphide, sulphur dioxide and nitrogen oxides. The same compounds also arise from human activity but it is the current high use of fossil-fuel energy and the developing manufacturing industries which now contribute such large quantities of the oxides.

Carbon dioxide has been excluded from the list in Table 1 because all rain has become saturated with carbon dioxide as it falls through the atmosphere. Indeed, when we talk about acid rain we actually mean acidity over and above that caused by carbon dioxide. That is to say that acid rain is considered to be any rain water which has a pH below about 5.0.

This is because of the natural equilibrium set up with the carbon dioxide in the atmosphere to form the bicarbonate ion:

$$CO_{2(g)} + H_2O_{(l)} + H_2CO_{3(aq)} = H^+_{(aq)} + HCO^-_{3(aq)}$$

$$\text{and } 5.6 = pH = -\log_{10}(H^+)$$

so that rain can be expected to have a pH of 5.6 quite naturally. Values of pH less than 2 have been recorded but values between 4 and 5 are much more usual. These elevated values of hydrogen ion concentration are attributed to the presence of highly ionised sulphuric, sulphurous, nitrous and nitric acid. The acids are formed by the solution of sulphur dioxide and nitric oxide in water or by the intermediary oxidation of these oxides followed by their solution[2]:

Natural:	
Geothermal	H_2S
Volcanoes	SO_2, H_2S
Electrical storms	NO_x
Man-made:	
From fossil fuels	
— energy production	SO_2, NO_x
— transportation	NO_x
Manufacturing	SO_2, NO_x
Refuse incineration	Acid gases
Forest fires	NO_x

Table 1

$$SO_2 + H_2O \rightarrow H_2SO_3$$

$$2SO_2 + O_2 \rightarrow 2SO_3 \text{ and } SO_3 + H_2O \rightarrow H_2SO_4$$

$$2NO + O_2 \rightarrow 2NO_2 \text{ and } 2NO_2 + H_2O \rightarrow HNO_2 + HNO_3$$

Nitrogen oxides are formed naturally from nitrogen and oxygen in the air during electrical storms. They are also formed in high compression internal combustion engines and in gas turbines. In general emissions are also known to be related to the type of fuel being used.

Acid rain has several known damaging effects including damage to trees (notably pines)1, and the leaching of calcium from the topsoil resulting in a drop in soil fertility as the land becomes sour. The sustained addition of acid to streams and ponds may cause their pH to drop as well. Table 2 shows the species most likely to be killed as stream acidity increases.

The formation of acid rain from the transported oxides of nitrogen and sulphur is presented diagrammatically in Figure 1.

pH	Organism lost
6.0	Snails and crustaceans
5.5	Salmon, trout, whitebait
5.0	Perch and pike
4.5	Eel and brook trout

Table 2

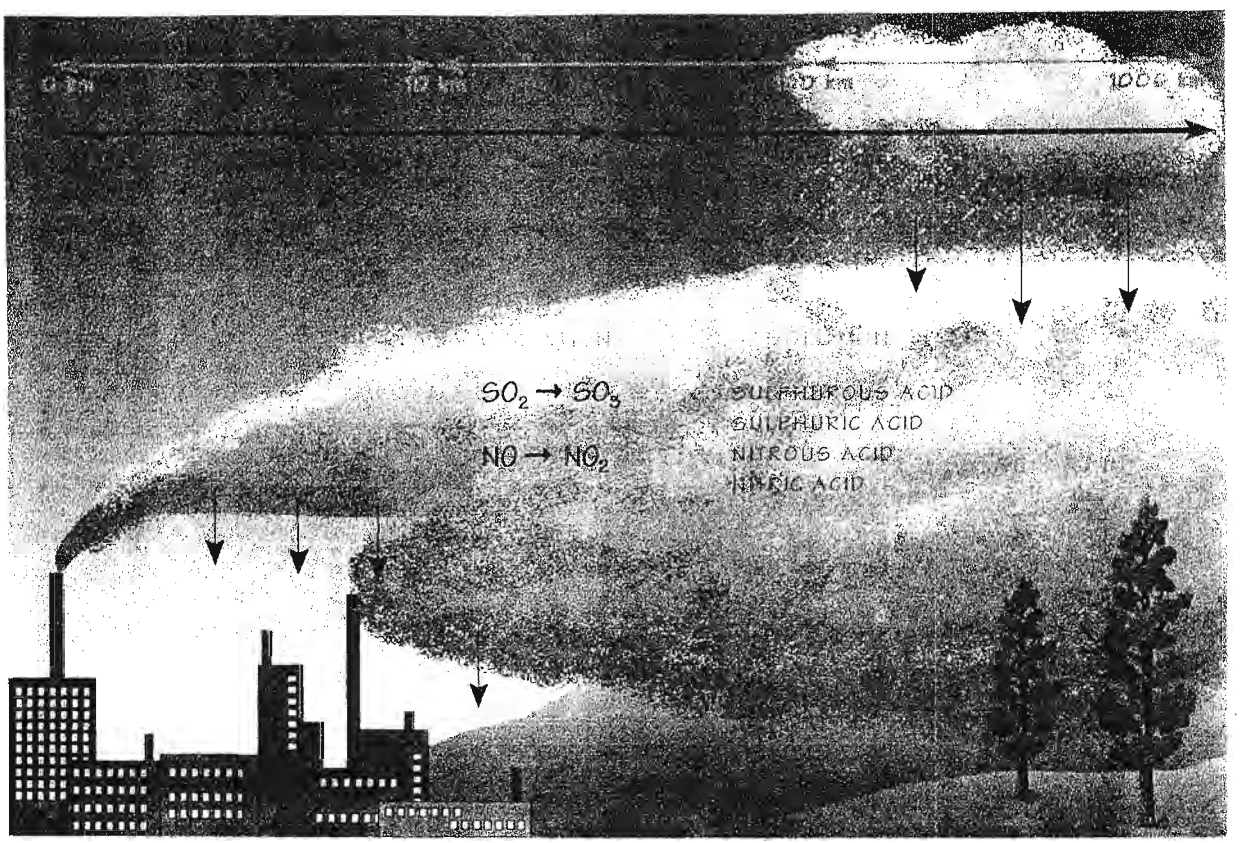


Figure 1 - The formation of acid rain from nitrogen and sulphur oxides

Dispersion modelling

Gaussian dispersion modelling has proved most useful in predicting the effect of industrial sources over a short-range for many years. The original work to determine dispersion coefficients took place under the auspices of the US Atomic Energy Commission and was carried out in Operation Prairie Grass. Arising from this work, Pasquill defined six forms of atmospheric stability and presented

the actual dispersion occurring over a downwind distance of 800 metres. Later work has extended the range of these dispersion coefficients and provided algorithms for their prediction[3].

The technique is called Gaussian modelling because the concentration gradient across the plume is presumed to follow a Gaussian distribution which may be delineated by a mean value and a distribution coefficient (standard deviation).

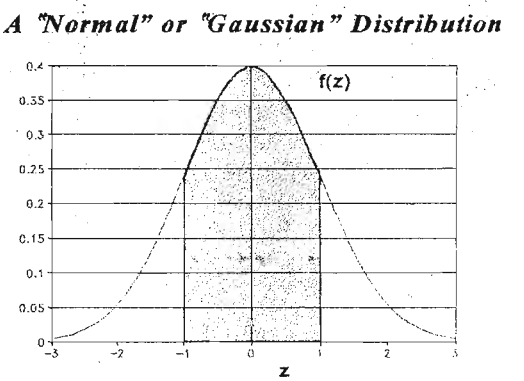


Figure 2 — A normal Gaussian distribution

Gaussian modelling presumes that the source is emitting continuously and that meteorological conditions (including the stability) are constant over the time in which a sample might be taken throughout the down-wind area affected by the plume.

Bierly & Hewson[4] (1962) showed that the concentration, χ at any point in the coordinate space shown in Figure 3 could be presented in terms of wind velocity u, dispersion coefficients σ_x and σ_y :

$$X_{(x,y,z,H)} = \frac{Q}{2\pi\sigma_y\sigma_z u}\left[\frac{-y^2}{2\sigma_y^2}\right]\left\{\left[\exp\left(-\frac{(z-H)^2}{2\sigma_z^2}\right)+\exp\left(-\frac{(z+H)^2}{2\sigma_z^2}\right)\right]\right.$$
$$+\sum_{N=1}^{N=4}\left[\exp\left(-\frac{(z-H-2NL)^2}{2\sigma_z^2}\right)+\exp\left(-\frac{(z+H-2NL)^2}{2\sigma_x^2}\right)\right. \qquad (1)$$
$$\left.\left.+\exp\left(-\frac{(z-H+2NL)^2}{2\sigma_z^2}\right)+\exp\left(-\frac{(z+H+2NL)^2}{2\sigma_z^2}\right)\right]\right\}$$

where Q is the rate of pollutant production, H is the height of the source and L is the height of an inversion layer which constrains the plume. σ_y and σ_z are the dispersion coefficients which can be expressed as a function of downwind distance and Pasquill stability.

Dispersion modelling can be applied to any pollutant provided that the pollutant is not being removed from the air by washing out or by settling. (Additional algorithms can be incorporated in most models to account for removal where the kinetics of the process can be quantified). Many regulatory models have been devised based upon Gaussian Dispersion Modelling and the technique has

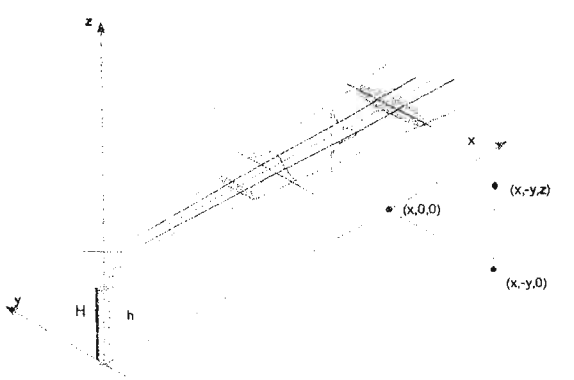


Figure 3 — Coordinate system

atmosphere should be considered in setting the maximum value which can be attained by the vertical dispersion coefficient (σ_z). Bearing these constraints in mind, the program S.ASIA was constructed.

(S.ASIA incorporates many of the useful features of the author's other programs PLANDIS, ROADIS and GASDIS).

Figure 4 shows the application of S.ASIA to a number of sites in southern India which might, perhaps, have an impact on the aerial environment of Sri Lanka.

S.ASIA is presented here as an example of the strengths and limitations of such methods and the implied ground level concentrations should not be interpreted literally. The source strengths quoted in Table 3 are entirely arbitrary and have no validity at this time. However the program allows for more accurate figures to introduced when and where they become available. This will greatly increase its value.

Stability condition D and a wind velocity of 1 m/s were used for much of the modelling because condition D is the most common condition of atmospheric stability (see Figure 5) and 1 m/s is a velocity which allows the least dispersion in the Gaussian model. This means that the conditions modelled would have to prevail for about 1000*1000 seconds (278 hours) for the plume to develop across 1000 km. In effect, Figure 4 shows that in exceptionally stable conditions , a mechanism occurs for the transportation of sulphur oxides from south Indian cities to Sri Lanka.
The model as presented indicates possible ground level

City	SO_2 (kg/hr)
Madras	1000
Trivandrum	400
Madurai	80
Cochin	120
Mysore	180
Bangalore	900
Pondicherry	100
Coimbatore	100
Salem	100
Nagercoil	10
Colombo	250
Kandy	50
Jaffna	50
Trincomalee	10
Batticaloa	10
Galle	5

Table 3

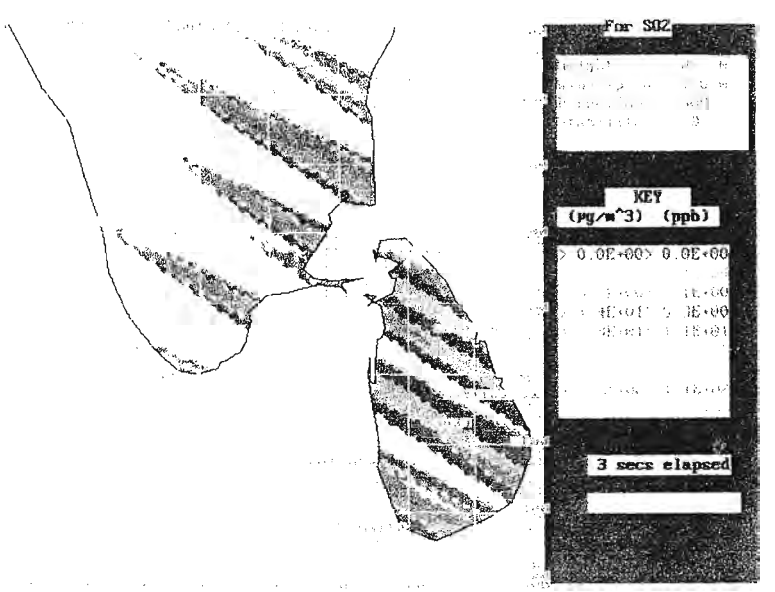


Figure 4

concentrations and shows that emissions from Sri Lankan towns would be superimposed upon the low background level provided by south India.

It can be seen from equation (1) that the ground level concentration is proportional to the emission rate and inversely proportional to the air velocity. Thus an increase in the source emission rate or a reduced mean air

velocity would both proportionately increase the predicted ground level concentration. As a consequence, provided the ratio of emissions from each city remain the same, the resultant pattern of pollution dispersion will not qualitatively change. However more accurate data of emission rates will certainly be necessary if the results are to have any quantitative validity: Actual monitored data would greatly assist in this process of "model refinement".

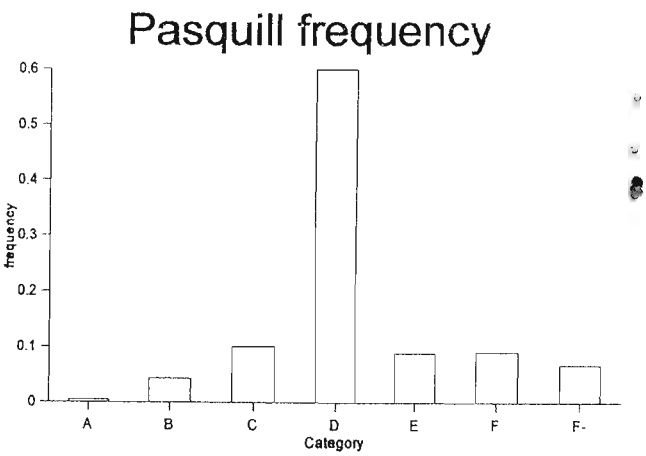


Figure 5 - Typical occurrence of Pasquill categories

S.ASIA can similarly be used to predict the concentration at any height above the ground. Figure 6 shows that plumes from the cities of south India may reach 5 km over Sri Lanka under Pasquill condition D. This implies that any rainfall in southern India and rainfall from above this height in Sri Lanka could remove the major portion of the sulphur oxides originating in this region. (Pidurutalagela in central Sri Lanka rises to 2.5km.).

Using Pasquill condition A and a wind velocity of 5 m/s we can simulate the ability of the lower 10 km of atmosphere to disperse pollutants on a hot summer day (rather than on the typical overcast day/night shown in Figure 6). Figure 7 shows the results. Here it is apparent that vertical dispersion is greatly enhanced so that a column of relatively high concentration pollutants quickly reaches to the upper limits of the weather patterns. The implication is that hot dry days greatly assist the passage of pollutants into the jet-stream layers above the 10 km layer of the lower atmosphere.

There are several limitations to Gaussian dispersion modelling which have been mentioned earlier. Thus the implication that the same conditions apply simultaneously throughout the study area is obviously questionable. And with a time of passage for the plume of days rather than hours it is obvious that diurnal effects will be significant in all but the most overcast weather. To study such time-dependant effects requires that we consider sections of the plume from each source in isolation from the rest of the plume. Further, we must consider how plumes might merge and divide.

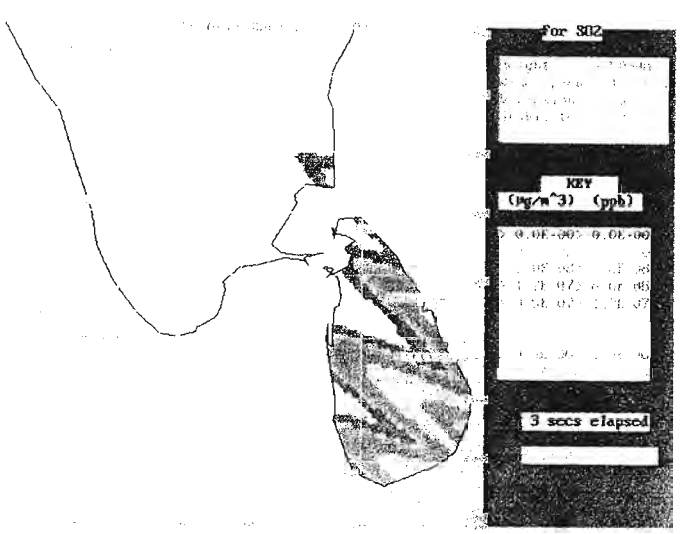


Figure 6 - Dispersion at 5km during overcast weather

Puff models

For chemical spillages, plumes are less appropriate than puffs because the time taken for the emission will almost certainly be less than the time it takes to collect a sample. Puff modelling in effect uses Lagrangian coordinates to delineate the puff dimensions rather than the Cartesian coordinates used by Gaussian dispersion models.

emission will almost certainly be less than the time it takes to collect a sample. Puff modelling in effect uses Lagrangian coordinates to delineate the puff dimensions rather than the Cartesian coordinates used by Gaussian dispersion models.

$$X_{(x,y,z,H)} = \frac{2Q_T}{(2\pi)^{1.5}\sigma_x\sigma_y\sigma_z} \exp\left(-\frac{(x-ut)^2}{2\sigma_x^2}\right) \exp\left(-\frac{y^2}{2\sigma_y^2}\right)\left[\exp\left(-\frac{(z-H)^2}{2\sigma_z^2}\right) + \exp\left(-\frac{(z+H)^2}{2\sigma_z^2}\right)\right] \quad (2)$$

Q_T here represents the total mass released into the atmosphere rather than a rate of release with time. It should also be noted that in a puff model, the wind velocity is irrelevant to the dispersion of the puff. Wind only affects the location of the puff centre. σ_x, σ_y and σ_z are now functions of time and are not directly related to down-wind distance. As a result, while equation 2 is structurally similar to equation 1, the dispersion coefficients for the two models can only be identical when the wind velocity is constant and distance travelled and time taken are simply related. For a given time interval, an increasing wind velocity with dispersion models shows greater downwind distance and hence greater dispersion whereas puff models just show a greater distance travelled : the dispersion is unchanged.

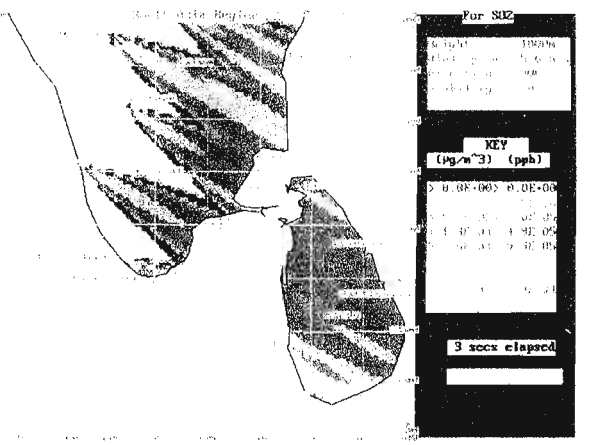


Figure 7 - Dispersion at 10km on a hot summer day with clear skies

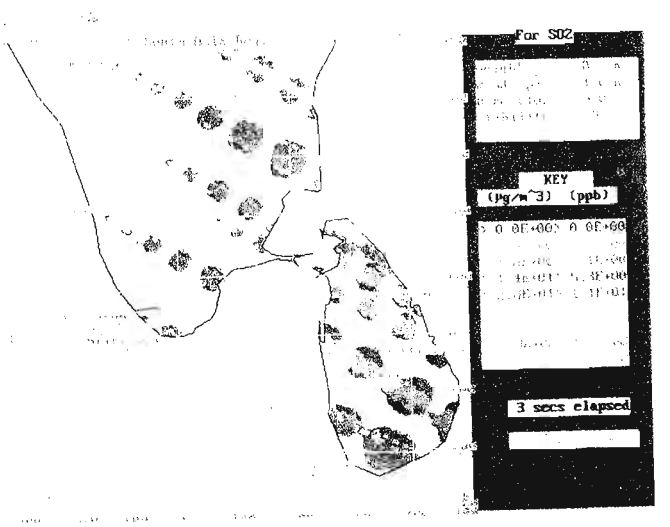


Figure 8

Regrettably dispersion coefficients (σ) for puffs of unconstrained emissions have not yet been determined accurately for dispersion in the x, y and z directions over periods of hours (i.e. the time it would take for such a puff to travel across regions rather than nations). Nevertheless, the expected results would probably look rather like Figure 8 with each puff getting larger and more dilute as time passes. Again the model is presenting ground level concentrations which provide a background concentration onto which a local (and higher) concentration might be superimposed. It should be stressed that the model presented as Figure 8 is purely conceptual. However it does make it possible to consider how each puff might behave with actual wind variations if they were accurately known. It can be readily appreciated that puff models require

much more knowledge of meteorological conditions than Gaussian models because it is necessary to know the conditions to which the puff become exposed in its complete journey.

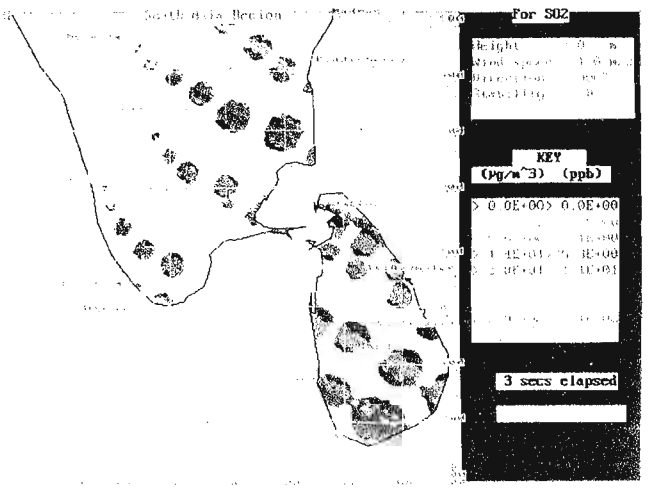


Figure 9

Figure 9 shows the possible effect of the local wind direction over south India. Again the isobars drawn are purely to illustrate how such a model might be constructed: They do not present any known conditions. The implications are that the whole puff is moved by a wind constant in both strength and direction but different in both strength and direction from winds working on other puffs. In fact we can expect the puff to be shaped by differential wind velocities and to lose their generally circular shape. In addition, some puffs might break into smaller puffs while other coalesce as shown in the figure. However it is not currently possible to predict how or where such an event will take place. We do know that distortion of the puff will be related to the terrain and that hills and mountains present real obstacles to the passage of puffs.

Figure 10 shows how the Nilgiris & Cardamom Hills and the Sri Lankan hills might perhaps break up the puffs, redirect them or conceivably force them to climb to higher altitudes. Any of these mechanisms would enhance dispersion.

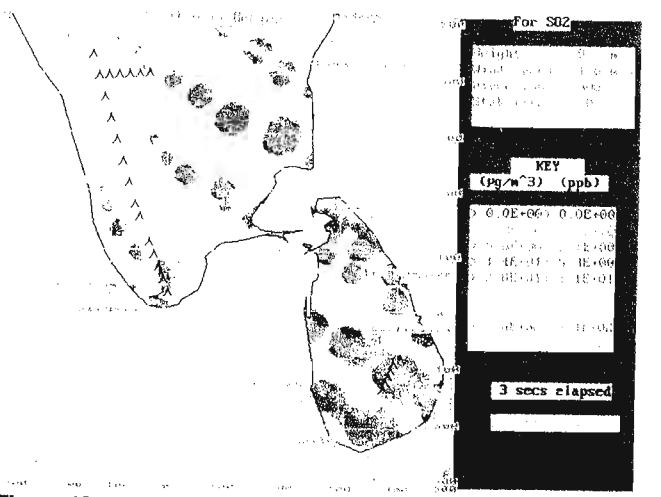


Figure 10

Even more difficult to predict is the effect of microclimate on the puffs as they pass over the land. In some places, sunshine will break through and cause convection currents, in others a valley will funnel the puff through and increase pollutant concentrations. If an inversion layer forms a lid over a valley it may trap an hold the pollutants in a large eddy. Even a lake or the burning of a field of stubble will cause the dispersion of the puff into smaller puffs while individual villages may be superimposing their pollution onto the base of a passing puff. Very few of these effects are likely to be exactly predictable but a Monte Carlo technique for randomising these events within known constraints could be effective. Local knowledge would seem to be essential in building a useful model of such a system and in interpreting the results from a model.

Figure 11 shows what might happen even during a period of relatively stable meteorology due to the effects of micro-climate.

Each progression of the dispersion/puff model so far presented has been based on the idea that sulphur oxides originating in India can be transported to Sri Lanka. However this can only be

true if the puff has not encountered rain. A small shower can wash much of the sulphur oxides from the puff and deposit them (Sulphur dioxide has a solubility of 228 gms/litre in cold water[6]). Such a puff is therefore greatly depleted of its sulphur oxides and cannot transport significant quantities any further.

Unfortunately the occurrence of such showers is partly a random event. However it can be conjectured that the arrival of the monsoon prevents the transportation of sulphur oxides more or less within the whole region. (The electrical storms which precede the arrival may, of course, increase the presence of nitrogen oxides in the atmosphere).

Figure 12 presents one possible outcome of showers within the region: Some puffs disappear entirely while others are cut into two.

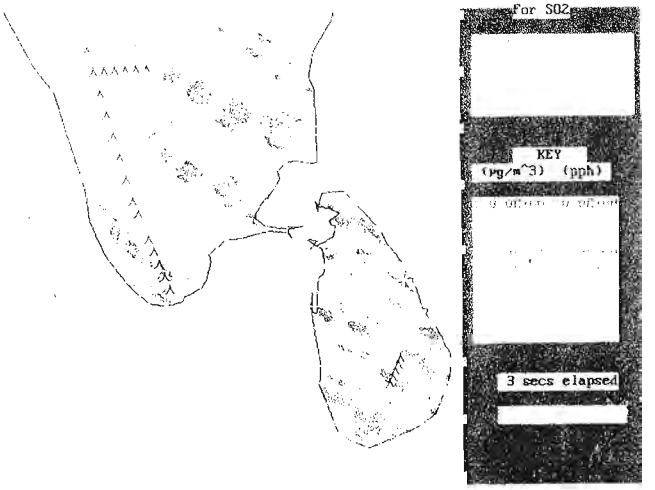


Figure 11

The cooling of the land caused by rain may also cause air flows to be locally reversed thus drawing in fresh air from a higher level and pushing polluted air away from the shower. Similar comments with regard to modelling micro-climatic effects would apply.

Discussion

The basic S.ASIA model presented here is a Gaussian dispersion model which has been modified to present puff behaviour. As pointed out earlier, dispersion models show greater dispersion with down-wind distance from the source (x) while puff models show greater dispersion with time (t). The two kinds of model can only be strictly reconciled for a fixed wind speed where $x = ut$. Nevertheless, we can get a qualitative understanding of plume behaviour by considering the paths of discrete puffs within that plume. Until suitable values of puff dispersion coefficients become available, the general form predicted by Gaussian dispersion modelling will provide some guidance.

It is apparent that σ_z, the dispersion coefficient in the vertical direction must be constrained by the limited depth of atmosphere. However this depth will change with the seasons and between day and night. Ten kilometres has been used in this study as an indication of where pollutants might escape into the upper troposphere. This is quite arbitrary but it could easily be made a variable in the proposed model.

Without further information about dispersion in the x direction (σ_x), we have little choice but to

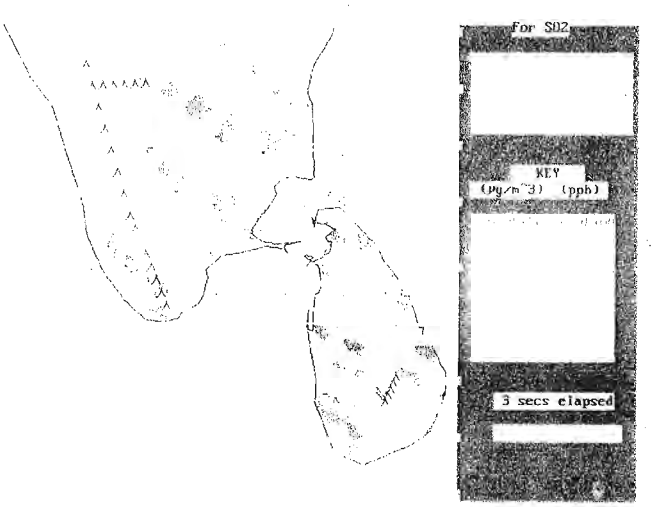


Figure 12

assume that it is roughly the same magnitude as the dispersion in the y direction (σ_y). For this reason, it is conjectured that puffs will start off being roughly circular in plan view. By using the model in an iterative mode, perhaps linked to real time monitoring, it might be possible to update the puff shape as it drifts downwind.

Known and measured variations in wind direction and speed (σ_θ and σ_u) can also be used in a modified Monte Carlo technique to provide a realistic scenario for the probability of a puff turning up at any particular location. Similarly models based upon wind-tunnel measurements and monitoring programmes can be used to predict/measure the effect of hills on the movement of puffs or a steady plume. However we also need a filter mechanism based on local knowledge to properly model the effect of microclimate. Similarly, the source strength (Q) and the number of significant sources we will have to model will be needed and this too will depend upon local knowledge. Detailed meteorological knowledge of the occurrence of showers could be used with Monte-Carlo techniques to refine the model to take account of sulphur oxide removal mechanisms. However, even with maximum cooperation between engineers and scientists from within a region, the final results will be capable of varied interpretation (particularly by politicians). As a consequence, while hybrid models of the form proposed in S.ASIA can provide much useful insight into mechanisms affecting regional and global acid rain, it is unlikely that it will present unequivocal proof of its precise origin.

Conclusions

Gaussian dispersion modelling can be used to indicate "worst case scenarios" caused by industrial and urban pollution over distances of up to 10 km. Simple puff models are better suited to short-term emergency responses.

It is possible to combine some of the features of dispersion and puff modelling to provide qualitative information for distances up to 1000 km. However quantitative assessment of the results presented by such a hybrid model require the incorporation of many additional factors including:

a) Seasonal and daily variations in meteorology (stability, wind velocity, wind direction etc.);
b) Topographic effects due to hills, rivers, lakes, mountains, sea etc.;
c) Effects of microclimate requiring local knowledge;
d) The relationship between shower density, location and general meteorology.

Until such information can be obtained and incorporated, S. ASIA and comparable models will remain qualitative tools. As a consequence, even where a plausible mechanism for pollution transfer across a region exists, the exact origin of any sulphur or nitrogen oxides and their relationship to any local acid rain will be capable of varied interpretation.

In the particular case of India and Sri Lanka, we can see that sulphur oxides from the major southern Indian conurbations is most likely to affect rural southern India: Ground level concentrations are higher and local showers will deposit the sulphurous/sulphuric acid mix on southern India. That is not to say that such oxides cannot reach Sri Lanka but rather that they will be in relatively low concentrations when they do. As a consequence, any acid rain measured in Sri Lanka downwind of its cities is more likely to have come from Sri Lankan sources. Simple

mass balances on fuels used etc. should facilitate the location of such sources.

For any regional modelling, an inventory study would be vital for indicating the average number of tonnes/km2 of sulphuric acid which are being formed by the use of high sulphur fuels. Dispersion modelling would then provide a useful tool in indicating how much of this is likely to pollute the atmosphere within (say) 50 km of the source. A hybrid model developed from S.ASIA (as outlined in this paper) may indicate what is happening within 1000 km of the sources. Whatever cannot be accounted for by these methods must be falling on the land elsewhere, on the sea or being carried out of the region in the upper atmosphere.

Although not demonstrated in this paper, the most productive site for setting up monitoring programmes can be indicated by simple Gaussian dispersion models, by puff models or a hybrid combination. The results of such monitoring can be used to further refine all forms of models including S.ASIA.

It is unlikely that ownership of regional acid rain anywhere in the world will be satisfactorily proven until much more reliable monitored data become available.

While the conclusions presented in this paper are based on a hybrid dispersion/puff model using the specific case of the south Asia region, they are applicable to most regions.

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AIR POLLUTION AND ACIDIFICATION - AN OVERVIEW OF INDIA

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1. INTRODUCTION

The deposition of acidifying substances from the atmosphere to our ecosystem, popularly known as "acid rain", is a high profile issue in both scientific and public forums. This is because acidifying substances and their emitted, gaseous precursors are transported over long distances in the atmosphere, often far from the sources of emission.

The most widely accepted view in regard to acidic precipitation is that the increased acidity is a result of the precipitation of increased quantities of sulphuric and nitric acids. These acids are believed to result from oxidation of S and N oxide gases. But a variety of emissions also influence acidity, notably HCl, ammonia, volatile organic compounds and alkaline dusts (Freedman, 1995). The description of major gaseous air pollutant substances that are mainly responsible for the acidic precipitation are given below :

1.1 Air Pollutants

The most important gaseous pollutants are sulphur dioxide (SO_2), hydrogen sulphide (H_2S), oxides of nitrogen (NO_x), ammonia (NH_3), carbon monoxide (CO), carbon dioxide (CO_2), methane (CH_4), ozone (O_3), and peroxyacetyl nitrate (PAN). In addition, there are pollutant vapours of hydrocarbons, elemental mercury and small diameter (< 1 um) particulate that behave aerodynamically like gases and remain suspended in the atmosphere for a long time. Many of these air pollutants have both natural and anthropogenic sources of emission. O_3 and PAN, however, are not emitted directly into the atmosphere, but are produced secondarily in the atmosphere by complex photochemical reactions.

1.1.1 Sulphur Gases

Gaseous sulphur is largely emitted as SO_2 and H_2S. In the atmosphere H_2S has a residence time of <1 day, as it is rapidly oxidized to SO_2.Atmospheric SO_2 is transformed ultimately to the anion sulphate (SO_4^{-2}). The rate of oxidation of SO_2 ranges from < 1 to 5%/ hr during day, and the process is influenced by the intensity of sunlight, humidity, and the presence of nitrogen oxides, hydrocarbons, strong oxidants, and catalytic metal-containing particulate (Meszaros, 1981; Newman, 1981, Wilson, 1981; Anlauf et al., 1982; Fox 1986). Because of its moderately long residence time (about 4 days), most SO_2 is transported over a long distance from its point of emission before it is oxidized to SO_4^{-2} or deposited to the surface of landscapes.

The largest natural sources of SO_2 emissions are volcanos and forest fires. Emissions of SO_2 by the oxidation of organic sulphur during forest fires have not been well quantified, but the volcanic emissions are estimated to be 12 million tonnes of sulphur per year (i.e. 12 x 10^6 tonnes/year).
The anthropogenic emission of SO_2 to the atmosphere has been estimated as 63-72 X 10^6 tonnes/year (Anonymous 1993b). The largest source of SO_2 is from the burning of fossil fuels, accounting for 54% of the total anthropogenic emission (Moller, 1984). Fossil fuel contain sulphur in both mineral and organic forms, and during combustion more than 90% of the sulphur is oxidized to gaseous sulphur dioxide.

The global, anthropogenic emissions of SO_2 has increased greatly in the past century and projected emission of SO_2-S during 2000 AD is100 x 10^6 tonnes (Moller ,1984) . In the near future, increasing demands for electric power will be at least partly met by the construction of additional fossil-fuelled power plants. This will result in even larger emissions of SO_2, unless there are increased efforts toward emission reduction by the removal of SO_2 from flue gases, fuel desulphurisation, fuel switching, and energy conservation (Moller, 1984). The total natural emission of H_2S -S has been estimated as 100 X10^6 tonnes /year (Bates et al., 1987). Anthropogenic emissions of H_2S is about 3 x 10^6 tonnes/year .

The typical concentration of SO_2 and H_2S in clean, unpolluted air are each less than about 0.2 ppb. Concentrations of SO_2 in polluted air are extremely variable, but they average about 0.2 ppm in urban air (Anonymous 1993b) and can range to more than 3 ppm near major sources of emission (Shriner, 1990).

1.1.2. Nitrogen Gases

From a pollution perspective, the most important nitrogen gases are ammonia (NH_3), Nitric oxide (NO), Nitrogen dioxide (NO_2), and nitrous oxide (N_2O), Together, NO and NO_2 are often abbreviated as NOx.

The major source of ammonia is from the natural emissions from wetland and total natural emissions of NH_3 are estimated as > 10^9 tonnes/year. Anthropogenic emissions of NH_3 are much smaller, and sources include coal combustion (3 x 10^6 tonnes/year), oil and gas combustion (1 X10^6 tonnes/year), and cattle feedlots (0.2 x10^6 tonnes/ year) (Whelpdale and Munn, 1976). Ammonia is oxidized to NOx in the atmosphere, where it has an average residence time of 7 days.Ammonia gas and the ammonium cation are both non-acidic substances which can cause acidification when they are chemically transformed.

The background concentration of N_2O in the atmosphere is 0.3 ppm, and it has a long residence time of 4 years. Industrial emissions of N_2O are mostly associated with fuel combustion and amount to about 6 X10^6 tonnes/year, but there are larger biological emissions of about 18 x 10^6 tonnes/year. Fertilized agricultural soils can have particularly large rates of N_2O emission. It has been estimated that modern agriculture has increased the global emission of N_2O by 50% and that the concentrations of atmospheric N_2O have been increasing by 0.2% - 0.3% per year during the most recent 20-30 years.

The background atmospheric concentrations of NO are 0.2 - 2 ppb, while that of NO_2 is 0.5 - 4 ppb. In polluted atmospheres, these gases are present at ca. 0.2 ppm (expressed as NO_2). In the atmosphere, NO is oxidised relatively rapidly to NO_2. NO_2 is eventually oxidised photochemically and catalytically to nitrate, an anion that contributes substantially to the acidity of precipitation.

1.2 Deposition of Acidifying Substances from the Atmosphere

There are several pathways by which acidifying substances can be deposited from the atmosphere to aquatic and terrestrial ecosystems. These are :

* The wet deposition of materials entrained in rain, snow, and fog, i.e. "acidic precipitation"
* The uptake of certain gases by vegetation, soil, and water surfaces, and
* The dry deposition of the particulate

1.3 Chemistry of precipitation

Acidic precipitation is usually defined functionally as having a pH less than 5.65. This is the degree of acidity that is produced by carbonic acid (H_2CO_3) at its equilibrium concentration that occurs when atmospheric CO2 at ca. 350ppm is in contact with pure water

$$CO_2 + H_2O \text{ --------> } H_2CO_3 \text{ <----- } H+ + HCO_3^- \text{ <----} H+ + CO_3^{2-}$$

Therefore, the slightly acidic pH is considered to be the acid-rain threshold, and not pH 7.0, which corresponds to zero acidity (Cogbill and Likens, 1974; Reuss, 1975). Atmospheric moisture is not, however, merely distilled water in pH equilibrium with CO_2. There is a neutralizing influence of other atmospheric gases and some natural soilderived cations such as Ca^{++} and Mg^{++} occur in trace concentration on the acidity of rain water. The pH of non acidified rain water can be higher than pH 5.65 in many areas, especially in agricultural and prairie landscapes.

The most abundant cations in precipitation are generally H^+, NH_4^+, Ca^{++}, Mg^{++}, and Na^+, while the most abundant anions are SO_4^{++}, Cl^-, and NO_3^-.

2. EFFECT OF ACIDIFICATION

2.1. Terrestrial Vegetation

Acidic deposition can potentially affect vegetation in several direct and indirect ways. As summarised by TAMM and Cowling (1976), the potential, direct effects include the following.

* The integrity of the leaf cuticle could be damaged as a result of accelerated erosion of the protective waxy layer or by direct injury to surface cells by acidic droplets or acidic particles, causing micro or macroscopic surface injuries.

- There could be interference with the functioning ofstomatal guard cells. To a degree, the turgidity of these cells is influenced bycytoplasmic pH, which may be affected by precipitation pH. An effect on guard cels could result in decreased control over stomatal aperture and thus over the transpiration and fluxes of CO_2, O_2 and other gases.

* Acute injury could be caused tofoliar cells due to the penetration of acidic substances through the cuticle or stomata.

* Hidden-injury metabolic effects could result from changes in the rates of photosynthesis, reparation, or some other metabolic function. Hidden injuries are not manifested by obvious damages such as necrotic tissues, butthey may result in growth decrements, dysfunctions, or premature senescence.

* The chemistry or quantity of root or foliar exudate could be altered, with potential secondary effects on the microflora and microfauna of foliar and root surfaces, including organisms that are important in nutrient cycling and nutrient uptake and pathogens that cause disease.

* There could be interference with plant reproduction, for example, by decreasing the viability of pollen, by interfering with stigmaticreceptability, or by otherwise decreasing fruit set or viability.

2.2. Aquatic Ecosystems

In surface waters, acidification is accompanied by increases in concentration of some metals.

Aluminium concentration appears to be very important in determining the effect of acidification on fish. Cronan and Schofield (1979) and Baker and Schofield (1980) showed that mortality of Brook trout in New York is caused by Al and pH in combination, rather than by either factor singly.

In coastal waters, acidification has been recorded to contribute to the increased leaching of trace elements via run off and may be one of the factors determining succession of phytoplankton. Biomass yields, in turn , are increased byeutrophication (Sangfors, 1988).

The species richness of phytoplankton in acidic lakes decreased as pH declined (Almer et al., 1974; 1978; Yan 1979) . In case of zooplankton, species present in a lake decrease with decrease in pH (Almer et al., 1974).

2.3. Amphibians

Acidic rain can directly affect the eggs and tadpoles of frogs and salamanders that breed in small forest ponds. Increase in acidity of these waters may impair hatching success or survival of young animals. Glass and Loucks (1980) cited a study that documents the decline of the frog (*Rana temporaria*) and the toad (*Bufo bufo*) in a Swedish lake where the pH had declined to 4.0 - 4.5 and from which all fishes have disappeared.

2.4. Fish

Effect of acidic precipitation on fishes include mortality, reproductive failure, reduced growth rate, skeletal deformities and increased uptake of heavy metals (Dovland, 1981). Death of fish at low pH has been attributed to failure of ion regulation or asphyxiation, or low pH.

2.5. Forest Soil

The effect of acidic air pollutants on soil can lead to instability in the forest stand. Acidic deposition has caused changes in the pools of major ions in the soil. Almost all soils in the high deposition area have undergone long-term, gradual changes in their nutrient status (Haughs and Ulrich, 1989). These rapid changes in soil conditions are very poorly tolerated by the microorganisms in the surrounding soil and rhizosphere. Consequently, the mycorrhizal fungi that promote water and nutrient supply to the tree disappear. Also, in acidic soils with an impaired nutrient balance, wreaking of the protective role of the rhizosphere may affect the rhizodermis of the thin roots, rendering their cells or intercellular cavities pervious to toxicant (Meyer, 1987; Puhe et al , 1986).

3. BACKGROUND INFORMATION AND PRESENT STATUS

India's growing concern about acidic precipitation is chiefly due to air pollution as a consequence of rapid development of industries and infrastructures facilities. The same is for the south Asian countries. Acidic precipitation has been measured in many parts of the developing countries, such as in southern part of India, south-eastern Asia and eastern China (Postel, 1984). Acidic rain was first noticed in India at Trombay and Chembur in Bombay in 1974 (Melkania and Melkania, 1987; 1988). Later it was also recorded at Vashi (Bombay), Delhi, Nagpur and Pune. Rain with a pH 4.5 or below has been measured in India (Varshney, 1983 a), although harmful effects have not been recorded so far on human beings, vegetation and crops.

A few studies regarding the quality of rain water are cited here. Sahoo et. al., 1997 analysed the rain water at 15 different locations in Rourkela, an important industrial town in Orissa. They found that the pH of the rain water is almost alkaline (6.8 to 8). In addition they measured the concentration of

sulphate and total solids which was found to be varying in the range of 20.1 to 31.3 mg/l and 10.8 to 40.0 mg/l respectively.

The natural pH of rain water in rural areas in India also depend upon the geographical location of the observation site. The dust load in the atmosphere in the northwest parts of India is significantly higher than that in the eastern parts. It is reported that as dust particles are potentially basic in nature they can neutralize the H ion concentration and maintain the pH in the alkaline range. However, the extent to which the air-borne dust influences the chemistry of rain water in certain geographical regions varies with its composition and abundance. In view of the above Rao et al., (1990) collected 16 rain water samples from Mukzar in Punjab representing north west India and 34 rain water samples from Goraur in Bihar representing north east India. These two locations represent rural India and there are no local pollution sources (Table 1).

Table 1: Rain Water Quality of Rural India (Mg/l)

Parameters	Mukzar	Goraur
Cl	2.66	0.95
SO_4	1.59	1.85
NO_3	4.38	0.60
NH_4	0.16	0.25
Na	1.84	0.59
K	1.70	0.67
Ca	5.56	1.54
Mg	0.63	0.22
pH	7.34	5.30

Alkaline component (Ca, K and Mg) neutralizes the H ions and increases the pH of rain water. High concentration of NO_3 of Mukzar has not decreased the pH, most of the nitrates are in the form of salts rather than acids.

Kulshrestha et al., (1995) analysed the rain water of Delhi. They collected rain water at New Delhi during the monsoon of 1994 at a height of 30 m above the ground level using a wet only collector. Simultaneously, bulk samples from two different heights at 30 m and 13 m were collected. Four out of 23 events were observed to be acidic where the ratio of $(Ca+Mg+NH_4)/(SO_4+NO_3)$ was very low. pH and and ionic constituents were higher in bulk samples than in wet-only samples. On an average, the concentration in bulk samples at 30 m height exceeded the wet-only samples by 13% while bulk samples collected at 13 m height had 19% higher concentration than the bulk samples at 30 m height and 32% higher than wet-only. The acidity of rain water was mainly contributed by sulphuric acid rather than nitric acid. At the height of 30 m, the acidity was mainly neutralised by NH_4^+ while at 13 m height, it was buffered byCa^{++} and Mg^{++} indicating the influence of dust particles.

Parashar et al., (1997) analysed the rain water in Delhi, Pune, Singhabad and Goa. The rain water was on average alkaline with a pH of between 6.2 and 6.8. Major acidifying and neutralizing components had a similar concentration except in Delhi where the SO_4^{-2} and NH_4^+ and K^+ were present in a higher concentration and the concentration ofCa^{++} and Mg^{++} was lower.

Sharma and Rao (1993) had undertaken studies to determine the factors affecting the composition of acidic precipitation at Vishakhapatnam an industrialized city of south India. They collected samples at nine locations 3 in each, from residential, commercial and Industrial zones. Chemical analysis were performed on the rain water samples for SO_4^-, SO_3, Cl^-, and Na^+. The seasonal variation in the values of each of the chemical constituents have been studied. The trend in the concentration of the

chemical constituents as follows:

$$SO_4^{2-} > Cl^- > Na^+ > NO^{3-} > K+ . Ca^{++} > H+ > NH^{4+}$$

In Vishakhapatnam only 40% of the samples had a pH less than 5.8. It is assumed that if the sulphate or nitrate to H^+ ratio is 1.0 or more, then the maximum contribution that sulphate or nitrate can make to acidity is approximately 100%. In this study in all the sampling points the sulphate/H^+ ratio factor is more compared to nitrate/H^+ ratio factor . This may be due to the fact that SO_2 is more soluble in water than NOx (Graedel and Weschler, 1981) and nitrogen dioxide decomposes in pure water to nitric and nitrousacids.

Gogoi and Das (1994) analysed the rain waters of Duliajan area of Dibrugarh in Assam. The pH was measured in 6 locations along with some other parameters. Although there are several natural gas flare-up points in and around Duliagan oil town area which send considerable pollutant gases to the atmosphere, the pH of rain waters of different locations are in alkaline nature and ranged between 6.0 to 9. The alkaline nature of pH is due to high concentration of CO_2 in air.

Naik et al., (1995) studied the chemistry of precipitation in remote sites such as mountain tops which is of interest in the study of atmospheric pollution and acid rain. The chemical composition measured at a mountain site which is away from industrial and urban areas is useful as a reference level and it allows us to determine the extent of anthropogenic contamination. Hence, rain water samples were collected at Sinhagad, a hill top area in Maharashtra during monsoon and were analysed for the major ions. The rain water were found alkaline in nature and pH values ranged between 5.9 to 6.76. The ionic composition was dominated by soil dust. The concentration of Ca^{++} was highest among all the ions. The concentration of excess SO_4^{--} and NO_3^- were small (23.8 and 15.2 ueg/l respectively). compared to the values of polluted regions in India. The correlation coefficient between the ions and pH values were calculated and it was found to be maximum in case of Ca^{++}. Precipitation samples collected at Sinhagad were alkaline owing to higher concentration of Ca^{++} and lower levels of acidic pollutants such as SO_4^{--} and NO_3^-.

In 1956, India adopted an Industrial Policy Resolution and during the last three decades the country has made big strides toward ushering in her own industrial revolution. During 1984-86, the rate of growth of industrial production in the country (Based on the revised index of industrial production with 1980-81 as the base year and taking the growth and production of new critical growth areas into account) was of the order of 8-9 percent per annum (Bhatt 1987). However, very little care has been taken against the ill effects of the industrial revolution on occupational health hazards and intra- and extra- industrial environments.

The problems of environmental pollution in India will grow with increased industrialization if the atmospheric emissions are not markedly controlled. Fossil fuel consumption is also increasing steadily. In India the coal production was 78.17 in 1973-74 and increased upto 270.12 million tonnes in 1995-96 and projected 294 mnMT in 1996-97 and . It is now the third largest coal producing country in the world. Coal is the main source of energy in the country and its accounts for about 67% of country's commercial requirements. SO_2 emissions from coal and oil have nearly tripled since the early 1960s and estimated 3.2 million ton in 1979- slightly less than current emissions from West Germany (Varshney and Garg, 1978). Sulphur content for bituminous coal is about 4%. From a consideration of atomic weight it can be concluded that each tonne of sulphur in fuel will yield 2 tonne of SO_2 in flue gases. It is also estimated that nearly 3 tonne of deadly SO_2 is emitted from every 100 tonne of coal or coke burnt (Jain 1993). Undoubtedly, the problem is alarmingly serious and calls for greater control over emissions from exiting sources. A vast expansion of thermal power generation and the rapid pace of industrialisation will certainly affect the biogeochemical cycling both qualitatively and quantitatively (Varshney 1983b).

It has been reported that India produces every year 5 million tonnes of sulphur dioxide and 1.0 million tonnes of nitrogen oxides (Sharma and Rao, 1993). In Indian cities the dry deposition of sulphate was about 95 mmol m^{-2} yr^{-1}. Which could be from two thirds to almost all of the surface deposition. In case of nitrogen oxides the dry deposition was about 95 mmol m^{-2} yr^{-1} or 50-90% of the total surface deposition (Whelpdale et al., 1997). On the basis of anthropogenic sources the dry and wet deposition was calculated by **MATCH** (Masoscale Atmospheric Transport model) is the south Asian region. In India the dry deposition of SO_2 and SO_4^{-2} were 100 and 6.0 mg m^{-2} yr^{-1} respectively. The wet deposition and over all total deposition was 180 and 280 mg m^{-2} yr^{-1} respectively (Robertson et al., 1995). The relative load with respect to country's own emissions, the deposition in India was calculated in percentage for dry deposition of SO_2 and SO_4^{-2} and was found to be 14 and 0.9 respectively and wet and total deposition were 25 and 40% respectively (Robertson et al, 1995).

In India, the per capita commercial energy consumption is considerably less in comparison with other developed and even some developing countries (Table 2).

Thus, there is enough scope to increase the energy consumption or need of power for acceleration of development and industrialization. Presently the demand for electricity in the entire economy has risen at the rate of 9.73 per cent during 1986-8, the demand for residential and agricultural sectors has been increasing at an alarming rate of 14.03 and 14.50%per year respectively. The installed power generation capacity in the country has increased form meagre 1,400 MW in 1947 to 83,287.96 M.W at the end of 1995-96 with PLF of 60%. An overall increase of about 7.4% over the generation was achieved during 1994-95. Only thermal power including diesel and wind generated 72.14 per cent. India is turning to super thermal power stations served by captive coal mines. In India the power plant burned 165.3 million metric tonnes of coal followed by steel and cement for 20.5 and 8.3 million metric tonne respectively in 1995-96. The concept of energy parks-clusters of high-capacity power stations built as initiated by Indian Energy Planing Commission in the last decade, if not managed properly, may pose serious air and water pollution problems. In a study of potential environmental problems in the Singruali belt (30 km^2 area with five thermal power plants) in eastern central India, Tata Energy Research Institute, New Delhi recorded SO_2 concentrations 10 times higher (1.3 to 1.5 g/m^3) than the 8-hour standard for industrial areas (0.12 g/m^3) set by the Central Pollution Control Board in October, 1990, New Delhi. The Ministry for Environment, Govt. Of India, once warned a group of industrialists that if pollution control measures were not taken by thermal power plants, acidic precipitation would hit India within 19 years.

Rampant air pollution in the Jharia-Raniganj coal belt, bordering Bihar and West Bengal at Dhanbad, is exposing both inhabitants and miners to hazards of respiratory and intestinal disorders. A recent study conducted by scientists of Central Mining Research station, Dhanbad has indicated that the pollutants in the air of the area far exceed the standard air quality measures. This conversion of effluent into sulphuric pollutants is higher during winter and lower during summer but exceeds the desirable limits in both seasons. A greater percentage of SO_2, NO_2 and CO_2 is recorded in and around the Jagarnath open cast mines. Approximately 100 water samples tested in the Jharia coalfields were found "Unsuitable" for drinking purposes. Of the total mining population in Jharia and Raniganj, nearly 24 per cent and 23 per cent, respectively are affected by intestinal disorders.

If the present day approach is followed, based on the projections of the Energy Demand Screening group of the Planning Commission, the extent of annual emission would increase to dangerously high level and spell disaster not only for the fragile locations, but also nationally in the aggregate (Anon, 1990). Rodhe's estimates have suggested that the western coastal regions of Andhra Pradesh, part of Karnataka and Tamil Nadu, Kerala and Pondichery would be the potential problem areas for future increase in acidic emissions (Rodhe, 1989). The core committee for National Strategy for Conservation and Sustainable Development (Anon, 1990) has suggested greater emphasis on energy

efficiency improvement and conservation as a short term solution with respect to the energy sector.

Table 2 : Per Capita Consumption of Commercial Energy by Selected Country

Country	1965	1985	1990	1994
USA	6,535	7,278	7,822	7,905
Canada	6,007	9,224	10,009	7,795
France	2,468	3,673	3,845	3,839
UK	3,841	3,603	3,646	3,758
Japan	1,474	3,117	3,563	3,825
China	178	515	598	647
India	100	201	231	243
Pakistan	136	218	233	255

India has one of the largest network of roads in the world, the total length being nearly 20,65,209 km in 1990-91. Swaminathan and Sundaresan (1980) anticipated about 1.25 million vehicles on the road during 1980 and 23, 412 million tons of emissions per annum, including 6.76 per cent from automobiles, 29.82% from the domestic sector and 63.42 percent from industries. Studies carried out at traffic junctions in Bombay and Calcutta indicated the average concentration of CO_2 to be about 35 ppm. The rapidly growing transport and communication system may pose a serious problem of air pollution and health hazards if attention is not given to the matter now.

In the recent year, vehicle generated air pollution has become a matter of concern in developing countries like India too. Although the vehicle population in this country, is comparatively much lower than in the European countries and the USA. A comparative number of vehicles in different countries is given in table 3.

Vehicles contribute significantly to air pollution in the metropolitan cities. At the end of 1991, India had 21 million vehicles out of which two wheelers alone numbered around 14 million. The passenger cars and diesel vehicles numbered about 2.9 and 1.78 million perspectively. The comparative yearwise data regarding no of vehicles registered in India is given in table 4.

In Delhi, for example automobiles are responsible for 65% of the air pollution, there being 2.6 million registered vehicle (Sangal 1996) with about 700 of them added each day. Delhi is the third most polluted city in the world. More than 2000 metric tonne of pollutants in the form of hydrocarbons, SO_2, SPM, lead etc. are pumped into the atmosphere each day. According to the Central Pollution Control Board the emission of CO_2, nitrogen dioxide, hydrocarbons and SO_2 are estimated at 1063, 323, 320 and 179 MT per day. The amount of SPM was 800 and 1,100 MT respectively in 1990-91. The concentration of SPM in the air has crossed the prescribed safety level. Though Sulphur dioxide (SO_2) and NO_2 in the air are still within the safety levels of pollution, their concentrations are considered high.

The remaining 35% of the air pollution is caused by the thermal plants (about 16%) followed by industry (12%) and domestic operation (7%).Sangal (1996).
The number of deaths due to respiratory diseases in Delhi has gone up from about 250 per month in the late eighties to about 600 in the mid nineties. Death due to circulatory ailments has also increased from 9.9 to 11.1% in the same period.

Table 3 : Motor Vehicles in Selected Countries

CountryCars	Buses& Trucks		All Vehicle	Person per car
Japan	37086	22839	59913	3.3
India	2491	2177	4668	356
China	1765	4349	6114	652
W. Germany	31309	2114	33423	2
France	23810	5030	28830	2.4
Italy	28200	2521	30721	2
USA	142956	45416	188372	1.7
Canada	13061	3744	16805	2.1
Australia	7734	1915	9649	2.2

All value 'th no. (1991)

Table 4 : Cumulative Registration of Motor Vehicle (h no.) in India

Year	Cars& Jeep	Buses	Trucks	Two wheeler	Other	Total
1971	682	94	343	576	170	1,865
1981	779	115	351	1,057	398	2700
1991	3,013	333	1411	14047	2506	21310
1992	3209	358	1514	15661	2769	23507
1993	3344	388	1592	17060	2970	25346
1994P	3617	411	1650	18338	3203	27227
1995P	3829	430	1791	20800	3359	30209
1996E	4,109	447	1,952	22675	3604	32797

E = Estimated , P = Projected.

The ambient air quality of Bhopal city of M.P. of India was studied by Bansal (1996) with reference to NO_2 concentration in commercial, Industrial and residential areas during 1992-1994. In commercial areas maximum concentration of NO_2 was as recorded 96.4 ugm/m^3 (3.6 to 96.4 ugm/m^3). corresponding value in the industrial area was 66.3 ug/m^3. Monthly average values were well below the prescribed standards (table 5).

National Environmental Engineering Research Institute (NEERI), Nagpur (1995) is operating a nation-wide air quality monitoring network since 1978 to generate the database for ten major Indian cities, viz . Ahmedabad, Mumbai, Calcutta, Delhi, Hyderabad, Jaipur, Kanpur, Kochi, Madras and Nagpur. The analysis results shows that the SPM exceeds the Central Pollution Control (CPCB) standards in all the cities most of the time throughout the year. The ratio <P10 (RSPM) to the total SPM varies between 30 - 60%.

Evaluation of wet deposition of air pollution by the analysis of rain water samples at all the monitoring sites indicates that the rate of removal/precipitation of air pollutants is higher in the first rain event with low pH values and higher sulphate and nitrate contents. The acid rain phenomenon thus prevails, albeit for a limited period, in the urban atmosphere of Indian cities. The lowest pH of

4.8 was observed in the rain water samples at Delhi in industrial area.

Studies of ambient air quality of Lucknow city (UP) were conducted by ITRC during summer season in 1997 in residential, commercial and industrial locations. Major source of pollution is vehicular traffic. The concentration of SPM, SO_2 and NOx in all the locations except one residential area was much more in the higher side than the prescribed limit by the Central Pollution control Board.

The ambient air quality in Madras city with respect to SPM, SO_2 and NOx was conducted by Krishna Mohan and Mukthukrishnan (1996) in 4 locations classified as commercial, residential and sensitive area.
The results showed that the SPM in most of the locations has been found to be exceeding the permissible limits. The average SPM levels on 2 locations one in residential and other is rural was much higher on both working days (1782.6 ug/m^3) and in holidays (1418.06 ug/m^3). The average concentrations of SO_2 surprisingly was found to be much less than permissible limits.

The average concentration of NOx was found to be within limits in both the two locations. But in the sensitive (Hospital) area the NOx was higher on working days (59.52 ug/m^3) and than in holidays (38.69 ug/m^3) which exceeded permissible limit of 30 ug/m^3. The total number of vehicles (all types) as on 1.4.1995, was 7,67,146.

The slow yellowing of the white marble of the Taj Mahal at Agra has been a deeply discussed subject among archaeologists and environmentalists and still remains a subject of controversy. The foundries in Agra have been exonerated of the charge of discolouring the Taj. The pollutants that can damage this monument are NO_2 and SO_2; they corrode the marble by producing corrosive acids on combining with rain or humidity. In the same way, over two decades ago, the growing air pollution in the Chembur suburb of Bombay, have shown that the main sources of NOx and SOx are thermal power stations. In Bombay, an early 1970s study showed that 85% of the total air pollution in Chembur came from the thermal power plant located at Trombay. In Agra, in the same way, setting down of two old thermal power plants has reduced the SO_2 level in the air by 75 per cent. The experience of Agra confirms what the residents of Delhi are reminded of every year. Winter tightens its grip on the city, most of the choking fumes they breathe come from the coal based thermal power plants at Indrapastha and Badarpur.

Table 5 :Indian Ambient Air quality Standards

Category	Area	Concentration in ug/m^3			
		SPM	SO_2	NOx	CO
A	Industrial and mixed use	500	120	120	5000
B.	Residential and rural	200	80	80	2000
C.	Sensitive	100	30	30	1000

3.1 AIR QUALITY MONITORING

Air quality monitoring is a 2 fold process. It includes monitoring of emission from stationary source and ambient air monitoring. In both cases the location of monitoring devices, the type of equipment, the duration of sampling and pollutants discrimination are of paramount importance in the quantitative appraisal of air quality. Source monitoring requires a relatively elaborate set of

measurements. Bureau of Indian Standards has specific reference methods for stack sampling (Table 6).

Table 6 : Methods of Measurement of emission from stationary sources

Contaminants	Method	IS CODE
SPM	Isokinetic Sampling	IS : 11255 (Part 1) 1990
SO_2	Hydrogen Peroxide	IS: 11255 (Part II)1990

In atmospheric (ambient air quality) monitoring, air monitoring network is established to supply the aerometric data necessary to support air pollution prevention, control and abatement activities. Central Pollution Control Board, New Delhi under the Air (Prevention & Control of Pollution) Act, 1981 recommended the improved methods in 1994 for ambient air quality monitoring as given in table 7.

3.2. Air Pollution Dispersion

Installation of pollution control equipment does not guarantee complete abatement of air pollution. In fact some emissions still be dispersed into the atmosphere. Chemicals released into the atmosphere are transported by wind. Dispersion due to turbulent nature of the atmosphere, and removal is due to deposition on the ground, vegetation and buildings (CEP, 1992). Atmospheric dispersion depends upon turbulent structure of the wind field whereas vertical transport depends upon lapse ratio (rate of temperature decrease with increasing height), Wind rose which shows wind speed and direction over a long period, is used to predict pollutant dispersion directions and distance from source.

The behaviour of plumes emitted from any stack depends upon localized air stability, a measure of atmosphere's stability to disperse chemicals. A standard stability classification scheme, known as Pasquill-Gifford-Turner classification, divides air stability into 6 classes ranging from A (very unstable) to F (very stable) based upon such factors as wind speed, insolation and cloudiness (CEP 1992). In air pollution modelling, contaminant concentration, is assumed to decay with time in an Gaussian way. Computer based air quality modelling are used to perform computations necessary to find ground level concentrations. Under neutral or even slightly unstable atmospheric conditions, the highest ground level concentration will usually be found with 30 times stack height downwind. For an elevated point source, Gaussian mathematical model to compute ground level concentration (Canter, 1977) :

4. RESEARCH ACTIVITIES AND MONITORING PROGRAMME :

No novel research work and monitoring programmes have been carried out since last two decades because the acidic precipitations or acid rain is not an immediate threat to our country. Some work has been carried out at randem by the different research institutes or universities. But the ambient air quality specially in metrocities and industrial areas are of high concern. In this line National Environmental Engineering and Research Institute (NEERI), Nagpur a national laboratory has been conducting national ambient air quality monitoring since 1978 in collaboration with Central Pollution Control Board, New Delhi. NEERI has generated the database facilities for evaluation of long term air quality trends. The research and monitoring programme have been carried out in India by various research centres, Institutions and Universities which are depicted in table 8.

Table 7 : Method of measurement for ambient air quality.

Contaminant	Measurement method
Sulphur dioxide as SO_2	Improved West & Gaeke method,
Oxides of Nitrogen as NO_2	Jacob & Hochheiser Modified (Na-Arsenite) Method
SPM	High Volume Sampling, (Average flow rate not less than 1.1)
RSPM (size less than 10 um)	Respirable particulate matter sampler
CO	Non dispersive infrared spectroscopy

Ref : S.O. 384 (E), Air (Prevention & Control of Pollution) Act, 1981

Table 8 : Involvement of Research Centres, Institutions and Universities in Research on Air Pollution and Acid Rain.

1. Lucknow, U.P.	:	Industrial Toxicology Research Centre P.O. Box - 80, M.G. Marg, Lucknow-226 001
	:	National Botanical Research Centre (NBRI) Rana Pratap Marg, Lucknow - 226 001.
2. New Delhi	:	School of Environmental Sciences, Jawaharlal Nehru University, New Delhi - 110 067
	:	Department of Chemistry, National Physical Laboratory, Dr. K.S. Krishnan Road, New Delhi - 110 012
	:	Indian Institute Of Technology (IIT) New Delhi.
	:	Central Pollution Control Board (CPCB) New Delhi.
3. Nagpur	:	National Environmental Engineering Research Institute Nagpur. M.P.
4. Varanashi	:	Department of Environmental Science Banaras Hindu University, Varanashi- 221 00 U.P.
5. Roorkee	:	Department of Environment, Roorkee University.

6. Pune	:	Indian Institute of Tropical Meteorology. Pashan, Pune - 411 008 Maharastra.
7. Orissa	:	Department of Chemistry, University of Sambalpur, Burla - 768 019, Orissa.
8. Mumbai	:	Tata Energy and Research Institute (TERI) Mumbai.
9. Agra	:	Department of ChemistryDayalbagh Educational Institute, Dayalbagh, Agra - 282 005

4.1 CAPABILITIES OF INDUSTRIAL TOXICOLOGY RESEARCH CENTRE (ITRC)

Industrial Toxicology Research Centre (ITRC), Lucknow a constituent of Council of Scientific and Industrial Research, Govt. of India, has been rendering the following services to industries, public sector undertakings and Government R & D organisations.

* Epidemiological surveys/studies on occupational diseases in industrial workers and suggesting remedial measures.

* Safety evaluation of agrochemicals, dyes, food additives, plastics and polymers, petrochemicals, cosmetics, detergents, organic and mineral fibres and particulate material as per requirement of the registration authorities.

* Safety evaluation of drinking water.

* Waste water analysis from chemical, paper, pulp, distillery, sugar, leather and food industries.

* Environmental and air monitoring studies including environmental Impact Assessment

* Ecotoxicological Impact Assessment.

* Sponsored long-term studies in specific areas.

In the field of environmental risk assessment ITRC , developed and stressed on the following fields

* Environmental Impact Assessment (EIA), preparation of environmental management plan and Environmental monitoring.

* Stack/process emission evaluation for SPM.

* Ambient air quality monitoring with respect to SPM, SO_2, NOx, CO and HC.

* Particle size includingrespirable dust analyses.

* Physical and Chemicalcharacterization of soil and water

* Disaster preparedness and management plans.

* Environmental Audit.

For the above mentioned studies ITRC, developed a separate section, Environmental Monitoring Division, with fully equipped environmental Monitoring facilities. Some of the important equipments and instruments currently being used for monitoring purposes are presented in table 9.

Table 9 : Some Important Instruments which are being used by ITRC, Lucknow for Air quality study

Parameters	Name of Instruments	Sensitivity
SPM	High volume Sampler	10 mg/m^3
SO_2	High volume Sampler	4 mg/m^3
NOx	High volume Sampler	4 mg/m^3
SPM,	Particle Monitor -10 Graseby, USA	2 ug/m3
SO_2	Fluorescent SO2 analyzer, Model 100A, Advanced Pollution Instrument, INC San Diego.	50 ppb
NOx	Chemiluminescent NOx analyser, Model 200A, Advanced Pollution Instrument, INC San Diego.	50 ppb
O_3	Photometric O3 analyser- Model 400 Advanced Pollution Instrument, INC San Diego.	100 ppb
CO	Gas filter correlation CO analyser, Model - 300 Advanced Pollution Instrument, INC San Diego.	1 ppm
HC	HC analyzer, Model - TNMH 451 DANI	0.02 ppm
Micrometeorology For Wind speed, wind direction, temperature, RH, Rain fall, solar radiation,pressure	i. Model WM 300,Evt. Tech, New Delhi ii. Q-Net integrated systems, Qualimetric INC, USA iii. Model 200, Sunshine,Bangalore iv. MM 900, ELLE International, UK	

5. PROBLEMS ENCOUNTERED AND ENVIRONMENTAL MANAGEMENT

Problems and issues related to environment received the direct attention of the Government of India. A separate Department of Environment was set up in 1980, which was subsequently upgraded to a full-fledged Ministry of Environment and Forest in 1985.

Today, the Ministry of Environment of Forest is the nodal agency in the administrative structure of the Government of India for planning, promotion and co-ordination of Environmental and forest programmes for the country. Besides there are several other respective bodies which are the Ministry's partners in carrying out activity related to environmental Protection.

* The State Departments of Environment,
* Central Pollution Control Board
* State Pollution Control Board,
* Botanical and Zoological Survey Of India,
* The Forest Survey of India,
* The Natural River Conservation Authority,
* The National Afforestation & Eco- development Board,
* The Indian Council of Forest Research & Education,
* The National Museum For Natural History Etc.,

5.1 Environmental Legislation :

* Wildlife Protection Act, 1972 :
* The Forest (Conservation) Act, 1980 :
* The Water (Prevention and Control Pollution) Act, 1974
* The Water (Cess) Act, 1977
* The Air (Prevention and Control of Pollution)Act 1981
* The Air (Prevention and Control of Pollution)Act 1982.
* The Environmental (Protection) Act, 1986
* The Public Liabilities Insurance Act, 1991.
* The National Environmental Tribunal Act, 1995 :
* The Manufacture, Storage And Import Of Hazardous Chemicals Rules 1989.
* The Hazardous Wastes (Management And Handling) Rules. 1989

5.2.1 Environmental Impact Assessment (EIA) :

Environmental Impact Assessment was introduced in India in 1978. A notification issued in January 1994 makes EIA statutory for 29 categories of development Projects under various sector e.g. industrial, mining, irrigation, power, transport, communication etc.

5.2.2. Central Pollution Control Board (CPCB) :

The CPCB is a national apex body for assessments, monitoring and Control of Water and Air. The executive responsibilities for enforcement of the Act for prevention and control of pollution of water (1974) and **Air (1981)** and also of the water (cess) Act, 1977 are carried out through the Board the Environment (Protection) Act, 1986, effluent and emission standards in respect of 61 categories in Industries have been notified.

17 categories of heavy polluting industries have been identified namely cement, thermal power plant, distillery, sugar, fertilizer, integrated iron & steel, oil refining, pulp & paper, petrochemicals, pesticides, tanneries, basic drugs & pharmaceutical, dye & dye intermediates, caustic soda, Zinc smelter. Out of the total 1,551 units identified under these 17 categories, 1220 units have installed adequate facilities, for pollution control and 111 units have been closed.

The CPCB in consultation with State Pollution Control Board has identified 22 critically polluted areas in the country which need special attention for control of pollution. These are Vapi (Gujrat), Singruali (UP), Kobra, Ratlam, Nagda (MP), Digboi (Assam), Talcher (Orissa), Bhadravati (Karnataka), Howrah (WB), Dhanbad (Bihar), Pali & Jodhpur (Rajasthan), Manali & North Arcot (M), Najafgarh (Delhi), Gobendgarh (Punjab), Udyog Mandal (Kerala) and Parwanos & Kala Amb (HP).

An intense ambient air quality network is proposed to be established in the National Capital Region (NCR) and monitoring of SO_2, NOx and SPM has been initiated in the cities, town and villages of Haryana, UP, Rajasthan and Delhi. The CPCB and SPCB regularly conducted vehicular and noise pollution survey in different cities of the country.

5.2.3 Environmental Information Systems (ENVIS):

Environmental Information System has been set up by the Ministry in 1982 as a decentralised information system network for collection, storage, retrieval and dissemination of environmental information.

6. AREAS WHICH NEED STRENGTHENING :

* Sufficient awakening regarding air pollution and acidic deposition and its consequences needs to be generated among the public in India.

* There is no alternative to the acid-precursor gaseous emissions of sulphur dioxide and oxides of nitrogen being reduced.

* The industries and power plants still lack adequate measures to control emissions; In most cases either the technology for controlling air pollutants is not available or it is handled carelessly. In fact, at least the new industries and power plants should install flue gas desulphurisation equipment, often called 'Scrubbers' well in advance. The NO_2 emissions can be reduced to 50 per cent with combustion modifications. More stringent controls will

require such technologies as selective catalytic reduction, which treats flue gases for NO_2 as scrubbers do for SO_2. These systems can reduce NO_2 by about 90 percent

* So far, pollution control in the public sector has consisted of merely building tall chimney stacks in order to disperse the emissions over a wide area. Needless to say, dispersal at an elevated level is not a control measure.Electrostaticprecipitators are currently being installed to remove ash from the emissions. But attempts are negligible even now toeliminate NO_2 and SO_2.

* Co-ordination of research and exchange of knowledge between scientists within the national and international level is essential. In case of India, proper co-ordination and strong data base should be maintained among the neighbouring countries like Bangladesh, Sri Lanka, Pakistan, Nepal, China etc. Experience from policy action, especially in the European region, could also be very useful.

* Development of infrastructure to carryout the long time R & D work within and also with neighbouring countries.

* More attention should be given to smaller, individual sources such as automobiles and oil or coal burning furnaces in homes.

* Need to develop low costequipments and scientific knowledge for reduction of acidic precipitation.

* Need to estimate the critical load factor with respect to specific regions.

* Strategies should be developed to decrease emissions of acidifying air pollutants and to reduce their harmful effects & have to be based on a comprehensive approach with regard to other environmental concerns and inputs, including climate change, health and corrosion.

* Since emissions of a large part of the acidifying pollutants are associated with energy and food production, improved energy and agricultural efficiencies have to be a central part of any control strategy.

* Techniques are available to decrease substantially the emissions of NOx, SO_2 and NH_3 from stationary and mobile sources. Efforts are needed to stimulate the implementation of such techniques.

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