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ENVIS NEWS LETTER

Acid Rain and Atmospheric Pollutant Modeling

(A project of the Ministry of Environment and Forests, Govt. Of India)

Volume 3, Issue 1 JANUARY-JUNE 2005.

CONTENTS

Editors' Foreword

It is a matter of great satisfaction and pleasure that the ENVIS node at IITM, Pune has now been recognized and converted to "ENVIS Center" on the thematic area "Acid Rain and Atmospheric Pollution" under the ENVIS network of Ministry of Environment and Forest, Government of India from February 2005. This is the recognition of the importance of the subject area and the contributions made by the ENVIS team at IITM, which has been well received and appreciated. The encouraging comments and suggestions from the readers have been of considerable help in our efforts to further improve its format and contents.

The present ENVIS newsletter on the above subject area is the first issue after the establishment of ENVIS center. We have made an attempt to put together some of the recent happening in the area of atmospheric pollution including some fundamental aspect of acid rain. We hope to further enrich and expand the Bulletin in due course of time. This issue of the newsletter closely follows some of the emerging scientific aspects and issues, which are specific to our country. As for example, emissions of Carbon Monoxide, which is one of the important pollutants, are highest from Bio-fuel sources over the Indian Region due to its waste usage in rural population, rather than fossil fuel sources, which are found to be most important in majority of European countries. The impact of increasing concentration of atmospheric pollutants and greenhouse gases at the ground is not only confined to near earth region but it may modulate the atmosphere as high as 100 km. An interesting aspect related to the impact of secular increases in greenhouse gases and pollutants at the ground on the upper atmosphere has recently been established in India, which has received an international recognition. The city of Pune is chosen for a pilot case city by the United States Environmental Protection Agency (USEPA) in collaboration with Ministry of Environment and Forest (MoEF), Government of India to conduct a project on Clean Air Initiative: Pune Air Quality Management Program. A detailed report on this subject is included in this edition.

In addition, some discussion on related issues such as current energy sources and their impacts on the environment, opportunities and need of other alternative energy sources are discussed. The comments, suggestions and input material from all the related groups are most essential to make the Bulletin a truly effective forum for all atmospheric pollution related issues of the country and hence we will be delighted to have them from the readers. Lastly the active participation by Mr. Sachin Gunthe in preparation of this edition is greatly appreciated.

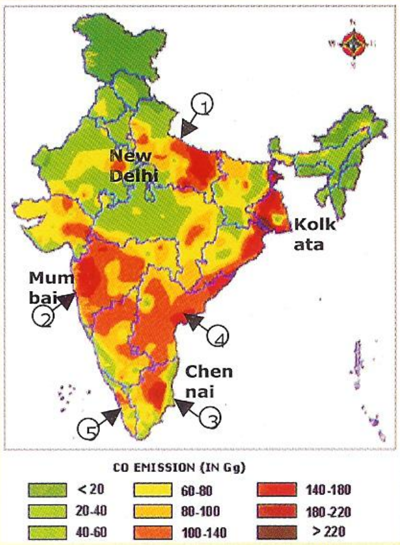
(G.B. Pant) Editors (G. Beig)

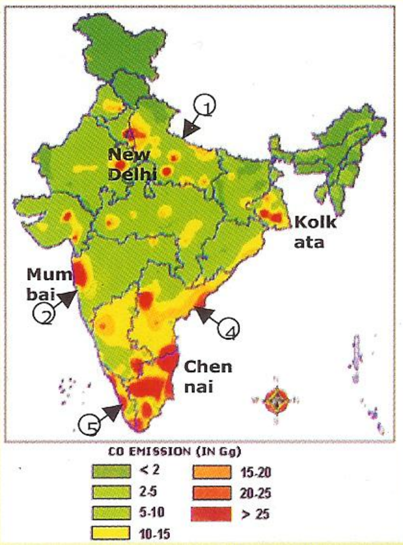
Carbon-Monoxide Emission from Bio-fuel sources over the Indian Region

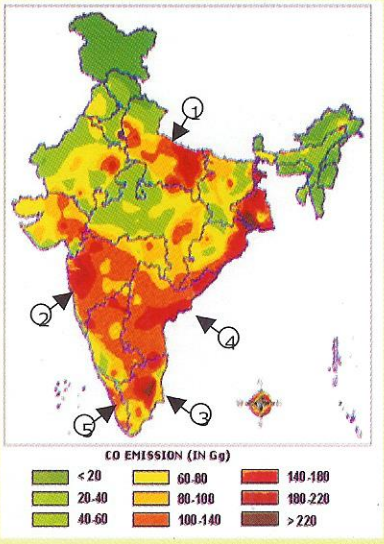
The issues related to emission of atmospheric pollutants are the key to understand the air pollution problems. To address the emission related issues United Nations Frame work convention on Climate Change (UNFCCC) has recognized the need of immediate preparation of national inventories of Greenhouse Gases (GHG) emissions and sink using comparable methodologies. National level inventories not only improve global emission estimates and consequent impacts but also provide a base line from which nation may develop their future emission strategies to streamline the anthropogenic activities. The Indian subcontinent is a rich source for ozone precursors where the predominant circulation pattern can carry the pollutants from one place to other. The concerned world scientific community is focusing their attention to explore chemical weather related to pollution which is mostly influenced by local or regional factors in which Indian subcontinent will be playing a major role. Bio-fuels are the main source of energy for cooking & other household use in rural areas and even many urban/ semi-urban areas. The consumption & composition of bio-fuels differ from region to region in India. The combustion efficiency and hence emission of CO will also differ based on composition of the bio-fuel and the stoves/ *chullahs* (open stoves) used for cooking. There will thus be a marked difference between contribution to (bio-fuel) CO from rural & urban areas. To relate the CO emissions to the rural or urban population, it is necessary to first determine the relative contribution by the rural and urban sectors. The household data on biofuel consumption released till date gives the number of rural as well as urban households utilizing various fuels as a main energy source for cooking (Census of India, 2001).

The energy sources considered for Census survey were firewood, crop residue, cow-dung cake, coal (including lignite, charcoal), kerosene, LPG, electricity, biogas & others.

Households using firewood, crop residue & cow dung are considered as those consuming bio-fuels. As per the Census figures, out of the 192 million households in India, nearly 139 million use bio-fuel as main source of cooking, and nearly 90% of these are from the rural area. Based on the number of (rural/ urban) households using bio-fuels in a given state, the number of rural & urban persons depending upon bio-fuels can be determined. The proportion of this rural/ urban population is applied to the state-level bio-fuel CO value to determine the contribution from rural & urban sector to CO emission from that state. Based on the respective population & CO contribution, the per capita emission of CO (separately for rural & urban) is determined for each state. The interstate difference in per capita CO emission thus obtained can be said to represent the differences in proportion of population using bio-fuels, composition of bio-fuels used, types of stoves/ combustion efficiency, etc between the states. These per capita emission figures are then applied to the district-level population from the respective states, thus allocating the bio-fuel CO emissions from state to district level. Total CO emission from all the sources over the Indian geographical region for 2001 is estimated to be around 69376.085 Gg. The CO emission from bio-fuel sources are around 34,282 Gg for the same year, which is almost 50% of total CO emissions, thus signifying that the bio-fuel from the rural sector is the most important and major contributor for CO emission over Indian region. Figure 1 (a,b,c) show the distribution of bio-fuel CO-emission from the rural, urban and sum of both rural and urban sectors respectively for 2001 over the Indian region.







Index for States

1. Uttar Pradesh 2. Maharashtra 3. Tamil Nadu 4. Andhra Pradesh 5. Kerala

Figure 1a : Distribution of CO emissions (2001) for rural sector from biofuel source as obtained in this work after gridding

Figure 1b : Distribution of CO emissions (2001) for urban sector from biofuel source as obtained in this work after gridding

Figure 1c : Distribution of CO emissions (2001) combined for rural and urban sectors from biofuel source obtained after gridding

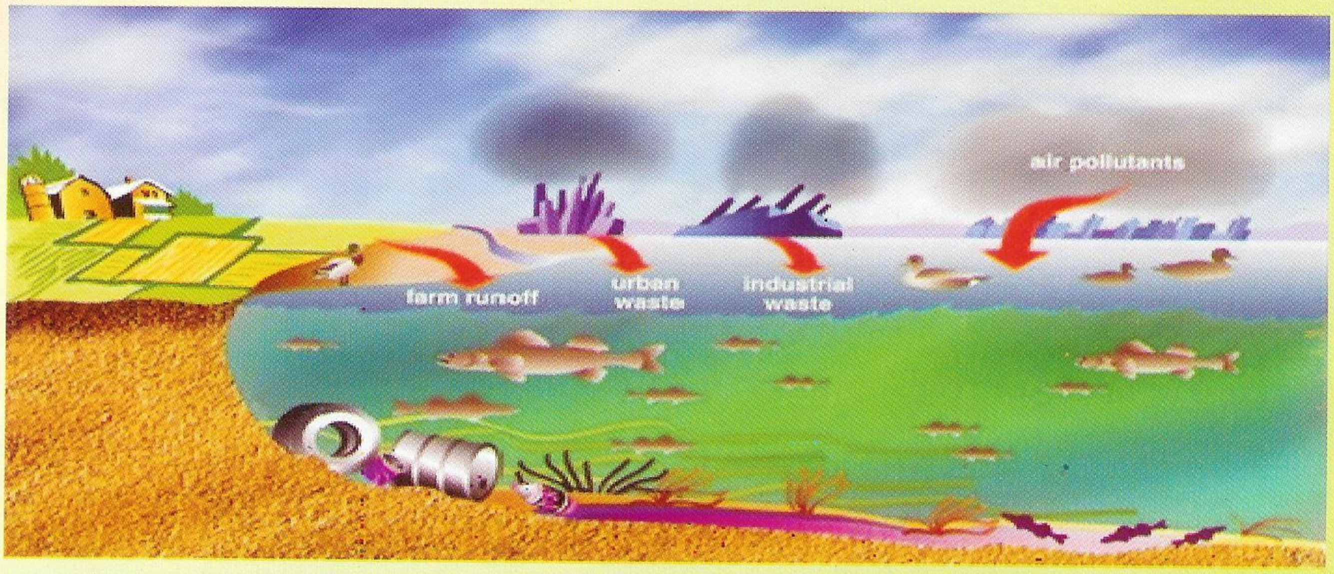
The maximum value is found to be from Southern Indian region where several high emission regions are located. Contribution from rural sector is also high from Maharashtra, Utter Pradesh and coastal areas. However, urban sector contribution is not much from these states excepting few major cities like Mumbai. The maximum urban contribution is seen to be from Tamilnadu (more than 20 Gg) and parts of Kerala and Andhra Pradesh. However, overall urban contribution is much less than that of rural sector as is seen in Figures 1 a & b

Sky is the limit: Pollution Impact reached as high as 100 km

The composition and thermal structure of the Earth's atmosphere has changed considerably over geological time. In recent time, several measurements and model calculations have made it clear that releases of trace gases from human activity have a potential for causing a change in the present-day climate of the Earth. The detection of global change signals in the upper part of the atmosphere (above the stratopause) is a topic of current interest. At the end of the 1980s, it became obvious that systematic variations of lower atmospheric properties should be accompanied by associated variations in the upper regions, the mesosphere and thermosphere. Unlike the lower atmosphere, there are not many routine measurements in the mesosphere, since they are considered to be of no value in operational weather forecasting. However, during the last decade, there has been an ever-growing impetus for investigations of temperature trend in this region, now that it has been established that the secular increases in greenhouse gases at the ground should have a substantial impact on the radiative-chemical-dynamical equilibrium of the middle atmosphere.

The contraction in the ionoshperic layer of the atmosphere (ranges from 50 to 300 km from the earth surface) due to the greenhouse gases is main cause of disturbance in the radio waves. The entire greenhouse gases emitted in the atmosphere causes heating in the lower and cooling in the upper part. This happens because they absorb heat in lower layer and emit it in the ionosphere. This type of cooling in the ionospheric level tends to contraction in its layer and consequently causes reduction in the density of electrons there. These are the electrons mainly responsible for the reflection of radio, television and satellite waves. Due to this decrease in the density of electrons short and medium wave radio signals are severally affected as a result of poor reflection. This reduction in the temperature may also cause considerable effect on the lower part of the atmosphere, weather patterns and also leads towards the "atmosphere drag" on space shuttles.

A first comprehensive review of long-term trends in the most vital meteorological parameter, namely, temperature of the region from 50 to 100 km which dealt with the above mentioned aspects in detail is published in an international journal "Review of Geophysics" of American Geophysical Union, USA by a team of scientists led by an Indian scientist G. Beig (ENVIS coordinator, IITM), which has won the prestigious NORBERT GERBIER - MUMM International Award 2005 of The World Meteorological Organization (WMO). This paper has convincingly established for the first time that greenhouse effect or the global change in the upper atmosphere. The obtained trends are attributed mainly to the human induced anthropogenic forcing from the ground (greenhouse gases like CO_2, CH_4, N_2O, CFCs, etc). If sustained, the observed apparent changes in temperature, and the resulting hydrostatic contraction (atmosphere is shrinking) could have future consequences for the ionosphere as described earlie.



Renewable energy and pollution aspects; Indian Perspectiv

World's supply of fossil fuel like oil, coal, and natural gas is being depleted slowly because of its constant use. These energy sources are mainly used by power stations and industries in the form of coal. On the road the vehicles in the form of petrol and diesel use them. Burning fossil fuels in this way releases a number of pollutants, including Sulphur dioxide, nitrogen oxides, carbon monoxide, particulate matter and VOCs, such as hydrocarbons, which can all lead to poorer air quality leaving harmful effect on the biosphere.

In India the reliance on coal-fired power plants, increased vehicular activities in some of the metros having population over 1 million (There are 20 cities in India having population more than 1 million) and use of biomass as an alternative fuel mainly in rural areas (around 72% of the population in India is rural) in excess amount are the major issues of concern for the increase in pollution. In India most of the consumption of fossil fuel takes place in the thermal power plants and in the vehicles. Coal accounts for just over 50% of India's energy consumption. The power generation sector uses the majority of this coal, with heavy industries standing second. Petroleum contributes 34.4 % of India's energy consumption while natural gas and hydroelectricity accounts for 6.5% and 6.3 % respectively (Figure 2). Between 1990 and 2001 carbon emissions in India has recorded an alarming increase.

Apart from increasing urbanization 72% of India's population still lives in rural areas. One of the critical issues of future would be providing energy in the areas of shortage generated from renewable energy projects.

As for the use of fossil fuel in the vehicles a strong alternative need to be put forward. CNG is one of the promising alternatives for the petrol and diesel at least in metros as an initial step. A considerable decrease in emissions of pollutants has been recorded in New Delhi after replacing some of the vehicles with CNG. In addition to this setting the standards for the engines of the vehicles will also result in improved air quality. A concept of catalytic converter in the vehicles also will provide a deep insight in reducing the emission from the vehicles.

Renewable energy sources, in addition to being non-depleting natural source unlike fossil fuels have the most important characteristic that they do not release the pollutants as byproduct in to the atmosphere. Renewable energy sources such as biomass, wind, solar, hydropower and geothermal can provide the sustainable energy solutions based on the available resources. A transition to renewable-energy source is now a must as they are commercially viable while the price of gas, oil and other related sources has shown a considerable increase since last decade. These sources particularly wind and solar are likely to be an active partner in energy race due to the following factors:

1. In declining capital costs and cost of electricity generated and
2. It will reduce the impact to the environment, ecosystem and human health.

The worsening power situation and the various environmental problems of large-scale power generation has led to increased appreciation of the potential of electricity generation from non-conventional sources, with special emphasis on Wind Energy. Five nations, Germany, USA, Denmark, India and Spain accounts for 80% of the world's installed wind energy capacity. During 1985-90 in India, importance was given to grid quality power generation by wind turbine technology. The 8th National Five Year Plan (1992-97) by India's Ministry of Non-conventional Energy Services (MNES) had targeted a capacity addition of 1900 MW through renewable technologies, and these have established a need for power planning in India. Since then, wind power generation has gained good response in the country. As a result of which, in 2003 India stood fifth in the world wind energy rankings, with over 1700 MW of installed capacity. Much of the installed capacity is in the states of Tamil Nadu (61 per cent), Gujarat (14 per cent), Maharahtra (12 per cent), and Andhra Pradesh (7 per cent).

Due to the technology improvement and its ease in transfer and adaptation, India established itself as the third biggest wind energy market worldwide in terms of new installations, and 875 MW was added during 2004. Country is expected to get ahead of the former pioneer country, Denmark soon and become number four in terms of total capacity. The installed capacity of wind power in India by the end of March 2005 has reached to 3595 MW.

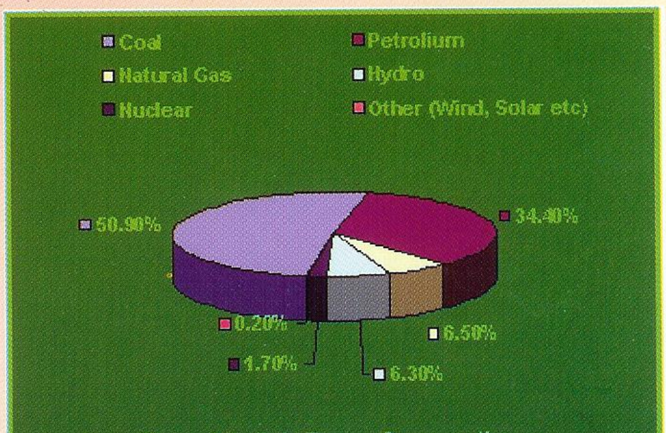
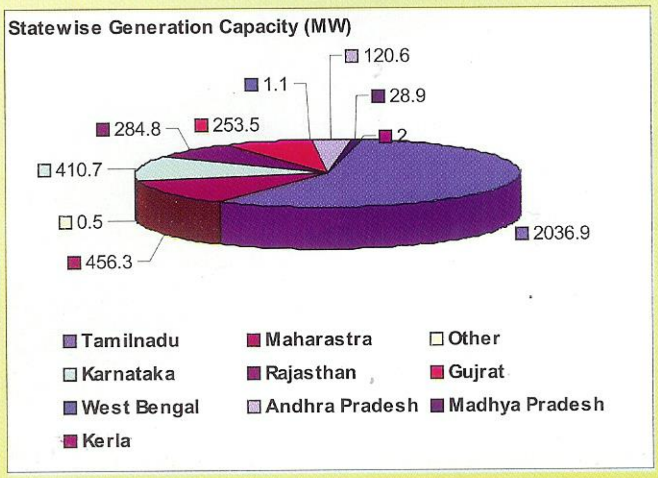


Figure 2. India's Energy Consumption



ACID RAIN DOWNPOUR IN ASIA

The dimensions of the acid rain problem are growing rapidly in Asia, with sulfur dioxide (SO2) emissions expected to triple from 1990 levels by 2010 if current trends continue.

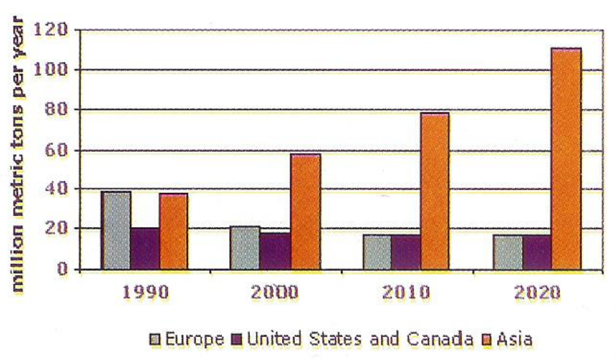
Acid rain emerged as a concern in the 1960s with observations of dying lakes and forest damage in northern Europe, the United States, and Canada. It was one of the first environmental issues to demonstrate a large-scale regional scope. The chief pollutants-oxides of sulfur (SOx) and nitrogen (NOx) from combustion of fossil fuels-can be carried hundreds of miles by winds before being washed out of the atmosphere in rain, fog, and snow.

Acid rain is now emerging as a major problem in the developing world, especially in parts of Asia and the Pacific region where energy use has surged and the use of sulfur-containing coal and oil-the primary sources of acid emissions is very high. An estimated 34 million metric tons of SO2 were emitted in the Asia region in 1990. Acid deposition levels were particularly high in areas such as southeast China, northeast India, Thailand, and the Republic of Korea, which are near or downwind from major urban and industrial centers. The effects are already being felt in the agriculture sector. Researchers in India found that wheat growing near a power plant where SO2 deposition was almost five times greater than the critical load (the amount the soil can safely absorb without harm) suffered a 49-percent reduction in yield compared with wheat growing 22 kilometers away (Pattel 1997:11). In southwestern China, a study in Guizhou and Sichuan provinces revealed that acid rain fell on some two thirds of the agricultural lands, with 16 percent of the crop area sustaining some level of damage. Other ecosystems are also beginning to suffer. A study of pines and oaks in acid rain-affected areas of the Republic of Korea, both rural and urban, showed significant declines in growth rates since 1970 (Downing et al. 1997:6).

Economic expansion and continued reliance on coal as a primary fuel is likely to increase acid rain in Asia in the next two decades. By 2020, Asian SO2 emissions could reach 110 million metric tons if no action is taken beyond current levels of control (Downing et al. 1997:1-3, 11).

SO_2 Emissions in Asia Could Triple

Figure 1: Past and Projected Sulfur Dioxide Emissions for Europe, the United States and Canada, and Asia



Source: Downing et al. 1997.

Montreal Protocol officially the Protocol on Substances that deplete the Ozone Layer, treaty signed on Sept. 16, 1987, at Montreal by 25 nations; 168 nations are now parties to the accord. The protocol set limits on the production of chlorofluorocarbons (CFCs), halons, and related substances that release chlorine or bromine to the ozone layer. On the basis of increasing scientific knowledge about the effects of CFCs and halons on the ozone layer, the original protocol has been amended several times. At meetings in London (1990), Copenhagen (1992), Vienna (1995), and Montreal (1997) amendments were adopted that were designed to speed up the phasing out of ozone-depleting substances. The production and consumption of halons was phased out by Jan. 1, 1994, and of CFCs, carbon tetrachloride, methyl chloroform, and hydrobromofluorocarbons by Jan. 1, 1996, subject to an exception for agreed essential users. Methyl bromide is to be phased out by 2005, and hydrochlorofluorocarbons are to be phased out by 2020. (Phaseout dates are later for developing countries.) Under the protocol, the ozone-depleting potential [ODP], of any substance is measured with respect to an equal mass of CCl3F, or CFC-11, which is assigned a value of 1.0. Most other CFCs have ODPs between 0.5 to 1.3. Hydrochlorofluorocarbons, which are being used as transitional replacements (until 2020) for CFCs in refrigeration, have ODPs that are < 0.5. Hydrofluorocarbons, which are also replacing CFCs as refrigerants, have ODPs of zero. ODPs potentials are based on existing scientific knowledge and are to be reviewed and revised periodically.

SEA SALT MAY IMPACT CLIMATE, ACID RAIN.

While a breeze over the ocean may cool beach goers in the summertime, a new scientific study has revealed that tiny sea salt particles drifting into the atmosphere participate in a chemical reaction that may have impacts on climate and acid rain.

Recent studies show that sea salt plays an important role in the chemistry of Sulphur in the atmosphere. Sulphur-dioxide, which is one form of sulphur, is a by-product of burning fossil fuels containing sulphur. It is also formed when naturally emitted sulphur-containing compounds react in the atmosphere. In the air, sulphur dioxide is converted to sulphuric acid, a major component of acid rain and a contributor to haze in the atmosphere. These haze particles can affect clouds, which play an important role in climate.

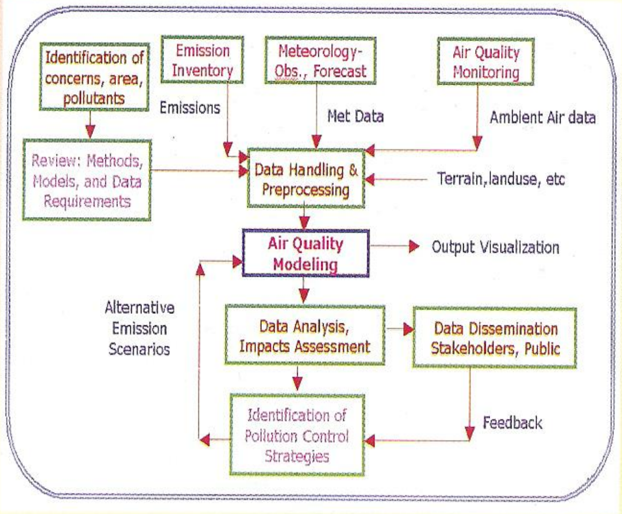
Clean Air Initiative Pune Air Quality Management Program

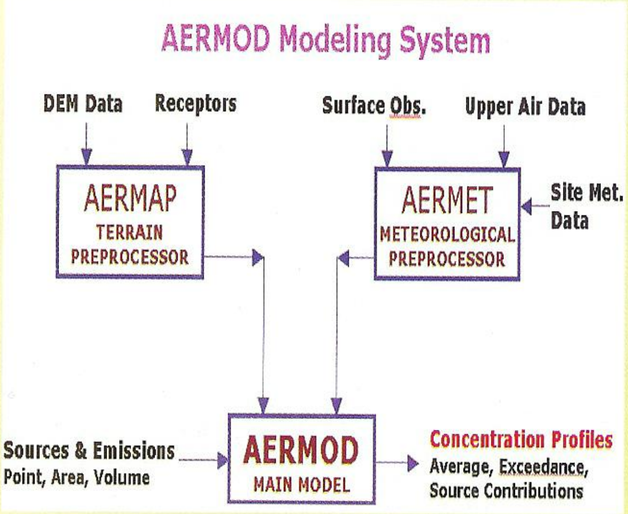
Pune Air Quality Management Program is a collaborative program of United States Environmental Protection Agency (USEPA) and Ministry of Environment and Forest (MoEF), Government of India. This activity began with joint brainstorming workshop on strengthening Air quality management efforts in India in 2001. These discussions led to a program for control strategy development where Pune is identified as a pilot city with initial focus on particulate matter (PM-10). Under this program, the Ambient Air monitoring activities field program began in September 2003. Mobile source, point and area source emission inventory study project was conducted in March 2004. In this program a pilot mobile source emission inventory was prepared.

With a focus on dispersion modeling for PM-10, USEPA, U.S Asia Environment program (USAEP), National Environment Engineering and Research Institute (NEERI) and Centre for Development of Advanced Computing (CDAC) jointly conducted a training program on Air Quality modeling in CDAC, Pune from March 14-17, 2005. Emphasis of this workshop was to develop a science based action plan for Pune AQM.

The key components of air quality management system are Air quality models are used to evaluate monitoring networks, effectiveness of various emission control strategies. For any air quality modeling the primary inputs are source information, receptor information, meteorological data, terrain data, land-use cover, atmospheric chemistry details and background air quality data. The types of commonly used regulatory models are steady state Gaussian models, Lagrangian models, Eulerian models. Since for Pune, the major impacts are local, Gaussian model with spatial scale of 10 km AERMOD is chosen; also, the model can resolve high spatial gradient and emission usage is easy. . Success of modeling activities depends on examination of impact of emission changes, interpretation of trends in air quality and forecasting of air quality. Models play a major role in AQM system.

Future state of the environment is affected by population growth, industrialization, transpose patterns, which can be simulated by changing emission and meteorological conditions based on seasons. Three major inputs to Air quality models are emissions, observations, and meteorology. Emission inventories are from point, area, mobile sources, dust concentration, open burning, brick kilns, etc. Meteorological inputs are wind fields, turbulence, boundary layer evolution, plume rise, radiation, temperature and precipitation. Apart from observational data, meteorological data from India Meteorology Department, for the first time in India, for trial runs using mesoscale models such MM5/ WRF is being planned. The meteorological inputs will be provided to the AERMOD model.





AERMOD Model

- In this model, concentration can be estimated based on mean and turbulence structure of the atmosphere boundary layer. Surface stress (wind) and heat flux is used to estimate structures. The AERMOD model has meteorology processor to convert measurements into micrometeorology variables required by the model, terrain processor and dispersion model. The AERMAP terrain processor uses Digital Elevation Model (DEM) Data and Receptor Locations Receptor coordinates - Modeling Domain: Gridded, Discrete, Flagpole receptors
- The AERMET meteorological processor extracts, quality checks and preprocesses raw meteorology data with inputs as Surface Observation Parameters (Hourly)Minimum: Station Pressure, Ambient Temperature, Wind direction & speed, sky cover
- The AEMOD model has inputs from AERMAP and AERMET.
- Source & Emission Information

- Point sources: Locations, Emission Rate, Stack parameters. Building dimensions
- AreaSources: Location & dimensions, Emissionrate
- VolumeSources: Location, 'initial' dimensions, Emission Rate

Variable emission rates - through coefficients or separate file

Urban Source Option - Population [and Surface Roughness]

The workshop had participants from academic institutions and other agencies in the country in addition to USEPA scientists. The participants from USEPA, C-DAC, Pune University, IITM Pune, IIT Delhi, PMC Pune, IMD Pune, NEERI Nagpur and MPCB Mumbai discussed various issues and aspects.

The workshop concluded with preparation of science based action plan with field experiments, emission inventory preparation, QA&QC activities, modeling and validation of the model outputs, information dissemination for policy makers.

(Contributed by Ms. Akshara Kaginalkar, C-DAC, Pune)

India : Environmental Issues

India has seen its population explode from 300 million in 1947 to approximately one billion today. This rapidly growing population, along with increased economic development, has placed a strain on infrastructure, and also on the environment. Deforestation, soil erosion, water pollution and land degradation continue to worsen and are hindering economic development in rural India. Rapid industrialization and urbanization in metropolises are also serious concerns. The Government of India (GOI), recognizing the severity of these problems, has adopted several comprehensive policies to address the environment. India is party to several other international environmental treaties, such as the Montreal Protocol, Law of the Sea, and the Convention limiting the movement of hazardous wastes and the Kyoto protocol.

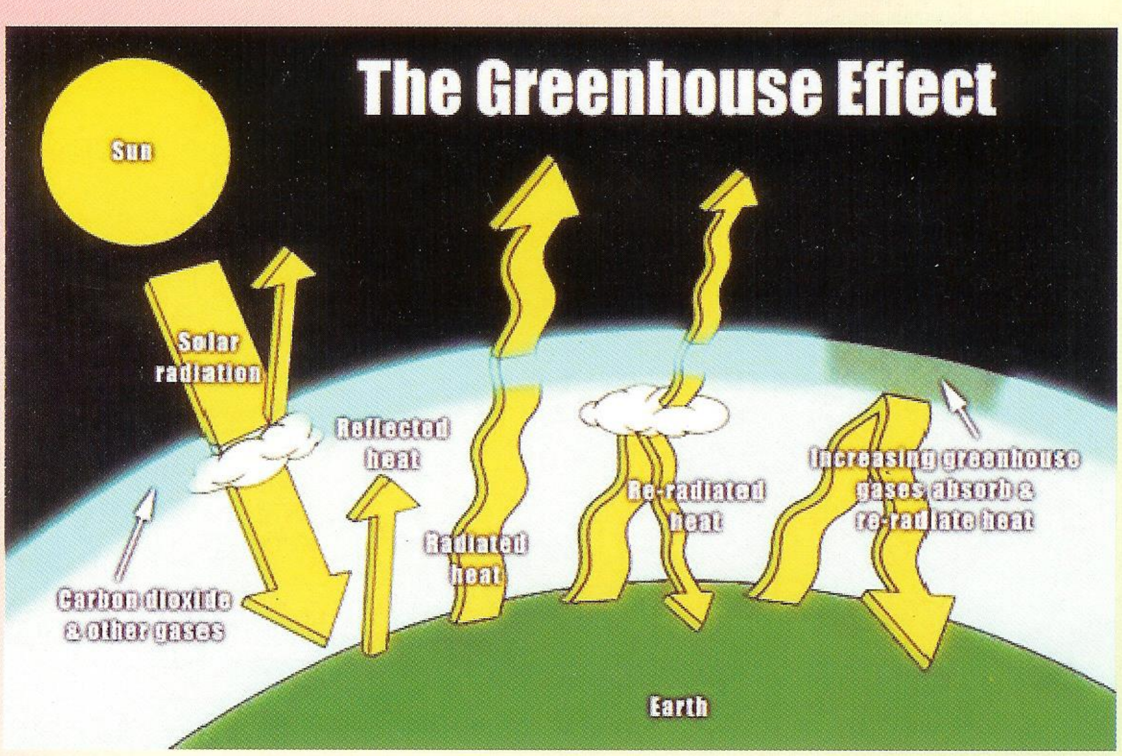
Energy Use and Carbon Emissions: Overall, 60% of energy needs in India are met by commercial energy sources, while the remaining 40% are comprised of non-conventional and renewable fuels. With 243.3 million metric tons of carbon released from the consumption and flaring of fossil fuels in 1999, India ranked fifth in the world behind the United States, China, Russia and Japan. India's contribution to world carbon emissions is expected to increase in coming years. Technologies to reduce the amount of coal consumed or the quality of coal combusted are a priority for a nation in which approximately 70% of electricity is generated from coal and 64% of all carbon emissions come from coal.

India has made significant efforts in the field of environmental protection, developing environmental standards for both products and processes, requiring environmental impact statements in certain areas, and introducing environmental audits. Sheer population growth and urbanization, however, dictate that these measures are only the first steps on a long and challenging road.

Greenhouse effect : Derect Observationl Evidence

A comparison of satellite data from 1970 and 1997 has yielded what scientists claim to be the first direct evidence that the greenhouse gases are building up in Earth's atmosphere and allowing less heat to escape into space. The study contains no evidence on whether the Earth's surface temperature is actually increasing. In fact, whether this greenhouse effect will lead to global warming or global cooling is unclear.

That is because the greenhouse effect could start a cycle in which more clouds are formed, stopping the sun's energy from reaching Earth's surface in the first place.



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