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Economic Valuation of Health Damage in North Chennai Using a Comparative Risk Assessment Framework

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MOEF IGIDR WORLD BANK

ECONOMIC VALUATION OF HEALTH DAMAGE IN NORTH CHENNAI USING A COMPARATIVE RISK ASSESSMENT FRAMEWORK

Project Report

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Executive Summary

Introduction

The general objective of the project was to rank a set of environmental problems faced by a municipality within an industrial zone of Chennai City using a comparative risk assessment framework (CRA). The CRA approach originally developed by the United States Environmental Protection Agency (USEPA), has been applied for aiding resource allocation for environmental management in several states of USA as well as in many cities of developing countries including Ahmedabad in India and Asansol in Bangladesh. One of the biggest impediments to successful application of the CRA framework in developing countries is the lack of both quantitative exposure and health effects information. The project demonstrates the usefulness of the CRA approach by addressing many of these deficiencies through rigorous primary and secondary data collection on environmental, health and economic parameters. The study represents one of the first studies in India to use a quantitative health risk assessment framework to address environmental health concerns at a municipal level with direct stakeholder involvement.

Objectives

The focus of the project was to assess human health risks associated with particular environmental exposures using both previously established dose – response information and cross-sectional epidemiological information collected during the course of the study. The economic costs associated with these health risks were then evaluated using local economic information to enable ranking of the particular environmental concerns on the basis of both the health and economic risks. The geographic focus of the project was the Thiruvottiyur Municipality in North Chennai. Since even within a single zone, there are a multitude of environmental concerns, the project sought to analyse only an identified set of problems as listed below.

List of Environmental Concerns

Air	Water	Solid waste
Particulates (Total / Respirable)	Microbial contamination	Access to sanitation
Indoor air pollutants	Heavy metals	Proximity to solid waste dumps
SO_2		
NO_2		
Lead		

Methodology

Population exposures to select air and water pollutants were assessed using a combination of secondary data sources as well as primary sampling. Health risks were then assessed using dose - response information established specifically from developing country studies. In addition, primary data on the prevalence of respiratory, gastro-intestinal and vector-borne diseases within the resident population of the study zone was also collected by administration of a health assessment questionnaire. To assess economic costs of the health damage, local information on costs of hospital visits, treatment and work-loss days specifically attributable to environmental exposures were collected. *Finally, the health and economic risks associated with each environmental problem were assessed on the basis of data collected from the preceding steps as well as on the basis of public perceptions and ranked accordingly.*

Results

Air Quality

Air quality information was collected from secondary sources as well as through primary sampling. Secondary sources included the National Ambient Air Quality Monitoring Database (NAAQM) and Environmental Impact Assessment (EIA) reports of area industries done over a period of last 5 years. Primary sampling was carried out for PM10 (Particulate matter less than 10 μm), CO, SO_2, NO_2, lead and indoor air-pollutants (in houses using bio-fuels) through a combination of personal sampling and area sampling techniques.

The environmental air quality data analyses revealed that levels of PM10 are the single biggest concern. The results of limited primary sampling show that a significant fraction of the population is exposed to PM 10 levels not adequately reflected in the area average reported by the NAAQ database. Populations that use bio-mass fuels in homes for cooking or live in slums adjacent to high traffic corridors, commuters, traffic police all represent categories that are exposed to concentrations well in excess of the standards. *Population exposure profiles show that nearly 95% of the population is exposed to concentrations in excess of the World Health Organisation (WHO) guideline values for PM10.*

Annual 24-hour averages of lead in air as established through high volume sampling were below the prescribed standards. However, blood lead levels were higher than the action level of the USEPA. Since the relative contribution from air borne lead could not be ascertained risks from elevated blood lead levels were separately calculated. Although the annual 24-hour averages of CO, SO_2 and NO_2 were below the standards, the short-term exposure limits was exceeded significantly during bio-mass burning while cooking or open refuse burning. The limits were also exceeded during sporadic releases by the industry. Based on the above results, health risk calculations were done only for PM 10 and for lead. Although the short-term exposure limits were exceeded for other pollutants, the consequent health risks could not be quantified due to the uncertainty in the dose -reponse relationship data for such exposures.

Water Quality

Data on physico-chemical and microbiological parameters were collected predominantly from the Ground water Cell of Chennai Metropolitan Water Supply and Sewerage Board (CMWSSB). EIA reports of area industries were additional sources of information. Some primary data was also collected, by sampling drinking water in select households. Secondary data collected over a period of last five years revealed that microbiological contamination with faecal coliforms was the most significant concern within the municipality. The data showed presence of faecal coliforms in almost all sampling locations spread across the municipality over multiple time frames.

Data on heavy metals including lead, chromium, arsenic, copper, iron and zinc showed that levels were predominantly below the prescribed standards. Limited data on pesticides showed no significant contamination of drinking water sources. Since the available data did not show significant presence for any of the major chemical contaminants, health risk calculations for water contaminants were limited to the assessment of prevalence of gastro-intestinal disorders attributable to microbial contamination.

Solid waste & Access to Sanitation

Qualitative information on solid waste was collected both from municipal sources and from household level surveys. Nearly 35% of the population did not have access to a private toilet and made use of open grounds or public toilets. In slum populations nearly 80% did not have access to private toilets. Around 55% of the population reported being severely affected by rain- water stagnation. 30% lived in houses that were less than 100m meters from solid waste dumps. The municipality was operating three of the solid waste dumps. Most of the dumps were also found to contain large quantities of chemical and other hazardous wastes. The access to these dumpsites was unrestricted. Rag pickers included many children from the neighbouring slums. Improper solid waste disposal and lack of access to private sanitation was cited as the most important environmental health concern in community perception surveys. Quantitative health risk assessments were not performed for solid waste concerns, as quantitative exposure information was not available. Prevalence of vector borne and water borne infectious disease were collected from area hospitals as well as from study households.

Health risk assessment and economic valuation of health damage using previously established dose-response information

PM 10

Health End point	Estimated Impact on study population*	Unit costs** (in Rs.)	Total costs (Lakhs of Rs.)
Pre mature deaths	202	393,879	797
Respiratory hospital admissions	285	1713	4
ERV (Emergency room visits)	5598	228.3	12
RAD/1000(Restricted activity days)	1367	41	563
RSD/1000(Respiratory symptom days)	4352	20	870
COPD (Chronic obstructive pulmonary disease)	1455	69,997	1018
LRI (Lower respiratory infections) in children	16,078	346	55
Asthma attacks	54275	200	108

TOTAL: 3432 LAKHS

* **Study population (covering an industrial municipality in North Chennai) - 211,000**
****All costs are annual costs**

Indoor air pollutants

Indoor air pollutants monitored included respirable particulates, carbon monoxide, SO_2 and NO_2. Biomass combustion made the greatest contribution for exposures to these pollutants in households (where in it was being used for cooking). The health risks from respirable particulates were taken into account while reconstructing PM 10 exposures for the population. Short term exposure guidelines for carbon monoxide was exceeded in 67% of homes during cooking with bio-mass fuels while the guideline values for SO2 and NO2 were exceeded in about 15% of the homes. Although gas exposures exceeded prescribed standards, the consequent health risks could not be quantified due to the lack of definitive dose- response relationships for short-term exposure.

Blood lead

Although lead levels in air and water were below the permissible standards, the blood lead levels were still higher than the action level set by the USEPA. The mean blood lead levels in children were 22µg/dl while in adults it was 16 µg/dl. Applying dose response information cited in the main report, the calculated health risks for the study zone population were as follows.

Mean Blood lead levels	Health End point	Estimated Impact on study population
Children- 22µg/dl	Loss of IQ points	2 points/ child
	Increase in infant deaths	4.5 deaths /year
Adults - 16 µg /dl	Increase in Blood pressure Men Women	 2.6 - 3.2 mm Hg 1.6 - 1.8 mm Hg
	Heart Attacks	114/year
	Strokes	14/year
	Premature deaths	110/year

The economic costs associated with these health end points have not been computed. Unlike PM10, studies on lead have come only from the developed country settings wherein the doses are nearly an order of magnitude less than what has been observed in this study. These risk calculations are therefore uncertain. Also, the cost of these health endpoints could not be ascertained in this study and as there are no national figures available, a cost estimation for these risks was not carried out.

Microbial contaminants in water and sanitation related issues were not examined using the dose- response framework. Instead their contribution to health impacts was assessed from the cross-sectional health and economic information gathered through the household survey and the health information available at the local health care facilities.

Health impact assessment and economic valuation from cross-sectional epidemiological information gathered through the household survey

Prevalence of respiratory, gastrointestinal and vector borne illness was assessed in the study zone through the administration of a household level questionnaire that collected both the health and economic information. Treatment costs, wage loss days and defensive expenditure attributable to specific health end points associated with air, water or sanitation related issues were assessed to value the associated economic loss. Although, this method was media specific (i.e. air/ water/solid waste) and not pollutant specific , this allowed comparisons to be made between estimates that were obtained from applying previously established dose-response functions and those obtained through direct assessment methods.

Health end point	Prevalence	Treatment costs (lakhs of rupees)	Wage loss (lakhs of rupees)	Defensive expenditure (lakhs of rupees)	Total annual costs for study zone (lakhs of rupees)
Respiratory illness	12%	710	942		1652
Gastro-intestinal disorders	16%	1167	1111	85	2363
Vector-borne illness	5%	1175	338	243	1757

The economic costs of respiratory illness as determined from the house - hold survey is in broad agreement with the economic costs for respiratory illness calculated using the dose-response information for PM 10 exposure. Also the preceding calculations show that while the health costs associated with air pollution are high, they are outweighed by water and sanitation related concerns in the municipality.

Relative ranking of environmental concerns on the basis of health and economic risks

The health and economic risks obtained from the preceding steps were ranked relatively as follows after taking into account the uncertainties surrounding these estimates as well as people's perception (that was assessed as a part of the household survey).

High risks	Microbial contamination of water
	PM 10
	Sanitation and solid waste disposal
Medium risks	Lead
	Indoor air pollutants from bio-mass combustion
Low risks	NO2
	Volatile organics
Uncertain risks	CO
	SO2
	Chemical contaminants in drinking water
	Hazardous wastes

Conclusions

The study has been one of the first exercises within the city of Chennai, that has used the quantitative health risk assessment framework to value environmental health damage. Exposure assessment is one of the most crucial components for conduct environmental health risk assessments and the present study through a combination of primary and secondary data collection has generated a large database of population exposure information for several key pollutants in the study zone. Although uncertainties still surround the application of the dose-response information as well the use of cross sectional epidemiological information, the study has clearly identified the need for initiating remedial action for environmental concerns listed in the high risk category. The scheme of relative ranking of risks allows one to prioritize between the concerns without the need to be concerned about the absolute value of these risks. The economic valuation of health damage assessed in this study can easily be used in subsequent cost-benefit analyses to choose between alternate methods for reducing population exposures.

Most importantly the study has been executed with significant stakeholder participation including members of the Tiruvottiyur Municipality, The Tamil Nadu State Pollution Control Board and The Chennai Metropolitan Development Authority. The involvement of these members will greatly facilitate the subsequent design and implementation of an environmental management plan for the region. Institutional capacity building exercises in the form of training in health risk assessment methodologies were carried out twice during the course of this study. This would serve to further strengthen the local network of professionals to refine these estimates for this zone as well as undertake similar exercises that would cover the entire Chennai Metropolitan Area.

Finally the study has identified areas, where the largest gaps in data accuracy are likely to be present. Recognition of these areas will contribute to refining the framework for conduct of subsequent longitudinal environmental health studies. This will in turn ensure that the actual health and economic costs are captured with the least degree of uncertainty for local policy interventions. In that sense, it is hoped that the study will serve as good proto- type for other studies in the region to recognize the importance of environmental health risks and initiate action plans aimed at protecting the health of the public.

Background

Metropolitan cities across the world have a multitude of environmental concerns that affect human health. Burgeoning populations, worsening air quality, polluted rivers, congested roads, and hazardous occupational environments all represent problems faced by environmental managers of all countries. Understanding the linkages between environment and health is now well recognised as a key determinant of improved decision making during the design of sustainable development plans for the regions. Addressing these issues in developing country settings is all the more challenging as these compete with each other for limited resources allocated for environmental improvement. A crucial task for environmental decision-makers is therefore to decide on what would be the most efficient way of resource allocation that would provide the most benefit to the concerned communities. Since the Rio Earth Summit in 1992, the World Health Organisation (WHO) has augmented efforts for understanding the environmental contribution to global ill health. The WHO in the 1997 report on " Health and Environment and Sustainable Development ", made the first estimates of the environmental contribution to the global burden of disease. These indicate that *roughly 25-33% of the global burden of disease is attributable to environmental factors with children under 5 bearing the largest environmental burden.* Figures 1 shows the environmental contribution for all categories of diseases responsible for at least 1% of the total global burden of disease (expressed as disability adjusted life years or DALYs*). The distribution of DALYS in the major world regions is shown in Figure 2.

While the available statistics clearly identify the need for addressing environmental concerns within development plans, regional environmental management plans have to rely on direct assessments of the impact of local environmental degradation. In recent years, quantitative health risk assessment and comparative risk assessment (CRA) procedures have been used to quantify human health risks associated with particular environmental exposures and rank them according to the magnitude and severity of health damage. These estimates can then be subsequently used for assessing the economic impact of such damage. Together, they can serve as the basis for the design of an environmental management plan that will integrate this information with resource availability and assign priorities for allocation of resources.

The CRA process was originally developed by the United States Environmental Protection Agency (USEPA) to determine how environmental priorities, based on health risks, lined up with the level of resources devoted to mitigating problems within the EPA's mandate (USEPA, 1989). The CRA approach is being used now, not only in the United States, but also in several cities throughout the world, for the design of environmental management programs. Two studies of this kind have been completed in India recently, in Ahmedabad and in Asansol (USAID, 1995). A list of recent studies and environmental rankings arrived in these studies are listed in Table 1.

While procedures for environmental health impact assessment have been used extensively to quantify health benefits, the benefit may be viewed in terms other than health consequences. The World Bank (Carter Brandon, 1995) has initiated such efforts, whereby the economic costs of environmental degradation have been estimated for the several cities in India. Economic costs associated with health impacts and productivity impacts have been calculated, for several priority areas identified under the Government's National Environmental Action Programme (NEAP1993). These estimates give a good overview of the issues and the costs at a national level and serve to demonstrate, qualitatively, the usefulness of such an approach for setting of environmental priorities. Key economic estimates from these studies for major Indian studies are summarised in Tables 2 and 3.

The health and economic estimates have been used to perform cost-benefit analyses for interventions as well. The recent set of URBAIR documents published by the World Bank present city specific data on air pollution as well as a framework for action plans for air pollution control showing the viability of many of the technical control options.

For a rigorous cost benefit analysis of proposed environmental interventions in a region, it is necessary that both the health impact assessments and the economic assessments be well quantified. In the earlier CRA efforts in developing countries, the lack of accurate population exposure information has resulted in considerable uncertainties in the health risk estimates, which in turn cloud the economic damage estimates. These have been largely the result of inadequate information in the available environmental and health databases. The existing secondary data sources often do not have data amenable to apply the quantitative health risk assessment framework. Further, in the absence of local information on the linkages between the levels of exposures to particular pollutants and their health impacts (dose-response information), often, developed country dose-response functions are applied to estimate the magnitude of environmental health damage in populations of developing countries.

In India efforts by local institutions aimed at economic valuation of environmental health damage have been few and far in between. A few studies that have been taken place have focussed on Delhi and Mumbai. Metropolitan cities in Southern India have not applied a risk assessment framework to begin addressing environmental concerns. It is with this background that the present project was conceived in the city of Chennai. The present project sought to demonstrate the usefulness of the CRA approach by addressing many of these deficiencies through rigourous primary and secondary data collection on environmental, health and economic parameters within one municipal zone of Chennai.

The Chennai metropolitan area is the fourth largest metropolis in India. Urban development has been rapid over the last two decades. Much of the development has been through World Bank and IDA supported initiatives under the Madras Urban Development Projects and the Tamil Nadu Urban Development Project. The Chennai Metropolitan Development Authority (CMDA) has been the coordinator for most of these efforts. Efforts to ensure sustainable development have been initiated through programmes under the Sustainable Chennai project of the United Nations Development Programme. The project has identified several strategies for urban growth and development that would be compatible with environmental preservation. Under the Sustainable Chennai project an exhaustive environmental profile has been prepared that identifies several areas of environmental concern within the city (Appasamy, Paul 1997). The concerns are based on review of the prevailing conditions in the city, in terms of provision of essential services to the public, the civic infrastructure, environmental pollution levels and other indicators that are likely to be detrimental to the quality of human life. The issue of the impact of the prevailing environmental conditions on human health has not been directly addressed.

The proposed project represents an effort, whereby the environmental health impacts have been assessed through a combination of using previously established dose-response information in conjunction with local exposure information as well as through collection of primary environmental, health and economic information. This allowed cross-comparisons to be made between the predicted and observed estimates as well as address the relative uncertainties. The study represents one of the first studies in India to use a quantitative health risk assessment framework to address environmental health concerns at a municipal level with direct stakeholder involvement

Table 1: Recent Comparative Risk Assessment Studies

Study	Ranking	
Comparative Environmental Risk Assessment for Ahmedabad, India USAID (1995)	Highest Risk	Air pollution from mobile sources
	High Risk	Ambient Air Pollution
		Indoor Air Pollution
	Moderate Risk	Drinking Water and Waste Water
	Low Risk	Food Contamination
		Occupational Hazards
		Traffic Hazards
	No Rating	Solid waste
Comparative Environmental Risk Assessment for Cairo, Egypt USAID (1994)	Higher Risks	Particulate Matter Air Pollution
		Lead (in all media)
		Microbiological Diseases From Environmental Causes
	Middle Risks	Microbial Food Contamination
		Ozone Air Pollution
	Middle/Lower Risks	Sulphur dioxide Air Pollution
		Carbon Monoxide Air Pollution
		Indoor Air Pollution
		Drinking Water Contamination by Chemicals
		Drinking Water Contamination by Microbiological Agents
		Solid and Hazardous Wastes
	Lower Risks	Toxic Air Pollutants
		Other Water Pathways: Direct Contact, Irrigation, Fish Consumption
	Uncertain Risks	Nitrogen oxides air pollution
		Metals in Foods
		Pesticides in Foods
Comparing Risks and Setting Environmental Priorities Overview of Three Regional Projects USEPA (1989)	High Health Risks	Indoor Radon
		Indoor air pollution other than radon
		Pesticides (primarily residues on food)
		Drinking water contamination
	Low Health Risks	Underground storage tanks
		Active hazardous waste (RCRA) sites
		Abandoned hazardous waste (CERCLA) sites
		Non hazardous (solid) waste sites
		Nonpoint source discharges to surface waters

Table 2 : Estimates of Annual Health Incidences in Indian Cities due to Ambient Air Pollution Levels exceeding WHO Guidelines

Cities	Premature deaths	Hospital admissions and sicknesses requiring medical treatment	Incidence of minor sickness (including RADs and RSDs)
Ahmedabad	2,979	1,183,033	72,177,644
Bangalore	254	135,887	8,326,282
Bhopal	663	277,847	17,024,691
Bombay	4,477	2,579,210	156,452,916

Calcutta	5,726	3,022,786	179,479,908
Delhi	7,491	3,990,012	241,958,219
Hyderabad	768	420,958	25,177,173
Jabalpur	683	286,214	17,537,333
Jaipur	1,145	520,947	31,708,958
Kanpur	1,894	812,381	49,247,224
Madras	863	461,966	27,859,487
Patna	725	319,242	19,561,109
Shimla	32	18,160	1,112,754
Shillong	0	0	0
Varanasi	1,851	785,414	48,125,143

Table 3 : Annual Costs of Ambient Air Pollution Levels in Indian Cities Exceeding WHO Guidelines, in US$

Cities	Premature deaths		Hospital admissions and sicknesses requiring medical treatment		Incidence of minor sickness (including RADs and RSDs)	
	Lower estimate ($)	**Upper estimate** ($)	Lower estimate ($)	Upper estimate ($)	Lower estimate ($)	Upper estimate ($)
Ahmedabad	12,537,800	119,225,175	1,432,532	2,875,979	19,336,059	26,239,527
Bangalore	1,068,293	10,158,669	161,452	322,291	2,230,573	3,026,944
Bhopal	2,789,222	26,523,430	330,119	658,987	4,560,837	6,189,172
Bombay	18,839,236	179,147,155	3,201,644	6,474,425	41,913,018	56,877,036
Calcutta	24,094,972	229,125,302	4,088,226	8,462,469	48,081,843	65,248,289
Delhi	31,523,529	299,765,367	4,959,218	10,032,288	64,819,496	87,961,712
Hyderabad	3,230,756	30,722,096	553,527	1,137,350	6,744,849	9,152,932
Jabalpur	2,873,210	27,322,095	340,060	678,830	4,698,171	6,375,538
Jaipur	4,819,636	45,831,164	637,250	1,283,189	8,494,684	11,527,504
Kanpur	7,971,626	75,804,248	1,011,128	2,046,290	13,193,105	17,903,381
Madras	3,629,785	34,516,561	587,568	1,196,394	7,463,429	10,128,063
Patna	3,050,326	29,006,340	379,302	757,166	5,240,331	7,111,264
Shimla	133,985	1,274,093	21,577	43,072	298,102	404,532
Shillong	0	0	0	0	0	0
Varanasi	7,789,537	74,072,712	933,177	1,862,814	12,892,505	17,495,458

Pollutants : Particulate matters (PM10); Sulphur dioxide (SO2); Nitrogen oxides (NO2)

Source: Carter Brandon and Kirsten Homman, ***The cost of inaction: valuing the economy – wide cost of environmental degradation in India***. World Bank working paper,1995.

SCOPE OF PRESENT STUDY

The principal focus of the project was on assessing human health risks associated with particular environmental exposures using both previously established dose – response information and cross-sectional epidemiological information collected during the course of the study. The economic costs associated with these health risks were then evaluated using local economic information to enable ranking of the particular environmental concerns on the basis of both the health and economic risks**. The geographic focus of the project was the Thiruvottiyur Municipality of Chennai,** located in the industrial corridor just outside the northern city limits, along the coast of the Bay of Bengal. Since even within a single zone, there are a multitude of environmental concerns, the project sought to analyse only an identified set of problems as listed below.

List of Environmental Concerns

Air	Water	Solid waste
Particulate Matter (Total / PM 10*)	Microbial contamination	Access to sanitation
Indoor air pollutants	Heavy metals	Proximity to solid waste dumps
SO_2		
NO_2		
Lead		

* PM 10 - Particulate matter less than 10 μm in aerodynamic diameter.

Population exposures to select air and water pollutants were assessed using a combination of secondary data sources as well as primary sampling. Health risks were then assessed using dose - response information established specifically from developing country studies. In addition, primary data on the prevalence of respiratory, gastro-intestinal and vector-borne diseases within the resident population of the study zone was also collected through the administration of a health assessment questionnaire. To assess economic costs of the health damage local information on costs of hospital visits, treatment and work-loss days specifically attributable to environmental exposures were collected. *Finally, the health and economic risks associated with each environmental problem was assessed on the basis of data collected from the preceding steps as well as on the basis of public perceptions and ranked accordingly.*

The core team of investigators was drawn from the Sri Ramachandra Medical College & Research Institute. In addition the study involved members from other academic and governmental organisations including the Madras School of Economics, the Tamil Nadu Pollution Control Board (TNPCB), the CMDA and most importantly the members of the Thiruvottiyur Municipality. Since these Governmental bodies will be responsible for the implementation of an environmental management plan at a later date, their participation was sought to facilitate translation of the recommendations of the study into an action plan.

Finally, the project sought to specifically strengthen the technical capacity of institutions in environmental health risk assessment and economic valuation procedures. Although not explicitly listed in the original scope of the project, the investigators have developed a training module on environmental epidemiology using the insight gained by the execution of this project. The module has been administered to scientists and engineers of the regional pollution control boards twice during the project period.

OBJECTIVES

Overall objective of the study

- ❖ To rank a set of environmental problems in the Thiruvottiyur Municipality located within the Chennai Metropolitan area on the basis of human health risks and the economic impact of the health risks.

Specific Objectives of the study

- ❖ To obtain available secondary environmental monitoring data for air and water
- ❖ To conduct primary sampling and analyses for pollutants that are not routinely monitored
- ❖ To assess the prevailing status of solid and hazardous waste disposal
- ❖ To assess population exposures for pollutants based on primary and secondary environmental data
- ❖ To assess health risks for select pollutants on the basis of previously established dose-response information
- ❖ To value the calculated health risks using local economic information

- To collect information on prevalence rates for health end points such as respiratory ailments, gastrointestinal and vector borne diseases that are specifically attributable to environmental exposures, through the administration of a household level questionnaire

- To collect information on health expenditure and wage loss, specifically associated with health end points described above and thereby compute the specific economic costs.

- To compare costs computed through the direct household level survey and those estimated using predicted health risks

- To collect information on community perceptions about relative magnitudes of environmental problems of the zone

- To rank the environmental problems on the basis of information collected in the preceding steps

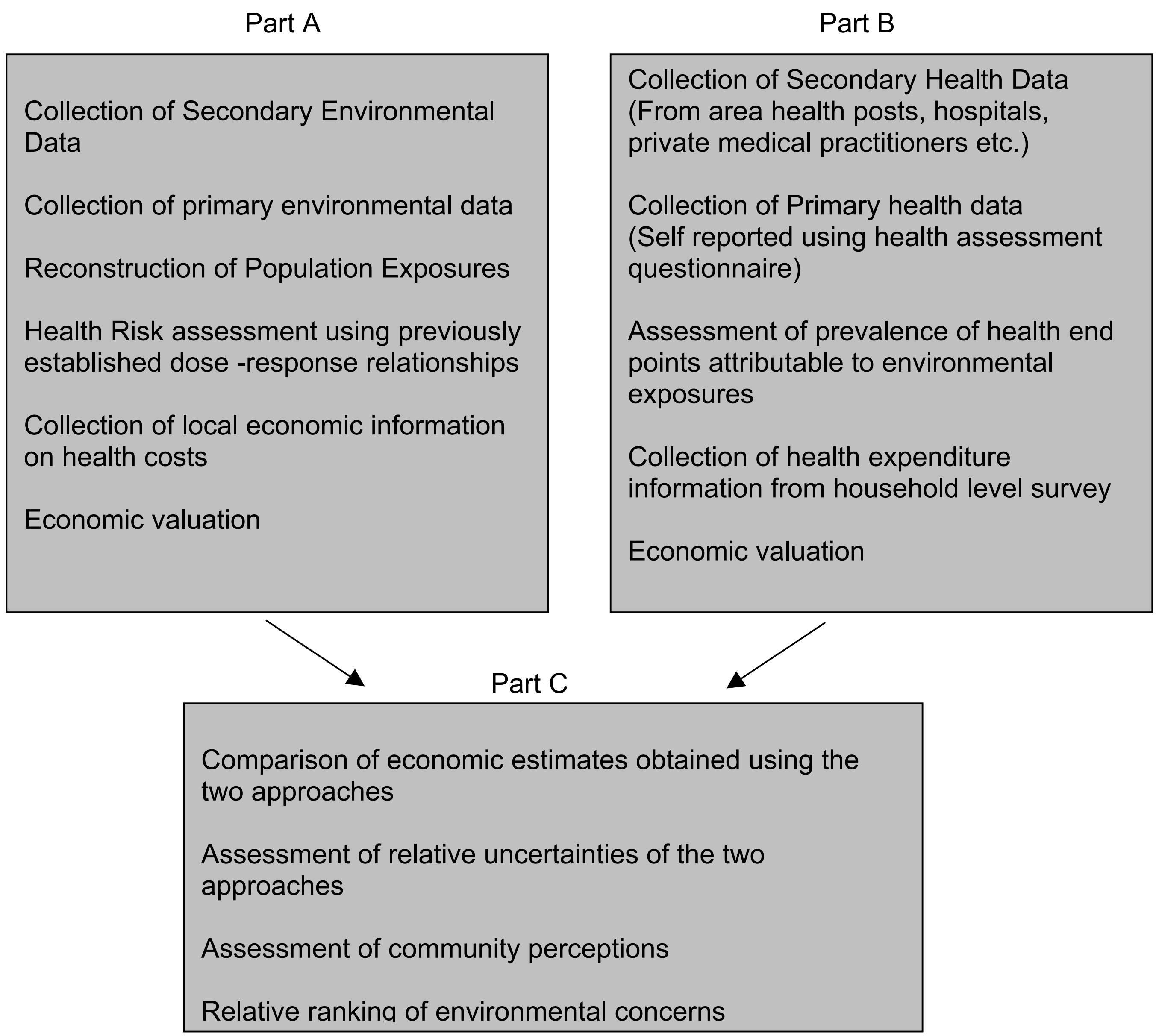
- To provide the framework for the design of an environmental management plan for the zone

- To strengthen institutional capacity for CRA analyses through administration of training

METHODOLOGY

Overall framework of data collection

The population of the study zone is distributed across 48 municipal wards. The municipality, for the provision of public health services has established five health posts. Since an essential focus of the present project has been to demonstrate linkages between health and environment and much of the secondary health data was available at the health post level, the entire framework of data collection was centered around the health posts. Socioeconomic, environmental and health data collected was organised under the areas covered by each of the five health posts. Since the wards covered by each health post differed somewhat in environmental quality this allowed cross comparisons to be made within the municipality. The sequence of data collection proceeded along paths outlined as part A and B simultaneously and were merged in Part C to make the final rankings.


Part A
Collection of Secondary Environmental Data
Collection of primary environmental data
Reconstruction of Population Exposures
Health Risk assessment using previously established dose -response relationships
Collection of local economic information on health costs
Economic valuation
Part B
Collection of Secondary Health Data (From area health posts, hospitals, private medical practitioners etc.)
Collection of Primary health data (Self reported using health assessment questionnaire)
Assessment of prevalence of health end points attributable to environmental exposures
Collection of health expenditure information from household level survey
Economic valuation
Part C
Comparison of economic estimates obtained using the two approaches
Assessment of relative uncertainties of the two approaches
Assessment of community perceptions
Relative ranking of environmental concerns

Part A

Collection of Secondary Environmental Data

For assessment of environmental exposures, all secondary data sources were covered first prior to assessing the need for primary data collection.

Secondary data sources for air quality included the National Ambient Air Quality (NAAQ) data available with the Tamil Nadu Pollution Control Board and the National Environmental Engineering Institute, Chennai and environmental impact assessment (EIA) reports conducted for the industries situated within the municipality over the preceding 5 to 7 years. NAAQ data provided information on annual and monthly average concentrations for suspended particulate matter, respirable particulate matter, sulphur-dioxide and nitrogen dioxide. Occasionally information on lead concentrations was available. EIA reports usually gave 24-hour averages of the above pollutants. In addition data such as hydrocarbon levels, lead levels and carbon monoxide levels were also available from few reports. Ozone, volatile organics and indoor air pollutant data was not available in any of the secondary sources.

Secondary data sources for water quality included the data from the groundwater cell of Chennai Metropolitan Water and Sewage Board (CMWSSB) and EIA reports of area industries. The groundwater cell data contained information on physico-chemical and bacteriological parameters while EIA reports provided additional information on heavy metal concentrations as well.

Information on solid waste collection and disposal was collected from the municipality office. Access to sanitation was assessed both on the basis of information provided by the municipality in terms of wards connected through municipal sewer lines as well as on the basis of information provided by the household level survey.

Collection of primary environmental data

Air

A preliminary analysis of secondary data was carried out which identified the areas where available information was inadequate to estimate population exposures. Secondary air data from the NAAQM and EIA reports revealed that concentrations of SO2 and NOX were consistently below the prescribed National standards (National Air Quality standards shown in Annexe 1). However, data on PM 10 concentrations showed the area annual average reported by the NAAQM stations may not be truly reflective of average population exposures. Several EIA reports showed PM 10 concentration to be significantly in excess of the prescribed 24- hour standards. Although annual averages were not computed in EIA reports, the figures pointed out to the possibility of underestimating population PM 10 exposures using a single area average value that was reported in the NAAQ database. Additional primary sampling was carried out for PM 10 to improve the secondary data estimates.

Primary sampling was carried out mostly through personal sampling (Reference Procedure described in Annexe 1) using battery operated pumps that draw air through impactors or cyclones designed to capture particles less than or equal to 10μm in diameter. A few area samples using high volume samplers were also taken. Personal samplers were attached to select groups that are likely to receive excessive exposures. These included traffic policeman, slum dwellers, commuters who spent more than 8 hours on the roads and women cooks using bio-mass fuels for cooking. The population exposures was reconstructed by taking the base exposure from the annual averages reported in the NAAQ data and adjusting exposures of the high risk groups listed above, upward on the basis of personal sampling data.

Similarly primary sampling was conducted through real time, direct read out data-logging electrochemical sensors for carbon monoxide, sulfur - dioxide and nitrogen -dioxide. These were done mostly in homes that used bio -mass fuels for cooking. They were also used in traffic junctions to assess if the exposures exceeded the prescribed short -term guidelines.

Monitoring for indoor air pollutants associated with combustion of bio-mass fuels in homes using them for cooking was carried out as described above using personal samplers for assessment of PM-10 exposures and direct read out instruments for gas exposures. Personal samplers were attached to cooks or were placed near the cooking spots both while cooking was going on and at other times. 24-hour personal exposures for PM 10 were reconstructed on the basis of the area and personal measurements using the time- activity information gathered from the members of the household. A schematic for measurement locations and times is shown in Annexe 1. Gas measurements were taken only while cooking was going on as at other times the concentrations were below the threshold of detection. Indoor air quality monitoring was conducted in a total of 86 households spread across the five

A limited set of measurements was carried out for volatile organics at traffic junctions using a portable IR Analyser (MIRAN Sapphire supplied by Foxboro).

Water

Water samples were taken from drinking water sources (tap/ well/tanker) in all 48 wards of municipality. The measurements were repeated twice during the study period. The samples were analysed for physico-chemical parameters, bacteriological quality and heavy metals as per procedures laid out in CPEEHO Manual (Cited in References section). Results are shown as average of the two sets of measurements. Locations for sampling are shown in the result section along with the results of analyses.

Collection of blood lead samples

Since lead was identified as one of the key environmental concerns and data on air concentrations as well as water concentrations were limited, it was decided to ascertain population exposures directly by analysing for blood lead levels. Detailed procedures are listed in Annexe 1. Briefly, venous blood was collected in heparinised lead free tubes and analysed using atomic emission spectroscopy (Inductively coupled). Analysis was carried out at the Regional Sophisticated Instrumentation Centre of IIT Chennai. A total of 143 samples were collected (56 children and 87 adults). Since the procedure involved collection of venous blood, samples were collected only from people in the municipality checking into area hospitals for other routine clinical chemistry investigations. Informed consent was obtained prior to collection. However, since complete addresses were not available it was not possible to assess if the population was randomly distributed across the municipality or if they were drawn from particular sections that may have had high end exposures (e.g traffic policemen, people living in the vicinity of contaminated soils etc.). Since no other baseline information was available, these levels are taken as the best possible estimates of population exposure.

Methodology for health risk assessment and economic valuation using previously established dose- response relationships

Environmental pollutants from the generators reach the humans after transportation and transformation through environmental media. Since direct measurements of health effects from environmental causes are rarely available, the process of risk assessment quantifies health effects based on established dose –response relationships (i.e. relationship between a dose of pollutant received and the expected magnitude of heath damage). The dose or human exposure is quantified on the basis of either extrapolating from environmental concentrations or through direct measurements in human body fluids. The USEPA that first developed this procedure for risk assessment, has compiled the health risk information on most of the major environmental contaminants in the form of an electronic database termed IRIS (Integrated Risk Information System). Data from IRIS was used in conjunction with recent epidemiological studies that have shown significant correlation between exposures and health effects. Specific dose response functions used for the various categories of pollutants are shown below.

PM10

Health impacts from PM 10 exposure are divided into mortality (excess deaths) and morbidity (excess illness). These estimates are derived from a series of time series studies that have looked at changes in mortality and morbidity over time as the PM levels change or on the basis of cross sectional studies that compare effects across different cities that differ in PM levels. While most of these dose response relationships have been derived from studies in the developed countries, Ostro et. al. (Ostro, 1994) have compiled dose -response information with specific reference to developing countries. Empirical associations have been verified in studies carried out in Jakarta and Metro Manila that have PM 10 exposures similar to what is observed in this study. The dose- response function used for health risk calculations are based on those published in the above reference and listed below.

Dose - response functions for PM 10 (based on Ostro, 1992 and URBAIR 1997)

The health impacts are defined on a per unit change of PM 10 concentration

(expressed as μg/m3) . For this study the PM 10 benchmark is taken as 41 μg/m3 based on the WHO air quality guidelines (1986). Although the latest guidelines (WHO, 2000) show no threshold for health effects for PM 10 exposures, the risks in this study are calculated based on the previous guideline. The risks may be therefore interpreted as what may be avoided by bringing the PM 10 exposure levels to the guideline value of 41 ug/m3 and not as all risks associated with the current PM 10 exposures.

Following are the dose- response functions used in the study

1. % change in mortality =0.00112*(PM10-41)*Population exposed* Crude mortality rate

    PM 10 = annual average concentration of PM 10 expressed in μg/m3

    Crude mortality rate used in study = .0076

    Exposed population = Fraction of population exposed to particular concentrations

    (derived from population exposure profile that was reconstructed on the basis of primary and secondary environmental data)

2. Respiratory Hospital Diseases (RHD) per year per 100, 000 persons

= 1.2*(PM10-41)*Exposed Population

3. No: of emergency room visits (ERV) per year per 100, 000 persons

=23.54*(PM10-41)*Exposed Population

4. Restricted Activity days (RAD) per person per year

=0.0575*(PM10-41)*Exposed Population

5. Respiratory symptom days (RSD) per person per year

=0.183*(PM10-41)*Exposed Population

6. Change in yearly cases of chronic bronchitis per 100000 persons

= 6.12*(PM10-41)*Exposed Population

7. Chronic bronchitis in children below 18 years

=0.00169*0.4*(PM10-41)*Population

A population restriction factor of 0.4 is applied, as approximately 40% of the study population is under 18 years old.

8. Change in daily asthma attacks per asthmatic person

=0.0326*0.07*(PM10-41)*Population

A population restriction factor of 0.07 is applied as approximately 7% of the population are estimated to be asthmatic.

Valuation of Health Impacts for PM 10

The valuation of the health impacts determined above was done, using local economic information that was obtained from the household level survey. The local economic information collected included average annual income, average daily wages, cost of doctor's visits, cost of medication, costs of hospital admissions etc. Using this information the following unit costs were computed for each of the following health end points. The unit costs for each health end point used computed in the study on the basis of these local costs is listed below.

Unit costs of health impacts for PM 10

1. Change in Mortality (Premature deaths)

   Premature deaths were valued using the value of a statistical life (VSL) which is estimated as discounted value of expected future income at the average age. If the average age of population is 24 years and the life expectancy at birth is 62 years, the VSL formula

$$VSL = \sum_{t=0}^{t=38} w/(1+d)^t$$

where w = annual average income = Rs.22,044.

d = discount rate= 5%

Using the formula VSL for the study zone was estimated at Rs.393,880.

2. Respiratory hospital diseases

   The valuation was based on an average of 9.1 days of hospital stay for each admission resulting in a wage loss of Rs.88.3/day and a cost of Rs.100/day for hospital charges and medication.

The unit cost of respiratory health diseases was estimated to be Rs. 1713.

3. Emergency room visits

   The valuation was based on one wage loss day at Rs.88.3/day, cost of medication at Rs.100/- per visit and cost of transportation at Rs.40 per visit.

The unit cost of respiratory health diseases was estimated to be Rs. 228.

4. Restricted Activity days

   The valuation was based on Ostro's (1992) calculation of 20 % work-loss (valued at average daily wage) and 80% lower productivity (valued at one third of average daily wage).

The unit cost of restricted activity days estimated to be Rs. 41.

5. Respiratory symptom days

The valuation was based on average value reported in the Mumbai URBAIR study as no information on willingness to pay to prevent a respiratory symptom day is available.

The unit cost of restricted activity days is estimated to be Rs. 20.

6. Change in yearly cases of chronic bronchitis

The average age at which people become chronically ill with bronchitis is 35 years. Average life expectancy at birth is 62 years. It has been estimated that this results in 50 days of wage loss/year. Also, it results in hospital visits at .5 times in a year for an average of 13.1 days /visit. Finally medication costs are also involved every year. Based on an average daily wage of Rs 88, a cost of hospitalisation of Rs.1300 per admission and a cost of Rs.1000 per year for medication and applying a discount of 5%, the total cost for an average of 27 years works out to be Rs. 105,043.

The unit cost of a case of chronic bronchitis is estimated to be Rs. 105,043.

7. Chronic bronchitis in children below 18 years

The duration of bronchitis averages 13.2 days, and is valued at respiratory symptoms day (Rs.20). In addition two days of a parent's restricted activity day valued at Rs41 per day was used.

The unit cost of respiratory health diseases was estimated to be Rs. 346.

8. Asthma attacks per asthmatic person

The valuation was based on information collected specifically from the household level survey on expenditure incurred on medication / wage loss by asthmatics.

The unit cost of an asthma attack was estimated to be Rs. 200/ attack.

Other air pollutants

Health risk calculations were not performed for other air pollutants including gases as the levels were below the prescribed standards for annual averages. Although short-term exposure limits were violated, dose - response information specific for short-term exposures is not currently available.

Blood lead

Changes in health risks to men, women and children with an increase in blood lead levels were computed using various dose-response functions. The Centers of Disease Control (CDC, 1991) has estimated that an increase in maternal blood lead levels by 1 μg/dL during pregnancy will result in an increased risk of infant mortality of 10^{-4}. Schwartz (1993) has estimated that for an increase of 1 μg/dL blood lead levels in children, a decrease of 0.25 IQ points can be expected.

Elevated blood lead levels have been linked to elevated blood pressure in adults (Schwartz, 1992). A meta-analysis of several studies estimated that a 1.4 mm Hg increase in blood pressure can be expected for a 1 μg/dL increase in blood lead, in adult males. In women the effect of an increase in blood lead levels is similar to that on men; with diastolic blood pressure increasing by 0.8 mm of Hg with a 1 μg/dL increase in blood lead level. The final dose response functions are as follows.

Increase in infant mortality: 10^{-4} /ug/dL decrease in blood lead level

Change in blood pressure (Men) =1.44(PbB_1 - Pb B_2)_

where B_1 = current blood lead level

B_2 = blood level desired

Change in blood pressure in women = .6*1.44(PbB_1 - Pb B_2)_

The desired blood lead level was taken as 10μg/ dL the action level set by the USEPA. The change in blood pressure was converted to increase in cardiovascular accidents such as heart attacks and strokes using the age specific dose -response functions described in McGee and Gordon(1976), Shurtleff(1974) and USEPA (1987).

Water Contaminants

Microbial contaminants in water and sanitation related issues were not examined using the dose- response framework. Instead their contribution to health impacts was assessed from the cross-sectional health and economic information gathered through the household survey and the health information available at the local health care facilities. Since chemical contaminants levels were less than prescribed standards

(albeit established on the basis of scanty environmental monitoring data), risk assessment was not performed for chemicals in water.

Part B

Collection of secondary health data

Initial survey of hospitals and health posts revealed that record keeping in these facilities was extremely poor and therefore could not be used for estimating prevalence of health endpoints attributable to environmental exposures. The Infectious diseases hospital at Tondiarpet had available records of inpatient data. The hospital was the main referral hospital for acute diarrheal diseases and other viral diseases including chicken pox, measles and mumps. However, outpatient data was not available. Other area hospitals including Stanley Medical Hospital, the Govt. peripheral hospital and the clinics attached to the health posts had no records of outpatient visits. Some basic health statistics were available at the Municipality office. The available health records therefore were not used in estimating prevalence of various health end points but only to qualitatively assess the relative degree of prevalence.

Collection of primary health data and economic valuation

Because of the inadequacy of the secondary health data, primary health information was collected through the administration of a health assessment questionnaire at the household level. The health assessment questionnaire focused only on recording respiratory symptoms, gastrointestinal disease symptoms and vector borne illness. For vector borne illness only physician- diagnosed illness was recorded.

A total of 759 households were covered through questionnaires. A total of 3024 individual people were administered the questionnaire. The complete questionnaire is furnished in Annexe 1. The questionnaire recorded general socio-economic information and self reported symptoms based on a two- week recall. The questionnaire for respiratory ailments was patterned after the questionnaires set by the British Medical Research Council and the American Thoracic Society. The questionnaire also included information on gastrointestinal illness episodes and vector/sanitation related disease episodes. Information on disease specific health expenditures was also recorded including wage loss days for particular classes of ailments.

Also, the study team recorded visits to the area hospitals/health post clinics/ private practitioners either by deploying project staff to record the physician diagnosis or have the concerned physician fill out a form that recorded their diagnosis. This was done to find out the degree of reconciliation between hospital/ doctors office recorded illness episodes and what was assessed through the primary household level survey. Although prevalence of illness in the community is usually much higher than what is recorded by area health care facilities, collection of this data allowed an assessment of population patterns in seeking healthcare.

Total environmental health costs for the municipality was estimated on the basis of the prevalence of particular health end points, the costs of treatment, costs of wage loss days and defensive expenditure. Costs of treatment included costs of doctor visits, costs of medication and costs of hospitalisation. Defensive expenditure included items such as boiling water, purchasing water filters and purchasing mosquito control devices.

RESULTS

DESCRIPTION OF STUDY AREA

The town of Thiruvottiyur is located adjacent to the Chennai Metropolitan area, sandwiched between Bay of Bengal on the eastern side and the Buckingham canal on the western side. A single railroad divides the town into two parts. Most of the industrial and residential developments have taken place on the eastern side of the railway line. The jurisdiction of the municipality extends over 21.42 sq. km. The economic base is one of mixed nature with both organized industrial activities and numerous unorganized small-scale operations. The population of Thiruvottiyur is estimated to be 2.11 lakhs as per the 1999 census data.

Socioeconomic Profile

The population is distributed across 48 municipal wards. The municipality, for the provision of public health services has established five health posts. Since an essential focus of the present project has been to demonstrate linkages between health and environment and much of the secondary health data was available at the health post level, the entire framework of data collection has centered around the health posts. Basic socio-economic information describing the municipality is furnished in the following tables.

Table 1: Historical Decadal Growth Rate of Population in Thiruvottiyur

Year	Population	Decadal Growth Rate
1901	15,919	-
1911	9409	-40.9
1921	8100	-13.9
1931	10732	32.5
1941	13909	29.6
1951	22393	61.0
1961	37764	68.6
1971	82853	119.4
1981	134014	61.7
1991	168642	25.8

Source: Census of India, Tamil Nadu, 1971 & 1991

Table 2: Annual Population Growth in Thiruvottiyur

YEAR	POPULATION	ANNUAL GROWTH RATE	NET ANNUAL ADDITION
1991	168139	-	-
1992	171202	1.82	3063
1993	174193	1.75	2991
1994	181525	4.21	7332
1995	186703	2.85	5178
1996	191275	2.45	4572
1997	195364	2.14	4089

1998	205019	4.94	9655
1999	211100	2.97	6081

Source: Mid Year Population, Thiruvottiyur Municipality, Thiruvottiyur, 1999.

Table 3: Population Distribution By Health Posts In Thiruvottiyur (1999)

S. No.	Name of the Health Post	Population	Distribution (%)
1	Ernavoor	46095	21.8
2	Sathangadu	43497	20.6
3	Thiruvottiyur	53238	25.3
4	Thiruvottiyur Kuppam	27465	13.0
5	Thangal	40805	19.3
	Total	211100	100

Source: Mid Year Population, Thiruvottiyur Municipalilty, Thiruvottiyur, 1999.

Table 4: Literacy Rate in Thiruvottiyur

Sex	1971	1981	1991
Male	65.0	72.2	75.9
Female	43.2	54.8	61.4

Source: Census of India, Tamil Nadu, 1971, 1981 & 1991.

Table 5: Sex Ratio in Thiruvottiyur

Year	No. of Females per 1000 Males
1961	938
1971	865
1981	916
1991	927

Source: Census of India, Tamil Nadu.

Table 6: Birth and Death Rate in Thiruvottiyur

	1997	1998
Birth Rate	8.9	7.9
Death Rate	3.2	2.9

Source: Municipal Health Office, Thiruvottiyur Municipality, Thiruvottiyur, 1999.

Table 7: Occupational Structure in Thiruvottiyur (in %)

Type of Occupation	1971		1981		1991	
	Male	Female	Male	Female	Male	Female
Main Workers	33.9	2.9	32.8	4.1	31.4	5.3
Cultivators, Agrl. Labourers & Allied Activities	2.3	.10	.12	-	1.6	.1
Household Industry and Other Industrial Workers	17.3	.4	.38	.31	12.7	1.4
Construction	1.3	.18	32.3	3.7	2.2	.4
Trade, Commerce, Transport & Communication	8.1	.9	.2	.1	8.1	1.1
Others	4.9	1.42	-	-	6.7	3.0
Non-Workers	32.2	94.1	34.2	91.8	37.3	88.7

Source: Census of India, Tamil Nadu, 1971, 1981 & 1991.

Environment Profile

Water Supply

Presently, this municipality gets water from an integrated scheme of MMWSSB, Bore-wells and open wells. About 82% of the total population is covered by all the water supply schemes. However, only 24% of the population is covered by protected water supply. The per capita supply is only 15 lpcd. The integrated scheme is operated by MMWSSB and the other schemes are operated and maintained by Thiruvottiyur municipality.

Sanitation

The municipality has an underground sewage system for one-third of the area. However, well water is used for flushing by most houses with individual toilet facilities. Sanitary waste-water is discharged to the septic tanks for most parts. In terms of percentage of population covered through various means of sullage disposal, while cesspools cover 45%, earthen drains cover 39%, and the combined underground drainage system covers 15-30% of the households. All sullage and night soil is disposed in the nearby low-lying areas without any treatment. The operation and maintenance of this service in the town is therefore very poor.

Solid Waste Disposal

About 150 metric tonnes of solid wastes are generated per day in the municipality from the individual households, industrial and commercial centers of which only about 80-90 tonnes are removed daily. These wastes are mainly collected and removed by sweeping. While the frequency of sweeping at major roads, bus stand, railway station, temple street etc is high, most other areas are swept on alternate days, some even once in three days. The municipality employs 155 Male workers and 164 Female workers for the conservancy work. Of these, 261 are permanent workers. A small fleet of vehicles has been deployed by the municipality for transportation of the wastes to the dump-yards, but a poor road infrastructure prevents access to collection for a majority of houses.

About 12 acres of open vacant land at Manali near the railway track has been sanctioned for solid waste dumping and composting. While municipal solid waste is dumped here everyday no efforts have been taken to segregate waste categories and initiate the composting facility.

Roads

The municipality being located very close to the Manali industrial area and the Chennai port the volume of traffic is very high along the main arteries. The municipality has a road density of 2.96 km/sq. km and surface road length of 47%. Ennore Express Way and Thiruvottiyur High Road record the maximum volume with 17,409 pcu/day and 35934 pcu/day respectively. Kamaraj Salai also takes 10,221 pcu/day because of access restrictions at the port for containers transporting hazardous materials. Establishment of container freight stations and warehouses in the adjacent municipalities of Ennore and Manali, has resulted in a high percentage of vehicles plying on the road to take multiple trips. Sea erosion has lead to the shrinking of the right of way on Ennore Expressway for a length of about 2 Kms. Pedestrians, parking, high levels of commercial activity and accelerated degradation due to continuous exposure to the marine environment have resulted in the residents facing severe and frequent congestion on the roads.

Industries

The industrial make up includes a mixture of fertilizer, pharmaceutical, heavy chemicals, automotive manufacturing, heavy engineering industries. Further, municipality is located adjacent to the largest electric thermal power plant in Ennore industrial complex. Some of the keys environmental issues associated with these industries are as follows;

- Industrial plants produce gaseous emissions, released in different ways treated or untreated to the atmosphere. Fugitive emission of particulates from sources such as fertilizer plants are common. Incineration and flaring operations also release SO_x, NO_x, Chlorinated organics, Hydrocarbons through the stacks. Fly ash generation from the Ennore power plant is substantial.

- Industrial discharges also are a major source of ground and surface water pollution. A large number of industrial plants generate significant quantities of hazardous wastes in the form of sludges that are highly toxic (e.g., mercury bearing sludges from chloralkali operations, acid sludges from petrochemicals, lime sludges etc.). These sludges together with chemical by-products, off specification chemicals and discarded chemical containers accumulate in large quantities on industrial sites. Their storage is not done in a manner so as to prevent entry into surface or ground water.

- Discharges of fly ash slurry into the sea are carried out routinely and the resultant damage to the marine ecology remains to be quantified.

- Storage of large piles of fluoride containing gypsum wastes has resulted in elevated fluoride levels in ground water near plants where such wastes are stored.

- Intrusion of sea - water into subsurface water as a result of excessive withdrawal of ground water is prevalent over the entire municipality.

- More than 50 red category industries are located in and around the municipality. Despite the requirement for performing environmental impact assessments, no single database was available with detailed air and water quality information that would allow an assessment of temporal and spatial variations in pollution loads for the municipality.

The basic socioeconomic and environmental profile information described above is shown in the following set of maps.

Analyses of environmental data

Air

PM 10

As described in the methodology section, air quality information was collected from secondary sources as well as through primary sampling. Secondary sources included the NAQM programme administered by the CPCB and TNPCB and EIA reports of area industries done over a period of last 5 years. Since most secondary data sources show data fro Suspended Particulate matter, they were converted to PM10 concentrations by taking PM 10 to be 55% of SPM concentrations. Examples of data obtained from the secondary sources are shown in graphs A1- A10. The results from the EIA reports show that averages are higher than what is reported in the NAAQ database. Therefore primary sampling was carried out for PM10 through a combination of personal sampling and area sampling techniques. The locations of primary sampling was decided on the basis of information collected on traffic density, proximity to roads, proximity to dump yards where refuse is burnt etc. In addition the contribution of biomass combustion to PM 10 exposures was also addressed in the study by sampling households where these fuels were being used for cooking. The primary and secondary environmental monitoring data was compiled for each of the five health posts and used in conjunction with relevant exposure information (e.g. whether using bio-fuels, living adjacent to roads etc.) to generate the population exposure profile.

The results of primary sampling reveal that a significant fraction of the population is exposed to pollutant levels not adequately reflected in the area average reported by the NAQM database. Populations that use bio-mass fuels in homes for cooking or live in slums adjacent to high traffic corridors, commuters, traffic police all represent categories that are exposed to concentrations well in excess of the standards. The environmental data analyses revealed that levels of PM10 are the single biggest concern and that biomass combustion is a significant source of PM 10 exposure to residents of homes using these fuels.

Reconstruction of population exposure profiles on the basis both primary and secondary environmental shows that nearly 95% of the study population is exposed to concentrations in excess of the World Health Organisation (WHO) guideline values for PM10.

Key environmental air quality data and locations for air quality monitoring are shown in the next set of figures.

The population exposure profiles were used to estimate health risks based on the fraction of people at each exposure level and the dose –response relationships described in the methodology section.

Lead

Annual averages of lead in air were available only for some years in the NAAQ database and in a few EIA reports. All results indicated these levels to be below the prescribed standards. However, blood lead levels were higher than the action level of the 10 μg/dL prescribed by the USEPA. Since the relative contribution from air borne lead could not be ascertained, risks from elevated blood lead levels were separately calculated. Risks from air lead were not separately calculated.

Other air pollutants

Although the annual 24hour averages of CO, SO2 and NOX were below the standards, the short-term exposure limits was exceeded significantly during bio-mass burning while cooking or open refuse burning. The limits were also exceeded during sporadic releases by the industry.

The levels of ozone and volatile organics were determined in areas with potential for high exposures such as traffic junctions, through a combination of limited personal sampling and area measurements. The 24-hour averages were below the standards. However the measurements were too limited to make any deductions about annual averages.

Based on the above results, health risk calculations were done only for PM 10 and for lead. Although the short-term exposure limits were exceeded for other pollutants, the consequent health risks could not be quantified due to the uncertainty in the dose - reponse relationship data for such exposures.

Water

Data on physico-chemical and microbiological water parameters were collected predominantly from the Ground water Cell of CMWSSB. EIA reports of area industries were additional sources of information. Some primary data was also collected, by sampling drinking water in select households. Secondary data collected over a period of last five years revealed that microbiological contamination with faecal coliforms was the most significant concern within the municipality. The data showed presence of faecal coliformsin the range of 2- 2000 in all sampling locations spread across the municipality and over multiple time frames.

Data on heavy metals including lead, chromium, arsenic, copper, iron and zinc showed that levels were predominantly below the prescribed standards. Fluoride levels were however significantly in excess in the adjacent Ennore municipality where large amounts of fluoride containing gypsum waste were found stored. Limited data on pesticides showed no significant contamination of drinking water sources.

Since the available data did not show significant presence for any of the major chemical contaminants, health risk calculations for water contaminants were limited to the assessment of prevalence of gastro-intestinal conditions in the population.

Solid waste & Access to Sanitation

Qualitative information on solid waste was collected both from municipal sources and from household level surveys. Nearly 35% of the population did not have access to a private toilet and made use of open grounds or public toilets. In slum populations nearly 80% did not have access to private toilets. Around 55% of the population reported being severely affected by rain- water stagnation.30% lived in houses that were less than 100m meters from solid waste dumps.The municipality was operating three of the solid waste dumps. Most of the dumps were also found to contain large quantities of chemical and other hazardous wastes. The access to these dumpsites was unrestricted. Rag pickers included many children from the neighbouring slums. Improper solid waste disposal and lack of access to private sanitation was cited as the most important environmental health concern in community perception surveys.

Quantitative health risk assessments were not performed for solid waste concerns, as quantitative exposure information was not available. Prevalence of vector borne and water borne infectious disease were collected from area hospitals as well as from study households.

HEALTH RISK ASSESSMENT AND ECONOMIC VALUATION OF HEALTH DAMAGE

Health risk assessments using previously established dose response functions

Health risk assessments were done using both previously established dose response information and prevalence information for respiratory, gastro-intestinal and vector borne problems gathered through the administration of a health assessment questionnaire.

Economic information collected included wage information; costs of medical treatment (medicines/ consultation/ hospitalisation costs) for private and Municipal health care facilities; average number of work loss days for specific ailments and associated wage loss.

Economic valuation was done using this information and applying it to either the calculated health risks or the prevalence information gathered through the primary health survey.

Other studies have used the dose –response relationships to estimate economic costs. As seen form the following tables, the costs tend to be higher when used with detailed exposure information as opposed to using zonal averages provided by the NAAQ database. This indicates that the available information may under represent both population pollutant loads and consequently the associated health and economic costs. The cost estimates for particular pollution loads are comparable between the present study and the URBAIR study in Mumbai.

PM-10

Use of previously published dose - response information with the local economic information gave the following results (Based on population exposure profiles)

Health End point	Impact on study Population*	Unit costs (Rs)	Total costs (in lakhs of rupees)
Pre mature deaths	202	393,879	797
Respiratory hospital admissions	285	1713	4
ERV (emergency room visits)	5598	228	12
RAD/1000(Restricted activity days)	1367	41	563
RSD/1000(respiratory symptom days)	4352	20	870
COPD	1455	69,997	1529

Chronic bronchitis in Children	16,078	346	55
Asthma	54275	200	108

* Study population- 211,000

Total : Rs. 3432 Lakhs

Comparison of economic estimates for health damage resulting from PM 10 exposures with other studies using same dose response information

Study zone (Using only NAAQ Data)	Rs.865/person
Study zone (Using both NAAQ and primary sampling data; includes population exposure profiles)	Rs.1626/person
Chennai Average (World Bank estimates using NAAQ data)	Rs275/person
Bombay Average (World Bank estimates using NAAQ data)	Rs.734/person
Bombay (URBAIR, World Bank estimates using modelling+ monitoring data; includes population exposure profiles)	Rs.1840/person

Lead

Similar to PM 10, previously published quantitative dose-response information is available for calculation of health risks from lead. Since lead enters the human system through several routes, including air water and soil, blood lead is usually considered the best surrogate for total exposure. Further, in the study zone, average lead levels in air and water were below the national standards and therefore could not be used for calculation of health risks. Blood lead measurements carried out on 150 adults and 243 children of the study zone showed them to be in excess of the action level prescribed by the USEPA. The health risks were therefore calculated on the basis of blood lead levels.

Risks from lead on study population

Loss of IQ points	2 points/child
Reduction in infant mortality	4.5deaths/year
Reduction in Blood pressure ***Men*** ***Women***	 2.6 - 3.2 mm Hg 1.6 - 1.8 mm Hg
Cardiovascular illness Heart attacks Strokes Premature deaths	 114 /year 14/year 110/year

The dose response relationships used to derive these risks are based on studies carried out in the United States and with very little inputs from developing countries where exposures tend to be much larger. The economic valuation for health risks from lead are also therefore significantly more uncertain than those derived for PM 10.

Nevertheless, estimations have been done based using developed country figures and using percapita income ratios to adjust the costs. Assuming an income loss of $1248/child for an IQ loss of nearly 2 points/child, and using a percapita GNP ratio of .0133 between the US and India applied across 50,000 children in the study zone, the net cost of children's IQ loss is estimated at Rs. 373 lakhs. Further, using a statistical value of Rs. 393,879 for the study zone population the net cost of premature mortality is valued at Rs.433.26 lakhs. The costs of cardiovascular morbidity could not be estimated.

The total costs for lead exposures are estimated at not less than Rs. 806 Lakhs.

Health Impact assessment using data from primary health survey

Since the available secondary data on disease prevalence at area hospitals was scant, much of the cross-sectional epidemiological information was collected through the house- hold survey that included a health assessment questionnaire. Accordingly ward wise prevalence of respiratory, gastro-intestinal and vector borne illness was assessed. Limited information was also gathered from the municipal health posts, The Govt. Infectious Disease hospital, Govt. Peripheral hospital and Stanley hospital.

Comparison of risks between air/water/solid waste amongst the five health posts as determined by primary health survey

	Respiratory	Gastrointestinal	Vector-borne
	(%prevalence of symptoms)		
Thangal	*11.4*	*16.06*	*8.31*
Ernavoor	*12.7*	*16.59*	*7.46*
Sathangadu	*8.6*	*9.49*	*5.47*
Kuppam	*19.8*	*19.07*	*5.00*
Thiruvottiyur	*14.2*	*14.6*	*7.8*

The household information also collected specific information regarding costs of treatment, work days lost, lost wages, costs of hospitalisation etc. A significant fraction of the population made use of the government run municipal health posts and the peripheral hospital. Therefore the percapita health costs for each category was computed by taking onto account the direct expenditures for treatment/ hospitalisation, the cost of work days lost and the costs borne by the municipality. Since the costs tended to differ across the health posts, these percapita costs were applied to the population of each health post to compute total costs for the municipality. For gastro-intestinal and vector-borne disease there was a component of defensive expenditure, incurred in terms of boiling water, purchase of water filters and purchase of mosquito nets/ mats. There was however no significant expenditures reported by the study population for air pollution.

Annual environmental health costs as estimated from primary health survey

Health Post	Annual Per capita Health Expenditure (Rs.) for treatment	Total Annual Income loss (WLD) (Rs.)	Per capita costs borne by the Municipality (Rs.)	Total percapita costs (Rs.)	Population of health post	Total costs for each health post (Rs.)
Respiratory Problems						
Thangal	441	194.10	6.17	641.75	45,000	28878709
Ernavoor	365	555.89	6.17	927.70	50000	46385040
Sathangadu	122	442.39	6.17	571.44	50,000	28571950
Kuppam	467	706.86	6.17	1180.19	39,000	46027410
Thiruvottiyur	266	295.02	6.17	567.71	27,100	15384951
					Direct Health Costs	**Rs.1652lakhs**
Gastrointestinal problems						
Thangal	482	459.84	12.17	954.65	45,000	42959128
Ernavoor	1138	835.30	12.17	1986.03	50000	99301540
Sathangadu	318	492.58	12.17	823.35	50,000	41167450
Kuppam	122	376.30	12.17	510.51	39,000	19909851
Thiruvottiyur	546	345.34	12.17	903.99	27,100	24498110
					211,100	227836079
					Direct Health costs	**Rs. 2278 lakhs**
					Defensive expenditure	**Rs. 85 lakhs**
					Total Costs	**Rs.2363 lakhs**
Vector borne diseases						
Thangal	120	183.69	54.6	358.29	45,000	16123050
Ernavoor	174.6	835.30	54.6	1064.50	50000	53225040
Sathangadu	30.72	301.14	54.6	386.46	50,000	19323000
Kuppam	122.04	856.55	54.6	1033.19	39,000	40294332
Thiruvottiyur	100.08	345.34	54.6	500.02	27,100	13550523
					Direct health costs	**Rs. 1425 lakhs**
					Defensive expenditure	**Rs. 243 lakhs**
					Total Costs	**Rs.1668 lakhs**

The total impact of all health costs for air, water and solid waste concerns amounts to a total of Rs.5683/- lakhs with air concerns contributing to Rs. 1652/- lakhs, water concerns contributing to Rs. 2278/- lakhs and solid waste concerns contributing to Rs. 1668/- lakhs. These total costs do not include costs of premature mortality. The total health care cost translates to roughly Rs. 2693/- per person/year for the study zone.

For the case of PM 10 wherein there exists scope for comparison between predicted damage (on the basis of previously established dose-response functions) and observed damage (on the basis of cross-sectional epidemiological data), there is a fair degree of reconciliation between the estimates. If the cost of premature mortality are added to the cost of air concerns obtained above the total cost of observed damage it amounts to Rs.2446 lakhs as opposed to a figure of Rs.3942 lakhs for predicted damage.

Ranking of Environmental Concerns

Based on the health risk estimates, the economic costs and community perceptions and a careful assessment of uncertainties, the study proposes the following ranking for the list of environmental concerns taken up in the study zone.

High risks	Microbial contamination of water
	PM 10
	Sanitation and solid waste disposal
Medium risks	Lead
	Indoor air pollutants from bio-mass Combustion
Low risks	NO2
	Volatile organics
Uncertain risks	CO

	SO2
	Chemical contaminants in drinking water
	Hazardous wastes

Conclusions

In the study zone it has been clearly established that the overall environmental quality is poor and that the associated health and economic impacts are significant. The study has been one of the first exercises within the city of Chennai, that has used the quantitative health risk assessment framework to value environmental health damage.

Quantitative health risk assessment is a procedure that is effective in settings where the dose response information is clear for the concerned pollutant and accurate exposure information is available. While the pollutants examined in the study are ones for which a great deal of scientific understand already exists for the dose-response relationships, exposure assessment becomes one of great concern. The present study through a combination of primary and secondary data collection has generated a large database of population exposure information for several key pollutants in the study zone. Although some uncertainties still surround the application of the dose-response information that has been largely developed based on developed country studies, the dual use of cross sectional epidemiological information along with dose –response information has clearly identified a fair degree of reconciliation between predicted and observed health and economic estimates.

The scheme of relative ranking of risks allows one to prioritize between the concerns without the need to be concerned about the absolute value of these risks. The risk calculation has brought out the need for addressing certain pollutants such as PM 10, indoor air pollutants associated with biomass combustion and lead within the community. Prior to the study while the regulatory bodies, the development agencies and the communities were quite aware about the need for improving water quality and access to sanitation. The fact that risks from PM 10 exposures could be as high for the community as from drinking unsafe water has been clearly brought out in the study. This will enable the design of strategies for air pollution control along with efforts to control water pollution and solid waste problems.

The data on air pollution and sources for air pollution compiled for the study can be used to aid the generation of a complete emissions inventory. Source attribution would then allow the economic valuation of health damage assessed in this study to be used in subsequent cost-benefit analyses to choose between alternate methods for reducing population exposures.

The study has been executed with significant stakeholder participation including members of the Tiruvottiyur Municipality, The Tamil Nadu State Pollution Control Board and the The Chennai Metropolitan Development Authority. The involvement of these members will greatly facilitate the subsequent design and implementation of an environmental management plan for the region. Institutional capacity building exercises in the form of training in health risk assessment methodologies were carried out twice during the course of this study. This would serve to further strengthen the local network of professionals to refine these estimates for this zone as well as undertake similar exercises that would cover the entire Chennai Metropolitan Area.

Finally the study has identified areas, where the largest gaps in data accuracy are likely to be present. Recognition of these areas will contribute to refining the framework for conduct of subsequent longitudinal environmental health studies. This will in turn ensure that the actual health and economic costs are captured with the least degree of uncertainty for local policy interventions. In that sense, it is hoped that the study will serve as good proto- type for other studies in the region to recognize the importance of environmental health risks and initiate action plans aimed at protecting the health of the public.

Recommendations

The most important requirement for the initiation of the design of environmental management plans for any area is the availability of reliable environmental quality information. Currently available secondary sources are not easily accessed and the means of verifying quality is limited as raw data is seldom available. Further, several pollutants are not routinely monitored and therefore it is impossible to judge the associated health impacts. There is therefore a tremendous need to set up a environmental database that is easily accessible on the public domain. The database should include all information on monitoring including short and longterm averages and not just annual averages. Both temporal and spatial variations must be adequately captured.

The environmental health impact assessments done in developing country settings have been plagued with uncertainties both about using developed country information on health risk estimates as well as the quality or paucity of local environmental data. Setting up such databases would be an essential pre-requisite for initiating environmental epidemiological studies that have been executed in the developed countries.

Environmental epidemiological studies rely not only on good environmental quality information but also on good health records at existing healthcare facilities. While this may appear to be a daunting task with the level of infra-structure available at most health care facilities in developing country settings, establishing a health records system has benefits that extend beyond assisting environmental health assessments. Currently, virtually no information at heath care facilities is in a form that is amenable to data retrieval or analysis.

There is therefore a great need to develop record systems that will go beyond reporting just cause of death. Cause of disease records that has been collected on a standardised acceptable format would greatly aid future studies. The existence of significant alternative medicine practise, the lack of enforcement for requiring prescriptions for the purchase of medicines are all situations peculiar to Indian conditions. Recording systems need to address this as well while being designed.

Inadequacies exist in the economic database of information needed for environmental health assessments. In the absence of health insurance schemes, which usually is a big source of information on categories health expenditure assessment from secondary sources tends to be extremely unreliable. More surveys that collect economic information both directly form the population as well as form institutions need to be initiated.

Finally, the success of environmental health programs in the developed world has been in large measure due to capacity building in technical skills required in the diverse areas of environmental toxicology, health risk assessment, environmental economics, environmental management to name just a few. This capacity building has been possible through extensive collaborations between academic institutions, the Government and the industry. Rigorous scientific academic research has been responsible for the development and revision of many an environmental standard. Currently, few academic institutions are involved in environmental health and economics related research. Very few even offer degree programs specifically in environmental health. Measures must undertaken to encourage such educational and research efforts.

It is hoped that the study has served a prototype for the initiation of similar and larger scale studies aimed at addressing economics of environmental health damage within settings that prevail in most Indian cities. With the identification of the major areas where efforts need to be directed for the successful execution of such studies, it is hoped that future studies will decisively catalyse policy changes that will result in permanent improvement of the environmental quality.

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HEALTH CHECK-UP - THIRUVOTTIYUR

(Fill-up appropriate number, wherever applicable, in the box provided)

I. INDIVIDUAL INFORMATION:

Name:_____________________________

Address:____

____

1. Sex: Male (1) Female (2) □1
2. Health Posts:

   Thiruvottiyur(1) Kuppam (2) Sathangadu(3) Ernavoor(4) Thangal(5) □2

3. Age group:

Less than 7(1) 7 to 13(2) 14 to 32(3) 33 to 60(4) Above 60 (5) □3

4. Marital Status: Married(1) Unmarried(2) □4

5. Education □5

   Primary (Up to 5th) _____________________(1)
   Middle (6th to 8th) _____________________(2)
   Secondary and HS (9th to 12th) _________________(3)
   College ___________________________ ____(4)
   Professional (MBA, MCA, BE, MBBS etc.) __(5)
   Illiterate ______________________________(6)

6. Occupation □6

   Housewife ___________________________(1)
   Administrative or Accounts______________(2)
   Industry (hazardous) ___________________(3)
   Industry (non-hazardous) _______________(4)
   Labour (light to medium) __________ ____(5)
   Labour (heavy) ______________________(6)
   Others (hazardous) __________________(7)
   Others (non-hazardous)______________ _(8)
   Unemployed _________________________(9)

II. HOUSEHOLD INFORMATION

7. No. of persons in the family: _________ □7

8. Total family Income (in Rs) : ___________

9. Expenditure on mosquito control:

Equipment Type Used	Cost of Equipment	Monthly Expenditure Involved (Rs)
1. Mat Holder		On mats:
2. All out		Refill:
3. Netlon Cover		Not Applicable: x
4. Others: ______________		Coils:

10. Expenditure on water purification:

Source of water supply	Average boiling time (minutes)	Amount spent on water filter	Life of Filter Candles	Cost of the Candles

III. HEALTH INFORMATION:

11. Specify below if you suffer from any of the following symptoms/illness at present:

Respiratory Symptoms:

☐ 1 Cough

☐ 2 Sputum/Phlegm

☐ 3 Breathlessness

☐ 4 Wheezing

☐ 5 Hemoptysis

Gastro-Intestinal Problems:

☐ 6 Vomiting

☐ 7 Vomiting with blood

☐ 8 Loose stools

☐ 9 Yellowness of eyes

☐ 10 Stools with worms

Water Borne Symptoms:

☐ 11 Malaria

☐ 12 Filariasis

Skin Problems:

☐ 13 Boils with pus

☐ 14 Boils without pus

☐ 15 Itching or redness of skin

☐ 16 Foot drop or wrist drop

Eye Problems:

☐ 17 Irritation of eyes

☐ 18 Irritation of eyes with redness

☐ 19 Irritation of eyes with watery

☐ 20 Loss of vision

Miscellaneous Problems:

☐ 21 Mottling of teeth

☐ 22 Dental Carries

☐ 23 Pre-mature birth

☐ 24 Miscarriages

☐ 25 Still births

☐ 26 Mental Retardation

☐ 27 Kidney problem

☐ 28 Cancer

12. Specify the disease(s) that affected you during the last one month:

Respiratory			Gastro-intestinal			Water/Vector Borne			Skin Problems			Eye Problems		
Code		Diseases	Code		Diseases	Code		Diseases	Code		Diseases	Code		Diseases
1		Asthma	5		Typhoid	9		Jaundice	13		Black Pat	17		Redness
2		Hemoptysi	6		Worms	10		Malaria	14		White Pat	18		Watery
3			7			11		Filarial	15		Rashes	19		Irritation
4			8			12			16			20		

13. Total number of work loss days due to illness during the last one month: ___________

15. Average number of visits made to doctor during illness: ☐17

16. Type of hospital visited during illness:

a. Government: ☐18 b. Private: ☐19 c. Both: ☐20

17. If you consult a private doctor, how much fee do you pay per visit : Rs. __________ □21

18. In the last one month how much expenditure have you incurred on your health:. _______□22

FIELD QUESTIONNAIRE FOR COLLECTION OF SOCIO-ECONOMIC AND HEALTH DATA

I GENERAL INFORMATION

1. Name of the Respondent:
2. Address: House Number: __________; Street Name: _______________; Locality Name: _____________; Municipality/Town/Village ________________;
   Postal Index Number:________________
3. Type of Locality: Slums/ Low Income Settlement/ High Income Settlement

II SOCIO-ECONOMIC DETAILS

1. Religion: _______________; Community:____________________
2. Education and Income:

Name	**Member's ID**	**Relationship with the Respondent**	**Age**	**Sex**	**Marital Status**	**Level of Education**	**Monthly Income (in Rs.)**

2.Occupational details of household members:

*	Place of work	Nature of occupation		Daily working hrs.	Income per month (Rs)
		Primary	Secondary		

(*: Specify members ID number)

3. Expenditure incurred as House Rent*: Rs.___________

(* If the house is owned specify imputed rental value):___________

4. Housing Details

Type of House: Pucca/ Semi-Pucca/ Katcha; Briefly describe the type of house:___________

Number of Years residing in the present place:________________

Ownership Status: Owner/ Tenant

Total living area (excluding kitchen, bathroom & latrine)(sq. m): ______

Number of rooms (excluding kitchen bathroom and latrine): ________

Movable Assets owned at the household level:

Type of Assets	**Specify 'A' for Available or 'NA' for Not available**
Radio/Tape recorder	
Bicycle	
Motor Cycle	
TV	
VCP or VCR	
Washing Machine	
Telephone	
Refrigerator	
Four Wheeler	
Others	

III. ASSESSMENT OF ENVIRONMENTAL QUALITY :

A. Air Pollution:

Indoor Air Pollution

1. Is the ventilation in the house: Good/ Moderate/ Bad
2. Do you have a separate kitchen: Y/ N
3. If yes is it a properly enclosed room in the house: Y/ N
4. What is the total workspace of the kitchen (sq ft):
5. Type of roof in the kitchen/ cooking room:

   Thatched (leaves/straws. Etc)/ Asbestos/ Tin/ Tiles/ Concrete/ Others (specify)______
6. Number of doors/ windows in the kitchen: Doors: ______; Windows:______
7. Where and how many times do you cook:

Activity & Time	**Indoor**	**Outdoor**	**Both**	**Not done**
Food Cooking				
Water Boiling				

7. Members involved in cooking: (specify Member's ID)
8. How many members stay at home during the day: (specify the member's ID)
9. Type and quantity of fuel used every month:

Type of fuel used	Quantity per month	Unit cost
LPG		
Kerosene		
Wood		
Others specify:		

10. If fuel wood is used, is it gathered or purchased: _______________
11. If gathered, what is the distance and time spent for gathering:
    a) Distance (Km): ___________
    b) Time (Hours): _____________
12. Is cooking smoke a problem in your household: Y/ N
13. Have you ever changed the fuel: Y/ N (if yes, specify fuel used earlier):___________
14. Has the shift in fuel cost you any additional expenditure: Y/ N (if yes, specify amount): __________

Vehicular Air Pollution:

1. How far is vehicular traffic from your residence (in meters): ______
2. Total number of hours the household members travel:

Type of vehicle	Travel time per day
Cycle	
2 wheeler	
Three wheeler	
4-wheeler	
Others	

3. Do you use any protective equipment during travel: Y/ N (If Yes, specify): __________________________
4. Cost of protective equipment used (in Rs):
5. Do you take any diversions to avoid vehicular emissions: Y/ N
6. If yes, what is the extra distance you travel (in km):
7. What is the extra time involved due to additional distance involved: _________
8. What is the extra cost of the travel involved (in Rs):

Industrial Air Pollution:

1. Is there an industry close to your residence: Y/ N
2. If yes, specify type of industry:
3. Approximate distance of industry from your residence:
4. Do you have any implements in your house to protect yourself from industrial pollution (for eg, air conditioners): Y/ N
5. Amounts spent on such implements (in Rs):

B. Water Pollution

1. What is the source of drinking water:

Source of drinking water	**Quantity**	**Own/Private/Public**
Well		
Tube well		
Tank		
Public Supplies		
Stand Post		

2. Do you provide any treatment before drinking the water: Y/ N
3. If yes, specify the purification method used and the costs involved:

Purification method	**Cost of Equipment (Rs)**	**Per Month Expenditure Incurred**
Boiling		
Filter		
Chlorination		
Specify others:		

5. Where do you store the treated drinking water (specify the equipment used like utensils etc.):
6. How much time is spent in storage and purification of water (minutes/day): ______
7. Who is involved in the storage and purification (ID No.):_________

C. Solid Waste / Sanitation

1. Do you have access to a toilet facility: Y/ N
2. Type of toilet facility: Septic Tank / Dry Pit/ Others (specify):__________
3. Is there a public toilet facility in your area: Y/ N
4. Does this toilet facility affect the sanitation of your area: Y/ N
5. If yes, how: ____________________________________

6. Do you use paid toilets: Y/ N (if yes, specify amounts spent)
7. Do you have access to a garbage collection facility: Y/ N
8. Frequency of collection:______________
9. Is there a garbage dump near your area: Y/ N
10. Is waste burnt in the dump: Y/ N
11. Is there waste water stagnation near your area: Y/ N
12. During monsoon rains does the rain water stagnate: Y/ N
13. If yes, how many days does the inundation remains: ___________
14. Do you have problems with insects/ rats/ other disease vectors: Y/ N
15. Describe them: ____
16. Do you spend on vector treatment/ prevention (for eg. Mosquito mats/ insecticide spray/ fumigation): Y/ N (if yes, specify amount): _______________

D. Household Perception of Environmental Problems in the locality

Environmental Problems	Ranking
Industrial Air Pollution	
Indoor Air Pollution	
Vehicular Air Pollution	
Groundwater Pollution due to Industries	
Groundwater Pollution due to Sewage discharge	
Pollution resulting from inundation during rains	
Vehicular Noise Pollution	
Hazardous Waste Pollution	
Solid Waste Pollution	

HEALTH CHECK UP QUESTIONNAIRE

(Data to be collected on all members of the family)

PART I General Information

1. Household ID and number of members in household:
2. Member's name:
3. Age:
4. Sex:
5. Height (cm):
6. Weight (kg):
7. Immunization history (all immunization details):
8. Smoking habits: Y/ N
9. Type of tobacco smoked: Cigarette / Bidi / Hukka / Others _______________
10. Smoking history (frequency and duration):
11. Alcohol habits: Y / N
12. If yes, frequency and duration of consumption:
13. No. of days unable to do work due to ill health during
    past 15 days: past three months:
14. Whether seen by a doctor: Y / N
15. Number of doctor visits:
    past 15 days: past three months:
16. Type of treatment:
17. Place of treatment (Govt./ private):
18. Fee paid per visit:
19. Amount spent on medicines, past 15 days: past three months:

PART – II Respiratory Assessment

1. Respiratory Symptoms

a) Cough

-Do you usually cough first thing in the morning: Y/ N

-Do you cough on most days for as much as 3 months of the year: Y/N

-For how many years have you had this cough

b) Sputum/ Phlegm

- Do you usually bring up phlegm first thing in the morning: Y/N
- Do you bring up phlegm on most days for as much as 3 months of the year: Y/N
- For how many years have you had the phlegm:

c) Breathlessness

- Do you usually get breathlessness while working on level grounds: Y/N

d) Wheezing

- Do you wheeze: Y/ N
- How often do you experience attacks of wheezing: Y/ N
- At what age did wheezing first occur:

e) Hemoptysis

- Have you ever coughed blood: Y/N
- At what age did you cough blood for the first time: Y/N

f) Any other

- During the past 3 years, have you had any other chest illness which has kept you away from usual activities: Y/ N

2. No. of days unable to do work due to respiratory problems:
3. Whether seen by a doctor: Y / N
4. Number of doctor visits:
   past 15 days: past three months:

PART III Gastrointestinal Assessment (Feco-oral diseases)

1. Do you experience frequent loss of appetite: Y/ N

2. Do you experience frequent vomitting: Y /N

   with blood : without blood: accompanied by pain in stomach:

3. Do you pass loose stools frequently: Y/ N

   watery stools: with phelgm & mucous: with blood:
   with fever: accompanied by giddiness:

4. Have you noticed yellowness of eyes: Y/ N

5. Have you passed worms in motion: Y/ N

6. Number of days unable to do work due to stomach/GI related problems:

7. Whether seen by a doctor: Y / N

8. Disease diagnosed:

9. Number of doctor visits:

   past 15 days: past three months:

PART IV Water/ Solid waste Related Vector Borne Diseases

1. Have you suffered from any of the following diseases:
   - Malaria Y/ N
   - Dengue Y/ N
   - Encephalitis Y/ N
   - Leptospirosis Y/ N
   - Filariasis Y/ N
   - Plague Y/ N

2.Whether seen by doctor: Y/ N

3. Disease diagnosed:

4. Number of doctor visits:

   past 15 days: past three months:

PART V Skin Problems

1. Do you have rough patches in your skin: Y/ N

2. Do you experience itching or redness of skin: Y/N

5. Do you have boils with / without pus: Y/ N

6. Do you have hyper pigmented skin lesions on palm/soles: Y/ N

7. Do you experience weakness of hands/ legs: Y/ N

8. Whether seen by doctor: Y/ N

9. Disease diagnosed:

10. Number of doctor visits:

    past 15 days: past three months:

PART VI Eye Problems

1. Do you experience irritation of eye: Y/ N
   - with redness Y/ N
   - with watery discharge Y/ N

2. Do you have difficulties seeing at night: Y/ N

3. Have you experienced any loss of vision: Y/ N

4. Whether seen by doctor: Y/ N

5. Disease diagnosed:

6. Number of doctor visits:

    past 15 days: past three months:

PART VII Miscellaneous

Record incidence of any of the following miscellaneous health conditions:

- Mottling of teeth (Fluorosis): Y/ N
- Dental caries: Y/ N
- Pre-mature births: Y/ N
- Miscarriages: Y/ N
- Still births: Y/ N
- Mental retardation: Y/ N
- Kidney problems : Y/ N
- Cancers: Y/ N
- Others (please specify)

PRIVATE MEDICAL PRACTITIONERS SURVEY

Name of the Doctor: ________________________________
Specialization: __________________________
Office address: ____
Name of the Health Post:______________________________

1. How many patients do you attend every day: ______________

2. A) What are the commonly occurring diseases in your area (rank them from maximum occurring to least)
B) Specify average number of visits a patient makes when affected by these diseases.
C) Specify the average expenditure a patient would be incurring for treatment of these diseases.

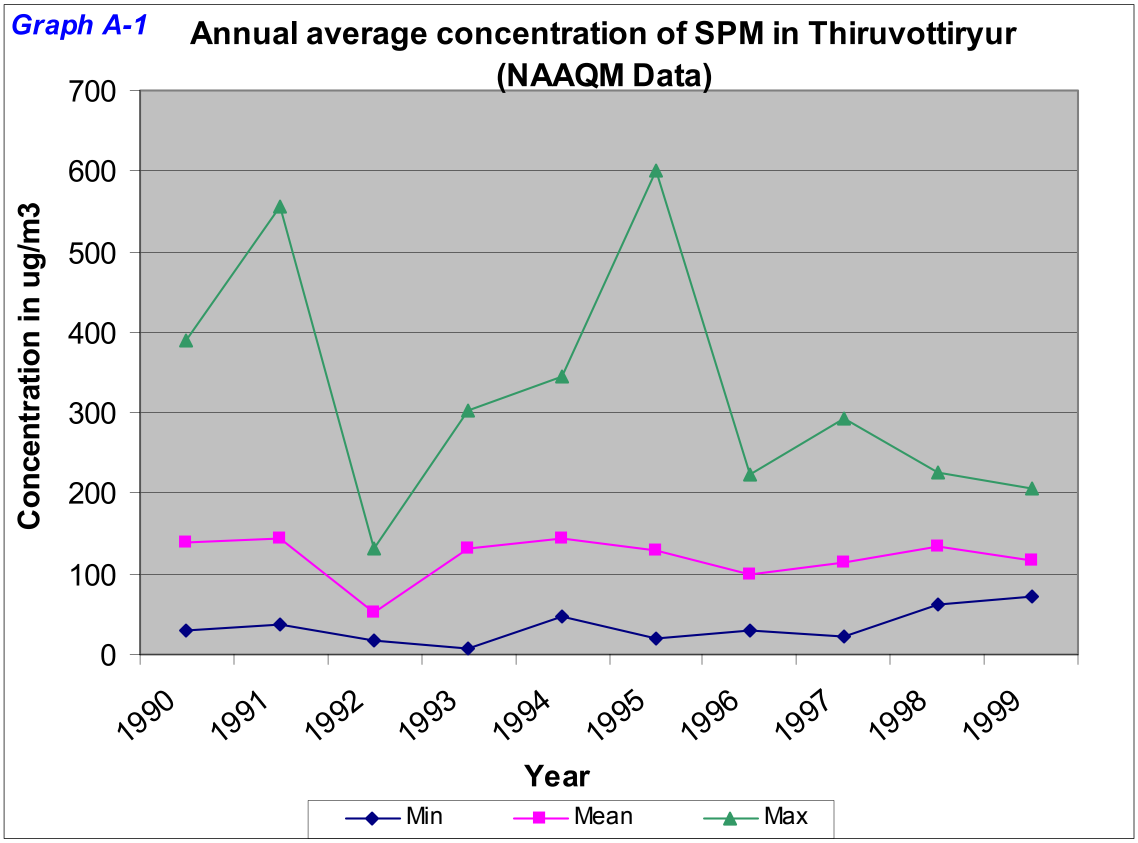
S.No.	(A) Diseases reported by its frequency	(B) No. of visits to Doctor	(C)Average Expenditure incurred towards treatment (Rs)	
			When reported at early stage	When reported late
1				
2				
3				
4				
5				
6				
7				
8				
9				
10				

4. What percentage of the patients come to you at an early stage of illness (specify percentage): ________

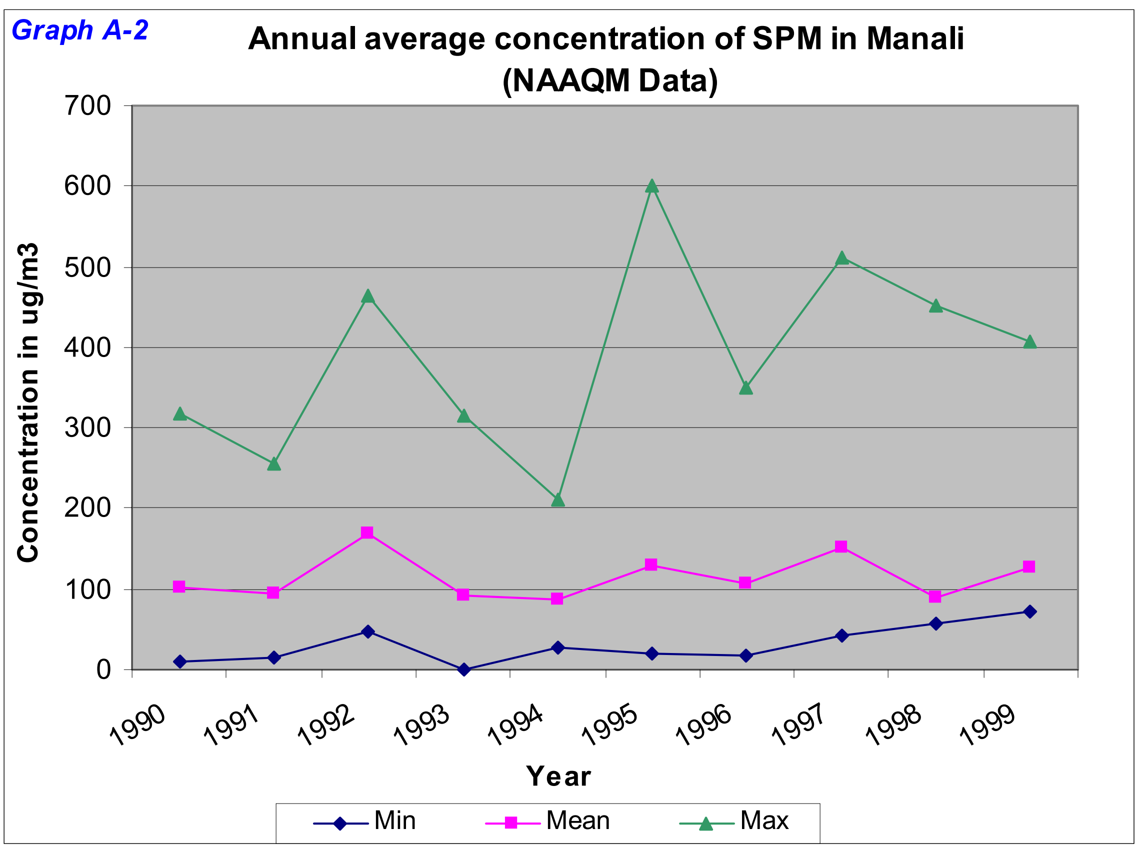
3. What are the frequently reported symptoms among your patients (specify the symptoms from high to low)
a. ______________________________ g. ______________________________
b. ______________________________ h. ______________________________
c. ______________________________ i. ______________________________
d. ______________________________ j. ______________________________
e. ______________________________ k. ______________________________
f. ______________________________ l. ______________________________

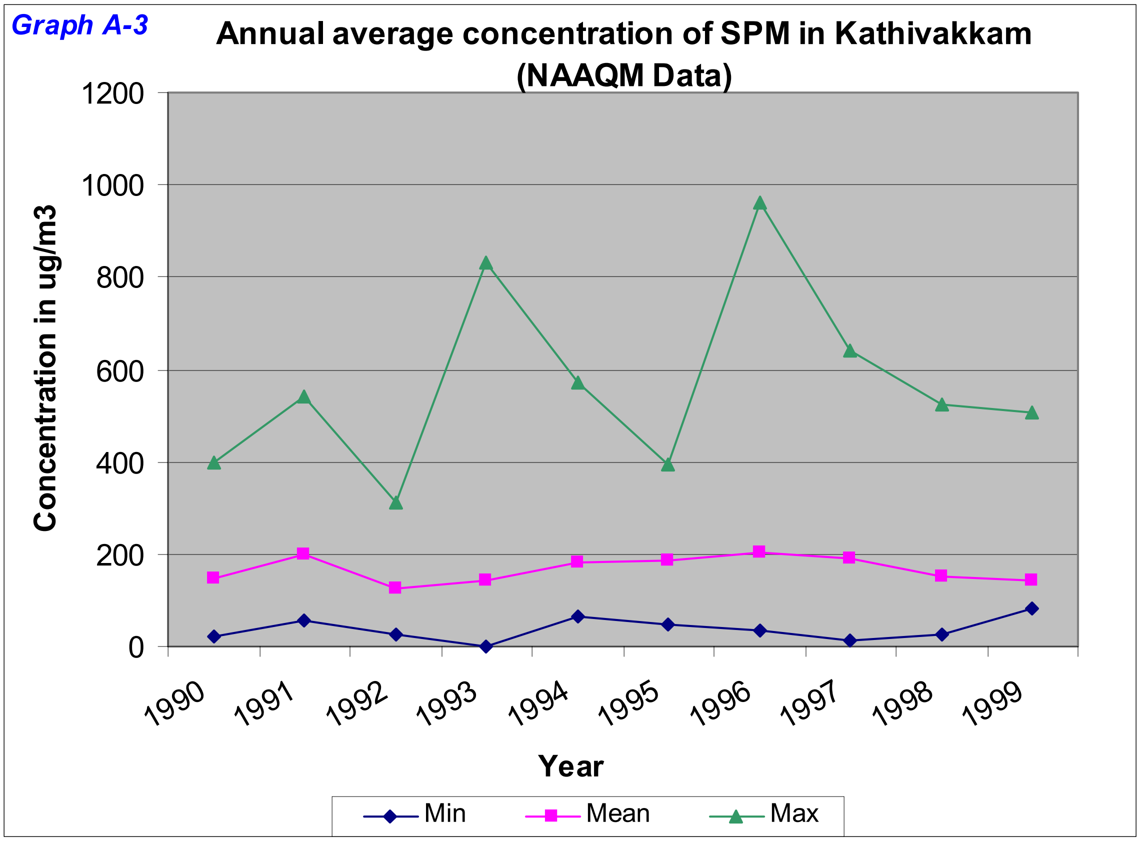
4. What do you think are the main causes of these diseases or illnesses:
a. ______________________________ e. ______________________________
b. ______________________________ f. ______________________________
c. ______________________________ g. ______________________________
d. ______________________________ h ______________________________

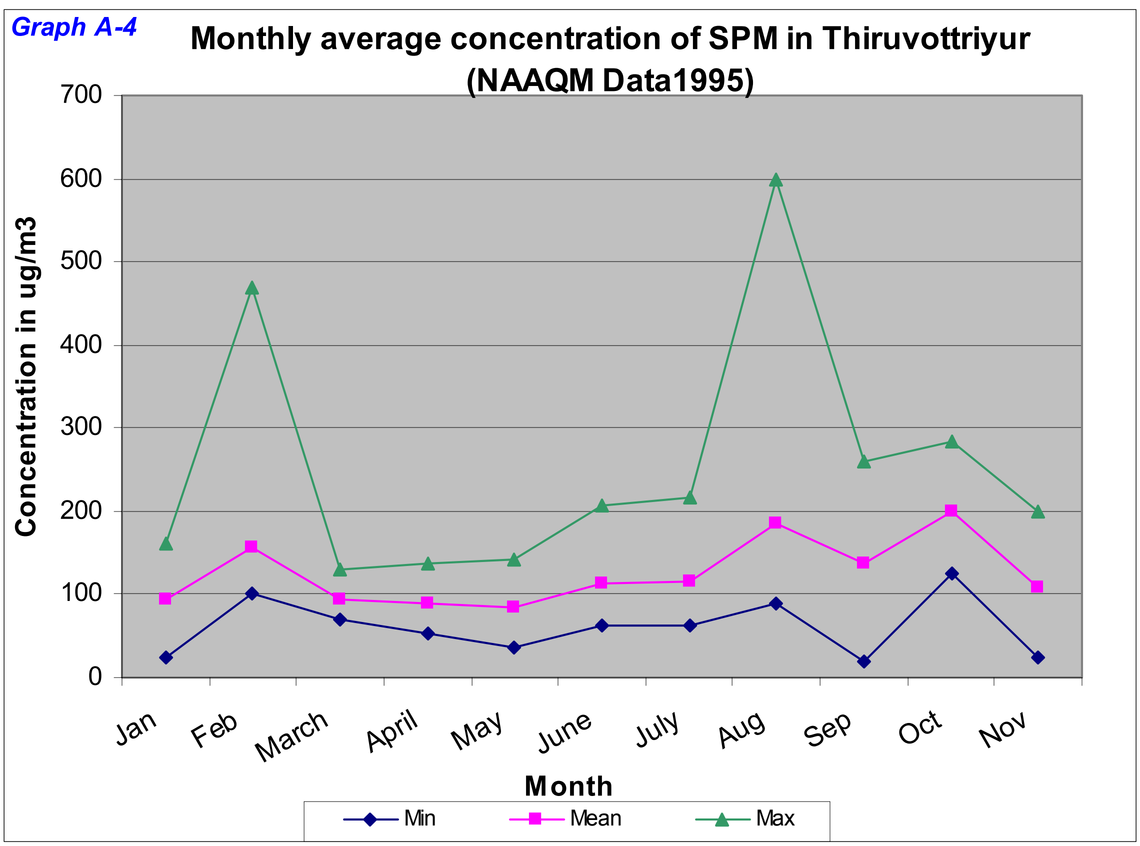
Graph A-1

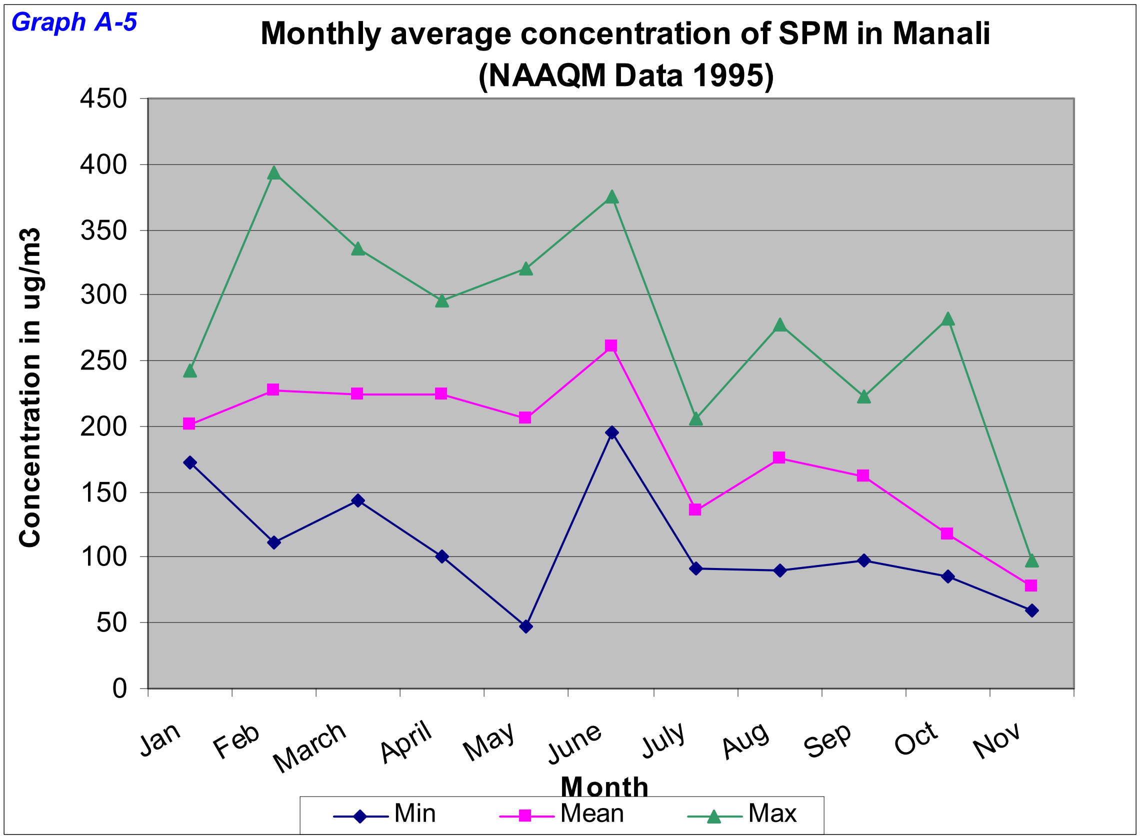


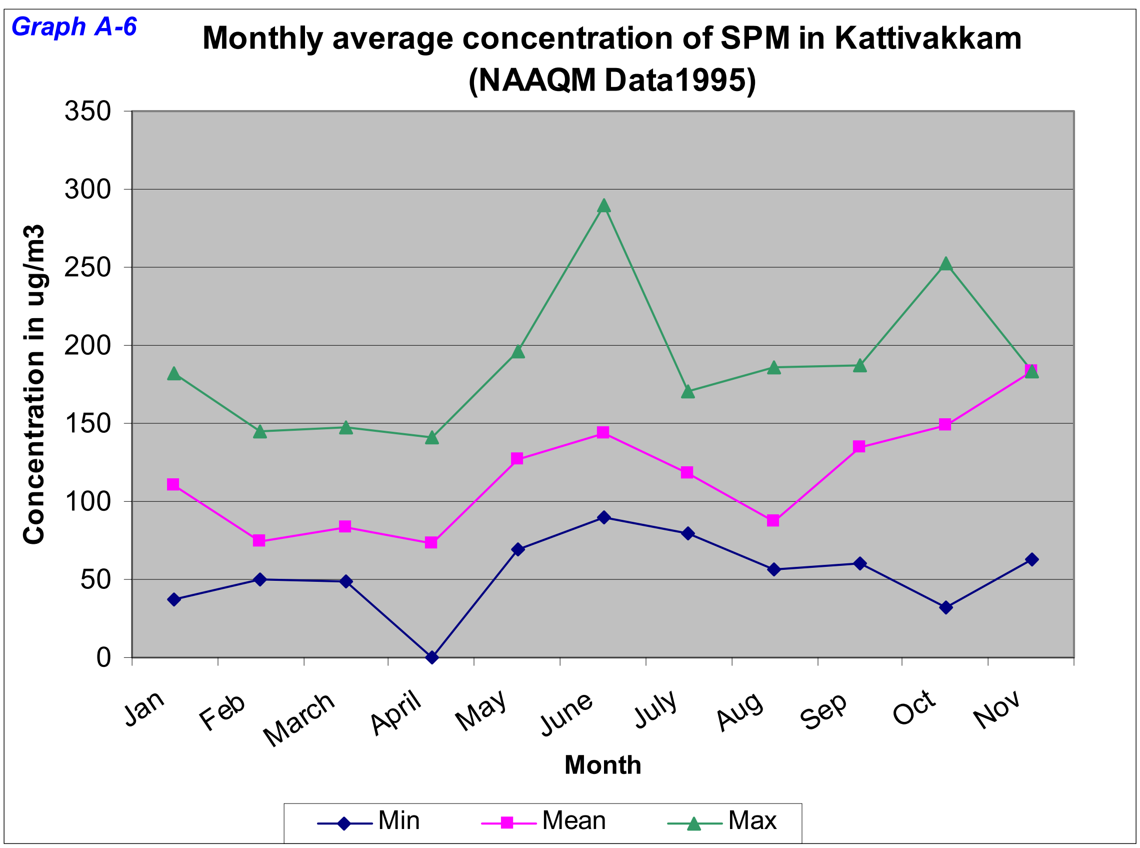
Graph A-2



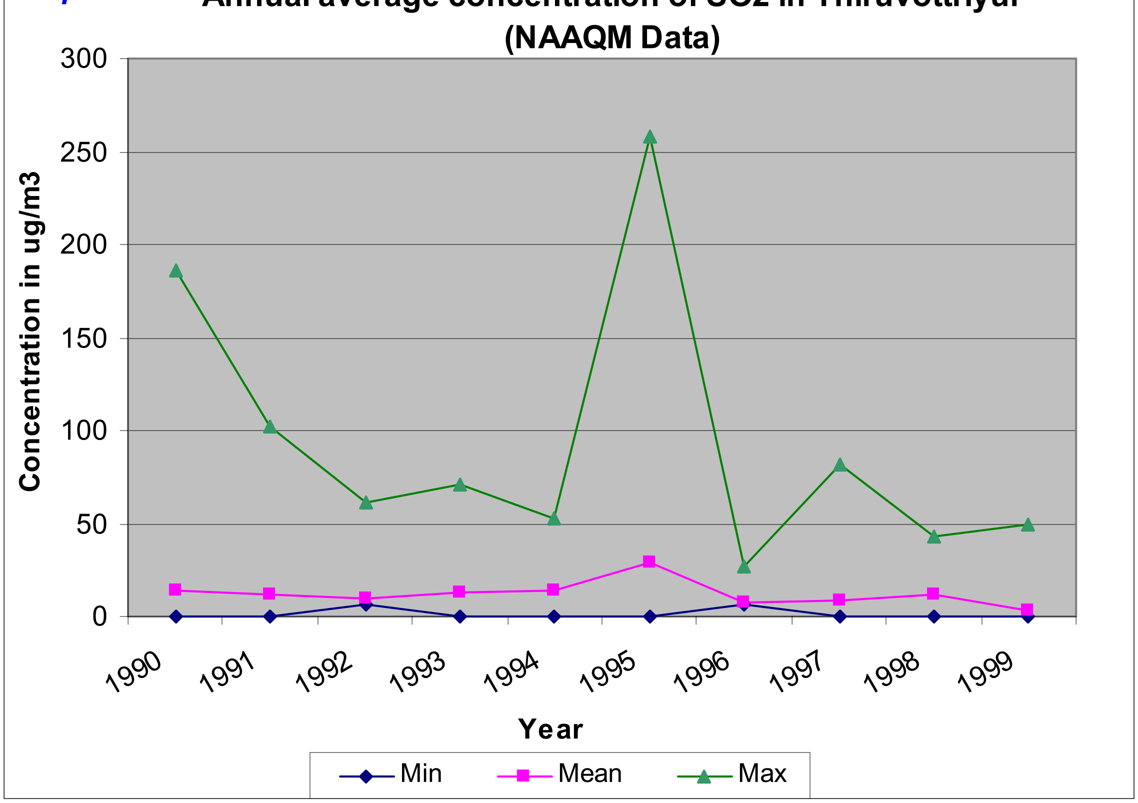

Graph A-3
Annual average concentration of SPM in Kathivakkam (NAAQM Data)
Concentration in ug/m3
1200
1000
800
600
400
200
0
1990
1991
1992
1993
1994
1995
1996
1997
1998
1999
Year
Min
Mean
Max


Graph A-4
Monthly average concentration of SPM in Thiruvottriyur (NAAQM Data1995)
Concentration in ug/m3
700
600
500
400
300
200
100
0
Jan
Feb
March
April
May
June
July
Aug
Sep
Oct
Nov
Month
Min
Mean
Max

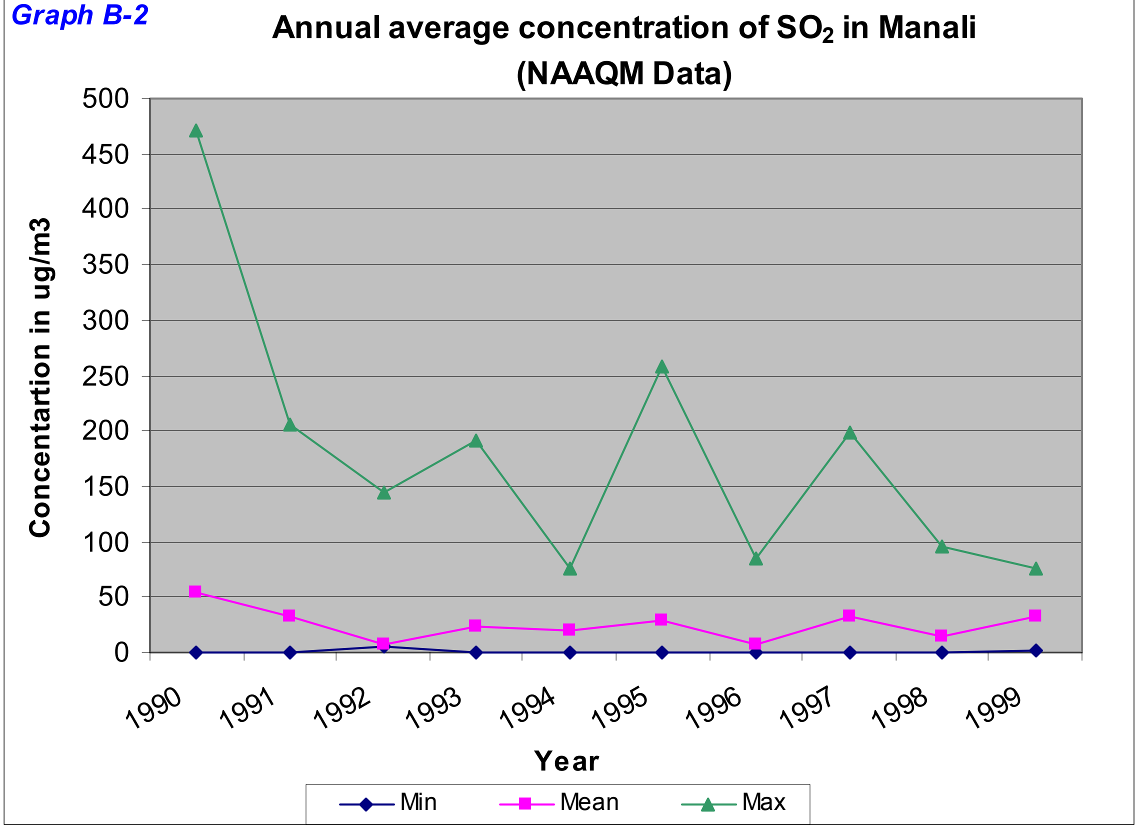

Graph A-5
Monthly average concentration of SPM in Manali
(NAAQM Data 1995)
Concentration in ug/m3
0
50
100
150
200
250
300
350
400
450
Jan
Feb
March
April
May
June
July
Aug
Sep
Oct
Nov
Month
Min
Mean
Max


Graph A-6
Monthly average concentration of SPM in Kattivakkam
(NAAQM Data1995)
Concentration in ug/m3
0
50
100
150
200
250
300
350
Jan
Feb
March
April
May
June
July
Aug
Sep
Oct
Nov
Month
Min
Mean
Max

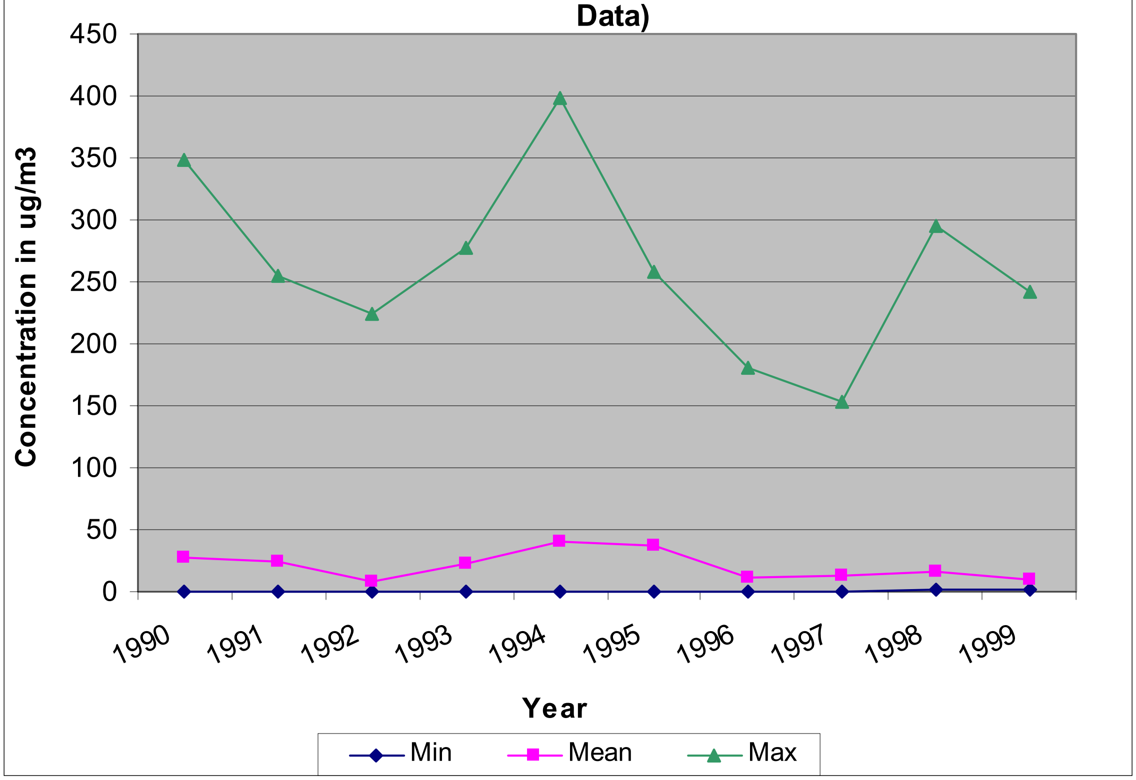
Graph B-1



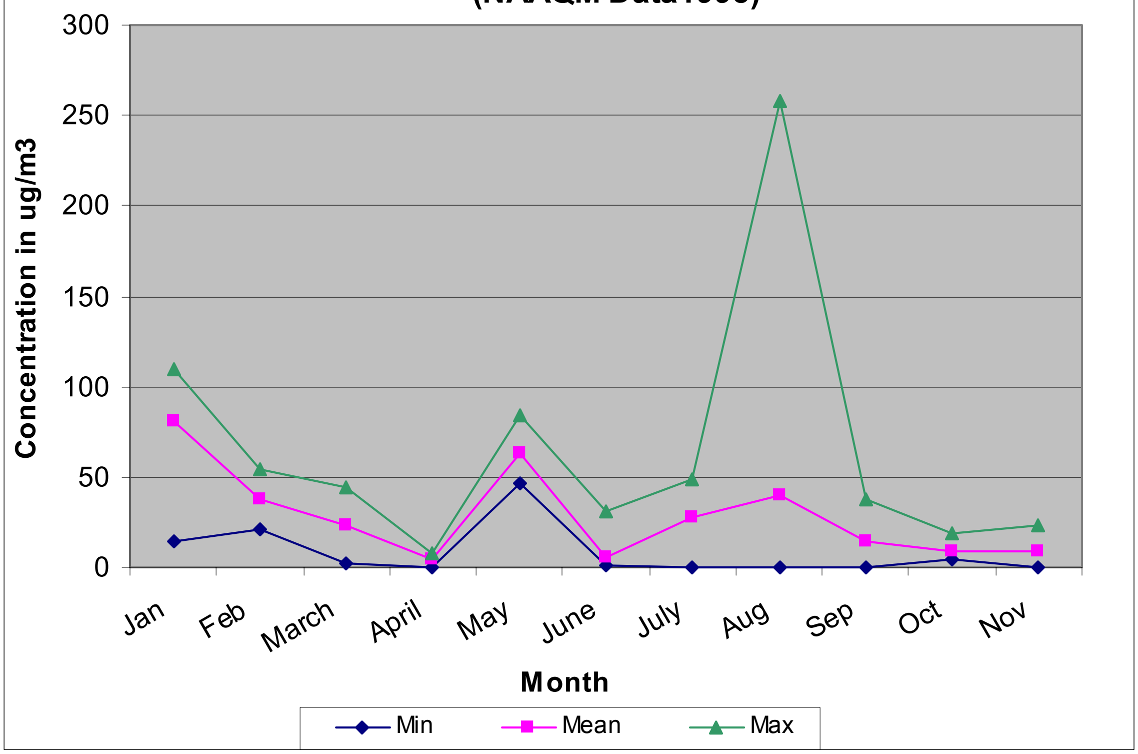
Graph B-2

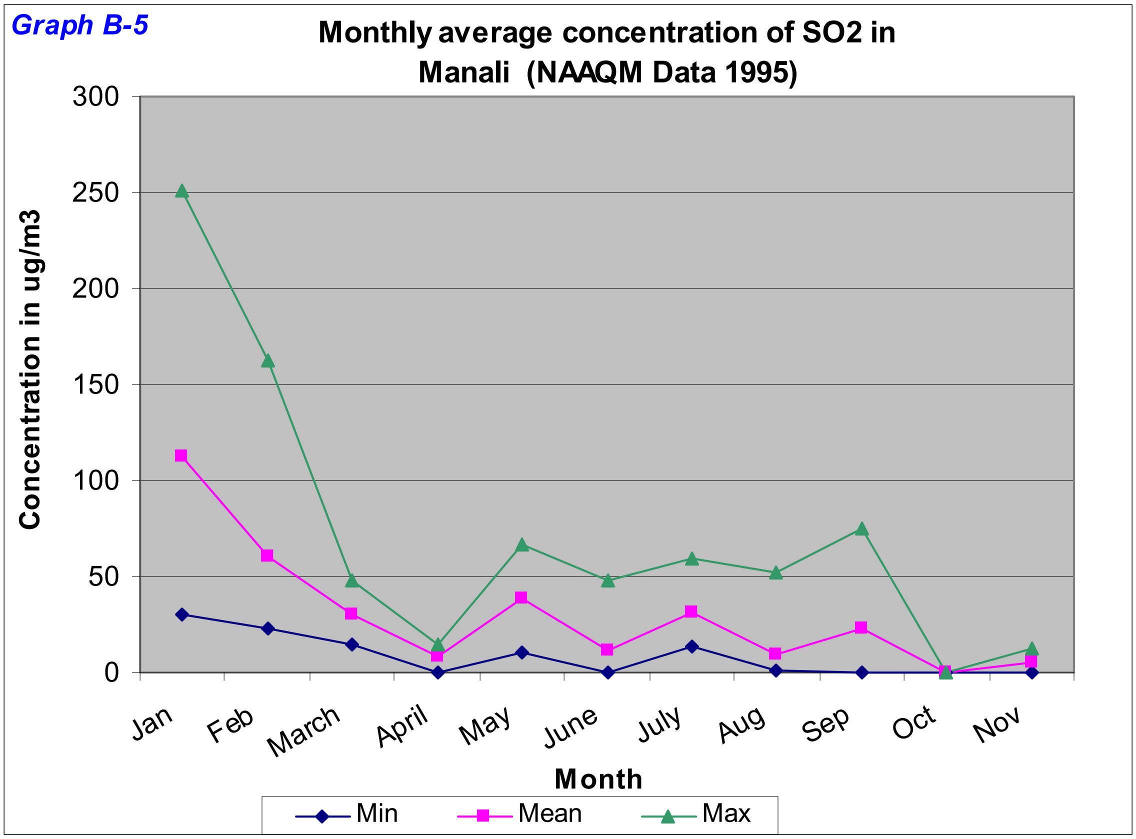


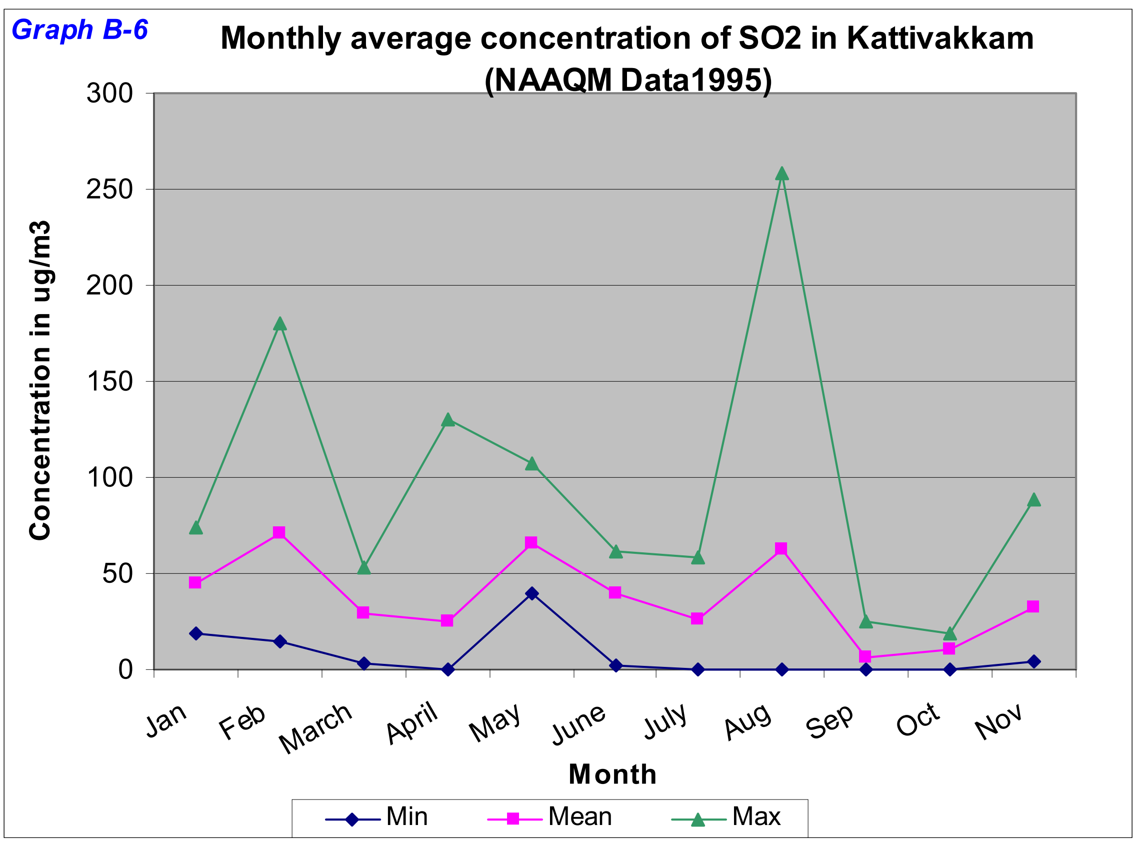
Graph B-3 **Annual average concentartion of SO2 in Kathivakkam (NAAQM Data)**

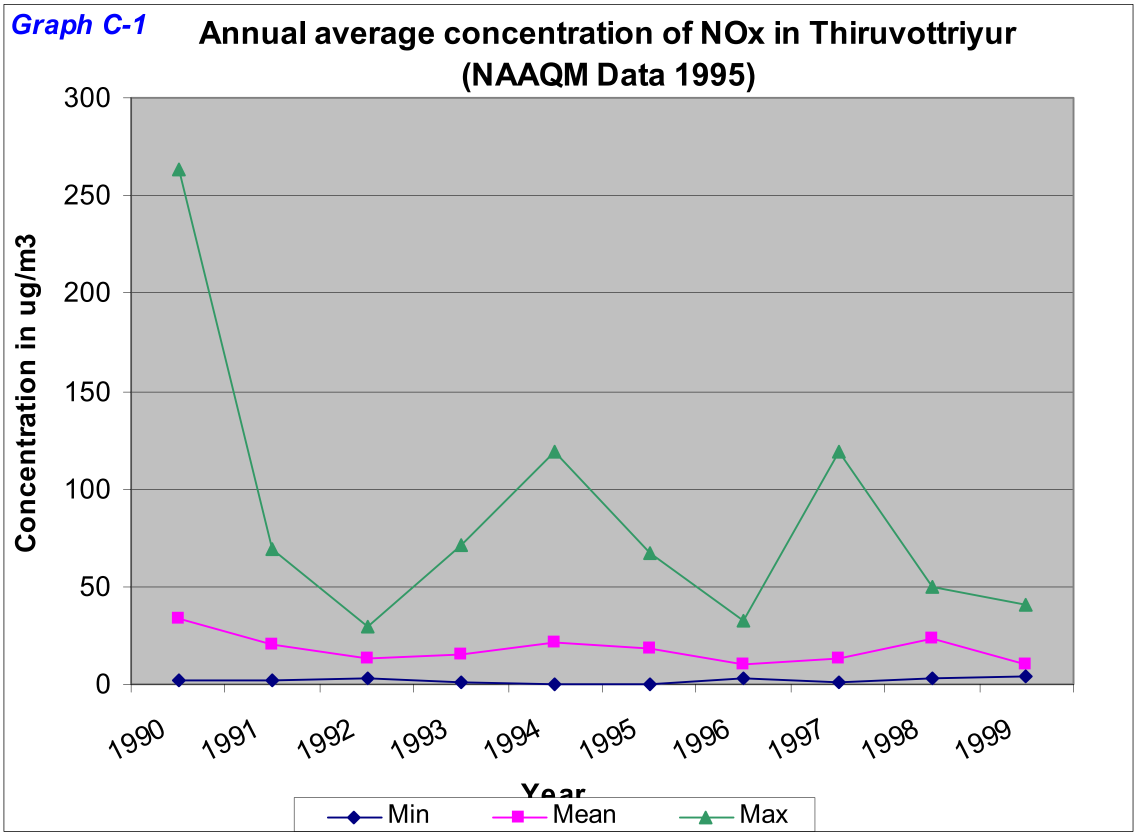


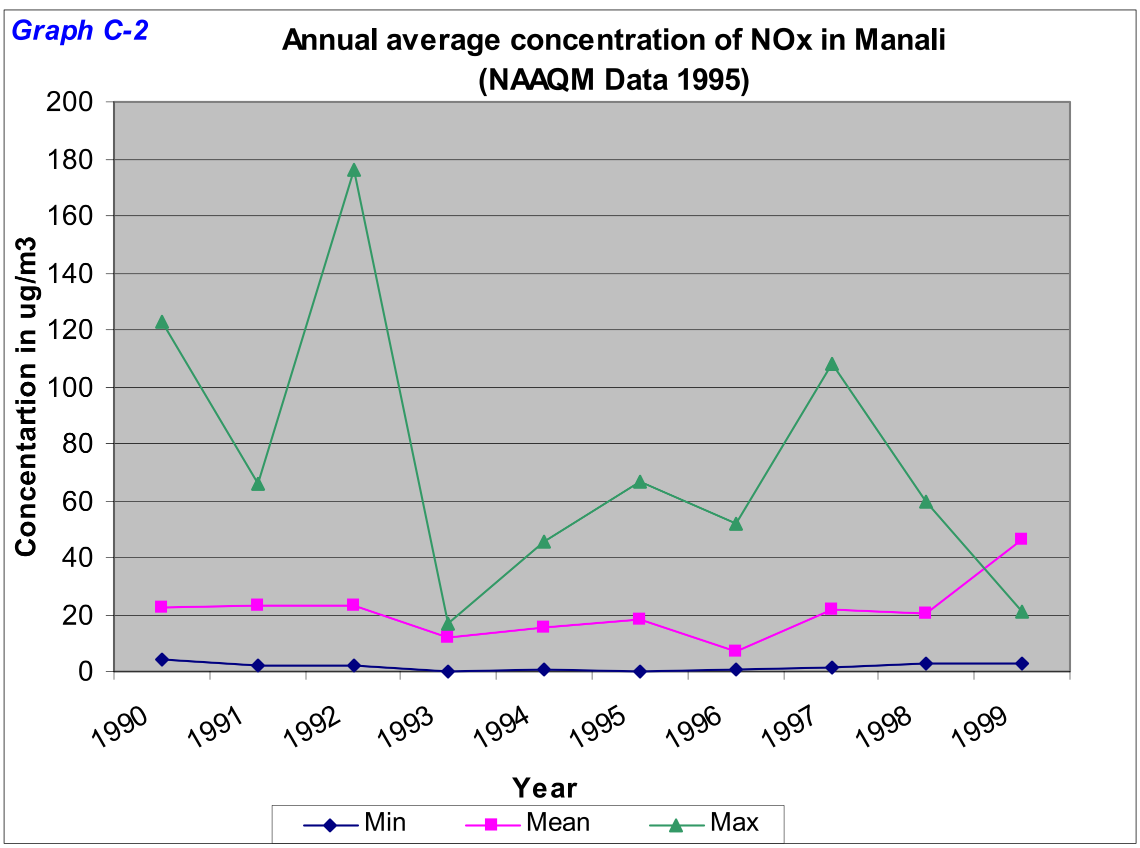
Graph B-4 **Monthly average concentration of SO2 in Thiruvottriyur (NAAQM Data1995)**

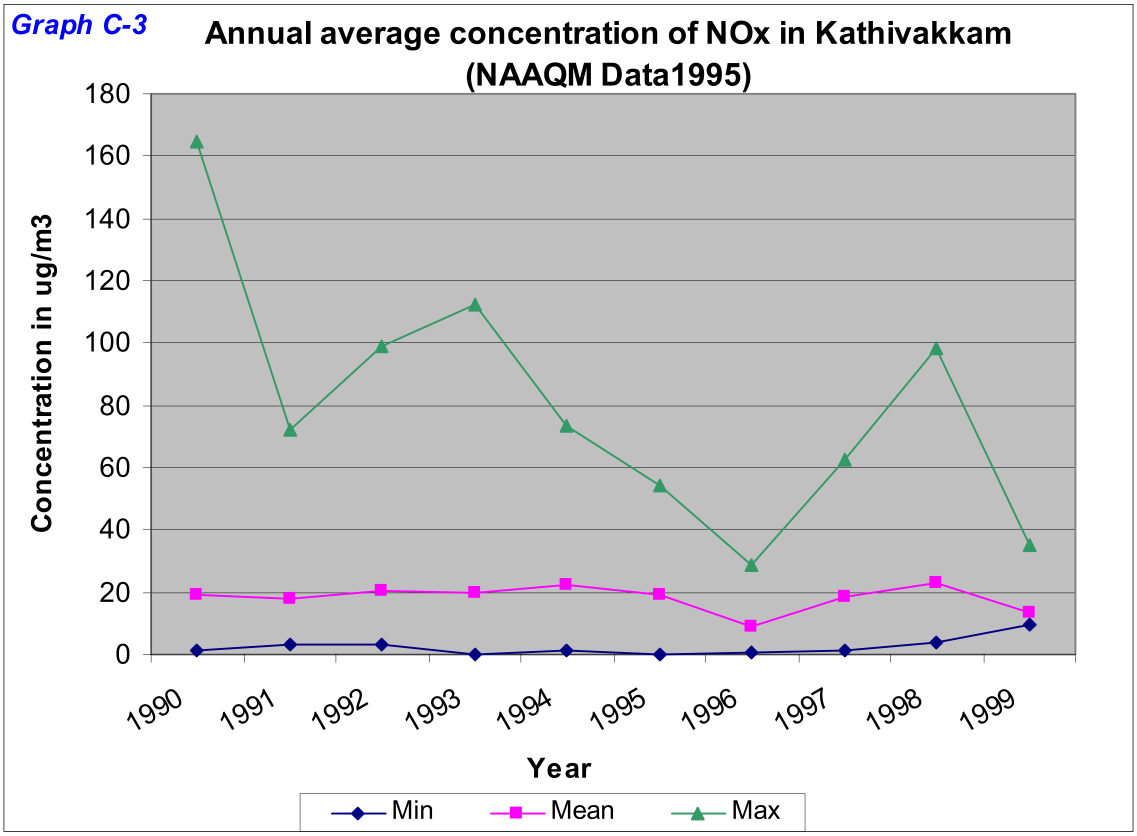


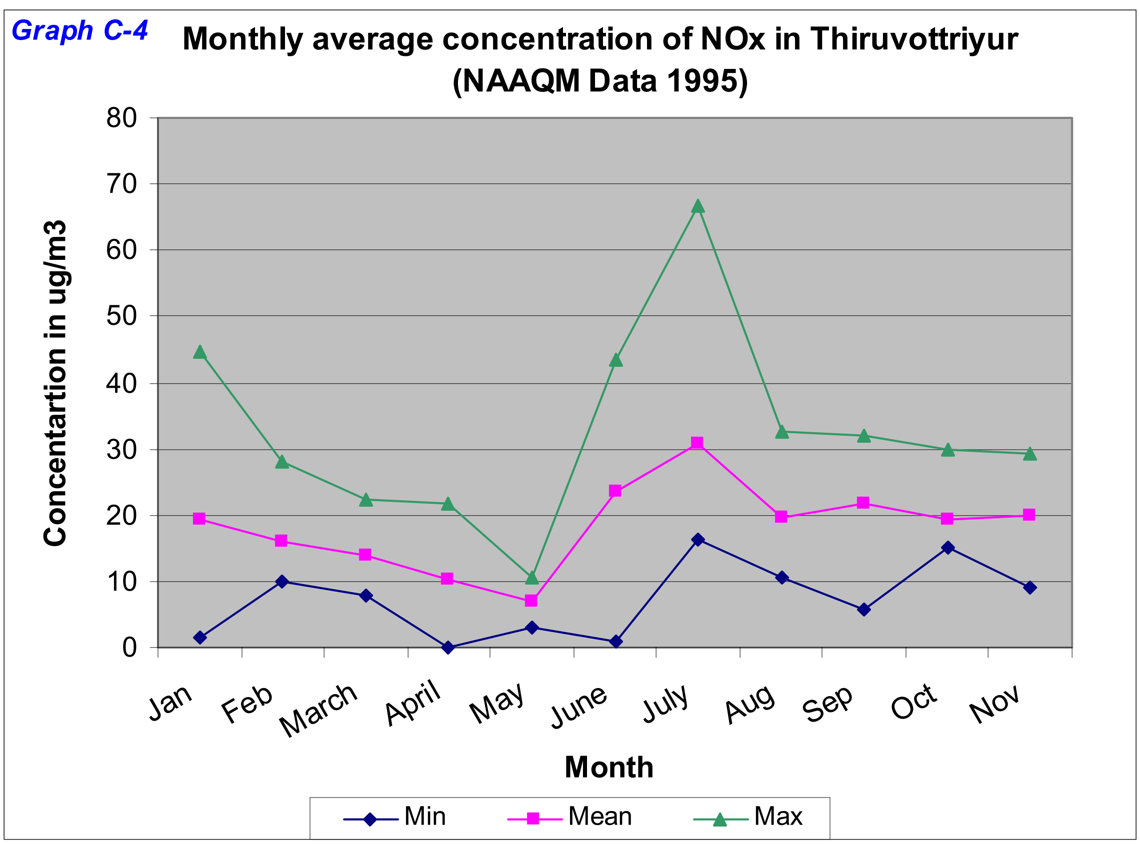

Graph B-5
Monthly average concentration of SO2 in Manali (NAAQM Data 1995)
300
250
200
150
100
50
0
Concentration in ug/m3
Jan
Feb
March
April
May
June
July
Aug
Sep
Oct
Nov
Month
Min
Mean
Max


Graph B-6
Monthly average concentration of SO2 in Kattivakkam (NAAQM Data1995)
300
250
200
150
100
50
0
Concentration in ug/m3
Jan
Feb
March
April
May
June
July
Aug
Sep
Oct
Nov
Month
Min
Mean
Max

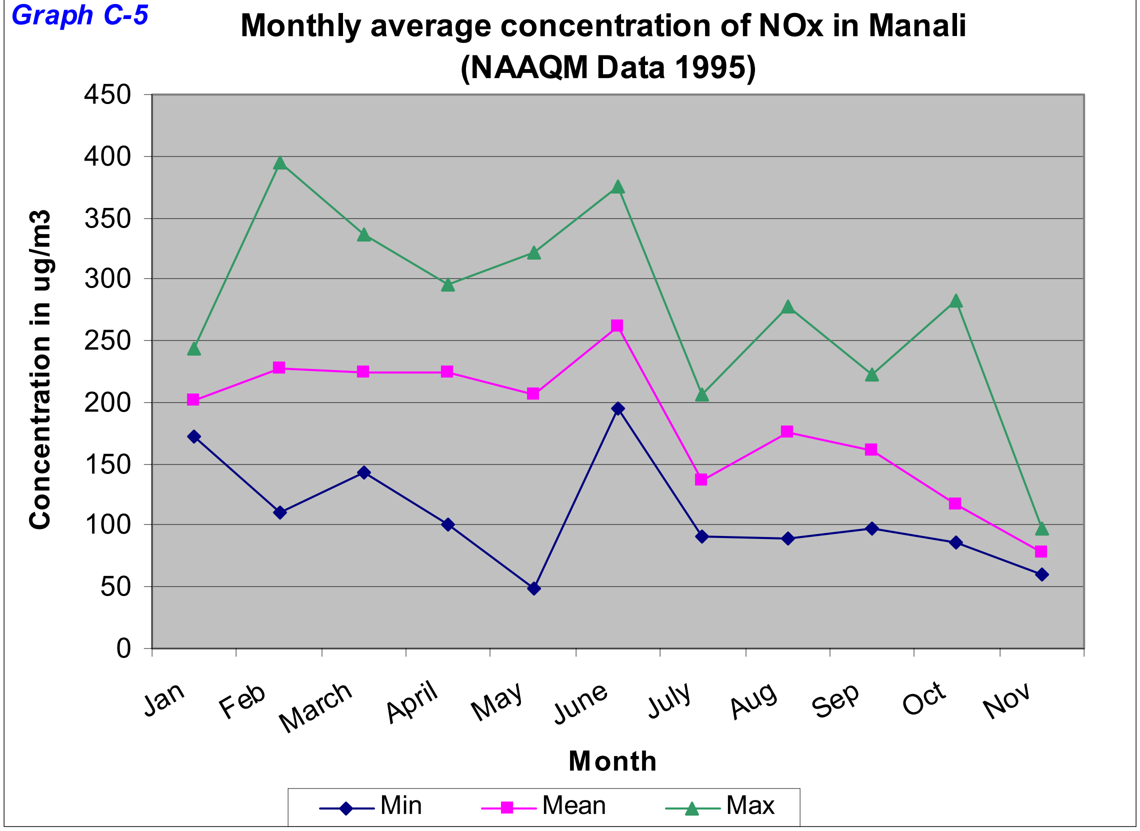

Graph C-1
Annual average concentration of NOx in Thiruvottriyur
(NAAQM Data 1995)
Concentration in ug/m3
300
250
200
150
100
50
0
1990
1991
1992
1993
1994
1995
1996
1997
1998
1999
Year
Min
Mean
Max


Graph C-2
Annual average concentration of NOx in Manali
(NAAQM Data 1995)
Concentartion in ug/m3
200
180
160
140
120
100
80
60
40
20
0
1990
1991
1992
1993
1994
1995
1996
1997
1998
1999
Year
Min
Mean
Max

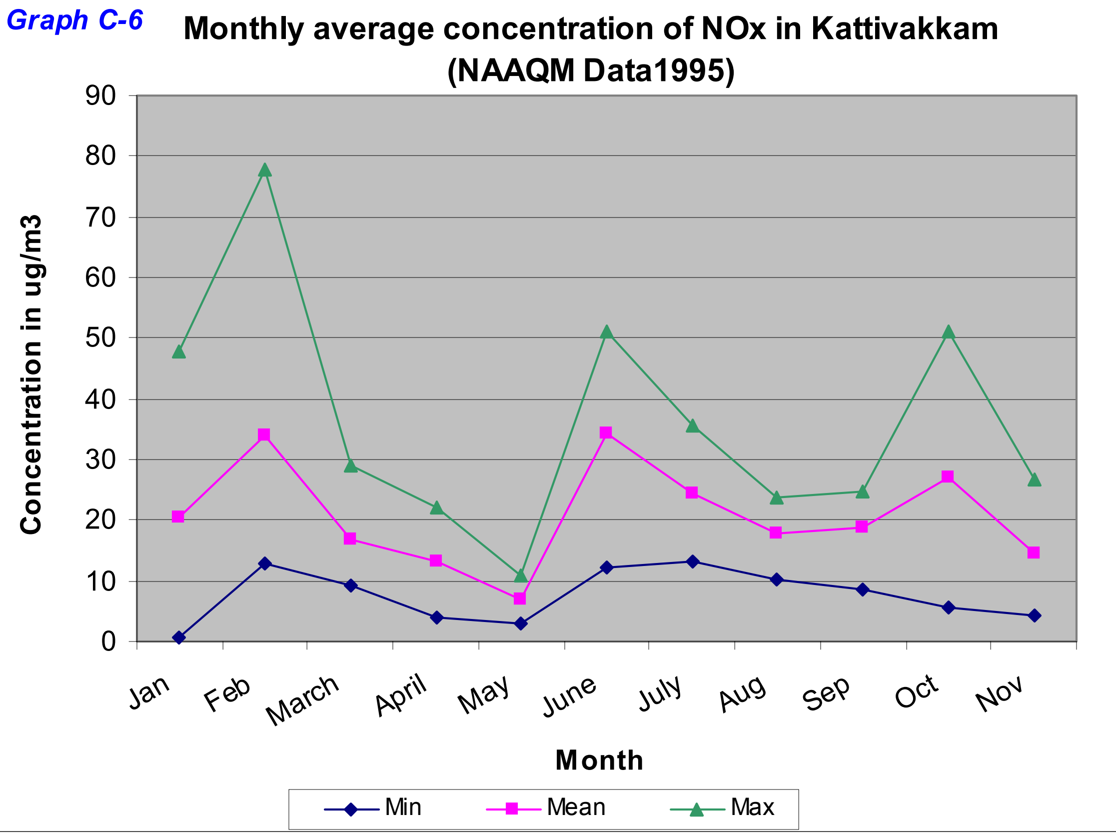

Graph C-3
Annual average concentration of NOx in Kathivakkam
(NAAQM Data1995)
180
160
140
120
100
80
60
40
20
0
Concentration in ug/m3
1990
1991
1992
1993
1994
1995
1996
1997
1998
1999
Year
Min
Mean
Max

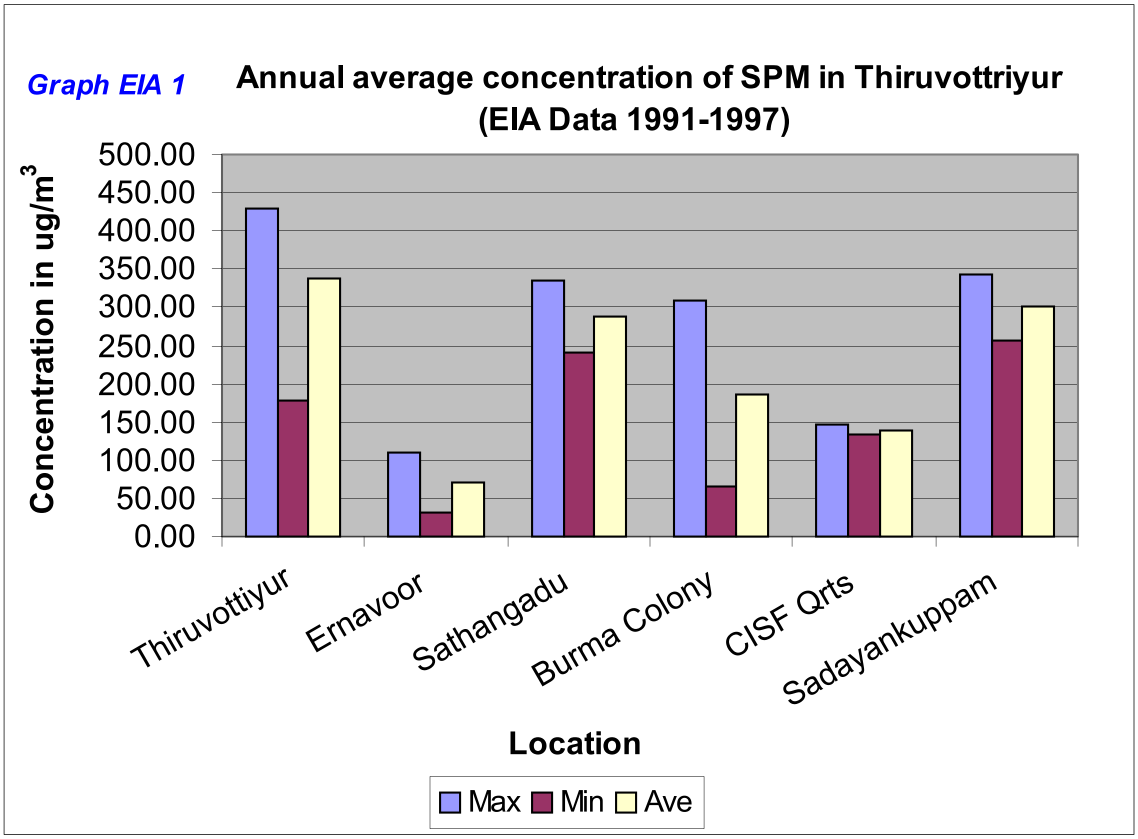

Graph C-4
Monthly average concentration of NOx in Thiruvottriyur
(NAAQM Data 1995)
80
70
60
50
40
30
20
10
0
Concentartion in ug/m3
Jan
Feb
March
April
May
June
July
Aug
Sep
Oct
Nov
Month
Min
Mean
Max

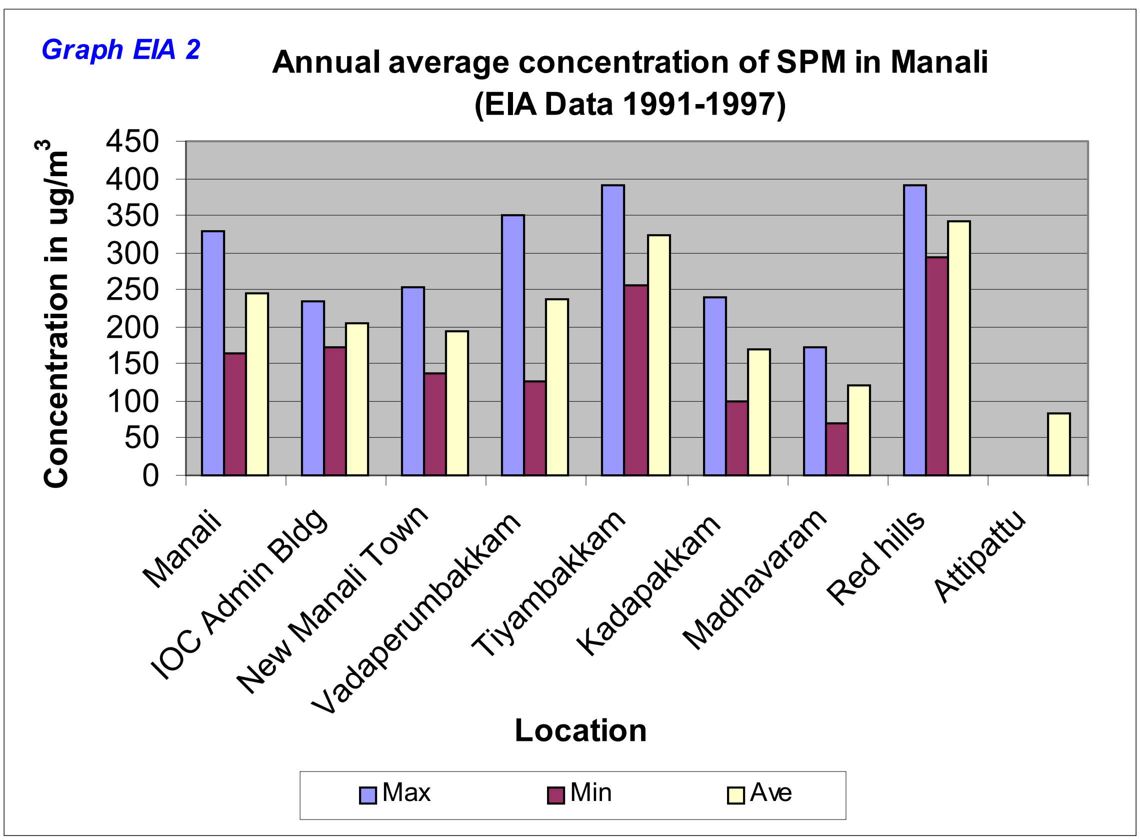
Graph C-5



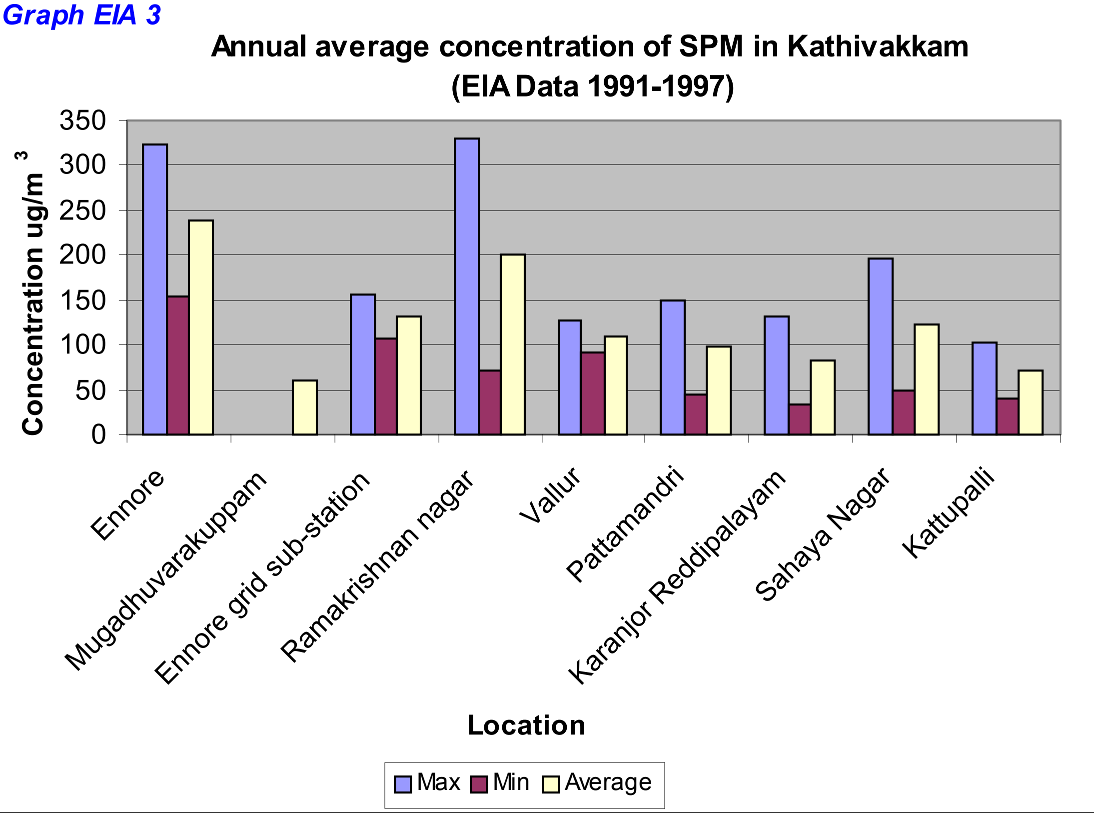
Graph C-6



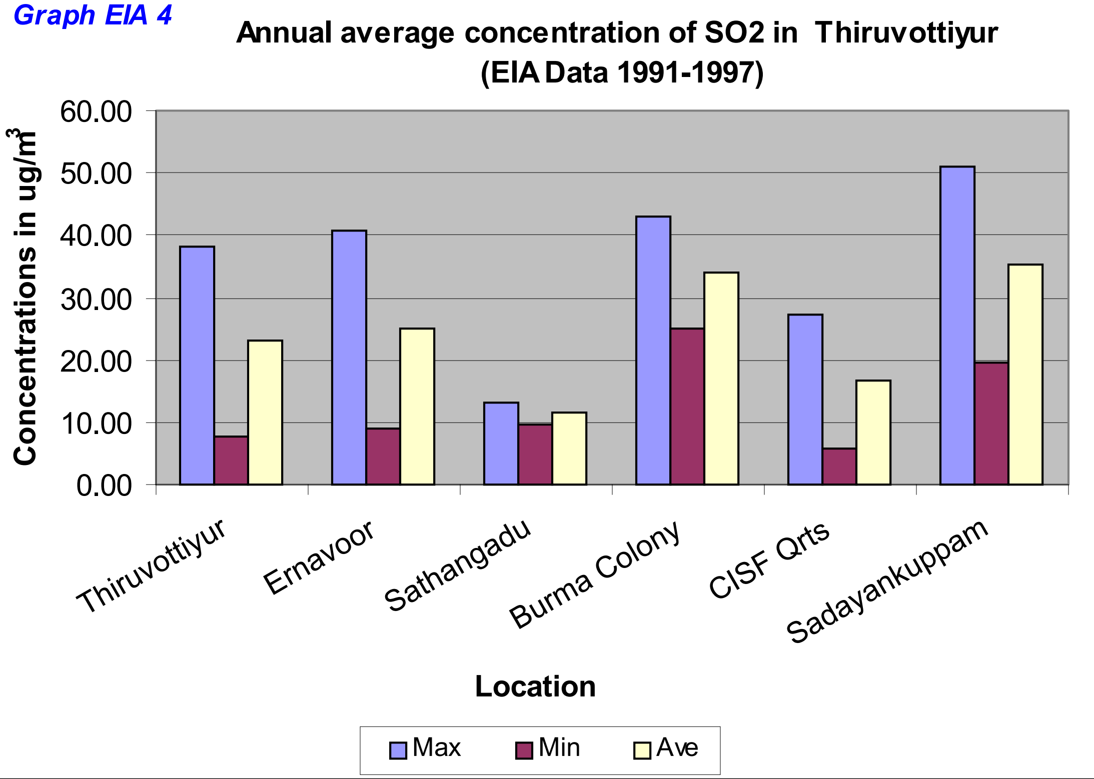

Graph EIA 1
Annual average concentration of SPM in Thiruvottriyur (EIA Data 1991-1997)
Concentration in ug/m3
500.00
450.00
400.00
350.00
300.00
250.00
200.00
150.00
100.00
50.00
0.00
Thiruvottiyur
Ernavoor
Sathangadu
Burma Colony
CISF Qrts
Sadayankuppam
Location
Max
Min
Ave

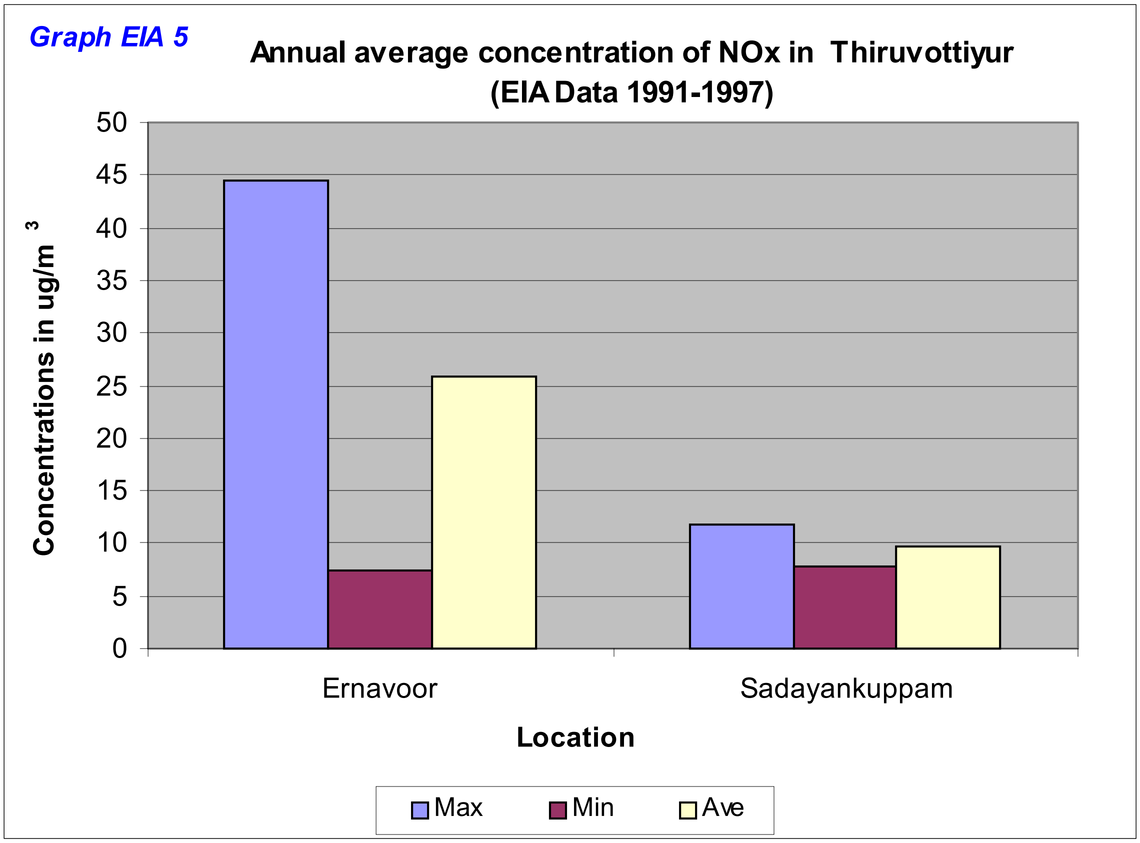

Graph EIA 2
Annual average concentration of SPM in Manali (EIA Data 1991-1997)
Concentration in ug/m3
450
400
350
300
250
200
150
100
50
0
Manali
IOC Admin Bldg
New Manali Town
Vadaperumbakkam
Tiyambakkam
Kadapakkam
Madhavaram
Red hills
Attipattu
Location
Max
Min
Ave

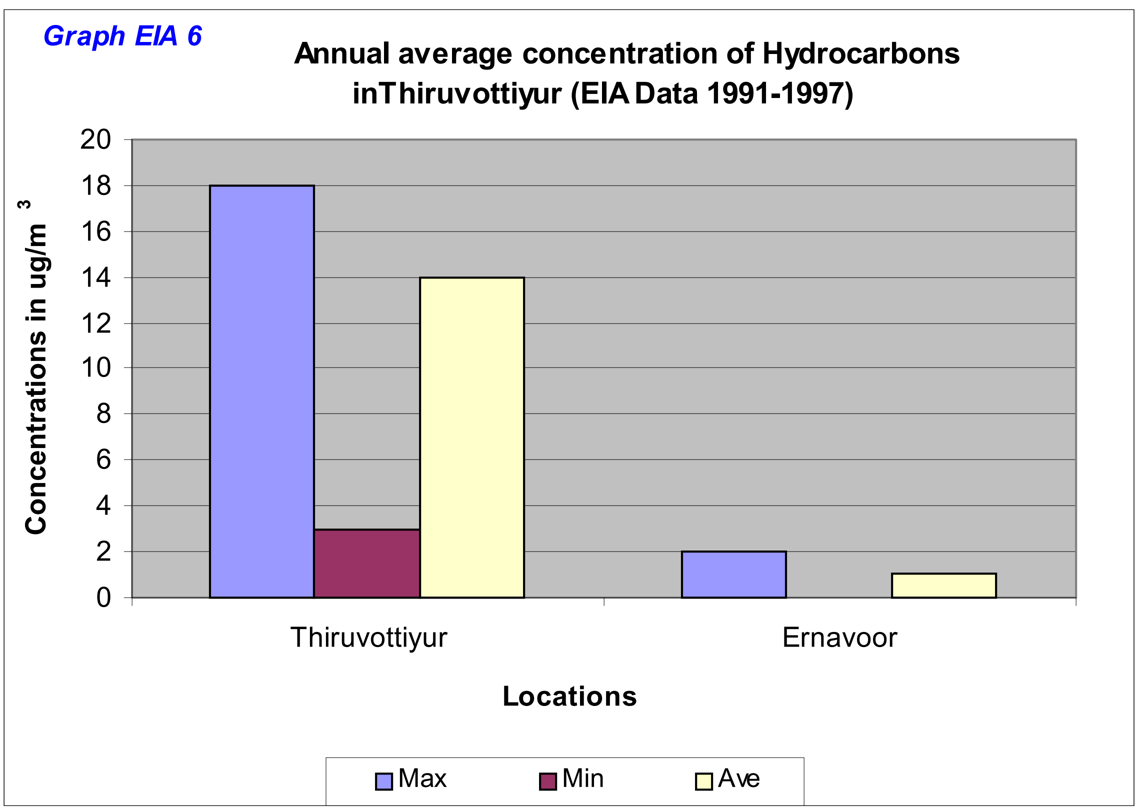
Graph EIA 3



Graph EIA 4




Graph EIA 5
Annual average concentration of NOx in Thiruvottiyur (EIA Data 1991-1997)
Concentrations in ug/m 3
50
45
40
35
30
25
20
15
10
5
0
Ernavoor
Sadayankuppam
Location
Max
Min
Ave


Graph EIA 6
Annual average concentration of Hydrocarbons inThiruvottiyur (EIA Data 1991-1997)
Concentrations in ug/m 3
20
18
16
14
12
10
8
6
4
2
0
Thiruvottiyur
Ernavoor
Locations
Max
Min
Ave

Results of Indoor Air Quality Measurements

Graph IAQ-1

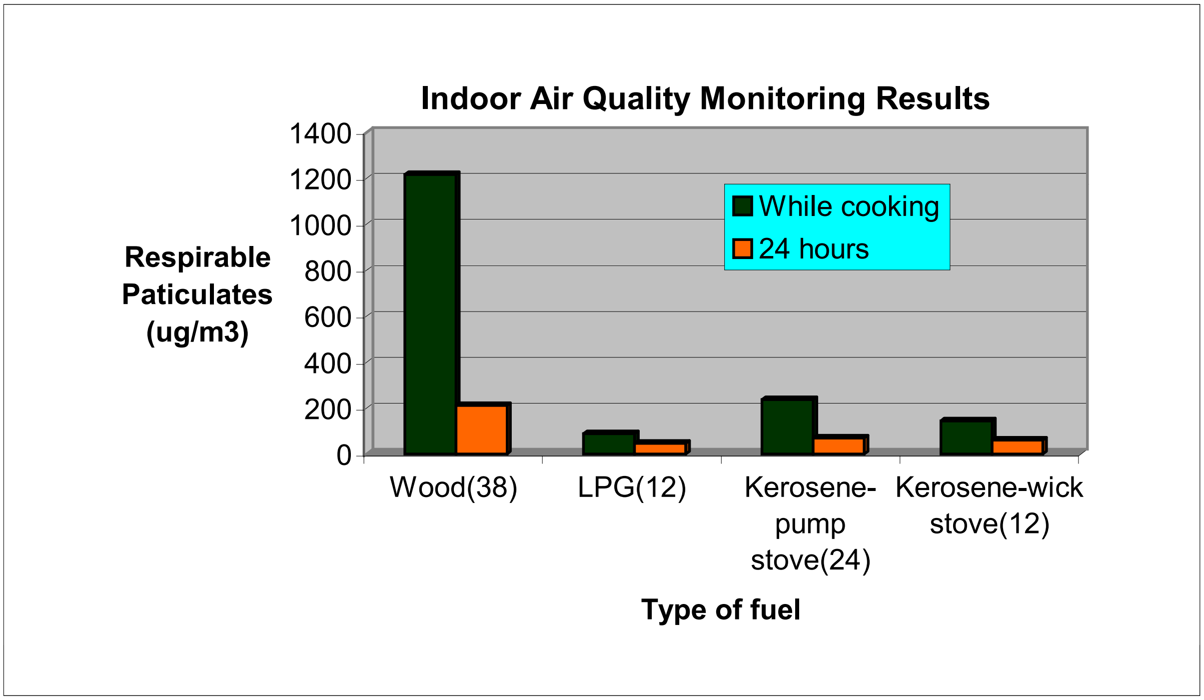
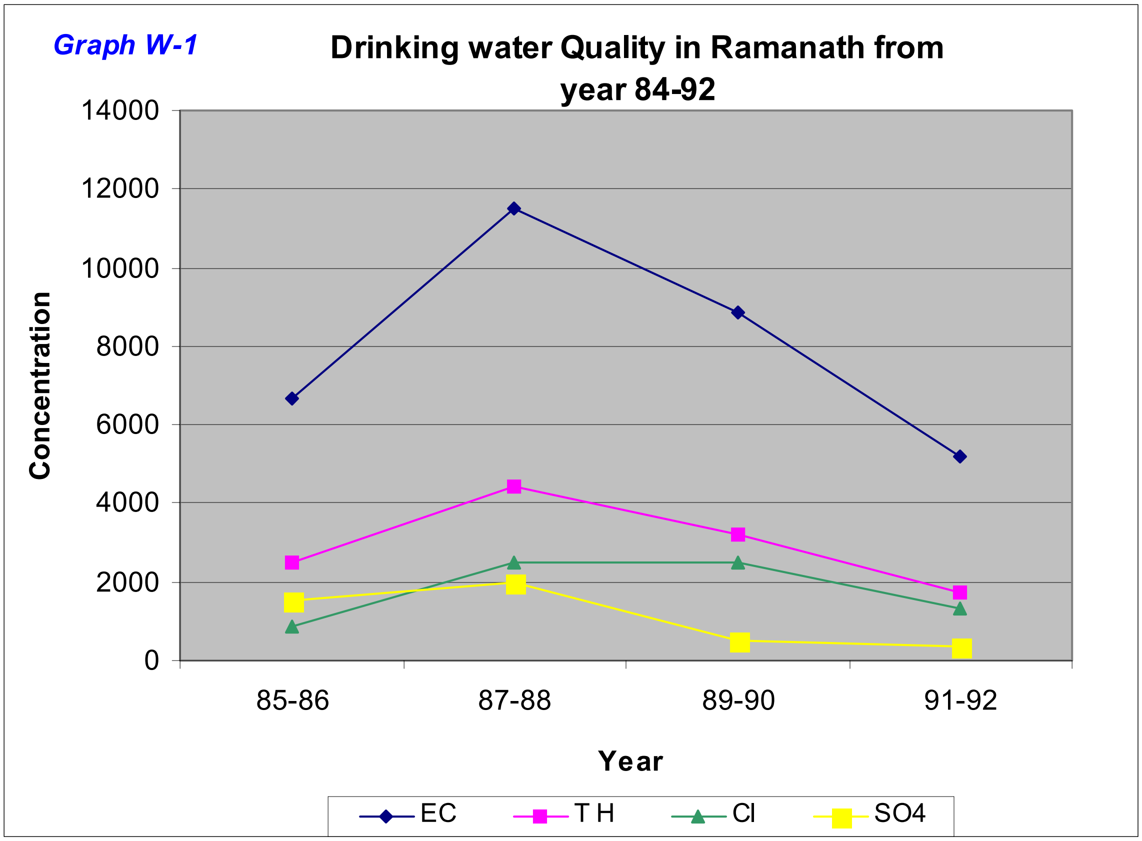
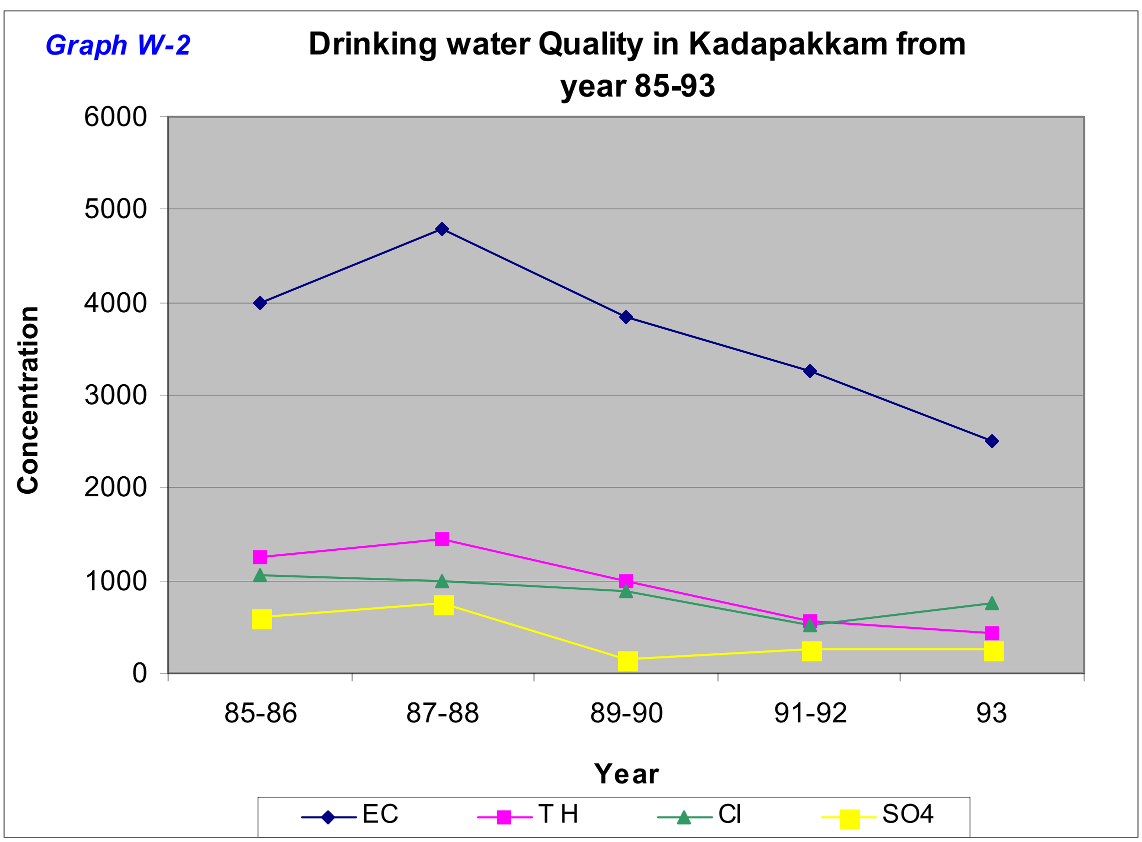
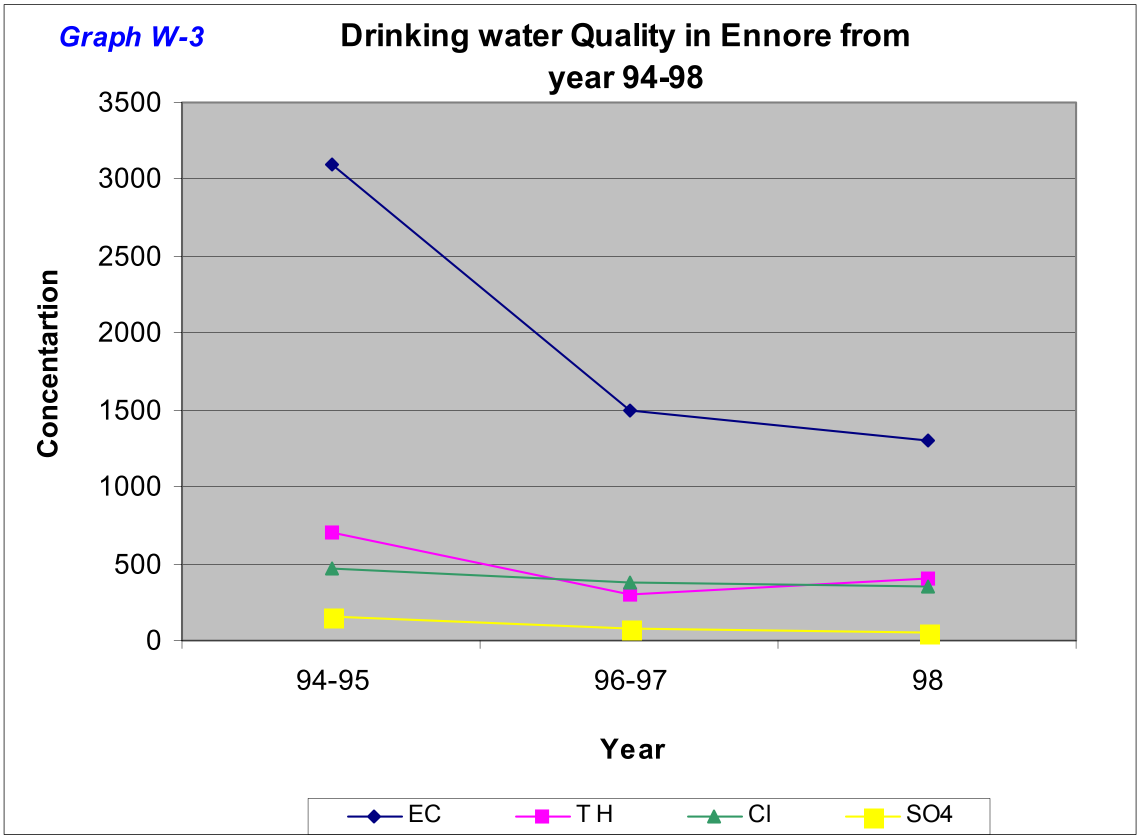


Table IAQ-1

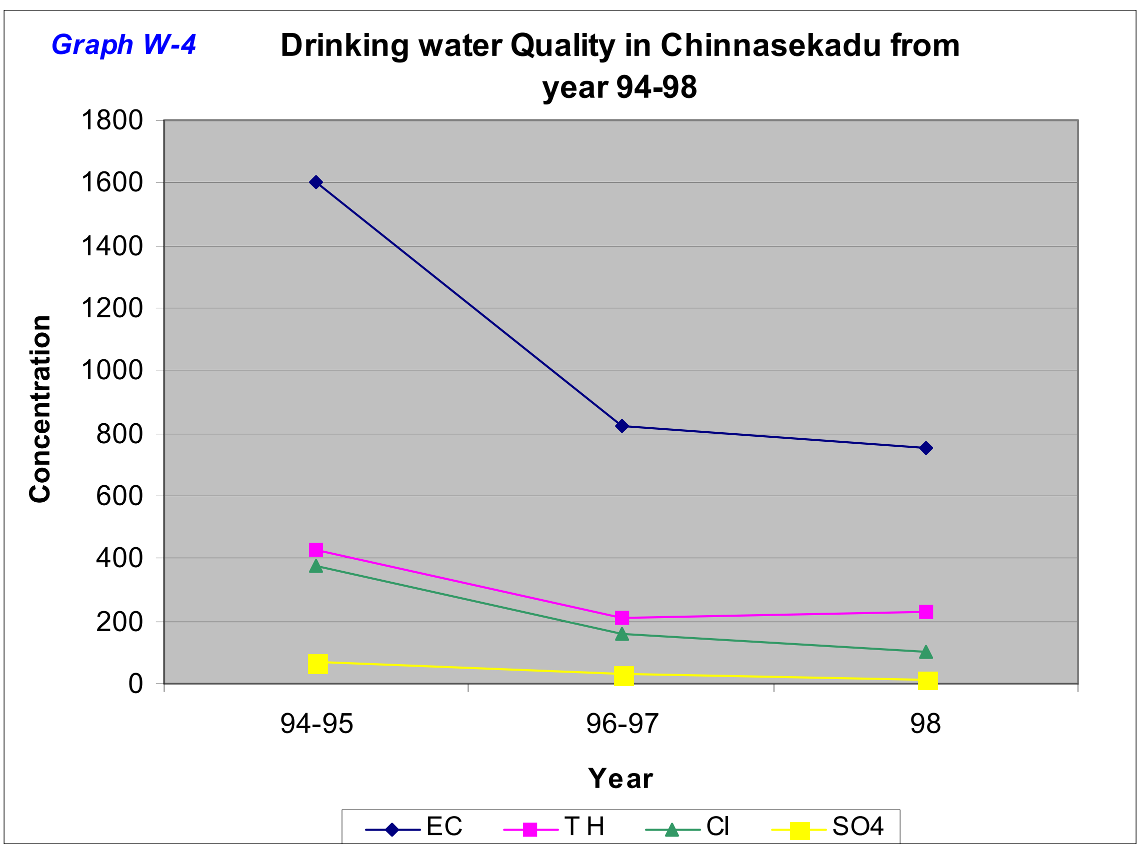
Percentage of homes exceeding WHO short term guidelines while cooking			
Type of Fuel	**CO**	**SO2**	**NO2**
Wood	67%	14%	12%
Cow dung + Kerosene	54%	16%	15%
Kerosene	1%	0	0


Graph W-1
Drinking water Quality in Ramanath from year 84-92
14000
12000
10000
8000
6000
4000
2000
0
Concentration
85-86
87-88
89-90
91-92
Year
EC
T H
Cl
SO4

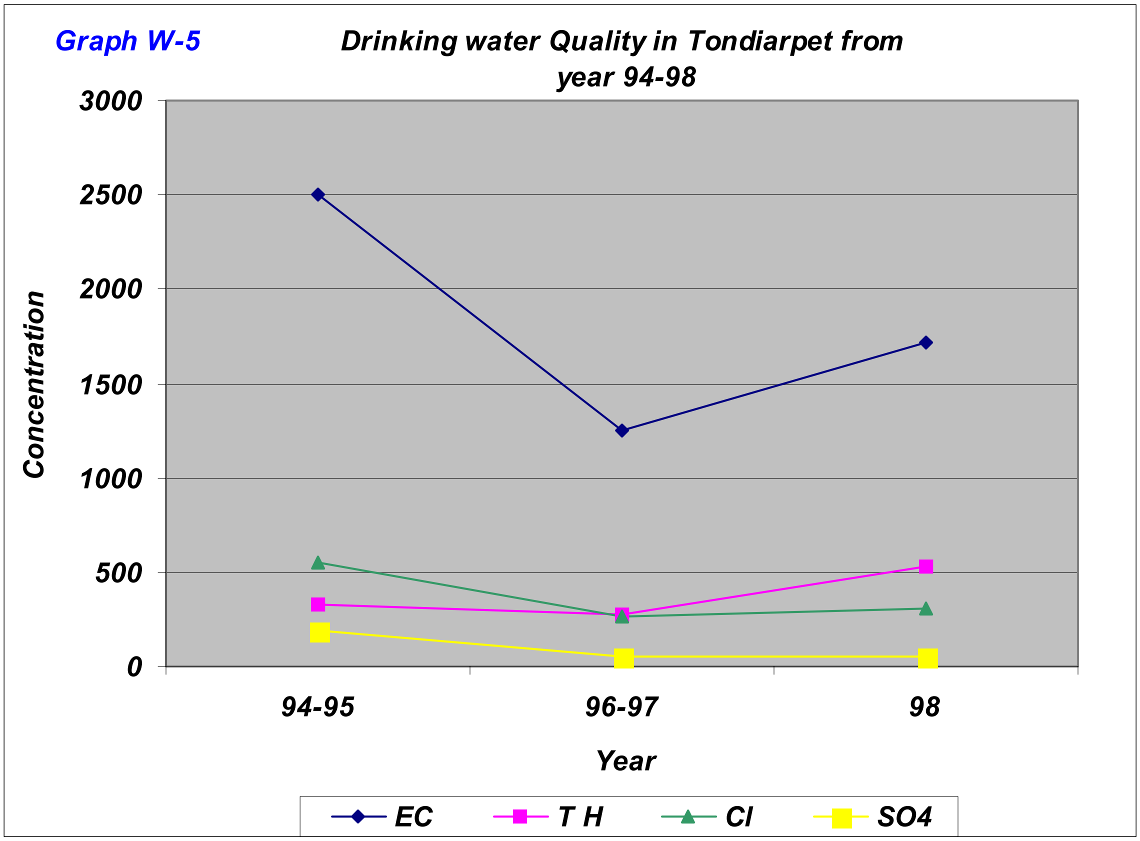

Graph W-2
Drinking water Quality in Kadapakkam from year 85-93
6000
5000
4000
3000
2000
1000
0
Concentration
85-86
87-88
89-90
91-92
93
Year
EC
T H
Cl
SO4



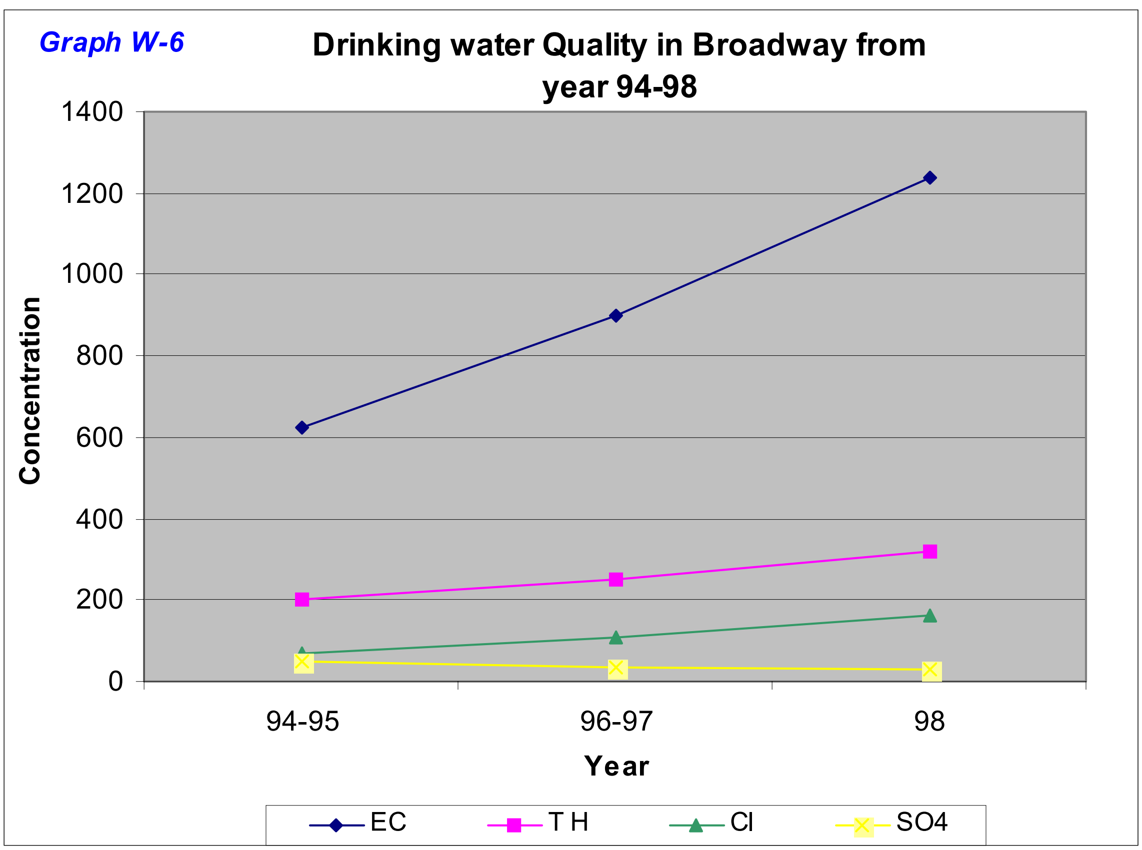
Graph W-3
Drinking water Quality in Ennore from year 94-98
3500
3000
2500
2000
1500
1000
500
0
Concentartion
94-95
96-97
98
Year
EC
T H
Cl
SO4



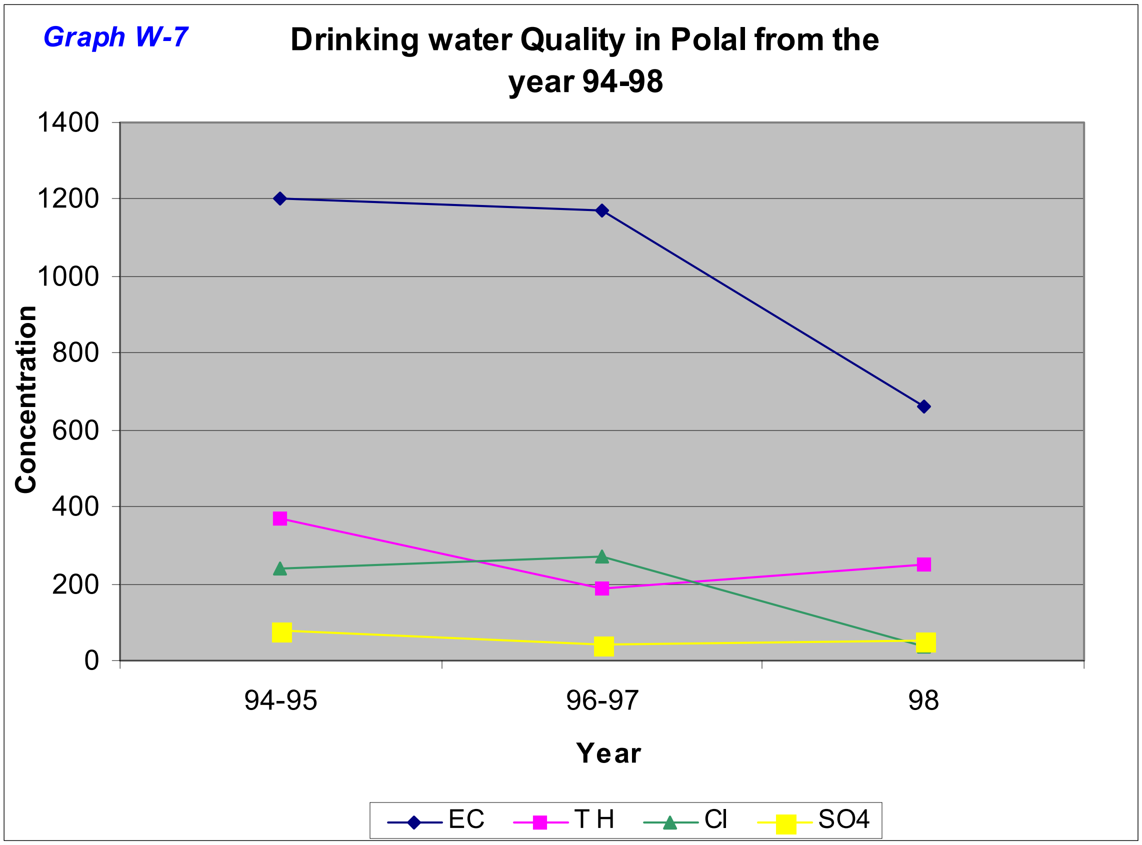
Graph W-4
Drinking water Quality in Chinnasekadu from year 94-98
1800
1600
1400
1200
1000
800
600
400
200
0
Concentration
94-95
96-97
98
Year
EC
T H
Cl
SO4

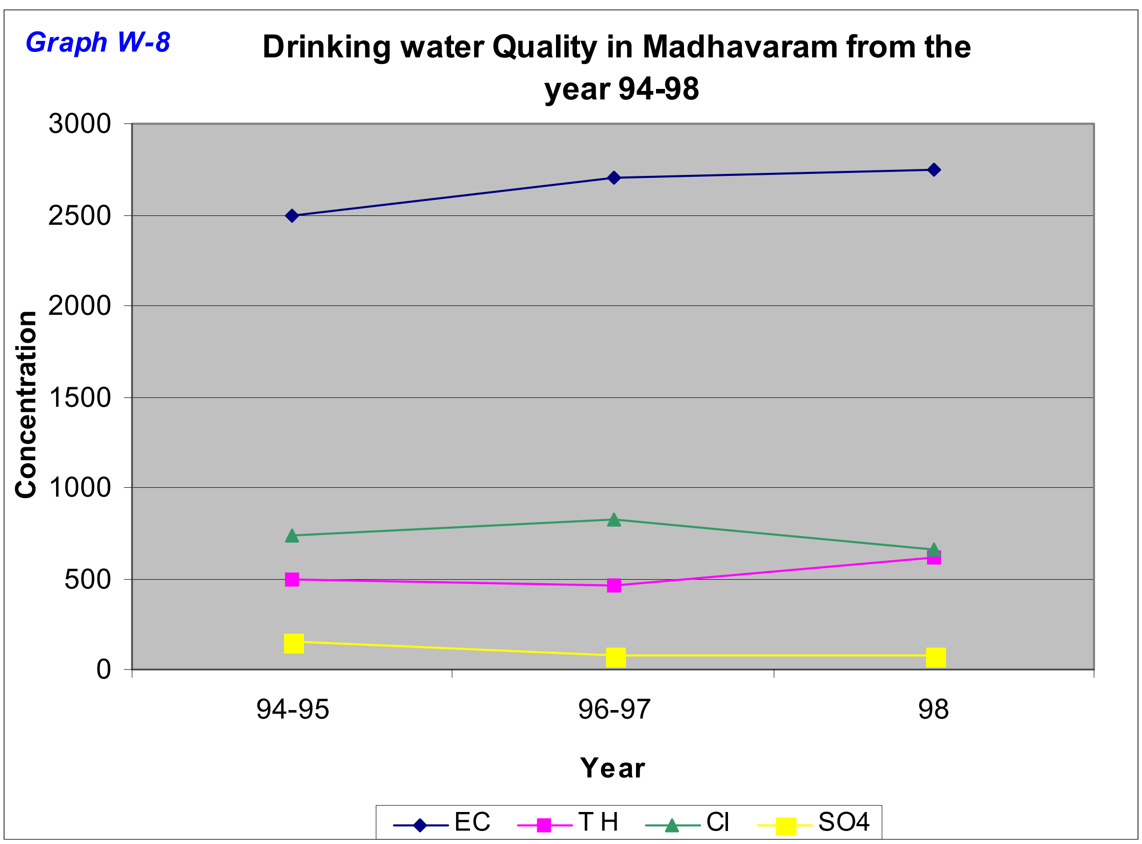


Graph W-5
Drinking water Quality in Tondiarpet from year 94-98
3000
2500
2000
1500
1000
500
0
Concentration
94-95
96-97
98
Year
EC
T H
Cl
SO4

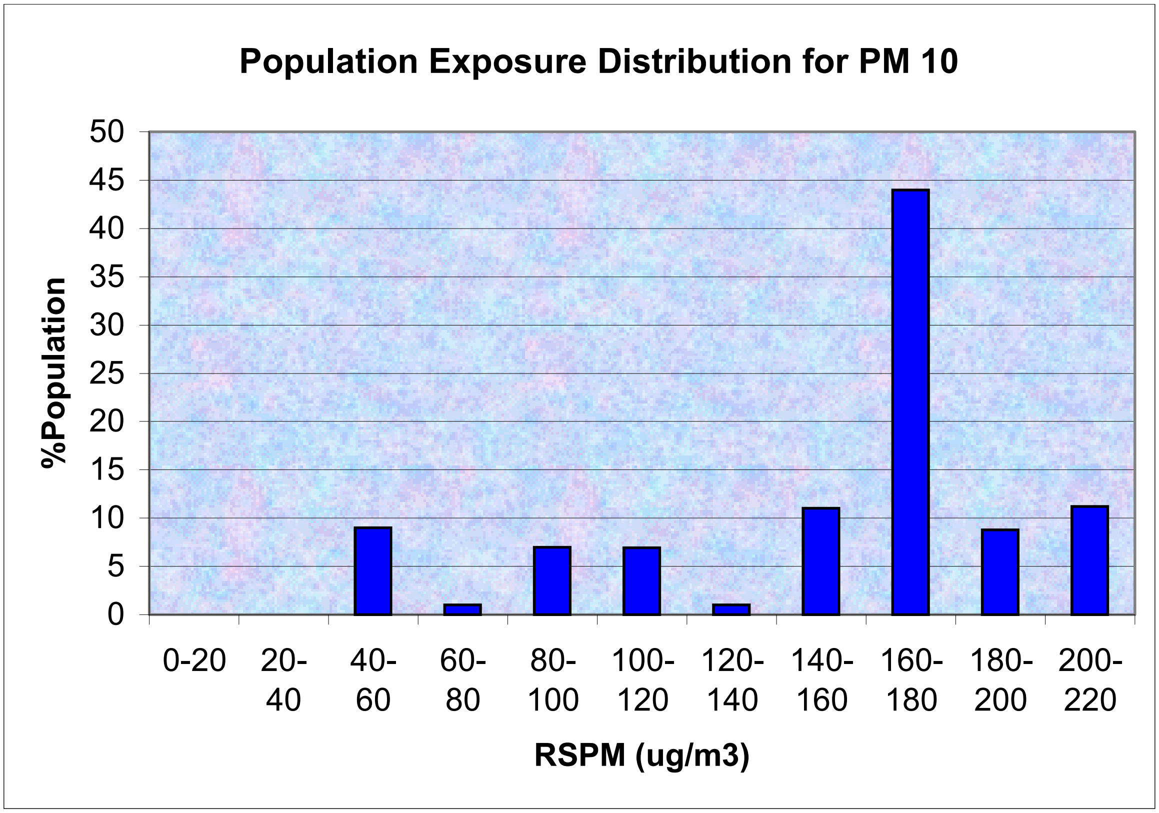


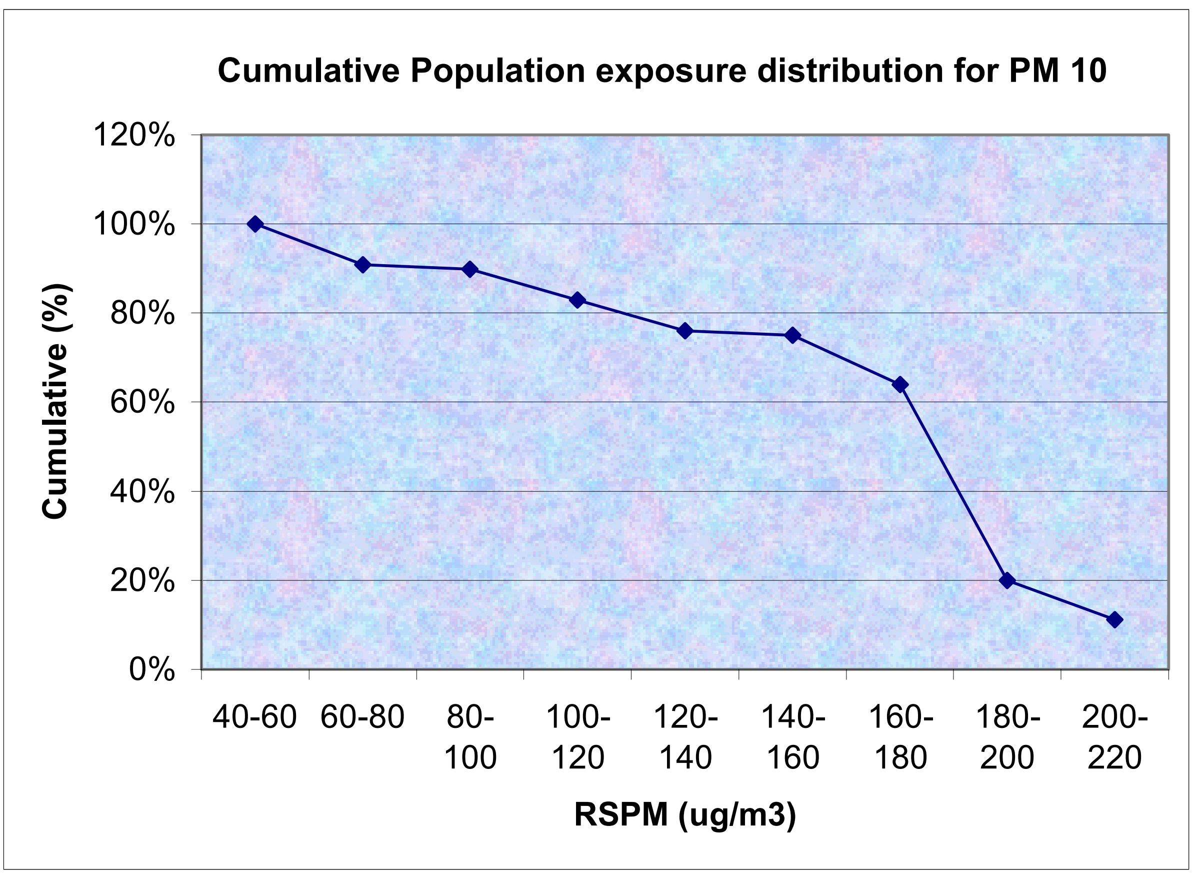
Graph W-6
Drinking water Quality in Broadway from year 94-98
1400
1200
1000
800
600
400
200
0
Concentration
94-95
96-97
98
Year
EC
T H
Cl
SO4


Graph W-7
Drinking water Quality in Polal from the year 94-98
1400
1200
1000
800
600
400
200
0
Concentration
94-95
96-97
98
Year
EC
T H
Cl
SO4

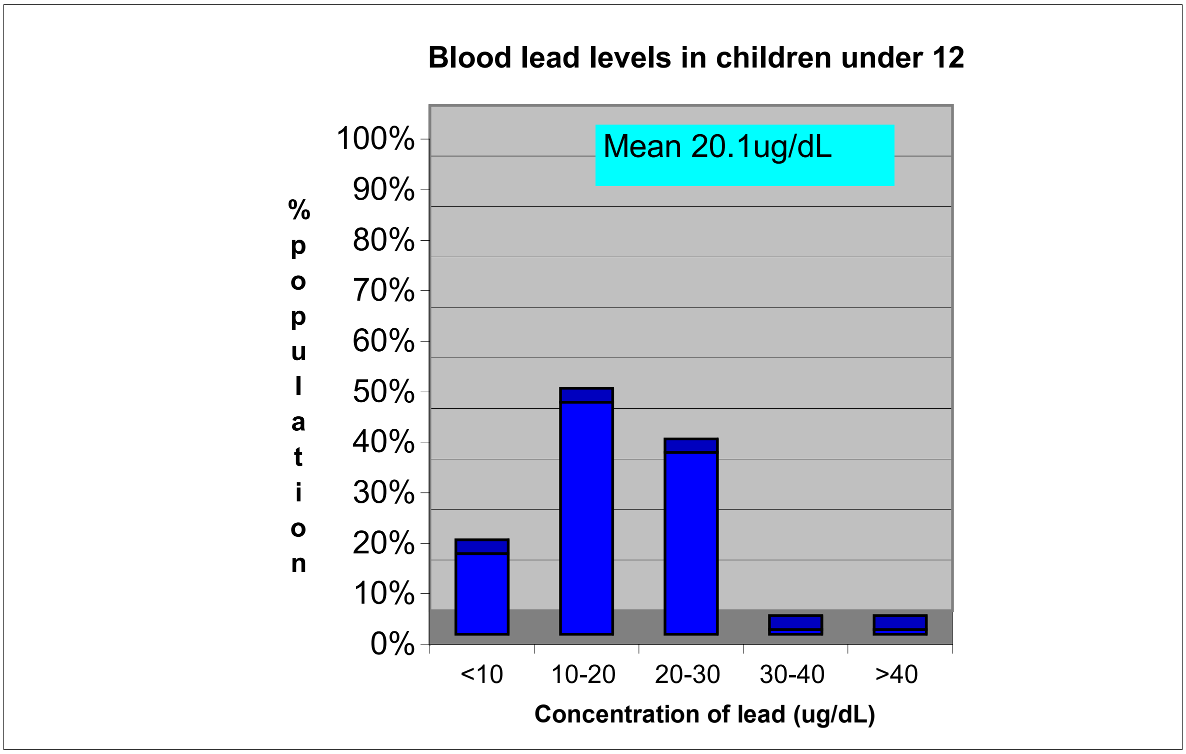

Graph W-8
Drinking water Quality in Madhavaram from the year 94-98
3000
2500
2000
1500
1000
500
0
Concentration
94-95
96-97
98
Year
EC
T H
Cl
SO4

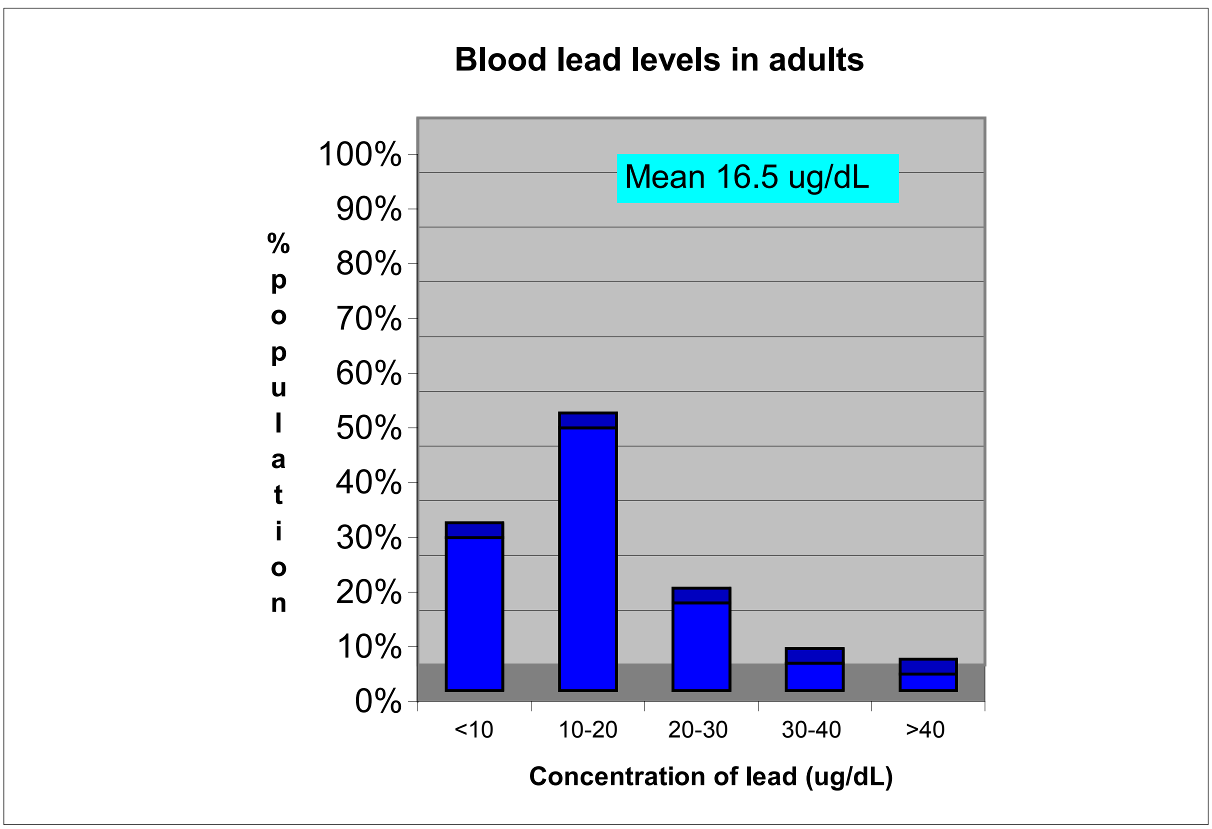
Results of Population Exposure Calculations for PM10 (Graph P1 & P2)





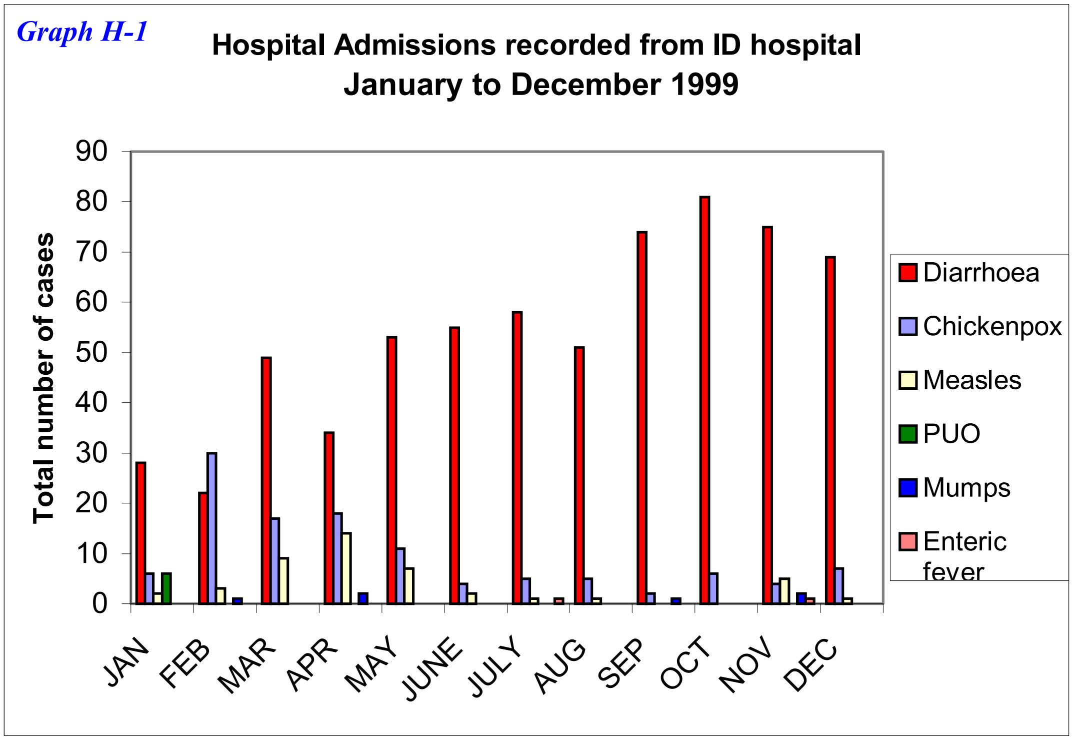
Results of Blood Lead Measurements (Graph L-1 & L-2)



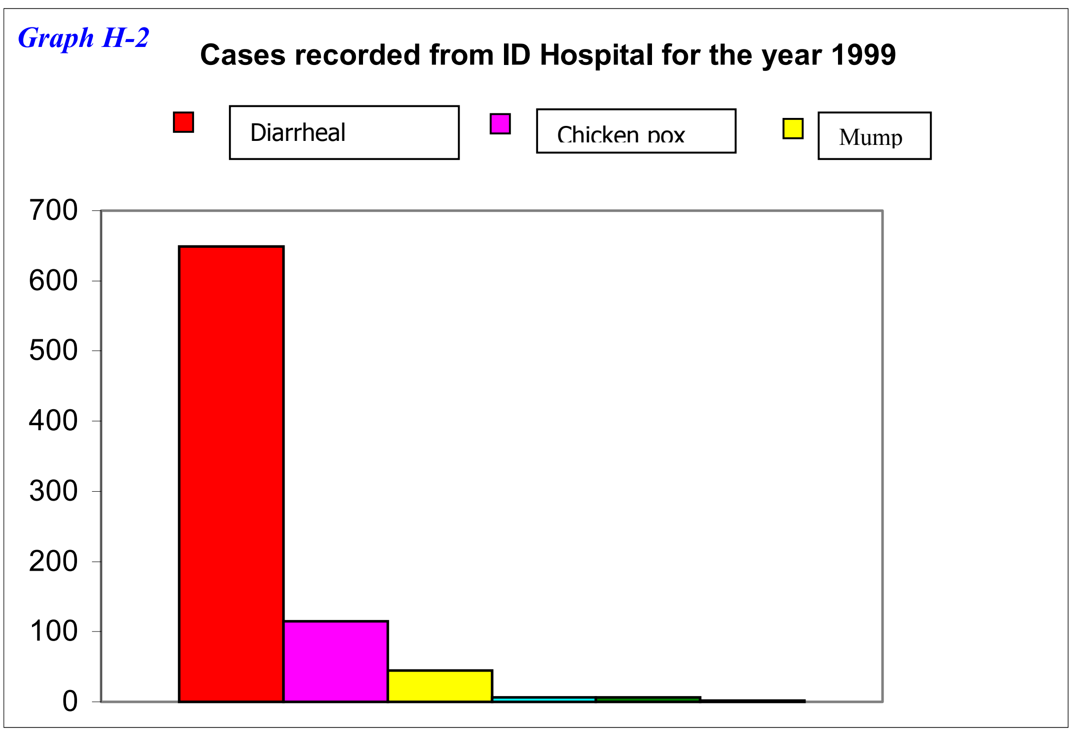


CASES RECORDED FROM VARIOUS HEALTH CARE FACILITIES WITHIN THIRUVOTTIYUR MUNICIPALITY-1999

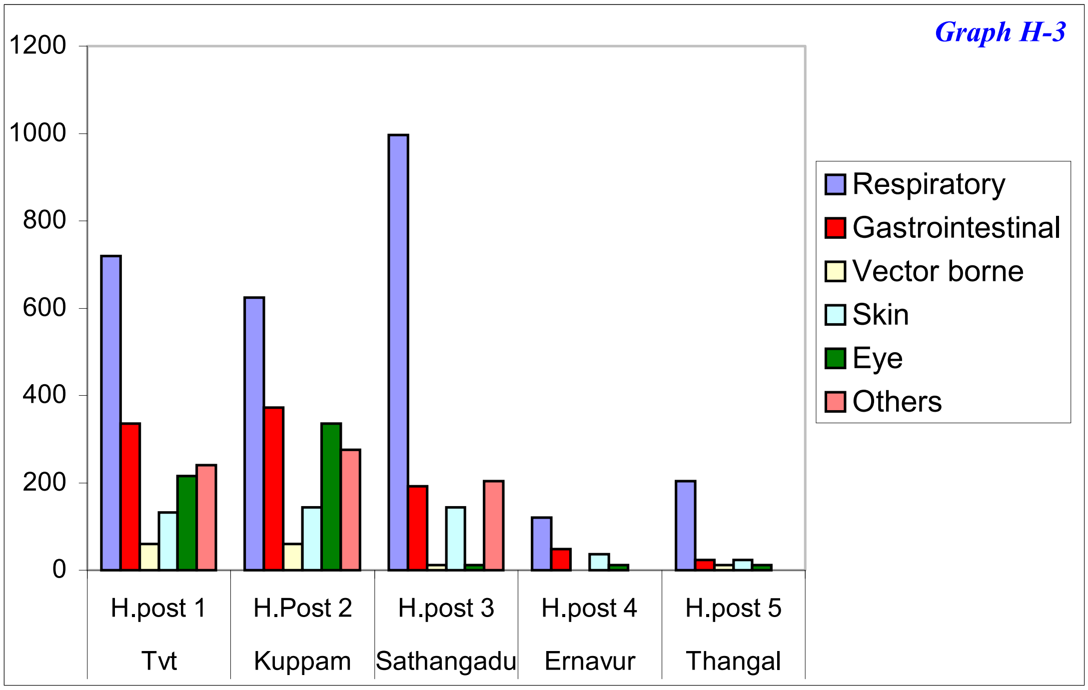
Graph H-1

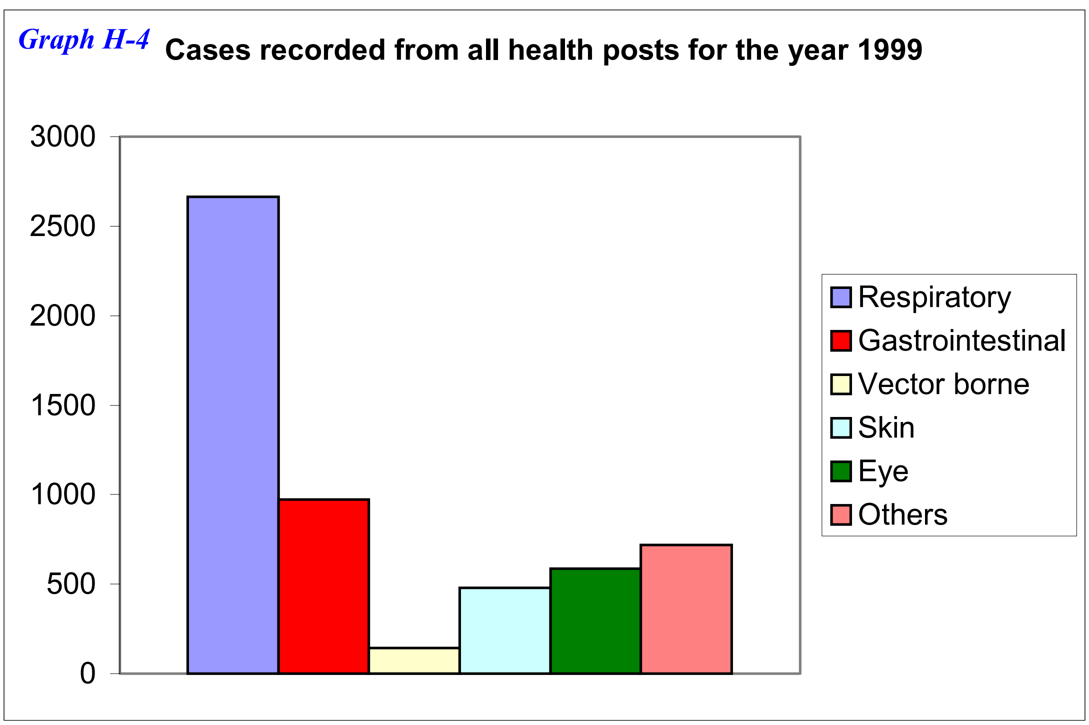


Graph H-2

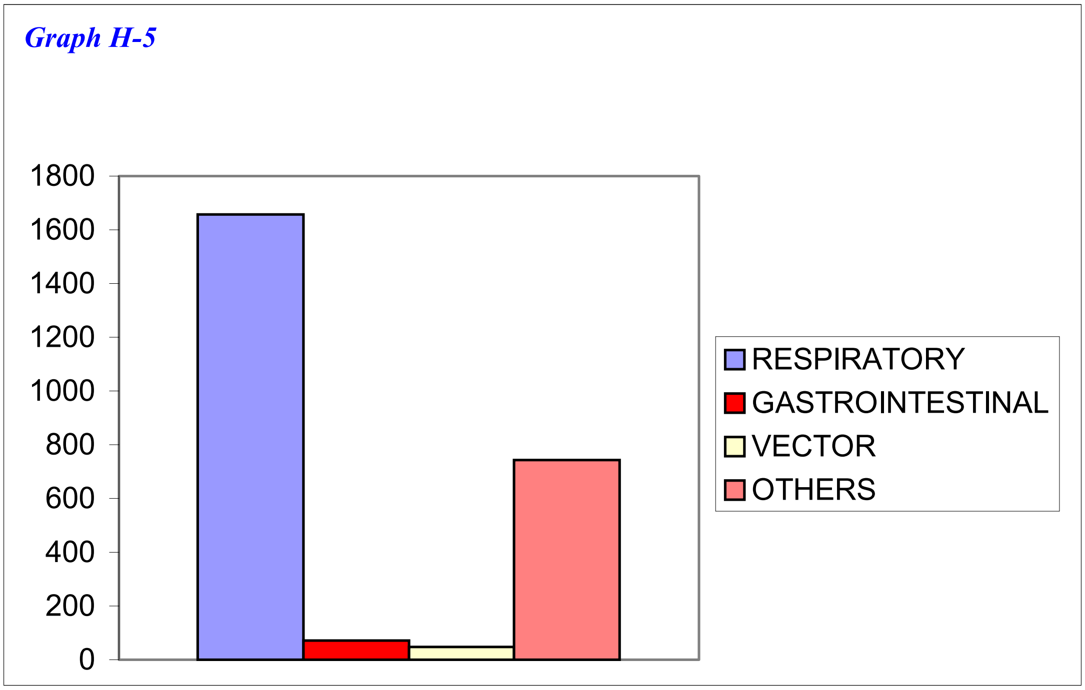


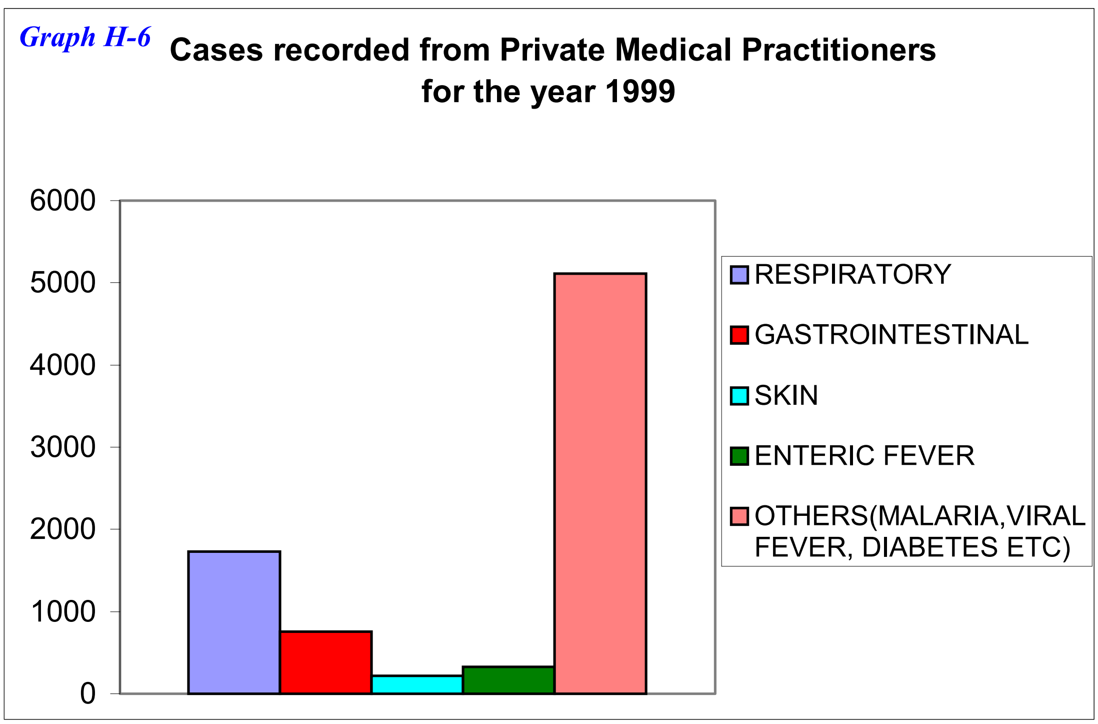
Cases recorded from Health posts within the Municipality for the year 1999



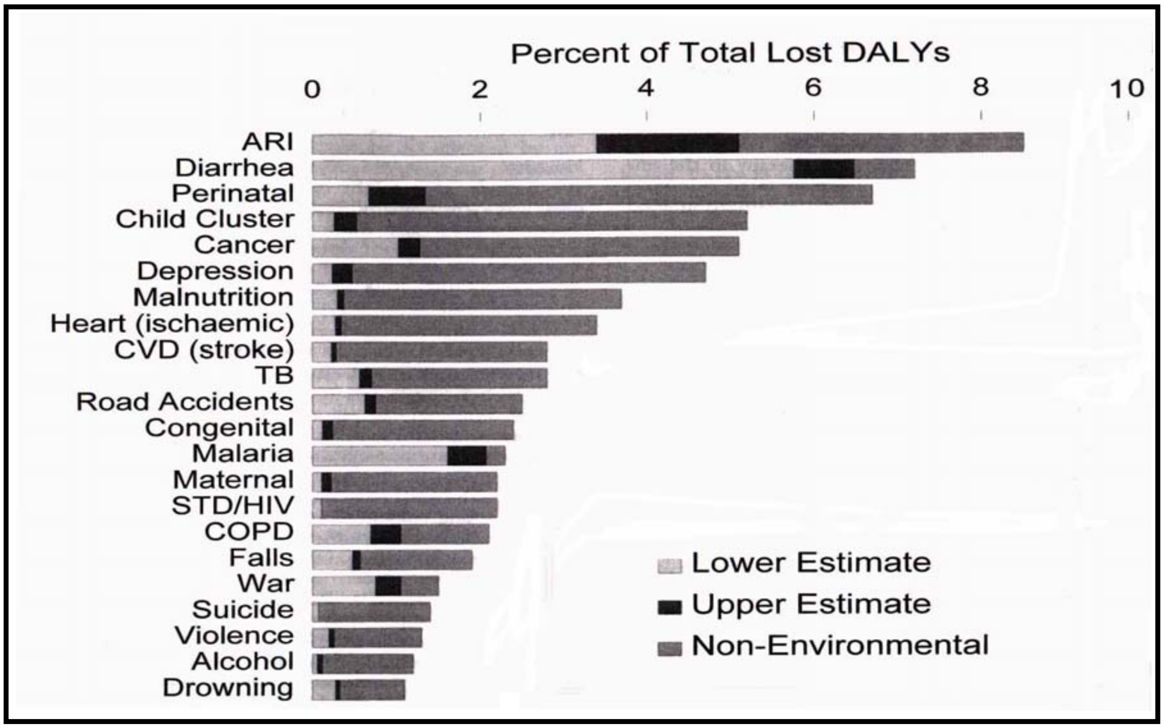


Outpatient Cases recorded from Stanley and Thondiarpet Peripheral Hospitals for the year 1999

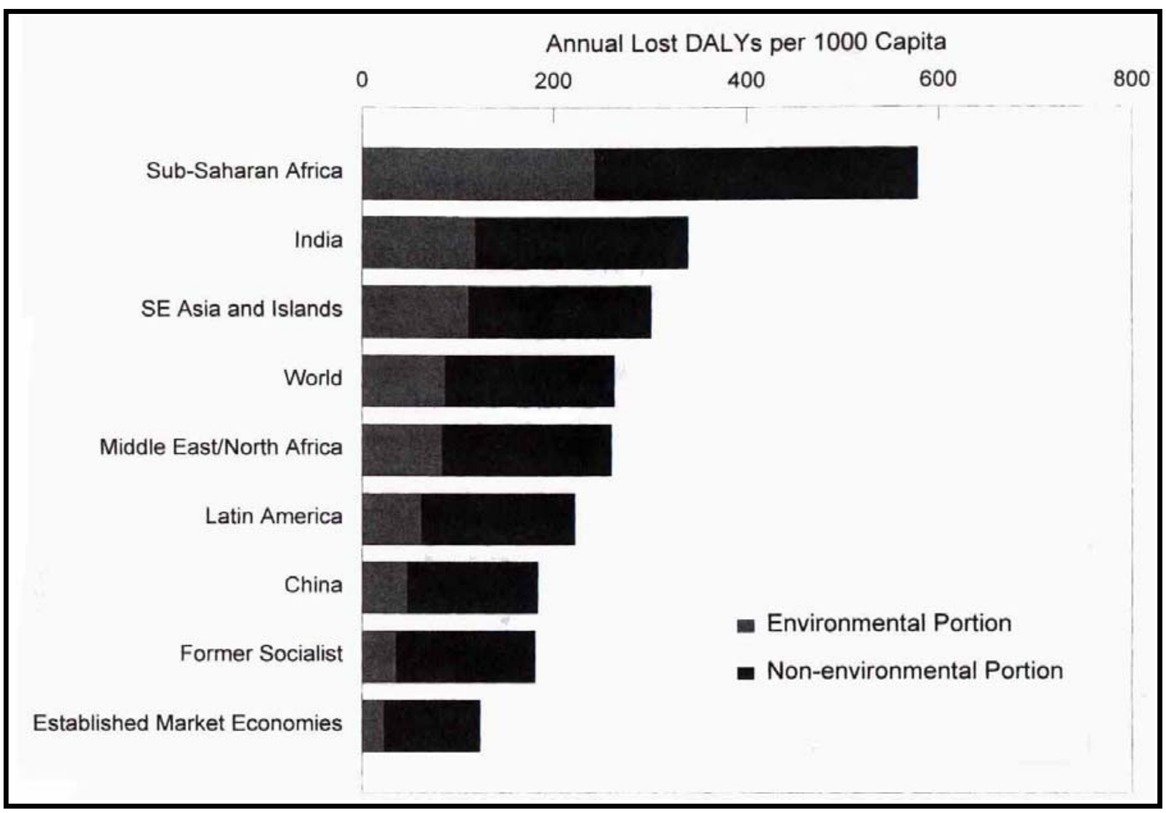




Environmental contribution to the global burden of disease-All disease categories, each responsible for at least one percent of lost disability-adjusted life years (DALYs)



Environmental portion of disease in the major world regions



Source : Epidemiology, 10 (5), 573-584, September 1999