Reconciling Environment and Economics: Executive Summaries of EERC Projects

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Sponsored by
Ministry of Environment and Forests
The World Bank

CITATION:

Jyoti K Parikh and T.L. Raghu Ram eds. (2003). ***Reconciling Environment and Economics: Executive Summaries of EERC Projects***. Environmental Economics Research Committee under the Ministry of Environment and Forests implemented, World Bank aided "India: Environmental Management Capacity Building (EMCaB) Project. Indira Gandhi Institute of Development Research, Mumbai.

ENVIRONMENT, HEALTH AND ECONOMICS

Economic Analysis of Rural Pollution and Health Impacts in Northern India: A Multi-institutional Project

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Introduction

The rural population of India, and many other developing countries, suffer from serious problems of indoor air pollution due to kitchen smoke, unsafe water and lack of sanitation. These problems are critical to local environment. The World Bank estimates that improvements in local environmental conditions faced by the poor could lower incidences of the major killer diseases by up to 40 percent.

Much of the previous research on environment and health issues facing rural areas of developing countries is fragmented and contains only partial analysis. Causal links between symptoms and rural conditions have not been convincingly established. For example, disease analysis may be done, but pollution levels are not measured; or in some surveys, pollution levels are recorded, but socio-economic data is not collected. Wide-ranging and coherent studies are needed to address the problems prevalent in rural areas. It was with this objective in mind that the survey on *Energy, Water, Sanitation and Health Issues in Rural North India* was undertaken. The *comprehensive* and *multi-disciplinary study* was conducted in three states of rural north India; namely Uttar Pradesh, Rajasthan and Himachal Pradesh. It has a large random and representative sample population and incorporates a number of other relevant factors. It investigates the links between health and household fuel use, *indoor* air pollution, water safety and sanitation; concentrating in particular, on the role of and effects on *women*. A focus on economic aspects such as "willingness to pay" for clean fuels or infrastructure improvements and the health costs incurred due to illness are also key features included in the survey. A number of questions were addressed within each of these areas.

Objectives

The major objectives of the study are to:

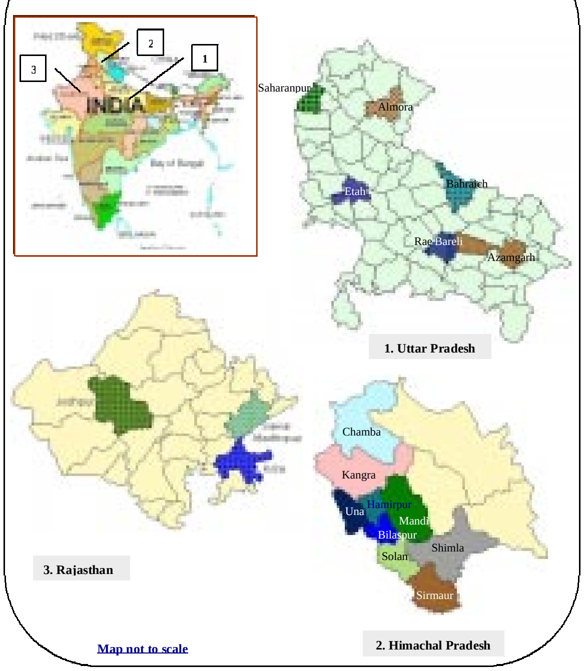
- Analyse energy consumption pattern, its procurement and energy transition.
- Factors affecting the use of clean fuels.
- Find out the levels of indoor air pollution due to cooking.
- Analyse water and sanitation issues.
- Record health impacts due to lack of clean energy, water and sanitation facilities.
- Assess willingness to pay to improve energy, water and sanitation facilities.
- Assess economic burden of using dirty fuels, unsafe water and inadequate sanitation facilities.
- Assess people's environmental priorities.

The Integrated Survey

To understand the impact of lack of energy, water and sanitation on health and human resources, an integrated survey was conducted covering 10,265 rural households (HHs) from 118 villages of 18 districts in three states of Rural North India (RNI) namely: Gangetic plains of Uttar Pradesh (UP includes Uttaranchal), dry desert zones of Rajasthan and the mountainous ecosystem of Himachal Pradesh (HP). These states were selected because of their geo-ecologic, socio-economic and locational conditions that represent Rural North India (RNI). Location of these states is given in Figure 1. The three sampled states represent a large share of many attributes of RNI. They cover over 87 percent of the inhabited villages, 83 percent of rural households, 82 percent rural population (187 million of 226.23 million people) and 69 percent of the land area in RNI. These three states constitute 63 percent of net domestic product at current prices (1998-99).

Data was collected from households and individuals relating to use of different fuels, access to clean water, sanitation facilities, symptoms of diseases, expenditure on health, demographic and socio-economic information. At the same time, measurements of air quality in the kitchen and outside the home were carried out in UP. Health surveys were carried out for 58,768 individuals. Indicators for lung functions (Peak Expiratory Flow) were measured for most of the adult individuals present at the time of the survey. Doctors examined a sub-sample of individuals for presence of diseases. Village level data on health centres, water related and other infrastructure facilities was also collected.

Figure 1: Schematic Map Showing Sampled Districts in Uttar Pradesh, Rajasthan and Himachal Pradesh



Methodology

Selection of Villages and Households: The survey was designed in such a way that it represented various socio-economic and geo-ecological and location zones. Accordingly, three states namely UP, Rajasthan and HP were selected from northern India. The households were selected by using multistage stratified sampling design to have a representative sample. At ***stage one***, stratification of each state was done on the basis of its broad socio-cultural regions (SCRs). A representative district from the median population was selected from each SCR. At ***stage two,*** stratification of districts was done by village population sizes. The villages were divided into four strata on the basis of population data available from Census 1991. In stratum 1, villages with population less than 1000 were included; stratum 2 had villages with population 1000-3000, whereas in stratum 3, villages with population between 3000-5000 were included. The 4th stratum with village population more than 5000 were excluded from the sample because these villages resemble semi urban areas. At ***stage three,*** the selection of the villages from each stratum was done using probability proportional to size (PPS) sampling method. Selection of households (***stage four***) within selected villages was done using systematic random sampling. The number of sample households in each district were in proportion with the universe distribution of rural households in these selected districts.

Survey Coverage: The survey was conducted at two levels, viz. individual level and household level. Pollution survey was conducted to record indoor air quality at household level and water quality analysis was done at village level. Additional surveys were carried out at village and health centre level, to get an overall picture of the village and health centre facilities.

Individual level survey: The individual level survey included physiological characteristics. viz. age, sex, height, weight, health related data and behavioural characteristics such as smoking habit, literacy, occupation, time activity pattern and cooking behaviour. The household level data was collected to get a comprehensive picture of socio-economic conditions, energy use pattern, water and sanitation related facilities, housing characteristics, cooking behaviour, environmental priorities of women, willingness to pay to reduce kitchen smoke and to improve water and sanitation facilities.

Health Survey: At the individual level, the Medical Research Council (MRC) questionnaire, 1986, UK, for respiratory symptoms was followed, which included questions regarding six symptom categories. The inquiry was made *direct*ly from those who were present during the survey for analysis, according to the MRC protocol. In addition, proxy responses for those who were absent during the survey were obtained from the main respondent and mostly mother's responses for children below 15 years. According to the MRC protocol, only the *direct* responses can be analysed for the respiratory diseases. Therefore, the information collected for absent members and children are analysed separately. This gave us a picture of overall prevalence of respiratory diseases for the adults and also for the children. Measurement of PEF rate, an indicator of airways obstruction, which reflects lung function and the extent to which it is impaired, was conducted for direct cases. Information regarding pregnancy and childbirth related problems were also recorded from women.

Household level Survey:

Survey of energy use pattern and practices: Data on energy use patterns included information on the use of biofuels and commercial fuels for cooking, sources of procurement of cooking fuel, time, distance and effort involved in procurement, progress along the energy ladder of increasingly more convenient fuel, etc. Housing characteristics included information on the number of rooms, type of house and type of kitchen, location of kitchen and number of doors and windows in the kitchen. Further data collected on cooking behaviour, number of meals cooked using different fuels in a day, time spent for cooking, cooking involvement of different groups of individuals and type of involvement. Time activity pattern of the members of household was also recorded. Data collected to assess people's willingness to reduce the impact of indoor air pollution included information on people's choice of type of intervention, reason for not using clean fuels, willingness to pay for additional amount of clean fuel and additional demand for kerosene.

Survey of water and sanitation facilities and health: Data on water availability, source of collection, efforts required to fetch water, problems faced in collection, type of problems, water quality, water storage and purification practices, etc, was obtained. The occurrence of water related diseases such as worms in stool, diarrhoea and jaundice, and associated health expenditure and days lost due to suffering were recorded. Data on availability of sanitation and sewerage facilities and willingness to contribute to improve water, sanitation and sewerage facilities was also collected.

Additional Surveys

Measurement and monitoring of indoor air quality: (IAQ) were carried out in 519 households of UP. Kitchens were categorised into four types- i) inside living room; ii) separate kitchen - inside the house, iii) separate kitchen - outside the house, and iv) no kitchen - open air cooking. Locations of the personal samplers were decided based on the type of kitchen and layout of the house. To assess the personal exposure, one sampler was attached to the chief cook during the cooking period. One sample was collected at a distance of about 2m away from the stove but inside kitchen/room to assess exposure of other family members. One sample each was collected from the living room and one from the open space of house i.e. veranda, etc., where people spend most of their time, to assess the effects of cooking operations in these areas. In addition to Respirable Suspended Particulate Matter (RSPM) observations, measurements for SO_2, NOx and CO were taken during the cooking operation at these locations. Indoor air pollution monitoring was carried out during the cooking period extending upto 3 hrs.

Water quality tests were performed in all the selected villages across the three states. Water samples were taken directly from the sources accessed by the villagers. A total of 137 samples were tested for dissolved oxygen, biological oxygen demand (BOD), nitrate, total coliform and fecal coliform.

Village level surveys were done to corroborate the data acquired at the household and individual level, and also to get an overall picture of the village. The distances of a village from the nearest road, bus stop and railway station, as well as the distance from any air polluting industry were also recorded.

The *health centre survey* established the type of health facilities available to village residents in terms of number of beds, medical equipment and sanitation standards. Through the use of a questionnaire (that differed in content from the household questionnaire), facts about patient numbers and prevalence of respiratory and water borne diseases including information about seasonal variations were gathered.

The data was analysed and then extrapolated for RNI to gain some macro level understanding and to get some policy insights. For energy and water related issues, extrapolations based on sample proportions were applied to the total rural households in RNI, whereas health related extrapolations were based on sample proportions applied to rural population in RNI.

The states wise break up of the sample is given in Table 1.

Table 1: State wise break up of the Sample

Coverage level	State			Total
	Uttar Pradesh	Rajasthan	Himachal Pradesh	
Districts	6	3	9	18
Villages	51	13	54	118
Households	7564	1989	712	10265
Individuals	42713	11955	4100	58768

Demographic profile of the individuals and socio-economic profile of the sample households are given in the Annexure.

Results

Highlights of the Energy Scene in Rural North India

A large proportion of households in RNI, as shown in Box 1, depend on biofuels, which are gathered by spending 8 billion human hours annually. Such a high amount of human labour, if put to better use, can bring prosperity in the region. In spite of high willingness to pay to purchase kerosene even at *higher than market price*, the kerosene supply is not adequate. If the demand of 49 percent of the households, who are willing to pay *more than market price,* to purchase kerosene for cooking is met, it can reduce pressure on human and forest resources substantially and also provide better living conditions. Twenty seven percent of the non-electrified houses, if electrified, could help divert kerosene (which is currently used for illumination) for cooking. This would also give relief to women from exposure due to kitchen smoke that cause serious health impact.

BOX 1: HOUSEHOLD ENERGY – Rural North India

- 96.6% of households (HHs) use biofeus, 4.9% use kerosene and 4.95% use LPG for cooking. Most of them however use multiple fuels.
- Forests contribute 39% of the fuel wood need.
- 56 million tonnes of biofuels (of which 37 million tonnes of fuel wood) are gathered annually.
- 23 million households spend 8 billion hours annually in fuel wood gathering.
- 35 million households use 1.74 million tonnes of kerosene per annum for cooking and lighting.
- 34% of HHs (out of the HHs using kerosene for cooking) procure kerosene form open market and 97% procure it from fair price shops.
- 49% of HHs are willing to pay more than market price to purchase kerosene for cooking.
- 0.2% HHs use Biogas for cooking.
- 63% of HHs are electrified.

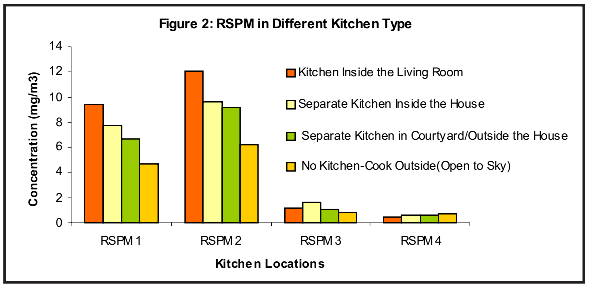
Exposure to Indoor Air Pollution and its Measurements

- When the kitchen is inside the living room or inside the house, the chief *cook* and other family members are exposed to a significant level of pollution during cooking hours (~ 3 hrs per day).
- *Cooks* are exposed to an average of 6.8 mg/m^3 of respirable suspended particulate matter (RSPM) while burning biofuels during cooking hours.
- While cooking with biofuels, RSPM concentration in the kitchen (about 2 meters away from stove) has a mean value of 9.2 mg/m^3. This shows that *those* who assist or

are in close proximity to the stove are exposed to even higher level of pollution than the *cook,* especially if they are in the direction of the plume of smoke.

- When the kitchen is located outside the house RSPM concentration inside the house reduces significantly.

- *Cook's* personal exposure to CO, SO_2 and NO_x are higher than the National Air Quality Standards. However, the concentration of SO_2 and NO_x reduce significantly below the NAQS as the *sampler* moved away two or more meters from the stove. Outside the house, SO_2 and NO_x levels sometimes drop below the detection level. RSPM concentration for different kitchen types is given in the Figure 2.



Respirable suspended particulate matter (RSPM) in Different Kitchen Types

RSPM 1 = Personal exposure, RSPM 2 = Concentration at 2 meter away from the stove,

RSPM 3 = Concentration in the living room, RSPM 4 = Concentration outside the house

Highlights of Water and Sanitation Coverage in Rural North India

Sixty two percent of the households (Box 2) do not have water supply in their homes; so they spend 32 billion hours annually, for water collection. Perhaps the same hours could be used to improve water supply in the region. The low economic development is both a cause and effect of low accessibility to clean drinking water, sanitation and sewerage facilities. However, some households are willing to contribute financially to avail clean drinking water, better sanitation and sewerage facilities, which could improve these facilities, if supported and integrated with other government programmes.

BOX 2: WATER and SANITATION : Rural North India

- 62% of HHs do not have water supply in or near their homes.
- 22.8 million HHs spend 32 billion hours per year to collect water from outside home.
- Only 5% of HHs are connected with sewerage facility.
- 10% of HHs have toilet facility inside the house
- 1 % of HHs use community toilets

Proportion of households *willing* to pay for:

◆ Clean drinking water:	7 %
◆ Community based drinking water supply:	25 %
◆ Sewerage facilities:	28 %
◆ 'In-home' toilets:	29 %
◆ Community toilets:	25 %

Water Quality Report

Water Quality data from 137 samples revealed that:

- Dissolved oxygen was in the range of 1.9 mg/l to 17.5 mg/l.
- BOD was above the drinking water/human use standard of 2 mg/l in 105 samples. In UP, all the 100 samples had BOD above the standard.
- Total coliform count was above the standard of 50 MPN/100 ml in 76 samples, whereas the fecal coliform count was found in 73 samples.
- In Rajasthan, all the water samples had fecal coliform, which as per standard should be nil in potable water.

Toll on Human Health

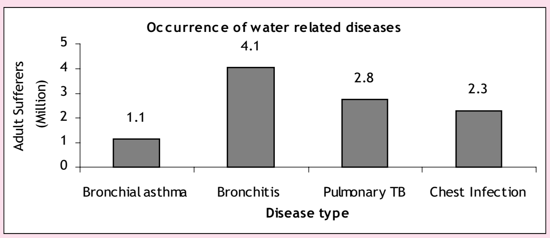
Analysis of prevalence of respiratory diseases (Box 3), shows that 17 percent of rural adults (24 million adults) have some respiratory symptoms. Nearly 13 percent (17 million adults) have serious respiratory symptoms and 7 percent (about 10 million adults) may have respiratory diseases. Prevalence of respiratory diseases works out as follows:

- 4.3 percent (6 million rural adults) suffer from Bronchitis
- 2.9 percent (4 million adults) suffer from Pulmonary TB
- 2.1 percent (3 million adults) suffer from Chest infection
- 1.45 percent (2 million) suffer from Bronchial asthma.

While the former two are strongly associated with indoor air pollution, the latter two are possibly triggered by indoor air pollution.

BOX 3: RESPIRATORY AND EYE DISEASES

- Respiratory symptoms are prevalent among 24 million adults, of which 17 million have serious symptoms
- Adults suffer from various respiratory diseases as given in the figure below:



LRI/ ARI prevalence among **children below 5 years:** 4.4 million (15.4%)

Expenditure on Respiratory Diseases

- Total private expenditure on health:
  - Rs. 15 billion per year for respiratory diseases
  - Rs.6 billion per year for eye related diseases
- Of the total expenditure incurred on:
  - **Respiratory diseases:** 56% is spent on medicine, 19% on special diet and doctor's fee each and 6% on hospitalisation
  - **Eye related diseases:** 70% is spent on medicine and 30% on doctor's fee.

Only about 20 percent of sufferers (adults and children) took some treatment and spent about Rs.15 billion$ on doctors' fees, medicines, hospitalisation and special diets. Similarly, on eye related diseases, sufferers spent about Rs.6 billion on doctors' fees and medicines. This is a huge loss to this deprived community. Though all the health aliments leading to monetary loss are not due to exposure to indoor air pollution, it has a significant impact on health.

About 15.5 percent of children below 5 years of age (4.4 million rural children in RNI) suffer from Lower Respiratory Infections (LRI)/ Acute Respiratory Infections (ARI).

Risk Factors for Respiratory and Eye Diseases

Odd ratios* for respiratory and eye diseases among female adults for several important variables are given in Table 2.

Table 2: Odd ratios for respiratory and eye diseases among female adults

Variables	Splitting Criteria	Respiratory Disease				Eye Irritation
		Bronchitis	Asthma	Chest Infection	TB	
Age	More than 30 Yrs/ Upto 30 Yrs	**3.99**	**4.05**	**2.64**	**2.85**	**2.53**
Smoking Habit	Smokers/ Non-smokers	**3.22**	**2.94**	**2.66**	**1.66**	-
Illiteracy	Illiterate/ Literate	**3.95**	**6.43**	**3.97**	**3.00**	**1.95**
Fuel index~	>15.56/ Up to 15.56	**2.53**	**2.47**	**2.08**	**1.94**	**1.99**
Asset index*	<0.25/>= 0.25	**1.88**	**3.51**	**3.01**	**1.93**	**1.53**
Type of Fuel used	Biofuel/Both fuel or Clean fuel	**1.99**	**2.55**	**1.83**	**2.36**	1.37
Number of rooms	<2/>2 rooms	1.39	**1.81**	**1.64**	1.43	1.39

Number in bold represents statistical significance

~ A composite indicator based on multiple variables such as age, type of involvement (such as chief cook, assisting in cooking, etc), number of years spent cooking and fuel type used.

*Asset index has negative impact on respiratory diseases

$ Rs. 44 = 1 US Dollar in 2000

** Commonly used in epidemiological studies to describe the likely harm an exposure might cause. It is calculated by dividing the odds in the more susceptible group by the odds in the less susceptible group. Higher the odd ratio, higher is the chance of a symptom.*

Table 2 shows that:

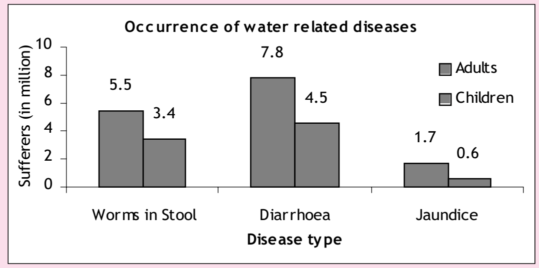
- Women above 30 years are at higher risk than younger women by a factor of 3.99 for Bronchitis, 4.05 for Asthma, 2.64 for chest infection and 2.85 for TB.
- Smoking is a high risk factor for all respiratory diseases but not for eye irritation.
- Illiterate women are at 3 to 6 times higher risk compared to literates for *all respiratory diseases*. Most benefits of literacy occur at the primary level education itself. i.e. odd ratios sharply fall with primary education.
- Fuel index was constructed to capture lifetime exposure. Higher index is associated with high lifetime exposure and risk for all respiratory and eye diseases.
- Asset index (used as a proxy for income or economic status, as enquiry on income is usually less reliable) shows negative impacts on respiratory and eye related diseases.
- Biofuel users have higher risk of respiratory diseases as compared to clean fuel users.
- Number of rooms has significant impacts only on Asthma and chest infection.
- Water and sanitation related diseases (Box 4) occur in 13 million rural adults and 7.7 million rural children as recorded in the survey for water related diseases in the past. Diarrhoea and worms in stool in the past one month and jaundice in past 2 years were recorded. These diseases lead to an expenditure of Rs.13 billion per year (by adults and children in RNI).

Risk Factors for Water Related Diseases

- Water storage in an open bucket or drum has 3 times higher risk for diarrhoea and 2 times for worm in stool, compared to safe water storage practices such as *pot covered with a lid.*
- Adults from the households not using any *purification methods* have high risk by a factor of 1.5 for diarrhoea and 4 for worm in stool.

BOX 4: WATER RELATED DISEASES *

- 13 million adults (9.7% of total adults) and 7.7 million children (8.7% of total children) in RNI suffered from *some water related diseases* in the past. Occurrence of major diseases are as given in the figure below:



- Prevalence of diarrhoea is high among children below 5 years (in 9% children).

Expenditure

Total expenditure for water related diseases for adults and children: Rs. 13 billion per year.

- Of the total expenditure incurred, 37% is spent on special diet, 33% on doctor's fee, 17% on hospitalisation and 13% on medicine.

Total Medical Expenditure

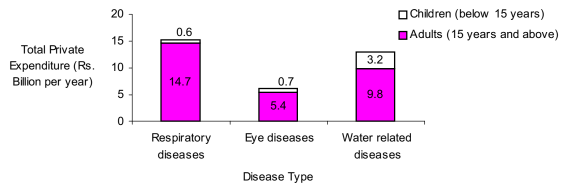
Rs.29.9 billion per year is spent for adults and Rs.4.5 billion for children in RNI towards healthcare related to inadequate energy and water facilities. Disease-wise expenditure is as given in Figure 3. Improved medical care facilities with a reach to all the villages and improved energy, water, sanitation can help reduce the expenditure substantially.

Total Economic Burden

Total economic loss due to lack of energy, water and sanitation and its impact on health and human resources is summarised in Box 5, which shows that, 4,815 million days per year are spent or lost, due to inadequate facilities and resources. The total *economic loss* due to the health impact of dirty fuel, unsafe water and time spent in their procurement is over Rs.323 billion per year in RNI. Availability of clean energy and water sources, accessibility to

**** Notes:***
1. *Worms in stool was taken for an individual where worms were passed any time during past one month*
2. ***Diarrhoea** was taken for an individual when it lasted for more than 2 days during past one month*
3. ***Occurrence of Jaundice** was considered any time in past 2 years*

Figure 3: Expenditure on respiratory, eye and water related diseases



better sanitation and health facilities can improve economic and social conditions of the rural poor. Also, better access to energy and water resources could improve efficiency of agriculture and allied activities, which can create opportunities for better employment and better livelihood. When such a large human resource is spent, just to meet the basic survival need, how can people improve their living conditions and participate in economic growth process? An integrated approach and participation from various ministries, government departments, NGOs and village communities are required to achieve the sustainable economic development of Rural North India.

BOX 5: Economic burden due to energy, water, sanitation and health problems (per year)

	Energy (a)	Water (b)	Total (a + b)
Days spent/ lost (Million)			
• Days+ spent in collection	822	3,212	4,034
• Days lost due to diseases	260	521	78
TOTAL	1,082	3,733	4,815
Monetary value* of working days spent/ lost (Rs. Billion)			
• Fuelwood gathering and water collection	49	193	242
• Due to diseases	16	31	47
Direct expenditure on health (Rs. Billion)	21	13	34
Total economic loss (due to improper energy and water facilities and due to health impacts of their procurement and use)	86	237	323

Notes:

1. Days spent in fuel wood gathering and water collection are given in column (a) and (b) respectively
2. Diseases includes: respiratory and eye related diseases under energy column (a) and water and sanitation related diseases under water column (b)

+ Taking 10 hrs as a standard working hours per day

* Includes imputed cost per working day taken at Rs. 60 per day (approx. wage rate)

Transportation Burden

Collection of fuel wood and water require transporting them. While the number of hours are accounted, physical strain from carrying heavy loads is not. It leads to headache, neckache, backache and also bruises, injuries and dangers of snakebites etc. Box 6 shows that on an average, members of a household walk 325 km per year for fuel wood collection and 2,774 km per year for water collection.

BOX 6: Transportation burden (per year per households) due to due to lack of energy and water facilities

	Fuelwood	Water
Proportion of households collecting (%)	62	62
Average distance walked per trip (km)	2.6	0.8
Average number of trips	125	3468
Total distance walked (km)	325	2774
Average quantity collected (tonnes/Kilolitres)	1.3	73

Conclusions and Recommendations

Access to energy, water, sanitation and health need to be stressed for social and economic development. They also concern poverty - gender - environment linkages and need a holistic view so as to reach a consensus to achieve the common goals. In addition to current status of energy, water, sanitation and people's priorities, health impacts of exposure to pollutants due to cooking with biofuels and lack of clean drinking water are also recorded.

In Himachal Pradesh, which has good access to clean fuels and water, one notices a sharp difference in all socio-economic indicators such as literacy, female/male ratio, health, income levels and other infrastructure. Could this be due to the decision taken to give them clean fuels to prevent deforestation in the hilly areas 10 years ago? If so, this decision has had many unintended benefits beyond preventing deforestation. One wishes that such a decision was taken for all the states in India. Almora district, which is a hilly district and was under UP at the time of the survey, also is well ahead of the other districts in UP, where the same government prevails.

A comprehensive policy and programme is needed that could integrate energy, water, sanitation and health with development goals such as employment generation, poverty alleviation and sustainable livelihood so as to bring about cohesive development in all arenas of life of the rural people. This requires focused linkages, participatory, collective and coordinated efforts of different ministries such as the Ministries of Education, Environment and Forests, Petroleum, Rural Development, Health, Agriculture, Non-conventional Energy Sources and the Central Water Commission along with local government and non-government organisations. Multipronged approach is needed as suggested below.

Energy Supply and Utilisation:

Biofuels:

- It is clear from the survey that substantial proportions of households have developed their own fuel wood supply (60% in UP, 47% in Rajasthan and 64% in HP). In spite of this, large proportions of households procure fuel wood from forests (36% in UP, 40% in Rajasthan and 49% in HP). To reduce this pressure on forests and to ensure fuel wood supply, afforestation on common lands, village lands and wastelands should be promoted. The Wasteland Development Board, Forest Department, Rural Development Department and MNES should come together to improve the fuel wood supply, by either supplying it as it is or converting it into clean fuel by means of biogasification.
- There are many factors that hinder the use of clean fuels, the most important being affordability and availability. Government intervention plays a crucial role in promoting any technology, but lack of effective financial and institutional mechanisms have proved to be the barriers. Therefore, we need to invent new financial and institutional mechanisms, which would help people to avail of better fuel sources and other facilities and services of their choice.
- *Reduce biofuel use* for cooking either by improving efficiency of usage or by replacing it with available alternative fuels such as kerosene, LPG or renewable energy technologies such as biogas, solar cookers and so on.
- *Biomass gasification:* Huge quantity of biomass available in rural areas is currently used inefficiently. This can be brought to productive and efficient use if it is converted into electricity by *biogasification*. Afforestation and energy plantation programmes can be connected with this initiative so that supply of raw material is ensured. However, this would require a feasibility study before it is taken up. This programme can generate large employment, satisfy local needs with local resources and avoid transmission and distribution loss that is currently incurred by state electricity boards.

Kerosene:

- Kerosene is an inferior lighting fuel compared to electricity, but is still used in majority of the households in the absence of regular electrical supply. Even the minimum allocated quantity of 3 to 5 litres per month does not reach the target households regularly, due to its diversion to other *lucrative* uses such as transportation. The quota was fixed as per lighting needs several decades ago. It has not been revised except in hilly areas. It is easy to adulterate or use subsidised kerosene for adulteration of other petroleum products. Therefore, it is necessary to streamline kerosene supply and direct it to the targeted users below the poverty line.
- However, kerosene can be a cleaner cooking fuel compared to biofuels, if burned with a blue flame in a pressured stove. Moreover, it is the most preferred cooking fuel in the energy ladder after fuel wood, even in low-income households due to the convenience of turning on and off as and when required.
- To strengthen kerosene supply and to ensure that the subsidy is given to the target population, we suggest the following policy options:
    - Restructure subsidy pattern and deliver it directly to the consumer. It could be done by issuing *coupons* to the poor

households, instead of the subsidy at the supplier level. *IT Enabled Electronic Card (ITEE-Card)* can be issued to each household. This concept, which was suggested by Reliance Ltd. during a meeting at IGIDR in September 2001, where petroleum minister Shri. Ram Naik presided. This can be explored further to understand the pros and cons of such *technology*. This could assure accountable and assured benefits to the target consumers.

- If 49 percent of the households are willing to pay a price for additional quantity of kerosene, which is much higher than the subsidised price, the open market needs to be improved. Open market can take care of some share of demand of the households that are economically better off and in a position to pay a higher price. This would help to reduce pressure on fuel wood sources and associated impacts.

LPG:

- LPG (liquefied petroleum gas) is the *best available* cooking fuel, but access to LPG is very low in the rural areas of Uttar Pradesh and Rajasthan. The situation in HP however, is far better. Therefore, it is important to improve access to this fuel. Currently available cylinders are heavy and difficult to carry to remote areas due to inadequate transportation facilities, and require a large investment upfront. LPG, if available in small containers, would be convenient even for poor people located in remote villages.
    - Bottling of small cylinders (Union Minister for Petroleum and Natural Gas, announced during a discussion in a seminar at IGIDR in September 2001 that 5 kg cylinders of LPG would be introduced for domestic purpose). These cylinders are targeted at low-income group households in the rural and hilly terrain areas due to ease of transportation, compared to the existing 14.2 kg cylinder. Every town or village with a population of 10,000 or more would be given an LPG distribution agency (as against 20,000 now) for easy transportation and affordability. This initiative can play a crucial role in breaking the barriers of affordability and availability of LPG in rural north India. This programme would also have a social impact on people's lives.

Biogas:

- Biogas is another feasible option available in rural areas of north India. The government, with support from NGOs and the community, has a crucial role to play if this potential is to be tapped.
- The survery shows that about 3.7 percent of the households have more than 3 to 5 animals, which is sufficient to install a biogas plant of 2 cubic meter capacity that can satisfy cooking energy needs of 5 to 8 individuals. These households fall into the economically *better off* class and therefore, with strategic promotion it is possible to install biogas plants.
- The survey showed that over 24 percent of households have less than 3 animals per household, but together they can install family size biogas plants if '*sharing mechanism for dung, slurry and cost'* can be developed.
- Apart from family sized biogas plants, there is a large potential for community biogas plants. In fact, in many cases community size biogas plants would be beneficial in many ways. The advantages community biogas plants provide are:
    - Cater to the energy needs of the households who do not possess livestock
    - Generate employment
    - Remote villages without access to electricity are best suitable for community biogas installation, which can also be used to generate electricity
- Training programmes can be initiated in industrial training institutes with the emphasis on installation, management and service of biogas plants. This would ensure better functioning of biogas plants.

Conservation, Technology and Institutions:

- For illuminating homes, night schools, etc, solar lanterns are suitable in rural areas, where, power supply is erratic. Servicing and perhaps assembling of these lamps, can be initiated in some villages so that employment is generated and people have access to such products and services

- Promotion of energy conserving systems, where integrated choices of fuels, improved stoves and appropriate pots and lids have to be made. Improved cooking stoves and pressure cookers can save large quantities of fuel wood. It is a less expensive and feasible option to save biofuels. However, the survey showed lack of awareness about the advantages and functioning (though simple) of improved stoves. It is therefore, necessary to initiate community awareness programmes.

- Improved and accessible financial mechanism: Initial investment is the main constraint in promotion of most technologies in rural areas. Therefore, financial support through Self Help Groups (SHGs) formed in villages across these states can be very effective in their promotion.Due to their financial strengths, SHGs can generate and use money for such purposes.

Water and Sanitation Facilities

Water scarcity is the most important issue that leads to all other related problems. Availability of safe drinking water, upon which, health of individuals and welfare of the people depend, requires an integrated approach for comprehensive and sustainable solutions.

The aim of the policy should be to provide safe sources of drinking water within people's reach, and to minimise the hardships faced by people in collecting water. Priorities in sanitation should be to provide people with sanitation facilities so that water does not get contaminated and does not harm health. We recommend the following policy measures and interventions:

- In many villages people use surface water sources such as ponds and lakes. These sources are prone to contamination from poor sanitation, agriculture run off, etc. that contains harmful disease causing agents, which affect human health. Therefore, such open sources should be restricted from use and alternative water sources should be strengthened. If these sources are used, water testing and monitoring should be practiced regularly at delivery point.

- On an average, 2,774 km is walked per year per households to collect 73 kilolitres of water. This takes substantial time and hard work. Therefore, it is necessary to improve local water resource base by various methods:
  - Improving ground water resource and rain water harvesting and storing water for use during scarcity seasons
  - Tapping rainwater by various rainwater harvesting techniques can minimise water shortage. The advantages of rainwater harvesting are that it provides safe water supply and helps in groundwater recharge. Therefore, area-specific rainwater harvesting should be promoted with community, government and NGOs participation.
  - Watershed management programmes can also play a crucial role in improving water resource base

- It is observed that water is contaminated further in households, due to poor storage and unhygienic conditions, especially in poor households. Contamination occurs mainly due to lack of awareness about simple methods, which, if practiced, can influence health outcome in a positive way.
  - Covering water storage pots, use of pots with long handles (this would avoid contamination of water by dirty hands and dirt in the air) and other hygienic storage methods need to be popularised
  - *Water pots should be kept* above the ground level so that dust does not enter into the pots
  - Simple cloth filter can avoid many diseases

- Boil water before drinking

- Awareness programmes (especially for women) on these *simple* techniques should be popularised in villages so that people practice these methods. NGOs could play a crucial role in this endeavour.
- Development of village level information systems on various aspects of water resources: As stressed in India's National Water Policy document of 2001, a village level information system need to be developed so that information about various water related issues is easily available to people.
- Human excreta are the most important disease-carrying agents due to defecation in open spaces. In some villages, community toilets can be popularised with awareness programmes about keeping them clean. The survey suggests that people are willing to contribute to the construction of in-home and community toilets. This contribution can reduce the burden on the government funds and provide the required facility.

Health Care Facilities

- Training of healthcare professionals is needed to spot the problems relating to pollution and to sensitise them to be alert. Many villages do not have convenient health facilities. In many cases, in spite of having health centre facilities, the centres are not equipped with basics instruments/ infrastructure required for simple treatment.
- Many diseases spread due to negligence, lack of awareness of their origin and lack of measures to check them. Such diseases can be avoided by simple precautions such as cleaning hands and utensils properly and avoiding delay in treatment. Awareness about such techniques can be promoted with the support NGOs, the Health Ministry and Rural Development Ministry.
- Exposure to air pollutants can be minimised by structural changes in housing e.g. by improving ventilation of the kitchen and house, and having a separate kitchen or installing chimanys.
- The study shows that with improvement in female literacy, adverse health impacts of respiratory and water related diseases could be reduced.
- Health centres should be networked with information systems to communicate with each other for better implementation of public health policy.
- It is reported that sick people and pregnant women suffer as they travel long distances to reach to health centres, due to lack of medical facilities nearby. To minimise their drudgery and to support them with health care access, mobile vans can be introduced that go around villages to provide medical aid.

Transportation Facilities

- As the results suggest, over 822 and 3,212 million days are spent in fuel wood and water collection respectively, which impose hardship and loss of productive time on the rural poor. This also creates physical strain and health damage. To reduce this damage:
  - Village level cooperative transport facility such as trolleys or wheelbarrows to carry water pots and fuel wood loads could be made available.
  - Alternatively, small motorised vehicles can be provided to communities to carry fuel wood and water on a cooperative basis. This would substantially reduce the physical burden on women and children if collectively financed.

Annexure

Household and Population of Northern India, 2001 (Million)

	UP	Rajasthan	HP	Total (Rural North India)
Total number of households	22.27	7.10	1.00	36.73
Total Rural Population	137.85	43.27	5.48	226.23
• Male	72.24	22.39	2.75	118.42
• Female	65.61	20.87	2.73	107.81

Socio-demographic profile of the sample (percent)								
	All		UP		Rajasthan		HP	
Gender	Female	Male	Female	Male	Female	Male	Female	Male
Base: All individuals	28,560	30,208	20,921	21,792	5,552	6,403	2,087	2,013
Proportion (%)	49	51	49	51	46	54	51	49
Age								
Up to 15 years	42	45	42	45	43	46	30	32
16 – 40 years	40	36	40	36	41	38	48	44
> 40 years	18	19	18	19	16	16	22	24
Literacy *(adults)*	26	59	24	56	17	59	69	84
Occupation (adults)								
Farm based	2	40	2	42	3	35	4	30
Industry/Service	2	20	2	16	2	26	4	35
Home based/Housewife	85	4	88	4	83	4	69	3
Unemployed/Others	10	36	8	38	12	35	23	32
Base: All adults (above 14 yrs.)	17,417	17,410	12,583	12,346	3,325	3,662	1,509	1,402

Socio-Economic profile of the sample households (percent)				
Land holding	All	UP	Rajasthan	HP
Landless and non-farm households	48	53	27	60
Marginal & small (up to 5 acres)	42	41	48	35
Medium & large (more than 6 acres)	10	6	25	5
Annual household income (in Rs)				
Up to Rs. 20,000	58	61	50	43
More than Rs 20,000	42	39	50	57
Kitchen appliances				
Kerosene Stove	22	21	18	49
Pressure Cooker	17	14	5	86
Gas Stove	9	6	4	57
Water Filter	1	1	0.2	5
Livestock				
Buffalo	46	46	49	43
Cow	37	33	44	58
Bullock	24	26	13	31
Sheep / Goat	25	21	42	17
Number of rooms				
1 Room	35	36	34	18
2 Rooms	32	32	30	26
3 or more rooms	33	31	34	55
Kitchen location				
Inside living room (No separate kitchen)	26	28	23	9
Separate Kitchen: Inside home	39	44	12	57
Separate Kitchen: Outside home	14	9	29	31
No kitchen room: Open air cooking	21	18	36	3
Base: All Households	10,265	7,564	1,989	712

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

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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 the successful application of the CRA framework in developing countries is the lack of information about quantitative exposure and health effects. 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 is 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 objectives of the study are 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.
- Evaluate the economic costs associated with these health risks using local economic information to enable ranking of the particular environmental concerns on the basis of both the health and economic risks.

Study Area

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
SO2		
NO2		
Lead		

Methodology

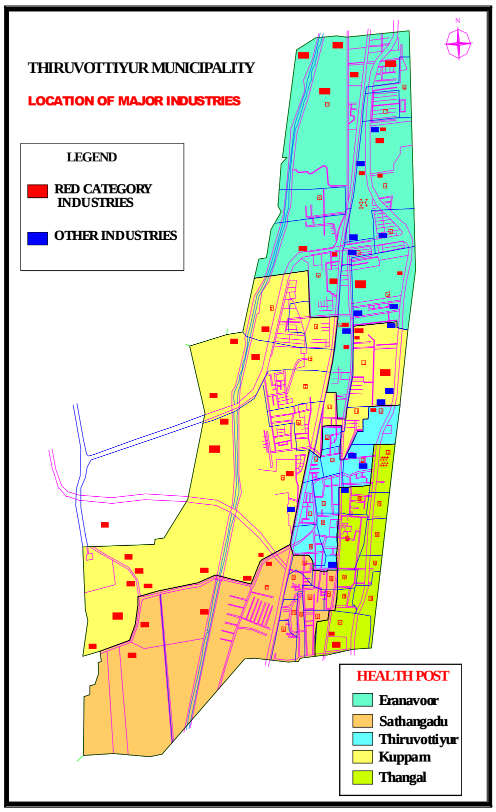
- Population exposure to selected air and water pollutants were assessed using a combination of secondary data sources as well as primary sampling.
- Health risks were then assessed using dose-response information established specifically from developing country studies.
- Primary data on the prevalence of respiratory, gastro-intestinal and vector-borne diseases within the resident population of the study zone was collected through the administration of a health assessment questionnaire.

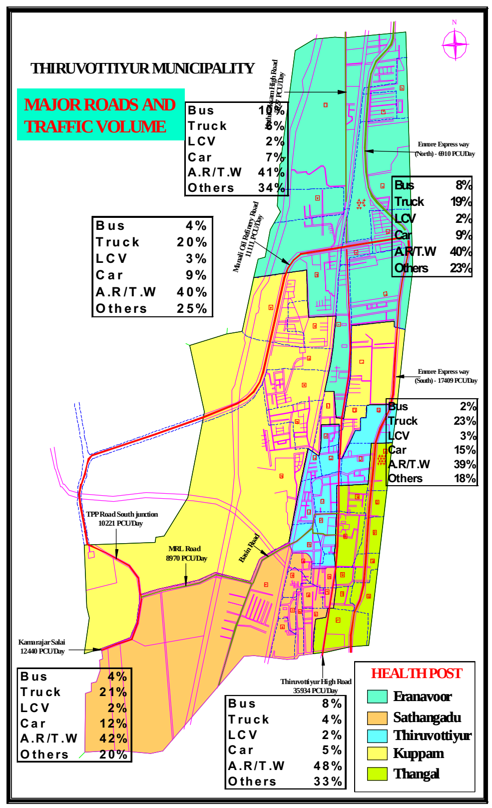
- Local information on costs of hospital visits, treatment and work-loss days specifically attributable to environmental exposure were collected to assess economic costs of the health damage.
- Health and economic risks associated with each environmental problem were assessed on the basis of data collected 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 the past five years. Primary





Maps showing location of study area in Thiruvottiyur Municipality in North Chennai, along with industry and vehicular traffic profiles and organisation of health posts for health data collection.

sampling was carried out for PM10 (Particulate matter less than 10 mm), CO, SO2, NO2, 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 percent 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, SO2 and NO2 were below the standards, the short-term exposure limits were exceeded significantly during bio-mass burning while cooking or burning of open refuse. 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 was 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 the last five years revealed that microbiological contamination with faecal coliforms was the most significant concern within the municipality. The data showed the 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 and Access to Sanitation

Qualitative information on solid waste was collected both from municipal sources and from household level surveys. Nearly 35 percent 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 percent did not have access to private toilets. Around 55 percent of the population reported being severely affected by rain - water stagnation. 30 percent 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 diseases was 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 rupees)	Total costs (Lakhs of rupees)
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, SO2 and NO2. 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 were exceeded in 67percent of homes during cooking with bio-mass fuels while the guideline values for SO2 and NO2 were exceeded in about 15 percent 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 22ìg/dl while in adults it was 16 ìg/dl. Applying dose response information cited in the main report, the calculated health risks for the study zone population were as follows.

Blood lead

Mean Blood lead levels	Health End point	Estimated Impact on study population
Children- 22mg/dl	Loss of IQ points	2 points/ child
	Increase in infant deaths	4.5 deaths /year
Adults - 16 mg /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

The prevalence of respiratory, gastrointestinal and vector borne illnesses was assessed in the study zone through the administration of a household level questionnaire that collected both 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 evaluate the associated economic loss. Although, this method was media specific (i.e. air/ water/solid waste) and not pollutant specific , it allowed comparisons to be made between estimates that were obtained from applying previously established dose-response functions and those obtained through direct assessment methods.

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.

Health End point	Prevalence (Lakhs of Rs.)	Treatment Costs (Lakhs	Wage Loss (Lakhs of Rs.)	Defensive Expenditure costs for of Rs.)	Total annual study zone (Lakhs of Rs.)
Respiratory illness	12%	710	942		1652
Gastrointestinal disorders	16%	1167	1111	85	2363
Vector-borne illness	5%	1175	338	243	1757

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 biomass 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, to use the quantitative health risk assessment framework to value environmental health damage. Exposure assessment is one of the most crucial components to 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 prioritise 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 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 conducting 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 recognise the importance of environmental health risks and initiate action plans aimed at protecting the health of the public.

A Study of Environmental Exposure to PAHs in Economically Underprivileged Population of Urban/Rural Areas of Uttar Pradesh

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Introduction

Polycyclic Aromatic Hydrocarbons (PAHs) are one of the most hazardous (carcinogenic) contaminants of the present ambient air environment. These are a well-known class of carcinogens emitted largely due to emissions from auto-exhaust or fuel biomass combustion. Ambient and indoor air pollution due to PAHs, both in rural and urban areas, is an environmental health hazard. The gasoline/ diesel exhaust emissions constitute the most important source of PAH pollution in urban India. Busy traffic channels are one of the worst polluted sites. Several subjects such as roadside vendors, traffic constables and controllers, cycle-rikshaw or trolley pullers and daily commuters in these areas are exposed to PAHs everyday.

Emission from fuel biomass is the source of PAH pollution in rural India. Biomass is a common type of traditional fuel, viz. fuel wood, crop waste and endurable animal dung, which is used frequently as an inexpensive source of energy for cooking food in rural parts of India. In winter months, it is also used to warm the houses. Emission from biomass burning is the single largest source of PAH pollution in rural ambient/indoor air. The women folk get relatively more exposed to PAHs, especially while cooking food for extended periods of time particularly due to low energy value of the biomass fuel.

No available study has reported on the site-specific environmental load of pollutants and the exposure assessment of population dwelling specifically in PAH polluted urban traffic channels, rural huts and the vicinal areas in India. There is a complete paucity of information on the exposure and health risk assessment of Indian urban/rural subjects exposed to PAHs in India.

Herein, we report (a) total PAH content and its profile in ambient/indoor air of urban/rural areas in Lucknow district, (b) PAHs exposure assessment in subjects living/working near PAH polluted sites, and (c) prevalent morbidities in PAH exposed destitute subjects. There is a lack of human data on these aspects.

Objectives

The objectives of the present study are to:

- Determine PAH concentrations in urban ambient/rural indoor air environment.
- Assess the potential risk of adverse health effects in the PAH exposed subjects.
- Evaluate the health damages caused by exposure to PAHs in economic terms.

Methodology

Ambient Air Monitoring

The rural parts of Lucknow were monitored for the ambient/indoor air of High Traffic Density (HTD) and Low Traffic Density (LTD) sites of urban and biomass/fossil fuel.. The sampling was done both in summer (March through June) and in winter (November through February). The ambient air was sampled using respirable dust sampler. Sampling was done at three different locations and in two seasons. Two HTD sites (site 1 Charbagh and site 2 Hussainganj) with idling/slow moving traffic and one LTD site (Janakipuram) with relatively fast moving traffic were monitored (Annexure I). The HTD sites were among the busiest traffic channels of the city. The LTD site was scarcely busy. The parameters monitored were SPM, RSPM, SO_2, NO_x and PAHs. The study was done for a total of 384 adult subjects dwelling specifically in PAH polluted traffic channels in urban areas or the PAH polluted huts in rural areas. The study was limited to the 100-km radius of Lucknow.

Indoor Air Monitoring

The indoor air was sampled at locations in Village-Mall (Tehsil-Malihabad, District-Lucknow), approximately 40 km north west of Lucknow City (Annexure II). Rural huts with single room accommodation and of similar volume were selected. The types of fuel used in this area were wood, Cow Dung Cake (CDC) and Liquefied Petroleum Gas (LPG). Kerosene and electric heaters were not prevalent in these areas. Agricultural waste was also not found in use during the survey. The cooking areas and the smoke-less non-cooking areas were monitored. The sampling was done at the time of cooking approximately for one hour using both Personal/Area Samplers. RSPM, SO_2, NO_x and PAHs were monitored in indoor air. For active or passive exposure, only RSPM and PAHs were monitored.

Health Effects and Exposure Estimates

Representation of economically underprivileged users of biomass fuel (especially in rural areas) and other demographic variables that may have a bearing on PAH exposure like smoking, etc. were ensured. Informed consent was taken from each study subject before their inclusion in the study. The study subjects were interviewed for details about personal, occupational and clinical history, which were noted on a pre-tested schedule. A complete clinical examination (viz. general health physical examination, respiratory, cardiovascular, gastro-intestinal, musculo-skeletal and central nervous system) of each subject was done and recorded by a medical doctor.

Exposure Assessment

Urine samples were collected from each studied subject after the verbal consent. Following enzymatic digestion, clean up and the enrichment of sample, 1-pyrenol was isolated and quantified over HPLC with fluorescence detectors. The results were corrected for the percent recovery and expressed as mmol1-OH-pyrene/mol urinary creatinine, which is an index biomarker for PAH exposure.

Economic Valuation

The purpose was to make a rough estimate of the total magnitude of economic cost associated with health damage due to PAH exposure in Lucknow. These costs measured the economics of health impacts. In valuing the costs of morbidity, three types of costs were considered: (a) medical expenses; (b) lost wages, and (c) individual disutility (discomfort, suffering, and the opportunity cost of time). The questions pertaining to sickness during the last one month and one year for each subject were recorded. The total expenditure incurred on medical treatment was recorded. Loss of earnings in Rupees due to absence from work (days with symptoms) and due to poor quality / less work (restricted study with days) due to illness were also recorded. A rough estimate of the total magnitude of economic costs associated with PAH exposure was calculated. These costs were calculated only in terms of health damage. The calculation is as follows:

Total cost = (Incidence of deaths x value of life) + Incidence of sickness due to PAH exposure x (cost of treatment + cost wages)

Considering that sources of PAH exposure include transport, industry, energy, smoking, exposure to bio-mass fuel burning and food, etc., no attempt was made to differentiate the health impacts by the sources of PAH exposure. The cost due to death in the family was excluded as the design of the study was cross-sectional, and hence death could not be attributed to PAH exposure. The overall limitations of this "back-of-the envelope" approach to value environmental costs were very clear. The methodologies, data and estimates of 'average' costs and values are all subject to extensive refinement.

Data Processing and Statistical Analysis

The data generated was compiled and transferred to the personal computer through the use of Lotus, MS Excel and EPI INFO. Analysis was done using software EPI INFO and Systat

9.0. The significance of the mean value of different parameters in different exposure groups were analysed using analysis of variance techniques after ascertaining the assumptions of normality and homogeneity of variance. Significance of prevalence of different signs and symptoms in different exposed and control groups were analysed using Chi square or Fisher exact test depending upon the expected cell frequencies. Odds ratio for exposed (Urinary pyrene excretion µmol/mol >0.5) in comparison to non- exposed (Urinary pyrene excretion µmol/mol =0.5) for different explanatory variables were calculated and the significance tested using Mental Hanzel's procedure.

Results

Ambient Air Pollution

SPM and RSPM levels at all the monitored locations in summer were close to or within the permissible limit of the residential area (Table 1). The results were compared with National Ambient Air Quality Standard (NAAQS) values. The SPM and RSPM levels at all the monitored locations in winter exceeded the permissible limit for residential area.

SO_2 and NO_x levels at all the monitored locations in both summer and winter were within the permissible limit for residential area. Results were compared with NAAQS values.

PAHs

In Summer

The analysis of PAHs profile revealed the presence of all the examined types (both auto-exhaust/biomass emission specific PAHs) in the sampled air (Figure 1). The mean values of SPAHs (20.97 & 24.76 ng/m3) at HTD sites and at LTD site (9.44 ng/m3) were much greater (Table 1) than the guide value of 1ng/m^3 set for PAH by the World Health Organisation (WHO). PAHs are not included in the Indian National Ambient Air Quality Standard (NAAQS). The mean values of SPAHs were more at HTD sites than the LTD site by a factor of 2X. The range of SPAHs (92.67, 48.06) at HTD sites was more than the same (29.65) at the LTD site. Benzo(ghi)perylene, chrysene and acenaphthylene registered maximum at the monitored sites, whereas anthracene registered the minimum (Figure 1). Each type in the PAH profile at HTD locations registered an excess over its LTD site value and the increase was 1-2X. The two HTD sites when compared together, showed a dissimilar pattern in their PAH profile. Acenaphthylene, acenapthene, anthracene, fluoranthene and chrysene were higher at Site 2 whereas benzo(ghi)perylene was highest at Site 1. Levels of benzo(a)pyrene at HTD Site 2 were <1ng/m3 and were surprisingly similar to that of the LTD site. The unusually low levels of benzo(a)pyrene at the HTD site in summer may be related to meteorological and topographical conditions at the monitored sites. A percent composition study of the PAH profile at the investigated sites revealed that benzo(ghi)perylene alone constituted 50 percent of all the investigated PAHs at HTD Site 1. At other monitored sites the percent composition was similar and evenly distributed.

In Winter

The analysis of PAH profile revealed the presence of all the examined varieties (both auto-exhaust/biomass emission specific PAHs) in the sampled air (Figure 1). The mean values of SPAHs (106.08 and 100.33 ng/m^3) at HTD sites and at the LTD site (26.64 ng/m^3) were much greater than the guide value of 1ng/m3 set for PAH by WHO (Table 1). PAHs are not included in the Indian National Ambient Air Quality Standard (NAAQS). In winter, very few types of PAHs registered <1ng/m^3 levels at the LTD site (Figure 1). The mean values of SPAHs at HTD sites increased by a factor of 4X over the LTD site mean value. The range observed at the HTD site (78.87, 220.81), was more than the same (80.20) observed at the LTD site (Table 1). Mean PAHs concentrations at the same monitoring locations hiked by a factor of 2-4X in winter. Benzo(ghi)perylene, benzo(a)pyrene and chrysene registered a maximum level at the monitored locations whereas anthracene registered a minimum, as it did in summer (Figure 1). Each type in the PAH profile at HTD locations registered an excess over its LTD value and the hike was 2-10X. Unlike summer, the two HTD sites showed a similar pattern in PAHs profile. Levels of acenaphthylene, anthracene, chrysene, phenanthrene, benzo (a) pyrene and benzo(ghi)perylene were higher but similar at both the sites. Levels of benzo(ghi)perylene were surprisingly similar at all the locations. The unusually high ambient air levels of PAHs in winter may be related to meteorological and topographical conditions viz. low wind speeds and relatively shorter cold-air columns of SPM/RSPM at the monitored sites. Chrysene, benzo(a)pyrene and benzo(ghi)perylene together constituted 60-70 percent of the sum PAHs levels. Chrysene alone constituted 20-40 percent among the examined ones. A moderate but statistically insignificant ($p<0.05$) correlation between RSPM and benzo(a)pyrene level was noticed in winter.

Rural Indoor Air Pollution

RSPM during Passive Exposure

RSPM levels at all the monitored locations, save the LPG site, exceeded the permissible limit for rural areas both in summer and winter season. The results were compared with NAAQS values. The mean concentration in summer was found to be 6.35 mg/m^3, 9.53 mg/m^3, below detection limit (BDL) and 0.44 mg/m^3 at the cooking sites using wood, CDC, LPG, and at non-cooking site respectively (Table 2). Similar mean concentrations were found for the monitored sites in winter. RSPM levels at the fuel biomass using-site were 5-10X greater than the LPG or non-cooking site in both the seasons.

RSPM during Active Exposure

RSPM levels at all the monitored locations, including the LPG site, far exceeded the permissible limit for rural areas both in summer and winter season. The results were compared with NAAQS values. The mean concentration in summer was found to be 12.86 mg/m^3, 13.85 mg/m^3, 0.95 mg/m^3 and 1.01 mg/m^3 at the cooking sites using wood, CDC, LPG and at non-cooking site respectively (Table 2). Similarly mean concentrations were found for the monitored sites in winter. RSPM levels at the fuel biomass using-site were 10X greater than the LPG or non-cooking site in both the seasons. The results were compared with NAAQS values.

Sulphur Dioxide (SO_2) during Passive Exposure

Mean SO_2 levels monitored at all the locations were more than the permissible limit for rural areas in both summer and winter. Results were compared with NAAQS values. The mean concentrations in summer were 39.58 µg/m^3, 49.07 µg/m^3, 7.97 µg/m^3 and 7.11 µg/m^3 at the cooking sites using fuel wood, CDC, LPG and at the non-cooking site respectively (Table 2). Similar mean concentrations were found for the monitored sites in winter. SO_2 levels were 5X higher at fuel biomass using sites.

Oxides of Nitrogen (NO_x) during Passive Exposure

Mean NO_x levels monitored at all the locations were more than the permissible limit for rural areas in both summer and winter. Results were compared with NAAQS values. The mean concentrations in summer were 51.08 µg/m^3, 61.28 µg/m^3, 11.47 µg/m^3 and 10.47 µg/m^3 at the cooking sites using fuel wood, CDC, LPG and at the non-cooking site respectively (Table 2). Similar mean concentrations were found for the monitored sites in winter. NO_x levels were 5X higher at fuel biomass using sites.

PAHs during Passive Exposure

All the examined varieties of PAHs were present in the indoor air sampled during passive exposure to biomass/fossil fuel combustion in summer. The mean values of SPAHs (19.98mg/m^3, 27.83mg/m^3) at the cooking sites using fuel wood, CDC were more than the LPG using sites (7.42mg/m^3) and the non-cooking sites (6.18 mg/m^3) values in summer (Table 2). Similarly, mean values of SPAHs in winter were more at the cooking sites using fuel wood, CDC than the LPG using sites and the non-cooking sites ,and were greater by a factor of 2X than summer. The range (44.49, 54.01, 12.73) of SPAHs values at biomass/fossil fuel using-sites in summer was more than the same (3.71) at the non-cooking site. Similarly, the range (99.79, 39.04, 27.94) in winter was also more than the same (20.58) at the non-cooking site in winter, but it was greater than in summer. These values were far more than the guide value of 1ng/m^3 set by the WHO for ambient air PAH. Compared to occupational exposure standard of 0.2mg/m3 (TLV) recommended by NIOSH, the obtained mean values were quite low. Mean SPAHs values at the non-cooking site and at the site using LPG fuel type appeared similar in both the seasons. Levels of all the examined PAHs at these sites ranged between 0.06 to ~5 mg/m^3 in summer and between 0.12 to ~16 mg/m^3 in winter. In both the seasons, acenaphthylene registered a maximum level at the monitored sites, whereas anthracene registered minimum (Figure 2). At the biomass using sites in summer, acenaphthylene, acenapthene and fluoranthene were major components and constituted >75 percent of all the investigated PAHs. Acenaphthylene and acenapthene, the volatile PAHs, alone constituted a total of 60 percent at the site using biomass fuel. In winter, acenaphthylene, acenapthene, fluoranthene, pyrene and chrysene were the major components and constituted >90 percent of all the investigated PAHs. Acenaphthylene and fluoranthene were the major components at sites using fuel LPG. At non-cooking sites, only acenaphthylene was the major component.

PAHs During Active Exposure

All the examined varieties of PAHs were present in the indoor air sampled during active exposure to biomass/fossil fuel combustion in summer and winter. The mean values of SPAHs (40.83 mg/m^3, 77.01 mg/m^3) at the cooking sites using fuel wood, CDC were more than the LPG using site and the non-cooking site value (11.10 mg/m^3, 11.36 mg/m^3) in summer (Table 3). Similarly mean values of SPAHs in winter were more at the cooking sites using fuel wood, CDC, than the LPG using or the non-cooking site and were than summer. Range (167.71, 206.44) of SPAHs at biomass/fossil fuel using-site in summer was more than the same (13.72, 14.45) at the LPG using or non-cooking site. Similarly, the range (150.27, 109.94) in winter was also more than the same (21.02, 32.09) at the LPG using or non-cooking site in winter but it was greater than in summer. These values were far more than the guide value of 1ng/m^3 set by W.H.O. for ambient air PAH. But considering cooking as an occupation and comparing it with occupational exposure standard of 0.2mg/m3 (TLV) recommended by NIOSH, the obtained mean values were quite low. Mean SPAHs values at non-cooking site and at the site using LPG fuel type appeared similar in both the seasons (Table 3). Levels of all the examined PAHs at these sites ranged in between 0.01 to 17.5 mg/m^3 in summer and between 0.25 to ~19 mg/m^3 in winter. At sites using bio-fuels, mean levels registered a hike over sites using LPG or non-cooking sites by a factor of 2-20X. In both seasons, acenaphthylene and acenapthene registered a maximum level at the monitored sites, whereas anthracene registered minimum (Figure 3). At the biomass using sites, acenaphthylene, acenapthene fluoranthene and pyrene were the major components and constituted >75 percent of all the investigated PAHs. In winter, chrysene showed more in the list of the major components, and together constituted >90 percent of all components. In both the seasons, acenaphthylene and acenapthene, the volatile PAHs, alone constituted a total of 50 percent at the site using biomass fuel. The percentage profile changed at non-cooking sites or at sites using LPG. In summer, only acenaphthylene and phenanthrene were the major components whereas the acenaphthylene, acenapthene and fluoranthene were the major components in winter.

Adverse Health Effects and Exposure Estimates in PAH Exposed Subjects

The general profile and 1-hydroxypyrene excretion pattern of the study population was recorded. Urinary hydroxy pyrene (UHP) is known to be a good exposure marker for PAH exposure. In our study we selected = 0.5umol/mol creatinine as the cut-off upper limit for computations. A higher percentage (82.8%) of population excreting more than normal levels of UHP was observed largely in congested areas. Mean pyrene levels in different PAH exposed population groups were not statistically significant. Factors affecting UHP excretion were found to be gender, vehicular emission exposure, non-vegetarian diet and smoking. Females excreted 1-hydroxypyrebne more than males in both rural and urban non-congested areas. In congested areas, males excreted more compared to females. The proportion of subjects excreting more than normal levels of UHP (> 0.5 µmol/mol) was significantly higher in the group exposed to vehicular emission (OR = 2.32, $p < 0.001$) compared to the proportion of subjects in the group less exposed to vehicular emission in low traffic density areas. Similarly, the proportion of rural subjects excreting more than the cut-off limit of UHP was higher in the group exposed to biomass emissions compared to the group not exposed to biomass emissions.

PAHs carcinogenic potential is often reported but the short-term clinical effects are hardly known. In our study, we detected a group of symptoms related to eye, ear, cardiovascular and respiratory systems that were significantly more in groups excreting greater than normal levels. Subjects with this symptoms-cluster who were excreting more than normal levels of UHP were observed to be 29.4 percent compared to 17.3 percent, who had the symptoms-cluster but excreted normal levels of UHP. Differences were statistically significant. As such this cluster of symptoms are effects of exposure to different air pollutants. But in subjects with high UHP excretion, exposure to PAHs could be an attributing factor for a proportion of these clinical symptoms-clusters. No statistical association could be observed in subjects with specific morbidity or specific affected organ system and high UHP excretion. No links of mortality with UHP could be detected. Average Year Life Loss (00) for deaths in the family of the groups excreting less than or above the cut-off limit were scored and found to be 15.9 years (below cut-off limit) and 21.3 years (above the cut-off limit), considering 63 years life expectancy at 0 age. Subjects excreting more UHP experienced more days of sickness and lost more money in the form of lost earnings. More than 20 percent of subjects both in low and high UHP excreting groups spent money on treatment. Total money spent on treatment and that spent on consultation and drugs was more in subjects with more excretion of UHP. This is also true for lost earnings due to sickness and poor quality work/less time devoted to work. *A population of 16.4 lakh (1.64 million) persons is estimated to excrete higher than the cut-off levels of UHP in Lucknow, and is thus exposed to PAHs. A sizeable population of 3.84 lakh (0.38 million) of these suffers form a symptoms-cluster that is attributable to PAHs.* The cost of PAH exposure related symptoms-cluster is estimated to range between Rs.20.0-163.3 crores for Lucknow with an average estimated cost to be Rs.91.9 crore.

Conclusion

PAH concentrations in ambient/indoor air in Lucknow are far greater than WHO prescribed limits. The source is petrol/diesel exhaust and biomass combustion. A substantially higher percentage of population is exposed to PAHs and faces the risk of short-term clinical symptoms related to cardiovascular, respiratory, ear and eye systems that are attributable to PAH exposure. The estimated cost of health damage in the PAH exposed population (1.64 million) on an average is Rs.90 crore (Rs.900 million) per annum for Lucknow.

Policy Recommendations

- Studies on a larger scale (e.g. National Coordinated Program) are needed in India to characterise more PAH polluted areas and PAH exposed subjects, especially for the health risk assessment plus health-damage cost evaluations vis-à-vis PAH pollution. It will establish a large database, not only to link the PAHs emissions exposure with prevalence of cardiovascular and respiratory system specific ailments, but also to compute a dose response relationship.
- A site investigation plan should be developed in the country that addresses the issues of potential sources, local hot spots or the geographical spreads of PAHs contamination and its affiliation with the prevalence rate of PAH exposure related health hazards.
- The PAH exposure assessment of urban/rural Indian subjects (by monitoring urinary exposure marker level as done in our project for the first time in the country) should be a priority, as it would help define areas where exposure point concentrations exceeded the levels of health concern.
- The site investigation plan should include environmental monitoring, exposure assessment, residential history information and health survey. The work-plan should be validated in various areas of the country to distinguish between the least and the most polluted areas, and for comparison of the environment and health in India. This will help to study the size and geographical spread of the population at risk.
- There is a paucity of data on the prevalent types of morbidities or cancer risk in PAH exposed Indian subjects, which needs to be met.
- The National Ambient Air Quality Standard for PAHs should also be prescribed with immediate effect.

- Widespread publicity on environmental levels of toxic air pollutants and the associated health risk for increased public awareness and political sensitivity to curb the PAHs levels, exposures and related health effects is recommended through various means, including web notice boards.

To contain the PAH pollution in ambient/indoor air in urban/rural areas in India, the following aspects should be prioritised:

Technology

- Low PAH emitting vehicles.
- Change in fuel policy to limit the environmental levels of PAHs.
- Phasing out of the combustion engines with outdated designs.
- Discouraging gasoline/diesel-powered transport by suitable alternatives of mass transport.
- Biomass substitution with safer fuels e.g. LPG.
- Ventilated housing and work environment.
- Raise the current speed limits on well-protected highways.
- Increase the number of high-speed roads and the high-speed fly-overs in PAH polluted cities.

Environment

- Geographical spread and intensification of Green Belts.
- Regular monitoring of the ambient/indoor air PAH levels to contain it within the limit or the targetted value.

Medical

- Exposure assessment of PAH exposed subjects to study the pattern and change in the prevalent rate of associated morbidities by environmental or technological interventions.
- Lung cancer (target tissue) risk assessment particularly in view of extraordinarily high levels of benzo(a)pyrene & RSPM content of ambient air environment.
- Study mortality rate association with ambient air PAHs/RSPM content.
- Study PAHs burden in body tissues.

The main objective however, is to bring down PAHs environmental levels, exposure levels and the frequency of related adverse health effects to normal values.

Table 1: Ambient Air Pollutant Level at Low Traffic Density & High Traffic Density Sites in Urban Lucknow in 2001- 02

Pollutant	Permissible Limit in India	SUMMER			WINTER		
		LTD Site	HTD Site 1	HTD Site 2	LTD Site	HTD Site 1	HTD Site 2
SPM[a]	200	137.54	159.6	153.35	222.61	361.86	332.82
RSPM[a]	100	72.98	100.37	96.37	165.22	288.67	264.32
SO_x [a]	80	15.21	16.12	16.71	15.10	17.33	18.46
NO_x [a]	80	17.34	23.63	21.54	20.61	23.36	24.45
?PAHs[b]	*Not specified*	9.44	20.97	24.76	26.64	106.08	100.33
Range		29.65	92.67	48.6	80.2	78.87	220.81

a: µg/m[3] b: ng/m[3]

Table 2: Indoor Air Pollutant Level during Passive Exposure in Rural Lucknow

Pollutant	Permissible Limit in India	SUMMER				WINTER			
		At cooking site			At non-cooking site	At cooking site			At non -cooking site
		Wood	Cowdung	LPG		Wood	Cowdung	LPG	
RSPM[a]	0.1	6.35	9.53	BDL	0.44	9.71	9.91	0.86	0.89
SO_x [b]	*Not specified*	39.58	49.07	7.97	7.11	64.98	69.18	8.84	9.53
NO_x [b]	*Not specified*	51.08	61.28	11.47	10.47	88.80	91.44	12.04	11.85
?PAHs[b]	*Not specified*	19.98	27.83	7.42	6.18	37.5	42.3	20.2	19.06
Range		44.49	54.01	12.73	3.71	99.79	39.04	27.94	20.58

a: mg/m^3 b: $\mu g/m^3$

Table 3: Indoor Air Pollutant Level during Active Exposure in Rural Lucknow

Pollutant	Permissible Limit in India	SUMMER				WINTER			
		At cooking site			At non-cooking site	At cooking site			At non -cooking site
		Wood	Cowdung	LPG		Wood	Cowdung	LPG	
RSPM[a]	0.1	12.86	13.85	0.95	1.01	15.79	15.18	1.02	0.81
?PAHs[b]	*Not specified*	40.83	77.01	11.10	11.36	69.23	90.50	26.78	23.73
Range		167.71	206.44	13.72	14.45	150.27	109.94	21.02	32.09

a: mg/m^3 b: ug/m^3

Figure-1: PAHs Profile in Ambient Air of Urban Lucknow during 2001/02

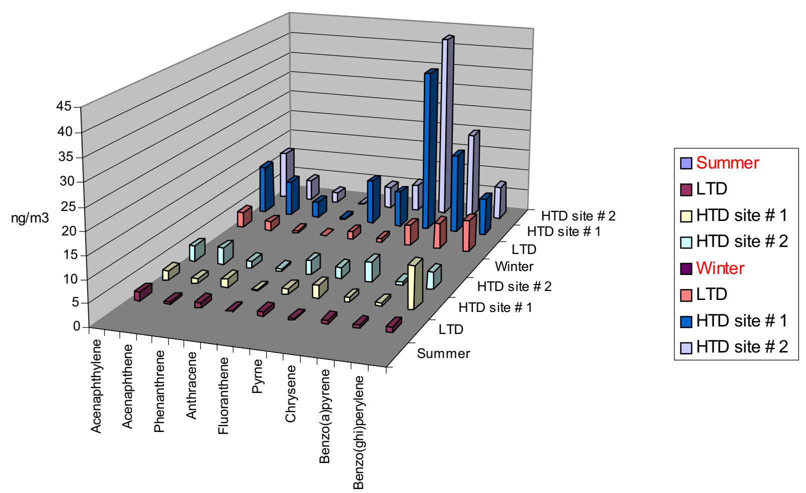


Figure-2: Indoor PAHs Profile during Active Exposure at Rural Lucknow

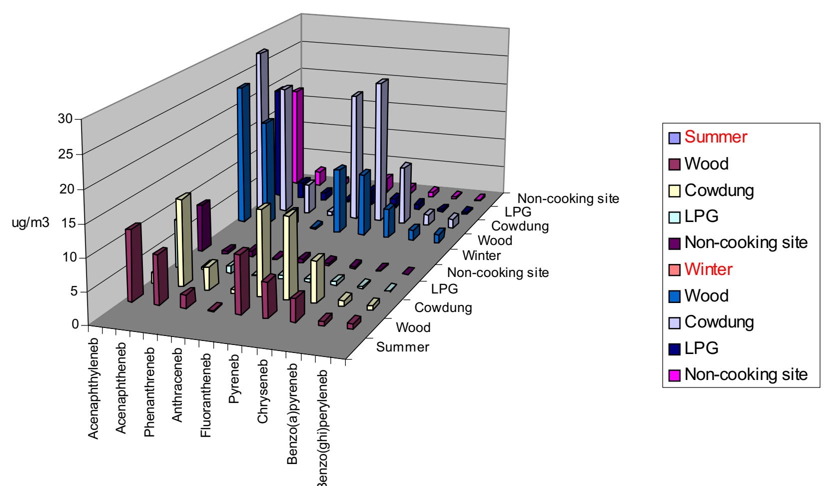
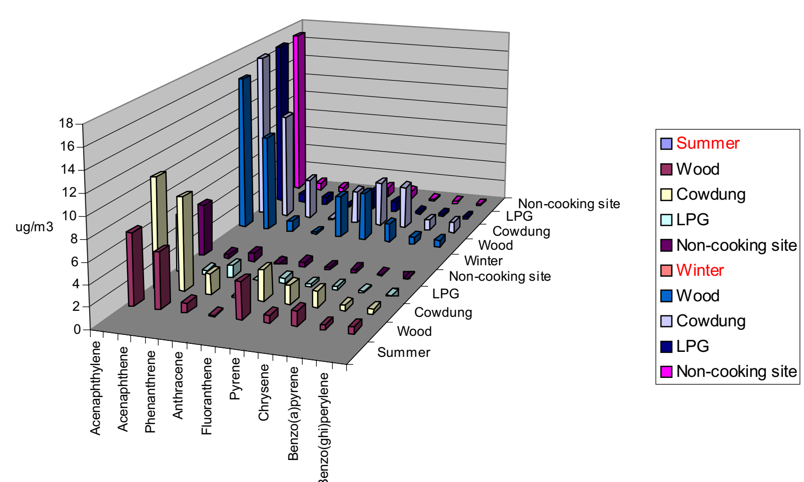


Figure-3: Indoor PAHs Profile during Passive Exposure at Rural Lucknow



Estimating the Environmental Cost of Industrialisation in Gujarat: A Case Study of Ankleshwar GIDC

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Introduction

Industrialisation is considered to be one of the factors leading to growth. The Government of Gujarat (GOG) has repeatedly offered many concessions to attract capital. Gujarat tried to encourage industrialisation by offering infrastructural facilities for small and medium scale industrial units by establishing the Gujarat Industrial Development Corporation (GIDC) in 1962. Thus, Ankleshwar Industrial Estate (AIE) was established by the GIDC with a view to develop a backward tribal belt of Gujarat and place it on the industrial map of the country. As a result of the efforts of the GOG, Gujarat did emerge as one of the most industrialised states in India.

Presently, the AIE ranks second among all the 122 fully developed estates in terms of employment, investment and production. AIE has been the subject of study by quite a few researchers, but these have not addressed the environmental economic issues of industrialisation.

Objective

The objectives of this project are to:

- Estimate the environmental cost of industrialisation taking Ankleshwar GIDC as a case study, and focus on a relatively neglected area of study viz; cost in terms of loss of property value.

It is expected that property in a cleaner environment would fetch a higher price than a similar property in a polluted environment. This price differential can be taken as willingness to pay for clean air. One can directly estimate people's willingness to pay by using contingent valuation. In our study both methods have been used, viz. direct as well as indirect, to calculate this element of environmental cost. In a poor economy like India, it is expected that the real estate market is not very developed. Further, in a situation of severe unemployment and underemployment people may not put a high value on clean environment. This should not lead us to a situation where we do not even attempt to estimate environmental costs.

Study Area

This study concentrates on Ankleshwar GIDC, which falls in the Golden Corridor of Gujarat state. AIE is strategically important for the industrial scene of Gujarat. It is strategic because of the following locational advantages:

- Its proximity to urban industrial conglomerates of Bharuch, Valsad, Vadodara and Ahmedabad.
- Availability of subsidies under the special backward area upliftment programme promoted by the state.
- Availability of oil and natural gas in and around Ankleshwar.
- Existence of a convenient outlet for effluent disposal due to its proximity to the sea as well as to the Narmada River. The AIE has two creeks - Amlakhadi and Sarangpur Khadi - that carry treated wastewaters to the Narmada River.

The Ankleshwar Industrial Estate houses mainly dye factories, chemical and allied industries, paper and pulp producers, pesticides, textiles, pharmaceuticals, paint manufactures and engineering companies. To get a comparative picture of real estate price behaviour between two different areas - one polluted and another non- / less polluted - we selected Ankleshwar town along with Ankleshwar GIDC. Ankleshwar town is close to Ankleshwar GIDC and is supposed to be non-polluted or less polluted. People residing in Ankleshwar town commute to Ankleshwar GIDC for work.

Methodology

The Behaviour Linkage Method, which is a combination of revealed preference methods, particularly the hedonic pricing method and the stated preference method of contingent valuation for estimating the environmental cost as expressed in property / real estate value, has been used in this study.

An attempt is made to measure environmental externality through the housing value method. Hedonic Property Value [HPV] method tries to capture the value of clean environment by comparing the value of similar properties near a polluted site and a cleaner site. We have to bear in mind the fact that property values also depend, besides pollution levels, on income, size of the house, size of the family, quality of construction / fixtures, etc. To use this method, we need data on property values, pollution levels by different sites, income, family size, etc. This data is not readily available. In fact, there are only two monitoring centres in Ankleshwar GIDC, for which we get data on air pollution. We have therefore, considered the perceptions of the people regarding the value of their property and the pollution existing in their area. We have also gathered information on maintenance cost of property. The cost is to be estimated in terms of fall / not increasing the value of a given property as well as in terms of frequency of painting the house, changing of pipes, etc. The relationship between housing values and air pollution, in other HPV studies, did not turn out to be large. Thus, this relationship is observed to be small but significant in other studies. The HPV method is expected to give us the direction, rather than the magnitude of air quality's influence on residential property values.

In this study we have used the following techniques:

- Revealed preference method by estimating the Willingness To Pay (WTP) and Willingness To Accept (WTA), elasticities of WTP with respect to income for property owners and for tenants by zones (i.e. North or South) of GIDC.
- Hedonic Price Functions are estimated using Ordinary Least Squares (OLS) method. Four dependent variables –. Purchase Price, log of Purchase Price, Rent, and log of Rent – are used one after the other. Independent variables finally selected include annual income, distance from residence to school, number of children, number of rooms, Dummy for maintenance on account of discolouration, and concentration of SO_2.
- A new dependent variable is created named Relative value, which is defined as a Ratio of Purchase Price per average square feet of built-up area. Using OLS, its relation with SO_2 and age of the building is observed.
- 'Residualisation' has been done to take care of multi-collinearity between income and number of rooms. Hedonic Price Functions have been estimated using the residualised variable as well.
- Using a different Hedonic Price Function, we have estimated Marginal Rent / Marginal Purchase Price. In these functions five independent variables, - number of rooms, distance from residence to workplace, people's perception about pollution in their area, concentration of SPM/SO_2, and dummy for zone (i.e. North or South of GIDC) - are used. These estimated marginal rent / purchase price variables are then used to estimate the Marginal Willingness To Pay using OLS.

Total number of respondents in our sample is given below for Ankleshwar GIDC, Ankleshwar Town and Real Estate Agents.

Area	No. of Respondents	
Ankleshwar GIDC	1253	includes Residential + Commercial + Residential cum Commercial property owners / tenants.
Ankleshwar Town	667	households
Real Estate Agents	30	

Results

As noted earlier, Contingent Valuation Method (CVM) and Hedonic Pricing Method (HPM) were used in this study. Since data on property prices, and on other important variables was not available, we used the survey method to collect primary data. A sample of 1,253 people were surveyed in Ankleshwar GIDC. The findings of this study are discussed below:

- Ankleshwar GIDC is divided clearly into two zones, viz. North and South, characterised by different socio-economic backgrounds of the respondents. Respondents residing in the north of GIDC had, on an average, much lower annual income (lower than Rs.58,000/-) as compared to residents of the south of GIDC (slightly more than Rs.1,00,000/-). Further, on an average, residents of the north of GIDC had a marginally larger size of family with more children. There was a considerable concentration of single room houses in the north. The residents of the north complained about severe problems of air pollution at night, particularly after midnight when the industrial units released gases illegally. This finding indicated that relatively poor people resided in areas that were more polluted.

- Residential / Commercial properties located in the north zone of GIDC suffered from higher incidence of decolourisation, greater corrosion of iron fittings like grills on the windows, and greater chipping of the paint. All these show that these were the outcomes of higher levels of pollution.

- About 64 percent of the respondents were forced to keep their doors/windows closed on account of air pollution. 66 percent of the respondents expressed that their property prices have fallen in recent years,, but the reason for this was industrial recession, not air pollution. Presently, a situation exists where air quality has improved (on account of closing down of some industrial units) and properly prices have fallen. This should not lead us to believe that air pollution has no influence on property prices and this component of environmental cost should be treated as zero.

- An overwhelming majority (81%) of respondents were not ready to accept any monetary compensation for a 50 percent increase in levels of air pollution. As against this, a relatively smaller proportion (48%) of the respondents registered zero (nil) willingness to pay. These zero responses are mainly 'protest zeros.'

- From amongst the three socio-economic variables, viz. annual income; size of the family, and, number of children, used here, it was annual income that turned out to be significantly and positively correlated with each one of the four dependent variable, viz. purchase price, log of purchase price, rent and log of rent.

- Purchase price and log of purchase price were significantly correlated with all the six independent variables labelled as Structural Variables. From amongst these six independent variables, five, viz. built-up area, number of rooms, number of bathrooms, number of toilets and expected price of the property, were positively and significantly correlated with purchase price and its logarithm.

- From amongst the seven accessibility variables, it was the travel expenditure incurred by the respondents to reach the workplace that was positively and significantly correlated with purchase price and its logarithm. The same independent variable had a negative and significant relation with log of rent. The other two, viz. distance from residence to garden and distance from residence to theatre, had negative and significant correlation with purchase price and log of purchase price. These two independent variables were not significantly correlated with rent and its log.

- Data on air pollution was not available for different areas of GIDC as there are only two monitoring centres in GIDC. The respondents were asked to state whether they perceived air pollution in their area to be unbearable, bearable or moderate. We observed a negative regression coefficient between pollution being perceived as unbearable and the purchase price of the property / log of purchase price / rent / log of rent. These coefficients turned out to be statistically not significant. The perception of people that pollution is moderate was significantly and positively correlated with purchase price, log of purchase price and log of rent. This means that people did not mind paying a higher price / rent for areas that they thought were moderately polluted. It was the concentration of nitrogen oxide that was negatively and significantly correlated with rent. The same variable had a negative but a weak correlation with other three dependent variables.

- A strong positive correlation existed between income and distance from workplace, implying that people who can afford to stay in a cleaner environment did not mind commuting a longer distance to work and incurring higher transport cost.

- To estimate Hedonic Price Function, we used four dependent variables, viz. Purchase Price, log of Purchase Price, Rent, and log of Rent. Five independent variables, viz. annual income, no. of children, no. of rooms, distance from residence to school and dummy for maintenance cost on account of discolouration and corrosion, explained together about 31 percent, 42 percent, 34 percent, and 22 percent of variations in purchase price, Ln purchase price, rent and Ln rent, respectively. From amongst the five independent variables, only two - annual income and number of rooms - turned out to be significantly and positively associated with all the four dependent variables. Distance from residence to school was significantly and negatively associated with rent and Ln rent. The dummy for maintenance had negative and significant association with log rent. The results for respondents residing in the south of GIDC were similar.

- Incorporating variables on air pollution, i.e. SO_2 and SO_2^2, did not change our results significantly in terms of explanatory power of the equations. The explanatory powers of regression incorporating these two variables, along with other variables were lower than what they were without the pollution variables. But, with the introduction of SO_2 and $(SO_2)^2$ as additional variables, annual income and number of children lost their significance in explaining variations in purchase price. Annual income continued to be significant for explaining variations in Ln purchase price, rent and Ln rent. Number of rooms continued to be a significant variable in explaining variations in all the four dependent variables.

Given below is a table showing correlation between different variables.

Table 1: Correlation Matrix of GIDC Ankleshwar for Purchase Price, Ln Purchase Price, Rent, Ln Rent with Socio-Eco, Structural, Accessibility and Environmental Variables

	Purchase Price	Ln Purchase Price	Rent	Ln Rent
(I) Socio-Eco. Variables				
Annual Income	.139**	.201**	.178**	.125*
Size of Family	-.006	-.103*	.145**	.100*
No. of Children	-.118*	-.204**	-.070	-.048
(II) Structural Variables				
Built-up area sq.ft.	.329**	.433**	.152**	.140**
No. of Rooms	.564**	.573**	.469**	.360**
Age of House	-.224	-.327**	-.082	-.102
Bathroom	.541**	.460**	.419**	.272**
Toilets	.520**	.420**	.366**	.238**
Expected Price of house	.710**	.547**	.362**	.174**
Maintenance cost	.202**	.178**	.167**	.068
(III) Accessibility Variables				
Dist. from residence to work place	-.006	.022	.036	.064
Travel Expenditure	.125**	.154**	.010	-.160**
Time taken to reach work place	-.007	-.015	.019	.095*
Dist. from residence to School	-.061	-.088*	-.014	-.068
Dist. from residence to Market	-.041	-.077	-.044	-.049
Dist. from residence to Garden	-.142**	-.211**	.040	-.019
Dist. from residence to Theatre	-.142**	-.220**	.019	-.035
(IV) Environmental Variables				
Dup1=1 if perception of pollution is unbearable	-.065	-.076	-.051	-.029
Dup2=1 if perception of pollution is moderate	.115**	.098*	.057	.119*
Due2=1 if forced to keep doors/windows closed	-.018	-.004	.013	.070
Due3=1 if maintenance is for discolouration & corrossion	-.031	.003	-.104	-.155**
Due4=1 if rank of air pollution is ranked one	.022	.043	.028	-.018
SO_2	-.082	-.101	-.091	-.086
No_x	-.027	-.008	-.118*	-.097
SPM	.002	.041	-.078	-.059

Note: ** Correlation is significant at 0.01 level (2-tailed)

* Correlation is significant at 0.05 level (2-tailed)

- Since the annual income and number of rooms were majorly correlated, we used residualisation. Thus, from the effect of the number of rooms on purchase price / Ln purchase price / rent / Ln rent, we have taken out the effect of annual income on the number of rooms. The explanatory power of our regression equations is not expected to change, but the regression coefficient for income is expected to change as its effect captured in number of rooms is corrected for. With this correction, annual income turned out to be a more significant variable. The rest of the regression coefficients did not change.

- None of the four dependent variables mentioned above had significant association with environmental variables. A new dependent variable called Relative Value of the real estate was introduced. This variable is derived from the two variables of purchase price and built-up area. Thus,

  Relative Value = Purchase price per square feet of built-up area Average price per average square feet of built-up area.

Regressing this variable on two variables using step-wise regression, we got the following result.

Relative Value = 0.586 + 0.376 (age)* - 0.235 (SO_2)*

(Adjusted R^2 = 0.155) * significant at 1% level.

This indicates that the age of the building had a positive and significant relationship with the relative value of the real estate – as defined above. In this model SO_2 emerged as a strong negative effect on relative value of the property. The effect that was not captured in actual purchase price got reflected in the *relative* value of the real estate.

Our findings and results show that rigorous statistical exercises did not help us to indicate any effect of air pollution on property prices. One of the reasons for this is that our data was not robust enough to withstand such rigorous exercise. In spite of this, we did succeed in establishing the adverse effect of air pollution on property prices by using people's perceptions regarding levels of pollution and property price behaviour. Further, even when people residing in GIDC and working there had fear of unemployment, they were willing to pay for reducing air pollution. There were large numbers of respondents who registered a 'protest zero'. In sum, people did have a fairly clear idea about the relationship between air pollution and property prices.

Our study clearly brought out the fact that income is negatively, though weakly, correlated with SO_2, NO_x and SPM. We have also observed a strong positive effect of income on purchase price, Ln purchase price, rent and Ln rent. These two observations taken together indicate the existence of an inverse relationship between air pollution and property prices. The government should try to protect the value of properties in industrial estates by monitoring air quality of industrial units that are expected to start production when the economy comes out of industrial recession. The government should not allow growth of industrial output, ignoring the loss of property value whose existence this project has brought out.

Concluding Remarks and Recommendations

The present study is an attempt to estimate the environmental cost of industrialisation as expressed in terms of loss of property value on account of air pollution resulting from industrial development. Based on our experience and findings, the following recommendations are put forward:

- Reliable data on air pollution and property prices should be collected. The foremost requirement is establishment, of a number of monitoring centres for air/water quality. Mandatory auditing of industrial units in terms of pollutants emitted per unit of output, total volume of output, etc. should be introduced and records must be maintained. The data should be made available in the public domain.

- To encourage citizens' awareness and action, industrial units should be classified according to the type and quantity of pollutants they emit. A colour code should be adopted to identify the units that cross the permissible limits of different pollutants. Those that emit less than the acceptable quantity of given pollutants may be allotted a green colour, while those crossing limits and creating hazards may be given a red colour. These colour codes should be made public, and after a few warnings, the colour given to an industrial unit should also be made public. This would exert pressure on these units, emerging from fear of adverse public opinion. This knowledge will make it possible for people to select a site for their house where they are not forced to keep the windows and doors closed.

- The effect of air pollution on property price can be indicated by looking at the average purchase price per average built-up area between north and south of GIDC. The north-east area of GIDC falls in the wind direction and suffers air pollution more intensely as compared to the south. The ratio of average purchase price to average built-up area for the south and north turned out to be 1:9, implying that on an average, property price per square feet in the south was almost twice that in the north.
- Illegal release of gases at night must be stopped. Industrial units dumping wastes illegally at night and releasing harmful gases should be severely punished and heavy penalty should be imposed.
- Even poor people were willing to pay for an improvement in air/water quality, and were not willing to accept even a marginal deterioration in air quality. These costs do not get incorporated in our cost calculations while planning our industrial strategy. Unfortunately, the price for cleaner air was also not captured by our hedonic price function as all the regression coefficients for air pollution turned out to be statistically insignificant. This is so because for these people, having an employment, saving on transport and benefiting from other infrastructural facilities available in GIDC was more important than staying away and paying higher real estate prices in cleaner environments. However, it was observed that relatively poor people lived in areas that fall in the wind direction for most of the time during a year. Their property prices were lower, and as per their perceptions these prices did not increase as much as in other areas in the south of GIDC.
- Intense efforts should be made to monitor air and water quality, and the assistance of research institutes, university departments and NGOs should be sought by the GOG.
- The government should have a clear-cut policy on housing in industrial estates.