Environmental Health Effects Analysis

A study to estimate health impacts and social costs of ambient air pollution in Hyderabad, India

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Satish Kumar K[1]
Srinivasa Reddy N[2]
Dhanaraj[3]

[1] Faculty in Environmental Health, The Institute of Health Systems, HACA Bhavan, Hyderabad, AP 500 004
[2] Research Associate, The Institute of Health Systems, HACA Bhavan, Hyderabad, AP 500 004
[3] Research Associate, The Institute of Health Systems, HACA Bhavan, Hyderabad, AP 500 004

The Institute of Health Systems
HACA Bhavan, Hyderabad, AP - 500 004, India
Ph: 91-40-23210136/9,23211013/4; Fax:91-40-23241567
Email: ihs@ihsnet.org.in; http://www.ihsnet.org.in

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CONTENTS

Abbreviations and Acronyms

APHEBA	Air Pollution Health Effects Benefit Analysis
BAU	Business as Usual
BG	Biogas
CHC	Community Health Centre
COI	Cost of Illness
COPD	Chronic Obstructive Pulmonary Disease
CR Function	Concentration Response Function
CVD	Cardiovascular Disease
ESI	Employees State Insurance
GVH	Government Hospital
HCA	Human Capital Approach
HUDA	Hyderabad Urban Development Area
ICD	International Classification of Disease
IES	Integrated Environmental Strategies
IHS	Institute of Health Systems
MCH	Municipal Corporation of Hyderabad
NG	Natural Gas
PCI	Per Capita Income
PHC	Primary Health Centre
PM	Particulate Matter
PM_{10}	Particulate Matter less than 10 microns in diameter
RSP	Respiratory Ailment
SPM	Suspended Particulate Matter
TSP	Total Suspended Particulate
VSL	Value of Statistical Life
WHO	World Health Organisation

Environmental Health Effects Analysis

Executive Summary:

Adverse health effects attributable to air pollution are an important public health problem. Air pollutants such as particulate matter have damaging effects on human health. Estimates of the health damages associated with air pollution are required to assess the size of the problem and to evaluate the impact of specific pollution control measures. The health effects analysis as part of the larger Integrated Environmental Strategies (IES) India Program was carried out in Hyderabad, to develop an initial estimation of the health impacts of air pollution and their social costs, based on available data, ambient air quality and health effects modeling. PM_{10} was identified as the criteria pollutant for IES India analysis. The analysis was conducted for Business as Usual (BAU) and four identified alternative mitigation scenarios. The magnitude of health impacts in relation to PM_{10} exposure was calculated using both a health risk assessment approach and percentage increases of mortality or morbidity per unit increase of air pollutant concentration. The analysis is based on Concentration Response (CR) functions derived from available epidemiological studies. Health benefits were computed using Human Capital Approach (HCA) for mortality valuation, and the Cost of Illness (COI) Approach for valuing morbidity. Transportation sector is the largest contributor to air emissions (approx. 70% of the total load) in Hyderabad. The effective bus transit mitigation scenario resulted in, 1/3rd reduction of PM_{10} concentrations compared to BAU levels, and the most significant decreases in mortality and occurrence of CVD and other respiratory diseases. Implementation of this mitigation measure in Hyderabad would prevent **3,699** long-term deaths, **1,469** short-term deaths, **2,320** cardiovascular hospital admissions in 2011 and **21,552** long-term deaths, **7,544** short-term deaths, and **17,401** cardiovascular hospital admissions in 2021. The estimated annual health benefits in terms of long-term deaths, avoided from effective bus transit mitigation measures, ranges from **207** million US$ in 2011 to **1209** million US$ in 2021. The transportation sector was recognized as an area, where significant air quality and public health benefits could be realized through the IES, India Analysis.

Introduction:

Adverse health effects attributable to air pollution are an important public health problem in Hyderabad, India and throughout the world. Air pollutants such as particulate matter have damaging effects on human health. Estimates of the health damages associated with air pollution, namely particulate matter concentrations, are required to assess the size of the problem and to evaluate the impact of specific pollution control measures.

Worldwide, the World Health Organization (WHO) estimates that as many as 1.4 billion urban residents breathe air exceeding the WHO air guidelines[1]. On a global basis, an estimated 800,000 people die prematurely from illnesses caused by air pollution. Approximately 150,000 of these deaths are estimated to occur in South Asia alone[2]. Air pollution has also been associated with a variety of cardiopulmonary illnesses.

Particulate Matter and Health:

Particulate matter, or PM, is the term for particles found suspended in the air, including dust, dirt, soot, pollen, smoke, and liquid droplets. Particulate matter (PM) appears to be associated with adverse health outcomes ranging from acute respiratory symptoms to premature mortality. Particles in the air are classified by aerodynamic diameter and chemical composition. Particulate matter is classified into two categories based on the chemical composition, primary and secondary particles. Primary particles are composed of particles that are emitted directly into the atmosphere from sea spray, wind blown soil, road traffic, coal burning and Hcl and ammonium compounds under atmospheric conditions. Air borne particles in the air are referred to as Suspended Particulate Matter (SPM), and the term Total Suspended Particulate (TSP) implies that a gravimetric procedure was used to determine suspended particulate matter. Particulate matter is classified into course, fine and ultra-fine particles based on aerodynamic diameter. PM10 and coarse particles are synonymous terms, with an aerodynamic diameter of 10mm or less. PM2.5 are fine particles with a diameter of 2.5 mm, ultra fine particles are those with a diameter of <1.0mm.

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[1] World Health Organization (1997). Health and Environment in Sustainable Development: Five years After the Earth summit. Geneva: World Health Organization.

[2] A. Cohen, R. Anderson, B. Ostro, K.D. Pandey, M. Kryzanowski, N. Kunzli, K. Gutschmidt, A. Pope, I. Romieu, J. Samet and K. Smith. (2003). Mortality Impacts of Air Pollution in the Urban Environment. In M. Ezzati, A.D. Lopez, A.D. Rodgers and C.J.L. Murray, ed., Comparative Quantification of Health Risks: Global and Regional Burden of Diseases due to Selected Major Risk Factors. Geneva: World Health Organization.

Health effects due to PM10 exposure can be immediate / acute (short-term effects) or delayed / chronic (long-term effects). Extensive epidemiological evidence has demonstrated that increase in ambient particulate concentrations are associated with increase in total mortality from respiratory and cardiac diseases, increases in daily respiratory symptoms and decreases in pulmonary functions. Sensitive groups including the elderly, children and individuals with pulmonary and cardiovascular diseases such as asthma and COPD are at a higher risk of developing adverse health effects from particulate exposure.

In India, millions of people breathe air with high concentration of pollutants. This leads to a greater incidence of associated health effects on the population manifested in the form of sub-clinical effects, impaired pulmonary functions, increased demand for medications, reduced physical performance, frequent medical consultations, and increased hospital admissions.

Geographic Scope:

The health effects analysis for the Integrated Environmental Strategies (IES) Program was carried out in the Hyderabad Urban Development Area (HUDA), which encompasses approximately an area of 1850 sq. kms., and includes the Municipal Corporation of Hyderabad (MCH), 10 municipalities belonging to Ranga Reddy district and an industrial outgrowth area - Patancheru of Medak district. The IES health effects study aimed at developing an initial estimation of the health impacts of air pollution in Hyderabad, based on available secondary data and ambient air quality modeling.

Pollutant Considered:

Since PM10, particulate matter <10 microns in diameter, is most strongly associated (and documented) with respiratory morbidity and premature mortality, PM10 was identified by the IES team as the criteria pollutant for health effects analysis in Hyderabad. The base year for the health effects analysis, and the entire IES project was Calendar Year (CY) 2001.

Age Groups Considered:

For the health effects analysis, the following age groups were considered:

- Children: 0 to 17 yrs;
- Adults: 18 to 64 yrs;
- Elder: Greater than 65 yrs.;
- All: All ages (the whole population).

Objectives :

1. Develop an initial estimation of the health impacts of air pollution in Hyderabad and their social costs, based on available secondary data.
2. Identify the most relevant health and social welfare impacts.
3. Identify data gaps and research needs for future assessments**.**

Methodology:

<u>Data Collection Process</u>

Population data:

Age-wise and sex-wise population data of the study area were obtained from the Census of India 2001.

Mortality data :

Data on all cause and cause specific deaths, from non-external causes, excluding the trauma deaths, age and sex-wise for the year 2001 were obtained from the Directorate of Health / Municipal Health Offices falling under the MCH area and 10 municipalities of Ranga Reddy Districts.

Morbidity data :

Cause-specific morbidity data for the selected health endpoints were collected from Health Care Institutions (HCI) selected using APHIDB (Andhra Pradesh Health Institutions Database) an electronic database maintained by IHS. The selection of hospitals was done to be representative of the study area. Initial survey of all major hospitals and health posts within the study area revealed that record keeping, particularly with respect to retrospective data was very poor. Hence, data was collected from only 28 hospitals (Table 1) out of total 68 hospitals visited in and around HUDA area, based on availability of medical records.

Table-1: List of hospitals that provided cause-specific morbidity data

S. No.	Name of the Hospital	Type of Management	Bed strength
1	Osmania General Hospital	Government	1,168
2	Gandhi General Hospital	Government	1,012
3	Nizam's Institute of Medical Sciences	Government	735
4	A.P. General and Chest Hospital	Government	670
5	Sir Ronald Institute of Tropical & Communicable Disease Hospital	Government	330
6	ESI Hospital	Government	334
7	Niloufer Hospital	Government	300
8	King Koti District Hospital	Government	200
9	Vanasthalipuram Area Hospital	Government	100
10	Nampally Area Hospital	Government	100
11	Malakpet Area Hospital	Government	100
12	Golconda Area Hospital	Government	100
13	Rajendranagar CHC	Government	30
14	Dr. R. Vijay Kumar Clinic	Private	NA
15	Apollo Hospital	Private	350
16	Mediciti Hospital	Private	NA
17	Indo-American Cancer Hospital and Research Centre	Non-profit Registered trust	125
18	APVVP Government Dispensary	Government	NA
19	Balanagar PHC	Government	6
20	Government Unani Dispensary	Government	NA
21	Uppal PHC	Government	NA
22	Gatkesar PHC	Government	NA
23	Ramchandrapuram PHC	Government	NA
24	Kesara PHC	Government	NA
25	Serilingampally PHC	Government	NA
26	Alwal CHC	Government	NA
27	Quthbullapur PHC	Government	NA
28	Malkajgiri GVH	Government	NA

NA: Data not available

Health Effects Quantification:

The magnitude of health impacts in relation to PM10 exposure was calculated using both a health risk assessment approach and percent increase of mortality or morbidity per unit increase of air pollutant concentration.

Since most of the epidemiological studies linking air pollution and health endpoints are based on a relative risk model in the form of Poisson regression, the number of health effects at a given concentration C, is given by the following Equation:

$$\text{Effects}(C) = \exp(ß \times (C - C0)) \times R0 \times Pop$$

In the above Equation, ß is the slope of the CR function, C and C0 are concentrations of the air pollutants in one specific scenario and baseline scenario respectively, R0 refers to the base rate of effects at concentration C0, and Pop is the exposed population.

APHEBA Model

The Air Pollution Health Effects Benefits Analysis (APHEBA) Model was selected for the health effect analysis component of the IES - India Project. The APHEBA model is an integrated assessment model designed to evaluate the benefits or costs associated with changes in atmospheric pollutant concentrations in a given location and time period. It allows comparison of a base case and study case for a selected pollutant. This model has been developed by Dr. Luis Cifuentes (IES, Chile Project), and is coded in Analytica software. Analytica is an object oriented health effects modeling language. It incorporates Uncertainty Propagation and Analysis through Montecarlo Simulation. APHEBA makes it possible to manage complex multidimensional objects as simple objects. The Model also enables easy visualization of results by scenarios, using different metrics. Progressive refinement of the model is possible by defining interconnecting models.

The following is the summary of data sources and assumptions that were used for the health effects analysis.

Parameter	Time and Geographical Resolution	Observations
Demographic Data		
Population	For 2001, 2011 and 2021 For each municipality	
Health data		
Mortality Rate (All cause, CVD, RSP)	For 2001 only For each municipality	Rates extrapolated for other years
Incidence Rate for Hospital admissions (CVD, RSP, COPD, Asthma) and Outpatient visits	For 2001 only For each municipality	Rates extrapolated for other years
Average length of stay for hospital admissions (CVD, RSP, COPD, Asthma)	For 2001 only for the whole area	Rates extrapolated for other years and locations
C-R for short-term exposure mortality	HEI meta-analysis from Asian studies	
C-R for long-term exposure mortality	USA data	
C-R for morbidity endpoints	USA data	
Economics data		
VSL	USA data transferred using PCI	
Human Capital Value	Computed for Hyderabad	
Unit values for morbidity endpoints	USA data transferred using PCI	

Endpoints considered:

The endpoints considered for the study are as follows:

Endpoint
Mortality (long-term exp)
Mortality All
Hosp Adm CVD (Cardiovascular Disease) (ICD 390-429)
Hosp Adm RSP (Respiratory Ailment) (ICD 460-519)
Hosp Adm COPD (Chronic Obstructive Pulmonary Disease) (ICD 490-496)
Hosp Adm Asthma (ICD 493)
Outpatient visits (internal medicine)

Demographic Data:

The population data for the different localities falling under the study area are given in Table-2. The population figures for the analysis years of 2011 & 2021 were projected using the population growth rates corresponding to the base year 2001.

Table-2: Hyderabad localities and their population for the analysis years

MUNICIPALITY	Population		
	2001	2011	2021
HYDERABAD (MCH)	3,655,983	4,196,979	4,818,029
RAJENDRANAGAR	162,114	301,539	560,876
LB NAGAR	286,177	588,814	1,211,495
MALKAJGIRI	192,810	280,818	408,996
ALWAL	110,576	201,422	366,905
QUTHBULLAPUR	229,322	701,785	3,147,645
SERILINGAMPALLY	151,101	445,567	1,313,891
GADDIANARAM	53,622	90,546	152,896
UPPAL KALAN	118,747	210,923	374,651
KAPRA	159,176	359,247	810,791
KUKATPALLY	291,256	506,902	882,375
PATANCHERU	64,189	73,732	84,693
GHATKESAR	19,449	22,340	25,662
TOTAL	5,494,531	7,980,614	14,158,905

Notes: Patancheru and Ghatkesar are not municipalities. Patancheru is an industrial outgrowth, and Ghatkesar is the rural area selected from HUDA area for health data collection, to be able to extrapolate health effects analysis to the outlying rural areas of HUDA as it is a predominantly urban area.

Health Data:

The baseline mortality rates for the base year 2001 for the different localities are given in Table-3.

Table-3: Baseline mortality rate by municipalities for the year 2001 (cases/100,000)/year)

Mun.Corporation/ Municipality	All	Children	Adult	Elder
HYDERABAD (MCH)	433.78	184.43	430.72	4106.91
RAJENDRANAGAR	133.85	2.92	139.36	2240.48
LB NAGAR	288.63	15.73	315.14	4342.31
MALKAJGIRI	272.29	2.46	256.84	5210.30
ALWAL	260.45	184.43*	233.74	5290.04
QUTHBULLAPUR	175.30	5.17	210.40	2287.52
SERILINGAMPALLY	140.30	10.98	154.30	2029.37
GADDIANARAM	201.40	13.26	681.67	3386.00
UPPAL KALAN	176.85	184.43 *	319.63	3160.04
KAPRA	159.57	1.49	172.59	2560.20
KUKATPALLY	185.09	15.46	209.78	2521.82
PATANCHERU	433.78*	184.43*	430.72*	4106.90*
GHATKESAR	433.78*	184.43*	430.72*	4106.90*

NB: * Completed with data from Municipal Corporation of Hyderabad (MCH) Area.

The baseline incidence rate data for morbidity endpoints for Municipal Corporation of Hyderabad (MCH) area for the year 2001 is given in Table-4.

Table-4: MCH incidence rate data for morbidity end points

Endpoint	All	Children	Adult	Elder
Hosp Adm CVD (ICD 390-429)	100.62	3.14	139.75	788.22
Hosp Adm RSP (ICD 460-519)	118.11	89.27	136.52	194.47
Hosp Adm COPD	47.84	1.43	57.28	546.17
Hosp Adm Asthma (ICD 493)	33.15	19.25	40.01	107.58
Outpatient visits (internal medicine)	2996.5	3990.4	2250.8	2422.6

The average length of stay for different morbidity endpoints, were computed based on the date of admission and date of discharge recorded in the case sheets of public hospitals of HUDA area. The same is shown in Table-5.

Table-5: Average Length of Hospital Stay for Hospital Admissions Endpoints (days per event)

Age Group	Asthma	CVD	RSP	COPD
0-17	5.33	8.07	8.24	11.42
17-64	7.27	8.24	8.92	10.41
64+	6.66	9.34	9.02	8.79
All Ages	6.76	8.43	8.80	10.29

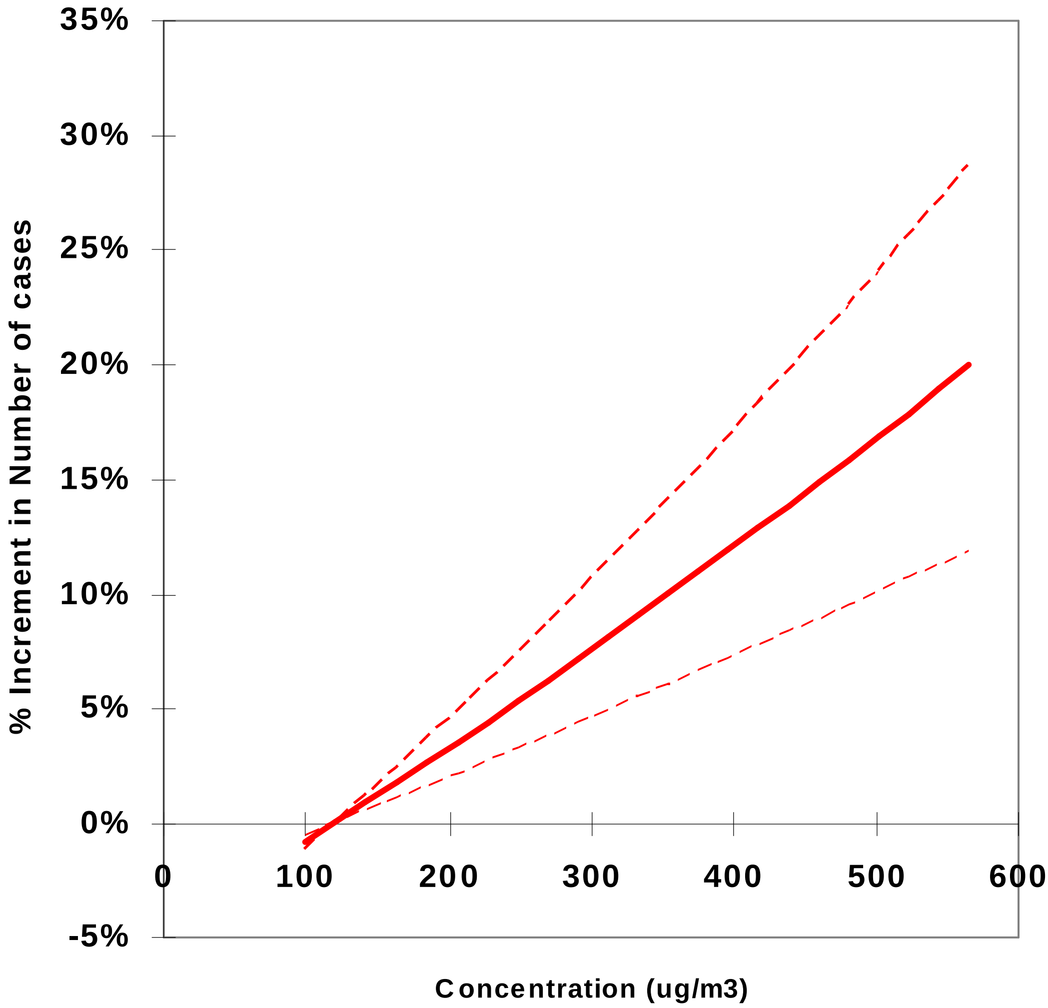
Source: Health records of public hospitals in HUDA area

Concentration-Response Functions:

Concentration-Response (C-R) functions are one of the most critical areas. Unfortunately, there are few studies conducted in India. However, a recent meta-analysis has been conducted on Asian studies. The results of the meta-analysis give a beta of 0.0004 and a Std. Dev. of 0.00008 for all cause mortality. These were used in the IES health effects analysis.

The following figure shows the C-R function in the relevant range of concentrations observed in the municipalities. We have assumed a base concentration of 121 μg/m^3, the population weighted mean of all localities.

Figure 1: C-R function for All cause mortality (mid value and 95% CI)



Note: Lower and upper dotted lines in the above graph represent low and high values, and solid line represents mid value respectively of the CR coefficient for all-cause mortality.

HEI International Scientific Oversight Committee (2004). Health Effects of Outdoor Air Pollution in Developing Countries of Asia: A Literature Review. Boston, MA, Health Effects Institute. Available at http://www.healtheffects.org/Pubs/SpecialReport15.pdf

For the other endpoints, C-R functions were used with the following relative risks:

Table–6: Estimated % increase in effects per 10 mg/m3 of PM10 for different endpoints

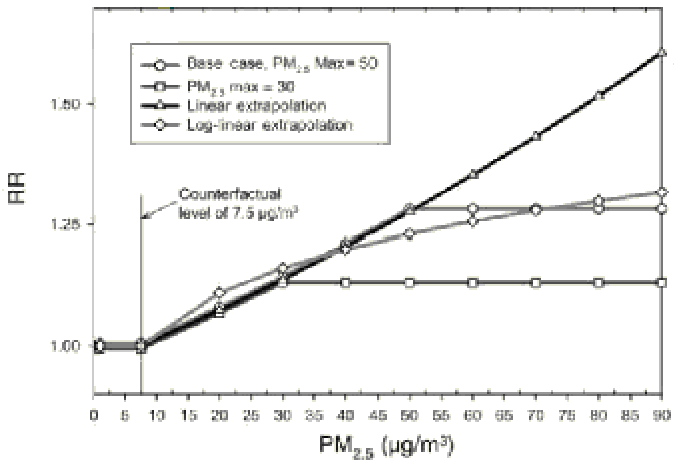
Endpoint	All	Children	Adult	Elder
Mortality (long-term exp)	3.40%	-	-	-
Mortality All	0.40%	4.00%	-	-
Hosp Adm CVD (ICD 390-429)	2.30%	-	-	1.20%
Hosp Adm RSP (ICD 460-519)	0.02%	-	-	1.70%
Hosp Adm COPD (ID 490-496)	-	-	-	2.6%

Long-term Effects of Particulate Matter:

Long term effects of Particulate Matter pollution are more difficult to consider. The risk coefficient for long-term mortality is much higher (see above Table-6, the coefficient is 8 times more) than that for short-term effects. That means that at higher concentrations, the risk is bigger. Also, there are problems with extrapolation outside the range of the original studies, which is about 10-30 $\mu g/m^3$ of $PM_{2.5}$.

Since there are no Asian studies at higher concentrations (all of them have been performed in the US), one should make some assumptions about the shape of the C-R function outside the range of the original study. The next figure shows some of such assumptions, proposed by the group that performed the Global Burden of Disease calculation for the WHO.

Figure-2: Alternative concentration-response curves for mortality from cardio-pulmonary disease, using different scenarios



Source: Figure 17.7 Cohen, A. J., H. R. Anderson, et al. (2004). Chapter 17: Urban air pollution. Comparative Quantification of Health Risks.

In this analysis we assumed a linear C-R function for long-term mortality. It must be noted that this probably results in an overestimation of the long-term exposure effects. Also, the original studies considered an exposure that lasted 18 or so years. If the pollution levels are growing rapidly, then the annual average will be higher than the moving average for the past years, also resulting in an overestimation of the impacts. Therefore, for the calculation of the impacts of the long-term exposure, we computed the average exposure during the last 20 years. For 2021, this corresponds to the average of 2001, 2011 and 2021 levels. For 2011, this corresponds to the averages of 1991, 2001, and 2011. For 1991 value, we assumed the same value as for 2001.

Control Scenarios:

The health effects analysis was conducted for Business as Usual (BAU) years: 2001, 2011, 2021 and four identified alternative mitigation scenarios. The scenarios considered are as follows:

Scenario		Definition
Base	Base Case	BAU for years 2001, 2011, 2021
C1	Control 1	Alternative – Transport – Bus Transit Mitigation Scenario
C2	Control 2	Combined Industrial (NG+BG) Mitigation Scenario
C3	Control 3	Industrial (Fuel Additives) Mitigation Scenario
C4	Control 4	Industrial Control Mitigation Scenario

Pollutant Concentrations

The PM10 concentrations municipality –wise and for the baseline and alternative scenarios are given in Table-7.

Table- 7: Concentrations for each scenario (mg/m^3)

Locality	Base			C1 Alternative - Transport - Bus Transit Mitigation Scenario		C2 Combined Industrial (NG+BG) Mitigation Scenario		C3 Industrial (Fuel Additives) Mitigation Scenario		C4 Industrial Control Mitigation Scenario	
	2001	2011	2021	2011	2021	2011	2021	2011	2021	2011	2021
HYDERABAD (MCH)	160	420	1010	260	490	420	1009	420	1009	420	1009
RAJENDRANAGAR	30	120	360	50	50	119	219	99	246	109	244
LB NAGAR	70	130	310	70	100	120	260	130	260	120	260
MALKAJGIRI	20	50	60	30	40	40	110	50	110	40	60
ALWAL	60	140	285	70	90	130	285	120	285	130	285
QUTHBULLAPUR	80	220	560	110	180	210	510	210	485	210	510
SERILINGAMPALLY	30	70	210	40	60	70	210	70	210	80	210
GADDIANARAM	70	230	310	100	140	170	310	170	310	180	310
UPPAL KALAN	40	110	260	60	100	100	260	110	260	110	260
KAPRA	20	70	110	30	40	40	110	50	110	40	110
KUKATPALLY	30	70	210	40	60	70	185	70	210	70	210

PATANCHERU	90	190	560	100	180	140	485	190	535	190	535
GHATKESAR	30	50	160	40	50	40	135	40	160	40	160

Table–8, presents population weighted average concentrations that were computed to have a sense of the changes in PM_{10} concentration:

Table-8: Population Weighted average Concentrations for each scenario (mg/m3)

Case	2001	2011	2021
Base	121	279	571
C1-Alternative – Transport – Bus Transit Mitigation Scenario	-	166	238
C2-Combined Industrial (NG+BG)	-	274	549
C3-Industrial (Fuel Additives)	-	275	546
C4-Industrial Control	-	275	550

Benefits Calculations:

Valuation of health effects is a crucial component in assessing the social costs of air pollution, since it allows the performance of cost-benefit analysis of pollution control measures and provides a basis for setting priorities for actions. In order to perform the economic valuation of health effects of air pollution, we need to know first the unit cost of valuation to translate health impacts into economic values. Benefits were computed using values derived from local data and values transferred from the USA.

Human Capital Approach (HCA):

Human Capital Approach (HCA) was followed for mortality valuation. Premature deaths were valued using the value of a statistical life (VSL), which is estimated as the discounted value of expected future income at the average age. The VSL was computed using a life expectancy at birth of 62.5 years, and an average age of the population of 27.5 years. The average annual wage considered was US$357.55 using an annual discount rate of 5%. The VSL for Hyderabad was estimated at US$ 6, 212.

Willingness To Pay (WTP):

There are no Indian studies of WTP to reduce risks of death. Therefore, the US values were transferred to India. The current value used in the US is 5.5M US$. The annual per capita income for USA is US$ 35,060. For India the per capita income (PCI) is US$ 480, while expressed in purchase power parity (PPP) it is $2570[4]. For PCI however, we used the value computed for India, that is $357. The following table shows the VSL values (US $ per case) transferred from USA to India for the present analysis.

4 World Development Report, 2002. Building Institutions for Markets. The World Bank. Washington, D.C. www.worldbank.org

Income Type	USA	India	Eta = 0	Eta = 0.4	Eta = 1.0
PPP	35,060	2,570	5,500,000	1,933,798	403,166
PCI	35,060	357	5,500,000	878,562	56,090
Eta = Income Elasticity Note: The unit values were not increased for projection years, assuming a growth in the per capita income, which is a limitation of the analysis					

Cost of Illness (COI):

The Cost of Illness (COI) Approach was used for valuing morbidity. The cost of illnesses includes both direct (medical) and indirect (lost work days) costs. The medical costs were estimated based on local information on costs of hospital visits, and treatment, after taking expert opinion of General Practitioners, Consultant Pulmonologists and Consultant Cardiologists.

The Unit values for morbidity endpoints derived locally for Hyderabad for the base year 2001(US$ per case) is given below:

Endpoint	Age Group	Type of value	
		Medical Costs	Lost Productivity
Hosp Adm COPD	All	122.23	14.30
Hosp Adm CVD (ICD 390-429)	All	119.22	11.44
Hosp Adm RSP (ICD 460-519)	All	74.76	12.87
Hosp Adm Asthma (ICD 493)	All	87.31	10.01
OP Visits IM	All	8.26	1.43

Results:

Change in Ambient Concentrations:

Table-9 shows the reductions in annual average concentrations for each scenario.

Table- 9: Concentration reductions for control scenarios with respect to base scenario (mg/m^3)

Locality	2011				2021			
	C1	C2	C3	C4	C1	C2	C3	C4
HYDERABAD (MCH)	160	0	0	0	520	1	1	1
RAJENDRANAGAR	70	1	21	11	310	141	114	116
LB NAGAR	60	10	0	10	210	50	50	50
MALKAJGIRI	20	10	0	10	20	-50	-50	0
ALWAL	70	10	20	10	195	0	0	0
QUTHBULLAPUR	110	10	10	10	380	50	75	50
SERILINGAMPALLY	30	0	0	-10	150	0	0	0
GADDIANARAM	130	60	60	50	170	0	0	0
UPPAL KALAN	50	10	0	0	160	0	0	0
KAPRA	40	30	20	30	70	0	0	0
KUKATPALLY	30	0	0	0	150	25	0	0
PATANCHERU	90	50	0	0	380	75	25	25
GHATKESAR	10	10	10	10	110	25	0	0

Change in Health Effects:

The change in health effects is computed using the formula based on the Poisson CR functions. The excess cases in each scenario with respect to base case scenario are computed based on the change of population exposure levels to PM_{10} under each scenario, CR functions, and baseline rates for the health outcomes. The baseline for 2001 corresponds to the population multiplied by the mortality rate. For the years 2011 and 2021, the mortality rate was increased corresponding to the increase in air pollution levels.

The baseline number of deaths (cases per year) municipality-wise is shown in Table-10.

Table-10: Baseline number of deaths by municipality (cases per year)

Municipality	2001	2011	2021
HYDERABAD (MCH)	15,859	20,254	29,614
RAJENDRANAGAR	217	418	859
LB NAGAR	826	1,741	3,858
MALKAJGIRI	525	774	1,132
ALWAL	288	542	1048
QUTHBULLAPUR	402	1303	6,718
SERILINGAMPALLY	212	625	1,985
GADDIANARAM	108	138	160
UPPAL KALAN	210	384	725
KAPRA	254	585	1,342
KUKATPALLY	539	954	1,758
PATANCHERU	521	333	445
GHATKESAR	158	98	117
TOTAL	20,119	26,130	39,083

The total number of mortality / morbidity cases for all localities for the base and projection years are summarized in Table-11.

Table-11: Baseline number of mortality & morbidity cases (Total for all localities, cases per year)

End point	All Population			Elder		
	2001	2011	2021	2001	2011	2021
Mortality	19,702	28,035	49,625	6,006	8,107	12,052
Hosp Adm CVD (ICD 390-429)	6,500	8,676	13,007	1,324	1,742	2,513
Hosp Adm RSP (ICD 460-519)	5,188	6,691	9,957	670	973	1,518
Hosp Adm COPD (ICD 490-496)	2,128	2,745	4,072	134	170	229

The number of cases of short-term mortality avoided in the projection years of 2011 and 2021 municipality-wise and scenario-wise is presented in Table-12.

Table–12: Change in short-term mortality by municipality (cases avoided in each year)

Locality	2011				2021			
	C1	C2	C3	C4	C1	C2	C3	C4
Hyderabad (MCH)	1,286	0	0	0	5,686	12	12	12
Rajendranagar	12	0	4	2	103	48	39	40
LB Nagar	42	7	0	7	318	78	78	78
Malkajgiri	6	3	0	3	9	23	23	0
Alwal	15	2	4	2	81	0	0	0
Quthbullapur	57	5	5	5	969	136	203	136
Serilingampally	8	0	0	3	118	0	0	0
Gaddiannaram	1	0	0	0	2	0	0	0
Uppal Kalan	8	2	0	0	46	0	0	0
Kapra	10	7	5	7	38	0	0	0
Kukatpally	12	0	0	0	105	18	0	0
Patancheru	12	7	0	0	64	13	5	5
Ghatkesar	1	1	1	1	5	1	0	0
Total	1,470	34	20	30	7,544	329	360	271

The avoided cases of mortality and morbidity by scenarios and projection years are presented in Table-13.

Table–13: Change in health effects by scenarios - Total for All localities (cases avoided per year)

(a) All Population								
End point	2011				2021			
	C1	C2	C2	C4	C1	C2	C3	C4
Mortality (Long-term exposure)	3699	90	49	65	21552	847	845	780
Mortality (short -term exposure)	1469	34	19	25	7544	284	314	271
Hosp Adm CVD (ICD 390-429)	2320	304	196	173	17401	821	683	582
Hosp Adm RSP (ICD 460-519)	56	13	9	8	181	20	14	16
Hosp Adm COPD (ICD 490-496)	0	0	0	0	0	0	0	0
(b) Elder Population								
End point	2011				2021			
	C1	C2	C3	C4	C1	C2	C3	C4
Mortality (Long-term exposure	771	28	17	20	4052	179	161	163
Mortality (short -term exposure	0	0	0	0	0	0	0	0
Hosp Adm CVD (ICD 390-429)	301	27	14	13	1922	90	77	68
Hosp Adm RSP (ICD 460-519)	278	43	39	28	2553	471	360	357
Hosp Adm COPD (ICD 490-496)	70	15	7	6	667	46	24	22

Table-13 shows the heath benefits in different scenarios in Hyderabad in the years 2011 and 2021. Transportation sector is the largest contributor to air emissions (approx. 70% of the total load) in Hyderabad. It is clear from the results that **C1** Scenario (i.e., Alternative-Transport-Bus Transit-Mitigation Scenario) could have significant impact on the health status for Hyderabad residents in the future. The most significant reductions in PM_{10} concentrations were also observed in this scenario. Implementation of Alternative-Transport-Bus Transit-Mitigation Scenario in Hyderabad would prevent **3,699** long-term deaths, **1,469** short-term deaths, **2,320** cardiovascular hospital admissions in 2011 and **21,552** long-term deaths, **7,544** short-term deaths, and **17,401** cardiovascular hospital admissions in 2021. In elderly population, **4,052** long-term deaths, **1,922** cardiovascular hospital admissions and **2,553** RSP hospital admissions will be avoided in 2021. The effective bus transit mitigation measures resulted in 1/3rd reduction of PM_{10} concentrations compared to BAU levels.

Benefits estimation:

The following table presents the total benefits by endpoint in Millions of US$ per year, for two transfer scenarios: using PPP and Eta=0.4, and using PCI and Eta = 1.0. These two scenarios are the upper and lower bound values of benefits. The values shown are the total values, i.e. COI and WTP.

The estimated annual health benefits in terms of deaths (long-term mortality) avoided from effective bus transit mitigation measures (C1 Scenario), ranges from 207 million US$ in 2011 to 1209 million US$ in 2021. The economic benefits of the cardiovascular and other respiratory diseases avoided from the effective bus transit mitigation (C1 Scenario) ranges from 0.0096 million US$ in 2011 to 2.27 million US$ in 2021. The transportation sector was recognized as an area where significant air quality and health benefits could be realized through the IES, India Analysis.

Table –14: Total Benefits by Endpoint, COI plus WTP (Millions of US$ per year)

(a) PCI and 1.0

End point	2011				2021			
	C1	C2	C2	C4	C1	C2	C3	C4
Mortality (Long–term exposure)	207.46	5.02	2.77	3.66	1,208.9	47.53	47.40	43.73
Mortality (short –term exposure)	82.41	1.92	1.06	1.407	423.15	15.94	17.62	15.21
Hosp Adm CVD (ICD 390-429)	0.303	0.04	0.026	0.023	2.274	0.111	0.093	0.076
Hosp Adm RSP (ICD 460-519)	0.042	0.006	0.006	0.004	0.378	0.079	0.062	0.061
Hosp Adm COPD (ICD 490-496)	0.0096	0.0021	0.001	0.0009	0.0911	0.0063	0.0033	0.003

(b) PPP and 0.4

End point	2011				2021			
	C1	C2	C3	C4	C1	C2	C3	C4
Mortality (Long-term exposure	7,152.3	173.1	95.5	126.2	41,678	1,639	1,634	1,508
Mortality (short –term exposure	2,841.0	66.2	36.4	48.2	14,589	550	608	524
Hosp Adm CVD (ICD 390-429)	0.3032	0.0397	0.0256	0.0230	2.274	0.111	0.093	0.076
Hosp Adm RSP (ICD 460-519)	0.0420	0.006	0.0061	0.0044	0.3776	0.079	0.0619	0.0613
Hosp Adm COPD (ICD 490-496)	0.0096	0.0021	0.0010	0.0009	0.0911	0.0063	0.0033	0.0030