Economic Valuation of Health Impacts of Air Pollution in Mumbai

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ECONOMIC VALUATION OF HEALTH IMPACTS OF AIR POLLUTION IN MUMBAI

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Abstract. Air pollution leads to serious negative impacts on health. The physical evidence is compelling. An attempt has been made in this paper to establish dose-response relationship of Ambient Air Quality Index and human health, based on time spent by an individual in different microenvironments during one day. Economic valuation of morbidity and mortality has been attempted through lost salary approach. The results show that the avoidance cost is 29% of the total health damage cost.

Keywords: air pollution, Air Quality Index, asthma, economic valuation, health impact, integrated daily exposure, Logit Model, morbidity, mortality, Mumbai

List of Symbols used

Σ	=	Summation
μg	=	microgram
m^3	=	cubic meter
hr	=	hour
log	=	logarithm to the base 10
%	=	percent
δ	=	differential
Δ	=	change in value of parameter
μ	=	micron.

1. Introduction

Urbanization and extensive energy utilization have made urban air pollution a growing problem. Deteriorating air quality in cities is a result of rapid economic expansion, rise in population, increased industrial output and unprecedented growth in the use of passenger vehicles. Emissions from automobiles, factories, domestic sources and refuse burning threaten the wellbeing of city dwellers, imposing not only a direct economic cost for human health but also reducing long term pro-

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ductivity of the population. Physical evidence of serious negative impacts on health has been observed by Kamat (1992), Ostro (1989) and many others.

With development and industrial growth, the environment and its bountiful resources have become scarce. The techniques of environmental economics, therefore, involve specific applications of the general principles of normative economics aimed at assessing which alternative situations and strategies for the management of the environment best promote social welfare.

An attempt has been made here to estimate the air pollution loads and their impacts on health in Mumbai city caused mainly by automobiles and domestic sources in the year 1997. These impacts have also been translated into economic values.

2. Methodology

The health impacts due to different air pollutants can be estimated by ascertaining the exposure level and duration of individuals.

An individual is exposed to air pollution of different levels during the day while travelling, working or staying at home. Various places where an individual is present for a significant period are termed microenvironments.

Therefore,

$$\sum_{i=1}^{n} t_i = 24h \tag{1}$$

Each microenvironment has different air pollutant levels and hence the time spent in each and the level of pollutants play a decisive role in estimating the health impact.

Different pollutants cause different impacts on health, property and ecology (Lee James, 1985). Hence, use of a single Air Quality Index (AQI) incorporating all the adverse impacts of various pollutants is not feasible. An Air Quality Index designed to capture health impact will be different from the one designed to capture impacts on property values. An AQI for respiratory diseases, as developed by Sterling *et al*. (1967), can be presented as

$$AQI = 1 * [NO_x] + 0.02\,[CO] + 0.055\,[HC] + 4.15\,[SO_2] + 2.81\,[RSPM] \tag{2}$$

where NO_x are nitrogen oxides, CO is carbon monoxide, HC are hydrocarbons and RSPM is respirable particulate matter, i.e. particulate matter below 10 μ in size.

The coefficients of the above equations are a function of the pollutant's ability to cause the respiratory disease symptoms. It is assumed that the ability of the pollutant to cause the disease symptom is not likely to alter with location. The concentration of the pollutants will, however, vary with location, altering the AQI.

Integrated daily exposure (DE) of an individual in μg m^{-3} can be estimated as

$$DE = \sum_{i=1}^{n} t_i^* [AQI]_i \quad (3)$$

where

$[AQI]_i$ = Air Quality Index in the ith microenvironment in μg m^{-3}

t_i = Time spent by an individual in the micro environment (hr)

n = Number of microenvironments

Three microenvironments, viz. workplace, outdoor and indoor locations have been considered for a typical individual in Mumbai.

The relationship between DE and health impacts has been established based on the studies conducted by Mahasur *et al*. (1996). The data of Mahasur *et al.* form a cross section of three hundred households, observation having been collected discreetly. The options have been aggregated into two choices, that is presence or absence of a symptom in order, to apply simple logit formulation. Pollutant levels monitored by the National Environmental Engineering Research Institute (NEERI) and Brihanmumbai Municipal Corporation (BMC) have been used to arrive at DE values.

By modelling the air quality and plotting the isoconcentration lines the population exposed to a particular pollutant level has been estimated. A population falling between two contours has been assumed to have been exposed to the average concentration of the bordering isopleths. Exposure to pollutants while cooking has been estimated using the data given by Smith (1989).

The logit model (Demaris, 1992) has been used to analyse the effect of change in air pollution level on the population due to exposure to pollutants. The logit model estimates the probability of occurrence of a certain event, given a certain set of independent variables. We have considered integrated daily exposure, smoking habits and sex to be statistically significant variables in deciding upon the probability of dyspnea.

$$\begin{aligned} \text{logit (Dyspnea)} &= \text{f (integrated daily exposure, smoking, sex)} \\ \text{logit (Dyspnea)} &= (0.012)DE + (0.477)sex + (0.901)SM - (5.682) \end{aligned} \quad (4)$$

Similarly logit for cough was taken as

$$\begin{aligned} \text{logit (Cough)} &= \text{f (smoking, DE, DE}^2) \\ \text{logit (Cough)} &= (-6.9242) + (1.46575)SM + (0.015)DE + \\ &\quad (0.227 \pm 0.23)\, DE^2 \end{aligned} \quad (5)$$

To account for days of workloss the following estimates have been made:

$$\begin{aligned} \text{Absenteeism (\%)} &= f(DE) \\ \text{Absenteeism} &= (0.039) + (0.32085)DE \end{aligned} \quad (6)$$

$$\text{TDR\%} = (4.1517) - (0.6723)\text{logPop} + (5.77 \times 10^{-6})\text{DENS} + (1.69 \times 10^{-4})\text{slum} + (0.00168)\text{Hosp} + (0.0059)\text{DE} \tag{7}$$

where

TDR%	=	total death rate, percent of
Pop	=	population
slum	=	slum population
DENS	=	population density per sq. km
Hosp	=	persons per health service
SM	=	smoking population

Total death rate rises with the rising levels of DE, slums and population density.

Considering normal death rate in Numbai as 0.76%, (as in the records maintained by Brihanmumbai Municipal Corporation) the number of excess deaths is estimated as 7045. This has been computed by taking a partial differential of the Equation (7) with respect to DE, which gives the excess rate of death attributable to DE

$$\delta\text{TDR}/\delta\text{DE} = 0.0059$$

$$\Delta\text{TDR (\%)} = 0.0059 * \Delta\text{DE}$$

Excess death rate = 0.0059 * 10
Normal death rate in Mumbai = 0.76%
Population in Mumbai = 15.6 Million
Number of normal deaths = 0.76 * 15600000/100 = 118560
Number of excess deaths = 0.059 * 118560 = 7045

The Daily Exposures (DE) estimated in the present paper are fairly representative of Mumbai.

Estimation of exposure of various population sub groups has been conducted to aggregate the results. The information used for this purpose is presented in Table I.

Economic valuation of health impact has been based on income lost due to mortality. The value of statistical life (VSL) is estimated as the discounted value of expected future income at the average age, if the average age of the population is 24 yr and the life expectancy at birth is 62 yr.

$$\text{VSL} = \sum_{t=0}^{38} \text{w}/(1+\text{d})^{\text{t}} \tag{8}$$

where,

w	=	average annual income,
t	=	life expectancy – average age of population
d	=	the discount rate (Shin *et al.*, 1992).

TABLE I
Population sub groups and vehicle population

Total population of Mumbai[a]	15.6 million
Slum population	60%
Low Activity-based population	
Male workers	15%
Female workers	15%
House-wives	8%
Infants (0–5 yr)	20%
School and College children	35%
Elderly > 65	7%
Vehicular population[b]	
4 wheelers Jeep/Car/Wagons	3,28,259
2 wheelers	3,28,940
Autorickshaws	72,007
Buses	12,809
Delivery Vehicles	48,206

[a] Interntional Institute for Population Sciences, Mumbai
[b] Transport Commissioners Office, Maharashtra State, Mumbai.

Mortality can also be valued by the willingness to pay (WTP) approach. Willingness to pay to prevent a day of illness has not been developed for India. Simply adjusting for wage differentials between India and any other country where relevant data are available, and attributing the resulting number to India, may not provide any useful inference.

Restricted activity days have been valued as 20% workloss and 80% lower productivity. Considering average wage in Mumbai to be Rs. 80.00 per day and lower productivity valued as one third average wage, a restricted activity day is valued to be Rs. 37.50. An emergency room visit (ERV) has been estimated as

$$\text{ERV} = 1 \text{ workday loss} + \text{hospital charge} + \text{medication} + \text{transport} \qquad (9)$$

For Mumbai an ERV is estimated to cost Rs. 380 to 430. Here private hospital charge for emergency room visit is considered to be Rs. 15-/– to Rs. 200/– (including medication) and transport as Rs. 150/–. Asthma attack can last for 9.1 days. Accounting for Hospitalisation charges (Rs. 1500 per day in private hospitals) and lost workdays the cost of an asthma attack is estimated at Rs. 300 to 14378. Milder asthma attacks are more frequent and are valued as for ERV. The average valuation is estimated as Rs. 1500/– per attack. Similarly, chronic bronchitis is estimated as Rs. 2,12,600 per incident. Here life expectancy is taken to be 62 yr and the age

TABLE II

Individual exposures of various population sub groups in Mumbai

Category	Daily exposure (μg m^{-3})	Exposure burden %
Male Workers	9	16
Female Workers	15	26
House-wives	10	9
Infants	8	18
School College Children	6	24
Elderly	8	7

at which a patient may become chronically ill with bronchitis to be 35 yr. The costs include 50 loss days per year, valued at Rs. 80/– per day, and an average of 13.1 hospital visits of 10 days each, valued at Rs. 1500/– per day, and a yearly expenditure on medication of Rs. 1500/–. Final estimate is arrived at discounting at 5%.

3. Discussion

It is estimated that exposure in slum area is approximately 16 μgh m^{-3}, while in other places it is 6 μgh m^{-3}. Estimates of exposure burden expressed as a product of population and daily exposure show that slum population, which is 60% of the total population, bear the exposure burden of 80%. Female workers whose population is 15% bear the maximum exposure burden (20%), followed by school and college children. Exposure and percent exposure burden of various population sub groups are presented in Table II.

3.1. Health Valuation

The valuation of mortality and morbidity in the present work has been carried out taking into account an average income for different strata of society. So also, willingnes to pay for health damage has also been taken as an average for the different strata of society.

Considering wage in Mumbai as Rs. 80 per day and assuming 200 working days a year and 5% discount rate, the value of statistical life in Mumbai is estimated as Rs. 2,85,000 as per Equation 8.

The estimated impact of air pollutant on health is summarized in Table III.

TABLE III
Estimated impacts of air pollutants on health

Type of health impact	No. of Cases (Thousand)
Chronic Bronchitis	24
Restricted Activity days	20,200
Emergency room visits	87
Bronchitis in children	220
Asthma	901
Respiratory symptom days	75,000
Respiratory hospital admission	5.8

TABLE IV
Valuation of health impacts

Type of health impact	Specific cost Rs.	Total cost million Rs.
Mortality		
Loss in salary approach	2,85,000	2,007.84
Morbidity		
Restricted activity days	37.50	767.50
Emergency room visit	380–430	35.24
Bronchitis children	390	85.80
Asthma attacks	1,500	1,351.50
Respiratory symptom days	24	1,800.00
Respiratory Hospital admission	14,378	83.39
Chronic Bronchitis	2,12,600	5,102.40
Total cost		11,224.17

Valuation of illness is presented in Table IV. Total health cost figures have been evolved combining figures for mortality and morbidity. The costs have been estimated as discussed earlier.

Tables V and VI give the avoidance costs of vehicular pollution in Mumbai and pollution due to fuel wood and kerosene burning during cooking. The avoidance cost for vehicular pollution has been estimated, considering prices of non-noble, metal-based catalytic converters for four and two wheelers and particulate straps for diesel vehicles. To arrive at the avoidance cost due to cooking, the cost incurred in shift of fuel per kg change in emission has been used.

It is seen that total avoidance cost is about Rs. 3281 million, which is much less than the health damage cost of Rs. 11224 million.

TABLE V
Avoidance cost by adopting pollution control methods for vehicles

Vehicle category	Cost per catalytic converter (Rs).	Avoidance cost (million Rs.)
Jeeps/cars/wagons	3960	1299.90
Two wheelers	1980	651.30
Autorickshaws	880	63.37
Buses	6500	83.26
Goods vehicles	6500	313.34
Total		2411.17

TABLE VI
Avoidance cost for emission due to cooking

Measure	Avoidance cost Rs./kg of emission	(million Rs.) (million Rs.)
Fuel wood to LPG	3956.4	869.50
Kerosene to LPG	15.0	0.04
Total		869.54

4. Conclusion

The economic valuation done here has several associated problems. The nature of problems varies from nature of data availability, existence of data gaps, nature of sample studies etc. to the econometric analysis. Mortality and morbidity evaluation in the present work considers an average scenario for the society. Daily wage and average annual income in Mumbai needs to be considered for different income groups of the society for morbidity and mortality evaluation. The valuation methodology adopted gives a good, but conservative, idea of health damage costs. However, inclusion of carcinogenic effects of certain air pollutants and consideration of damage to health due to a greater number of pollutants, will give higher damage costs. Further studies are being aimed at including property damages, carcinogenic effects and ecological damages, and more extensive air quality monitoring both indoors and outdoors. As it is clear that avoidance cost is 29% less than damage cost, the policy and government intervention and public awareness in this regard needs to be created so as to save the individual and government expenditure. The quality of life will also be enhanced if pollution avoidance measures are promoted.

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