Valuation of Health Effects due to Air Pollution: A Review

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Abstract- **One of our era's greatest scourges is air pollution, on account not only of its impact on climate change but also its impact on public and individual health due to increasing morbidity and mortality. However, there are many pollutants that are major factors in disease in humans. The present paper is an attempt to provide a review on estimation of health effects due to air pollution**

***Keywords*: Air Pollution, health effects, climate change**

INTRODUCTION

Human activities have an adverse effect on the environment by polluting the water we drink, the air we breathe, and the soil in which plants grow. Although the industrial revolution was a great success in terms of technology, society, and the provision of multiple services, it also introduced the production of huge quantities of pollutants emitted into the air that are harmful to human health. Without any doubt, the global environmental pollution is considered an international public health issue with multiple facets. Social, economic, and legislative concerns and lifestyle habits are related to this major problem. Clearly, urbanization and industrialization are reaching unprecedented and upsetting proportions worldwide in our era. Anthropogenic air pollution is one of the biggest public health hazards worldwide, given that it accounts for about 9 million deaths per year.

Environmental pollution is a global concern with enormous potential to negatively influence the population. Over the past decade, there have been increasing concerns over the public health effects attributable to environmental pollution, especially in developing countries (Khan and Ghouri 2011; Mojarrad *et al*., 2020). Air pollution is considered one of the most prominent public health (WHO 2021) and environmental hazard in the world (Ansari and Ehrampoush 2019), primarily arising from traffic as well as industrial and residential activities (Tohid *et al*., 2019). The range of the adverse effects of air pollution is wide, exerted in direct and indirect ways (Fouladi-Fard *et al*., 2018; Ansari and Ehrampoush 2019; WHO 2021). Exposure to air pollution increases the risk of death and hospitalization due to cardiovascular and respiratory diseases, type 2 diabetes, hypertension, and various types of cancer (Yousefi *et al*., 2019; Tainio *et al*., 2021; Zhao 2022); in addition to effects of air pollution on physical health; recent studies have shown the possibility of negative effects of air pollutants on brain and mental health, such as cognitive decline, neurodegenerative disease, and Alzheimer's disease (AD), (Alemany *et al*., 2021; Balboni *et al*., 2022). Some recent studies on the association between air pollution and COVID-19 have shown long term exposure to air pollution did not increase the number of cases, but the amount of antibodies was higher in infected and exposed individuals. This means that body was facing a severe disease or infection (Kogevinas *et al*., 2021) and one study found a relationship between increase of COVID- 19 cases and NO_2 pollution in Italy (Filippini *et al*., 2021); of note, 90% of the world's population live in areas where air pollution exceeds World Health Organization's (WHO) guidelines (Tainio *et al*., 2021).

The urban air pollution is the byproduct of rapid urbanization, high demand for fossil fuel and exponential growth of vehicles. The United Nations Environment Programme (UNEP) has estimated that globally 1.1 billion people breathe unhealthy air (UNEP 2002). Epidemiological studies also show that, the concentration of pollutants like Particulate matter (PM), oxides of nitrogen (NOx), ozone (O_3) etc., are associated with a wide range of health effects on human, especially on the cardiorespiratory system (Ostro *et al*., 1995, Pope *et al*., 2002). The urban air pollution is responsible for 800,000 deaths and 4.6 million losses of life years each year around the globe (WHO, 2003). The burden of disease attributable to outdoor air pollution causes 39% of loss of life years in South-East Asia and 20 percent in other Asian countries (WHO, 2004).

Therefore, studies have stressed the urgent need for efficient air quality monitoring and management to reduce adverse effects of urban air pollution on human beings and material (Sharman, 1996). With the increase in air pollution, the society is incurring high environmental cost in the form of environmental management and pollution control. The estimation of economic cost in the form of ill health, loss of productivity, depleted natural resources and reduced recreation of nature will help to determine the most efficient way to impose urban air quality standards and also to compare the cost of environmental damage to the cost of mitigation (World Bank, 2000).

Air pollution is considered the most prominent risk to public health. Economically, air pollution imposes additional costs on governments. A study by Safari *et al.* (2022) aimed to quantify health effects and associated economic values of reducing $PM_{2.5}$ air pollution using BenMAP-CE in Qom in 2019. The air quality data were acquired from Qom Province Environmental Protection Agency,and the population data were collected from Qom Province Management and Planning Organization website. The number of deaths due to Stroke, Chronic Obstructive Pulmonary Disease, Lung Cancer, and Ischemic Heart Disease attributable to $PM_{2.5}$ were estimated using BenMAP-CE based on two control scenarios, 2.4 and 10 µg/m3, known as scenarios I and II, respectively. The associated economic effect of premature deaths was assessed by value of a statistical life (VSL) approach. The annual average of $PM_{2.5}$ concentration was found to be 16.32 $\mu g/m^3$ (SD: 9.93). A total of 4694.5 and 2475.94 premature deaths in scenarios I and II were found to be attributable to $PM_{2.5}$ in overall, respectively. The total associated cost was calculated to be 855.91 and 451.40

million USD in scenarios I and II, respectively. The total years of life lost due to $PM_{2.5}$ exposure in 2019 was 158,657.06 and 78,351.51 in scenarios I and II, respectively. The results of both health and economic assessment indicate the importance of solving the air pollution problem in Qom, as well as other big cities in Iran. The elimination of limitations, such as insufficient local data, should be regarded in future studies.

The impact of air pollution on human health and the associated external costs in Europe and the United States (US) for the year 2010 were modeled by a multi-model ensemble of regional models in the frame of the third phase of the Air Quality Modelling Evaluation International Initiative (AQMEII3) (Im *et al*. 2018). The modeled surface concentrations of O_3, CO, SO_2 and $PM_{2.5}$ were used as input to the Economic Valuation of Air Pollution (EVA) system to calculate the resulting health impacts and the associated external costs from each individual model. Along with a base case simulation, additional runs were performed introducing 20 % anthropogenic emission reductions both globally and regionally in Europe, North America and east Asia, as defined by the second phase of the Task Force on Hemispheric Transport of Air Pollution (TF-HTAP2) (Im *et al*. 2018).

Economic Quantification of Urban Air Pollution Impact – Global Perspective

The economic valuation methods are classified as physical linkage method and behavioural linkage method. In physical linkage method, the dose response functions are estimated in terms of monetary valuations of changes in the environmental services. These methods are also called damage function or dose-response function approaches and are meant for measuring the effects of deterioration of air qualityusing market prices.

Behavioural linkage method is based on the behavioural linkages between a change in the supply of an environmental good and its effects. The measurement of damages or benefits from a change in the supply of the environmental good depends on the behavioural responses of users in the observed or hypothetical situations (Murthy, 2003). The values of three categories of health impact are generally considered while carrying out the economic analysis of air pollution impact (Ready, 2003). They are as follows:

- The social costs of providing medical treatment to the victim.
- Loss of labour productivity resulting from ill health.
- The pain, discomfort, loss of working days and inconvenience suffered by the victim.

The studies in the international context have mainly concentrated on the health effects of air pollution on human population. They used Cost of Illness (COI) approach, Willingness to pay (WTP)/accept (WTA) based on Contingent Valuation Method (CVM), Human Capital Approach (HCA) and DALYs to value health effect of air pollution. Lave *et al*. (1973), have made an attempt to estimate association of mortality with measured level of air pollution, based on 1960 and 1961 data across 117 metropolitan areas in the USA. Multivariate regression is used to control some of the important factors affecting mortality. The study revealed that air pollution has significant association with mortality and magnitude of association of the relationship is substantial.

Harrington and Portney (1987) estimated that the mean WTP for reduction of pollution is usually three to four times higher than the COI, hence hypothesized that the COI is lower bound to WTP for change of illness. Berger et al. (1987) reported the mean WTP of $27 to eliminate a day of sinus congestion compared with COI of $7. The corresponding figures for throat congestion are $44 and $14 respectively.

Farber *et al*. (1993) have used CVM approach to estimate Willingness to Pay (WTP) for ambient air quality improvement in East Baton Rouge, Louisiana. They have estimated WTP to obtain thebenefits for attaining Environmental Protection Agency (EPA) ozone standards. The estimated annual median and mean WTP values are US$ 94 and US $191 per person per year (as per 1991 US dollars) for an assurance that ozone level will not become un-healthful on any day.

Dixon *et al*. (1994) has also studied the health effects of air pollution in Jakarta, Indonesia. Based on the dose-response functions, the study looked at the factors affecting premature mortality and morbidity. He used COI method to value the cost involved in days lost due to the disease and cost incurred in hospital for illness/respiratory ailments like Bronchitis and asthma.

Pearce (1996) argued that, studies of air pollution epidemiology have resulted in the use of transferable dose-response conflicts, whereby the statistical relationships between air pollution and human health are applied outside the countries. The main aim was to predict the changes in premature mortality and morbidity. The studies have then applied for economic valuation in order to see if health damages from air pollution should be treated as a priority concern in the countries to which these coefficients are applied.

Further, two more studies by Bradon *et al*. (1995) have looked into the health effectsof air pollution for the city of Santiago, Chile and three cities of Taiwan respectively. In this study dose-response function showing the cause-effect relationship of the urban air pollution on health was borrowed from two sets of US data. It was found that the health conditions of the households have significantly influenced WTP values for reduction in air pollution. The health effects were mainly due to PM_{10}, SO_2 and NO_2 emission and used cost-benefit analysis to find out the benefits of air pollution control.

Aunan *et al*. (1998) have conducted a study to assess the cost and benefit of the implementation of a specific energy saving programme in Hungary by considering damage to public health, building material and agricultural crops. The results indicated that low level of air pollutants reduces prevalence of chronic respiratory diseases and mortality by 6 percent.

Larson *et al*. (1999) undertook a combined health risk assessment, cost effective analysis and benefit–cost analysis for PM emissions from 29 stationary source in the city of Volgograd, Russia. Annual PM related mortality from these stationary sources is in the range of 960-2667 additional deaths per year in this city of 1 million population. The cost per life saved was also very low in spite of several emission reduction projects. The total net benefit of US$ 40 million leads to 25 percent reduction in mortality risk.

Alberini and Krupnick (2000) compared COI and WTP estimates of the damage from minor respiratory symptoms associated with air pollution in Taiwan. A contingent valuation (CV) survey was conducted to estimate WTP to avoid minor respiratory illness. Health dairies were used in analysis to predict the likelihood cost of seeking relief from symptoms and absence from work. The ratios of COI to WTP were similar to those for the US, despite the differences between the two countries. The WTP values have exceeded by 1.61 -2.26 times depending on the air pollution level.

Thanh and Lefevre (2000) have applied the impact pathway approach (IPA) to estimate the health impact and corresponding damage cost of SO_2 and PM_{10} from four power plants using lignite, oil, natural gas and coal as fuel and are located at four different places in Thailand. The results showed that the damage cost of health effect caused due to cumulative effect of these pollutants ranged from US$ 0.006 to US $ 0.05 per KWh.

According to the study by El-Fadel *et al.* (2000), who estimated economic value of mortality and morbidity for Lebanon urban area, the total emergency hospital visits avoided due to 10 μg/Nm^3 reduction in PM_{10} are in the range of 609-25578 numbers. The corresponding total economic benefit (estimated by using the HCA) is US $ 0.05-1.9 million per year.

Table 1 provides the summary of some studies conducted in the global context on economic analysis of air pollution.

Table 1: Studies on economic analysis of air pollution (Global context)

S. No.	Author	Year	Region	Methodology	Results
1	Gerking and Stanley	1986	St Louis,USA	WTP approach using contingent valuation	The WTP values were lowas the people are not affected by ill effects of air pollution
2	Berger *et al.*	1987	USA	COI	The study calculated the COI due to air pollution causing respiratory ailments.
3	Farber and Rambaldsi	1993	East Baton Rouge, Louisiana.	CVM approach to estimate WTP	The estimated annual median and mean WTP values are US$94 andUS$191 per person per year (as per 1991 US dollars) for an assurance of healthful ozone level.
4	Loehman	1994	San Francisco Bay Area	CVM approach toestimate WTP tovalue the benefits associated with improved air quality	Average estimates of WTP to avoid a decline in bothhealth and visibility effects ranged from US $ 6 to US$ 73 per month (in 1980 US dollars terms) results of further statistical analysis confirmed that both socio- economic variables andinitial health status had an impact on the magnitude of WTP estimates.
5	Lang	1995	Canadian air qualitypolicy study	CVM approach toestimate WTP foravoided hospital admissions for both respiratory and cardiac cases.	The estimates for avoidingrespiratory and cardiac admissions are US$ 5700and US$ 7200 respectively.
6	Baulista *et al.*	1996	Santiago, Chile	WTP approachusing CV survey in three cities.	The WTP increased with illness episodes for the people affected by urban air pollution.
7	Furst *et al.*	1996	Taiwan	Cost benefit and cost effectivenessanalysis from the US data	The health effects were mainly due to PM_{10}, SO_2 and NO_2.
8	Ostro	1994	Jakarta, Indonesia	COI approach usingdose response from the US data.	The health cost due to air pollution was significantly high.

9	Chestnut *et al.*	1997	Bangkok, Thailand	WTP approach, Dose response function from theUS data was used in the analysis	The study compares the WTP for air quality improvements between Bangkok and the US and finds that Bangkok residentsare willing to pay a higher share of their income to protect their health.
10	Larson *et al.*	1999	Volgogrd, Russia	Health risk assessment, costeffectiveness analysis.	The study calculated themortality due to airpollution and found thatapproximately 960-2267 people died in the city and concluded that the cost oflife saved from pollution averting projects was low.
11	Alberini and Krupnick	2000	Taiwan	Contingent valuation surveyand WTP approach	The WTP values exceededby 1.61-2.26 times depending upon thepollution level. The CVM estimates exceeded the COI approach.
12	El-Fadel and Masood	2000	Lebanon urban areas	Estimated by usingthe HCA	The total emergency visitsavoided due to 10 μg/Nm^3 reduction in PM_{10} are reported to be in the range of 609-25,578. The corresponding total economic benefit is reported to be US $ 0.05-1.9 million per year.
13	Hansen *et al.*	2000	Oslo	Estimated usingLogit model	Revealed that the number of sick leaves is significantly associated withconcentration of PM. An increase in the average levelof PM_{10} by 1 μg/Nm^3 leads to an increase in the number of sick leaves by 0.6percent.
14	Pope *et al.*	2002	California	Estimated by usingthe HCA	There is an excess risk of approximately 16% dying from lung cancer due to fine particulate air pollution.

Economic Quantification of Urban Air Pollution Impact-Indian Perspective

The economic loss due to lost output from premature deaths and morbidity attributable to air pollution is high in India, equivalent to 1.36% of India's GDP in 2019 (Pandey *et al*., 2021). A further source of economic loss is the health-care cost of treating diseases attributable to air pollution. Based on National Health Accounts data, Pandey *et al*. (2021) estimated the total health-care cost in India in 2019 to be $103·7 billion. With air pollution responsible for 11·5% of the disease burden (measured as DALYs) in India in 2019, a crude estimate of the health-care cost for air pollution related diseases would be $11·9 billion (or 0·44% of India's GDP). The total health expenditure in India is 3·8% of GDP (National Health Systems Resource Centre, 2019) while the economic loss due to lost output from premature deaths and morbidity attributable to air pollution estimated in this study was 1·36% of GDP, indicating that the total economic impact of air pollution is high. The loss of output in monetary terms attributable to air pollution at the state level is associated with the number and the age-distribution of deaths and morbidity in each state and state GDP per worker. The economic loss due to air pollution as a percentage of state GDP was highest in northern states of India because people in these states are exposed to very high concentrations of ambient PM2·5 and a high proportion of their population uses solid fuels. The states of Uttar Pradesh and Bihar, with the highest economic loss as a percentage of their GDP, had the lowest per-capita GDP among the states of India, indicating that these poor states are most vulnerable to the adverse economic impacts of air pollution.

Table 2 summarize some of the studies conducted in the Indian context on economic analysis of air pollution.

Table 2: Studies on economic analysis of air pollution (Indian context)

S. No	Author	Year	Region	Methodology	Results
1	Abubacker	1994	Tiruchanpalli Tamil Nadu	COI Approach.	The workers were affectedby the fine dust and were suffering from respiratory illness and had high COI due to high dust exposure
2	Brandon and Homman	1995	All India	COI approachusing dose - response from Western countries and HCA.	The study revealed thecost of inaction due to environmental degradation. The health cost and the productivity loss were high.
3	World Health Organization	1995	36 Cities of India	COI and HCA.	The economic loss due to air pollution alone is at US$ 2,102 million per yearand consequent premature deaths at 40,351 per year. Major environmental costsfrom all sources have been

					estimated to be US$9,715million per year in Indiaamounting to 4.53% of GDP.
4	Parikh *et al.*	1997	Mumbai	COI approach with data on air quality from pollution controlboard.	Provided the estimates of the health damages due to air pollution and argued that it could be a component in the national system of accounts.
5	Lvovsky *et al.*	1998	Mumbai	COI approachwith the US dose–response data.	Based on 1992 inventory, amounted to US$150 million and it is about 3per cent of their total individual income.
6	Indira Gandhi Institute of Development Research	1998	Chembur region ofMumbai	WTP and COI approach	For every 10 μg/Nm^3 increase in atmospheric sulphur dioxide concentration, the annual social and health costs has exceeded Rs 10 crore in Mumbai. People living in the Chembur area have spent as much as Rs 35 lakhs annually due to poor air quality.
7	World Bank	1999	India	COI approachwith the US dose–response data.	The estimated environmental damage in the year 1992 amounted to approximately US$10 billion or Rs 34,000 crores,which is 4.5 per cent of GDP.
8	Markanday and Murthy	2000	Delhi and Kolkata	HCA	The annual marginal benefit to a typical household is Rs 2,086 inDelhi and Rs 950 in Kolkata, if the level ofSPM is reduced from the current average level to the prescribed safe level.
9	Kumar and Rao	2001	Haryana—Panipat Thermal Power Station	WTP approach	For a 67% reduction in the level ofambient mean PM10concentration, which is required to meet national and WHO standards,residents of Panipat arewilling to pay on an average an amount that ranges from Rs 12 to Rs 53 per month.
10	Giri *et al.*	2007	Kathmandu Valley	Attributable fraction method	Estimated the number ofdeaths associated with exposure to excess ambient PM_{10} in the Kathmandu valley area. The study reveals that 95 deaths out of 10,000 deaths are due to particulate pollution in the study area.
11	Sacratees	2009	Chennai city	WTP approachand COI.	The annual cost of health damage due to air pollution was estimated to be Rs 58,98,087.

CONCLUSION:

The air pollutants, such as Suspended Particulate matters (PM_{10} and $PM_{2.5}$), cause wide range of health effects, especially on the cardio-respiratory system when compared to other air pollutants. It is found that 23 Indian cities are critically polluted with the PM_{10}, $PM_{2.5}$, CO_2 and NO_X in the ambient air exceeding the standard prescribed by WHO. Air pollution causes 25% of respiratory ill health in the world and PM along with SO_2 causes 500,000 premature deaths and 4–5 million new cases of chronic bronchitis each year in the world (Safari *et al.*, 2022).

Studies have revealed that the health damage cost is 9% of the respective income (GDP/capita) in the 12 large Indian cities. It is more than 10% of the income generated from all economic sources. The study also estimates the social cost of US$3 billion due to urban air pollution, of which 64% is only towards health cost. It is also found that the total number of emergency hospital visits avoided due to 10μg/m^3 reduction in PM_{10} is in the range of 609–25,578. The corresponding total economic benefit is US$0.05–1.9 million per year (National Health Systems Resource Centre, 2019).

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