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 NO2 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 (O3) 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 PM2.5 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 PM2.5 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 PM2.5 concentration was found to be 16.32 µg/m³ (SD: 9.93). A total of 4694.5 and 2475.94 premature deaths in scenarios I and II were found to be attributable to PM2.5 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 quality using 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 the benefits 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 effects of 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\textsubscript{2} and PM\textsubscript{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\textsuperscript{3} reduction in PM\textsubscript{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>
<thead>
<tr>
<th>S. No.</th>
<th>Author</th>
<th>Year</th>
<th>Region</th>
<th>Methodology</th>
<th>Results</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Gerking and</td>
<td>1986</td>
<td>St Louis, USA</td>
<td>WTP approach using contingent valuation</td>
<td>The WTP values were lowas the people are not affected by ill effects of air pollution</td>
</tr>
<tr>
<td>2</td>
<td>Berger et al.</td>
<td>1987</td>
<td>USA</td>
<td>COI</td>
<td>The study calculated the COI due to air pollution causing respiratory ailments.</td>
</tr>
<tr>
<td>3</td>
<td>Farber and</td>
<td>1993</td>
<td>East Baton Rouge, Louisiana.</td>
<td>CVM approach to estimate WTP</td>
<td>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 of healthful ozone level.</td>
</tr>
<tr>
<td>4</td>
<td>Loehman</td>
<td>1994</td>
<td>San Francisco Bay Area</td>
<td>CVM approach to estimate WTP</td>
<td>Average estimates of WTP to avoid a decline in both health 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 and initial health status had an impact on the magnitude of WTP estimates.</td>
</tr>
<tr>
<td>5</td>
<td>Lang</td>
<td>1995</td>
<td>Canadian air quality policy study</td>
<td>CVM approach to estimate WTP for avoided hospital admissions for both respiratory and cardiac cases.</td>
<td>The estimates for avoiding respiratory and cardiac admissions are US$ 5700 and US$ 7200 respectively.</td>
</tr>
<tr>
<td>6</td>
<td>Baulista et al.</td>
<td>1996</td>
<td>Santiago, Chile</td>
<td>WTP approach using CV survey in three cities.</td>
<td>The WTP increased with illness episodes for the people affected by urban air pollution.</td>
</tr>
<tr>
<td>7</td>
<td>Furst et al.</td>
<td>1996</td>
<td>Taiwan</td>
<td>Cost benefit and cost effectiveness analysis from the US data</td>
<td>The health effects were mainly due to PM\textsubscript{10}, SO\textsubscript{2} and NO\textsubscript{2}.</td>
</tr>
<tr>
<td>8</td>
<td>Ostro</td>
<td>1994</td>
<td>Jakarta, Indonesia</td>
<td>COI approach using dose response from the US data.</td>
<td>The health cost due to air pollution was significantly high.</td>
</tr>
</tbody>
</table>
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 in 2019, a crude estimate of the health-care cost of treating air pollution related diseases was $103.7 billion. With air pollution responsible for 11.5% of the disease burden (measured as DALYs) in India in 2019, the workers were affected by the fine dust and were suffering from respiratory illness and had high COI due to high dust exposure.

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

<table>
<thead>
<tr>
<th>S. No</th>
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<th>Year</th>
<th>Region</th>
<th>Methodology</th>
<th>Results</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Abubacker</td>
<td>1994</td>
<td>Tiruchanpalli Tamil Nadu</td>
<td>COI Approach.</td>
<td>The workers were affected by the fine dust and were suffering from respiratory illness and had high COI due to high dust exposure.</td>
</tr>
<tr>
<td>2</td>
<td>Brandon and Homman</td>
<td>1995</td>
<td>All India</td>
<td>COI approaching dose-response from Western countries and HCA.</td>
<td>The study revealed the cost of inaction due to environmental degradation. The health cost and the productivity loss were high.</td>
</tr>
<tr>
<td>3</td>
<td>World Health Organization</td>
<td>1995</td>
<td>36 Cities of India</td>
<td>COI and HCA.</td>
<td>The economic loss due to air pollution alone is at US$ 2.102 million per year and consequent premature deaths at 40,351 per year. Major environmental costs from all sources have been...</td>
</tr>
<tr>
<td></td>
<td>Authors</td>
<td>Year</td>
<td>Location</td>
<td>Methodology</td>
<td>Description</td>
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<tr>
<td>4</td>
<td>Parikh et al.</td>
<td>1997</td>
<td>Mumbai</td>
<td>COI approach with data on air quality from pollution control board</td>
<td>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.</td>
</tr>
<tr>
<td>5</td>
<td>Lvovsky et al.</td>
<td>1998</td>
<td>Mumbai</td>
<td>COI approach with US dose–response data.</td>
<td>Based on 1992 inventory, amounted to US$150 million and it is about 3 per cent of their total individual income.</td>
</tr>
<tr>
<td>6</td>
<td>Indira Gandhi Institute of Development Research</td>
<td>1998</td>
<td>Chembur region of Mumbai</td>
<td>WTP and COI approach</td>
<td>For every 10 μg/Nm³ 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.</td>
</tr>
<tr>
<td>7</td>
<td>World Bank</td>
<td>1999</td>
<td>India</td>
<td>COI approach with US dose–response data.</td>
<td>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.</td>
</tr>
<tr>
<td>8</td>
<td>Markanday and Murthy</td>
<td>2000</td>
<td>Delhi and Kolkata</td>
<td>HCA</td>
<td>The annual marginal benefit to a typical household is Rs 2,086 in Delhi and Rs 950 in Kolkata, if the level of SPM is reduced from the current average level to the prescribed safe level.</td>
</tr>
<tr>
<td>9</td>
<td>Kumar and Rao</td>
<td>2001</td>
<td>Haryana—Panipat Thermal Power Station</td>
<td>WTP approach</td>
<td>For a 67% reduction in the level of ambient mean PM10 concentration, which is required to meet national and WHO standards, residents of Panipat are willing to pay on an average an amount that ranges from Rs 12 to Rs 53 per month.</td>
</tr>
<tr>
<td>10</td>
<td>Giri et al.</td>
<td>2007</td>
<td>Kathmandu Valley</td>
<td>Attributable fraction method</td>
<td>Estimated the number of deaths associated with exposure to excess ambient PM10 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.</td>
</tr>
<tr>
<td>11</td>
<td>Sacratees</td>
<td>2009</td>
<td>Chennai city</td>
<td>WTP approach and COI.</td>
<td>The annual cost of health damage due to air pollution was estimated to be Rs 58,98,087.</td>
</tr>
</tbody>
</table>

**CONCLUSION:**

The air pollutants, such as Suspended Particulate matters (PM₁₀ and PM₂.₅), 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 PM₁₀, PM₂.₅, CO₂ and NOₓ 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 SO₂ 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 10 μg/m³ reduction in PM₁₀ 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).

**REFERENCES:**


