Air Pollution and Health: A Review of Measurement Techniques

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Abstract

Air pollution is one of the significant causes of loss of healthy life years due to illness originating from indoor and outdoor air pollution sources like burning of biomass, vehicular emissions, etc. In the presented study, review of various methods used to assess health risks in terms of mortality and morbidity has been described. The use of precise instruments is essential for monitoring of health determinants causing serious health effects in urban regions. Data obtained from monitoring can be fed into the mathematical models in order to get the overall impact. These models are fed with specific concentration value for specific compounds, and they provide calculated number of population at risk. The main problem in using such models is the inability to calculate health risks for every pollutant. To validate the results obtained from mathematical models surveying needs to be synergies with the results. In air pollution impact assessment studies, public perception is one of the important components which these mathematical models do not incorporate, hence we recommend integrated assessment models for such studies. Perception based surveys generate huge data set and require statistical tools like SPSS, STATA for further analysis. It is essential to carry out exposure assessment studies as well to determine the pollution source and its impact on health in a more holistic way. Knowledge of these factors will help us to take measures to reduce pollutant concentration and recommend alternative solutions.

Keywords: **Air pollution, Health Impacts, Exposure Assessment, Aerosol Measurement Techniques, Risk Assessment Methodologies.**

Introduction

Atmospheric aerosols are defined as a collection of liquid or solid particles suspended in air. It typically ranges from 1nm to 100 µm. Aerosols play a very significant role in affecting our surroundings as they pollute the atmosphere and the air that we breathe. Atmospheric aerosols cause severe effects on health and hence are important to the study. Some of these particles when inhaled can have serious repercussions on the respiratory and cardiovascular systems. When air containing these particulates is inhaled, the pollutants get directly transferred to the lungs and are further carried around the body by blood.[6] Increasing air pollution has led to the rise in number of cases registered for Asthma, Chronic bronchitis, Chronic Obstructive Pulmonary Disease (COPD), Emphysema, and Lung cancer (Physicians for Social Responsibility, 2009).

Numerous studies show that due to urbanization, there is a rapid change in the Land Use/ Land Cover in megacities with addition of more concrete each day than the previous. Due to this, urban heat islands are formed, thereby creating patches of area with higher temperature than the surrounding areas. This heat gets trapped in that particular area and leads to heat stroke amongst its inhabitants. Prolonged hot and humid conditions cause more stress as the body cannot dissipate heat through evaporation leading to even more discomfort. This effect of heat on human body due to temperature and moisture content is referred to as 'heat-stress index'. Primary and secondary aerosols combined with high temperatures have been associated with lung cancer and heat stroke.[7]

In order to assess the effects of aerosol on human health, we need to understand different measurable properties of aerosols like particle size, number, mass, composition etc. Mostly particle size is used to study the behavior of aerosol particle. To characterize these properties of aerosols, different methodologies are used to measure the levels of aerosol and the mortality caused due to them.[15]

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Two main measures used by Environmental Protection Agency (EPA, 1997) to quantify aerosols in atmosphere with respect to air quality and health effects are Total Suspended Particulate (TSP) and Particulate Matter (PM). The TSP measures all particles suspended in air. They are mostly dust particles and do not have serious health implications. The PM, on the other hand, includes particles smaller than 10µm and is easily respired through the nasopharynx area and cause several respiratory disorders.[17]

The aim of this article is to assess human health effects due to air pollutants by considering various factors such as increased mortality and morbidity based on air quality standards. According to World Health Organization (WHO) guidelines, even at lower concentrations, morbidity and mortality occur if the conditions are prevalent for extended periods. On the other hand, if higher concentrations are present for a short duration, morbidity and mortality can still occur. A disadvantage to this kind of study is that air quality data is not available for all the compounds and also there is a constant increase in pollution level. Therefore, while considering the level of pollutant, we are assuming it to be the lower limit.[4]

Amongst the various methodologies described in this article, most of them are mathematical models and consider specific values for each pollutant. Some of them include Risk of Mortality/ Morbidity due to Air Pollution (Ri-MAP), Greenhouse gases and Air Pollution Interactions and Synergy (GAINS), Smith's method, Schwela's method; others are Air Q 2.2 software, Dust Track Aerosol monitor 8520, TSI 3080 Differential Mobility Analyzer (DMA), GRIMM Spectrometer, and Nanoscan SMPS. Various studies are done at cellular level such as sputum cytology, hematology study, and immunological study (not mentioned here) while other non-cellular surveying includes spirometry and questionnaire method.

Methods used for measuring Aerosols

The most common technique to measure particle mass concentration involves *filtration*. Filters are weighed under controlled temperatures and relative humid conditions before and after sampling and mass concentrations are determined for increase in filter mass and volume of air sample. Its limitation is that handling of filter media leads to uncertainties.

DMA or *Differential Mobility Analyzer* sizes particles by their electrical mobility. It first neutralizes the aerosol and then uses an electrical mobility principle to classify and strip out a very narrow, predictable size. Due to the accuracy of this instrument, it is used as a standard aerosol instrument and therefore used for testing and validating new instrument's performance.[15]

Dust Track Aerosol Monitor 8520 provides reliable exposure assessment by measuring particle concentration, corresponding to PM_{10}, $PM_{2.5}$, and $PM_{1.0}$. It measures aerosols in a wide range of surroundings from indoor air pollutants to ambient air pollutant[13].

GRIMM Spectrometer permits an individual particle size selection and consequently proper aerosol properties. The optical particle counters rely on the amount of incident light scattered at 90° by a particle to measure particle number concentration by optical particle size (www.grimm-aerosol.com).

Nanoscan SMPS has four components that together measure aerosol particles in air. It has a cyclone that removes larger particles entering the instrument. The unipolar particle charger charges nanoparticles more effectively than a bipolar charger. To select specific particle size, radial DMA is used for better resolution. Isopropanol-based CPC is used to accurately count the particles (www.tsi.com).

Methods used in measuring health impact

Ri-MAP i.e. Risk of Mortality/ Morbidity due to Air Pollution is utilized in estimating human health effects of air pollutants in urban areas by calculating the number of excess cases registered for different types of respiratory and cardiovascular diseases and deaths. It takes international air quality standards as a standard value for concentration of each particulate matter in atmosphere. It can be used for various pollutants like SO_2, NO_2, and TSP. Its advantage is that it specifically takes into account the effects of individual pollutant. Its major limitations are:

- Air quality data is limited (i.e. not available for all the compounds),
- It always takes into account the lower limit of concentration and does not take the increased concentration value,
- We have to assume uniform exposure due to air pollution throughout the study.

According to Gurjar, the model uses values of relative risks and baseline for different pollutants from WHO.[4] The following is the equation for assessment of risks to population due to a specific particulate matter:

$$RR(c) = \frac{C - T}{\{10 \times (RR - 1) + 1\}}$$

Where, C – Ambient air concentration of a pollutant

T – Threshold level of pollutant as per WHO norms

RR – Relative risk for selected health outcome

c – Category (industrial / residential)

Air Q software is an Air Quality Impact Assessment (Air Q 2.2.3) software that is used to quantify effects of exposure to air pollution and estimate life expectancy reduction. It was proposed by WHO European Centre for Environmental health, Bilthoven Division. The assessment is based on the assessment of certain population attributable to exposure to a given atmospheric pollutant. It calculates the following:

- The effect of short- term changes in air pollution (based on risk estimates from time- series studies)
- The effects of long- term exposure to air pollution (using life- tables approach and based on risk estimates from cohort studies) (www.who.com).

In Smith's Method, the mean risk of death per unit increase in the concentration of ambient particles is applied to population at risk using information about risk estimate and levels of pollution. Risk estimate is derived from urban studies on ambient air pollution and yields a range of 1.2 - 4.4% increase per 10µg/m^3 PM_{10}. The levels of pollution are obtained from studies of mean particle concentrations indoors in urban and rural settings in developed and developing countries. Its major drawbacks are that it uses lowest risk estimate; the risk is halved above 150 µg/m^3, PM_{10} levels are 50% of total suspended particles.[2]

Schwela's method determines the number of people at risk on the basis of numbers exposed to annual mean levels of suspended particle matter exceeding the WHO guidelines. Analysis is done using air pollution data desired from Global Environmental Monitoring Strategy (GEMS) and Air Management Information System (AMIS) and estimated increased mortality associated with pollution. The number of people at risk is determined on the basis of numbers exposed to annual mean levels of suspended particle matter exceeding the 1987 WHO guidelines. The mortality rate per 100,000 is determined without influences of air pollution (levels below WHO guidelines). The estimate of increase in mortality attributable to air pollution is taken as 100µg/m^3 suspended particle matter.[2]

GAINS i.e. Greenhouse gases and Air Pollution Interactions and Synergies developed by International Institute for Applied System Analysis (IIASA), Austria estimates $PM_{2.5}$ concentration. The model "adjusts for urban increment" for major urban agglomerations. The model considers emissions of CO_2, CH_4, NO_x, N_2O, TSP, PM, SO_2, Volatile Organic Compounds (VOCs). The GAINS model consists of information displayed on the activities causing emission, evolution of emissions, emission control costs, and impact on human health. The model can follow the path of emission from source to their impacts and also provides estimates of costs for emission control strategies.[3]

According to *Guttikunda and Goel method*, health impact can be measured using following equation:

$$\delta E = \beta \times \delta C \times \delta P$$

where,

δE - Number of estimated health effects (various end points for mortality and morbidity)

β - The concentration- response function, which is defined as the change in number of cases per unit change in concentration per capita

δC - The change in concentrations (change in concentrations modeled above a threshold value of 20µg/m^3).

δP - The population exposed to the incremental concentration δC, defined as the vulnerable population in each grid, of age less than 65 years.[5]

The *WHO method for Global Burden of Disease Assessment* determines the population exposure to $PM_{2.5}$. It involves applying appropriate concentration response functions, estimating baseline mortality and finally estimating number of deaths that can be attributed to air pollution.

The model can be expressed as

$$PAF = \frac{[P \times (RR - 1)]}{[P \times (RR - 1) + 1]}$$

where,

PAF – Population Attributable Fraction
P – Exposure expressed as PM $_{2.5}$ concentration
RR – Relative risk for exposed and non- exposed population[3]

Disability Adjusted Life Year (DALY) is a measure of disease burden consisting of two basic components- YOLL (mortality effect) and YLD (morbidity effect). The major benefit of using DALY is that it can combine and compare different kinds of health effects. The DALY can be compared with the other disease burdens through the results of the Global Burden of Disease studies. The main problem with DALY is that some morbidity outcomes, like hospital admissions, are not directly transferable to any specific diseases, and therefore, all the common morbidity outcomes, associated with air pollution, cannot be expressed as DALYs.[10]

Other Methods

Questionnaire Method takes into account people's perspective about their surrounding air quality and its impact on their health. Typically Likert scale is utilized in answering questions. Amongst many questions asked, few are- the medical history of the family, incidence of any respiratory problem in the past few years, and if present, then did it require any medical attention, household income, yearly expenditure on medical treatment, etc. Major limitation of this method is that perception of people is relative and needs to be validated with actual data of air quality in the region and epidemiological studies.

Spirometry is used to measure the bronchial hyper responsiveness using an instrument called spirometer. The technique measures the air flow through the lungs and deduces the broad range of diseases associated with improper respiratory capacity. It is used to check for any obstruction in the airway (like in case of asthma).

Health Impact Assessment (HIA) method (fig. 1) is a practical approach used to judge the potential health effects of a policy, program or project on a population. Recommendations are produced for decision- makers and stakeholders, with the aim of maximizing the proposal's positive health effects and minimizing its negative health effects (www.who.com).

Integrated Environmental Health Impact Assessment method (fig. 2) assesses health- related problems deriving from the environment, and health- related impacts of policies and other interventions that affect the environment. It takes into account the complexities, interdependencies and uncertainties of the real world.[1]

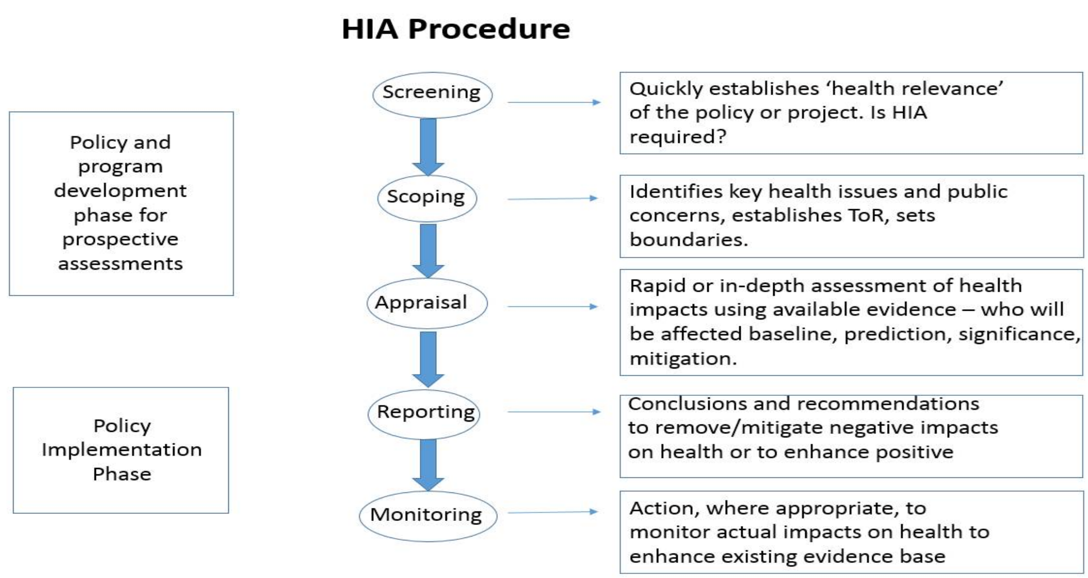

Figure 1.Policy development and implementation of HIA procedure (WHO)

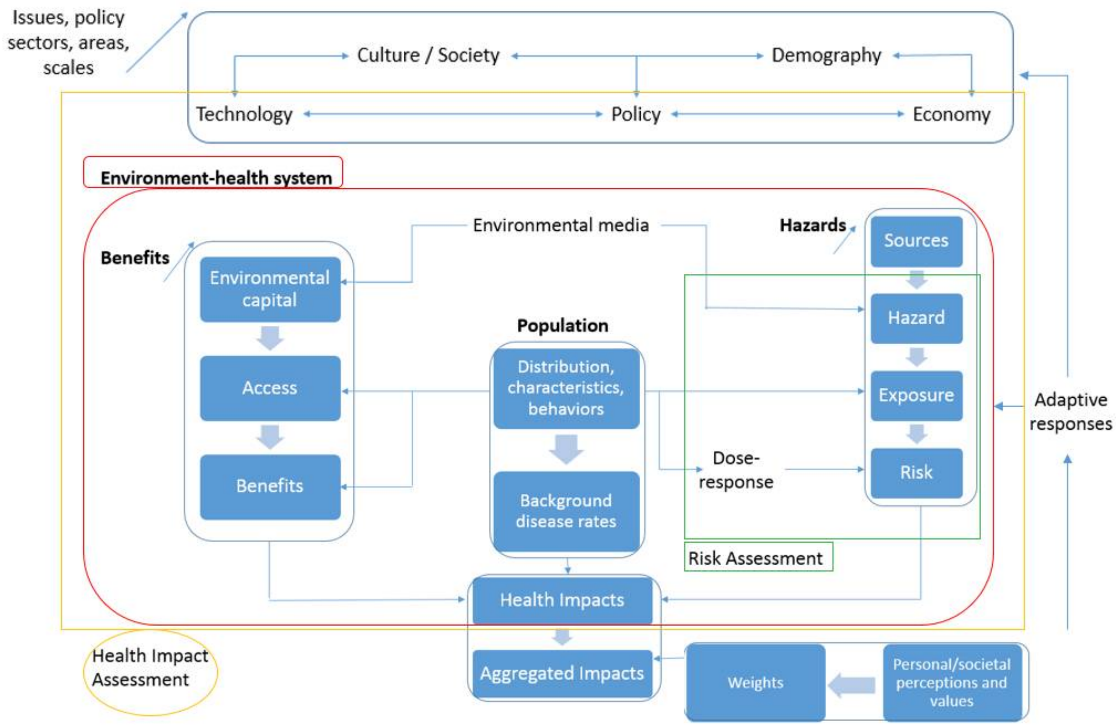

Figure 2.Integrated Environmental Health Impact Assessment[1]

Conclusion

There are various methodologies available to assess the impact of air pollution on health but all these methodologies are constantly evolving. Moreover, data collection to complete the assessment frameworks is also a very tedious task. There are various steps for evaluating the health risk assessment for a population which include: locating the emission source, determining the concentration of pollutant and its dispersion rate, population exposure, and finally the impact on health which is a function of concentration and time. All these steps require costly and time taking instrumentation. Further meteorology such as seasonal variations also plays an important role in this process. For example, asthma patients suffer more attacks during winter season than summer because the concentration of pollutants is higher during lower temperatures.

Soaring air pollution emissions are becoming a major concern for megacities like Delhi. Their inhabitants are vulnerable to air pollution induced adverse health impacts. Control of exposure conditions must be made to ensure an accurate estimation of inhaled dose and subsequently, the best possible correlation between the concentration of material presented and the biological response at cellular level. The regulatory authorities are also putting great efforts to minimize the effect of pollutants on the urban population by constantly monitoring the criteria pollutants.

Population is generally exposed to a mix of pollutants, both indoor and outdoor air, possibly associated with synergistic effects which we cannot consider using single methodology. Hence, the results obtained from such studies need to be matched with other supporting data such as historic and published records.

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