Chapter 9
Health Risk Assessment and Management of Air Pollutants

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Abstract Air pollution is a vital global public health concern which is generally addressed by collective societal action, particularly to control emissions, i.e. primary air pollutants which are precursors in the formation of secondary air pollutants via different atmospheric chemical reactions. The massive increase in emission of air pollutants in the atmosphere is major cause of human health and environmental problems. According to WHO, it is revealed that particulate matter (PM) exposure is responsible for ~800,000 premature deaths alone each year as compared to other air pollutants. Therefore, more systematic studies for the measurement of various air pollutants are still required to examine the current scenario and their physicochemical characteristics especially focused on PM. This will aid in health risk assessment of air pollutants by using various tools and estimation methods. The present chapter describes the brief introduction of air pollutants and their emission source characteristics along with detailed systematic findings and outcomes of the different studies. In addition, the methods/equations and diverse tools used for risk assessment by scientific community and various researchers have been introduced at regional and global level. Also, the methods and approaches that can be employed for the management of air pollutants (indoor and outdoor) in Indian context have been described. Overall, the chapter gives an idea about the deterioration of air quality due to emission of various pollutants, their formation and management methods along with the concerned health issues. This will serve as an imperative document for the scientific community and policy makers to develop effective mitigation policies with respect to air quality improvement.

Keyword Air quality · Pollutants · Health risks · Sources and pollutant's management

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9.1 Introduction

Air is the principal liable constituent of our environment that is prone to pollution (Agarwal 2009). Air pollution may be defined as an undesirable state of natural air being contaminated with harmful substances as a consequence of human activities and natural disasters (Manahan 1999). This state of the air is termed as air pollution. It may be also defined as *"an introduction of harmful substance and chemicals into the natural environment which can have undesirable effects on human life, climate and the ecosystem"*. Air pollution can be present in both indoor and outdoor environment and characterise in terms of physical, chemical and morphological properties (Taneja et al. 2008; Pipal et al. 2014; Pipal and Satsangi 2015; Saxena and Sonwani 2019). Apart from this, meteorological conditions, sources and spatial characteristics are the factors that play a vital role to contribute towards air pollution.

9.1.1 Indoor Air Pollution (IAP)

IAP also known as Household Air Pollution (HAP) is defined as pollution arising from pollutants released in homes or working places or any closed environment from the various sources (furniture, paints, pets, etc.) and other burning activities such as cooking, cigarette burning, consumption of fuels (biomass, dung, wood, leaves), dusting, burning of incense and candles etc. Indoor air pollution occurs when the building is not properly ventilated and the pollutants get accumulated and concentration becomes higher than outdoor air pollutants (Daly and Zannetti 2007).

9.1.2 Outdoor/Ambient Air Pollution

The pollution in which pollutants are released in outdoor atmosphere is known as outdoor/ambient air pollution. The most common source of ambient air pollution are man-made activities which include combustion of fossil fuels (coal, oil and gas) in industries, power stations, homes and road vehicles. In addition oxides of sulphur and nitrogen from volcanic eruption, biological decay, oceans, lightning strike, forest fires, Volatile Organic Compounds (VOCs) and pollen from plants, trees and PM from dust storm are known as natural sources (Saxena and Ghosh 2018, 2019).

9.2 Air Pollutants

The substances that are in excess amount in the air are known to be air pollutants. These substances in air are present in high enough concentration that could harm animals, humans, vegetation, and materials. They may exist in the form of solid, liquid, gas or PM in the atmosphere.

9.2.1 Classification of Air Pollutants

Air pollutants may be released directly in atmosphere and can be formed by the substances that already exist in environment. They may also be released from natural as well as anthropogenic sources. On the basis of formation, air pollutants may be categorised as primary and secondary air pollutants.

9.2.1.1 Primary Air Pollutants (Precursors)

Pollutants that are released directly into the atmosphere and can be formed on their own are known as primary pollutants. They can be emitted from anthropogenic, biological and geogenic sources. The main primary pollutants which affect the human being are:

- Carbon compounds like CO, CO_2, CH_4 and VOCs
- Nitrogen compounds (NO, NO_2 and NH_3)
- Sulphur compounds such as SO_2, H_2S
- Halogen compounds such as chloride (Cl^-), fluoride (F^-), bromide (Br^-)
- Solid or liquid form of PM and it is classified into many classes on the basis of aerodynamic diameter of the particles (Harrison 2000)

9.2.1.2 Secondary Air Pollutants

Secondary pollutants are substances that are formed in atmosphere from precursor gases via different chemical reactions as they are not emitted directly into the atmosphere. The main secondary pollutants which affect human beings are:

- NO_2 and HNO_3 formed from NO precursors via chemical reaction
- Photochemical oxidation of nitrogen oxides and VOCs leads to the formation of O_3
- Sulphuric acid droplets formed from SO_2, and nitric acid (HNO_3) droplets formed from NO_2

- Reactions of sulphuric acid (H_2SO_4) and nitric acid (HNO_3) droplets with NH_3 and water vapours leads to the formation of sulphates (SO_4^{2-}) and nitrates (NO_3^-) aerosols (i.e. NH_4SO_4 and NH_4NO_3)

9.3 Sources of Air Pollutants

Air pollutants present in the atmosphere can be released from both natural as well as anthropogenic sources that are discussed below.

9.3.1 Natural Sources

Natural sources of air pollutants include volcanic eruption which release dust, ash, and other gases, pollen grains from flowers, forest fires that are naturally caused by lightning. The emission of air pollutants from natural sources have short life period in atmosphere and also play important role in changing the composition of atmosphere (Falkowska 2015).

9.3.2 Anthropogenic (Human-Made) Sources

Man-made activities such as fuel and biomass burning, household combustion of coal; sewers and domestic drains emanating foul gases, agriculture equipment's, vehicle exhausts, factories, shipping, airplanes are known as anthropogenic sources. They produce many harmful primary pollutants such as carbon monoxide (CO), nitrogen dioxide (NO_2), nitrogen oxide (NOx), sulphur dioxide (SO_2), ammonia (NH_3), PM, VOCs along with secondary pollutants like SO_3, HNO_3, H_2SO_4, H_2O_2, O_3 and various organic components. The environmental air pollution is thus evil of all anthropogenic processes leading to the unfavourable alteration of the environment (Volkamer et al. 2006; Sonwani and Saxena 2016).

9.4 Effect of Air Pollutants on Human Health

The various particle and gaseous pollutants released from natural and anthropogenic sources results into different respiratory acute and severe diseases. When people are exposed to these pollutants, they would cause distinct adverse health effects. However, the effects of pollutants depend upon the concentration of pollutants as well as the exposure period. More the concentration and exposure time of pollutants, more will be the harmful effects on human health as well as climate change.

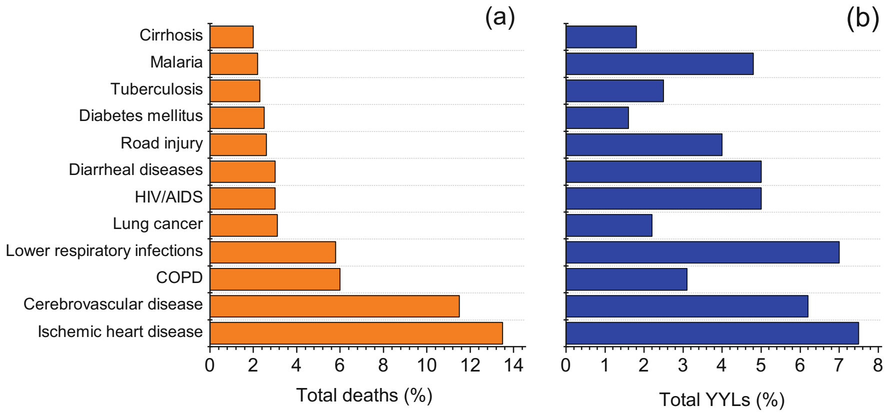

Fig. 9.1 (**a** and **b**) Leading causes of global deaths and premature deaths

In the year of 2012, 7 million deaths globally were caused due to both ambient and household air pollution in which ambient air pollution was responsible for 3.7 million deaths while household air pollution was attributable for 4.3 million deaths (WHO 2014a). In the year 2017, air pollution had taken away life of 12.4 lakh people in India. In Indian perspective, even some of the air pollutant levels were less than the permissible level but still they are causing health problems and subsequently, the loss of life expectancy would have been 1.7 years higher and declared as the leading risk factor for deaths (Saxena and Naik 2018). (https://economictimes.indiatimes.com/news/politics-and-nation/around-12-4-lakh-deaths-in-india-in-2017-attributable-to-air-pollution-study/articleshow/66972252.cms?from=mdr). Recently, the study conducted by Balakrishnan et al. (2019) indicated that 26.2% of global air pollution Disability Adjusted Life-years (DALYs) occurred in India in 2017.

Outdoor air pollution has been ranked among top 10 health risks in India as per assessments of global burden of disease (GBD). The study conducted by Institute for Health Metrics and Evaluation (IHME) found that outdoor $PM_{2.5}$ and O_3 lead to 0.695 million premature deaths and loss of 18.2 million healthy life years (IHME 2013). In order to assess health risk factor, it is found that outdoor air pollution ranked fifth in terms of mortality while overall health burden is on seventh rank. However, a million additional premature deaths in India have been caused from household air pollution due to solid fuel combustion.

Figure 9.1a and b shows the total deaths and Years of Life Lost (YLLs) (%) because of different diseases caused due to air pollutants. From Fig. 9.1a, it is inferred that highest proportion of deaths is because of ischemic heart disease followed by cardiovascular disease and lowest due to cirrhosis. In case of years of life lost (YLL) the same trend of deaths gained is seen (Fig. 9.1b). This statistical data on number of deaths and YLLs caused due to different diseases shown in above figures was obtained from Global Burden of Diseases (2010) report published by IHME (2013). According to the State of Global Air Report 2019, India is facing third leading risk factor for mortality accounting for 1.2 million deaths due to air

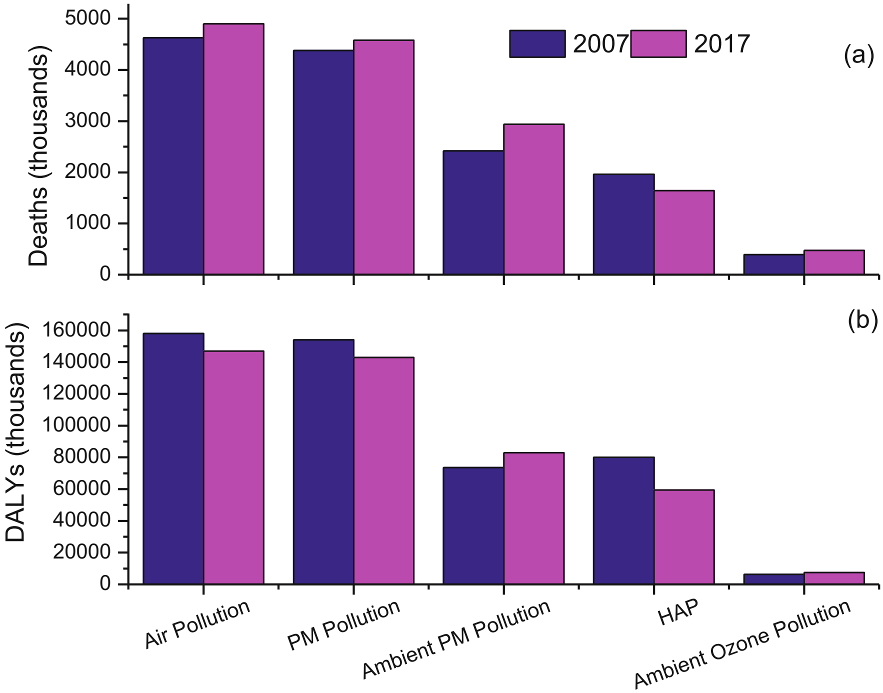

Fig. 9.2 (**a** and **b**) Number of deaths and DALYs due to different types of air pollution (all causes). *HAP* House hold air pollution

pollution. Further, the percentage distribution of various diseases indicates that 49% of deaths are attributed by COPD cases followed by lung cancer, diabetes, and ischemic heart diseases.

According to Global Burden Disease Study (2017) published by IHME (2018), the number of deaths attributed due to different types of air pollution was found to have increased except household air pollution which recorded a decrease of 320 thousands deaths (Fig. 9.2a) while the number of DALYs was found to be decreased in all type of pollution cases (i.e. air pollution, PM pollution, household air pollution), whereas in case of ambient PM pollution it has increased by 520 thousands (Fig. 9.2b).

The different types of air pollutants released from distinct sources and activities both in indoor and outdoor environment along with their health effects have been discussed in Table 9.1.

Table 9.1 Different pollutants, their sources and associated health effects

S. no.	Pollutants	Sources	Associated health effects
1.	Carbon monoxide (CO)	Fossil fuel combustion in vehicles, industries and power plants, fireplaces, cook tops, ovens, wood/coal stoves and tobacco smoke	Interference in the blood's ability to carry O_2, slows reflexes and causes drowsiness. It also leads to headache and stress on heart (Mofenson et al. 1984)
2.	Nitrogen dioxide (NO_2)	Same as carbon monoxide	It makes the body vulnerable to respiratory infections, lung diseases and may cause cancer (Chauhan et al. 1998)
3.	Sulphur dioxide (SO_2)	Same as carbon monoxide	Short-term exposure leads to breathing difficulties and obstructive airways. Long-term exposure causes chronic bronchitis, emphysema and respiratory illness (Chen et al. 2007)
4.	Volatile organic compounds (VOCs)	Glues, cleaning materials, fabric softeners, paints, moth repellents, deodorisers, pesticides	It affects eye, upper and lower respiratory irritation, nasal congestion, headache, rash, dyspnoea, epistaxis and may cause cancer (Berglund et al. 1992)
5.	Environmental tobacco smoke (ETS)	Cigarettes, cigars and pipes	It may cause diseases like acute respiratory symptoms, tuberculosis, asthma, etc. to non-smokers. Lung cancer, impaired breathing and cardiovascular disease in smokers (Yanbaeva et al. 2007)
6.	Particulate matter (PM)	Construction materials, unpaved roads, burning activities fields, smokestacks, cooking; combustion of candles, incense; heaters, and environmental tobacco smoke	PM causes a variety of respiratory problems and cardiovascular diseases. It also leads to cancer due to long-term exposure (Englert 2004)
7.	Heavy metals	Combustion processes, industrial activities, insecticides, manufacturing of steel, smelting, dust, combustion process, ETS	Kidney failure, abnormalities in skeleton system, different kinds of cancers such as liver, lung, nose, larynx and prostate, skin and lungs problem, anaemia, cardiovascular diseases, birth defects, asthma and chronic bronchitis, heart disorders (Mahurpawar 2015)
8.	Ozone (O_3)	O_3 formed from precursors released by road transport, power plants, industrial boilers, paint, dry cleaning, and other solvent uses	Respiratory and cardiovascular problems, premature mortality (Tager et al. 2005)
9.	Aerosols	Various natural and anthropogenic activities such as aerosol sprays, hair sprays, perfumes, solvents, glues, cleaning agents	It can cause asthma, skin irritation, breathing difficulty, cough, lung problems, headache, diarrhoea, cancer, effects infants and pregnant women (Poschl 2005)

9.5 Health Risk

Health risks are a measure of the chance that anyone has to experience health issues, due to exposure of toxic air pollutants (https://www3.epa.gov/airtoxics/3_90_024.html). In order to know health-related issue due to air pollutants, various tools and methods have been applied by different researchers at regional and global level.

9.5.1 Estimation of Health Risk

The health risk of air pollution in inhabitants is represented by the concentration–response function. It is typically based on estimates of Relative Risk (RR) and obtained from epidemiological studies. It outlines the possibility of adverse health outcome such as premature death, heart attack, asthma attack, emergency room visit, and hospital admission occurring in the population who is exposed to the higher level of air pollution as compared to the population that are at comparatively lower exposure level. It also defines the proportional increase in the evaluated health outcome related with an increase in the concentration of pollutants (μg/m^3 or ppb) (Katsouyanni 2003). However, RR also estimates the health risk only in a defined population and for a specific person, i.e. no individual health risk can be measured (McAuley and Hrudey 2006; Australian Department of Health 2012).

9.5.2 Quantification of Health Impact

Number of attributable deaths or cases of diseases, years of life lost (YLL), disability-adjusted life years (DALYs) and change in life expectancy occur due to total exposure to air pollution or change in exposure and are the terms that are used to describe air pollution health risk assessment (AP-HRA) (WHO Regional Office for Europe 2016). These matrices collect different types of health impact and can also be used to highlight the different aspects of the population with respect to health (Murray and Lopez 2013).

9.5.2.1 Number of Attributable Deaths or Cases of Diseases

It is calculated as the difference in number of deaths or cases of diseases between the incidence/rate at the exposure measured over a specific period at baseline exposure (WHO Regional Office for Europe 2016).

9.5.2.2 Years of Life Lost (YLL)

It is a measure of the years of life lost as a result of premature death. In general term, the calculated number of deaths attributable to changes in exposure to air pollution is multiplied by the standard life expectancy at the age at which death occurs (WHO 2014b).

9.5.2.3 Years Lost Due to Disability (YLD)

It measures the years of lost due to disability and estimated by multiplying the number of incident cases of a particular health outcome in a particular period. It is measured by the average duration of the case until remission or death (years) and a disability weight factor that reflects the severity of the disease on a scale from 0 (perfect health) to 1 (dead) (WHO 2014b).

9.5.2.4 Disability-Adjusted Life Years

One DALY is one lost year of healthy life. The sum of DALYs across a population—the burden of disease can be thought of as a measurement of the gap between actual health status and an ideal situation in which the entire population lives to an advanced age, free of disease and disability. Total DALYs for a particular disease or health condition in a population are calculated as the sum of YLL and YLD (Murray and Lopez 2013; WHO 2014b).

9.5.3 Health Risk Assessment (RA)

RA is the process used by various scientists, researchers and government agencies to estimate the increased risk of health problems in humans exposed to toxic substances. The RA approach outlined by the WHO in the Environmental Burden of Disease (EBD) series (Prüss-Üstün et al. 2003; Ostro 2004) includes the following steps:

1. Evaluation of the air exposure of the population through data obtained from air model or monitoring networks. A target concentration is also required to determine the attributable disease or the potential gains of a management plan.
2. Ample number of persons exposed to air pollutants.
3. Baseline data of incidence of the adverse health outcomes associated with air pollutants (like mortality rate).
4. Concentration–response functions (CRFs) related to the incidence of adverse health effects.

There are various steps and methods which are used by various researchers in their study to estimate the health risk assessment of different air pollutants especially heavy metals.

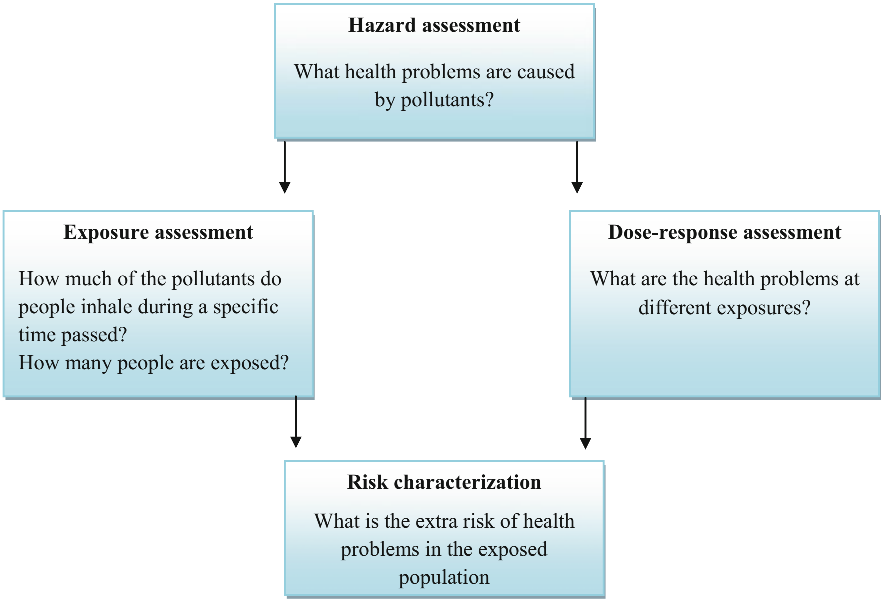

Fig. 9.3 Different steps given by USEPA for risk assessment

The entire process used for risk assessment is divided into four steps by US Environmental Protection Agency (USEPA) as depicted by the flow chart (Fig. 9.3).

The mechanism of risk assessment and various factors which are responsible for health issues due to air pollutants in different ways are mentioned in A Citizen's Guide (1991), Risk Assessment for Toxic Air Pollutants published as EPA 450/3-90-024. March 1991.

In the year 1992, USEPA produced different equations in order to calculate the health risk associated with PM-bound metal. It is known that the time of exposure to pollutants is a major factor to determine the health hazard due to that pollutant. Firstly, the average daily dose (A_{DD}) is calculated with the Eq. (9.1):

$$A_{DD} = C \times InhR \times ED/BW \times AT \tag{9.1}$$

where C = concentration ($\mu g/m^3$) of contaminants in air
InhR = average inhalation rate
ED = exposure duration;
USEPA has given standard value of all these terms
BW = body weight
AT = average exposure time

With the help of A_{DD} the non-carcinogenic risk of metals can be calculated by Eq. (9.2):

$$HQ = A_{DD}/Rfc \tag{9.2}$$

Rfc = Reference concentration of metals or other toxicity value.

When HQ value is found to be >1 the metal causes non-carcinogenic risk while HQ value <1, it does not cause any risk.

The carcinogenicity of four metals (Cr, Ni, Cd and Pb), i.e. Lifetime cancer risk (R_{ic}) can be calculated as:

$$R_{ic} = C \times ED \times UR/\text{Average life} \tag{9.3}$$

UR = unit risk.

Using the above formula, Kushwala et al. 2012; Li et al. 2015; Wang et al. 2015; Fang et al. 2013; Jan et al. 2018 and many others have calculated health risk of various metals associated with PM exposure.

Along with the above method the health risk analysis (both for adult and child) for receptor due to metal-bound PM can also be done by the following formulas provided by USEPA 2009.

The exposure concentration can be determined by using Eq. (9.4):

$$EC = \quad (CA \times ET \times EF \times ED)/AT \tag{9.4}$$

where: EC (μg/m^3) = exposure concentration
CA (μg/m^3) = contaminant concentration in air
ET = exposure time usually 24 h/day
EF (days/year) = exposure frequency (350 days/year)
ED (years) = exposure duration
AT = average time (period over which exposure is averaged)

Risk characterisation for a person who is exposed to air pollutants through inhalation pathway can be examined by calculating Hazard Quotient (HQ) (Eq. 9.5):

$$HQ = EC/(\text{Toxicity Value} \times 1000\ \mu g/mg) \tag{9.5}$$

while Eq. (9.6) helps to calculate Excess Lifetime Cancer Risk (ELCR) for non-carcinogenic and carcinogenic risk, respectively:

$$ELCR = IUR \times EC \tag{9.6}$$

Chronic Reference concentration (RfC) (mg/m^3) and IUR (μg/m^3) = Inhalation Unit Risk.

Among various epidemiological studies in which these equations have been used for the estimation of health risk of metals associated with PM include Hieu and Lee (2010), Taner et al. (2013), and Rohra et al. (2018). These researchers have estimated health risk of different metals in various pathways and their findings with respect to health risk caused due to chemical constituent associated with PM.

Apart from estimation process, health risk is also accessed by various tools that have been devised by various organisations. The details of some of the tools which are used for health risk assessment from ambient air pollution are provided in Table 9.2 (WHO Regional office 2016).

Table 9.2 Different tools developed by various organisations for health risk assessment caused due to air pollutants

Tools	Developing institution	Geographical scope	Health endpoint addressed
Air Counts	Abt Associates	Global (42 cities, additional 3000 under development)	Mortality
AirQ2.2 (update under development	World Health Organization	Population specified by size, mortality and morbidity characteristics	Mortality and morbidity
Aphekom	French Institute of Public Health Surveillance	Global (current version focuses on Europe)	Mortality and morbidity
Economic Valuation of Air Pollution (EVA)	Aarhus University	Northern hemisphere, continental (e.g. Europe), local areas	Mortality and morbidity
EcoSense	University of Stuttgart	Europe	Mortality and morbidity
Environmental Benefits Mapping and Analysis Program—Community Edition (BenMAP-CE)	USEPA	Continental USA and China predefined	Mortality and morbidity
EBD Assessment tool for ambient air pollution	World Health Organization	Global	Mortality and morbidity
GMAPS	World Bank	Global	Mortality and morbidity
IOMLIFET	Institute of Occupational Medicine	Places where background mortality data and measured and predicted pollutant concentrations level	Mortality and morbidity
Rapid Co-benefits Calculator	US Environmental Protection Agency, Stockholm Environment Institute	Underdevelopment for all countries globally	Mortality
SIM-Air	Urban Emissions	Asia, Africa, Latin America	Mortality
TM5-FASST	European Commission Joint Research Centre	Global	Mortality and morbidity
ICRP	International Commission on Radiological Protection	Global	Morbidity

USEPA, EBD

The health risk of air pollutants accessed by estimation process (using values or equations and software methods) are not as accurate as the function of epidemiological studies. As these methods are based on the values given by various organisations from various places having different environmental conditions they are not perfect but these results are useful to researcher for further assessment of risk concerned with exposure of toxic air pollutants. Moreover, the factors which are used for health estimation help the government bodies to set regulatory standards to reduce people's exposures from toxic air pollutants and assessment of health issues.

There are various standards set out by national and international bodies for ambient air that provide the concentration limit of exposure according to time (annual and 24 h) of toxic pollutants. Environmental protection agency (EPA) has assigned a specific air quality index (AQI) category and range to make it easier for people to understand quickly whether air pollution is reaching unhealthy levels in their communities (Table 9.3). For example, the mass concentration of fine particle ($PM_{2.5}$) in the range of 36–66 μg m^{-3} is unhealthy for sensitive groups, while 66–150 μg m^{-3} means that conditions may be unhealthy for everyone. The overall average concentrations of PM ($PM_{2.5}$: 98 μg m^{-3} and PM_{10}: 148 μg m^{-3}) in the study conducted by Pipal et al. (2019) was found to be much higher than its standards and AQI values over atmosphere in Pune. This may cause respiratory problems and health issue to people who have been continuously affected by these pollutants along with climatic problems. This may be due to less application of emission control measures, which are responsible for respiratory problems and human health. The CPCB and other government monitoring programmes also reported that concentration of PM in Indian cities is higher than the common guidelines. However, no such standards exist till date for indoor air. Such standards should be framed for indoor air quality as people spend majority of their time in indoor and exposed to various toxic pollutants which lead to acute and severe diseases.

In this connection, some relevant research work done at national and international level so far which focused on risk assessment and epidemiology are discussed and examined; their major findings and outcomes have been discussed in Table 9.4. Exposure to toxic pollutants results in increased health risk and leads to different acute and severe diseases. However, concentration and exposure time are also important factors for health risk. On the basis of assessment methods and tools,

Table 9.3 Air quality index and recommendations

AQI level	AQI values	$PM_{2.5}$	PM_{10}
Good	0–50	0–15	0–50
Moderate	51–100	16–35	51–155
Unhealthy for sensitive groups	101–150	36–65	155–254
Unhealthy for sensitive groups	151–200	66–150	255–354
Very unhealthy	201–300	>150	>354

Air quality index: a guide to air quality and health (Anderson et al. 2012)

Table 9.4 List of epidemiological studies that relate pollutants with health risk

References	Year	Region	Findings
American Industrial Hygiene Association (AIHA)	1968	US	Exposure to formaldehyde is toxic which results in strong irritating to eyes, skin, nose, respiratory tract or mucous membrane
Pandey et al.	2005	India	Exposure to NO_2 and Suspended Particulate Matter (SPM) is more harmful as compared to SO_2. The average health risk possessed by NO_2 and SPM was found to be 22.11 and 16.13 times more than that of SO_2 for all age categories
Brook et al.	2010	US	Cardiovascular effects of PM exposure have been linked to oxidative stress (OS), pulmonary and systemic inflammation, endothelial cell dysfunction, atherosclerosis and altered cardiac autonomic function (ACAF)
WHO	2011	–	Respiratory system and lungs function can be affected due to exposure of SO_2, causing various problems of coughing, mucus secretion, aggravation of asthma and chronic bronchitis that "make people more prone to infections of the respiratory tract". Also reported that SO_2 is the main cause of irritations of the eyes. Long-term exposure to NO_2 leads to proportional increase in the symptoms of bronchitis in asthmatic children. Ozone initiates asthmatic problems, reduces lung function and leads to lung diseases
Yeh et al.	2011	Taiwan	Sewer gas releases hazardous pollutants, i.e. benzene and trichloromethane. Its cancer risks reached the ranges of $2.77–3.98 \times 10^{-3}$ and $29.74–42.7 \times 10^{-3}$, respectively, for workers without protective equipment as the cancer risk assessment
Wichmann and Voyi	2012	South Africa	Exposure to PM is strongly associated with respiratory, cardiovascular and cerebrovascular risks
Sancini et al.	2014	Italy	Systematic adverse effects are related with repeated instillations of $PM_{2.5}$. Susceptible population which include elder people and people who have unrecognised coronary artery or structural heart disease are more prone to $PM_{2.5}$
Maji et al.	2017	India	The number of morbidity cases (except COPD) have increased by 30% from 1992–2002 to 2003–2013 and PM_{10} resulted in the excess number of mortality and morbidity as compared to gaseous pollutants

(continued)

Table 9.4 (continued)

References	Year	Region	Findings
Chen et al.	2017	China	Home environment alone contributes 96% of the total average health risk. The carcinogenic health risks were found to be in the bedrooms (6.8×10^4 for male, 7.4×10^4 for female) and living rooms (4.4×10^4 for male, 4.0×10^4 for female) with long exposure time. These all values were higher than the acceptable risk threshold
Khaniabadi et al.	2019	Iran	With increase in each 10 μg/m^3 concentration of PM_{10} the risk of mortality for all causes and cardiovascular diseases increase by 0.74% and 0.80%, respectively while the risk of hospitalisations for respiratory disease and cardiovascular diseases increased by 0.80% and 0.90%. In case of SO, increases in each of 10 μg m, the risk for cardiovascular mortality increased by 1.2%. while the case of hospitalisations for COPD and acute myocardial infarction increased by 0.44% and 1.0%, respectively
Satsangi et al.	2014	India	In silico study suggested that Ni actively formed coordination complex with histone proteins by maintaining strong hydrogen bonding interactions with Aspartic acid and Glutathione. The structural consequence of Ni in nucleosomal proteins and assessment epigenetic changes ultimately causing lung and nasal cancer

various national and international studies have been conducted which prove the relation of health risk due to exposure of pollutants.

9.6 Approaches to Improve Ambient Air Quality

In order to improve ambient air quality different measures can be taken. As is well known, plants are able to purify the air but reckless cutting of plants has led to the rise in the problem of ecological imbalance and also hinder in the process of purification of air. Along with this, source control is also an important step that helps in improving ambient air quality. Some of the common steps to control or manage pollutant concentration in the atmosphere can be taken by the citizens of a country who can help a lot in controlling air pollution which results to improve air quality.

9.6.1 Source Control

Source control is one of the most effective ways to improve ambient air quality. Reduction in the number of source that causes air pollution can effectively reduce the pollutants level in the atmosphere. The different sources that cause ambient air pollution in the Indian context (Guttikunda et al. 2014) and their control have been discussed below.

9.6.1.1 Transportation

It plays a vital role in urbanisation and industrialisation in which road transportation is one of the major growing transports in developing country and also plays a vital role in Indian economy. The fossil fuels combustion in vehicles release a lot of pollutants leading to the deterioration of air quality. Of the total, transport sector contributes 14% of the air pollution in India (https://en.wikipedia.org/wiki/Air_pollution_in_India) which is an abundant number. So, vehicles that are run by Compressed Natural Gas (CNG), biodiesel, solar technology and electricity must be used instead of those vehicles in which combustion of fossil fuels occur, specially diesel. However, in recent years, the use of CNG in vehicles has increased. Still, other steps must also be taken by the government in order to reduce the contribution of pollution due to transportation. Current effective policies related to transportation are needed to be implemented with strictness and if needed new policies must be formed in order to tackle air pollution.

Figure 9.4 shows that the largest contributor to air pollution is dust and construction followed by diesel generators and lowest is from domestic cooking (https://en.wikipedia.org/wiki/Air_pollution_in_India).

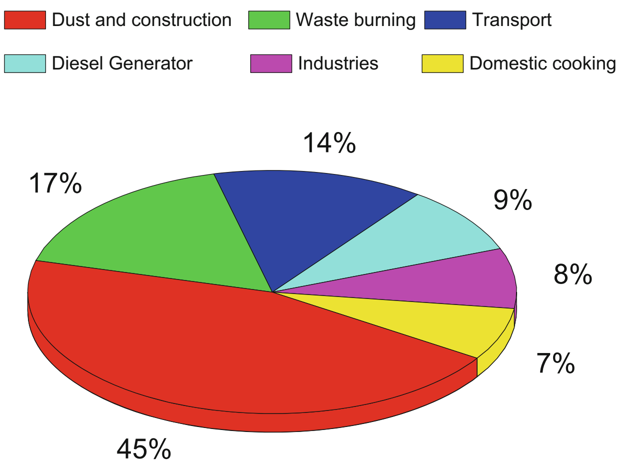

Fig. 9.4 Different sources contribute to air pollution

9.6.1.2 Waste Burning

Open waste burning contributes 17% of the air pollution in India. Waste collected by Municipal Corporation is usually burnt in open spaces which lead to emission of toxic pollutants such as SOx, NOx, PM, VOCs and other pollutants. There is no fixed procedure for management of these wastes and also landfill facilities are not maintained in a proper manner which is the main cause for burning of waste especially in small and medium cities. There is an urgent requirement for waste management programme that helps to tackle the problem related to air pollution.

9.6.1.3 Industries

Industries contribute 8% of air pollution in India. With increase in modernisation large number of industries has been set up which produce large number of pollutants along with goods. The percentage contribution of air pollution from industries in India alarms that immediate and effective measures to be taken for controlling the toxic pollutants emission from industries. Smoke from chimneys comes out without any purification and mixes in clean air leading to deterioration of ambient air quality day by day. For that air purification technique such as precipitators must be employed on the ejection point of smoke from chimneys in industries so that clean air may come out. An environment monitoring device known as Aurassure has been employed for the monitoring of different air quality parameters from different locations and it also helps industries to know the level of their pollutants emission.

9.6.1.4 Diesel Generator

The supply of electricity in India is also a big deal and due to improper supply of electricity people use diesel generators in homes and other working places that lead to emission of different pollutants in the air. Diesel generators contribute about 9% of air pollution in India which can be stopped by improving the electricity supply in India especially in small cities. However, the patented Chakr Innovation is a very important intervention that converts diesel soot from generator into purified carbon-based pigment after removing heavy metals and carcinogens from soot. The purified carbon-based pigment can be further used as ink and paints for various purposes.

9.6.1.5 Dust and Construction

Dust and construction activities are the largest contributor of air pollution which shares 45% of the air pollution in India. With increase in modernisation, massive construction work leads to large number of pollutants. The contribution of dust and construction towards air pollution in India is in such an alarming state that effective measures are needed to be taken for the control of pollutants from these types of activities (Sonwani and Kulshrestha 2018, 2019). According to a report of CPCB, particles released from wear and tear of tyres and brakes and dusts composed of particles from road's material, pavement and street furniture is a major concern for many cities in India. Unpaved roads lead to increase in dust loading (CPCB 2010). Intervention should also be taken in order to control dust as it contributes to 30–40% of course particulate matter (PM_{10}) pollution in most Indian cities (CPCB 2010; Guttikunda and Jawahar 2012).

9.6.1.6 Coal: Fired Power Plant

It is known that coal is usually used for the production of electricity in India. According to World Bank collection of development indicators, in the year 2014 coal shared 75.08% of the total source used for total electricity production in India. The amount of pollutants released from the combustion of coal used for electricity generation can be understood. According to a study, Indian coal that is used for electricity production comprises low level of sulphur as compared to other coal and leads to production of ash in large amount which finally may act as a contributor of PM emission (Pant and Harrison 2012). The production of electricity from renewable source and hydroelectricity should be focused rather than electricity production from coal to achieve better outcomes.

9.6.2 Other Measures

Use of public transportation instead of private vehicles can help in reducing air pollutant especially PM concentration which is emitted from combustion of fossil fuel and wearing and tearing of tyres.

9.6.3 Purification of Air

There are various air cleaning tools available that can be employed to purify the polluted air. China has recently established world's biggest (100-m-high) air purification tower in Xian, Shaanxi province that helps to tackle problem of smog. This is a good initiative to improve air quality. Such steps should also be taken in large scale by Indian government bodies and other agencies towards the most polluted areas and heavy traffic junctions. We know that Indian government has already started a start-up named "Kurin Systems" to develop air purifiers that can be installed in Delhi in order to improve the air quality. If it will be an effective device to improve the air quality of Delhi, then government can approach other cities also.

9.6.4 Implication of Policies

The harmful effects of air pollution have been confirmed by various studies and concern that there are several policies which have been assigned by the government to attain the goal of healthy air. These policies are required to be implemented in the right way to achieve the required goal.

9.7 Approaches to Improve Air Quality in Indoor Environment

The problem of air pollution is not only concerned with ambient air but it is a major topic of concern for indoor air pollution. People spend majority of their time indoor so it cannot be taken lightly. A number of studies have been conducted in indoor environment which shows that the concentration level of pollutants are enough to lead to ill health effects.

The following are three basic strategies used for improving indoor air quality:

1. Source control
2. Improved ventilation
3. Air cleaners

9.7.1 Source Control

The elimination of sources that cause air pollution is the best way to deal with the problem of poor indoor air quality. Sources that release asbestos can be sealed or enclosed; combustion process can be controlled; gas stoves can be maintained so that complete combustion can take place which lead to decrease in the amount of emissions. Source control is the most effective solution for indoor air quality problems in home.

9.7.1.1 Domestic Cooking

Domestic cooking is the main source of indoor air pollution and contributes to 7% of the air pollution of India. In 2011, 35% of urban and 89% of rural household depend on non-LPG fuels according to census of India (Census-India 2012).

The combustion of biomass leads to emission of pollutants which cause various acute and severe diseases. Most of the women are not aware about the harmfulness of biomass fuel smoke and some are aware but still they cannot use LPG for cooking purpose due to economic condition. In this connection, Indian government has started a scheme called Ujjwala Yojana on May 1, 2016 at Ballia which support free cooking LPG connection for the families who are living below the poverty line. Use of clean fuel will improve women's health who has to cook on unclean fuel. (http://yojana.gov.in/June%20Yojana%20Final.pdf).

9.7.2 Ventilation Improvements

The concentration of pollutant can be diluted by ventilating (opening door and windows and using exhaust fans) in homes. However, it is not always helpful as the pollutants from outdoor air seep in indoor and increase the level of pollutants.

Air quality of indoor environment can be effectively improved by introducing outdoor air as it helps in dispersion of indoor pollutants concentration. There are several ways that aid in introduction of good air in indoor spaces; such as:

- Natural ventilation through doors and windows.
- Mechanical means, such as Heating, Ventilation and Air Conditioning (HVAC) system uptake outdoor air which helps to promote good indoor air quality.
- Infiltration is the process which involves the circulation of outdoor air from opening in house, joints and cracks in walls, ceilings and floors; and also doors and windows.

9.7.3 Air Cleaners

Air cleaners with different technologies and sizes are available in the market which help to reduce the indoor pollutants to a large extent. These air cleaners are available at the cost that can be afforded by low income families also. The effectiveness of these air cleaners depends on the amount of air drawn from cleaning or filtering element and efficiency to collect pollutants from indoor air (https://www.epa.gov/indoor-air-quality-iaq/improving-indoor-air-quality). In this regard; one of the campaign studies conducted at Agra by using two air purifiers found that they are able to reduce 12–73% of PM from indoor chamber.

9.8 Conclusion

The problem of air pollution has increased with great pace from the times of urbanisation, industrialisation and modernisation. From the various reports and literature it is concluded that air pollution leads to large number of diseases and deaths worldwide. Pollutants are not only harmful for human health but they also affect our environment and other living organism. Therefore, the pollutants released in indoor and outdoor environment from various sources and activities are needed to be controlled. Urbanisation and modernisation are indicators of the development of a country but it seems to be a sin when they lead to ill health and deaths. As the awareness about harmfulness regarding air pollution has increased, the management of air pollutants has been introduced. There are large number of pollution control tools which are available these days that are widely used to purify the air but these will not be fruitful until we stop damaging our environment. Source control is the best solution to tackle the problem of air pollution. The study conducted recently in China by Huang et al. (2018) has confirmed that reduction in air pollution can also reduce the cases of mortality and YLL. Overall, our findings revealed that the ambient and indoor air pollutants concentration levels are above the prescribed standard values in many cities and associated with increased risk of various health issues. Therefore, the effective policies to reduce emissions sources are obviously preferable and evidences support the effectiveness of individual actions to reduce exposure levels and health risks of air pollutants.

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