

REVIEW ARTICLE

Health Implications of Air Pollution: A Review

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ABSTRACT

There are many air pollutants that are major factors in disease in humans. Among them, Particulate Matter (PM) penetrate the respiratory system via inhalation, causing respiratory and cardiovascular diseases, reproductive and central nervous system dysfunctions, and cancer. Furthermore, nitrogen oxide, sulfur dioxide, Volatile Organic Compounds (VOCs), dioxins, and polycyclic aromatic hydrocarbons (PAHs) are all considered air pollutants that are harmful to humans. Diseases occurring due to short-term exposure include respiratory problems such as Chronic Obstructive Pulmonary Disease (COPD), asthma, bronchiolitis, and long term effects are lung cancer, cardiovascular events, central nervous system dysfunctions, and cutaneous diseases. Public awareness coupled with a multidisciplinary approach by scientific experts; national and international organizations must address the emergence of this threat and propose sustainable solutions. Global measures, that aim to reduce exposure to air pollutants, are highly needed for the entire environment.

Keywords: Air pollution; air quality; particulate matter

Introduction

In today's world air pollution is a major problem, not only because of its impact on climate change but also because of its impact on public and individual health. The World Health Organization defines air pollution as contamination of the indoor or outdoor environment by any chemical, physical, or biological agent that modifies the natural characteristics of the atmosphere¹.

In 2018, during the first WHO Global Conference on Air Pollution and Health, the WHO's General Director, Dr. Tedros Adhanom Ghebreyesus, called Air pollution a "*Silent Public Health Emergency*" and "*The New Tobacco*".

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Worldwide, it is estimated that 4.2 million and 3.8 million premature deaths were attributable to outdoor and indoor air pollution, respectively². More than 99% of the population live in areas where the air pollution is above WHO air quality guidelines and 4.2 million deaths are attributed to ambient air pollution each year.

According to the survey, in year 2019 it was discovered that 21 out of the 30 most polluted cities were in India and this pushed India’s ranking to 5th place in Air pollution Index. The main sources in India are, more than 50 percent comes from industry, followed by 27 percent from vehicles, 17 percent from crop burning and 7 percent by domestic cooking³. In India, as electricity or other cleaner fuels are not available in remote areas, so about 100 households use their chullahs/ stoves for 3-4 times a day for 7 days a week and that results in smoke and other pollutants.

According to WHO report in a survey of 7,000 world cities by the US-based Health Effects Institute in August 2022, Delhi is the worst of any major city in the world. According to the report by the Ministry of Environment and Forests, in Delhi it was estimated that about 3000 metric tons of air pollutants were emitted every day, with a major contribution from vehicular pollution (67%), followed by coal-based thermal power plants (12%) and the percentage is increasing as monitored by the Central Pollution Control Board (CPCB). The concentrations of carbon monoxide from vehicular emissions showed abundant increase due to increase in vehicular population⁴.

In order to control the air pollution index in country, Indian government has also taken number of measures in recent past, introduction of LNG (Liquid Natural gas) for household cooking purpose and auto rikshaws, use of Electric vehicles (EV)/ Electric buses, the Government in New Delhi introduced the “odd/even” rule in late 2017, to completely banned the vehicle solder than 15 years or that fall below the BS6 emission standards. The Delhi government has also launched an initiative to bring 5,000 acres of agricultural land under bio-decomposer usage to prevent stubble burning.

Air Pollutants and its sources

Air pollutants may be “criteria pollutants” or “hazardous air pollutants”. Criteria pollutants are used to determine whether a region is meeting air quality standards, i.e. is in “attainment” status. Hazardous air pollutants, known as “air toxics”, are chemical compounds suspected of causing cancer and other chronic human health risks⁵.

Table- 1: Major sources of Air Pollutants and their impacts⁶

Categories of Pollutant	Pollutants	Sources	Health Impacts
Gaseous Pollutants	SO ₂ , NO ₂ , CO, ozone, volatile organic compounds.	Motor Vehicles, combustion of fossil fuels, emission from volcanoes and oceans.	Asthma and other respiratory conditions (SO ₂ , NO ₂), breathing problems, trigger asthma, reduce lung function and lead to lung disease (ozone), breathing problems, exhaustion, dizziness, and other flu-like symptoms (CO).
Persistent Air Pollutants	Dioxins, furans and polychlorinated biphenyls PCBs.	Chemicals in bio-organisms over time	Cardiovascular diseases, liver diseases and diabetes.

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Categories of Pollutant	Pollutants	Sources	Health Impacts
Toxic Air pollutants	Lead, mercury, cadmium, nickel, vanadium, chromium and manganese	Combustion, waste water discharges and manufacturing facilities	Children exposed to lead include behaviour and learning problems, lower IQ and hyperactivity, slowed growth, hearing problems, and anaemia. For pregnant women, health risks include fetal retardation and premature births. In Adults cardiovascular effects , hypertension, decreased kidney function and risk of reproductive problems in both men and women.
Particulate matter (PM)	PM _{2.5} and PM ₁₀	Industries, power plants, incinerators, motor vehicles, construction activity, fires, and natural windblown dust.	PM is capable of penetrating deep into the lung and enter the blood stream causing cardio-vascular (ischaemic heart disease), cerebrovascular (stroke) and respiratory impacts.

Disease specific manifestations of Air Pollution

Air pollution has various health effects. The health of susceptible and sensitive individuals can be impacted even on low air pollution days. Short-term exposure to air pollutants is closely related to COPD (Chronic Obstructive Pulmonary Disease), cough, shortness of breath, wheezing, asthma, respiratory disease, and high rates of hospitalization (a measurement of morbidity). The long-term effects associated with air pollution are chronic asthma, pulmonary insufficiency, cardiovascular diseases, and cardiovascular mortality. According to a Swedish cohort study, diabetes seems to be induced after long-term air pollution exposure⁷. Moreover, air pollution seems to have various malign health effects in early human life, such as respiratory, cardiovascular, mental, and perinatal disorders, leading to infant mortality or chronic disease in adult age.

Air pollution contributes to 9% of all global human deaths, and of these, 58% are from ischemic heart disease and cerebrovascular disease, 18% are from chronic obstructive pulmonary disease and acute lower respiratory tract infections, 6% are from lung cancer. Causes of death in the remaining 18% are mixed and many⁸.

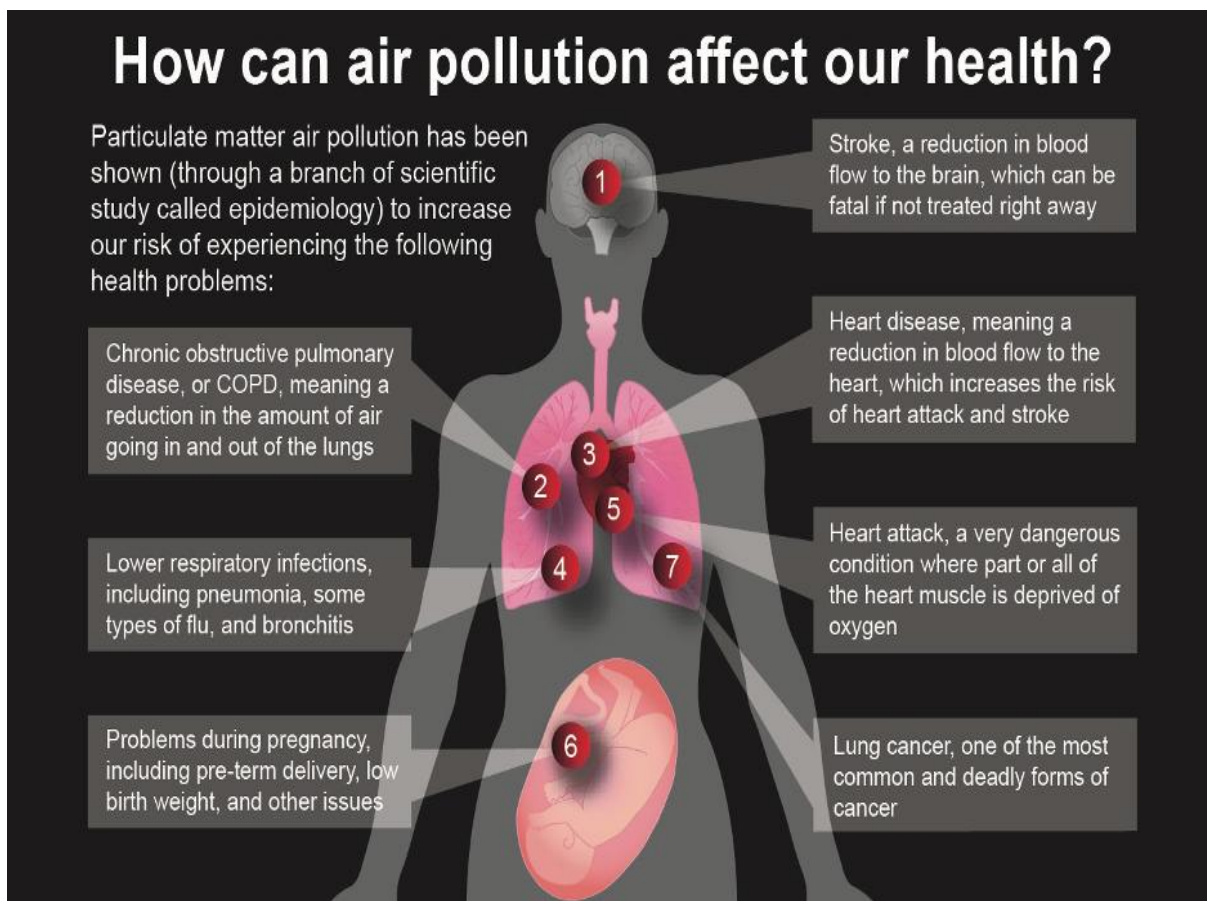
Respiratory Disease

Air pollution is considered as the major environmental risk factor for respiratory diseases such as asthma and lung cancer. Air pollutants, especially PMs and other respirable chemicals such as dust, O₃, and benzene cause serious damage to the respiratory tract.

Asthma is a chronic inflammatory airway disease characterized by respiratory symptoms such as wheeze, dyspnoea, cough and chest tightness associated with variable expiratory airflow limitation. Some studies have found validated associations between both traffic-related and/or industrial air pollution and increasing the risk of COPD.

The prevalence of asthma is estimated at between 1 and 18% of the population in different countries. Evidence suggests that 13% of global incidence of asthma in children could be attributable to traffic-related air pollution (TRAP). Data showed that air pollution has a negative impact on asthma outcomes in both adult and pediatric populations.

Figure 1: Particulate matter air pollution is associated with numerous adverse health effects. Credit: NASA/JPL-Caltech



A recently published birth cohort study including 184,604 children born between 2004 and 2011 in Taiwan demonstrated that both prenatal and postnatal exposures to air pollutants, in particular PM_{2.5}, were associated with later development of asthma. Another large population-based birth cohort study found a positive association between perinatal exposure to air pollution and asthma incidence during preschool years⁹.

A study, conducted in an urban population, demonstrated that the association between asthma morbidity and air pollutions was stronger in children than in adolescents and adults. A meta-analysis of published birth cohort studies reported significant associations between long-term exposure to black carbon and PM_{2.5} and the risk of asthma in childhood up to 12 years of age¹⁰.

Systematic reviews and meta-analyses have demonstrated that maternal smoking during pregnancy is a risk factor of wheezing and asthma in children, especially in the first years of life¹¹.

Even during pregnancy, NO₂ exposure could impair lung function in early life. A systematic review showed a significant association between NO₂ exposure and moderate/severe asthma exacerbations in children and adults (OR: 1.024; 95% CI [1.005, 1.043])¹².

The effects of chronic exposure have been associated with increased overall mortality from respiratory diseases, increased incidence of asthma and COPD, increased incidence of and mortality from lung cancer, reduced lung function, and a deficit in lung development during childhood.

Women seem to be more susceptible to the effect of tobacco smoking than men. Recently, it has been demonstrated that lung cancer is highly linked to indoor air pollution exposure in females as they are spending more time in cooking and thus lung cancer is more common in females than males in non-smoking cases. In more than 80% of females, lung cancer cases in east and south Asia are not related to smoking whereas it is only 15% in the USA¹³.

Emissions from the combustion of solid fuels for cooking or heating have been associated with a high risk of lung cancer. It has been demonstrated that people using solid fuel, such as coal and wood, for heating and cooking throughout their life have a four times higher risk of lung cancer as compared with those combusting clean energy. It is the incomplete combustion that highly emits various particle and gaseous carcinogens, including SO₂, CO, NO₂, PAHs, formaldehyde, heavy metals, and PM_{2.5}¹⁴. These pollutants have been found to be related to morbidity and mortality from respiratory diseases, especially lung cancer.

Allergic Diseases

Allergic diseases such as asthma and allergic rhinitis are very common in children and young adults. In most cases, asthma in these groups of patients is characterized by increased synthesis of immunoglobulin E against common allergens. There is growing evidence that PM exposure could be associated with impaired asthma control. A study found a correlation between poor asthma control, elevated PM_{2.5} and pollen severity in a pediatric population¹⁵.

In a study conducted on Dutch children attending schools that were within 400 m of a major roadway showed increased sensitization to outdoor allergens; the relationship between symptoms and traffic-related pollution was observed mainly in children who were sensitive to allergens¹⁶.

Exposure to PM₁₀ and PM_{2.5} appears as a factor that has a major impact in increasing the prevalence of allergic diseases, especially in children and adolescents.

NO₂ is a traffic-related pollutant, as it is emitted from automobile motor engines. High exposure to NO₂ during the first year of life was associated with increased risk of sensitization to pollens at age 4 years.

Cardiovascular Disease

PM_{2.5} exposure is linked to higher risk of heart attack, heart failure, ischemic heart disease, stroke, atherosclerosis, arrhythmia, hypertension, preeclampsia and neonatal hypertension¹⁷.

It has been reported that PM can cause cardiovascular diseases due to inducing oxidative stress, systemic inflammation, increased blood coagulability, and autonomic and vascular imbalance. It is also a main factor causing significant increases in fibrinogen, platelet activation, plasma viscosity, and release of endothelins, a family of potent vasoconstrictor molecules.

A study on animal models suggested the close relationship between hypertension and air pollution exposure. The traffic-related air pollution, especially exposure to high levels of NO₂, is associated with right and left ventricular hypertrophy¹⁸.

According to a National Toxicology Program (NTP) report, TRAP exposure also increases a pregnant woman's risk for dangerous changes in blood pressure, known as hypertensive disorders, which are a leading cause of pre-term birth, low birth weight, and maternal and fetal illness and death.

Gastrointestinal System

In few studies it was observed that there is an association between exposure to air pollution and different gastrointestinal diseases including inflammatory bowel disease (IBD), appendicitis, irritable bowel syndrome, and enteric infections in infants¹⁹.

Recent data has also shown link between high levels of NO₂, SO₂ with early-onset Crohn's disease and ulcerative colitis, respectively.

Urinary System and Renal System

In a recent study a very fine Particulate matter exhibited increased oxidative stress, inflammation, and DNA damage in kidney tissue. Because of prolonged exposure, it may result in Chronic Kidney diseases²⁰. Excretion of mutagenic metabolites of inhaled air pollutants through the urinary system could also increase the urological system cells' exposure to carcinogens²¹.

Immune System

Air pollution can enhance T helper lymphocyte type 2 (Th2) and T helper lymphocyte type 17 (Th17) adaptive immune responses, as seen in allergy and asthma, and dysregulate anti-viral immune responses²². Particulate matter and other pollutants in household air pollution results from incomplete combustion of solid fuels, cause inflammation of airways and lungs, impair immune response and reduce the oxygen-carrying capacity of the blood.

Diabetes

In recent years, the prevalence of diabetes has progressed incessantly in both developed and developing nations. Further more, current studies indicate that air pollutants may be associated with impaired glucose metabolism, insulin resistance (IR), and type 2 diabetes mellitus (T2DM)²³.

The increasing concentration of air pollutants can lead to clinically significant disturbances in the autonomic nervous system, oxidative stress, inflammation, endoplasmic reticulum stress (ERS), apoptosis, and broad metabolic derangements in glucose and insulin homeostasis, including glucose intolerance, decreased insulin sensitivity and impaired secretion, and increased blood lipid concentrations. These types of changes provide biological mechanistic plausibility in the dose relationship of the association between PM_{2.5} exposure and risk of T2DM.

Honda and colleagues evaluated the association between long term average air pollutant levels and the prevalence of T2DM and HbA1c levels among older Americans, and found that air pollution was associated with abnormal glucose metabolism and T2DM in elderly participants²⁴. Shen and colleagues conducted a case-control study on 6717 mothers with gestational diabetes mellitus (GDM) in Taiwan, and concluded that higher maternal pre- and post-pregnancy exposures to PM_{2.5} and SO₂ were associated with a modestly elevated, but significant, risk of GDM²⁵.

Neurologic and Psychiatric System

Observational evidence has implicated outdoor air pollutants as risk factors for a variety of mental health problems, including depression, anxiety, personality disorders and schizophrenia²⁶.

Recent systematic review shows convincing evidence of associations between depression and PM_{2.5}.

Prenatal air pollution exposure has been linked with cognitive impairments at 5 years of age, but there is no greater risk of anxiety and depressive symptoms²⁷.

During pregnancy, exposure to PM10, PM2.5, nitrogen dioxide and nitrogen oxides were associated with a 29–74% increased odds of unspecified mental disorders that complicated pregnancy. Exposure pathways in utero and early childhood also differ from those in adulthood; for example, in utero, neo-natal and infancy related pathways may include ingestion (non-nutritional as well as nutritional), inhalation, transplacental, transdermal and breastfeeding²⁸.

Skin Diseases

Human skin is exposed not only to natural environmental factors but also to pollutants of anthropic origin. Whenever a prolonged and repetitive exposure to environmental stressors exceeds the skin's normal defensive potential, there is a disturbance in the skin barrier function leading to the development of various skin diseases.

Rapid urbanization and increased energy consumption worldwide have exposed the human body to increased quantities of ambient air pollution. The skin, being the largest and outermost body organ, acts as a physical, chemical and an immunological barrier against the environmental factors.

Major air pollutants which affect the skin are solar ultraviolet radiation, polycyclic aromatic hydrocarbons, volatile organic compounds, nitrogen oxides, particulate matter, cigarette smoke, heavy metals and arsenic.

Ultraviolet A and B both have been implicated in cutaneous immuno-suppression and skin cancers (photo-carcinogenesis) such as malignant melanoma, basal cell carcinoma and squamous cell carcinoma.

Smoking causes premature aging which clinically manifests as deeper periorbital wrinkling. Premature facial skin aging in smokers, with a characteristic pattern of wrinkling and orange-purple skin discoloration, was defined as smoker's face.

An association between cigarette smoke and psoriasis has been reported in several epidemiologic studies. In a Norwegian cross-sectional study, male smokers had a significantly increased risk of developing psoriasis²⁹.

Conclusion

In Today's world air pollution and climate change are an important public health challenges faced by us. There is effect on all vegetations, materials/monuments, animals and humans. The harmful effects on human is very difficult to measure and thus requires epidemiological data for the same. As air pollution affects all age groups, including fetus and most of the human body systems with both acute and chronic effects. Adverse Health effects due to air pollution have an important economic impact and also societal impact due to absences from productive work and school. A joint collaboration of authorities, national and international organizations and doctors will help to regularize the situation. Governments should spread awareness and educate people and should involve professionals so as to control the emergence of the problem.

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