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Major Ambient Air Pollutants and Toxicity Exposure on Human Health and Their Respiratory System: A Review

Gourav Kumar SINGH
Department of Environment Science, Amity University, India
gouravsingh1993ab@gmail.com

Swapnil RAI
Department of Environment Science, Amity University, India
ssrai31@gmail.com

Nimisha JADON
School of Studies in Environmental Chemistry, Jiwaji University, India
drnimishajadon@gmail.com

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Abstract:

Indoor and outdoor air pollution is causing environmental and health issues globally. It is more challenging mainly in developing countries like India, china, and others. According to recent World Health Organization (WHO) reports, nearly 4.2 million people die prematurely because of AAP (Ambient Air Pollution). Air pollution is made up of a variety of contaminants, including gases, liquids, heavy metals in the air, and particulate matter. Suspended particulate matter (SPM), surface ozone (O_3), sulfur dioxide (SO_2), nitrogen oxides (NO_2), and other contaminants have become major environmental threats to plant health. These pollutants also have an effect on human health because they affect the consistency of the air we breathe. They usually cause inflammation in the upper respiratory tract, resulting in cough and shortness of breath. These are also significant contributors to the exacerbation of current respiratory conditions like asthma and chronic obstructive pulmonary disease. Epidemiological, toxicological, and clinical research all support the connection between air pollution and increased incidence and severity of respiratory and cardiovascular diseases. This pollution is a major public health problem in the locations where maximum pollution sources exist. To improve air quality and reduce the adverse effects of airborne toxicity due to AAP on human health, significant approaches are needed. The main objective of this review article is to provide evidence on the adverse effects of AAP on human health, as well as to make recommendations to policymakers on how to minimize exposure to this risk factor. Only public awareness combined with a multidisciplinary approach by scientific specialists will be able to handle this problem; national and international organizations must address the rise of this threat and suggest long-term remedies.

Keywords: AAP; WHO; PM; O_3; SO_2; NO_2; epidemiological; toxicological.

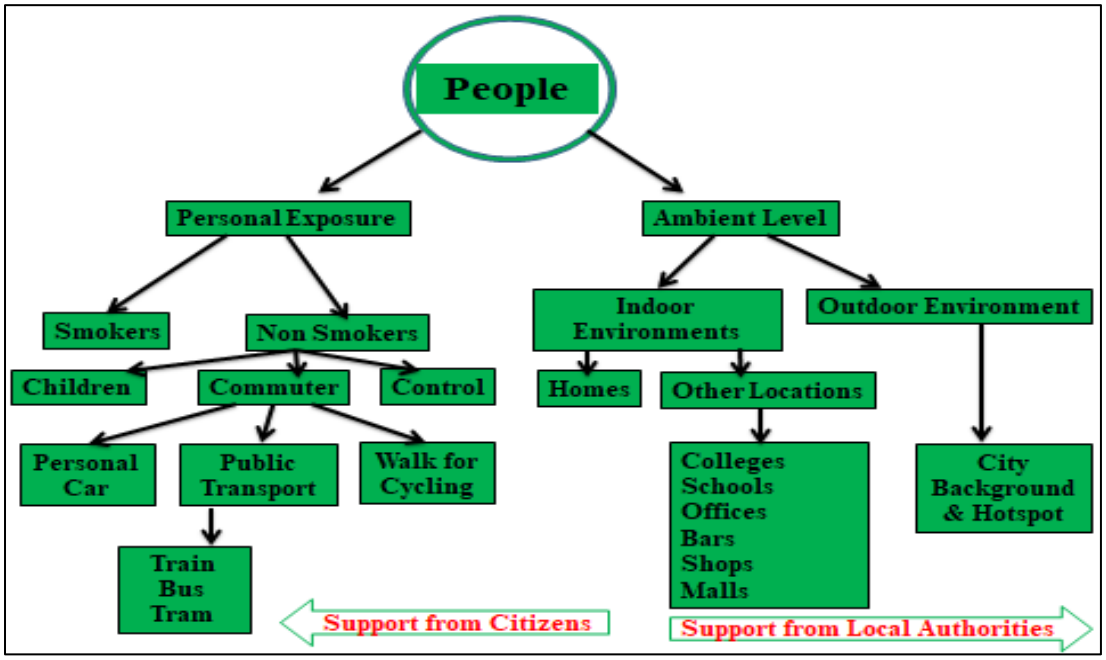
JEL Classification: Q53; Q52; I12.

Introduction

Air pollution has been a significant environmental threat, posing a threat to all forms of life. Natural factors such as volcanic eruptions, forest fires, wind erosion, and pollen dispersal, among others, contribute to ambient air emissions

(Vallero, 2008). Different emission factors lead to air emissions as a result of human activity, but vehicle engines and manufacturing activities account for the majority. There is clear proof that large air contaminants such as particulate matter (PM), ozone (O_3), nitrogen dioxide (NO_2), and sulfur dioxide (SO_2) cause significant damage. The amount of air pollution in India has reached an all-time peak. India is one of the most polluted countries in the world. Kanpur, Varanasi, Lucknow, and Agra are among the top twelve most polluted cities in the country, with Kanpur, Varanasi, and Lucknow belonging to Uttar Pradesh. Kanpur is at the top of the list, with an annual average of 319 g/ m3 of PM_{10} (WHO, 2018). The main environmental risk factors in the occurrence and development of many diseases in humans are air pollutants. The risk of stroke, coronary disease, lung cancer, and chronic and acute respiratory conditions such as chronic obstructive pulmonary disease and asthma is rising in the human population as air quality declines. Every year, air pollution kills millions of people around the world. Approximately 91% of the world's population resides in areas where air pollution levels meet WHO guidelines. In the year 2016, AAP was responsible for 7.6% of all deaths, with a reported 4.2 million deaths annually attributed to untreated respiratory illnesses, lung cancer, stroke, and heart disease (WHO, 2018).

Figure 1. People and Air Pollution relations



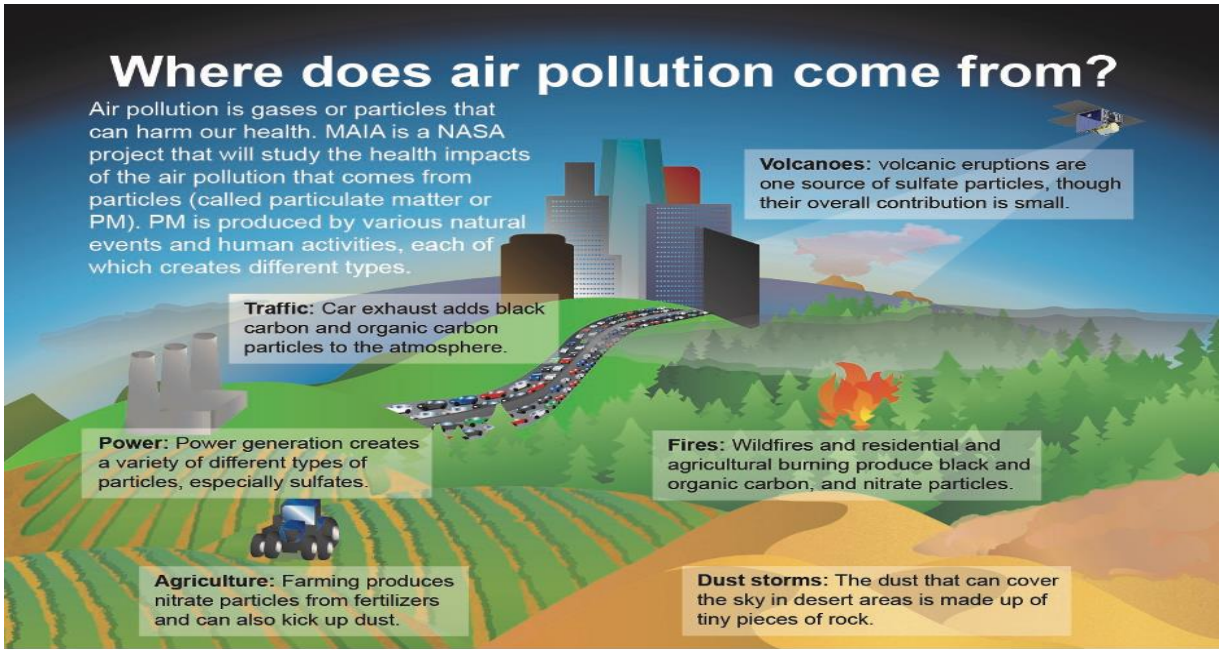
Source: https://nptel.ac.in/course.html

Global warming is due to emission of greenhouse gases and temperature inversions are additional impacts of air pollution (Ghorani-Azam *et al*. 2016).

1. Major Air Pollutants and Their Sources:

The main air pollutants are particulate matter (PM), surface O_3, SO_2, NO_2, carbon monoxide (CO), and lead (Pb) (US EPA, 2014). The complex combination of solid and liquid particles trapped in the air is referred to as PM. They can develop either spontaneously or as a result of human actions. PM is naturally produced by forest fires, suspended dusts in the air, and pollens, while anthropogenic PM is produced by the burning of fossil fuels in automobiles and coal-fired power plants. Pollutants and their sources also vary place to place because of some physical, chemical and biological parameters. Daily mortality and hospital admissions have been linked in the literature to different gaseous pollutant concentrations in metropolitan areas, such as O_3, SO_2, NO_2, and CO (Yang *et al.* 2003).

Figure 2. Major sources of Air Pollution



Source: https://climate.nasa.gov/news/3027/getting-to-the-heart-of-the-particulate-matter/

The combustion of fossil fuels in the transportation sector, as well as other urban sources such as waste burning, contributes to urban air pollution, which includes both gases and particulates (Dandotiya, Jadon, and Sharma 2018). There are various sources through which the Air Pollutants reach in the atmosphere and it also mixed with other chemicals and becomes toxic for human and animals. They are described as ultrafine, fine, coarse and super-coarse depending on their aerodynamic particle diameter ranging from 0.1 µm to >10 µm. Construction sites, road dust, etc. leads to the formation of coarse particles whereas burning of fossil fuel and automobile emissions are responsible for the formation of fine particles. Particles which have aerodynamic diameter 10 µm are known as PM_{10} and are inhalable while the particles having aerodynamic diameter 2.5 µm are called $PM_{2.5}$. $PM_{2.5}$ is very small and easily cross into the pulmonary and circulatory system (Ghorani-Azam *et al*. 2016; US EPA 2016c; Laumbach and Kipen 2012; Nelin *et al*. 2012).

Figure 3. Comparison of India's NAAQS, WHO and USEPA

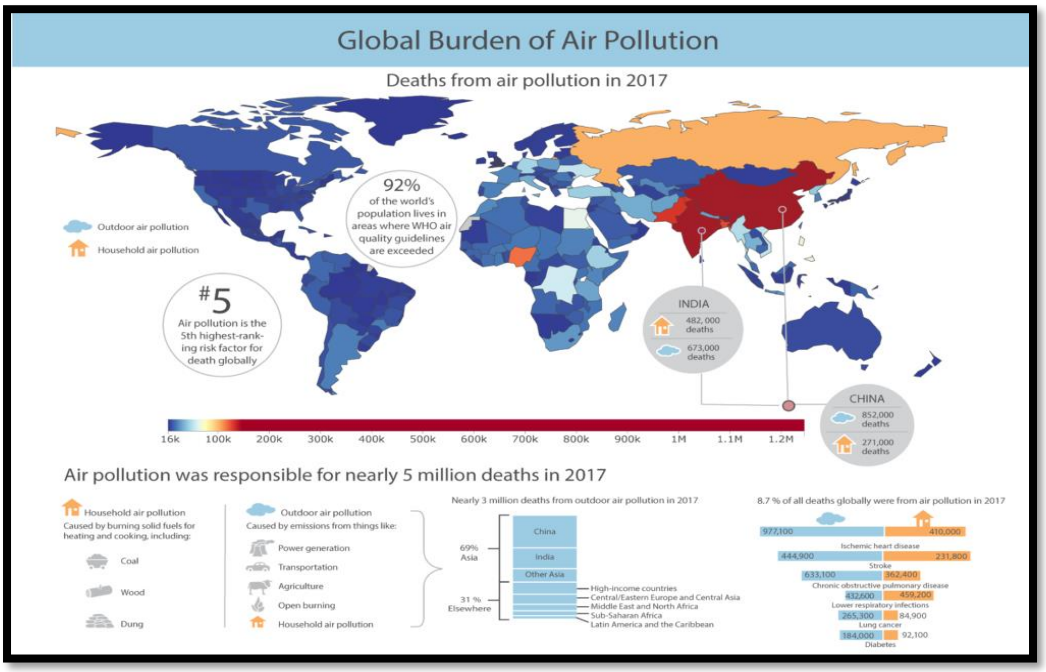
Air Pollutant	Time-weighted Average	India (µg/m³)[a,b]			WHO[c] (µg/m³)	US EPA July 1997 (µg/m³)
		Industrial	Residential	Sensitive		
NO_2	Annual	80.00	60.00	15.00	40.00	100.00
	24 hours	120.00	80.00	30.00		
SO_2	Annual	80.00	60.00	15.00	50.00	80.00
	24 hours	120.00	80.00	30.00	20.00	365.00
CO	8 hours	5,000.00	2,000.00	1,000.00	10,000.00 (d)	10,000.00
	1 hour	10,000.00	4,000.00	2,000.00	30,000.00 (d)	40,000.00
Pb	Annual	1.00	0.75	0.50	0.50 (d)	1.50
	24 hours	1.50	1.00	0.75		
PM_{10}	Annual	120.00	60.00	50.00	20.00	
	24 hours	150.00	100.00	75.00	50.00	150.00
SPM	Annual	360.00	140.00	70.00		
	24 hours	500.00	200.00	100.00		
NH_3	Annual		100.00			
			400.00			

CO = Carbon monoxide; NAAQS = national ambient air quality standard; NH_3 = ammonia; NO_2 = Nitrogen dioxide; Pb = lead; PM_{10} = particulate matter with diameter less than 10 micrograms; SO_2 = Sulfur dioxide; SPM = suspended particulate matter; US EPA = United States Environmental Protection Agency; WHO = World Health Organization; and ug/m³ = micrograms per cubic meter
[a] Annual average of minimum of 104 measurements in a year, taken twice a week, 24-hourly uniform intervals.
[b] 4-hourly/8-hourly values should be met 98% of the time in a year, it could exceed 2% of the time but not on 2 consecutive days.
[c] WHO 2006.
[d] WHO 2000.
Source: WHO (2006), WHO (2000), US EPA.

Source: https://nptel.ac.in/course.html

O_3 is a colorless gas that exists in two layers on the surface of the earth. It acts as a pollutant near the earth's surface at 0-10 km (troposphere) and is known as bad ozone; it is a major component of smog. In the upper atmosphere at 10-40 Km from earth surface (stratosphere) it functions as a protective layer and is called as good ozone, which filters out the harmful ultraviolet rays coming from the sun. In the troposphere, the formation of Ozone (O_3) takes place because of combination of NO2 (Nitrogen dioxide) and VOCs (Volatile Organic Compounds) in the presence of Sun light. The combustion of fossil fuels produces NOX, whereas VOC is created by both natural and anthropogenic reactions (US EPA 2016c; Cacciottolo 2013; Sierra-Vargas and Teran 2012; Harmens *et al.* 2011).

Figure 4. Global Burden of Air Pollution & Deaths from Air Pollution



Source: https://cleantechnica.com/files/2019/05/air-pollution-deaths.png

The NO_2 is a reddish brown color gas. It is a traffic-related air pollutant that is released mostly by vehicle engines and power plants as a result of the combustion of fossil fuel gas. When nitrogen in the air interacts with oxygen, it produces this substance. SO_2 is a highly reactive colorless gas formed by volcanic eruptions and coal combustion in locomotives or coal-fired power plants. CO is a colorless, odorless gas that results from incomplete carbon combustion. In limited supply of air, when hydrocarbon fuels such as natural gas, petrol, diesel etc. are burned, only half as much oxygen combines with the carbon atom, CO is formed (US EPA 2016d, 2016b; Thompson 2005).

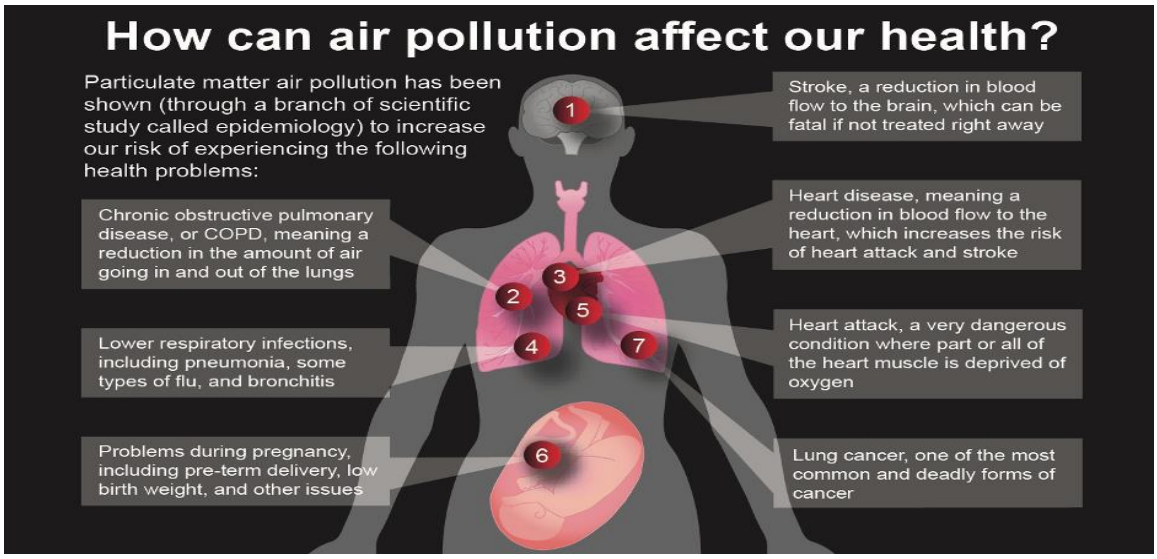
Pb emissions vary from one location to the next. Ore and metals recycling plants, lead smelters, lead-acid battery production plants, waste incinerators, and cars running on leaded fuel are also major sources of lead in the air. Tetra-ethyl lead (TEL), an organo-lead compound, was first used as a petro-fuel additive in the early 1920s to reduce knocking and improve the performance of petrol (gasoline) engines, which generate Pb emissions in the air after exhaust combustion. Due to EPA's (US Environmental Protection Agency) regulatory guidelines, between 1980 and 2014 levels of Pb in the air decreased by 98 percent due to the elimination of TEL from motor vehicle fuel (US EPA 2016d).

2. Health Hazards of Air Pollutants on Human Life

- Air pollution has been related to several human health issues, including lung, respiratory, cardiovascular, and neurological issues.
- The health repercussions vary a lot from one person to the next. The elderly, babies, pregnant women, and persons with chronic heart and lung ailments are among those who are particularly vulnerable to air pollution.
- Children are at higher risk since they are more active outside, and their lungs are still developing.

- Exposure to air pollution can have both acute (short-term) and chronic (long-term) health effects.
- When a person is exposed to a pollutant for a short period of time, the acute effects are usually immediate and often reversible. Some of the most serious adverse effects include eye irritation, headaches, and nausea.
- Chronic impacts are typically delayed and irreversible until the contaminant has been removed from the environment. Long-term exposure to severe air pollution has a variety of long-term health implications, including a reduction in lung capacity and the development of lung cancer.

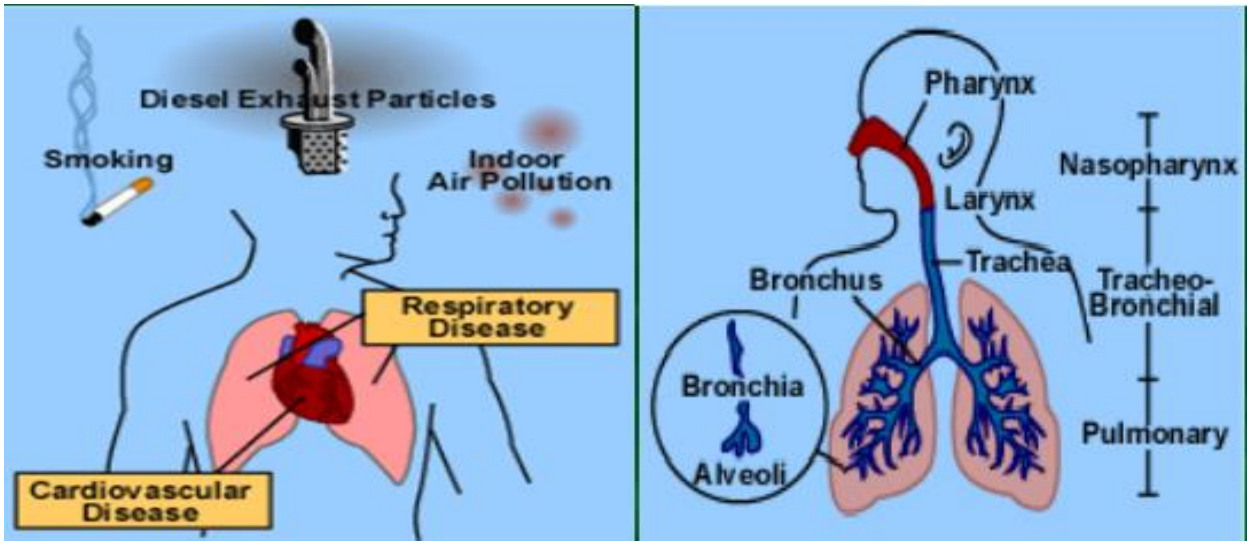
Figure 5. Air Pollution which affects the many organs of human body in different ways



Source: NASA/JPL-Caltech

Children's respiratory systems are more vulnerable to short-term exposure to air pollution in metropolitan areas than adults' (Dandotiya B, 2019), because their lungs are less developed at birth and do not become fully functional until they are roughly 6–8 years old (Burri 1984). Emissions of air pollutants from sources such as coal, oil, gas, wood, waste, or vegetation play a significant impact in child exposure (Smith 1987; Lee 2010). Many research have been undertaken to show the short-term health impacts of air pollution exposure and the link between gaseous pollutant levels and health outcomes (Samoli *et al.* 2008; 2013; Stafoggia *et al.* 2013; WHO 2013; Sharma, Dandotiya and Jadon 2017).

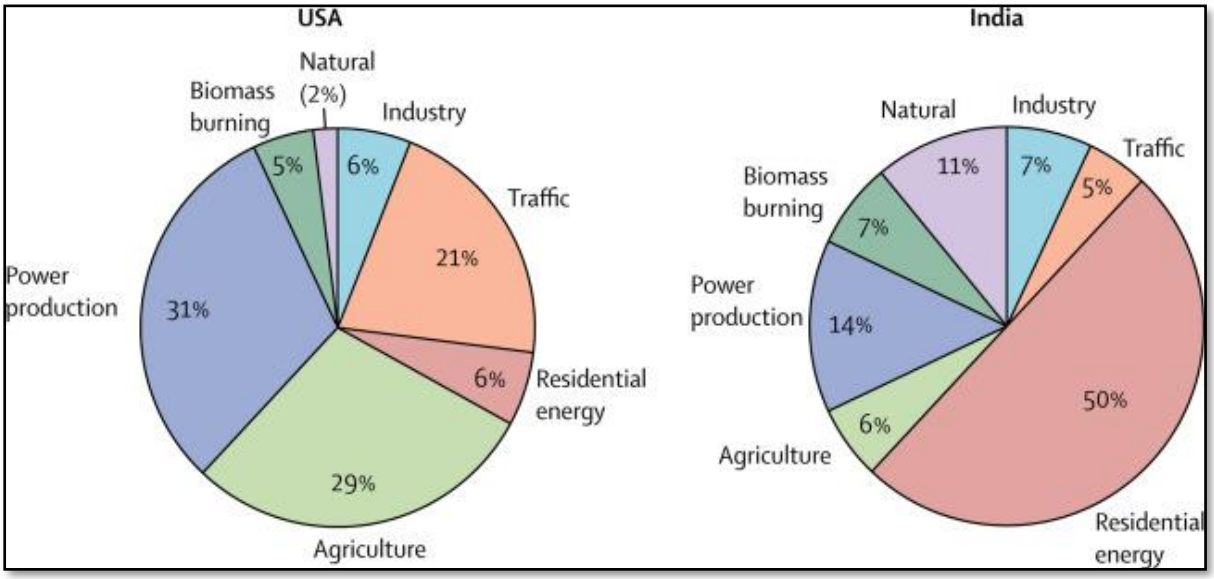
Figure 6. Various Airborne disease associate with Lungs and Heart



Source: https://nptel.ac.in/course.html

The lungs, on the other hand, are critical to the body's overall health, not just for gas exchange. The lungs also regulate the percentage of hydrogen ions in the blood (or pH). The ability of the lungs to filter tiny blood clots from the bloodstream is also critical. The spongy nature of the lungs also acts as a cushion for the heart. Because they execute so many crucial life-sustaining tasks, the lungs are one of the most important organs. Every cell in our bodies is affected by lung health. That is why indoor and outdoor air pollution, such as smog, may have such a broad and harmful influence on the entire body, particularly on newborns and children, the elderly, and people who are already unwell.

Figure 7. Main Sectors contributing Air Pollution in USA & India



Source: Lelieveld *et al.* 2018, with permission from The Lancet Planetary Health.

Sources, Health and Welfare Effects for Criteria Air Pollutants				
Pollutant	**Description**	**Sources**	**Health Effects**	**Welfare Effects**
Sulfur Dioxide (SO2)	Colorless gas that dissolves in water vapor to form acid, and interact with other gases and particles in the air.	Coal-fired power plants, petroleum refineries, manufacture of sulfuric acid and smelting of ores containing sulfur.	Eye irritation, wheezing, chest tightness, shortness of breath, lung damage.	Contribute to the formation of acid rain, visibility impairment, plant and water damage, aesthetic damage.
Nitrogen Dioxide (NO2)	Reddish brown, highly reactive gas.	Motor vehicles, electric utilities, and other industrial, commercial, and residential sources that burn fuels.	Susceptibility to respiratory infections, irritation of the lung and respiratory symptoms (e.g., cough, chest pain, difficulty breathing).	Contribute to the formation of smog, acid rain, water quality deterioration, global warming, and visibility impairment.
Ozone (O3)	Gaseous pollutant when it is formed in the troposphere.	Vehicle exhaust and certain other fumes. Formed from other air pollutants in the presence of sunlight.	Eye and throat irritation, coughing, respiratory tract problems, asthma, lung damage.	Plant and ecosystem damage.
Lead (Pb)	Metallic element	Metal refineries, lead smelters, battery manufacturers, iron and steel producers.	Anemia, high blood pressure, brain and kidney damage, neurological disorders, cancer, lowered IQ.	Affects animals and plants, affects aquatic ecosystems.
Particulate Matter (PM)	Very small particles of soot, dust, or other matter, including tiny droplets of liquids.	Diesel engines, power plants, industries, windblown dust, wood stoves.	Eye irritation, asthma, bronchitis, lung damage, cancer, heavy metal poisoning, cardiovascular effects.	Visibility impairment, atmospheric deposition, aesthetic damage.

Source: https://nptel.ac.in/course.html

Sources of air pollution-related mortality: The percentages represent the proportions of deaths caused by ambient air pollution. In 2015, excess deaths due to air pollution were reported to be 120,000 in the United States (95 percent confidence interval 81,000–156,000) and 967,000 in India (753,000–1,150,000). Natural sources of air pollution, primarily Aeolian dust, are referred to as "natural."

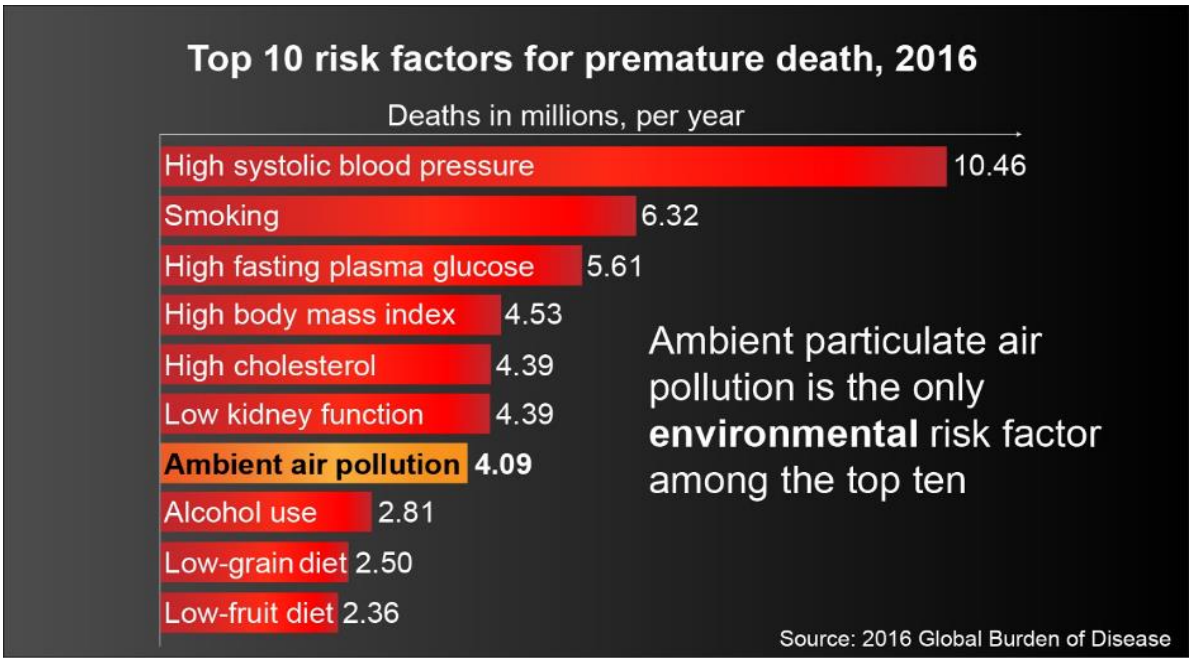
3. Effects of AAPs on Human Respiratory System:

- Continuous breathing of polluted/toxic air slows the lungs natural cleaning process, allowing more pollutants to reach the lower lungs.
- All gaseous and particulate air pollutants have the potential to damage our lungs.
- Solid particles may collect on the trachea, bronchi, and bronchioles' walls.

Air pollutants damage the lungs, slowing down this pathway and increasing the risk of respiratory illnesses like bronchitis, emphysema, and cancer.

The PMs are small enough to penetrate the capillaries present in lungs and enter into the blood circulation causing serious lungs and heart diseases (US EPA 2016a; Cacciottolo 2013; Sierra-Vargas and Teran 2012). Adverse effects of PM are determined by their size and composition, exposure time, age, gender, and the susceptibility of the individual who is exposed. Exposed person to these PM show most prevalent clinical symptoms of burning eyes, dry mouth, sore throat, persistent cough, wheezing, chest tightness and limited physical activities due to breathing problems (Bentayeb *et al*. 2013). PM has been linked to asthma and premature death in aged people with chronic obstructive pulmonary disease (COPD) and tuberculosis (TB) (Ostro et al., 2011; Künzli and Tager 2005). Increased physical exercise contributes to inhalation of more PM-containing air in the lungs, putting outdoor active people at greater risk (Carlisle and Sharp 2001).

Figure 8. Risk factors for premature deaths according to GBD 2016 Report

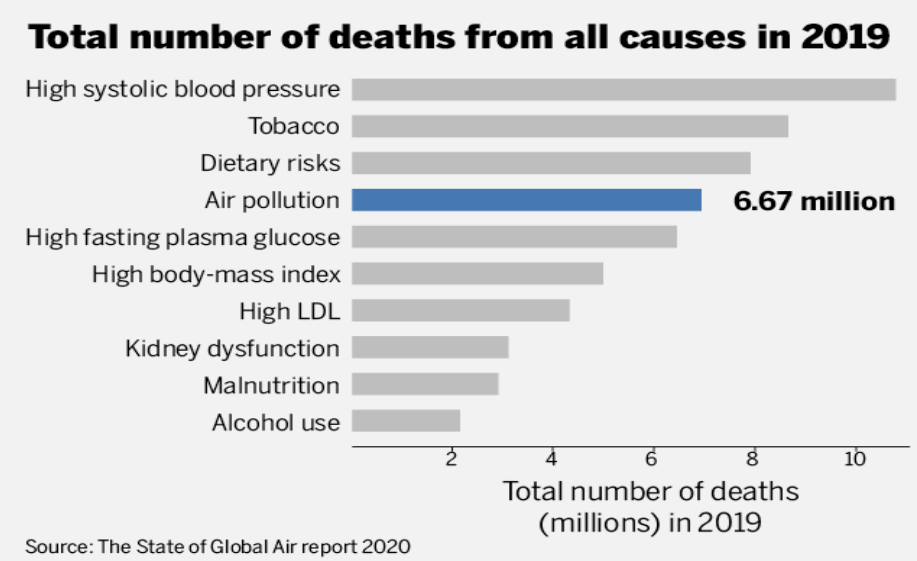


Source: GBD (Global Burden of Disease 2016)

For a long time, scientists have suspected that the air we breathe could be harmful to our health. According to WHO more than 90% of the world's population breathes air that contains hazardous levels of pollution. Particulate matter (PM) in the air is particularly hazardous. According to a recent international health survey called the Global Burden of Disease, breathing these small, airborne solid or liquid particles of organic and inorganic matter, also known as aerosols, causes more than 4 million premature deaths per year due to cardiovascular, respiratory, and other diseases (GBD).

As per the report published by State of Global Air Report 6.7 million people killed worldwide and 1.67 Million in India in 2019 by air pollution only. Long-term exposure to air pollution caused around 6.7 million deaths worldwide in 2019 from stroke, heart attack, diabetes, lung cancer, chronic lung diseases, and neonatal diseases, according to the annual 'State of Global Air 2020' report, with China (1.8 million) and India (1.6 million) accounting for more than half of these deaths.

Figure 9. Total number of deaths from all causes in 2019



Air pollution became 4th largest cause of death among all health risk Air pollution became 4th largest cause of death among all health risk, according to the Health Effects Institute (HEI), an independent, non-profit research institute funded jointly by the USEPA (Environmental Protection Agency), industry, foundations, and development banks. It ranks just behind high blood pressure, tobacco use, and poor diet (timesofindia).

Troposphere O_3 causes a number of health hazards. It is a powerful oxidizing agent. Along with irritation of the respiratory tract it also reduces lung function and is responsible for frequent asthma attacks, cough and breathing problems in asthmatic people. More physical exercise, increase the effect of O_3 exposure. Amâncio and Nascimento (2012) found that patients with respiratory conditions are more vulnerable to the effects of O_3. In hot weather, O_3 exposure can exacerbate asthma symptoms and even cause premature death from oxidation of air pollutants. Pollutants on the roadside can cause pollen to release allergens and increase the concentration of pollen allergens in the air (Gorai *et al.* 2014). Increased levels of O_3 and PM in hot weather lead to a greater incidence of respiratory allergic reactions. Fatty acids in cell membranes have fragile double bonds. O_3 has strong oxidizing nature. It combines with these bonds and converts them in to lipo-hydro peroxides, aldehydes and hydrogen peroxide which change the membrane integrity. It also damages the DNA and results into impaired cellular function (McCarthy *et al.* 2013; Lippmann 1989).

NO_2 may irritate deep in lung and induce pulmonary edema. Epidemiologic studies demonstrate the effects in the form of eyes, nose, throat irritations, headache, dyspnea, chest pain, bronchospasm and pulmonary edema at higher concentration. A high level of NO_2 exposure causes coughs and breathing difficulty by inducing more mucus secretion. Long time exposure of NO_2 is associated with a higher chance of getting respiratory infections (Kim *et al.* 2018; Ghorani-Azam *et al.* 2016).

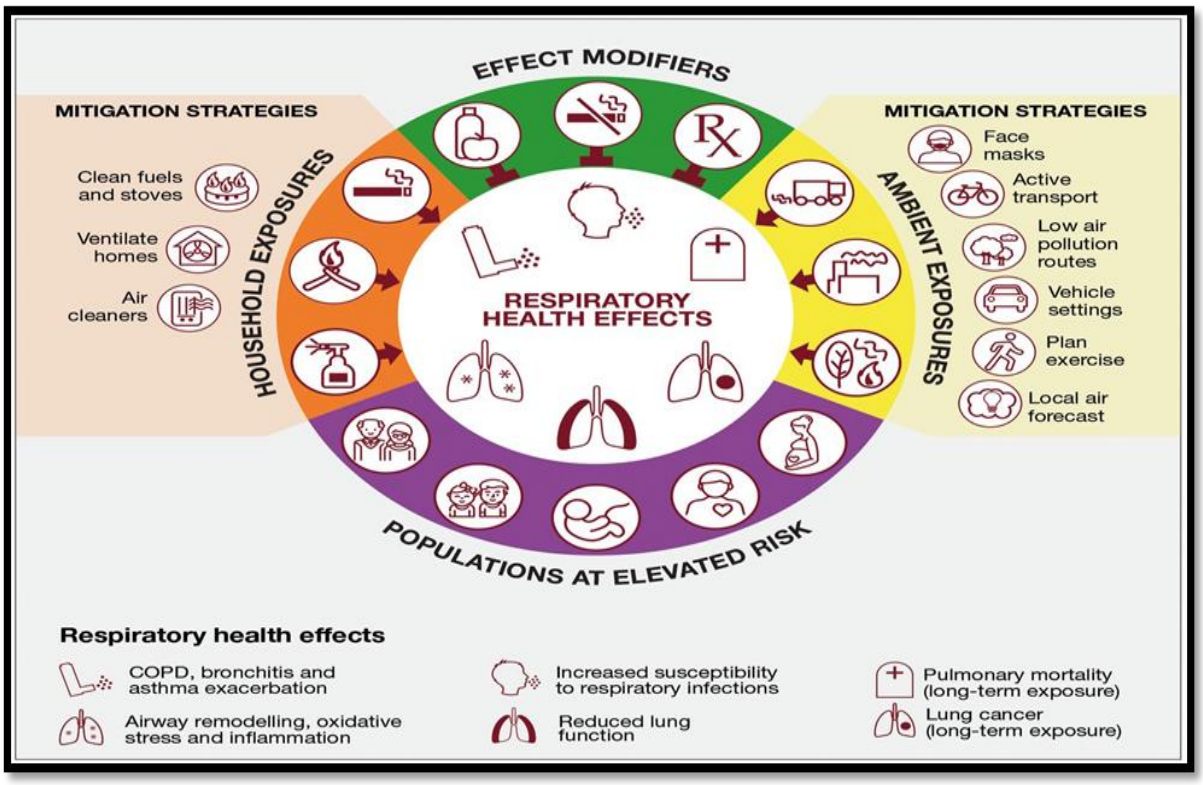
Presence of SO_2 in air affects those people who already have asthma or emphysema. It makes them more difficult to breathe. It also causes irritation in eyes, nose and throats. SO_2 destroys our vegetation and buildings, and make difficult to see long distance objects. A high level of SO_2 aggravates the existing cardiovascular disease. During mouth breathing, SO_2 is inhaled more deeply into the lungs than during normal nasal breathing. After deposition of SO_2 on surface lining of airways, it dissolves into sulfite or bi-sulfite and which get distributed throughout the body. In the form of sulfite or bi-sulfite it activates sensory receptors of airways and causes constriction of bronchi. SO_2 is readily soluble in water which results into acid rain formation and soil acidification. The presence of SO_2 in water lowers the amount of dissolved oxygen in the water, resulting in marine life death. SO_2 exposure also causes redness and blisters on skin (Chen *et al*. 2007; Dodge *et al*. 1985).

Breathing in an enclosed environment with increased level of CO, decreases the amount of O_2 in blood. Low oxygenated blood enters to the brain and heart, causing dizziness, anxiety, unconsciousness, and death. A very high level of CO is unlikely to occur in an open area. But under intensive physical activity or increased stress, CO may result in low supply of O_2 to heart which is accompanied by chest pain or angina (Ghorani-Azam *et al*. 2016; US EPA 2016e).

Pb is absorbed into the body by the inhalation of Pb particles produced by the burning of Pb-containing materials. It is spread to the brain, kidneys, liver, and bones after entering the body. Pb is preserved and collected

in the teeth and bones over time. During pregnancy, it is remobilized from bone into the blood and enters the fetus. In comparison to adults, undernourished children consume more Pb and are 4-5 times more vulnerable to Pb poisoning. Pb increases the risk of high blood pressure and kidney failure in adults. High concentrations of Pb in pregnant women can lead to miscarriage, premature delivery, low birth weight, and stillbirth. In children, high level of Pb affects brain development resulting in low intelligence quotient (IQ) and mental retardation which are believed to be irreversible (Ghorani-Azam *et al*. 2016; US EPA 2016d, WHO lead poisoning and health 2018).

Figure 10. Important factors in reducing air pollution exposure and safeguarding respiratory health



Source: https://erj.ersjournals.com/content/55/6/1902056

The Global Initiative for Asthma Guidelines 2019, based on the evidence, grade, and overall strength of evidence, recommended interventions to essential supporting evidence. The Pradhan Mantri Ujjwala Yojana Home (PUMYH-LPG) program's success, according to the government, helped to "dramatically boost access to clean energy, particularly for rural houses," as well as minimize "household air pollution exposure". Air pollution became 4th largest cause of death among all health risk (timesofindia). People who are exposed to excessive levels of air pollution develop disease symptoms and states of varying severity. These health impacts are divided into two categories: short-term and long-term (Manisalidis *et al.* 2020).

Conclusion & Recommendation

Air pollution has a major effect on human health, triggering and causing a variety of diseases with high morbidity and mortality rates, especially in developing countries such as India. Air pollution is a global environmental problem. The impact of major air pollutants on human health is explored in this review article. Children and healthy adults who are exposed to air pollution are more likely to develop asthma, respiratory illnesses, COPD, and cardiovascular diseases. Air pollutants cause premature mortality in the elderly and those with pre-existing respiratory or cardiovascular conditions. Owing to the inhalation of air pollution into their lungs, outdoor active people are at a higher danger. As a result, action to reduce pollution in the ambient air is critical, especially in the country like India having low and middle-income. The government's highest priority should be to monitor and decrease the emission of air pollution. Both air-related laws and regulations must be updated by policymakers and lawmakers in these countries. Both laws and regulations relating to air pollution must be updated by policymakers and lawmakers in these countries. A strong environmental protection agency must lead the coordination between various departments involved in air pollution. For an efficient environmental protection agency, budgets for administration, research, development, surveillance, and complete cooperation should be

appropriate. An effective environmental protection agency should have enough resources to maintain research, produce, oversee, and regulate the entire atmosphere, including air pollution control. Proper urban development, as well as the implementation of environmentally efficient cars that contain relatively less hazardous emissions, should be prioritized. A few effective approaches for mitigating air emissions include the introduction and application of new environmental regulations.

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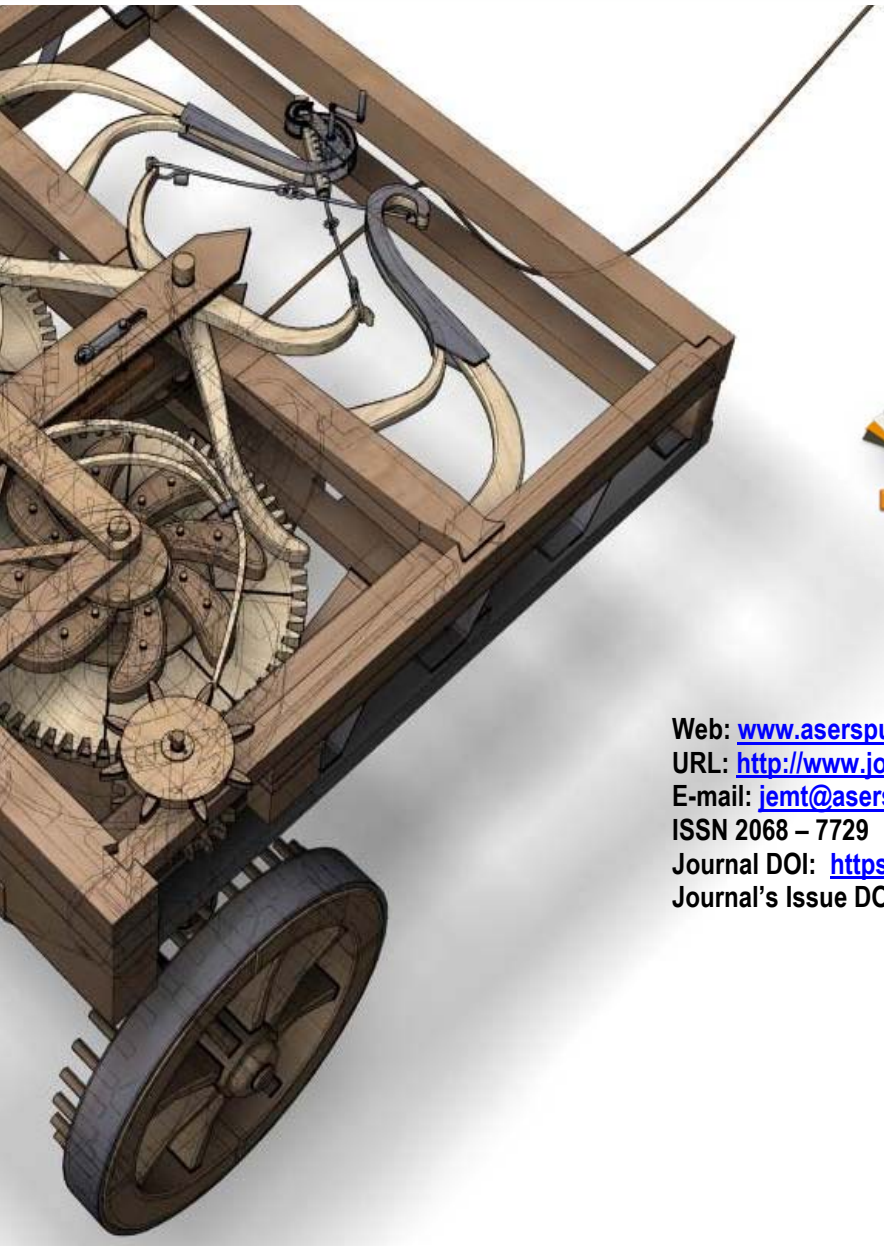

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