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Chapter 10

Air pollution in India, its sources, and their human health effects

Contaminación del aire en India, fuentes y sus efectos en la salud humana

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ABSTRACT

The problem of air pollution in India is a matter of great concern to the people living here, which is creating problems for humans and the environment. There are many different emission sources of air pollution, primarily motorcycles, vehicle/transportation emissions, domestic sectors, construction, demolition waste, industrial, agriculture, power plants, waste treatment, and biomass burning, all of which emit pollution. Makes a major contribution. According to the World Health Organization, some pollutants are more polluting the air including ozone, nitrogen oxides, carbon monoxide, volatile organic compounds, lead, dioxins, polycyclic aromatic hydrocarbons, particulates, and sulfur oxides. Exposure to air pollution causes respiratory problems, heart disease, skin diseases, eye irritation, neuropsychiatric, cancer, asthma, lung, fetal disorders, respiratory and mucous irritation, etc. Its impact on human health is mainly due to prolonged stay in air polluted places. According to research papers. In this review article, we have discussed the major sources of air pollution, toxicology, and their impact on human health.

Keywords: Air pollution, sources, human health effect and India.

RESUMEN

El problema de la contaminación del aire en la India es motivo de gran preocupación para las personas que viven aquí, lo que está creando problemas para los humanos y el medio ambiente. Hay muchas fuentes diferentes de emisión de contaminación del aire, principalmente motocicletas, emisiones de vehículos/transporte, sectores domésticos, construcción, residuos de demolición, industria, agricultura, centrales eléctricas, tratamiento de residuos y quema de biomasa, todos los cuales emiten contaminación. hace una gran contribución. Según la Organización Mundial de la Salud, algunos contaminantes contaminan más el aire, incluidos el ozono, los óxidos de nitrógeno, el monóxido de carbono, los compuestos orgánicos volátiles, el plomo, las dioxinas, los hidrocarburos aromáticos policíclicos, las partículas y los óxidos de azufre. La exposición a la contaminación del aire provoca problemas respiratorios, enfermedades cardíacas, enfermedades de la piel, irritación ocular, neuropsiquiátricas, cáncer, asma, trastornos pulmonares, fetales,

irritación respiratoria y de las mucosas, etc. Su impacto en la salud humana se debe principalmente a la permanencia prolongada en lugares con aire contaminado. , Según trabajos de investigación. En este artículo de revisión, hemos discutido las principales fuentes de contaminación del aire, la toxicología y su impacto en la salud humana.
Palabras clave: contaminación del aire, fuentes, impacto en la salud humana e India.

INTRODUCTION

Air pollution is a major problem in recent decades, which has a serious toxicological impact on human health and the environment. The sources of pollution vary from small units of cigarettes and natural sources such as volcanic activities to the large volume of emissions from motor engines of automobiles and industrial activities (Ghorani-Azam, A., et al., 2016, & Habre, R., et al., 2014). air pollution is linked with millions of death globally each year (Biggeri, A., et al., 2004, Vermaelen, K., & Brusselle, G. 2013, & Kan, H., et al., 2010). A recent study has revealed the association between male infertility and air pollution (Zhou, N., et al., 2014). Air pollution has now emerged in developing countries as a result of industrial activities and has also increased the number of emission sources such as inappropriate vehicles (Chen, B., & Kan, H. 2008, Molina, M. J., & Molina, L. T. 2004, & Chi, C. C. 1994). About 4.3 million people die from household air pollution and 3.7 million from ambient air pollution, most of whom (3.3 and 2.6 million, respectively) live in Asia (Air pollution, 2016). Air pollution is the introduction into the atmosphere of chemicals, particles, or biological matter that cause discomfort, disease, or death in humans, harm other living organisms such as food crops or harm the natural environment or the environment. The atmosphere is a complex dynamic system of natural gas essential to life on planet Earth. Stratospheric ozone depletion due to air pollution has long been recognized as a threat to human health and the Earth's ecosystems. Indoor air pollution and urban air quality are listed as two of the world's worst toxic pollution problems in the Blacksmith Institute's 2008 report "World's Worst Polluted Places" (Sharma, S. B., et al., 2013). The combustion of gasoline and other hydrocarbons in cars, trucks, and jet planes produces several primary pollutants: oxides of nitrogen, gaseous hydrocarbons, and carbon monoxide, as well as large amounts of particulate matter, primarily lead . In the presence of sunlight, oxides of nitrogen combine with hydrocarbons to form a secondary class of pollutants, the photochemical oxidants, including ozone and the eye irritant peroxyacetyl nitrate (PAN) (Sharma, S.B., et al., 2013). Air pollution and climate change are major threats to fast-growing cities today. Developing countries like India, changing from a predominantly rural to an increasingly urban country, face critical challenges in terms of climate protection and sustainable development (Van Duijne, R. J. 2017 and Singh, C., et al., 2021). India is projected to have 53% of the national population as the urban population with the addition of 416 million urban dwellers by the year 2050 (UNDESA, 2018). The change in land uses land cover patterns in urban areas due to ongoing urbanization affects regional climate by altering the surface and boundary layer atmospheric properties (Shepherd, J. M. 2005, Ren, G., et al., 2008, & Yang, B., et al., 2012). Further, urbanization by changing land use land cover affects climate via increased anthropogenic emissions, extreme precipitation (that may cause urban flooding), higher temperatures, and frequent heat waves with heat-related human health impacts (Chestnut, L. G., et al., 1998, Ramanathan, V. C., et al., 2001, & Shastri, H., et al., 2015). Regional climate changes are reflected in different weather conditions such as changes in temperature and precipitation. Anthropogenic emissions such as greenhouse gas (GHG) emissions trigger these local climate changes. In addition to the effects of urbanization on the climate, the increase in urban population and vehicular traffic increases pollutant emissions and aerosol pollution in the atmosphere. Increasing urbanization along with population growth and industrialization are cited as one of the main reasons for high aerosol pollution in the Indian subcontinent (Kaskaoutis, D.G., et al., 2011, Ramachandran, S., et al., 2012, & Krishna Moorthy, K., et al., 2013). Climate change and air pollution, therefore, remain one of the greatest threats to human health and well-being in cities and are interrelated, as discussed later in this study. According to a report by the World Health Organization (WHO), more than seven million people worldwide lose their lives due to diseases related to PM2.5 pollution (WHO 2015). India, a rapidly developing country with a growing population, suffers from severe air pollution; among the 10 most polluted cities in the world, nine are in India (WHO 2016). The increase in air pollution in most of India's megacities in recent decades and the resulting impact on human health (such as asthma and cardiovascular disease) has attracted a lot of attention in recent years (Guttikunda, SK, et al., 2014, Gautam, s. 2020, Gautam, S., et al., 2020 & Shaw, N., & Gorai, A. K. 2020).

Figure: 1 Foggy future: According to the report, 100% of the population in India lives in areas where PM2.5 levels are higher than the WHO guideline | Photo: Huffington Post

Source: https://carboncopy.info/india-air-pollution-worst-exposure-state-of-global-air-report-2020

POLLUTANTS

An air pollutant is a substance in the air that can be harmful to humans and the environment. Pollutants can be in the form of solid particles, liquid droplets, or gases. Also, they can be natural or man-made. Pollutants can be classified as primary or secondary. Primary pollutants are usually emitted directly from a process, such as ash from a volcanic eruption, carbon monoxide from motor vehicle exhaust, or sulfur dioxide released by factories. Secondary pollutants are not emitted directly. Instead, they form in the air when primary pollutants react or interact. An important example of a secondary pollutant is troposphere ozone, one of the many secondary pollutants that make up photochemical smog. Some pollutants can be both primary and secondary: i.e. they are emitted directly as formed by other primary pollutants (Sharma, S. B., et al., 2013).

Sources on air pollution in India:

Although several studies have addressed the issue of air pollution and its effects on Indian urban cities, most of these studies are limited to specific cities and do not necessarily provide a complete picture of the situation (Pandey, A., & Venkataraman, C. 2014). The impact of emissions from different modes of transport in India. Their study concluded that road transport accounts for more than 97% of estimated emissions in India compared to other modes of transport such as railways, waterways, and airways (Gurjar, B. R., & Nagpure, A. S. 2016, & Gurjar, B. R., et al., 2016). Conducted an in-depth study on various sources of anthropogenic emissions in Indian megacities such as Delhi, Mumbai, and Kolkata (Upadhyay, A., et al., 2018).

Sources of air pollution

1. Vehicle/transport emissions:

The transport sector is the main contributor to air pollution in almost all cities, but this phenomenon is worse in urban cities (Gurjar, B. R., et al. 2004). This could be due to the increase in the number of vehicles compared to existing infrastructure, such as roads, petrol stations, and the number of passenger terminals for public transport. In India, the amount of motorized transport increased from 0.3 million in 1951 to 159.5 million in 2012 (Gurjar, B. R., et al., 2016, & Gurjar, B. R., Ravindra, K., & Nagpure, A. S. 2016). A significant percentage of vehicle emissions come from urban cities, such as Delhi, Mumbai, Bengaluru, and Calcutta. Carbon monoxide (CO), NOX, and NMVOC are the main pollutants (> 80%) of vehicle emissions (Gurjar, B. R., et al., 2004). Other trace emissions include methane (CH_4), carbon dioxide (CO_2), sulfur oxides (SO_x), and total particulate matter (TSP) (Gurjar, B. R 2021).

In an urban environment, road traffic emissions are a major cause of air pollution. Road dust is a major contributor to particulate matter emissions in Delhi (37%), Mumbai (30%), and Calcutta (61%). Road transport is the main source of $PM_{2.5}$ in Bengaluru (41%), Chennai (34%), Surat (42%), and Indore (47%) (Nagpure, A. S, et al., 2016). In the Indian context, some of the essential factors of high traffic emissions are the extreme lack of exhaust measures, the very heterogeneous nature of the vehicles, and poor fuel quality (Gurjar, B. R. 2021).

2. Industrial processes:

Over the past few decades, India has witnessed large-scale industrialization. As a result, air quality in most urban cities has deteriorated. The Central Pollution Control Board (CPCB) has classified polluting industries into

17 types, which fall into small and medium airways (Gurjar, B. R., & Nagpure, A. S. 2016, & Gurjar, B. R., et al., 2016). Of these categories, seven have been identified as "critical" industries, including steel, sugar, paper, cement, fertilizers, copper, and aluminum. The main pollutants include SPM, SOX, NOX, and CO2 emissions (Gurjar, B. R. 2021). Small industries, which are not as regulated as large industries, use several sources of energy in addition to the primary source of electricity provided by the state. Some of these fuels involve the use of biomass, plastics, and crude oil. These energy sources are neglected in current emissions inventory studies. In Delhi, after court intervention in 2000, many industries were relocated from urban areas to adjacent rural areas (Nagpure, A. S., et al., 2016). In Delhi, much of the pollution comes from the brick industry, located on the outskirts of the city. Rajkot (42%) and Pune (30%) are the two cities where industry plays a prominent role in contributing to the highest level of PM2.5 (Nagpure, A. S., et al., 2016).

3. Agriculture:

Agricultural activities cause emissions that can pollute the environment. Ammonia (NH3) and nitrous oxide (N2O) are the main pollutants released during agricultural activities. Other agricultural emissions include methane emissions from enteric fermentation processes, nitrogen excretions from animal manure, such as CH4, N2O, and NH3, methane emissions from wetlands, and nitrogen emissions from agricultural soils (N2O, NOX, and NH3) from the addition of fertilizers and other residues in the soil (Gurjar, B. R. et al., 2004). Agricultural processes such as slash-and-burn agriculture are major sources of photochemical smog created by the smoke generated during the process. The incineration of crop residues is another process that leads to emissions of toxic pollutants. The neighboring towns of Delhi contribute to agricultural pollution. This is an example of how external sources contribute to the threat of urban air pollution (Gurjar, B. R., & Nagpure, A. S. 2016 and Gurjar, B. R, et al., 2016).

4. Power plants:

The contribution of power plants to air emissions in India is immense and worrying. Thermal power plants produce approximately 74% of the total energy generated in India (Gurjar, B. R., & Nagpure, AS 2016, & Gurjar, B. R., et al., 2016). According to the Energy and Resources Institute (TERI), SO2, NOX, and particulate emissions increased more than 50 times between 1947 and 1997. Thermal power plants are the main sources of SO2 and TSP emissions (Gurjar, B. R., et al., 2004) and therefore contribute significantly to emission inventories. In Delhi, power plants contributed 68% of SO2 emissions and 80% of PM10 concentrations between 1990 and 2000 (Gurjar, B. R., et al., 2004). Therefore, there is an urgent need for alternative energy sources, including green and renewable resources, to meet energy demand (Gurjar, B. R. 2021).

5. Waste Treatment and Biomass Burning:

In India, around 80% of municipal solid waste (MSW) is still disposed of in landfills and open dumps resulting in various greenhouse gas emissions in addition to the issues of foul odors and poor water quality.

water in the neighboring localities. The lack of adequate treatment of household waste and the burning of biomass is responsible for air pollution in urban cities. In Delhi alone, about 5300 tons of PM10 and 7550 tons of PM2.5 are generated annually from the burning of garbage and other municipal wastes (Gurjar, B. R., & Nagpure, A.S. 2016, & Gurjar, B. R., et al., 2016).

Methane (CH4) is the main pollutant discharged from landfills and sewage treatment plants. Ammonia (NH3) is another by-product released during composting. The open burning of waste, including plastic, produces toxic and carcinogenic emissions of serious concern (Gurjar, B. R., et al., 2004).

6. Domestic sector:

Households are identified as a major cause of air pollution in India. Emissions from the combustion of fossil fuels, stoves, or generators fall within this sector and therefore affect the overall air quality. Household energy is powered by fuels, such as cooking gas, kerosene, wood, crop scraps, or cow dung pies (Gurjar, B. R, et al., 2004). Although liquefied petroleum gas (LPG) is used as an alternative fuel source for cooking in most urban cities, most of India's rural population continues to depend on cow dung cake, biomass, charcoal, or wood as the main fuel for cooking and other energy sources. goals and needs. These lead to serious impacts on air quality, especially indoor air quality, which could directly affect human health. According to HEI (2019), about 60% of the Indian population was exposed to household pollution in 2017 (Gurjar, B. R. 2021).

7. Construction and Demolition Waste:

Another major source of air pollution in India is waste, which is an outcome of construction and demolition activities (Guttikunda, S. K., & Goel, R. 2013). Inferred from their study that around 10,750 tonnes of construction waste are generated in Delhi every year. Even after the construction phase, these buildings have the potential to be the major contributors to GHG emissions. Nowadays, the increasing interest in green building technologies and the application of green infrastructure and materials during construction could tackle this issue to a large extent, thereby preserving our biodiversity and maintaining cleaner air quality (Gurjar, B. R. 2021).

Sources of indoor air pollutants: Some very common sources of air pollutants and their possible health effects are shown in Table 1 below (Chaudhuri, S., & Pfaff, A. S. 2003, Bruce, N., et al., 2006, Chay, K. Y., & Greenstone, M. 2003, Dasgupta, S., et al., 2004, Duflo, E., et al., 2008, Environmental Protection Agency 2006, Zhang, J., & Smith, K. R. 2007, Chaudhuri, S., & Pfaff, A. S. 2003, & Gaikwad, A., & Shivhare, N. 2019).

Table: 1 Sources, permissible limits, and Possible Health Effects of Indoor Air Pollutants

S. No.	Pollutant	Sources	Limits	Health Effects
1	Asbestos fibres	• Fireproofing insulation, • vinyl floor, • ement products, • vehicle brake linings	0.2 fibres/mL for fibre larger than5 µm	• Skin irritatio, • lung cancer
2	Microorganisms	• Infectious agents, • ventilation, • air-conditioning system	Not available	• Disease, • weakened immunity
3	Carbon dioxide	• Motor vehicles, • gas appliances, • smoking	1,000 ppm	• Dizziness, • headaches, • nausea
4	Particulate matter	• Smoking, • fireplaces, • dust, • Combustion sources (burning trash, etc.)	55-110 µg/m3 annual; 350 µg/m3 for 1 hour	• Respiratory and mucous irritant, • carcinogen
5	Carbon monoxide	• Motor vehicles, • kerosene and gas heater, • gas and wood stoves, • fireplaces; • smoking	10,000 µg/m3 for 8 hours; 40,000 µg/m3 for 1 hours	• Dizziness, • headaches, • nausea, • death
6	Formaldehyde	• Foam insulation; • plywood, • particleboard, ceiling tile, • paneling • construction material	120 µg/m3	• Skin irritant, • carcinogen
7	Pesticides	• Sprays and strips, • outdoor air	5 µg/m3	• Possible carcinogens
8	Ozone	• Photocopying machines, • electrostatic air	235 µg/m3 for 1 hour	• Respiratory irritant, • causes

		cleaners, • outdoor air		fatigue
9	Metal particulates	• Smoking, • pesticides, • rodent poisons , • Smoking, • fungicides • fossil fuel combustion , • Gas and kerosene heaters, • gas stoves,	2 µg/m3 for 24 hours 1.5 µg/m3 for 3 months 2 µg/m3 for 24 hours 100 µg/m3 annual	• Toxic, carcinogen • Respiratory and mucous irritant
10	VOC's	• Smoking, • cooking, • solvents, • paints, • varnishes, • cleaning sprays, • carpets, • furniture, • draperies, • clothing • rubber lubricants		• Possible carcinogens
11	Nitrogen dioxide	• Gas and kerosene heaters, • Smoking, • fossil fuel combustion		• Toxic, carcinogen • Respiratory and mucous irritant
12	Sulphur dioxide	• Coal and oil combustion, • kerosene • Space heater, • outside air	80 µg/m3 annual; 365 µg/m3 for 24 hours	• Respiratory and mucous irritant • Irritant

Air pollutants and their toxicities:

Any material in the air that can affect human health or have a major impact on the environment is called an air pollutant. According to the World Health Organization (WHO), particulate pollution, O3, CO at ground level, sulfur oxides, nitrogen oxides and lead (Pb) are the six main air pollutants that harm human health and also the ecosystem. In the air, there are many atmospheric pollutants such as dust, fumes, smoke, mists, gaseous pollutants, hydrocarbons, volatile organic compounds (VOCs), polycyclic aromatic hydrocarbons (PAHs), and halogen derivatives which at high concentrations cause vulnerability to many diseases, including several types of cancer (Loomis, D., et al., 2014, Kjellstrom, T., et al., 2006, Rodopoulou, S., et al., 2014, &

Carugno, M., et al., 2016). The main air pollutants and their toxic effects on various organs of the human body and related diseases are briefly described below (Ghorani-Azam, A., et al., 2016).

1. Particulate pollutants:

Particulate pollutants are major components of air pollutants. In a simple definition, they are a mixture of particles present in the air. Particulate pollution, better known as PM, is associated with most pulmonary and cardiovascular morbidity and mortality (Sadeghi, M., et al., 2015 & Sahu, D., et al., 2014). Their size varied mainly between 2.5 and 10 µm (PM2.5 to PM10) (Ghorani-Azam, A., et al., 2016).

The size of particulate pollutants is directly related to the onset and progression of lung and heart disease. The smaller-sized particles reach the lower airways and therefore have a greater potential to cause lung and heart disease. In addition, numerous scientific data have shown that polluting fine particles cause premature death in people with heart and/or lung disease, including heart arrhythmias, non-fatal heart attacks, exacerbated asthma, and impaired lung function. Depending on the degree of exposure, the contaminating particles can cause mild to severe illness. Wheezing, coughing, dry mouth, and activity limitation due to respiratory problems are the most common clinical signs of respiratory disease due to air pollution (Guillam, M. T., et al., 2013, Bentayeb, M., et al., 2013, & Gao, Y., et al., 2014). Prolonged exposure to current PM concentrations in the environment can lead to a marked reduction in life expectancy. Increased mortality from heart and lung cancer is the main reason for the decrease in life expectancy. Impaired lung functions in children and adults leading to asthmatic bronchitis and chronic obstructive pulmonary disease (COPD) are also serious diseases that lead to a lower quality of life and a shortened life expectancy. Prolonged exposure to current PM concentrations in the environment can lead to a marked reduction in life expectancy. Increased mortality from heart and lung cancer is the main reason for the decrease in life expectancy. Reduced lung function in children and adults resulting in asthmatic bronchitis and chronic obstructive pulmonary disease (COPD) are also serious conditions that lead to reduced quality of life and life expectancy from cohort studies (Zhou, M., et al., 2014, Pelucchi, C., et al., 2009 & Jerrett, M., et al., 2009).

2. Ozone at ground level:

O3 with the chemical formula O3 is a colorless gas that is the main component of the atmosphere. It is found both near the ground and in the upper regions of the atmosphere called the troposphere. Ground level ozone (GLO) is produced by the chemical reaction between nitrogen oxides and VOCs emitted from natural sources and/or human activities. GLO is believed to have a plausible association with an increased risk of respiratory diseases, particularly asthma (Gorai, A. K, et al., 2016).

Being a powerful oxidizing agent, O3 accepts electrons from other molecules. There is a high content of polyunsaturated fatty acids in the surface fluid lining of the airways and in the cell membranes underlying the lining fluid. The double bonds present in these fatty acids are unstable. O3 attacks unpaired electrons to form ozonides and passes through an unstable zwitterion or trioxolane (depending on the presence of water). These eventually recombine or break down into lipohydroperoxides, aldehydes, and hydrogen peroxide. These pathways are thought to initiate the proliferation of lipid radicals and auto-oxidation of cell membranes and macromolecules. It also increases the risk of DNA damage in epidermal keratinocytes leading to impaired cell function (McCarthy, J. T., et al., 2013).

O3 induces a variety of toxic effects in humans and experimental animals at concentrations common in many urban areas (Lippmann, M. 1989). These effects include morphological, functional, immunological, and biochemical changes. Due to its low water solubility, a significant percentage of inhaled O3 penetrates deep into the lungs, but its reactivity is swept away from the nasopharynx of resting rats and humans at approximately 17% and 40%, respectively, respectively (Hatch, G. E., et al., 1994, & Gerrity, T. R., et al., 1988). From an ecological perspective, O3 can reduce carbon uptake by trees, leading to deforestation, which can affect global food security in the event of long-term exposure (Fares, S., et al., 2013, & Wilkinson, S., et al., 2012).

3. Carbon monoxide:

CO is a colorless and odorless gas produced by fossil fuels, especially when combustion is inappropriate, such as when burning coal and wood. The affinity of CO with hemoglobin (as a carrier of oxygen in the body) is approximately 250 times greater than that of oxygen. Depending on the concentration of CO and the duration of exposure, mild to severe poisoning can occur. Symptoms of CO poisoning can include headache, dizziness, weakness, nausea, vomiting, and possible loss of consciousness. The symptoms are very similar to those of other diseases, such as food poisoning or viral infections (Ghorani-Azam, A., et al., 2016). No effects on human health have been demonstrated for carboxyhemoglobin (COHb) levels below 2%, while levels above 40% can be fatal. Hypoxia, apoptosis and ischemia are known mechanisms underlying CO toxicity (Akyol, S., et al., 2014). The mechanism of such toxicity is the loss of oxygen due to the competitive binding of CO to hemoglobin groups. Cardiovascular changes can also be seen from CO exposures that generate COHb greater than 5%. In the early 1990s, the Health Effects Institute conducted a series of studies related to cardiovascular disease to determine the potential for angina pectoris with COHb levels in the range of 2-6% (Allred, E. N., et al., 1989).

The results indicated that premature angina pectoris can occur under these circumstances, but the possibility of ventricular arrhythmias remains unclear. Thus, reducing ambient CO can reduce the risk of myocardial infarction in predisposed individuals (Ghorani-Azam, A., et al., 2016).

4. Sulfur dioxide:

Sulfur dioxide is a noxious gas that is emitted mainly from the consumption of fossil fuels or from industrial activities. The annual standard for SO2 is 0.03 ppm (US EPA., 2019). It affects the life of people, animals and plants. Sensitive people, such as people with lung disease, the elderly, and children, are at greater risk of harm. The main health problems associated with sulfur dioxide emissions in industrialized areas are respiratory irritation, bronchitis, mucus production and bronchospasm, as it stimulates the senses and penetrates deep into the lungs and converts to bisulfite and interacts with sensory receptors, causing bronchoconstriction. In addition, skin redness, damage to the eyes (tears and corneal opacity) and mucous membranes, and exacerbation of pre-existing cardiovascular diseases have been observed (Chen, T. M., et al., 2007). Negative environmental effects, such as soil acidification and acid rain, appear to be related to sulfur dioxide emissions (Manisalidis, I., et al., 2020, & WHO. 2000).

5. Nitrogen oxide:

Nitrogen oxides are important air pollutants that can increase the risk of respiratory infections (Chen, T. M., et al., 2007). They are mainly emitted by engines and are therefore traffic-related air pollutants. They are deep lung irritants that can cause pulmonary edema when inhaled in high concentrations. They are generally less toxic than O3, but NO2 can pose significant toxicological problems. Exposures to 2.0-5.0 ppm have been shown to affect T cells, particularly CD8+ cells and natural killer cells, which play an important role in host defenses against viruses. Although these levels may be high, epidemiological studies show the effects of NO2 on the number of respiratory infections in children (Ghorani-Azam, A., et al., 2016). Coughing and wheezing are the most common complications of nitric oxide toxicity, but eye, nose or throat irritation, headache, shortness of breath, chest pain, diaphoresis, fever, bronchospasm, and pulmonary edema may also occur. Another report suggests that nitric oxide levels between 0.2 and 0.6 ppm are harmless to the human population (Hesterberg, T. W, et al., 2009).

6. Lead:

Lead is a heavy metal used in various industrial plants and emitted by some gasoline engines, batteries, radiators, incinerators and wastewater (Prüss-Üstün, A., et al., 2004). In addition, the main sources of lead pollution in the air are metals, minerals and aircraft with piston engines. Lead poisoning poses a threat to public health due to its harmful effects on humans, animals and the environment, especially in developing countries. Lead exposure can occur by inhalation, ingestion and absorption through the skin. Transplacental transport of lead has also been reported, as lead passes through the discharged placenta (Goyer, R. A., 1990). The younger the fetus, the more harmful the toxic effects. Lead toxicity affects the fetal nervous system; Edema or swelling of the brain is observed (National Institute of Environmental Health Sciences (NIH). (Lead and Your Health., 2013). When inhaled, lead accumulates in the blood, soft tissues, liver, lungs, bones , in the cardiovascular, nervous and reproductive systems.In addition, loss of concentration and memory, as well as muscle and joint pain, have been observed in adults (Goyer, R. A. 1990 and NIH 2013), Children and infants (Farhat, A., et al., 2013).

They are extremely susceptible to even minimal doses of lead, as it is a neurotoxic substance and causes learning difficulties, memory impairments, hyperactivity and even mental retardation. High levels of lead in the environment are harmful to plants and crop growth. Neurological effects are observed in vertebrates and animals in combination with high levels of lead (Assi, M. A., et al., 2016).

7. Dioxins:

Dioxins come from industrial processes, but also from natural processes, such as forest fires and volcanic eruptions. They accumulate in foods such as meat and dairy products, fish and shellfish, and especially in the adipose tissue of animals (Manisalidis, I., et al., 2020, & WHO 2019). Short-term exposure to high concentrations of dioxins can cause dark spots and lesions on the skin. Long-term exposure to dioxins can lead to developmental problems, immune, endocrine and nervous system disorders, reproductive infertility and cancer (Manisalidis, I., et al., 2020, & WHO 2019). There is no doubt that the consumption of fossil fuels is responsible for a significant amount of air pollution. This contamination can be anthropogenic, such as in agricultural and industrial processes or during transportation, but naturally occurring contamination is also possible. Interestingly, the air quality standards set by the EU Air Quality Directive are a bit more relaxed than the stricter WHO guidelines (Manisalidis, I., et al., 2020, & EEA).

8. Polycyclic Aromatic Hydrocarbons (PAHs):

The distribution of PAHs is omnipresent in the environment, as the atmosphere is the main means of dispersion. They are found in coal and tar deposits. Furthermore, they are generated by incomplete combustion of organic matter, as in the case of forest fires, combustion, and engines (Manisalidis, I., et al., 2020, & Abdel-Shafy, H.I., et al., 2016) IPA compounds, such as benzopyrene, acenaphthylene, anthracene, and fluoranthene are recognized as toxic, mutagenic and carcinogenic substances. They are an important risk factor for lung cancer (Manisalidis, I., et al., 2020, & Abdel-Shafy, H.I., et al., 2016)

9. Volatile organic compounds (VOCs):

Volatile organic compounds (VOCs), such as toluene, benzene, ethylbenzene, and xylene (Kumar, A., et al., 2014). Have been associated with cancer in humans (Mølhave, L., et al., 1997). The use of new products and materials has led to an increase in VOC concentrations. VOCs pollute indoor air (Kumar, A., et al., 2014) and can have negative effects on human health (Mølhave, L., et al., 1997). There are short and long-term negative effects on human health. VOCs are responsible for indoor air odors. Short-term exposure has been found to irritate the eyes, nose, throat, and mucous membranes, while long-term exposure results in toxic reactions (Gibb T., 2019).

The predictable assessment of the toxic effects of complex VOC mixtures is difficult to estimate, as these pollutants can have synergistic, antagonistic, or indifferent effects (Kumar, A., et al., 2014, & Lance, S., et al., 2012).

Effect of air pollution on human health

The most common air pollutants are ground-level ozone and particulate matter (PM). Air pollution is divided into two main types:

Outdoor air pollution is air pollution.

Indoor pollution is the pollution caused by the domestic burning of fuels.

People exposed to high concentrations of air pollutants experience symptoms of disease and conditions of greater and lesser severity. These effects are grouped into short- and long-term health effects (Manisalidis, I., et al., 2020, & Kloog, I., et al., 2013).

Sensitive populations who need to be aware of health protection measures include the elderly, children, and people with diabetes and predisposing heart or lung disease, especially asthma (Manisalidis, I., et al., 2020, & Kloog, I., et al., 2013). Short-term effects are temporary and range from simple symptoms such as irritation of the eyes, nose, skin, throat, wheezing, coughing, chest tightness, and difficulty breathing, to more serious conditions such as asthma, pneumonia, bronchitis, and lung and heart problems. Short-term exposure to air pollution can also cause headaches, nausea, and dizziness.

These problems can be exacerbated by prolonged exposure to pollutants that are harmful to the neurological, reproductive, and respiratory systems, causing cancer and, rarely, death.

Late sequelae are chronic, last for years of life, and can even lead to death. Moreover, the long-term toxicity of several air pollutants can also trigger various cancers (Nakano, T., & Otsuki, T. 2013). Particulate matter (PM), dust, benzene, and O3 cause severe damage to the respiratory tract (Kurt, O.K., et al., 2016). Furthermore, there is an additional risk of existing respiratory diseases such as asthma (Guarneri, M., & Balmes, J.R. 2014). Long-term effects are more common in people with predisposing medical conditions. If the trachea is contaminated with pollutants, voice changes may be noticed after acute exposure. Chronic obstructive pulmonary disease (COPD) can be induced by air pollution and increase morbidity and mortality (Jiang, X.Q., et al., 2016). Long-term effects of traffic, industrial air pollution, and fuel combustion are major risk factors for COPD (Jiang, XQ, et al., 2016).

Multiple cardiovascular effects have been observed after exposure to air pollutants (Troeger, C., et al., 2018). Changes in blood cells after prolonged exposure can affect heart function. Coronary arteriosclerosis has been reported after long-term exposure to traffic emissions (Heinz Nixdorf Recall Study Investigative Group., 2007). While short-term exposure is associated with hypertension, stroke, myocardial infarction, and heart failure. Ventricular hypertrophy has been reported in humans after prolonged exposure to nitric oxide (NO2) (Katholi, R.E., & Couri, D.M. 2011, & Leary, P. J., et al., 2014). Neurological effects have been observed in adults and children after prolonged exposure to air pollutants (Manisalidis, I., et al., 2020). Psychological complications, autism, retinopathy, fetal growth, and low birth weight appear to be related to long-term air pollution (WHO 2000). The causative agent of neurodegenerative diseases (Alzheimer's and Parkinson's) is not yet known, although long-term exposure to air pollution is believed to be a factor. In particular, along with the diet, pesticides and metals are mentioned as etiological factors. Mechanisms in the development of neurodegenerative diseases include oxidative stress, protein aggregation, inflammation, and mitochondrial dysfunction in neurons (Genc, S., et al., 2012).

Brain inflammation has been observed in dogs that have long lived in a highly polluted area in Mexico (Calderon-Garciduenas, L., et al., 2002). In adults, markers of systemic inflammation (IL-6 and fibrinogen) were elevated as an immediate response to PNC at the IL-6 level, possibly leading to acute phase protein production [88]. The progression of atherosclerosis and oxidative stress appear to be the mechanisms involved in neurological disorders caused by long-term air pollution. Inflammation is secondary to oxidative stress and appears to be involved in impaired developmental maturation, affecting multiple organs (Calderon-Garciduenas, L., et al., 2002 & Peters, A., et al., 2006). Likewise, other factors appear to be involved in developmental maturation that defines long-term air pollution susceptibility. These include birth weight, maternal smoking, genetic background, socio-economic background, and level of education (Manisalidis, I., et al., 2020).

Similarly, the genetic background can lead to differential susceptibility to the oxidative stress pathway (Boschi N (Ed.), 2012). For example, supplementation of antioxidants with vitamins C and E appears to modulate the effect of ozone in asthmatic children homozygous for the null allele GSTM1 (Heal, M.R., et al., 2012).

Neurodevelopmental disorders have been observed in children following lead exposure. These children developed aggressive and delinquent behaviors, decreased intelligence, learning difficulties, and hyperactivity (Bellinger, D. C. 2008), no lead exposure level appears "safe" and the scientific community has asked the Centers for Disease Control and Prevention (CDC) to lower the current screening guideline by 10 µg / dl (Bellinger, D.C. 2008).

It is important to remember that the impact on the immune system, which causes dysfunction and neuroinflammation (Genc, S., et al., 2012), is related to poor air quality. Nevertheless, increases in serum levels of immunoglobulins (IgA, IgM) and complement component C3 are observed (Barry, V., et al., 2013). Another problem is that antigen presentation is affected by airborne pollutants because costimulatory molecules such as CD80 and CD86 are up-regulated on macrophages (Balbo, P., et al., 2001).

As we know, the skin is our protective shield against ultraviolet (UV) rays and other pollutants since it is the outer layer of our body. Traffic-related pollutants such as PAHs, VOCs, oxides, and PMs can cause pigment spots on our skin (Drakaki, E., et al., 2014). On the one hand, as already mentioned organ damage is observed when pollutants penetrate through the skin or are inhaled since some of these pollutants are mutagenic and carcinogenic and attack the liver and lungs in particular. On the other hand, air pollutants (and those present in the troposphere) reduce the negative effects of UVR ultraviolet radiation in polluted urban areas (Drakaki, E., et al., 2014). Air pollutants absorbed by human skin can contribute to skin aging, psoriasis, acne, urticaria, eczema, and atopic dermatitis (Drakaki, E., et al., 2014), usually caused by exposure to oxides and photochemical smoke (Drakaki, E., et al., 2014). Exposure to PM and cigarette smoke ages the skin and cause blemishes, discoloration, and wrinkles. Finally, pollutants have been linked to skin cancer (Drakaki, E., et al., 2014).

Increased morbidity is reported in fetuses and infants when exposed to the above risks. Impaired fetal growth, low birth weight, and autism have been reported (Weisskopf, MG, et al., 2015).

Another external organ that can be affected is the eye. Contamination usually results from air pollutants and can lead to asymptomatic ocular findings, irritation (Weisskopf, M.G., et al., 2015), retinopathy, or dry eye syndrome (Mo, Z., et al., 2019 and Klopfer, J. 1989).

CONCLUSION

The problem of air pollution in India is a matter of great concern to the people living here, which is creating problems for humans and the environment. There are many different emission sources of air pollution, primarily motorcycles, vehicle/transportation emissions, domestic sectors, construction, demolition waste, industrial, agriculture, power plants, waste treatment, and biomass burning, all of which emit pollution. Making a major contribution. According to the World Health Organization, some pollutants are more polluting the air including ozone, nitrogen oxides, carbon monoxide, volatile organic compounds, lead, dioxins, polycyclic aromatic hydrocarbons, particulates, and sulfur oxides. Exposure to air pollution causes respiratory problems, heart disease, skin diseases, eye irritation, neuropsychiatric, cancer, asthma, lung, fetal disorders, respiratory and mucous irritation, etc. Its impact on human health is mainly due to prolonged stay in air polluted places. According to research papers. In this review article, we have discussed the major sources of air pollution, toxicology, and their impact on human health.

REFERENCES

Abdel-Shafy, H. I., & Mansour, M. S. (2016). A review on polycyclic aromatic hydrocarbons: source, environmental impact, effect on human health and remediation. Egyptian journal of petroleum, 25(1), 107-123.

Air pollution: Consequences and actions for the UK, and beyond. Lancet. 2016;387:817.

Akyol, S., Erdogan, S., Idiz, N., Celik, S., Kaya, M., Ucar, F., ... & Akyol, O. (2014). The role of reactive oxygen species and oxidative stress in carbon monoxide toxicity: an in-depth analysis. Redox Report, 19(5), 180-189.

Allred, E. N., Bleecker, E. R., Chaitman, B. R., Dahms, T. E., Gottlieb, S. O., Hackney, J. D., ... & Walden, S. M. (1989). Acute effects of carbon monoxide exposure on individuals with coronary artery disease. Research report (Health Effects Institute), (25), 1-79.

Assi, M. A., Hezmee, M. N. M., Sabri, M. Y. M., & Rajion, M. A. (2016). The detrimental effects of lead on human and animal health. Veterinary world, 9(6), 660.

Balbo, P., Silvestri, M., Rossi, G. A., Crimi, E., & Burastero, S. E. (2001). Differential role of CD80 and CD86 on alveolar macrophages in the presentation of allergen to T lymphocytes in asthma. Clinical & Experimental Allergy, 31(4).

Barry, V., Winquist, A., & Steenland, K. (2013). Perfluorooctanoic acid (PFOA) exposures and incident cancers among adults living near a chemical plant. Environmental health perspectives, 121(11-12), 1313-1318.

Bellinger, D. C. (2008). Very low lead exposures and children's neurodevelopment. Current opinion in pediatrics, 20(2), 172-177.

Bentayeb, M., Simoni, M., Norback, D., Baldacci, S., Maio, S., Viegi, G., & Annesi-Maesano, I. (2013). Indoor air pollution and respiratory health in the elderly. Journal of Environmental Science and Health, Part A, 48(14), 1783-1789.

Biggeri, A., Bellini, P., & Terracini, B. (2004). Meta-analysis of the Italian studies on short-term Effects of air pollution--MISA 1996-2002. Epidemiologia e prevenzione, 28(4-5 Suppl), 4-100.

Boschi N (Ed.). Defining an educational framework for indoor air sciences education. In: Education and Training in Indoor Air Sciences. Luxembourg: Springer Science & Business Media (2012). 245 p.

Bruce, N., Rehfuess, E., Mehta, S., Hutton, G., Smith, K., Jamison, D., ... & Evans, D. (2006). Indoor air pollution, Disease control priorities in developing countries. *Oxford University Press, New York. doi*, *10*, 978-0.

Calderon-Garciduenas, L., Azzarelli, B., Acuna, H., Garcia, R., Gambling, T. M., Osnaya, N., ... & Rewcastle, B. (2002). Air pollution and brain damage. Toxicologic pathology, 30(3), 373-389.

Carugno, M., Consonni, D., Randi, G., Catelan, D., Grisotto, L., Bertazzi, P. A., ... & Baccini, M. (2016). Air pollution exposure, cause-specific deaths and hospitalizations in a highly polluted Italian region. Environmental research, 147, 415-424.

Chaudhuri, S., & Pfaff, A. S. (2003). Fuel-choice and indoor air quality: a household-level perspective on economic growth and the environment. *New York: Department of Economics and School of International and Public Affairs, Columbia University*.

Chaudhuri, S., & Pfaff, A. S. (2003). Fuel-choice and indoor air quality: a household-level perspective on economic growth and the environment. *New York: Department of Economics and School of International and Public Affairs, Columbia University*.

Chay, K. Y., & Greenstone, M. (2003). The impact of air pollution on infant mortality: evidence from geographic variation in pollution shocks induced by a recession. *The quarterly journal of economics*, *118*(3), 1121-1167.

Chen, B., & Kan, H. (2008). Air pollution and population health: a global challenge. Environmental health and preventive medicine, 13(2), 94-101.

Chen, T. M., Kuschner, W. G., Gokhale, J., & Shofer, S. (2007). Outdoor air pollution: nitrogen dioxide, sulfur dioxide, and carbon monoxide health effects. The American journal of the medical sciences, 333(4), 249-256.

Chestnut, L. G., Breffle, W. S., Smith, J. B., & Kalkstein, L. S. (1998). Analysis of differences in hot-weather-related mortality across 44 US metropolitan areas. Environmental Science & Policy, 1(1), 59-70.

Chi, C. C. (1994). Growth with pollution: unsustainable development in Taiwan and its consequences. Studies in Comparative International Development, 29(2), 23-47.

Dasgupta, S., Huq, M., Khaliquzzaman, M., Pandey, K., & Wheeler, D. (2004). Who suffers from indoor air pollution? Evidence from Bangladesh. World Bank Policy Research working paper, vol. 3428. *Development research Group World Bank*.

Drakaki, E., Dessinioti, C., & Antoniou, C. V. (2014). Air pollution and the skin. Frontiers in Environmental Science, 2, 11.

Duflo, E., Greenstone, M., & Hanna, R. (2008). Cooking stoves, indoor air pollution and respiratory health in rural Orissa. *Economic and Political Weekly*, 71-76.

EEA (European Environmental Agency). Air Quality Standards to the European Union and WHO. Available online at: https://www.eea.europa.eu/ themes/data-and-maps/figures/air-quality-standards-under-the.

Environmental Protection Agency (2006). “Particulate Matter Standards,” U.S. Environmental Protection Agency. Last accessed 1/9/07.< http://www.epa.gov/oar/particlepollution/standards.html>

Fares, S., Vargas, R., Detto, M., Goldstein, A. H., Karlik, J., Paoletti, E., & Vitale, M. (2013). Tropospheric ozone reduces carbon assimilation in trees: estimates from analysis of continuous flux measurements. Global Change Biology, 19(8), 2427-2443.

Farhat, A., Mohammadzadeh, A., Balali-Mood, M., Aghajanpoor-Pasha, M., & Ravanshad, Y. (2013). Correlation of blood lead level in mothers and exclusively breastfed infants: a study on infants aged less than six months. Asia Pacific Journal of Medical Toxicology, 2(4), 150-152.

Gaikwad, A., & Shivhare, N. (2019). Indoor air pollution-A threat. *Indoor Air*, *7*(05).

Gao, Y., Chan, E. Y., Li, L., Lau, P. W., & Wong, T. W. (2014). Chronic effects of ambient air pollution on respiratory morbidities among Chinese children: a cross-sectional study in Hong Kong. BMC public health, 14(1), 1-11.

Gautam, S. (2020). COVID-19: air pollution remains low as people stay at home. Air Qual Atmos Health 13: 853–857.

Gautam, S., Talatiya, A., Patel, M., Chabhadiya, K., & Pathak, P. (2020). Personal exposure to air pollutants from winter season bonfires in rural areas of Gujarat, India. Exposure and Health, 12(1), 89-97.

Genc, S., Zadeoglulari, Z., Fuss, S. H., & Genc, K. (2012). Review Article: The Adverse Effects of Air Pollution on the Nervous System. Journal of Toxicology, 2012, 1-23.

Gerrity, T. R., Weaver, R. A., Berntsen, J., House, D. E., & O'Neil, J. J. (1988). Extrathoracic and intrathoracic removal of O3 in tidal-breathing humans. Journal of Applied Physiology, 65(1), 393-400.

Ghorani-Azam, A., Riahi-Zanjani, B., & Balali-Mood, M. (2016). Effects of air pollution on human health and practical measures for prevention in Iran. Journal of research in medical sciences: the official journal of Isfahan University of Medical Sciences, 21.

Gibb T. Indoor Air Quality May be Hazardous to Your Health. MSU Extension. Available online at: https://www.canr.msu.edu/news/indoor_air_ quality_may_be_hazardous_to_your_health (accessed October 5, 2019).

Gorai, A. K., Tchounwou, P. B., & Tuluri, F. (2016). Association between ambient air pollution and asthma prevalence in different population groups residing in eastern Texas, USA. International journal of environmental research and public health, 13(4), 378.

Goyer, R. A. (1990). Transplacental transport of lead. Environmental health perspectives, 89, 101-105.

Guarneri, M., & Balmes, J. R. (2014). Outdoor air pollution and asthma. Lancet, 383, 1581-1592.

Guillam, M. T., Pédrono, G., Le Bouquin, S., Huneau, A., Gaudon, J., Leborgne, R., ... & Ségala, C. (2013). Chronic respiratory symptoms of poultry farmers and model-based estimates of long-term dust exposure. Annals of Agricultural and Environmental Medicine, 20(2).

Gurjar, B. R. (2021), Air Pollution in India: Major Issues and Challenges –

TERI, https://www.teriin.org/article/air-pollution-india-major-issues-and-challenges.

Gurjar, B. R., & Nagpure, A. S. (2016). Indian megacities as localities of environmental vulnerability from air quality perspective. Journal of Smart Cities (Transferred), 1(1).

Gurjar, B. R., Ravindra, K., & Nagpure, A. S. (2016). Air pollution trends over Indian megacities and their local-to-global implications. Atmospheric Environment, 142, 475-495.

Gurjar, B. R., Van Aardenne, J. A., Lelieveld, J., & Mohan, M. (2004). Emission estimates and trends (1990–2000) for megacity Delhi and implications. Atmospheric Environment, 38(33), 5663-5681.

Guttikunda, S. K., & Goel, R. (2013). Health impacts of particulate pollution in a megacity—Delhi, India. Environmental Development, 6, 8-20.

Guttikunda, S. K., & Kopakka, R. V. (2014). Source emissions and health impacts of urban air pollution in Hyderabad, India. Air Quality, Atmosphere & Health, 7(2), 195-207.

Habre, R., Coull, B., Moshier, E., Godbold, J., Grunin, A., Nath, A., ... & Koutrakis, P. (2014). Sources of indoor air pollution in New York City residences of asthmatic children. Journal of exposure science & environmental epidemiology, 24(3), 269-278.

Hatch, G. E., Slade, R., Harris, L. P., McDonnell, W. F., Devlin, R. B., Koren, H. S., ... & McKee, J. (1994). Ozone dose and effect in humans and rats. A comparison using oxygen-18 labeling and bronchoalveolar lavage. American journal of respiratory and critical care medicine, 150(3), 676-683.

Heal, M. R., Kumar, P., & Harrison, R. M. (2012). Particles, air quality, policy and health. Chemical Society Reviews, 41(19), 6606-6630.

Heinz Nixdorf Recall Study Investigative Group. (2007). Residential exposure to traffic is associated with coronary atherosclerosis. Circulation, 116.

Hesterberg, T. W., Bunn, W. B., McClellan, R. O., Hamade, A. K., Long, C. M., & Valberg, P. A. (2009). Critical review of the human data on short-term nitrogen dioxide (NO2) exposures: evidence for NO2 no-effect levels. Critical reviews in toxicology, 39(9), 743-781.

Jerrett, M., Finkelstein, M. M., Brook, J. R., Arain, M. A., Kanaroglou, P., Stieb, D. M., ... & Sears, M. R. (2009). A cohort study of traffic-related air pollution and mortality in Toronto, Ontario, Canada. Environmental health perspectives, 117(5), 772-777.

Jiang, X. Q., Mei, X. D., & Feng, D. (2016). Air pollution and chronic airway diseases: what should people know and do?. Journal of thoracic disease, 8(1), E31.

Kan, H., Chen, B., Zhao, N., London, S. J., Song, G., Chen, G., ... & Jiang, L. (2010). Part 1. A time-series study of ambient air pollution and daily mortality in Shanghai, China. Research report (Health Effects Institute), (154), 17-78.

Kaskaoutis, D. G., Kharol, S. K., Sinha, P. R., Singh, R. P., Badarinath, K. V. S., Mehdi, W., & Sharma, M. (2011). Contrasting aerosol trends over South Asia during the last decade based on MODIS observations. Atmospheric Measurement Techniques Discussions, 4(4), 5275-5323.

Katholi, R. E., & Couri, D. M. (2011). Left ventricular hypertrophy: major risk factor in patients with hypertension: update and practical clinical applications. International journal of hypertension, 2011.

Kjellstrom, T., Lodh, M., McMichael, T., Ranmuthugala, G., Shrestha, R., & Kingsland, S. (2006).

Air and water pollution: burden and strategies for control. Disease Control Priorities in Developing Countries. 2nd edition.

Kloog, I., Ridgway, B., Koutrakis, P., Coull, B. A., & Schwartz, J. D. (2013). Long-and short-term exposure to PM2. 5 and mortality: using novel exposure models. Epidemiology (Cambridge, Mass.), 24(4), 555.

Klopfer, J. (1989). Effects of environmental air pollution on the eye. Journal of the American Optometric Association, 60(10), 773-778.

Krishna Moorthy, K., Suresh Babu, S., Manoj, M. R., & Satheesh, S. K. (2013). Buildup of aerosols over the Indian Region. Geophysical Research Letters, 40(5), 1011-1014.

Kumar, A., Singh, B. P., Punia, M., Singh, D., Kumar, K., & Jain, V. K. (2014). Assessment of indoor air concentrations of VOCs and their associated health risks in the library of Jawaharlal Nehru University, New Delhi. Environmental Science and Pollution Research, 21(3), 2240-2248.

Kurt, O. K., Zhang, J., & Pinkerton, K. E. (2016). Pulmonary health effects of air pollution. Current opinion in pulmonary medicine, 22(2), 138.

Lance, S., Raatikainen, T., Onasch, T., Worsnop, D. R., Yu, X. Y., Alexander, M. L., ... & Nenes, A. (2012). Aerosol mixing-state, hygroscopic growth and cloud activation efficiency during MIRAGE 2006. Atmospheric Chemistry & Physics Discussions, 12(6).

Leary, P. J., Kaufman, J. D., Barr, R. G., Bluemke, D. A., Curl, C. L., Hough, C. L., ... & Kawut, S. M. (2014). Traffic-related air pollution and the right ventricle. The multi-ethnic study of atherosclerosis. American journal of respiratory and critical care medicine, 189(9), 1093-1100.

Lippmann, M. (1989). Health effects of ozone a critical review. Japca, 39(5), 672-695.

Loomis, D., Huang, W., & Chen, G. (2014). The International Agency for Research on Cancer (IARC) evaluation of the carcinogenicity of outdoor air pollution: focus on China. Chinese journal of cancer, 33(4), 189.

Manisalidis, I., Stavropoulou, E., Stavropoulos, A., & Bezirtzoglou, E. (2020). Environmental and health impacts of air pollution: a review. Frontiers in public health, 14.

McCarthy, J. T., Pelle, E., Dong, K., Brahmbhatt, K., Yarosh, D., & Pernodet, N. (2013). Effects of ozone in normal human epidermal keratinocytes. Experimental dermatology, 22(5), 360-361.

Mo, Z., Fu, Q., Lyu, D., Zhang, L., Qin, Z., Tang, Q., ... & Yao, K. (2019). Impacts of air pollution on dry eye disease among residents in Hangzhou, China: A case-crossover study. Environmental Pollution, 246, 183-189.

Mølhave, L., Clausen, G., Berglund, B., De Ceaurriz, J., Kettrup, A., Lindvall, T., ... & Younes, M. (1997). Total volatile organic compounds (TVOC) in indoor air quality investigations. Indoor Air, 7(4), 225-240.

Molina, M. J., & Molina, L. T. (2004). Megacities and atmospheric pollution. Journal of the Air & Waste Management Association, 54(6), 644-680.

Nagpure, A. S., Gurjar, B. R., Kumar, V., & Kumar, P. (2016). Estimation of exhaust and non-exhaust gaseous, particulate matter and air toxics emissions from on-road vehicles in Delhi. Atmospheric environment, 127, 118-124.

Nakano, T., & Otsuki, T. (2013). Environmental air pollutants and the risk of cancer. Gan to kagaku ryoho. Cancer & chemotherapy, 40(11), 1441-1445.

National Institute of Environmental Health Sciences (NIH). Lead and Your Health. (2013). 1–4 p. Available online at: https://www.niehs.nih.gov/health/ materials/lead_and_your_health_508.pdf (accessed September 17, 2019).

Pandey, A., & Venkataraman, C. (2014). Estimating emissions from the Indian transport sector with on-road fleet composition and traffic volume. Atmospheric Environment, 98, 123-133.

Pelucchi, C., Negri, E., Gallus, S., Boffetta, P., Tramacere, I., & La Vecchia, C. (2009). Long-term particulate matter exposure and mortality: a review of European epidemiological studies. BMC public health, 9(1), 1-8.

Peters, A., Veronesi, B., Calderón-Garcidueñas, L., Gehr, P., Chen, L. C., Geiser, M., ... & Schulz, H. (2006). Translocation and potential neurological effects of fine and ultrafine particles a critical update. Particle and fibre toxicology, 3(1), 1-13.

Prüss-Üstün, A., Fewtrell, L., Landrigan, P. J., & Ayuso-Mateos, J. L. (2004). Lead exposure. Comparative quantification of health risks. Geneva: World Health Organization.

Ramachandran, S., Kedia, S., & Srivastava, R. (2012). Aerosol optical depth trends over different regions of India. Atmospheric Environment, 49, 338-347.

Ramanathan, V. C., & PJ, K. JT & Rosenfeld, D.(2001). Science, 294, 2119-2124.

Ren, G., Zhou, Y., Chu, Z., Zhou, J., Zhang, A., Guo, J., & Liu, X. (2008). Standardized Precipitation Index User Guide. J. Clim, 21, 1333-1348.

Rodopoulou, S., Chalbot, M. C., Samoli, E., DuBois, D. W., San Filippo, B. D., & Kavouras, I. G. (2014). Air pollution and hospital emergency room and admissions for cardiovascular and respiratory diseases in Doña Ana County, New Mexico. Environmental research, 129, 39-46.

Sadeghi, M., Ahmadi, A., Baradaran, A., Masoudipoor, N., & Frouzandeh, S. (2015). Modeling of the relationship between the environmental air pollution, clinical risk factors, and hospital mortality due to myocardial infarction in Isfahan, Iran. Journal of research in medical sciences: the official journal of Isfahan University of Medical Sciences, 20(8), 757.

Sahu, D., Kannan, G. M., & Vijayaraghavan, R. (2014). Carbon black particle exhibits size dependent toxicity in human monocytes. International journal of inflammation, 2014.

Sharma, S. B., Jain, S., Khirwadkar, P., & Kulkarni, S. (2013). The effects of air pollution on the environment and human health. Indian Journal of Research in Pharmacy and Biotechnology, 1(3), 391-396.

Shastri, H., Paul, S., Ghosh, S., & Karmakar, S. (2015). Impacts of urbanization on Indian summer monsoon rainfall extremes. Journal of Geophysical Research: Atmospheres, 120(2), 496-516.

Shaw, N., & Gorai, A. K. (2020). Study of aerosol optical depth using satellite data (MODIS Aqua) over Indian Territory and its relation to particulate matter concentration. Environment, Development and Sustainability, 22(1), 265-279.

Shepherd, J. M. (2005). A review of current investigations of urban-induced rainfall and recommendations for the future. Earth Interactions, 9(12), 1-27.

Singh, C., Madhavan, M., Arvind, J., & Bazaz, A. (2021). Climate change adaptation in Indian cities: A review of existing actions and spaces for triple wins. Urban Climate, 36, 100783.

Troeger, C., Blacker, B., Khalil, I. A., Rao, P. C., Cao, J., Zimsen, S. R., ... & Reiner Jr, R. C. (2018). Estimates of the global, regional, and national morbidity, mortality, and aetiologies of lower ections in 195 countries, 1990–2016: a systematic analysis for the Global Burden of Disease Study 2016. The Lancet infectious diseases, 18(11), 1191-1210.

Upadhyay, A., Dey, S., Chowdhury, S., & Goyal, P. (2018). Expected health benefits from mitigation of emissions from major anthropogenic PM2. 5 sources in India: Statistics at state level. Environmental Pollution, 242, 1817-1826.

US EPA. Table of Historical SO2 NAAQS, Sulfur US EPA. Available online at: https://www3.epa.gov/ttn/naaqs/standards/so2/s_so2_history.html (accessed October 5, 2019).

Van Duijne, R. J. (2017). What is India's urbanisation riddle. Economic and Political Weekly, 52(28), 76-77.

Vermaelen, K., & Brusselle, G. (2013). Exposing a deadly alliance: novel insights into the biological links between COPD and lung cancer. Pulmonary pharmacology & therapeutics, 26(5), 544-554.

Weisskopf, M. G., Kioumourtzoglou, M. A., & Roberts, A. L. (2015). Air pollution and autism spectrum disorders: causal or confounded?. Current environmental health reports, 2(4), 430-439.

WHO (2015). Countries: China: Country Health Profile. World Health Organization. Available online at: http://www.who.int/countries/chn/en/

WHO (World Health Organization). Dioxins and Their Effects on Human Health. Available online at: https://www.who.int/news-room/fact-sheets/detail/dioxins-and-their-effects-on-human-health (accessed October 5, 2019).

WHO Regional Office of Europe (2000). Available online at: https://euro. who.int/_data/assets/pdf_file/0020/123086/AQG2ndEd_7_4Sulfuroxide.pdf

WHO. (2016). WHO global urban ambient air pollution database (update 2016). World Health Organization.

Wilkinson, S., Mills, G., Illidge, R., & Davies, W. J. (2012). How is ozone pollution reducing our food supply?. Journal of Experimental Botany, 63(2), 527-536.

Yang, B., Zhang, Y., & Qian, Y. (2012). Simulation of urban climate with high-resolution WRF model: A case study in Nanjing, China. Asia-Pacific Journal of Atmospheric Sciences, 48(3), 227-241.

Zhang, J., & Smith, K. R. (2007). Household air pollution from coal and biomass fuels in China: measurements, health impacts, and interventions. *Environmental health perspectives*, *115*(6), 848-855.

Zhou, M., Liu, Y., Wang, L., Kuang, X., Xu, X., & Kan, H. (2014). Particulate air pollution and mortality in a cohort of Chinese men. Environmental Pollution, 186, 1-6.

Zhou, N., Cui, Z., Yang, S., Han, X., Chen, G., Zhou, Z., ... & Cao, J. (2014). Air pollution and decreased semen quality: a comparative study of Chongqing urban and rural areas. Environmental Pollution, 187, 145-152.

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