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# Air Pollution in a Major Metro City in India and their Managements by Plants

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**Abstract:** ***The present research was conducted for air pollution in a major metro city in India and their management by plants which are control the air quality and purified the air. Air pollution is one of the biggest issues in our world, this issue easily seen metro city in India such as Delhi. Present day Delhi survives by this issue as a result of many reasons which are describe below. One of the best solutions to manage the air quality is plants, plants have capability to improve and purify the air not only outdoor air, also indoor air. Some example: spider plant, palm tree, rubber plant, beshil, dracaena, ficus, snake plant and aloevera etc.***

**Keywords:** air pollution issue, reason f air pollution, management by plants

## 1. Introduction

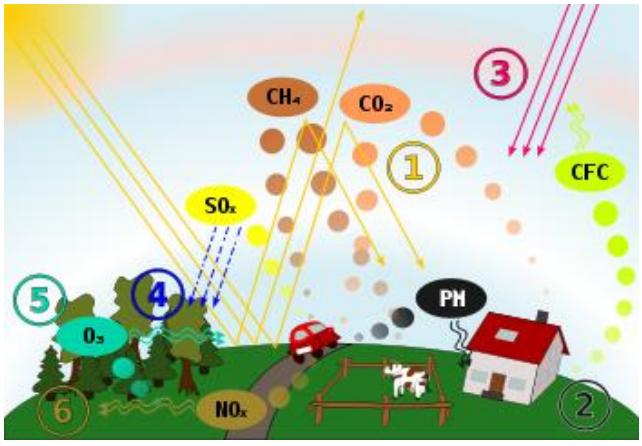
"Bad air quality" and "Air quality" redirect here. For the obsolete medical theory, see Bad air. For the measure of how polluted the air is, see Airquality index r. For the properties of air, see Qualities of air.

Air pollution occurs when harmful or excessive quantities of substances including gases, particles, and biological molecules are introduced into Earth's atmosphere. It may cause diseases, allergies and even death to humans; it may also cause harm to other living organisms such as animals and food crops, and may damage the natural or built environment. Both human activity and natural processes can generate air pollution.

Indoor air pollution and poor urban air quality are listed as two of the worlds worst toxic pollution problems in the 2008 Blacksmith Institute World's Worst Polluted Places report. According to the 2014 World Health Organization report, air pollution in 2012 caused the deaths of around 7 million people worldwide, an estimate roughly echoed by one from the International Energy Agency.

An air pollutant is a material in the air that can have adverse effects on humans and the ecosystem. The substance can be solid particles, liquid droplets, or gases. A pollutant can be of natural origin or man-made. Pollutants are classified as primary or secondary. Primary pollutants are usually produced by processes such as ash from a volcanic eruption. Other examples include carbon monoxide gas from motor vehicle exhausts or sulphur dioxide released from the factories. Secondary pollutants are not emitted directly. Rather, they form in the air when primary pollutants react or interact. Ground level ozone is a prominent example of secondary pollutants. Some pollutants may be both primary and secondary: they are both emitted directly and formed from other primary pollutants.

Before flue-gas desulphurization was installed, the emissions from this power plant in New Mexico contained excessive amounts of sulphur dioxide.




Schematic drawing, causes and effects of air pollution: (1) greenhouse effect, (2) particulate contamination, (3) increased UV radiation, (4) acid rain, (5) increased ground-level ozone concentration, (6) increased levels of nitrogen oxides. Thermal oxidisers are air pollution abatement options for hazardous air pollutants (HAPs), volatile organic compounds (VOCs), and odorous emissions.

Substances emitted into the atmosphere by human activity include:

**Carbon dioxide ($CO_2$)** - Because of its role as a greenhouse gas it has been described as "the leading

pollutant"] and "the worst climate pollution". Carbon dioxide is a natural component of the atmosphere, essential for plant life and given off by the human respiratory system. This question of terminology has practical effects, for example as determining whether the U.S. Clean Air Act is deemed to regulate $CO_2$ emissions. $CO_2$ currently forms about 410 parts per million (ppm) of earth's atmosphere, compared to about 280 ppm in pre-industrial times, and billions of metric tons of $CO_2$ are emitted annually by burning of fossil fuels. $CO_2$ increase in earth's atmosphere has been accelerating. [11]

**Sulfur oxides ($SO_x$)** - particularly sulphur dioxide, a chemical compound with the formula $SO_2$. SO2 is produced by volcanoes and in various industrial processes. Coal and petroleum often contain sulphur compounds, and their combustion generates sulphur dioxide. Further oxidation of $SO_2$, usually in the presence of a catalyst such as $NO_2$, forms $H_2SO_4$, and thus acid rain. This is one of the causes for concern over the environmental impact of the use of these fuels as power sources.

**Nitrogen oxides (**$NO_x$) - Nitrogen oxides, particularly nitrogen dioxide, are expelled from high temperature combustion, and are also produced during thunderstorms by electric discharge. They can be seen as a brown hazedome above or a plume downwind of cities. Nitrogen dioxide is a chemical compound with the formula $NO_2$. It is one of several nitrogen oxides. One of the most prominent air pollutants, this reddish-brown toxic gas has a characteristic sharp, biting odor.

**Carbon monoxide (**CO) - CO is a colorless, odorless, toxic yet non-irritating gas. It is a product of combustion of fuel such as natural gas, coal or wood. Vehicular exhaust contributes to the majority of carbon monoxide let into our atmosphere. It creates a smog type formation in the air that has been linked to many lung diseases and disruptions to the natural environment and animals. In 2013, more than half of the carbon monoxide emitted into our atmosphere was from vehicle traffic and burning one gallon of gas will often emit over 20 pounds of carbon monoxide into the air.

**Volatile organic compounds (**VOC) - VOCs are a well-known outdoor air pollutant. They are categorized as either methane ($CH_4$) or non-methane (NMVOCs). Methane is an extremely efficient greenhouse gas which contributes to enhance global warming. Other hydrocarbon VOCs are also significant greenhouse gases because of their role in creating ozone and prolonging the life of methane in the atmosphere. This effect varies depending on local air quality. The aromatic NMVOCs benzene, toluene and xylene are suspected carcinogens and may lead to leukemia with prolonged exposure. 1, 3-butadiene is another dangerous compound often associated with industrial use.

**Particulate matter / particles**, alternatively referred to as particulate matter (PM), atmospheric particulate matter, or fine particles, are tiny particles of solid or liquid suspended in a gas. In contrast, aerosol refers to combined particles and gas. Some particulates occur naturally, originating from volcanoes, dust storms, forest and grassland fires, living vegetation, and sea spray. Human activities, such as the burning of fossil fuels in vehicles, power plants and various industrial processes also generate significant amounts of aerosols. Averaged worldwide, anthropogenic aerosols-those made by human activities-currently account for approximately 10 percent of our atmosphere. Increased levels of fine particles in the air are linked to health hazards such as heart disease, altered lung function and lung cancer. Particulates are related to respiratory infections and can be particularly harmful to those already suffering from conditions like asthma. [15]

**Persistent free radicals** connected to airborne fine particles are linked to cardiopulmonary disease.

**Toxic metals**, such as lead and mercury, especially their compounds.

**Chlorofluorocarbons (**CFCs) - harmful to the ozone layer; emitted from products are currently banned from use. These are gases which are released from air conditioners, refrigerators, aerosol sprays, etc. On release into the air, CFCs rise to the stratosphere. Here they come in contact with other gases and damage the ozone layer. This allows harmful ultraviolet rays to reach the earth's surface. This can lead to skin cancer, eye disease and can even cause damage to plants.

**Ammonia (**$NH_3$) - emitted from agricultural processes. Ammonia is a compound with the formula $NH_3$. It is normally encountered as a gas with a characteristic pungent odor. Ammonia contributes significantly to the nutritional needs of terrestrial organisms by serving as a precursor to foodstuffs and fertilizers. Ammonia, either directly or indirectly, is also a building block for the synthesis of many pharmaceuticals. Although in wide use, ammonia is both caustic and hazardous. In the atmosphere, ammonia reacts with oxides of nitrogen and sulphur to form secondary particles.

**Odors** - such as from garbage, sewage, and industrial processes

Radioactive pollutants - produced by nuclear explosions, nuclear events, war explosives, and natural processes such as the radioactive decay of radon.

**Secondary pollutants include:**

Particulates created from gaseous primary pollutants and compounds in photochemical smog. Smog is a kind of air pollution. Classic smog results from large amounts of coal burning in an area caused by a mixture of smoke and sulphur dioxide. Modern smog does not usually come from coal but from vehicular and industrial emissions that are acted on in the atmosphere by ultraviolet light from the sun to form secondary pollutants that also combine with the primary emissions to form photochemical smog.

Ground level ozone ($O_3$) formed from $NO_x$ and VOCs. Ozone ($O_3$) is a key constituent of the troposphere. It is also an important constituent of certain regions of the

stratosphere commonly known as the Ozone layer. Photochemical and chemical reactions involving it drive many of the chemical processes that occur in the atmosphere by day and by night. At abnormally high concentrations brought about by human activities (largely the combustion of fossil fuel), it is a pollutant and a constituent of smog.

Peroxyacetyl nitrate ($C_2H_3NO_5$) - similarly formed from $NO_x$ and VOCs.

Minor air pollutants include:

A large number of minor hazardous air pollutants. Some of these are regulated in USA under the Clean Air Act and in Europe under the Air Framework Directive

A variety of persistent organic pollutants, which can attach to particulates.

**Sources**

There are various locations, activities or factors which are responsible for releasing pollutants into the atmosphere. These sources can be classified into two major categories.

**Anthropogenic (man-made) sources**

These are mostly related to the burning of multiple types of fuel.

Stationary sources include smoke stacks of fossil fuel power stations (see for example environmental impact of the coal industry), manufacturing facilities (factories) and waste incinerators, as well as furnaces and other types of fuel-burning heating devices. In developing and poor countries, traditional biomass burning is the major source of air pollutants; traditional biomass includes wood, crop waste and dung. [19] [20]

Mobile sources include motor vehicles, marine vessels, and aircraft.

Controlled burn practices in agriculture and forest management. Controlled or prescribed burning is a technique sometimes used in forest management, farming, prairie restoration or greenhouse gas abatement. Fire is a natural part of both forest and grassland ecology and controlled fire can be a tool for foresters. Controlled burning stimulates the germination of some desirable forest trees, thus renewing the forest.

Fumes from paint, hair spray, varnish, aerosol sprays and other solvents. These can be substantial; emissions from these sources was estimated to account for almost half of pollution from volatile organic compounds in the Los Angeles basin in the 2010s. [21]

Waste deposition in landfills, which generate methane. Methane is highly flammable and may form explosive mixtures with air. Methane is also an asphyxiant and may displace oxygen in an enclosed space. Asphyxia or suffocation may result if the oxygen concentration is reduced to below 19.5% by displacement.

Military resources, such as nuclear weapons, toxic gases, germ warfare and rocketry.

Fertilized farmland may be a major source of nitrogen oxides. [22]

**Natural sources**

Dust from natural sources, usually large areas of land with little or no vegetation

Methane, emitted by the digestion of food by animals, for example cattle

Radon gas from radioactive decay within the Earth's crust. Radon is a colorless, odorless, naturally occurring, radioactive noble gas that is formed from the decay of radium. It is considered to be a health hazard. Radon gas from natural sources can accumulate in buildings, especially in confined areas such as the basement and it is the second most frequent cause of lung cancer, after cigarette smoking.

Smoke and carbon monoxide from wildfires

Vegetation, in some regions, emits environmentally significant amounts of Volatile organic compounds (VOCs) on warmer days. These VOCs react with primary anthropogenic pollutants-specifically, $NO_x$, $SO_2$, and anthropogenic organic carbon compounds - to produce a seasonal haze of secondary pollutants.] Black gum, poplar, oak and willow are some examples of vegetation that can produce abundant VOCs. The VOC production from these species result in ozone levels up to eight times higher than the low-impact tree species. [24]

Volcanic activity, which produces sulphur, chlorine, and ash particulates

**Emission factors**

Air pollutant emission factors are reported representative values that attempt to relate the quantity of a pollutant released to the ambient air with an activity associated with the release of that pollutant. These factors are usually expressed as the weight of pollutant divided by a unit weight, volume, distance, or duration of the activity emitting the pollutant (e.g., kilograms of particulate emitted per tonne of coal burned). Such factors facilitate estimation of emissions from various sources of air pollution. In most cases, these factors are simply averages of all available data of acceptable quality, and are generally assumed to be representative of long-term averages.

There are 12 compounds in the list of persistent organic pollutants. Dioxins and furans are two of them and intentionally created by combustion of organics, like open burning of plastics. These compounds are also endocrine disruptors and can mutate the human genes.

The United States Environmental Protection Agency has published a compilation of air pollutant emission factors for a wide range of industrial sources. [25] The United Kingdom, Australia, Canada and many other countries have published similar compilations, as well as the European Environment Agency. [26] [27] [28] [29]

**Indoor air quality**

A lack of ventilation indoors concentrates air pollution where people often spend the majority of their time. Radon (Rn) gas, a carcinogen, is exuded from the Earth in certain locations and trapped inside houses. Building materials including carpeting and plywood emit formaldehyde ($H_2CO$) gas. Paint and solvents give off volatile organic compounds (VOCs) as they dry. Lead paint can degenerate into dust and be inhaled. Intentional air pollution is introduced with the use of air fresheners, incense, and other scented items. Controlled wood fires in stoves and fireplaces can add significant amounts of smoke particulates into the air, inside and out. [32] Indoor pollution fatalities may be caused by using pesticides and other chemical sprays indoors without proper ventilation.

Carbon monoxide poisoning and fatalities are often caused by faulty vents and chimneys, or by the burning of charcoal indoors or in a confined space, such as a tent. [33] Chronic carbon monoxide poisoning can result even from poorly-adjusted pilot lights. Traps are built into all domestic plumbing to keep sewer gas and hydrogen sulfide, out of interiors. Clothing emits tetrachloroethylene, or other dry cleaning fluids, for days after dry cleaning.

Though its use has now been banned in many countries, the extensive use of asbestos in industrial and domestic environments in the past has left a potentially very dangerous material in many localities. Asbestosis is a chronic inflammatory medical condition affecting the tissue of the lungs. It occurs after long-term, heavy exposure to asbestos from asbestos-containing materials in structures. Sufferers have severe dyspnea (shortness of breath) and are at an increased risk regarding several different types of lung cancer. As clear explanations are not always stressed in non-technical literature, care should be taken to distinguish between several forms of relevant diseases. According to the World Health Organization (WHO), these may defined as; asbestosis, lung cancer, and Peritoneal Mesothelioma (generally a very rare form of cancer, when more widespread it is almost always associated with prolonged exposure to asbestos).

Biological sources of air pollution are also found indoors, as gases and airborne particulates. Pets produce dander, people produce dust from minute skin flakes and decomposed hair, dust mites in bedding, carpeting and furniture produce enzymes and micrometre-sized fecal droppings, inhabitants emit methane, mold forms on walls and generates mycotoxins and spores, air conditioning systems can incubate Legionnaires' disease and mold, and houseplants, soil and surrounding gardens can produce pollen, dust, and mold. Indoors, the lack of air circulation allows these airborne pollutants to accumulate more than they would otherwise occur in nature.

**Health effects**

In 2012, air pollution caused premature deaths on average of 1 year in Europe, and was a significant risk factor for a number of pollution-related diseases, including respiratory infections, heart disease, COPD, stroke and lung cancer. [2] The health effects caused by air pollution may include difficulty in breathing, wheezing, coughing, asthma and worsening of existing respiratory and cardiac conditions. These effects can result in increased medication use, increased doctor or emergency department visits, more hospital admissions and premature death. The human health effects of poor air quality are far reaching, but

principally affect the body's respiratory system and the cardiovascular system. Individual reactions to air pollutants depend on the type of pollutant a person is exposed to, the degree of exposure, and the individual's health status and genetics. [30] The most common sources of air pollution include particulates, ozone, nitrogen dioxide, and sulphur dioxide. Children aged less than five years that live in developing countries are the most vulnerable population in terms of total deaths attributable to indoor and outdoor air pollution. [34]

**Mortality**

The World Health Organization estimated in 2014 that every year air pollution causes the premature death of some 7 million people worldwide. [2] India has the highest death rate due to air pollution. [35] India also has more deaths from asthma than any other nation according to the World Health Organization. In December 2013 air pollution was estimated to kill 500, 000 people in China each year. [36] There is a positive correlation between pneumonia-related deaths and air pollution from motor vehicle emissions. [37]

Annual premature European deaths caused by air pollution are estimated at 430, 000. [38] An important cause of these deaths is nitrogen dioxide and other nitrogen oxides (NOx) emitted by road vehicles. [38] In a 2015 consultation document the UK government disclosed that nitrogen dioxide is responsible for 23, 500 premature UK deaths per annum. [39]Across the European Union, air pollution is estimated to reduce life expectancy by almost nine months. [40] Causes of deaths include strokes, heart disease, COPD, lung cancer, and lung infections. [2]

Urban outdoor air pollution is estimated to cause 1.3 million deaths worldwide per year. Children are particularly at risk due to the immaturity of their respiratory organ systems. [41]

The US EPA estimated in 2004 that a proposed set of changes in diesel engine technology (Tier 2) could result in 12, 000 fewer premature mortalities, 15, 000 fewer heart attacks, 6, 000 fewer emergency department visits by children with asthma, and 8, 900 fewer respiratory-related hospital admissions each year in the United States. [42]

The US EPA has estimated that limiting ground-level ozone concentration to 65 parts per billion, would avert 1, 700 to 5, 100 premature deaths nationwide in 2020 compared with the 75-ppb standard. The agency projected the more protective standard would also prevent an additional 26, 000 cases of aggravated asthma, and more than a million cases of missed work or school. [43] [44] Following this assessment, the EPA acted to protect public health by lowering the National Ambient Air Quality Standards (NAAQS) for ground-level ozone to 70 parts per billion (ppb). [45]

A new economic study of the health impacts and associated costs of air pollution in the Los Angeles Basin and San Joaquin Valley of Southern California shows that more than 3, 800 people die prematurely (approximately 14 years earlier than normal) each year because air pollution levels violate federal standards. The number of annual premature deaths is considerably higher than the fatalities related to auto collisions in the same area, which average fewer than 2, 000 per year. [46] [47] [48]

Diesel exhaust (DE) is a major contributor to combustion-derived particulate matter air pollution. In several human experimental studies, using a well-validated exposure chamber setup, DE has been linked to acute vascular dysfunction and increased thrombus formation. [49] [50]

The mechanisms linking air pollution to increased cardiovascular mortality are uncertain, but probably include pulmonary and systemic inflammation. [51]

**Cardiovascular disease**

A 2007 review of evidence found ambient air pollution exposure is a risk factor correlating with increased total mortality from cardiovascular events (range: 12% to 14% per 10 microg/$m^3$ increase). [52]

Air pollution is also emerging as a risk factor for stroke, particularly in developing countries where pollutant levels are highest. [53] A 2007 study found that in women, air pollution is not associated with hemorrhagic but with ischemic stroke. [54] Air pollution was also found to be associated with increased incidence and mortality from coronary stroke in a cohort study in 2011. [55] Associations are believed to be causal and effects may be mediated by vasoconstriction, low-grade inflammation and atherosclerosis [56] Other mechanisms such as autonomic nervous system imbalance have also been suggested. [57] [58]

**Lung disease**

Research has demonstrated increased risk of developing asthma [59] and COPD [60] from increased exposure to traffic-related air pollution. Additionally, air pollution has been associated with increased hospitalization and mortality from asthma and COPD. [61] [62] Chronic obstructive pulmonary disease (COPD) includes diseases such as chronic bronchitis and emphysema. [63]
A study conducted in 1960-1961 in the wake of the Great Smog of 1952 compared 293 London residents with 477 residents of Gloucester, Peterborough, and Norwich, three towns with low reported death rates from chronic bronchitis. All subjects were male postal truck drivers aged 40 to 59. Compared to the subjects from the outlying towns, the London subjects exhibited more severe respiratory symptoms (including cough, phlegm, and dyspnea), reduced lung function ($FEV_1$ and peak flow rate), and increased sputum production and purulence. The differences were more pronounced for subjects aged 50 to 59. The study controlled for age and smoking habits, so concluded that air pollution was the most likely cause of the observed differences. [64] More recent studies have shown that air pollution exposure from traffic reduces lung function development in children [65] and lung function may be compromised by air pollution even at low

concentrations. [66] Air pollution exposure also cause lung cancer in non smokers.

It is believed that much like cystic fibrosis, by living in a more urban environment serious health hazards become more apparent. Studies have shown that in urban areas patients suffer mucus hypersecretion, lower levels of lung function, and more self-diagnosis of chronic bronchitis and emphysema. [67]

**Cancer (lung cancer)**

A review of evidence regarding whether ambient air pollution exposure is a risk factor for cancer in 2007 found solid data to conclude that long-term exposure to PM2.5 (fine particulates) increases the overall risk of non-accidental mortality by 6% per a 10 microg/$m^3$ increase. Exposure to PM2.5 was also associated with an increased risk of mortality from lung cancer (range: 15% to 21% per 10 microg/$m^3$ increase) and total cardiovascular mortality (range: 12% to 14% per a 10 microg/$m^3$ increase). The review further noted that living close to busy traffic appears to be associated with elevated risks of these three outcomes - increase in lung cancer deaths, cardiovascular deaths, and overall non-accidental deaths. The reviewers also found suggestive evidence that exposure to PM2.5 is positively associated with mortality from coronary heart diseases and exposure to $SO_2$ increases mortality from lung cancer, but the data was insufficient to provide solid conclusions. [69] Another investigation showed that higher activity level increases deposition fraction of aerosol particles in human lung and recommended avoiding heavy activities like running in outdoor space at polluted areas. [70]

In 2011, a large Danish epidemiological study found an increased risk of lung cancer for patients who lived in areas with high nitrogen oxide concentrations. In this study, the association was higher for non-smokers than smokers. [71] An additional Danish study, also in 2011, likewise noted evidence of possible associations between air pollution and other forms of cancer, including cervical cancer and brain cancer. [72]

In December 2015, medical scientists reported that cancer is overwhelmingly a result of environmental factors, and not largely down to bad luck. [68]Maintaining a healthy weight, eating a healthy diet, minimizing alcohol and eliminating smoking reduce the risk of developing the disease, according to the researchers. [68]

**Children**

In the United States, despite the passage of the Clean Air Act in 1970, in 2002 at least 146 million Americans were living in non-attainment areas-regions in which the concentration of certain air pollutants exceeded federal standards. [73] These dangerous pollutants are known as the criteria pollutants, and include ozone, particulate matter, sulphur dioxide, nitrogen dioxide, carbon monoxide, and lead. Protective measures to ensure children's health are being taken in cities such as New Delhi, India where buses now use compressed natural gas to help eliminate the "pea-soup" smog. [74] A recent study in Europe has found that exposure to ultrafine particles can increase blood pressure in children. [75] According to a WHO report-2018, polluted air is a main cause poisoning millions of children under the age of 15 years and ruining their lives which resulting to death of some six hundred thousand children annually. [76]

**Central nervous system**

Data is accumulating that air pollution exposure also affects the central nervous system. [83]

In a June 2014 study conducted by researchers at the University of Rochester Medical Center, published in the journal Environmental Health Perspectives, it was discovered that early exposure to air pollution causes the same damaging changes in the brain as autism and schizophrenia. The study also shows that air pollution also affected short-term memory, learning ability, and impulsivity. Lead researcher Professor Deborah Cory-Slechta said that "When we looked closely at the ventricles, we could see that the white matter that normally surrounds them hadn't fully developed. It appears that inflammation had damaged those brain cells and prevented that region of the brain from developing, and the ventricles simply expanded to fill the space. Our findings add to the growing body of evidence that air pollution may play a role in autism, as well as in other neurodevelopmental disorders." Air pollution has a more significant negative effect on males than on females. [84] [85] [86]

In 2015, experimental studies reported the detection of significant episodic (situational) cognitive impairment from impurities in indoor air breathed by test subjects who were not informed about changes in the air quality. Researchers at the Harvard University and SUNY Upstate Medical University and Syracuse University measured the cognitive performance of 24 participants in three different controlled laboratory atmospheres that simulated those found in "conventional" and "green" buildings, as well as green buildings with enhanced ventilation. Performance was evaluated objectively using the widely used Strategic Management Simulation software simulation tool, which is a well-validated assessment test for executive decision-making in an unconstrained situation allowing initiative and improvisation. Significant deficits were observed in the performance scores achieved in increasing concentrations of either volatile organic compounds (VOCs) or carbon dioxide, while keeping other factors constant. The highest impurity levels reached are not uncommon in some classroom or office environments. [87] [88] Air pollution increases the risk of dementia in people over 50 years old. [89]

Agricultural effects

In India in 2014, it was reported that air pollution by black carbon and ground level ozone had reduced crop yields in the most affected areas by almost half in 2011 when compared to 1980 levels

**Which are the most polluted cities in India?**

India for years has been striving to improve its air quality in urban areas, which takes a massive toll on the health of millions of its residents. Every year, a number of its cities figure in the most polluted list, but slight or no efforts are made to better its air quality. India for years has been striving to improve its air quality in urban areas, which takes a massive toll on the health of millions of its residents. Every year, a number of its cities figure in the most polluted list, but slight or no efforts are made to better its air quality.

The World Health Organisation (WHO) released its global air pollution database in Geneva and India constitutes 14 out of the 15 most polluted cities in the world in terms of particulate matter PM2.5 levels in 2016. The study considered PM 2.5 and PM10 concentration in the air of these cities for this report. The worst polluted Indian city is Kanpur followed by Faridabad, Gaya, and Varanasi, dehli. Other cities with high levels of PM2.5 pollutants are Faridabad, Gaya, Patna, Agra, Muzaffarpur, Srinagar, Gurgaon, Jaipur, Patiala and Jodhpur.

**Let's discuss these polluted cities in detail:**

**Kanpur**

Kanpur, known for its leather and shoe industries, has top-numbered the WHO's list of the most polluted Indian cities with the dirtiest air in a survey on 02nd April 2018. The pollution levels of the state were five times more than the WHO's recommended safe limit.

Harmful particles less than 2.5 micrometres (PM2.5): 173
Harmful particles less than 10 micrometres (PM10): 319µg/m3

**Faridabad**

Faridabad, a city in the National Capital Region, is the second most polluted city in the country as confirmed by the report on air pollution of World Health Organisation (WHO). Faridabad has become the dustiest city of Haryana as the construction of commercial complexes and highrises is in progress.

Harmful particles less than 2.5 micrometres (PM2.5): 172µg/m3
Harmful particles less than 10 micrometres (PM10): 316µg/m3

**Varanasi**

The holy city of Varanasi stands third among the 14 most polluted cities In India in the WHO's report on air pollution. The city has been facing acute problems of air pollution due to developmental activities.

Harmful particles less than 2.5 micrometres (PM2.5): 151µg/m3
Harmful particles less than 10 micrometres (PM10): 260µg/m3

**Gaya**

Gaya, the only heritage city in Bihar, has been declared the fourth most polluted city of the world according to the WHO report. The air of this holy place has become polluted due to developmental activities in the city and the open burning of garbage on the roads.

Harmful particles less than 2.5 micrometres (PM2.5): 149µg/m3
Harmful particles less than 10 micrometres (PM10): 275µg/m3

**Patna**

Patna is the fifth most polluted city in India in terms of PM 2.5 concentration as per the report of WHO. Suspended road dust particles, emission from vehicles and smoke undulating out of brick furnace have been linked to higher level of respiratory suspended particulate matter (PM 10) in Patna.

Harmful particles less than 2.5 micrometres (PM2.5): 144µg/m3
Harmful particles less than 10 micrometres (PM10): 266µg/m3

**Delhi**

The city occupies the sixth spot in the latest WHO's report and has recorded its highest pollution levels in six years. This increase in the pollution levels is caused due to the high industrial and vehicular emissions, construction work and the burning of crops in the adjoining states.

Harmful particles less than 2.5 micrometres (PM2.5): 143µg/m3
Harmful particles less than 10 micrometres (PM10): 292µg/m3

**Lucknow**

Lucknow is among the most polluted cities in the world in terms of PM 2.5 level. The traffic in the city, burning of garbage in the nearby areas and unproper construction work is the key contributor to the pollution.

Harmful particles less than 2.5 micrometres (PM2.5): 138µg/m3
Harmful particles less than 10 micrometres (PM10): 255µg/m3

**Agra**

Home to one of the Seven Wonders of the World, the TajMahal in Agra is one of the most sought after tourist destinations. However, increase in pollution due to increased mining and dry sand is affecting the tourism industry in Agra. It's also affecting one of the most magnificent monuments in the world.

Harmful particles less than 2.5 micrometres (PM2.5): 131µg/m3

Harmful particles less than 10 micrometres (PM10): 195µg/m3

**Muzaffarpur**

Muzaffarpur stands on the ninth position in the list of most polluted cities in WHO's report even thought this city is neither an industrial city nor a hub of factories. The main source of the air pollution is PM 2.5 which is a microscopic matter.

Harmful particles less than 2.5 micrometres (PM2.5): 120µg/m3
Harmful particles less than 10 micrometres (PM10): 221µg/m3

**Srinagar**

Srinagar hit a dangerous pollution levels every winters when PM 2.5 was recorded five times more than the permissible limit mainly due to the use of coal for domestic purpose. Rapid urbanisation, use of biofuel and the concentration of economic activity were the main contributors to air pollution in Srinagar.

Harmful particles less than 2.5 micrometres (PM2.5): 113µg/m3
Harmful particles less than 10 micrometres (PM10): 169µg/m3

**Gurugram**

Gurugram faces a spike in the pollution levels over the last decade due to diesel autos, use of diesel generators and massive construction projects running all over the city. Unchecked waste burning and dumping of construction and demolition (C&D) increases the PM 2.5 concentration and further adds to this grave situation

.Harmful particles less than 2.5 micrometres (PM2.5): 113µg/m3
Harmful particles less than 10 micrometres (PM10): 124µg/m3

**Jaipur**

Jaipur, the pink city of Rajasthan, is one of the most polluted cities in India. This city records the highest level of PM10 concentration in the state of Rajasthan. The air pollution in Jaipur has reached this critical level due to increase in the number of vehicles and congestion caused because of them.

Harmful particles less than 2.5 micrometres (PM2.5): 105µg/m3
Harmful particles less than 10 micrometres (PM10): 193µg/m3

**Patiala**

Patiala, along with 13 other Indian cities, recorded 101 micrograms per cubic metre (ug/m3) of PM2.5 concentration level from 2010 to 2016. The city struggles against poor air quality, especially in the post-harvest period twice a year.

Harmful particles less than 2.5 micrometres (PM2.5): 101µg/m3
Harmful particles less than 10 micrometres (PM10): 184µg/m3

**Jodhpur**

Jodhpur is among the top polluted cities of Rajasthan after Jaipur. Presence of particulate matter in the air can cause various health issues, including lung cancer, heart disease and strokes in the long term. Sometimes lack of rain in the region contributes to its poor air quality.

Harmful particles less than 2.5 micrometers (PM2.5): 98µg/m3
Harmful particles less than 10 micrometres (PM10): 180µg/m3

Agra Delhi Faridabad Gurugram Jaipur Jodhpur Kanpur Lucknow Muzaffarpur Patiala Patna Polluted Cities of India Srinagar

**Air pollution in Delhi**

The air quality in Delhi, the capital of India, according to a WHO survey of 1600 world cities, is the worst of any major city in the world. [1] [2] Air pollution in India is estimated to kill 1.5 million people every year; it is the fifth largest killer in India. India has the world's highest death rate from chronic respiratory diseases and asthma, according to the WHO. In Delhi, poor quality air irreversibly damages the lungs of 2.2 million or 50 percent of all children.

India's Ministry of Earth Sciences published a research paper in October 2018 attributing almost 41% of PM2.5 air pollution in Delhi to vehicular emissions, 21.5% to dust and 18% to industries. [3] The director of Centre for Science and Environment (CSE) alleged that the Society of Indian Automobile Manufacturers (SIAM) is lobbying "against the report" because it is "inconvenient" to the automobile industry. [4]

Air quality index of Delhi is generally Moderate (101-200) level between January to September, and then it drastically deteriorates to Very Poor (301-400), Severe (401-500) or even Hazardous (500+) levels in three months between October to December, due to various factors including stubble burning, fire crackers burning during Diwali and cold weather. [5] [6] [7]In November 2017, in an event known as the Great smog of Delhi, the air pollution spiked far beyond acceptable levels. Levels of PM2.5 and PM 10 particulate matter hit 999 micrograms per cubic meter, while the safe limits for those pollutants are 60 and 100 respectively

Present day this problem becomes a major problem day by day, which we can easily seen in Delhi.

Particulate matter levels in Delhi

Air quality or ambient/outdoor air pollution is represented by the annual mean concentration of particulate matter $PM_{10}$ (particles smaller than 10 microns) and $PM_{2.5}$ (particles smaller than 2.5 microns, about 25 to 100 times thinner than a human hair). [9]

The world's average $PM_{10}$ levels, for the period 2008 and 2013, based on data of 1600 cities in 91 countries, range from 26 to 208 micrograms per cubic meter of air ($\mu g/m^3$), with the world average being 71 $\mu g/m^3$. [1] 13 of the 25 cities worldwide with the highest levels of PM are in India. [10]

In 2010, the year of the WHO survey, the average $PM_{10}$ level in Delhi was 286 $\mu g/m^3$. In 2013, the $PM_{2.5}$ level was 153 $\mu g/m^3$. These levels are considered very unhealthy. In Gwalior, the city with the worst air quality in India, the $PM_{10}$ and $PM_{2.5}$ levels were 329 $\mu g/m^3$ and 144 $\mu g/m^3$ respectively. For comparison, the $PM_{10}$ and $PM_{2.5}$ levels in London were 22 $\mu g/m^3$ and 16 $\mu g/m^3$ respectively. The PM levels in Delhi have become worse since the WHO survey. In December-January 2015, in Delhi, an average $PM_{2.5}$ level of 226 $\mu g/m^3$ was noted by US embassy monitors in Delhi. The average in Beijing for the same period was 95. [11] Delhi's air is twice as bad as Beijing's air. [10] As of October 2017, experts in several monitoring stations have reportedly measured an air quality index (AQI) of 999. According to said experts this is the equivalent of smoking 45 to 50 cigarettes a day. This has led to some government officials, such as Arvind Kejriwal calling the nation's capital a "gas chamber". [12]

Safe levels for PM according to the WHO's air quality guidelines are 20 $\mu g/m^3$ (annual mean) for $PM_{10}$ and 10 $\mu g/m^3$ (annual mean) for $PM_{2.5}$. [13]

Causes of poor air quality

Motor vehicle emissions are one of the causes of poor air quality. Other causes include wood-burning fires, fires on agricultural land, exhaust from diesel generators, dust from construction sites, burning garbage [14] [15] and illegal industrial activities in Delhi.

The Badarpur Thermal Power Station, a coal-fired power plant built in 1973, is another major source of air pollution in Delhi. Despite producing less than 8% of the city's electric power, it produces 80 to 90% of the particulate matter pollution from the electric power sector in Delhi. [16] During the Great smog of Delhi in November 2017, the Badarpur Power Plant was temporarily shut down to alleviate the acute air pollution, but was allowed to restart on 1 February 2018. [17] In view of the detrimental effect to the environment, the power plant has been permanently shut down since 15 October 2018 [18]

The drift/mist emissions from the wet cooling towers is also a source of particulate matter as they are widely used in industry and other sectors for dissipating heat in cooling systems. [19]

Although Delhi is kerosene free and 90% of the households use LPG for cooking, the remaining 10% uses wood, crop residue, cow dung, and coal for cooking. (Census-India, 2012)

Fire in Bhalswa landfill is a major reason for airborne particles in Delhi. [20]

Agricultural stubble burning also affects Delhi's air quality when crops are being harvested. [21]

Lack of active monitoring and reaction by authorities.
Lack of political priority.
Effects of poor air quality

**Effects on children**

2.2 million children in Delhi have irreversible lung damage due to the poor quality of the air. In addition, research shows that pollution can lower children's immune system and increase the risks of cancer, epilepsy, diabetes and even adult-onset diseases like multiple sclerosis. [22]

**Effects on adults**

Poor air quality is a cause of reduced lung capacity, headaches, sore throats, coughs, fatigue, lung cancer, and early death. [13] [22]

**Smog in Delhi** is an ongoing severe air-pollution event in New Delhi and adjoining areas in the National Capital Territory of India. [23] Air pollution in 2017 peaked on both PM 2.5 and PM 10 levels. [24] It has been reported as one of the worst levels of air quality in Delhi since 1999. [25]

Low visibility has resulted in accidents across the city, notably a 24 vehicle pile-up on the Yamuna Expressway. [26]

"The Great Smog" also led to cancellation and delay of public transport, primarily trains and flights, causing much hindrance to the people.

**Source of pollution**

The current majority of analysis sources are hinting towards colder weather, stagnant winds trapping the various sources of smoke. The primary sources of smoke are stubble burning, lit garbage, road dust, power plants, factories, and vehicles.

Air quality can be measured by the amount of PM 2.5 and PM 10 particulates suspended in air. On 7 November 2017 the PM 2.5 levels in Delhi shot up to an awfully high 999, much above the recommended 60 micrograms. At the same time PM 10 shot to 999 (the maximum level for the monitors), instead of the recommended limit of 100. [8]

Again on 8 November 2017 the PM 2.5 levels shot up to 449. At the same time PM 10 shot to 663. [28]

**Weather**

The temperature in New Delhi during this period was from 15 to 29 degrees C (~66 degrees F).

**Incident**

During the second day of third test of Sri Lankan cricket team in India in 2017-18 at Delhi, smog forced Sri Lanka cricketers to stop play and wear anti-pollution masks. Cricketer LahiruGamage reported to have shortness of breath. [29] NicPothas, coach of Sri Lankan cricket team, reported that cricketer SurangaLakmal had vomited regularly due to severe pollution effect on the Delhi ground. There was a haltage of play between 12:32 pm to 12:49 pm which caused Indian coach Ravi Shastri to come out in an aggressive manner and have a talk with the field umpire David Boon. [30]

**State reaction**

A Health Emergency was declared in the capital by the Central Government of India in order to cope with the extrusive amount of polluted air. The day was declared as a holiday for schools, offices and other government centers.

**Effects**

**Health effects**

The government of Delhi has declared a health advisory. [25]

Breathlessness
Chest constriction
Irritation in eyes
Asthma
Allergy

**Control measures**

The Chief Minister of Delhi at that time, Arvind Kejriwal, came out with the following proposed [31] action items to attempt to reduce the air pollution.

All Delhi schools will remain shut for the next three days.

For the next five days, no construction and demolition work will take place in Delhi.

All diesel generator sets have been banned for the next ten days, except at hospitals and in emergencies.

The Delhi government will supply power to unauthorized colonies which use diesel generators.

The coal-based Badarpur power plant will be shut down for ten days. There will be no fly ash transportation from the power plant.

The Environment Department will launch an app to monitor the burning of leaves.

Vacuum cleaning of roads will start on 10 November.

Water sprinkling will start on all roads from the next following days.

People should stay at home as much as they can and they should try working from home.

It has been under public debate how much, if any, of the above steps actually help curtail pollution. Various bodies blamed various sources for the smog.

**Longer term measures**

On 25 November 2017, the Supreme Court of India banned the sale of firecrackers in Delhi to alleviate pollution. [32]

In another measure, the Badarpur power plant will remain shut until at least 31 January 2018. [33] This power plant is very old and polluting, and even before the Great Smog, environmentalists had advocated for its permanent shutdown. [34]

Air quality monitoring stations.

The Indian Meteorological Department (IMD) has air quality monitoring stations in Mathura Road, IMD Delhi (JorBagh area), IGI Airport, IITM Delhi, Guru Teg Bahadur Hospital (Ghaziabad area), Dhirpur, Delhi Technological University, Pitampura, Aya Nagar (Gurgaon), and Noida. [35] The air pollution monitor of the U.S. Embassy in New Delhi covers the area of Chanakyapuri. [36]

Response of expatriates

To contend with the poor air quality, embassies and international businesses in Delhi are considering reducing

staff tenures, advising staff to reconsider bringing their children to Delhi, providing high-end air purifiers, and installing expensive air purifiers in their offices. [2]

Students of Delhi University initiated a project (http://delhicleanairforum.tk) ( [1]) to combat air pollution by increasing awareness about causes, effects, ways to protect and tackle air pollution in Delhi, of groups most exposed and most responsible; in order to decrease pollution and exposure or impact on those most exposed and vulnerable.

Major incidents

In December 2017 during a test match between Sri Lankan and Indian cricket teams in New Delhi, Sri Lanka players began to feel breathing problems and several players vomited both in the rest rooms and in the field and had to use face masks until the match was stopped. [37] However Indian side was unsympathetic to the Sri Lankan team, Hindi commentators joked on air that Sri Lankan players were using masks to hide their faces after having taken the beating of their lives while prominent people lauded Indian cricket team's nationalism on Twitter claiming that they sacrificed their health to entertain the crowd that had turned up, while Virender Sehwag called it an act to stop Virat Kohli from scoring a triple century. [38] [37] However, after the resumption of the match Indian player Mohommad Shami also vomited. Before Shami had said that while pollution levels are a concern, Indian players are used to such conditions. [39] [40] In the opinion of the Indian Medical Association president the match should never have taken place and the ICC should have a policy on pollution. [41]

Management by plantation

The **NASA Clean Air Study** [1] was led by the National Aeronautics and Space Administration (NASA) in association with the Associated Landscape Contractors of America (ALCA). Its results suggest that certain common indoor plants may provide a natural way of removing toxic agents such as benzene, formaldehyde and trichloroethylene from the air, helping neutralize the effects of sick building syndrome. However, the study was not conducted under realistic home or office conditions, and the few studies that have been conducted under such conditions show mixed results.

The first list of **air-filtering plants** was compiled by NASA as part of a clean air study published in 1989, [3] [4] [5] which researched ways to clean air in space stations. As well as absorbing carbon dioxide and releasing oxygen, as all plants do, these plants also eliminate significant amounts of benzene, formaldehyde and trichloroethylene. The second and third lists are from B. C. Wolverton's book [6] and focus on removal of specific chemicals.

NASA researchers suggest efficient air cleaning is accomplished with at least one plant per 100 square feet of home or office space. Other more recent research [8] has shown that micro-organisms in the potting mix (soil) of a potted plant remove benzene from the air, and that some plant species also contribute to removing benzene.

Chart of air-filtering plants

| Plant, removes: | benzene [3] | Total µg/h of benzene removed [3] | formaldehyde [3] [6] [7] | Total µg/h of formaldehyde removed [3] [7] | trichloroethylene [3] | Total µg/h of trichloroethylene removed [3] | Xylene and toluene [7] | ammonia [7] | Toxic to dogs, cats [9] |
|---|---|---|---|---|---|---|---|---|---|
| Dwarf date palm (Phoenix roebelenii) | No | | Yes [6] | 1, 385 [7] | No | | Yes | No | non-toxic [10] |
| Areca palm (Dypsislutescens) | No | | Yes [6] | | No | | Yes | No | non-toxic [11] |
| Boston fern (Nephrolepisexaltata'Bostoniensis') | No | | Yes [6] | 1, 863 [7] | No | | Yes | No | non-toxic [12] |
| Kimberley queen fern (Nephrolepisobliterata) | No | | Yes [6] | 1, 328 [7] | No | | Yes | No | non-toxic [13] |
| English ivy (Hedera helix) | Yes | 579 | Yes [6] | 402 [3] -1, 120 [7] | Yes | 298 | Yes | No | toxic [14] |
| Spider plant (Chlorophytumcomosum) | No | | Yes [3] | 560 [7] | No | | Yes | No | non-toxic [15] |
| Devil's ivy, Pothos plant (Epipremnumaureum) | Yes | | Yes [3] | | No | | Yes | No | toxic [16] |

| Plant, removes: | benzene [3] | Total µg/h of benzene removed [3] | formaldehyde [3] [6] [7] | Total µg/h of formaldehyde removed [3] [7] | trichloroethylene [3] | Total µg/h of trichloroethylene removed [3] | Xylene and toluene [7] | ammonia [7] | Toxic to dogs, cats [9] |
|---|---|---|---|---|---|---|---|---|---|
| Peace lily (Spathiphyllum'Mauna Loa') | Yes | 1, 725 | Yes [6] | 674 [3] | Yes | 1, 128 | Yes | Yes | toxic [17] |
| Flamingo lily (Anthuriumandraeanum) | No | | Yes | | No | | Yes | Yes | toxic [18] |
| Chinese evergreen (Aglaonemamodestum) | Yes [6] [19] | 604 | Yes [6] [19] | 183 [5] | No | | No | No | toxic [20] |
| Bamboo palm (Chamaedoreaseifrizii) | Yes | 1, 420 | Yes [3] [6] | 3, 196 [3] | Yes | 688 | Yes | No | non-toxic [21] |
| Variegated snake plant, mother-in-law's tongue (Sansevieriatrifasciata'Laurentii') | Yes [6] | 1196 [5] | Yes [3] | 1, 304 [3] | Yes [6] | 405 | Yes | No | toxic [22] |
| Heartleaf philodendron (Philodendron cordatum) | No | | Yes [3] | 353 [3] | No | | No | No | toxic [23] |
| Selloum philodendron (Philodendron bipinnatifidum) | No | | Yes [3] | 361 [3] | No | | No | No | toxic [citation needed] |
| Elephant ear philodendron (Philodendron domesticum) | No | | Yes [3] | 416 [3] | No | | No | No | toxic [citation needed] |
| Red-edged dracaena (Dracaena marginata) | Yes | 1, 264 | Yes [3] | 853 [3] | Yes | 1, 137 | Yes | No | toxic [24] |
| Cornstalk dracaena (Dracaena fragrans'Massangeana') | Yes | | Yes [3] | 938 [7] | Yes | 421 | No | No | toxic [24] |
| Weeping fig (Ficusbenjamina) [25] | No | | Yes [6] | 940 [7] | No | | Yes | No | toxic [26] |
| Barberton daisy (Gerbera jamesonii) | Yes | 4, 486 | Yes [6] | | Yes | 1, 622 | No | No | non-toxic [27] |
| Florist's chrysanthemum (Chrysanthemum morifolium) | Yes | 3, 205 | Yes [3] [6] | 1, 450 [7] | Yes | | Yes | Yes | toxic [28] |
| Rubber plant (Ficuselastica) | No | | Yes [6] | | No | | No | No | toxic [29] |
| Dendrobiumorchids (Dendrobiumspp.) | No | | No | | No | | Yes | No | non-toxic [citation needed] |
| Dumb canes (Dieffenbachiaspp.) | No | | No | | No | | Yes | No | toxic [30] |
| King of hearts (Homalomenawallisii) | No | | No | | No | | Yes | No | toxic [citation needed] |
| Moth orchids (Phalaenopsisspp.) | No | | No | | No | | Yes | No | non-toxic [31] |

| Plant, removes: | benzene [3] | Total µg/h of benzene removed [3] | formaldehyde [3] [6] [7] | Total µg/h of formaldehyde removed [3] [7] | trichloroethylene [3] | Total µg/h of trichloroethylene removed [3] | Xylene and toluene [7] | ammonia [7] | Toxic to dogs, cats [9] |
|---|---|---|---|---|---|---|---|---|---|
| Aloe vera (Aloe vera) | Yes [32] | | Yes | | No | | No | No | toxic [33] |
| Janet Craig (Dracaena deremensis"Janet Craig") | Yes [1] | 1, 082 | Yes [1] | 1, 361 [7] - 2, 037 [3] | Yes [1] | 764 | No | No | toxic [34] |
| Warneckei (Dracaena deremensis"Warneckei") | Yes [1] | 1, 630 | Yes [1] | 760 [7] | Yes [1] | 573 | No | No | toxic [34] |
| Banana (Musa acuminata) | No | | Yes [1] | 488 [3] | No | | No | No | non-toxi |

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